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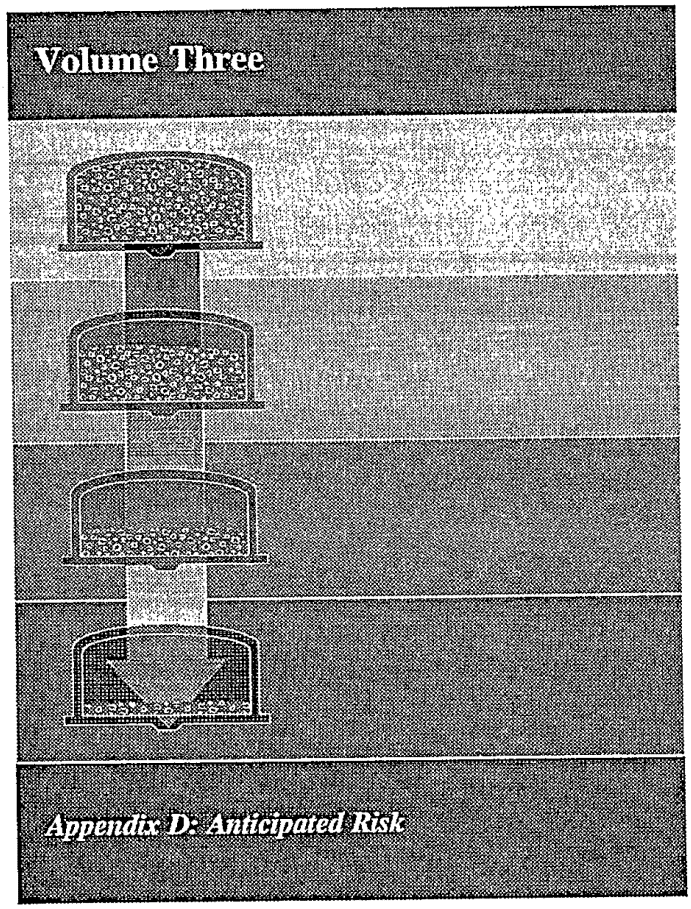
4 of 7

DOE/EIS-0189

# Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement

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*and*
Washington State Department of Ecology

August 1996

# Appendix D
# Anticipated Risk

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## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| CC | carcinogenic chemical |
| CFR | Code of Federal Regulations |
| DOE | U.S. Department of Energy |
| DST | double-shell tank |
| Ecology | Washington State Department of Ecology |
| EIS | Environmental Impact Statement |
| EPA | U.S. Environmental Protection Agency |
| GIS | Geographic Information System |
| HEAST | Health Effects Assessment Summary Tables |
| HI | hazard index |
| HLW | high-level waste |
| HSDB | hazardous substance data bank |
| HSRAM | Hanford Site Risk Assessment Methodology |
| ICRP | International Commission on Radiological Protection |
| ILCR | incremental lifetime cancer risk |
| IMUST | inactive miscellaneous underground storage tank |
| IRIS | Integrated Risk Information System |
| LADD | lifetime average daily dose |
| LAW | low-activity waste |
| LCF | latent cancer fatalities |
| LOEL | lowest observed effect level |
| MEI | maximally-exposed individual |
| MRA | modular risk assessment |
| NC | noncarcinogenic chemical |
| NCRP | National Council on Radiation Protection |
| NEPA | National Environmental Policy Act |
| NOAEL | no observed adverse effect level |
| NRC | Nuclear Regulatory Commission |
| PUREX | Plutonium-Uranium Extraction |
| RA | radionuclide |
| RfD | reference dose |
| SIF | summary intake factor |
| SST | single-shell tank |
| TWRS | Tank Waste Remediation System |
| URF | unit risk factor |
| VOC | Volatile organic compound |
| WESF | Waste Encapsulation and Storage Facility |

# NAMES AND SYMBOLS FOR UNITS OF MEASURE, RADIOACTIVITY, AND ELECTRICITY/ENERGY

**Length**

| | |
|---|---|
| cm | centimeter |
| ft | foot |
| in | inch |
| km | kilometer |
| m | meter |
| mi | mile |

**Area**

| | |
|---|---|
| ac | acre |
| $ft^2$ | square foot |
| ha | hectare |
| $km^2$ | square kilometer |
| $mi^2$ | square mile |

**Volume**

| | |
|---|---|
| $cm^3$ | cubic centimeter |
| $ft^3$ | cubic foot |
| gal | gallon |
| L | liter |
| $m^3$ | cubic meter |
| ppb | parts per billion |
| ppm | parts per million |
| $yd^3$ | cubic yard |

**Mass**

| | |
|---|---|
| g | gram |
| kg | kilogram |
| lb | pound |
| mg | milligram |
| mt | metric ton |

**Radioactivity**

| | |
|---|---|
| Ci | curie |
| MCi | megacurie (1.0E+06) |
| mCi | millicurie (1.0E-03 Ci) |
| $\mu$Ci | microcurie (1.0E-06 Ci) |
| nCi | nanocurie (1.0E-09 Ci) |
| pCi | picocurie (1.0E-12 Ci) |

**Electricity/Energy**

| | |
|---|---|
| A | ampere |
| J | joule |
| kV | kilovolt |
| kW | kilowatt |
| MeV | million electron volts |
| MW | megawatt |
| V | volt |
| W | watt |

**Temperature**

| | |
|---|---|
| °C | degrees centigrade |
| °F | degrees Fahrenheit |

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# APPENDIX D
# ANTICIPATED RISK

## D.1.0 INTRODUCTION

This appendix describes the analysis of anticipated risk for the Tank Waste Remediation System (TWRS) Environmental Impact Statement (EIS). Risk is defined as the number or degree of human health or ecological effects from exposure to radiation and chemicals resulting from TWRS activities during and after remediation. The mission of TWRS is to manage and dispose of TWRS waste, including current and future tank waste, associated inactive miscellaneous underground storage tanks (IMUSTs), and cesium (Cs) and strontium (Sr) capsules in an environmentally sound, safe, secure, and cost-effective manner. Sections D.1.0 through D.5.0 of this appendix address the methodology and results of the human health risk assessment. Section D.6.0 presents the methodology and results of the ecological risk assessment. Section D.7.0 presents the methodology and results of the assessment of risks from inadvertent human intrusion into the residual waste after remedial actions are complete. This EIS analyzes the following alternatives for remediation, which are discussed in Volume Two, Appendix B:

- Tank Waste
  - No Action alternative (Tank Waste)
  - Long-Term Management alternative
  - In Situ Fill and Cap alternative
  - In Situ Vitrification alternative
  - Ex Situ Intermediate Separations alternative
  - Ex Situ No Separations alternative
  - Ex Situ Extensive Separations alternative
  - Ex Situ/In Situ Combination 1 alternative
  - Ex Situ/In Situ Combination 2 alternative
  - Phased Implementation alternative
- Capsule
  - No Action alternative (Capsules)
  - Onsite Disposal alternative
  - Overpack and Ship alternative
  - Vitrify with Tank Waste alternative.

The scope of the risk assessment includes risk associated with conditions during and after the remedial actions. The assessment evaluates three primary types of risk: 1) risk associated with baseline conditions (No Action alternative); 2) risk associated with the TWRS EIS remedial action alternatives; and 3) risk associated with residual (post-remediation) contamination.

Baseline risk is the risk to a land user in the absence of remedial actions. Depending on the land-use scenario, the receptor for baseline conditions may be exposed to contaminated media through one or more pathways. For purposes of this assessment, the No Action alternatives (Tank Waste and Capsules) are considered the baseline.

Remedial action risk is separated into risk from routine operations and risk from accidents. Risk from routine operations is addressed in this appendix and consists of the risk to TWRS workers, noninvolved workers on the Hanford Site, and the general public resulting from remediation associated with the remedial action alternatives. Risk from accidents is addressed in Volume Four, Appendix E.

Post-remediation risk is the risk resulting from residual contamination remaining onsite after remediation is completed. The receptors and potential exposure pathways for post-remediation risk are based on land use and are identical to those used for baseline risk.

Table D.1.0.1 shows the three primary categories of risk along with key assumptions used in the analysis.

**Table D.1.0.1 Primary Risk Types and Risk Assessment Assumptions**

| Risk Category | Assumptions |
|---|---|
| Baseline (No Action) | • Waste remains in tanks<br>• All tanks eventually leak to soil<br>• Potential exposure pathways include air, soil, surface water, and groundwater. |
| Remedial Actions | • TWRS operations result in air emissions and direct exposure.<br>• There would be no access to groundwater during the 100-year institutional control period. |
| Post Remediation | • Contaminants currently in soil below tanks are not in scope and are not addressed in this risk assessment<br>• Onsite disposal of treated low-activity waste (LAW) may have releases<br>• Tanks contain residual waste following remedial actions<br>• Potential exposure pathways include air, soil, surface water, and groundwater. |

The objective of this risk assessment is to support the analysis of environmental consequences by providing estimates of the following:

- Noncarcinogenic toxic effects, expressed as a hazard index (HI), attributable to each EIS alternative. The hazard index is a comparison of the estimated exposure to a chemical threshold value below which no toxic effects are expected;
- Latent cancer fatalities (LCFs) and incremental lifetime cancer risks (ILCRs) attributable to each alternative from routine operations during remedial actions. LCFs are the increases in number of cancer fatalities resulting from exposure to potential radiological carcinogens. ILCRs are the increased probability of developing cancer as a result of exposure to chemical carcinogens;
- Incremental lifetime cancer incidence attributable to post-remediation conditions for each alternative and subalternative. Incremental lifetime cancer incidence is the increased probability of an individual developing cancer over a lifetime (70 years) from exposure to potential carcinogens (both radiological and chemical);

- Risk to ecological receptors for all alternatives; and
- Carcinogenic effects attributable to each alternative from inadvertent human intrusion into residual contamination following completion of remedial actions.

## D.2.0 METHODOLOGY

Risk associated with TWRS baseline and post-remediation conditions would result from long-term exposure to contaminants. Exposure would be controlled largely by how the land is used, and thus exposure scenarios based on land use serve as the basis for estimating risk. The five exposure scenarios selected for the analysis are the Native American, residential farmer, industrial worker, recreational shoreline user, and recreational land user. The Native American scenario was developed from the Columbia River Comprehensive Impact Assessment (Napier et al. 1996), which was modified at the request of and in consultation with the potentially affected Tribes. This scenario is in its initial stages of development and has not received a complete review by the scientific community, nor has it been approved by the potentially affected Tribes. Therefore, this scenario should be considered preliminary and may have more uncertainty associated with it than the other scenarios. However, the scenario does provide a bounding assessment of the potential health effects to a Native American who might engage in both subsistence lifestyle activities (e.g., hunting, fishing, and use of a sweat lodge) and contemporary lifestyle activities (e.g., irrigated farming). The residential farmer, industrial worker, recreational shoreline user, and recreational land user scenarios are modeled after scenarios in the Hanford Site Risk Assessment Methodology (HSRAM) (DOE 1995c). HSRAM was developed by an interagency working group for risk assessment that included technical representatives from the U.S. Department of Energy (DOE), the Washington State Department of Ecology (Ecology), and the U.S. Environmental Protection Agency (EPA). For each of the five scenarios analyzed, exposure to contaminants transported in four media is considered (i.e., groundwater, soil, surface water, and air).

By contrast, risk associated with operations for the TWRS remedial action alternatives would result from a shorter duration of exposure to contaminants. Such exposure would be largely controlled by the activities and processes associated with a particular remedial alternative or subalternative.
The receptors for remediation risk are the TWRS workers, the noninvolved workers at the Hanford Site, and the public. Based on the assumptions listed in Table D.1.0.1, routine operations for the remedial action alternatives would result in atmospheric emissions of contaminants and potential direct radiation exposure from the waste. Air is the only transport medium considered.

Detailed descriptions of the methodology used are presented in Section D.2.1 for baseline and post-remediation risk and in Section D.2.2 for remedial action risk.

### D.2.1 BASELINE AND POST-REMEDIATION RISK METHODOLOGY

A modular risk assessment (MRA) methodology was developed to analyze the risk associated with baseline and post-remediation conditions. The modular approach is based on separating the four basic components of the risk assessment process (i.e., source, transport, exposure, and risk) into discrete modules that can be assessed independently and then combined. The key concepts of the modular approach include the following:

- Defining the Hanford Site as a grid of cells, each 1 kilometer (km) by 1 km (0.6 mile [mi] by 0.6 mi);
- Aggregating contaminant sources located within each cell or several cells;
- Using transported unit concentrations (i.e., concentrations based on transport of a unit concentration of each contaminant) to develop concentration estimates at various locations as source terms vary;
- Using well-defined, land-use-based exposure scenarios;
- Using unit risk factors (URFs) (i.e., risk based on exposure to a unit concentration of each contaminant) to facilitate risk estimates as source terms vary; and
- Presenting risk in graphical contour plots developed using Geographic Information System (GIS) software.

The following is an overview of the modular risk-assessment approach.

The Hanford Site was divided into small sections or cells by superimposing a grid, based on state plane coordinates (Cartesian), on a map of the Hanford Site. All source cells (i.e., cells containing tank waste and other contaminant sources from TWRS EIS alternatives) were identified and the contaminants in the individual sources were quantified for both baseline and post-remediation conditions. Data for the individual sources were then aggregated for each source cell.

As an independent step, the release and transport of a unit of concentration of each contaminant from each source cell through different media was modeled for selected time periods ranging from the present to 10,000 years into the future. This time period was chosen because it is consistent with rationale presented by EPA in 40 Code of Federal Regulations (CFR) 191 for assessment of performance of repositories for disposal of radioactive waste. Modeling predicts how a unit concentration of each contaminant moves through the environment into surrounding cells after release from the source cell. This step results in transported unit concentrations for each medium and time period of interest.

Also as an independent step, a URF was calculated based on the dose to a receptor from exposure to a unit of concentration of each contaminant under each land-use scenario. Each scenario was evaluated for all potential transport media. The resultant risk values then were calculated. The source (baseline or post-remediation) was multiplied by the transported unit concentration at the selected time to obtain the future concentration of the source in a given cell (referred to as point concentration). The point concentration then was multiplied by the URF for the given land-use scenario to obtain the risk to a receptor in that cell. This process can be described in the following general equation:

$$(\text{Risk Value}) = (\text{Source}) \cdot (\text{Unit Transport Factor}) \cdot (\text{URF})$$

In the MRA methodology, four data sets were developed for each cell. These data sets consist of the individual source data, transported unit concentrations, URFs, and risk values, which are calculated by multiplying the values in the other three data sets for a given land use. Each of these data sets was

considered a module. A computerized spreadsheet was developed for each module to facilitate storage and mathematical manipulation of the data.

In converting exposures to risk, the primary source for health effects conversion factors is the International Commission on Radiological Protection (ICRP) Publication No. 60 (ICRP 1991), which recommends values for the public of 5.0E-04 fatal cancers per rem and 1.0E-04 nonfatal cancers per rem, for a total cancer incidence of 6.0E-04 per rem. The cancer incidence calculations for chemicals and radionuclides based on EPA slope factors include fatal plus nonfatal cancers. The EPA slope factors are not based on use of a single health effects conversion factor, but consider age-specific and organ-specific health risk in estimating the slope factors. EPA suggested use of 7.3E-04 total cancers per rem (for member of the public) for those radionuclides for which slope factors are not provided (by EPA). This factor is not used for analysis.

The modules developed for this risk assessment (i.e., source, unit transport, URF, and risk) are described in more detail in the following sections. The source module is described in Section D.2.1.1 followed by the unit transport module (Section D.2.1.2) and URF module (Section D.2.1.3). The combination of these factors gives an estimate of the human health impacts as described in Section D.2.1.4.

### D.2.1.1 Source Module

The source module contains information identifying and quantifying the sources of contamination under current and post-remediation conditions. To assess risk from exposure to contaminants transported through the environment, the amount of the contaminant that would be released into the environment was determined. The amounts released, referred to as release terms, are a calculated fraction of the total contaminant inventories available for release. Release terms are developed as part of the transport modeling process and are discussed in Section D.2.1.2. Contaminant inventories available for release comprise the data tabulated in the source module and are discussed in this section. These inventories are contaminant-specific and given as either inventory amounts or concentrations.

The source module for this assessment is divided into submodules, as shown in Table D.2.1.1. For each submodule shown, contaminant inventories are compiled and tabulated for use in the risk calculation.

For post-remediation conditions, source inventories are tabulated for the contamination sources estimated to exist after remedial actions are completed. Depending on the alternative, the anticipated post-remediation sources would consist of tank residuals, in situ disposed tank waste, and engineered storage/disposal facilities. The inventories for these sources are based on engineering analyses of the remedial action alternatives provided in a set of engineering data packages prepared to support this EIS (WHC 1995c, 1995d, 1995e, 1995f, 1995g, 1995h, 1995i, 1995j, and 1995n, and Jacobs 1996). Additional discussion of current and post-remediation inventories is presented in the following sections.

Table D.2.1.1 Elements of the Source Module

| Risk Category | | Module Element | Submodule |
|---|---|---|---|
| Remediation | Tank Waste Alternatives | No Action | -Tank Farm Operations |
| | | Long-Term Management | -Construction<br>-Tank Farm Operations<br>-Evaporator Operations (2)<br>-DST Retrieval Operations |
| | | In Situ Fill and Cap | -Construction<br>-Tank Farm Operations<br>-Evaporator Operations (2)<br>-Gravel Fill Operations<br>-Closure<br>-Post-closure Monitoring and Maintenance |
| | | In Situ Vitrification | -Construction<br>-Tank Farm Operations<br>-Evaporator Operations (2)<br>-In Situ Vitrification Operations<br>-Closure<br>-Post-closure Monitoring and Maintenance |
| | | Ex Situ Intermediate Separations | -Construction<br>-Tank Farm Operations<br>-Evaporator Operations<br>-Retrieval Operations<br>-Separation and Vitrification Operations<br>-Monitoring and Maintenance<br>-Closure<br>-Post-closure Monitoring and Maintenance |
| | | Ex Situ No Separations | -Construction<br>-Tank Farm Operations<br>-Evaporator Operations<br>-Retrieval Operations<br>-Vitrification or Calcination Operations<br>-Monitoring and Maintenance<br>-Closure<br>-Post-closure Monitoring and Maintenance |

**Table D.2.1.1 Elements of the Source Module (cont'd)**

| Risk Category | | Module Element | Submodule |
|---|---|---|---|
| Remediation | Tank Waste Alternatives | Ex Situ Extensive Separations | -Construction<br>-Tank Farm Operations<br>-Evaporator Operations<br>-Retrieval Operations<br>-Separations and Vitrification Operations<br>-Monitoring and Maintenance<br>-Closure<br>-Post-closure Monitoring and Maintenance |
| | | Ex Situ/In Situ Combinations (1 and 2) | Same as in In Situ Fill and Cap and Ex Situ Intermediate Separations Alternatives |
| | | Phased Implementation | -Construction<br>-Tank Farm Operations<br>-Evaporator Operations<br>-Retrieval Operations<br>-Separation and Vitrification Operations |
| | Cesium and Strontium Capsule Alternatives | No Action | -Capsule Storage at WESF for 10 Years |
| | | Onsite Disposal | -Capsule Storage and Packaging at WESF<br>-Capsule Storage in Drywell Storage Facility |
| | | Overpack and Ship | -Capsule Storage and Packaging at WESF |
| | | Vitrify with Tank Waste | -Capsule Storage at WESF<br>-Process Capsules included in Ex Situ Intermediate Separations alternative |
| Post Remediation | Tank Waste Alternatives | No Action | Eight Source Areas (177 existing tanks) |
| | | Long-Term Management | Eight Source Areas (177 existing tanks plus 52 new tanks) |
| | | In Situ Fill and Cap | -In Situ Gravel Filled Tank Residuals (177 existing tanks) |
| | | In Situ Vitrification | -In Situ Vitrification Tank Residuals (177 existing tanks) |
| | | Ex Situ Intermediate Separations | -Tank Residuals<br>-LAW Disposal Vaults |
| | | Ex Situ No Separations | -Tank Residuals |
| | | Ex Situ Extension Separations | -Tank Residuals<br>-LAW Disposal Vaults |

Table D.2.1.1 Elements of the Source Module (cont'd)

| Risk Category | | Module Element | Submodule |
|---|---|---|---|
| Post Remediation | Tank Waste Alternatives | Ex Situ/In Situ Combinations (1 and 2) | Same type but different amounts than In Situ Fill and Cap and Ex Situ Intermediate Separations |
| | | Phased Implementation Alternative | Post Remediation not included |
| | Cesium and Strontium Capsule Alternatives | No Action Alternative | Post Remediation not included |
| | | Onsite Disposal Alternative | Indefinite Storage of Capsules at Drywell Storage Facility |
| | | Overpack and Ship Alternative | No Residuals |
| | | Vitrify with Tank Waste Alternative | No Residuals |

D.2.1.1.1 Current Tank Waste Inventories

Current tank waste inventories were obtained from a supporting document for this EIS (WHC 1995d). Tank inventories are displayed on a total tank basis only (i.e., total inventory for single-shell tanks [SSTs] and total inventory for double-shell tanks [DSTs]). Total-tank inventories are shown in Appendix A, Tables A.2.1.2 and A.2.1.3 for radionuclides and nonradioactive chemicals, respectively.

The groundwater transport modeling separated contaminant sources in the 177 tanks into eight aggregated source areas, each of which contained groupings of either SST farms or DST farms. Tank farms in the 200 West Area were grouped into three source areas, designated 1WSS, 2WSS, and 3WDS (Figure D.2.1.1). Tank farms in the 200 East Area were grouped into five source areas, designated 1ESS, 2ESS, 3EDS, 4ESS, and 5EDS (Figure D.2.1.2). The groupings were based on tank farm location, tank type (SST or DST), and groundwater flow direction.

To generate inventories for the eight source areas, computer spreadsheets were developed from the data used to generate the tables from (WHC 1995d and Jacobs 1996). The spreadsheets contained farm-by-farm inventories for SSTs and tank-by-tank inventories for DSTs, from which inventories were allocated among the eight source areas.

Quantities of radionuclides are dependent on the time period of interest because of the spontaneous decay of radionuclides. The quantities of radionuclides were available for SSTs for a range of dates, including the year 1995. However, the concentration of radionuclides for DSTs was available only for the year 1999. Because the year 1995 is the designated starting time ($T_0$) for this risk assessment, a calculation was used to convert the DST inventory quantities to a December 31, 1995 date.

Figure D.2.1.1 Source Area Locations, 200 West Area

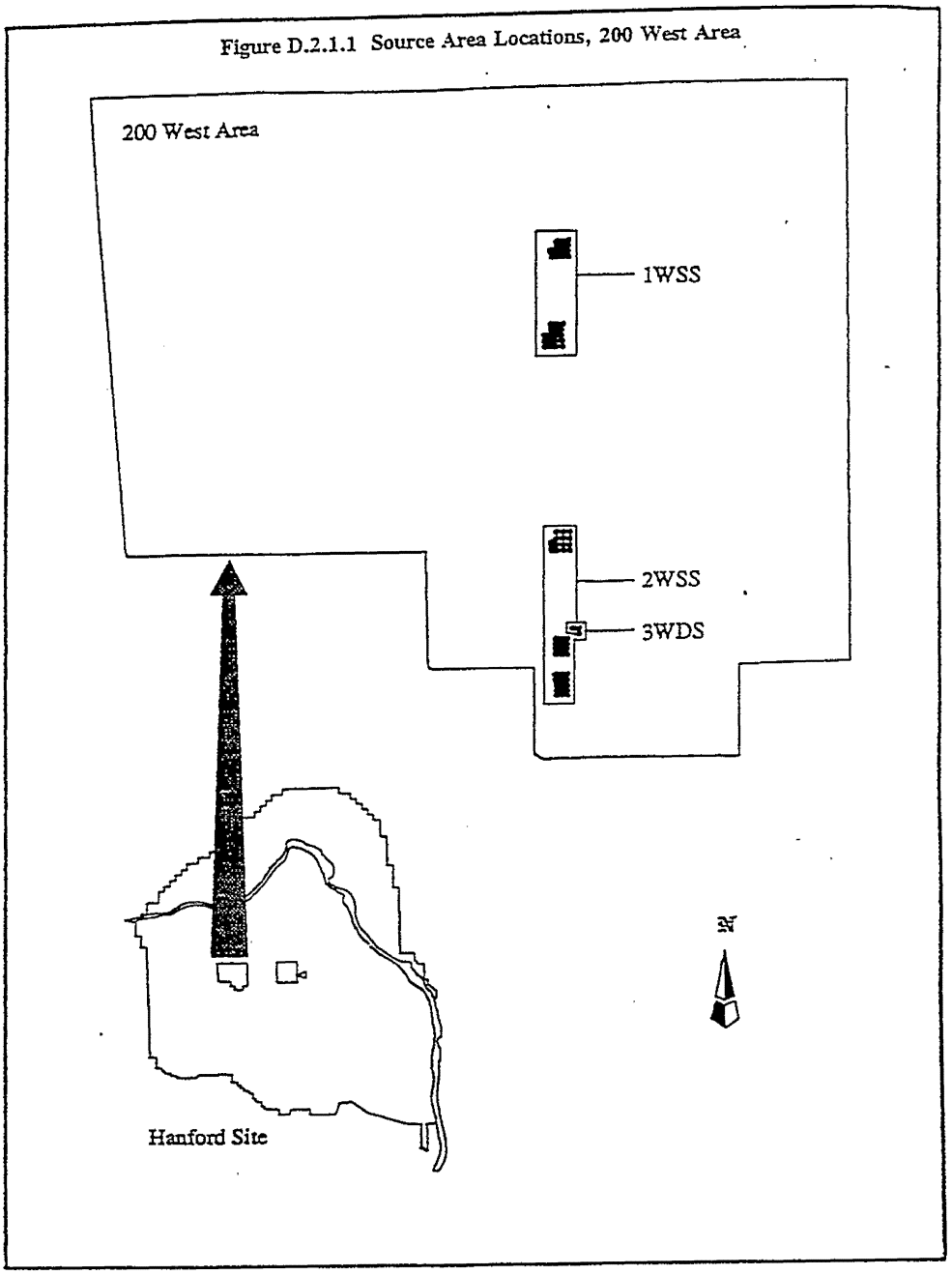
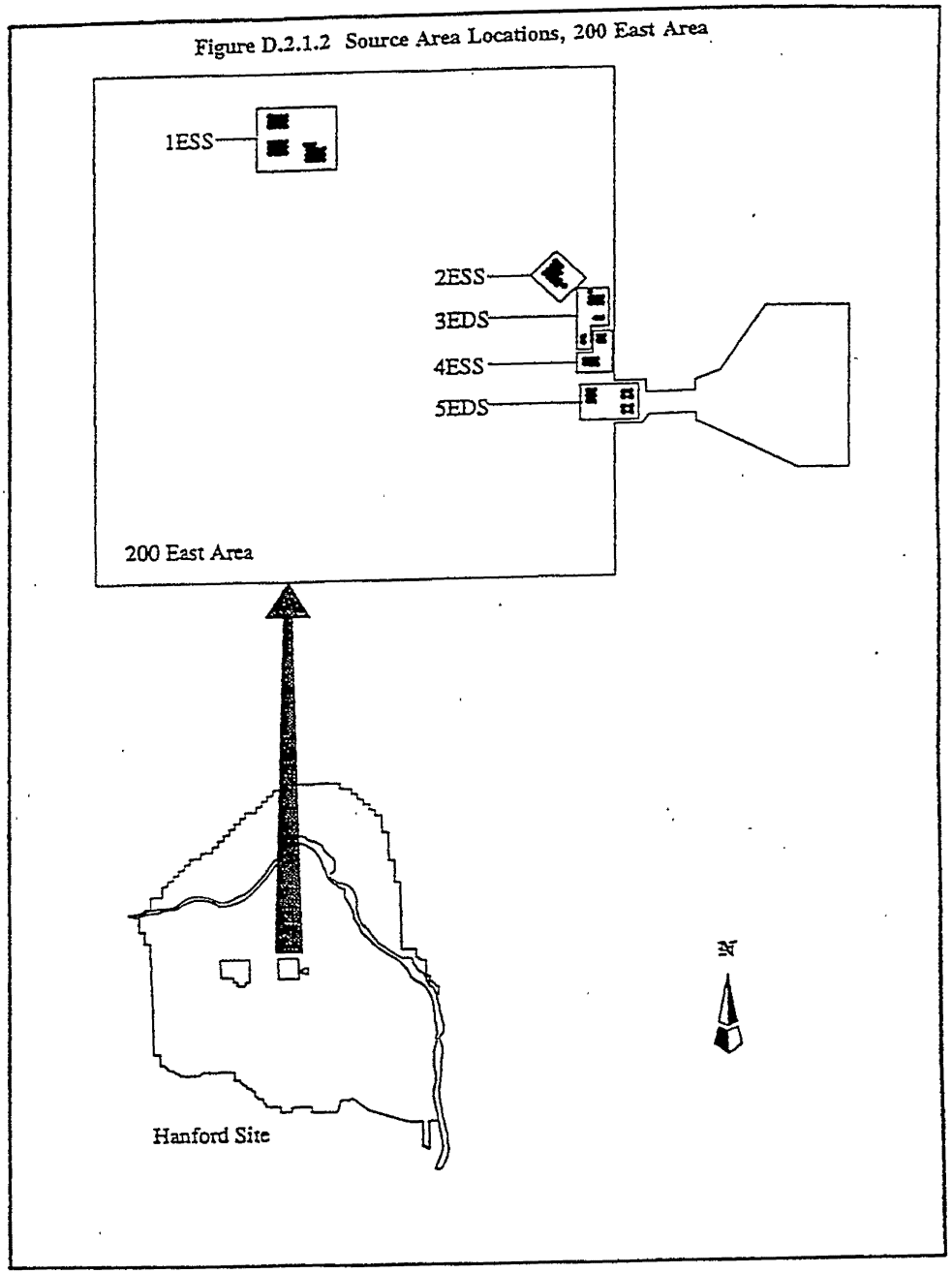


Figure D.2.1.2 Source Area Locations, 200 East Area



The calculation was performed using the following equation:

$$I_{(1999)} = I_{(1995)} e^{-\lambda t}$$

Where:

$I_{(1995)}$ = Inventory year 1995
$I_{(1999)}$ = Inventory year 1999
$\lambda$ = Decay constant = $\ln 2/T_{1/2}$
t = Decay duration (1999 - 1995 = 4 years)
$T_{1/2}$ = Radionuclide half-life

The short-lived progeny radionuclides were assumed to be in equilibrium with the parents.

**Single-Shell Tanks**

Current inventories for the five source areas containing SSTs are shown in Volume Two, Appendix A, Tables A.2.1.5 and A.2.1.6. Table A.2.1.5 shows the aggregated inventory of nonradioactive chemicals. Table A.2.1.6 shows the aggregated inventory of radionuclides for December 31, 1995 (totals for December 31, 1999 are also included for comparison purposes). The aggregated inventories were generated by summing the farm-by-farm inventories for the SST farms in each source area.

**Double-Shell Tanks**

Current inventories for the three aggregated source areas containing DSTs are shown in Volume Two, Appendix A, Tables A.2.1.7 and A.2.1.8. Table A.2.1.7 shows the aggregated inventory of nonradioactive chemicals. Table A.2.1.8 shows the aggregated inventory of radionuclides for December 31, 1995. The inventories were generated by summing tank-by-tank inventories for the DST in each source area.

**Miscellaneous Underground Storage Tanks**

There are approximately 40 inactive and 20 active MUSTs associated with the tank farms. These MUSTs contain small quantities of mixed radioactive and chemical waste. They contain less than one-half of one percent of the total tank farm inventory. Additional information on the MUST inventory can be found in Volume Two, Appendix A.

D.2.1.1.2 Current Cesium and Strontium Capsule Inventories

Radioactive decay calculations for Cs/Sr capsules stored at the Waste Encapsulation and Storage Facility (WESF) in the 200 East Area of the Hanford Site result in the following quantities:

- Cs: 1,328 capsules, 53.2 million curies (MCi) total inventory; and
- Sr: 601 capsules, 23.1 MCi total inventory.

D.2.1.1.3 Post-Remediation Inventories

The contamination sources anticipated to exist after remediation vary according to each alternative. These sources were identified and quantified based on engineering data packages developed by the Site

Management and Operations contractor and the TWRS EIS contractor (WHC 1995c, d, e, f, g, h, j, n, and Jacobs 1996). Depending on the alternative, the post-remediation sources would consist of tank residuals, in situ disposed tank waste, and engineered storage/disposal facilities. Contaminant inventories were developed from the engineering data packages, and entered into the source module for each of these post-remediation sources.

Tables displaying the post-remediation inventories by source for each alternative are presented in Volume Four, Appendix F, Groundwater Modeling.

### D.2.1.2 Transport Module

Transport refers to the movement of contaminants in the environment from the source location to the receptor. The transport analysis redistributes the contaminants at locations within and outside the grid cell sources. Transport of contaminants was modeled within the Hanford Site boundary and within an 80-km (50-mi) radius of TWRS facilities.

Development of release terms (i.e., the portion of current or post-remediation inventories in the source module that are estimated to be released from the source) is conducted as part of the transport analyses. Further discussions of the method for developing release terms, along with tables displaying the release terms used for each source, are provided in Volume Four, Appendix F for groundwater releases and in Volume Five, Appendix G for air releases.

Developing transport parameters for contaminants of concern in soil, groundwater, surface water, and air also is conducted during the transport analyses. Transport parameters consist of the contaminant- and site-specific data required to model the atmospheric, groundwater, and surface water transport of contaminants within and outside the boundaries of the Hanford Site. Transport parameters and radionuclide decay estimates result in new media concentrations specific to the location and time period of interest. Transport parameters are discussed further in Volume Four, Appendix F for groundwater transport and in Volume Five, Appendix G for air transport.

Transport modeling for this assessment was conducted as a unit transport analysis. This analysis involved modeling the transport of a single unit of contaminant from TWRS sources through the environment (groundwater, soil, air, and surface water) at different times in the future. Any cells that contain contaminants at the present time are set as the location of a unit inventory or concentration. A unit of contaminant is transported from one medium to other media and from a location (cell) to other locations, as time progresses, using a transport code. The transported unit concentration for each medium at selected modeling time periods (i.e., 300, 500, 2,500, 5,000, and 10,000 years in the future) is estimated and tabulated in the transport module. Point concentrations, which are the future concentrations at a given receptor originating from a particular source, are obtained by multiplying the current and post-remediation inventories by the transported unit concentrations at selected time periods.

### D.2.1.3 Exposure Module

Five exposure scenarios were used as the basis for the unit risk calculations: Native American, residential farmer, industrial worker, recreational shoreline user, and recreational land user (DOE 1995c). The Native American scenario represents potential use of the land for a subsistence Native American lifestyle as well as contemporary lifestyle activities such as irrigated agriculture. This scenario includes subsistence activities such as hunting, fishing, and gathering of plants and materials. The residential farmer scenario represents potential use of the land for residential and agricultural production. This scenario includes producing and consuming animal, vegetable, and fruit products. The industrial worker scenario involves mainly indoor activities that include consumption of groundwater, although outdoor activities (e.g., soil contact) also are included. The recreational shoreline user was assumed only to have access to the Hanford Reach of the Columbia River. The recreational land user was assumed to be a random Sitewide land user of the Hanford Site, excluding the Columbia River shoreline. The exposure scenarios were evaluated for five transport media, as appropriate: 1) soil defined per unit mass; 2) soil defined per unit area; 3) groundwater from wells; 4) surface water (including shoreline sediments); and 5) air. Soil was evaluated by mass to account for contaminants transported through the soil, and by area to account for contaminants deposited onto the soil from atmospheric transport.

The exposure module for human receptors is based on land-use patterns. For each grid cell, the exposure pathway and receptors associated with that cell were identified. This was done by activating or deactivating transport media within the cell. For example, by activating the residential farmer scenario, groundwater would be used to irrigate crops that are consumed directly by the surrounding population, and by milk- and meat-producing cattle that are consumed by the surrounding population. By activating the recreational land-user scenario, the groundwater medium would not be included because the recreational land user is assumed not to be a resident of the land and is assumed not to consume water from the aquifer.

The URF is the risk associated with exposure to one concentration unit (e.g., risk per pCi/g for radionuclides in soil, risk per mg/kg for chemicals in soil, risk per pCi/L for radionuclides in water) of a given contaminant for a human exposure scenario. The URFs were developed for each individual exposure pathway (i.e., ingestion, inhalation, and direct contact) for each scenario. Slope factors developed by EPA (Integrated Risk Information System [IRIS] 1995 and Health Effects Assessment Summary Tables [HEAST] 1995) were applied. The exposure module contains a set of URF tables for each exposure scenario and receptor. The URF values presented in the tables of this report were based on the summation of all relevant exposure pathways. For example, the residential groundwater URF values would include ingestion of drinking water, dermal contact while showering, incidental ingestion while showering, and inhalation of volatile emissions from domestic use.

The calculation of URFs is simplified by dividing the equations into two main terms, one containing parameters independent of contaminant properties (summary intake factors) and the other containing parameters dependent on contaminant properties (contaminant-specific parameters). The following sections describe methods used to calculate each of these types of parameters; Section D.2.1.3.1 -

Summary Intake Factors and Section D.2.1.3.2 - Contaminant-Specific Parameters. The use of these terms to estimate the URFs then is described in Section D.2.1.3.3 - Unit Risk Factors.

D.2.1.3.1 Summary Intake Factors

Exposure scenarios are described in terms of receptors, exposure media or pathways, and summary intake factor (SIF) values.

- The receptor is the type of human exposed in terms of age, weight, and exposure duration and other factors. Five receptors were modeled: Native American, residential farmer, industrial worker, recreational shoreline user, and recreational land user. Except where noted, receptor parameters used in the analysis are consistent with those established in HSRAM (DOE 1995c).
- The exposure pathway is the medium (e.g., groundwater) and activity (e.g., drinking) that would result in an exposure.
- The SIF value is the amount of exposure to the receptor through the media of interest. The SIF values were derived for each of three toxicity types: NC - noncarcinogenic chemicals, CC - carcinogenic chemicals, and RA - radionuclides.

The SIF concept is presented in HSRAM (DOE 1995c). The concept of SIF values involves structuring the intake equations for each exposure pathway so that contaminant-independent parameters are separated from the contaminant-specific parameters and the initial media concentration. Each exposure pathway model then can be described as the product of three factors: 1) a media concentration, 2) an SIF independent of the specific contaminants, and 3) a factor composed of all contaminant-specific parameters. The equation is as follows:

$$\text{Intake or Exposure} = (C_{iym}) \cdot (PF_{mix}) \cdot (SIF_{smyx}) \quad (1)$$

Where:

| | | |
|---|---|---|
| Intake | = | Average daily intake of chemical contaminants (mg/kg · day) |
| Exposure | = | Total intake or exposure received over the exposure duration (pCi or hour) |
| $C_{iym}$ | = | Concentration of contaminant i, of type y, in medium m (mg or pCi per unit quantity of medium liter, kilogram, $m^3$, or $m^2$) |
| $PF_{mix}$ | = | Contaminant-specific factor for medium m, contaminant i, and exposure pathway x (Strenge-Chamberlain 1994) (units specific to analysis) |
| $SIF_{smyx}$ | = | Summary intake factor for scenario s, medium m, contaminant type y, and exposure pathway x (units specific to analysis) |

The SIF values were evaluated for each toxicity type (i.e., NC, CC, and RA). The appropriate SIF value was used for each contaminant for the exposure pathway of concern. The methodology for calculating SIF values is described by Strenge and Chamberlain (Strenge-Chamberlain 1994). The SIF

values for the five exposure scenarios are described in more detail in the following sections. This is followed by a discussion of the contaminant-specific factors.

Following loss of institutional controls (assumed to be 100 years), the tank contents would be released to subsurface soils and be available for transport to groundwater from infiltration of rainwater and percolation through the soil column. Based on the existing depth of the tanks, the resulting soil contamination would be below the maximum depth of soil likely to be contacted by all potential receptors, with the exception of the intruder scenario. Consequently, the soil medium was not evaluated as a post-remediation transport mechanism for any of the alternatives because the soil contamination was not evaluated for any of the alternatives. Therefore, groundwater is the only post-remediation transport mechanism evaluated for all of the alternatives.

**Native American Scenario**

This scenario represents exposures received during a 70-year lifetime by a Native American who engages in both traditional lifestyle activities (e.g., hunting, fishing, and using a sweat lodge) and contemporary lifestyle activities (e.g., irrigated farming). The individual is assumed to spend 365 days per year on the Site over a 70-year lifetime. Some activities are assumed to continue year-round while others are limited by climate (e.g., frost-free days).

Pathways for this scenario include those defined for the residential farmer scenario in HSRAM, plus additional pathways representing activities unique to the Native American subsistence lifestyle (e.g., exposures in a sweat lodge). A composite adult was used as the receptor for some of the pathways. The composite adult was evaluated using child parameters for 6 years and adult parameters for 64 years. The child's body weight was assumed to be 16 kilograms (kg) (35 pounds [lbs]), and the adult body weight 70 kg (150 lbs). This approach was used for all contaminant types. Table D.2.1.2 presents the pathways included in the Native American scenario. The exposure parameters for each pathway are presented in Table D.2.1.3. The SIF values for each pathway are presented in Table D.2.1.4.

The ingestion rates of native foods are based on a combination of EPA-suggested intake rates (EPA 1989b), intake rates used for the Columbia River Comprehensive Impact Assessment (Napier et al. 1996), and data provided by the affected Tribes. Ingestion of animal organs and wild bird meat was accounted for by increasing the total meat intake rate. Animal organs were assumed to have contaminant concentrations 10 times the concentration in other animal tissue, and the organ intake rate was assumed to be 10 percent of the intake rate of other animal tissue. Animal meat plus organ intake was assumed to be 300 g/day. Intake of upland game birds and waterfowl was assumed to be 9 g/day and 35 g/day, respectively. The total meat ingestion rate was thus assumed to be 341 g/day. Ingestion of fish organs was accounted for by increasing the fish muscle intake rate in a manner similar to that for ingestion of animal organs. Fish organs were assumed to have contaminant concentrations 10 times the concentration in fish muscle, and the fish organ ingestion rate was assumed to be 10 percent of the fish muscle intake. The total fish ingestion rate was assumed to be 1,080 g/day.

This scenario, by incorporating the subsistence lifestyle activities and native food ingestion rates as described above, results in exposures that are approximately five times higher than the exposures for the residential farmer scenario.

Table D.2.1.2 Exposure Pathways Included in Native American Scenario

| Medium | Exposure Pathways | Chemicals | Radionuclides |
|---|---|---|---|
| Soil (mass) | Soil ingestion | Yes | Yes |
| | Soil dermal absorption | Yes | Yes |
| | Resuspended-soil inhalation | Yes | Yes |
| | External ground dose | No | Yes |
| | Fruit ingestion | Yes | Yes |
| | Vegetable ingestion | Yes | Yes |
| | Meat ingestion | Yes | Yes |
| | Milk ingestion | Yes | Yes |
| | Animal organ ingestion | Yes (in Meat) | Yes (in Meat) |
| | Upland Birds | Yes (in Meat) | Yes (in Meat) |
| | Waterfowl | Yes (in Meat) | Yes (in Meat) |
| | Wild bird eggs | No | No |
| Soil (area) | Soil ingestion | Yes | Yes |
| | Soil dermal absorption | Yes | Yes |
| | Resuspended-soil inhalation | Yes | Yes |
| | External ground dose | No | Yes |
| | Fruit ingestion | Yes | Yes |
| | Vegetable ingestion | Yes | Yes |
| | Meat ingestion | Yes | Yes |
| | Milk ingestion | Yes | Yes |
| | Animal organ ingestion | Yes (in Meat) | Yes (in Meat) |
| | Upland Birds | Yes (in Meat) | Yes (in Meat) |
| | Waterfowl | Yes (in Meat) | Yes (in Meat) |
| | Wild bird eggs | No | No |
| Air | Inhalation | Yes | Yes |
| | External air dose | No | Yes |
| | Fruit ingestion | Yes | Yes |
| | Vegetable ingestion | Yes | Yes |
| | Meat ingestion | Yes | Yes |
| | Milk ingestion | Yes | Yes |
| | Animal organ ingestion | Yes (in Meat) | Yes (in Meat) |
| | Upland Birds | Yes (in Meat) | Yes (in Meat) |
| | Waterfowl | Yes (in Meat) | Yes (in Meat) |
| | Wild bird eggs | No | No |

Table D.2.1.2 Exposure Pathways Included in Native American Scenario (cont'd)

| Medium | Exposure Pathways | Chemicals | Radionuclides |
|---|---|---|---|
| Groundwater | Drinking water ingestion | Yes | Yes |
| | Shower dermal absorption | Yes | Yes |
| | Indoor inhalation | Yes | Rn-222 Only |
| | Sweat lodge inhalation | Yes | Yes |
| | Sweat lodge dermal absorption | Yes | Yes |
| | Fruit ingestion | Yes | Yes |
| | Vegetable ingestion | Yes | Yes |
| | Meat ingestion | Yes | Yes |
| | Milk ingestion | Yes | Yes |
| | Animal organ ingestion | Yes (in Meat) | Yes (in Meat) |
| | Upland Birds | Yes (in Meat) | Yes (in Meat) |
| | Waterfowl | Yes (in Meat) | Yes (in Meat) |
| | Wild bird eggs | No | No |
| | Saturated soil ingestion | Yes (SL values) | Yes (SL values) |
| | Saturated soil dermal absorption | Yes (SL values) | Yes (SL values) |
| | Saturated soil external exposure | No | Yes (SL values) |
| | Semi-aquatic plants | Yes (SL values) | Yes (SL values) |
| | Fish | No | No |
| | Fish organ ingestion | No | No |
| Surface Water | Drinking water ingestion | Yes | Yes |
| | Swimming dermal | Yes | Yes |
| | Swimming ingestion | Yes | Yes |
| | Swimming external | No | Yes |
| | Shoreline dermal | Yes | Yes |
| | Shoreline ingestion | Yes | Yes |
| | Boating external | No | Yes |
| | Shoreline external | No | Yes |
| | Fish ingestion | Yes | Yes |
| | Fish organ ingestion | Yes (in Fish) | Yes (in Fish) |
| | Meat ingestion | Yes | Yes |
| | Milk ingestion | Yes | Yes |
| | Animal organ ingestion | Yes (in Meat) | Yes (in Meat) |
| | Upland Birds | Yes (in Meat) | Yes (in Meat) |
| | Waterfowl | Yes (in Meat) | Yes (in Meat) |
| | Wild bird eggs | No | No |
| | Indoor inhalation | Yes | Rn-222 Only |

Table D.2.1.3 Native American Scenario Exposure Factors

| Pathway | | Exposure Parameters | | | | | |
|---|---|---|---|---|---|---|---|
| Media | Exposure Route | Intake/Contact Rate | Exposure Frequency (d/yr) | Exposure Duration (yr) | Body Weight (kg) | Averaging Time (yr) | Other Factors |
| Soil (mass) | Ingestion | 200 mg/d (soil) | 365 | 6 (child) | 16 (child) | 6 | |
| | | 200 mg/d (soil) | 365 | 64 (adult) | 70 (adult) | 70 | |
| | | 330 g/d (fruit) | 365 | 70 | 70 (adult) | 70 | |
| | | 330 g/d (vegetables) | 365 | 70 | 70 (adult) | 70 | |
| | | 341 g/d (meat) | 365 | 70 | 70 (adult) | 70 | |
| | | 0.6 L/d (milk) | 365 | 70 | 70 (adult) | 70 | |
| | Dermal | 1 contact event/day | 365 | 6 (child) | 16 (child) | 6 | 2,500 $cm^2$ (skin surface area - child) 5,000 $cm^2$ (skin surface area - adult) |
| | | 1 $mg/cm^2$ (soil adherence factor) | 365 | 64 (adult) | 70 (adult) | 70 | |
| | Inhalation | 15 $m^3$/d (child) | 365 | 6 (child) | 16 (child) | 6 | 100 $\mu g/m^3$ (soil/air mass loading) |
| | | 30 $m^3$/d (adult) | 365 | 64 (adult) | 70 (adult) | 70 | |
| | External (radio-nuclides) | 24 hr/d | 365 | 70 | NA | NA | 0.8 (shielding factor) |
| Soil (area) | Ingestion | 200 mg/d (soil) | 365 | 6 (child) | 16 (child) | 6 | |
| | | 200 mg/d (soil) | 365 | 64 (adult) | 70 (adult) | 70 | |
| | | 330 g/d (fruit) | 365 | 70 | 70 (adult) | 70 | |
| | | 330 g/d (vegetables) | 365 | 70 | 70 (adult) | 70 | |
| | | 341 g/d (meat) | 365 | 70 | 70 (adult) | 70 | |
| | | 0.6 L/d (milk) | 365 | 70 | 70 (adult) | 70 | |
| | Dermal | 1 contact event/day | 365 | 6 (child) | 16 (child) | 6 | 2,500 $cm^2$ (skin surface area - child) 5,000 $cm^2$ (skin surface area - adult) |
| | | 1 $mg/cm^2$ (soil adherence factor) | 365 | 64 (adult) | 70 (adult) | 70 | |
| | Inhalation | 15 $m^3$/d (child) | 365 | 6 (child) | 16 (child) | 6 | 100 $\mu g/m^3$ (soil/air mass loading) |
| | | 30 $m^3$/d (adult) | 365 | 64 (adult) | 70 (adult) | 70 | |
| | External (radio-nuclides) | 24 hr/d | 365 | 70 | NA | NA | 0.8 (shielding factor) |

Table D.2.1.3 Native American Scenario Exposure Factors (cont'd)

| Pathway | | Exposure Parameters | | | | | |
|---|---|---|---|---|---|---|---|
| Media | Exposure Route | Intake/Contact Rate | Exposure Frequency (d/yr) | Exposure Duration (yr) | Body Weight (kg) | Averaging Time (yr) | Other Factors |
| Air | Inhalation | 15 $m^3$/d (child) | 365 | 6 (child) | 16 (child) | 6 | |
| | | 30 $m^3$/d (adult) | 365 | 64 (adult) | 70 (adult) | 70 | |
| | Ingestion | 330 g/d (fruit) | 365 | 70 | 70 | 70 | |
| | | 330 g/d (vegetables) | 365 | 70 | 70 | 70 | |
| | | 341 g/d (meat) | 365 | 70 | 70 | 70 | |
| | | 0.6 L/d (milk) | 365 | 70 | 70 | 70 | |
| | External (radio-nuclides) | 24 hr/d (air dose) | 365 | 70 | NA | NA | 1.0 (shielding factor) |
| Ground water | Ingestion | 1.5 L/d (child) | 365 | 6 (child) | 16 (child | 6 | |
| | | 3.0 L/d (adult) | 365 | 64 (adult) | 70 (adult) | 70 | |
| | | 200 mg/d (child: saturated soil) | 365 | 6 (child) | 16 (child) | 6 | 0.4 L water/kg dry soil |
| | | | 365 | 64 (adult) | 70 (adult) | 70 | |
| | | 200 mg/d (adult: saturated soil) | 365 | 70 | 70 (adult) | 70 | |
| | | 330 g/d (vegetable ingestion: saturated soil) | 365 | 70 | 70 (adult) | 70 | 0.4 L water/kg dry soil |
| | | 330 g/d (fruit) | 365 | 70 | 70 (adult) | 70 | 0.4 L water/kg dry soil |
| | | 330 g/d (vegetables) | 365 | 70 | 70 (adult) | 70 | |
| | | 341 g/d (meat) | 365 | 70 | 70 (adult) | 70 | |
| | | 0.6 L/d (milk) | 365 | 70 | 70 (adult) | 70 | |
| | Dermal | 1 hr/d (water) | 365 | 70 | 70 (adult) | 70 | 20,000 $cm^2$ (skin surface area) |
| | | 1 contact event/d, (saturated soil) | 365 | 6 (child) | 16 (child) | 6 | 2,500 $cm^2$ (skin surface area - child) |
| | | 1 mg/$cm^2$ (soil adherence factor) | 365 | 64 (adult) | 70 (adult) | 70 | 5,000 $cm^2$ (skin surface area - adult) 0.4 L water/kg dry soil |

Table D.2.1.3 Native American Scenario Exposure Factors (cont'd)

| Pathway | | Exposure Parameters | | | | | |
|---|---|---|---|---|---|---|---|
| Media | Exposure Route | Intake/Contact Rate | Exposure Frequency (d/yr) | Exposure Duration (yr) | Body Weight (kg) | Averaging Time (yr) | Other Factors |
| | Inhalation | 15 $m^3$/d (indoor inhalation) | 365 | 70 | 70 | 70 | 0.5 L/$m^3$ (indoor air VOC volatilization factor - VOCs) 2.5 L/$m^3$ (VOCs volatilization factor), 0.3 L/$m^3$ (non-volatile emission factor) |
| | | 1 hr/d, 15 $m^3$/d (sweat lodge) | 365 | 70 | 70 | 70 | |
| | External (radio-nuclides) | 12 hr/d (saturated soil) | 365 | 70 | 70 | 70 | 0.4 L water/kg dry soil (soil water content) |
| Surface water | Ingestion | 1.5 L/d (water: child) | 365 | 6 (child) | 16 (child) | 6 | |
| | | | 365 | 64 (adult) | 70 (adult) | 70 | |
| | | 3.0 L/d (water: adult) | 365 | 70 | 70 (adult) | 70 | |
| | | | 365 | 70 | 70 (adult) | 70 | |
| | | 1080 g/d (fish) | 365 | 70 | 70 (adult) | 70 | |
| | | 330 g/d (fruit) | 270 | 6 (child) | 16 (adult) | 6 | |
| | | 330 g/d (vegetables) | 270 | 64 (adult) | 70 (adult) | 70 | |
| | | 341 g/d (meat) | 270 | 70 | 70 (adult) | 70 | |
| | | 0.6 L/d (milk) | 270 | 70 | 70 (adult) | 70 | |
| | | 200 mg/d (child: sediment) | 270 | 6 | 16 (child) | 6 | |
| | | 200 mg/d (adult: sediment) | 270 | 70 | 70 (adult) | 70 | |
| | Dermal | 2.6 hr/d (swimming) | 70 | 70 | 70 (adult) | 70 | 20,000 $cm^2$ (skin surface area) 2,500 $cm^2$ (skin surface area - child) 5,000 $cm^2$ (skin surface area - adult) |
| | | 2.6 hr/d (child: sediment) | 270 | 6 (child) | 16 (child) | 6 | |
| | | 2.6 hr/d (adult: sediment) | 270 | 64 (adult) | 70 (adult) | 70 | |
| | | 1 mg/$cm^2$ (sediment adherence factor) | | | | | |

Table D.2.1.3 Native American Scenario Exposure Factors (cont'd)

| Pathway | | Exposure Parameters | | | | | |
|---|---|---|---|---|---|---|---|
| Media | Exposure Route | Intake/Contact Rate | Exposure Frequency (d/yr) | Exposure Duration (yr) | Body Weight (kg) | Averaging Time (yr) | Other Factors |
| | Inhalation | 15 $m^3$/d (indoor inhalation) | 365 | 70 | 70 | 70 | 0.5 L/$m^3$ (indoor air VOC volatilization factor - VOCs) |
| | External (radio-nuclides) | 2.6 hr/d (swimming) | 70 | 70 | 70 | 70 | - 0.5 (geometry correction) 0.2 (geometry correction) |
| | | 2.6 hr/d (boating) | 70 | 70 | 70 | 70 | |
| | | 12 hr/d (shoreline) | 270 | 70 | 70 | 70 | |

Table D.2.1.4 Native American Scenario Summary Intake Factors

| Exposure Pathways | Type | SIF Value | Units |
|---|---|---|---|
| Soil (mass) | | | |
| Soil: Ingestion | NC [1] | 1.33E-5 | kg/(kg d) |
| | CC | 3.68E-6 | kg/(kg d) |
| | RA | 5.11E-0 | kg |
| Soil: Dermal Absorption | NC[1] | 1.99E-4 | kg/(kg d) |
| | CC | 7.87E-5 | kg/(kg d) |
| | RA | 1.28E+2 | kg |
| Soil: Resuspension and Inhalation | NC [1] | 1.20E-7 | kg/(kg d) |
| | CC | 4.72E-8 | kg/(kg d) |
| | RA | 7.67E-2 | kg |
| Soil: External | RA | 4.91E+5 | h |
| Fruit Ingestion | NC | 4.71E-3 | kg/(kg d) |
| | CC | 4.71E-3 | kg/(kg d) |
| | RA | 8.44E+3 | kg |
| Vegetable Ingestion | NC | 4.71E-3 | kg/(kg d) |
| | CC | 4.71E-3 | kg/(kg d) |
| | RA | 8.44E+3 | kg |
| Meat Ingestion | NC | 4.87E-3 | kg/(kg d) |
| | CC | 4.87E-3 | kg/(kg d) |
| | RA | 8.72E+3 | kg |
| Milk Ingestion | NC | 8.57E-3 | L/(kg d) |
| | CC | 8.57E-3 | L/(kg d) |
| | RA | 1.53E+4 | L |

Table D.2.1.4 Native American Scenario Summary Intake Factors (cont'd)

| Exposure Pathways | Type | SIF Value | Units |
|---|---|---|---|
| Soil (area) | | | |
| Soil: Ingestion | NC [1] | 2.22E-7 | kg/(kg d) |
| | CC | 6.14E-8 | kg/(kg d) |
| | RA | 8.52E-2 | kg |
| Soil: Dermal Absorption | NC [1] | 3.32E-6 | kg/(kg d) |
| | CC | 1.31E-6 | kg/(kg d) |
| | RA | 2.13E-0 | kg |
| Soil: Resuspension and Inhalation | NC [1] | 1.99E-9 | kg/(kg d) |
| | CC | 7.89E-10 | kg/(kg d) |
| | RA | 1.28E-3 | kg |
| Soil: External | RA | 4.91E+5 | h |
| Fruit Ingestion | NC | 4.71E-3 | kg/(kg d) |
| | CC | 4.71E-3 | kg/(kg d) |
| | RA | 8.44E+3 | kg |
| Vegetable Ingestion | NC | 4.71E-3 | kg/(kg d) |
| | CC | 4.71E-3 | kg/(kg d) |
| | RA | 8.44E+3 | kg |
| Meat Ingestion | NC | 4.87E-3 | kg/(kg d) |
| | CC | 4.87E-3 | kg/(kg d) |
| | RA | 8.72E+3 | kg |
| Milk Ingestion | NC | 8.57E-3 | L/(kg d) |
| | CC | 8.57E-3 | L/(kg d) |
| | RA | 1.53E+4 | L |
| Air | | | |
| Inhalation | NC | 4.72E-1 | $m^3$/(kg d) |
| | CC | 4.72E-1 | $m^3$/(kg d) |
| | RA | 7.67E+5 | $m^3$ |
| External Air Dose | RA | 6.14E+5 | h |
| Fruit Ingestion | NC | 4.71E-3 | kg/(kg d) |
| | CC | 4.71E-3 | kg/(kg d) |
| | RA | 8.44E+3 | kg |
| Vegetable Ingestion | NC | 4.71E-3 | kg/(kg d) |
| | CC | 4.71E-3 | kg/(kg d) |
| | RA | 8.44E+3 | kg |
| Meat Ingestion | NC | 4.87E-3 | kg/(kg d) |
| | CC | 4.87E-3 | kg/(kg d) |
| | RA | 8.72E+3 | kg |
| Milk Ingestion | NC | 8.57E-3 | L/(kg d) |
| | CC | 8.57E-3 | L/(kg d) |
| | RA | 1.53E+4 | L |

Table D.2.1.4 Native American Scenario Summary Intake Factors (cont'd)

| Exposure Pathways | Type | SIF Value | Units |
|---|---|---|---|
| Groundwater | | | |
| Water Ingestion | NC [1] | 1.20E-1 | L/(kg d) |
| | CC | 4.72E-2 | L/(kg d) |
| | RA | 7.67E+4 | L |
| Shower: Dermal Absorption | NC | 2.86E-1 | L/(kg d) |
| | CC | 2.86E-1 | L/(kg d) |
| | RA | 5.11E+5 | L |
| Water Dermal Contact (Sweat Lodge) | NC | 2.86E-1 | L/(kg d) |
| | CC | 2.86E-1 | L/(kg d) |
| | RA | 5.11E+5 | L |
| Water VOC Inhalation (domestic water use) | NC | 1.07E-1 | L/(kg d |
| | CC | 1.07E-1 | L/(kg d) |
| | RA | 3.84E+4 | L |
| Water Contaminant Inhalation (sweat lodge) | NC | 1.79E-2 | L/(kg d) |
| | CC | 1.79E-2 | L/(kg d) |
| | RA | 3.20E+4 | L |
| Fruit Ingestion | NC | 4.71E-3 | kg/(kg d) |
| | CC | 4.71E-3 | kg/(kg d) |
| | RA | 8.44E+3 | kg |
| Vegetable Ingestion | NC | 4.71E-3 | kg/(kg d) |
| | CC | 4.71E-3 | kg/(kg d) |
| | RA | 8.44E+3 | kg |
| Meat Ingestion | NC | 4.87E-3 | kg/(kg d) |
| | CC | 4.87E-3 | kg/(kg d) |
| | RA | 8.72E+3 | kg |
| Milk Ingestion | NC | 8.57E-3 | L/(kg d) |
| | CC | 8.57E-3 | L/(kg d) |
| | RA | 1.53E+4 | L |
| Surface Water | | | |
| Water Ingestion | NC [1] | 1.20E-1 | L/(kg d) |
| | CC | 4.72E-2 | L/(kg d) |
| | RA | 7.67E+4 | L |
| Water VOC Inhalation | NC | 2.06E-2 | L/(kg d) |
| | CC | 2.06E-2 | L/(kg d) |
| | RA | 7.36E+3 | L |
| Swimming: Dermal Absorption | NC | 1.43E-1 | L/(kg d) |
| | CC | 1.43E-1 | L/(kg d) |
| | RA | 2.56E+5 | L |
| Swimming: Water Ingestion | NC | 3.57E-4 | L/(kg d) |
| | CC | 3.57E-4 | L/(kg d) |
| | RA | 6.38E+2 | L |

Table D.2.1.4 Native American Scenario Summary Intake Factors (cont'd)

| Exposure Pathways | Type | SIF Value | Units |
|---|---|---|---|
| Swimming: External | RA | 1.28E+4 | h |
| Shoreline: Dermal Absorption | NC [1] | 1.47E-4 | L/(kg d) |
| | CC | 5.82E-5 | L/(kg d) |
| | RA | 9.45E+1 | L |
| Shoreline: Sediment Ingestion | NC [1] | 9.87E-6 | L/(kg d) |
| | CC | 2.72E-6 | L/(kg d) |
| | RA | 3.79E+0 | L |
| Shoreline: External | RA | 4.54E+4 | h |
| Boating: External | RA | 6.38E+3 | h |
| Fish Ingestion | NC | 1.54E-2 | kg/(kg d) |
| | CC | 1.54E-2 | kg/(kg d) |
| | RA | 2.76E+4 | kg |
| Fruit Ingestion | NC | 4.71E-3 | kg/(kg d) |
| | CC | 4.71E-3 | kg/(kg d) |
| | RA | 8.44E+3 | kg |
| Vegetable Ingestion | NC | 4.71E-3 | kg/(kg d) |
| | CC | 4.71E-3 | kg/(kg d) |
| | RA | 8.44E+3 | kg |
| Meat Ingestion | NC | 4.87E-3 | kg/(kg d) |
| | CC | 4.87E-3 | kg/(kg d) |
| | RA | 8.72E+3 | kg |
| Milk Ingestion | NC | 8.57E-3 | L/(kg d) |
| | CC | 8.57E-3 | L/(kg d) |
| | RA | 1.53E+4 | L |

Notes:

[1] The SIF for these pathways includes a factor of 10 for heightened sensitivity of children to non-carcinogenic health impacts for the 6-year period represented by child parameter values.

CC = Carcinogenic chemicals

NC = Noncarcinogenic chemicals

RA = Radionuclides

### Residential Farmer (Agricultural) Scenario

This scenario represents use of the land for residential and agricultural production. This scenario includes producing and consuming animal, vegetable, and fruit products. The exposures are assumed to be continuous and include occasional surface water-related recreational activities, which include contact with surface water sediments. A composite adult was used as the receptor for some of the exposure pathways. The composite adult was evaluated using child parameters for 6 years and adult parameters for 24 years, with a total exposure duration of 30 years. The child's body weight was assumed to be 16 kg (35 lbs), and the adult body weight 70 kg (150 lbs). This approach was used for all contaminant types. Table D.2.1.5 presents the pathways included in the residential farmer scenario. The exposure parameters for each pathway are presented in Table D.2.1.6. The SIF values for each pathway are presented in Table D.2.1.7.

Table D.2.1.5 Exposure Pathways Included in Residential Farmer Scenario

| Medium | Exposure Pathway | Chemicals | Radionuclides |
|---|---|---|---|
| Soil (mass) | Soil ingestion | Yes | Yes |
| | Soil dermal absorption | Yes | Yes |
| | Resuspended-soil inhalation | Yes | Yes |
| | External ground dose | No | Yes |
| | Fruit ingestion | Yes | Yes |
| | Vegetable ingestion | Yes | Yes |
| | Meat ingestion | Yes | Yes |
| | Milk ingestion | Yes | Yes |
| Soil (area) | Fruit ingestion | Yes | Yes |
| | Vegetable ingestion | Yes | Yes |
| | Meat ingestion | Yes | Yes |
| | Milk ingestion | Yes | Yes |
| | Soil dermal absorption | Yes | Yes |
| | Soil ingestion | Yes | Yes |
| | Resuspended-soil inhalation | Yes | Yes |
| | External ground dose | No | Yes |
| Air | Fruit ingestion | Yes | Yes |
| | Vegetable ingestion | Yes | Yes |
| | Meat ingestion | Yes | Yes |
| | Milk ingestion | Yes | Yes |
| | Inhalation | Yes | Yes |
| | External air dose | No | Yes |
| Groundwater | Drinking-water ingestion | Yes | Yes |
| | Shower dermal absorption | Yes | Yes |
| | Shower-water ingestion | Yes | Yes |
| | Fruit ingestion | Yes | Yes |
| | Vegetable ingestion | Yes | Yes |
| | Meat ingestion | Yes | Yes |
| | Milk ingestion | Yes | Yes |
| | Indoor inhalation | Yes | Rn-222 Only |
| Surface water | Drinking-water ingestion | Yes | Yes |
| | Shower dermal absorption | Yes | Yes |
| | Shower-water ingestion | Yes | Yes |
| | Fruit ingestion | Yes | Yes |
| | Vegetable ingestion | Yes | Yes |
| | Meat ingestion | Yes | Yes |
| | Milk ingestion | Yes | Yes |
| | Fish ingestion | Yes | Yes |
| | Swimming-water ingestion | Yes | Yes |
| | Swimming dermal absorption | Yes | Yes |
| | Swimming external dose | No | Yes |
| | Shoreline dermal absorption | Yes | Yes |
| | Shoreline-sediment ingestion | Yes | Yes |
| | Shoreline external dose | No | Yes |
| | Boating external dose | No | Yes |
| | Indoor inhalation | Yes | Rn-222 Only |

Table D.2.1.6 Residential Farmer Scenario Exposure Factors

| Pathway | | Exposure Parameters | | | | | |
|---|---|---|---|---|---|---|---|
| Media | Exposure Route | Intake/Contact Rate | Exposure Frequency (d/yr) | Exposure Duration (yr) | Body Weight (kg) | Averaging Time[3] (d/yr · yr) | Other Factors |
| Soil (mass) | Ingestion | 200 mg/d (Child) 100 mg/d (Adult) | 365 | 6 (Child) 24 (Adult) | 16 (Child) 70 (Adult) | 365 · 30 | 80 g/d (vegetable); 42 g/d (fruit); 75 g/d (meat); 300 g/d (milk) |
| | Dermal | 1 contact event/day | 180 | 6 (Child) 24 (Adult) | 16 (Child) 70 (Adult) | 365· 30 | 2,500 $cm^2$ (skin surface area - child); 5,000 $cm^2$ (skin surface area - adult); 0.2 $mg/cm^2$ (soil adherence factor) |
| | Inhalation | 20 $m^3/d$ | 365 24 hr/d | 6 (Child) 24 (Adult) | 16 (Child) 70 (Adult) | 365 · 30 | 50 $\mu g/m^3$ (soil/air concentration) |
| | External (radionuclides) | | 365 | 6 (Child) 24 (Adult) | 16 (Child) 70 (Adult) | 365 · 30 | 0.8 (shielding factor) |
| Soil (area) | Ingestion | 200 mg/d (Child) 100 mg/d (Adult) | 365 | 6 (Child) 24 (Adult) | 16 (Child) 70 (Adult) | 365 · 30 | 80 g/d (vegetable); 42 g/d (fruit); 75 g/d (meat); 300 g/d (milk) |
| | Dermal | 1 contact event/day | 180 | 6 (Child) 24 (Adult) | 16 (Child) 70 (Adult) | 365 · 30 | 2,500 $cm^2$ (skin surface area - child); 5,000 $cm^2$ (skin surface area - adult) 0.2 $mg/cm^2$ (soil adherence factor) |
| | Inhalation | 20 $m^3/d$ | 365 | 6 (Child) 24 (Adult) | 16 (Child) 70 (Adult) | 365 · 30 | 50 $\mu g/m^3$ (soil/air concentration) 8.53E-10 $m^{-1}$ (resuspension factor) |
| | External (radionuclides) | | 365 24 hr/d | 6 (Child) 24 (Adult) | 16 (Child) 70 (Adult) | 365 · 30 | 0.8 (shielding factor) |
| Air | Ingestion | | 365 | 6 (Child) 24 (Adult) | 16 (Child) 70 (Adult) | 365 · 30 | 80 g/d (vegetable); 42 g/d (fruit); 75 g/d (meat); 300 g/d (milk) |
| | Inhalation | 20 $m^3/d$ | 365 | 6 (Child) 24 (Adult) | 16 (Child) 70 (Adult) | 365 · 30 | |
| | External (radionuclides) | | 365 24 hr/d | 6 (Child) 24 (Adult) | 16 (Child) 70 (Adult) | 365 · 30 | |

Table D.2.1.6 Residential Farmer Scenario Exposure Factor (cont'd)

| Pathway | | Exposure Parameters | | | | | |
|---|---|---|---|---|---|---|---|
| Media | Exposure Route | Intake/Contact Rate | Exposure Frequency (d/yr) | Exposure Duration (yr) | Body Weight (kg) | Averaging Time[3] (d/yr · yr) | Other Factors |
| Ground-water | Ingestion | 2 L/d<br>0.01 L/shower | 365 | 6 (Child)<br>24 (Adult) | 16 (Child)<br>70 (Adult) | 365 · 30 | 80 g/d (vegetable);<br>42 g/d (fruit);<br>75 g/d (meat);<br>300 g/d (milk) |
| | Dermal | | 365 | 6 (Child)<br>24 (Adult) | 16 (Child)<br>70 (Adult) | 365 · 30 | 10 min/d (showering rate);<br>20,000 $cm^2$<br>(skin surface area) |
| | Inhalation | 15 $m^3/d$ | 365 | 6 (Child)<br>24 (Adult) | 16 (Child)<br>70 (Adult) | 365 · 30 | 0.5 (indoor air volatilization factor - VOCs) |
| | External (radionuclides) | | 365 | 6 (Child)<br>24 (Adult) | 16 (Child)<br>70 (Adult) | 365 · 30 | 0.1 (indoor air volatilization factor - Rn-222) |
| Surface Water | Ingestion | 2 L/d; 200 mg/d (Child)<br>100 mg/d (Adult)<br>0.01 L/shower | 365 | 6 (Child)<br>24 (Adult) | 16 (Child)<br>70 (Adult) | 365 · 30 | 80 g/d (vegetable);<br>42 g/d (fruit);<br>75 g/d (meat);<br>300 g/d (milk) |
| | Dermal | | 365<br>7[1] | 6 (Child)<br>24 (Adult) | 16 (Child)<br>70 (Adult) | 365 · 30 | 2,500 $cm^2$ (skin surface area, sediment contact - child);<br>5,000 $cm^2$ (skin surface area, sediment contact - adult);<br>20,000 $cm^2$ (skin surface area); 2.6 $hr/d^2$;<br>10 min/d (showering rate) |
| | Inhalation | 15 $m^3/d$ | 365 | 6 (Child)<br>24 (Adult) | 16 (Child)<br>70 (Adult) | 365 · 30 | 0.5 (indoor air volatization factor - VOCs) |
| | External (radionuclides) | | 365 | 6 (Child)<br>24 (Adult) | 16 (Child)<br>70 (Adult) | 365 · 30 | 0.1 (indoor air volatilization factor - Rn-222) |

Notes:
[1] Exposure frequency for aquatic recreational pathway.
[2] Exposure time for aquatic recreational activity.
[3]Used for estimating noncarcinogenic effects only. For carcinogenic effects, the averaging time is always 70 years.
VOC = Volatile organic compound

Table D.2.1.7 Residential Farmer Scenario Summary Intake Factors

| Exposure Pathway | Type | SIF Value | Units |
|---|---|---|---|
| Soil (mass) | | | |
| Soil: Ingestion | NC | 3.64E-6 | kg/(kg d) |
| | CC | 1.56E-6 | kg/(kg d) |
| | RA | 1.32E+0 | kg |
| Soil: Dermal Absorption | NC | 8.71E-6 | kg/(kg d) |
| | CC | 3.73E-6 | kg/(kg d) |
| | RA | 5.40E+0 | kg |
| Soil: Resuspension and Inhalation | NC | 1.76E-8 | kg/(kg d) |
| | CC | 6.12E-9 | kg/(kg d) |
| | RA | 1.10E-2 | kg |
| Soil: External | RA | 2.10E+5 | ha |
| Vegetable Ingestion | NC | 1.14E-3 | kg/(kg d) |
| | CC | 4.90E-4 | kg/(kg d) |
| | RA | 8.77E+2 | kg |
| Fruit Ingestion | NC | 6.00E-4 | kg/(kg d) |
| | CC | 2.57E-4 | kg/(kg d) |
| | RA | 4.60E+2 | kg |
| Meat Ingestion | NC | 1.07E-3 | kg/(kg d) |
| | CC | 4.59E-4 | kg/(kg d) |
| | RA | 8.22E+2 | kg |
| Milk Ingestion | NC | 4.29E-3 | L/(kg d) |
| | CC | 1.84E-3 | L/(kg d) |
| | RA | 3.29E+3 | L |
| Soil (area) | | | |
| Soil: Ingestion | NC | 6.07E-8 | $m^2$/(kg d) |
| | CC | 2.60E-8 | $m^2$/(kg d) |
| | RA | 2.19E-2 | $m^2$ |
| Soil: Dermal | NC | 1.45E-7 | $m^2$ ev/(kg d) |
| | CC | 6.22E-8 | $m^2$ ev/(kg d) |
| | RA | 9.00E-2 | $m^2$ ev |
| Soil: Resuspension | NC | 2.95E-10 | $m^2$/(kg d) |
| | CC | 1.02E-10 | $m^2$/(kg d) |
| | RA | 1.83E-4 | $m^2$ |
| Soil: External | RA | 2.10E+5 | ha |
| Vegetable Ingestion | NC | 1.14E-3 | kg/(kg d) |
| | CC | 4.90E-4 | kg/(kg d) |
| | RA | 8.77E+2 | kg |
| Fruit Ingestion | NC | 6.00E-4 | kg/(kg d) |
| | CC | 2.57E-4 | kg/(kg d) |
| | RA | 4.60E+2 | kg |

Table D.2.1.7 Residential Farmer Scenario Summary Intake Factors (cont'd)

| Exposure Pathway | Type | SIF Value | Units |
|---|---|---|---|
| Meat Ingestion | NC | 1.07E-3 | kg/(kg d) |
| | CC | 4.59E-4 | kg/(kg d) |
| | RA | 8.22E+2 | kg |
| Milk Ingestion | NC | 4.29E-3 | L/(kg d) |
| | CC | 1.84E-3 | L/(kg d) |
| | RA | 3.29E+3 | L |
| Air | | | |
| Inhalation | NC | 3.54E-1 | $m^3$/(kg d) |
| | CC | 1.22E-1 | $m^3$/(kg d) |
| | RA | 2.19E+5 | $m^3$ |
| Air External Dose | RA | 2.63E+5 | hr |
| Vegetable Ingestion | NC | 1.14E-3 | kg/(kg d) |
| | CC | 4.90E-4 | kg/(kg d) |
| | RA | 8.77E+2 | kg |
| Fruit Ingestion | NC | 6.00E-4 | kg/(kg d) |
| | CC | 2.57E-4 | kg/(kg d) |
| | RA | 4.60E+2 | kg |
| Meat Ingestion | NC | 1.07E-3 | kg/(kg d) |
| | CC | 4.59E-4 | kg/(kg d) |
| | RA | 8.22E+2 | kg |
| Milk Ingestion | NC | 4.29E-3 | L/(kg d) |
| | CC | 1.84E-3 | L/(kg d) |
| | RA | 3.29E+3 | L |
| Groundwater | | | |
| Water: Ingestion | NC | 3.54E-2 | L/(kg d) |
| | CC | 1.22E-2 | L/(kg d) |
| | RA | 2.19E+4 | L |
| Water: Dermal Absorption | NC | 4.89E-2 | L h/(kg d cm) |
| | CC | 2.08E-2 | L h/(kg d cm) |
| | RA | 3.73E+4 | L h/cm |
| Shower Water: Ingestion | NC | 1.46E-4 | L/(kg d) |
| | CC | 6.24E-5 | L/(kg d) |
| | RA | 1.12E+2 | L |
| Indoor Inhalation | NC | 1.07E-1 | L/(kg d) |
| | CC | 4.59E-2 | L/(kg d) |
| | RA | 1.64E+4 | L |
| Vegetable Ingestion | NC | 1.14E-3 | kg/(kg d) |
| | CC | 4.90E-4 | kg/(kg d) |
| | RA | 8.77E+2 | kg |

Table D.2.1.7 Residential Farmer Scenario Summary Intake Factors (cont'd)

| Exposure Pathway | Type | SIF Value | Units |
|---|---|---|---|
| Fruit Ingestion | NC | 6.00E-4 | kg/(kg d) |
| | CC | 2.57E-4 | kg/(kg d) |
| | RA | 4.60E+2 | kg |
| Meat Ingestion | NC | 1.07E-3 | kg/(kg d) |
| | CC | 4.59E-4 | kg/(kg d) |
| | RA | 8.22E+2 | kg |
| Milk Ingestion | NC | 4.29E-3 | L/(kg d) |
| | CC | 1.84E-3 | L/(kg d) |
| | RA | 3.29E+3 | L |
| Surface Water | | | |
| Water Ingestion | NC | 3.54E-2 | L/(kg d) |
| | CC | 1.22E-2 | L/(kg d) |
| | RA | 2.19E+4 | L |
| Water: Dermal Absorption | NC | 4.86E-2 | L h/(kg d cm) |
| | CC | 2.08E-2 | L h/(kg d cm) |
| | RA | 3.73E+4 | L |
| Shower Water: Ingestion | NC | 1.46E-4 | L/(kg d) |
| | CC | 6.24E-5 | L/(kg d) |
| | RA | 1.12E+2 | L |
| Indoor Inhalation | NC | 1.07E-1 | L/(kg d) |
| | CC | 4.59E-2 | L/(kg d) |
| | RA | 1.64E+4 | L |
| Fish Ingestion | NC | 3.86E-4 | L/(kg d) |
| | CC | 1.65E-4 | L/(kg d) |
| | RA | 2.96E+2 | L |
| Swimming: Dermal Absorption | NC | 1.43E-2 | L h/(kg d cm) |
| | CC | 6.11E-3 | L h/(kg d cm) |
| | RA | 1.09E+4 | L h/cm |
| Swimming: Water Ingestion | NC | 3.57E-5 | L/(kg d) |
| | CC | 1.53E-5 | L/(kg d) |
| | RA | 2.74E+1 | L |
| Swimming: External Dose | RA | 5.47E+2 | h |
| Shoreline: Dermal Absorption | NC | 3.39E-7 | kg ev/(kg d) |
| | CC | 1.45E-7 | kg ev/(kg d) |
| | RA | 2.50E-2 | kg ev |
| Shoreline: Sediment Ingestion | NC | 6.98E-8 | kg/(kg d) |
| | CC | 2.99E-8 | kg/(kg d) |
| | RA | 2.52E-2 | kg |
| Shoreline: External Dose | RA | 1.09E+2 | h |
| Boating: External Dose | RA | 2.74E+2 | h |

Table D.2.1.7 Residential Farmer Scenario Summary Intake Factors (cont'd)

| Exposure Pathway | Type | SIF Value | Units |
|---|---|---|---|
| Vegetable Ingestion | NC | 1.14E-3 | kg/(kg d) |
| | CC | 4.90E-4 | kg/(kg d) |
| | RA | 8.77E+2 | kg |
| Fruit Ingestion | NC | 6.00E-4 | kg/(kg d) |
| | CC | 2.57E-4 | kg/(kg d) |
| | RA | 4.60E+2 | kg |
| Meat Ingestion | NC | 1.07E-3 | kg/(kg d) |
| | CC | 4.59E-4 | kg/(kg d) |
| | RA | 8.22E+2 | kg |
| Milk Ingestion | NC | 4.29E-3 | L/(kg d) |
| | CC | 1.84E-3 | L/(kg d) |
| | RA | 3.29E+3 | L |

Notes:
CC = Carcinogenic chemicals
NC = Noncarcinogenic chemicals
RA = Radionuclides

The ingestion rates of farm products for the residential farmer are based on EPA-suggested intake rates (EPA 1989b). The individual was assumed to consume a total of 200 g/day of vegetables of which 40 percent is homegrown and contaminated; 140 g/day of fruit of which 30 percent is homegrown and contaminated; 100 g/day of beef of which 75 percent is contaminated; and 300 g/day of dairy products of which 75 percent is contaminated. These intake rates are used by HSRAM and described by EPA as representing reasonable bounding estimates.

### Industrial Scenario

The industrial scenario represents potential exposures to workers in a commercial or industrial setting. The receptors are adult employees assumed to work at this location for 20 years and have an average body weight of 70 kg (150 lbs).

The scenario involves mainly indoor activities, although outdoor activities (e.g., soil contact) also are included. These exposures would not be continuous because the worker would go home at the end of each work day. The scenario is intended to represent nonremediation workers assumed to wear no protective clothing. Table D.2.1.8 presents the pathways included in this scenario. The exposure parameters for each pathway are presented in Table D.2.1.9. The SIF values for each pathway are presented in Table D.2.1.10.

Table D.2.1.8 Exposure Pathways Included in Industrial Scenario

| Medium | Exposure Pathway | Chemicals | Radionuclides |
|---|---|---|---|
| Soil (mass) | Soil Ingestion | Yes | Yes |
| | Soil Dermal Absorption | Yes | Yes |
| | Resuspended-Soil Inhalation | Yes | Yes |
| | External Ground Dose | No | Yes |
| Soil (area) | Soil Ingestion | Yes | Yes |
| | Soil Dermal Contact | Yes | Yes |
| | Resuspended-Soil Inhalation | Yes | Yes |
| | External Exposure | No | Yes |
| Air | Inhalation | Yes | Yes |
| | External Exposure | No | Yes |
| Groundwater | Drinking-Water Ingestion | Yes | Yes |
| | Shower Dermal Absorption | Yes | Yes |
| | Shower-Water Ingestion | Yes | Yes |
| | Indoor Inhalation | Yes | Rn-222 Only |
| Surface Water | Drinking-Water Ingestion | Yes | Yes |
| | Shower Dermal Absorption | Yes | Yes |
| | Shower-Water Ingestion | Yes | Yes |
| | Indoor Inhalation | Yes | Rn-222 Only |

### Recreational Shoreline User Scenario

The recreational shoreline user scenario represents exposure to contamination in the Columbia River and shoreline from recreational swimming, boating, and other shoreline activities. The scenario involves outdoor activities. These exposures would not be continuous, but would occur for 14 days/year for 30 years. Exposures to both adults and children were taken into account using the composite adult described for the residential farmer scenario. Table D.2.1.11 presents the pathways included in this scenario. The exposure parameters for each pathway are presented in Table D.2.1.12. The SIF values for each pathway are presented in Table D.2.1.13.

### Recreational Land User Scenario

The recreational land user scenario represents exposure to contamination from recreational camping, hiking, and other land-based recreational activities. These exposures would not be continuous, but would occur for 14 days/year for 30 years. Exposures to both adults and children were taken into account using the composite adult described for the residential farmer scenario. Table D.2.1.11 summarizes the pathways included in this scenario. The exposure parameters for each pathway are presented in Table D.2.1.14. The SIF values are the same as those in Table D.2.1.13, except that the recreational land user would not have access to or receive exposure from surface or groundwater. To account for this, the groundwater and surface water pathways were left open, but the media concentrations in the model were set to zero for both groundwater and surface water for the recreational land use scenario.

Table D.2.1.9 Industrial Scenario Exposure Factors

| Pathway | | Exposure Parameters | | | | | |
|---|---|---|---|---|---|---|---|
| Media | Exposure Route | Intake Rate | Exposure Frequency (d/yr) | Exposure Duration (yr) | Body Weight (kg) | Averaging Time[1] (d/yr · yr) | Other Factors |
| Soil (mass) | Ingestion | 50 mg/d | 146 | 20 | 70 | 365 · 20 | |
| | Dermal | 1 contact event/d | 146 | 20 | 70 | 365 · 20 | 5,000 $cm^2$ (skin surface area) 0.2 $mg/cm^2$ (soil adherence factor) |
| | Inhalation | 20 $m^3/d$ | 146 | 20 | 70 | 365 · 20 | 50 $\mu g/m^3$ (soil/air concentration) |
| | External (radionuclides) | | 146 8 hrs/d | 20 | 70 | 365 · 20 | 0.8 (shielding factor) |
| Soil (area) | Ingestion | 100 mg/d | 146 | 20 | 70 | 365 · 20 | |
| | Dermal | 1 contact event/d | 146 | 20 | 70 | 365 · 20 | 5,000 $cm^2$ (skin surface area) 0.2 $mg/cm^2$ (soil adherence factor) |
| | Inhalation | 20 $m^3/d$ | 146 | 20 | 70 | 365 · 20 | 50 $\mu g/m^3$ (soil/air concentration) |
| | External (radionuclides) | | 146 8 hrs/d | 20 | 70 | 365 · 20 | 0.8 (shielding factor) |
| Air | Inhalation | 20 $m^3/d$ | 250 8 hrs/d | 20 | 70 | 365 · 20 | |
| | External (radionuclides) | | 250 | 20 | 70 | 365 · 20 | |
| Groundwater | Ingestion | 1 L/d 0.01 L/shower | 250 | 20 | 70 | 365 · 20 | |
| | Dermal | | 250 | 20 | 70 | 365 · 20 | 20,000 $cm^2$ (skin surface area) 10 min/shower |
| | Inhalation | 20 $m^3/d$ | 250 | 20 | 70 | 365 · 20 | 0.5 (indoor air volatilization factor - VOCs) |
| | External (radionuclides) | | 250 | 20 | 70 | 365 · 20 | 0.1 (indoor air volatilization factor - Rn-222) |
| Surface Water | Ingestion | 1 L/d 0.01 L/shower | 250 | 20 | 70 | 365 · 20 | |
| | Dermal | | 250 | 20 | 70 | 365 · 20 | 20,000 $cm^2$ (skin surface area) 10 min/shower |
| | Inhalation | 20 $m^3/d$ | 250 | 20 | 70 | 365 · 20 | |
| | External (radionuclides) | | 250 | 20 | 70 | 365 · 20 | |

[1]Used for estimating noncarcinogenic effects only. For carcinogenic effects, the averaging time is always 70 years.

Table D.2.1.10 Industrial Scenario Summary Intake Factors

| Exposure Pathway | Type | SIF Value | Units |
|---|---|---|---|
| Soil (mass) | | | |
| Soil: Ingestion | NC | 2.86E-7 | kg/(kg d) |
| | CC | 8.16E-8 | kg/(kg d) |
| | RA | 1.46E-1 | kg |
| Soil: Dermal | NC | 5.71E-6 | kg/(kg d) |
| | CC | 1.63E-6 | kg/(kg d) |
| | RA | 2.92E+0 | kg |
| Soil: Resuspension | NC | 5.71E-9 | kg/(kg d) |
| | CC | 1.63E-9 | kg/(kg d) |
| | RA | 2.92E-3 | kg |
| Soil: External | RA | 1.87E+4 | ha |
| Soil (area) | | | |
| Soil: Ingestion | NC | 4.76E-9 | $m^2$/(kg d) |
| | CC | 1.36E-9 | $m^2$/(kg d) |
| | RA | 2.44E-3 | $m^2$ |
| Soil: Dermal | NC | 9.52E-8 | $m^2$ ev/(kg d) |
| | CC | 2.72E-8 | $m^2$ ev/(kg d) |
| | RA | 4.87E-2 | $m^2$ ev |
| Soil: Resuspension | NC | 9.52E-11 | $m^2$/(kg d) |
| | CC | 2.72E-11 | $m^2$/(kg d) |
| | RA | 4.87E-5 | $m^2$ |
| Soil: External | RA | 1.87E+4 | ha |
| Air | | | |
| Inhalation | NC | 1.96E-1 | $m^3$/(kg d) |
| | CC | 5.59E-2 | $m^3$/(kg d) |
| | RA | 1.00E+5 | $m^3$ |
| Air External Dose | RA | 4.00E+4 | hr |
| Groundwater and Surface Water | | | |
| Water ingestion | NC | 9.79E-3 | L/(kg d) |
| | CC | 2.80E-3 | L/(kg d) |
| | RA | 5.00E+3 | L |
| Dermal absorption of water | NC | 3.33E-2 | L h/(kg d cm) |
| | CC | 9.51E-3 | L h/(kg d cm) |
| | RA | 1.70E+4 | l h/cm |
| Ingestion of shower water | NC | 9.98E-5 | L/(kg d) |
| | CC | 2.85E-5 | L/(kg d) |
| | RA | 5.10E+1 | L |
| Indoor inhalation | NC | 9.79E-2 | L/(kg d) |
| | CC | 2.80E-2 | L/(kg d) |
| | RA | 1.00E+4 | L |

Notes:
CC = Carcinogenic chemicals
NC = Noncarcinogenic chemicals
RA = Radionuclides

**Table D.2.1.11 Exposure Pathways Included in Recreational Shoreline User and Recreational Land User Scenarios**

| Medium | Exposure Pathway | Chemicals | Radionuclides |
|---|---|---|---|
| Soil (mass) | Soil Ingestion | Yes | Yes |
| | Soil Dermal Absorption | Yes | Yes |
| | Resuspended-Soil Inhalation | Yes | Yes |
| | External Ground Dose | No | Yes |
| Soil (area) | Soil Ingestion | Yes | Yes |
| | Soil Dermal Contact | Yes | Yes |
| | Resuspended-Soil Inhalation | Yes | Yes |
| | External Ground Dose | No | Yes |
| Air | Inhalation | Yes | Yes |
| | External Air Dose | No | Yes |
| Groundwater | Drinking-Water Ingestion | Yes | Yes |
| | Shower Dermal Absorption | Yes | Yes |
| | Shower-Water Ingestion | Yes | Yes |
| | Indoor Inhalation | Yes | Rn-222 Only |
| Surface Water | Drinking-Water Ingestion | Yes | Yes |
| | Fish Ingestion | Yes | Yes |
| | Swimming-Water Ingestion | Yes | Yes |
| | Swimming Dermal Absorption | Yes | Yes |
| | Swimming External Dose | No | Yes |
| | Shoreline Dermal Absorption | Yes | Yes |
| | Shoreline Sediment Ingestion | Yes | Yes |
| | Shoreline External Dose | No | Yes |
| | Boating External Dose | No | Yes |

D.2.1.3.2 Contaminant-Specific Parameters

The evaluation of the average daily intake and lifetime radiation dose in a particular medium is the product of the SIF value times a contaminant-specific factor. This section discusses the contaminant-specific factors required for each exposure pathway. These contaminant-specific parameters were evaluated the same way for all scenarios. Therefore, the exposure pathways are discussed independently of the scenarios (Equation [1], Section D.2.1.3.1).

Drinking Water Ingestion - The drinking water ingestion pathway has two contaminant-specific considerations: the water-purification factor and decay during transport from either the water pumping station or the location of domestic use. The URF calculations did not use the water-purification factor (i.e., the contaminant concentration in the water was not reduced because of treatment). The transport time was set to 0.5 day for drinking water and all domestic use analyses except for the Native American scenario for which no delay was included. The decay was evaluated as an exponential reduction in concentration during the transport period, based on the half-time for the contaminant in confined water systems (no volatilization loss). For radionuclides, the half-time is the radiological half-life.

**Table D.2.1.12 Recreational Shoreline User Scenario Exposure Factors**

| Pathway | | Exposure Parameters | | | | | |
|---|---|---|---|---|---|---|---|
| Media | Exposure Route | Intake/Contact Rate | Exposure Frequency (d/yr) | Exposure Duration (yr) | Body Weight (kg) | Averaging Time[3] (d/yr · yr) | Other Factors |
| Soil (mass) | Ingestion | 200 mg/d (Child)<br>100 mg/d (Adult) | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 2.93 g/d (game) - 15.4 g/d[2] |
| | Dermal | 1 contact event/d | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 2500 $cm^2$ (skin surface area - child);<br>5000 $cm^2$ (skin surface area - adult);<br>0.2 $mg/cm^2$ (soil adherence factor) |
| | Inhalation | 20 $m^3/d$ | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 50 $\mu g/m^3$ (soil/air concentration) |
| | External (radionuclides) | | 14<br>8 hrs/d | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 0.8 (shielding factor) |
| Soil (area) | Ingestion | 200 mg/d (Child)<br>100 mg/d (Adult) | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 2.93 g/d (game) - 15.4 g/d[2] |
| | Dermal | 1 contact event/d | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 2500 $cm^2$ (skin surface area - child);<br>5000 $cm^2$ (skin surface area - adult);<br>0.2 $mg/cm^2$ (soil adherence factor) |
| | Inhalation | 20 $m^3/d$ | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 50 $\mu g/m^3$ (soil/air concentration)<br>8.33 E-10 $m^{-1}$ (resuspension factor) |
| | External (radionuclides) | | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 0.8 (shielding factor) |
| Air | Ingestion | | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 2.93 g/d (game) - 15.4 g/d[2] |
| | Inhalation | 20 $m^3/d$ | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | |
| | External (radionuclides) | | 14<br>24 hr/d | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | |

Table D.2.1.12 Recreational Shoreline User Scenario Exposure Factors (cont'd)

| Pathway | | Exposure Parameters | | | | | |
|---|---|---|---|---|---|---|---|
| Media | Exposure Route | Intake/Contact Rate | Exposure Frequency (d/yr) | Exposure Duration (yr) | Body Weight (kg) | Averaging Time[3] (d/yr • yr) | Other Factors |
| Ground-water | Ingestion | 2 L/d<br>0.01 L/shower | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | |
| | Dermal | | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 10 min/d (showering rate)<br>20,000 $cm^2$ (skin surface area) |
| | Inhalation | 20 $m^3$/d | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 0.5 (indoor air volatilization factor - VOCs) |
| | External (radionuclides) | | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 0.1 (indoor air volatilization factor - Rn-222) |
| Surface Water | Ingestion | 200 mg/d (Child)<br>100 mg/d (Adult)<br>365 (fish)<br>2 L/d | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 27 g/d (fish);<br>2.93 g/d (game) - 15.4 g/d[2] |
| | Dermal | 0.01 L/shower | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 2,500 $cm^2$ (skin surface area - child)<br>5,000 $cm^2$ (skin surface area - adult)<br>20,000 $cm^2$ (skin surface area); 2.6 hr/d; 10 min/d (showering rate) |
| | Inhalation | 15 $m^3$/d | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | |
| | External (radionuclides) | | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | |

Notes:
[1] Exposure time for aquatic recreational activities.
[2] Game ingestion rate with 19 percent hunting success rate.
[3]Used for estimating noncarcinogenic effects only. For carcinogenic effects, the averaging time is always 70 years.
VOC = Volatile organic compound

Table D.2.1.13 Recreational Shoreline User and Recreational Land User Scenario Summary Intake Factors

| Exposure Pathway | Type | SIF Value | Units |
|---|---|---|---|
| **Soil (mass)** | | | |
| Soil: Ingestion | NC | 1.39E-07 | kg/(kg d) |
| | CC | 6.00E-08 | kg/(kg d) |
| | RA | 5.04E-02 | kg |
| Soil: Dermal Absorption | NC | 6.78E-07 | kg/(kg d) |
| | CC | 2.90E-07 | kg/(kg d) |
| | RA | 4.20E-01 | kg |
| Soil: Resuspension | NC | 6.78E-10 | kg/(kg d) |
| | CC | 2.36E-10 | kg/(kg d) |
| | RA | 4.20E-04 | kg |
| Soil: External | RA | 2.68E+03 | ha |
| Game: Ingestion | NC | 4.28E-05 | kg/(kg d) |
| | CC | 1.83E-05 | kg/(kg d) |
| | RA | 3.29E+01 | kg |
| **Soil (area)** | | | |
| Soil: Ingestion | NC | 2.34E-09 | $m^2$/(kg d) |
| | CC | 1.00E-09 | $m^2$/(kg d) |
| | RA | 8.40E-04 | $m^2$ |
| Soil: Dermal | NC | 1.13E-08 | $m^2$ ev/(kg d) |
| | CC | 4.86E-09 | $m^2$ ev/(kg d) |
| | RA | 7.02E+03 | $m^2$ ev |
| Soil: Resuspension | NC | 1.13E-11 | $m^2$/(kg d) |
| | CC | 3.92E-12 | $m^2$/(kg d) |
| | RA | 7.00E-06 | $m^2$ |
| Soil: External | RA | 2.70E+03 | ha |
| Game: Ingestion | NC | 4.28E-05 | kg/(kg d) |
| | CC | 1.83E-05 | kg/(kg d) |
| | RA | 3.29E+01 | kg |
| **Air** | | | |
| Inhalation | NC | 1.36E-02 | $m^3$/(kg d) |
| | CC | 4.70E-03 | $m^3$/(kg d) |
| | RA | 8.42E+03 | $m^3$ |
| Air External Dose | RA | 3.36E+03 | hr |
| Game: Ingestion | NC | 4.28E-05 | kg/(kg d) |
| | CC | 1.83E-05 | kg/(kg d) |
| | RA | 3.29E+01 | kg |
| **Groundwater** | | | |
| Water: Ingestion | NC | 1.36E-03 | L/(kg d) |
| | CC | 4.70E-04 | L/(kg d) |
| | RA | 8.42E+02 | L |

Table D.2.1.13 Recreational Shoreline User and Recreational Land User Scenario Summary Intake Factors (cont'd)

| Exposure Pathway | Type | SIF Value | Units |
|---|---|---|---|
| Water: Dermal Absorption | NC | 1.87E-03 | L h/(kg d cm) |
| | CC | 8.00E-04 | L h/(kg d cm) |
| | RA | 1.43E+03 | L h/cm |
| Ingestion of Shower Water | NC | 9.32E-07 | L/(kg d) |
| | CC | 4.00E-07 | L/(kg d) |
| | RA | 7.16E-01 | L |
| Surface Water | | | |
| Water Ingestion | NC | 1.36E0-3 | L/(kg d) |
| | CC | 4.70E-04 | L/(kg d) |
| | RA | 8.42E+02 | L |
| Fish Ingestion | NC | 3.86E-04 | L/(kg d) |
| | CC | 1.65E-04 | L/(kg d) |
| | RA | 2.96E+02 | L |
| Swimming: Dermal Absorption | NC | 2.86E-02 | L h/(kg d cm) |
| | CC | 1.22E-02 | L h/(kg d cm) |
| | RA | 2.18E+04 | L h/cm |
| Swimming: Water Ingestion | NC | 7.14E-05 | L/(kg d) |
| | CC | 3.06E-05 | L/(kg d) |
| | RA | 5.48E+01 | L |
| Swimming: External Dose | RA | 1.09E+03 | h |
| Shoreline: Dermal Absorption | NC | 6.78E-07 | kg ev/(kg d) |
| | CC | 2.90E-07 | kg ev/(kg d) |
| | RA | 5.00E-02 | kg |
| Shoreline: Sediment Ingestion | NC | 1.40E-07 | kg/(kg d) |
| | CC | 5.98E-08 | kg/(kg d) |
| | RA | 5.04E-02 | kg |
| Shoreline: External Dose | RA | 2.18E+02 | h |
| Boating: External Dose | RA | 5.48E+02 | h |
| Game: Ingestion | NC | 4.28E-05 | kg/(kg d) |
| | CC | 1.83E-05 | kg/(kg d) |
| | RA | 3.29E+01 | kg |

Notes:
CC = Carcinogenic chemicals
NC = Noncarcinogenic chemicals
RA = Radionuclides

**Table D.2.1.14 Recreational Land User Scenario Exposure Factors**

| Pathway | | Exposure Parameters | | | | | |
|---|---|---|---|---|---|---|---|
| Media | Exposure Route | Intake/Contact Rate | Exposure Frequency (d/yr) | Exposure Duration (yr) | Body Weight (kg) | Averaging Time[3] (d/yr · yr) | Other Factors |
| Soil (mass) | Ingestion | 200 mg/d (Child)<br>100 mg/d (Adult) | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 2.93 g/d (game) - 15.4 g/d[2] |
| | Dermal | 1 contact event/d | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 2,500 $cm^2$ (skin surface area - child); 5,000 $cm^2$ (skin surface area - adult); 0.2 $mg/cm^2$ (soil adherence factor) |
| | Inhalation | 20 $m^3/d$ | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 50 $\mu g/m^3$ (soil/air concentration) |
| | External (radionuclides) | | 14<br>8 hrs/d | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 0.8 (shielding factor) |
| Soil (area) | Ingestion | 200 mg/d (Child)<br>100 mg/d (Adult) | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 2.93 g/d (game) - 15.4 g/d[2] |
| | Dermal | 1 contact event/d | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 2,500 $cm^2$ (skin surface area - child); 5,000 $cm^2$ (skin surface area - adult); 0.2 $mg/cm^2$ (soil adherence factor) |
| | Inhalation | 20 $m^3/d$ | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 50 $\mu g/m^3$ (soil/air concentration); 8.33 E-10 $m^{-1}$ (resuspension factor) |
| | External (radionuclides) | | 14<br>8 hrs/d | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 0.8 (shielding factor) |
| Air | Ingestion | | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 2.93 g/d (games) - 15.4 g/d[2] |
| | Inhalation | 20 $m^3/d$ | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | |
| | External (radionuclides) | | 14<br>24 hrs/d | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | |

Table D.2.1.14 Recreational Land User Scenario Exposure Factors (cont'd)

| Pathway | | Exposure Parameters | | | | | |
|---|---|---|---|---|---|---|---|
| Media | Exposure Route | Intake/Contact Rate | Exposure Frequency (d/yr) | Exposure Duration (yr) | Body Weight (kg) | Averaging Time[3] (d/yr · yr) | Other Factors |
| Ground-water | Ingestion | 2 L/d<br>0.01 L/shower | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | |
| | Dermal | | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 10 min/d (showering rate)<br>20,000 $cm^2$ (skin surface area) |
| | Inhalation | 20 $m^3/d$ | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 0.5 (indoor air volatilization factor - VOCs) |
| | External (radionuclides) | | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 0.1 (indoor air volatilization factor - Rn-222) |
| Surface Water | Ingestion | 200 mg/d (Child)<br>100 mg/d (Adult)<br>365 (fish)<br>2 L/d | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 27 g/d (fish);<br>2.93 g/d (game) - 15.4 $g/d^2$ |
| | Dermal | 0.01 L/shower | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | 2,500 $cm^2$ (skin surface area sediment contact - child)<br>5,000 $cm^2$ (skin surface area sediment contact - adult)<br>20,000 $cm^2$ (skin surface area); 2.6 hr/d; 10 min/d (showering rate) |
| | Inhalation | 15 $m^3d$ | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | |
| | External (radionuclides) | | 14 | 6 (Child)<br>24 (Adult) | 16<br>70 | 365 · 30 | |

Notes:
[1] Exposure time for aquatic recreational activity.
[2] Game ingestion rate with 19 percent hunting success rate.
[3]Used for estimating noncarcinogenic effects only. For carcinogenic effects, the averaging time is always 70 years.
VOC = Volatile organic compound

Shower Dermal Contact - The shower dermal contact pathway involves dermal contact with water while showering with domestic water. The water concentration was evaluated as described for drinking water. The daily intake estimation required using a skin permeability constant (cm/hour) to estimate the transfer from the skin surface to the blood. In addition, it was necessary to divide the intake estimate for chemicals by the gastrointestinal absorption factor to convert the dermal intake to an equivalent ingestion intake (Strenge-Chamberlain 1994).

Shower Water Ingestion - The shower water ingestion pathway involves inadvertent ingestion of water while showering using domestic water. The water concentration was evaluated as described for drinking water. There are no other contaminant-specific parameters or considerations.

Leafy Vegetable Ingestion - The leafy vegetable-ingestion exposure pathway was used to represent the ingestion of home-grown vegetables by the residential farmer. The contaminant-specific factor includes estimating the uptake from the contaminated medium of concern. This medium may be air, soil (from air deposition), or irrigation water (groundwater or surface water). The methods for estimating plant concentration from the contaminated media are presented in Strenge-Chamberlain (Strenge-Chamberlain 1995). The contaminant-specific parameters involved in this analysis are the soil-to-plant concentration ratio and the atmospheric deposition velocity. Numerical values for these parameters are presented in Strenge-Chamberlain (Strenge-Chamberlain 1994).

Other Vegetable Ingestion - The other vegetable ingestion pathway represents vegetable and fruit crops for which the edible portion is not associated with the leaves of the plant. As for the leafy vegetable ingestion pathway, the methods for estimating plant concentration from the contaminated media are presented in Strenge-Chamberlain (Strenge-Chamberlain 1995). The contaminant-specific parameters were the same as for the leafy vegetable pathway and are described in Strenge-Chamberlain (Strenge-Chamberlain 1994).

Meat Ingestion - Evaluating URFs for the meat-ingestion pathway required estimating contaminant concentration in meat from animals that ingested contaminated feeds and water. As for the leafy vegetable-ingestion pathway, the methods for estimating meat concentration from the contaminated media are presented in Strenge-Chamberlain (Strenge-Chamberlain 1995). The contaminant-specific parameters were the soil-to-plant (animal feed) concentration ratio, the animal feed-to-meat transfer factor, and the atmospheric deposition velocity. These parameters are described in Strenge-Chamberlain (Strenge-Chamberlain 1994).

Milk Ingestion - The milk-ingestion represents the dairy exposure pathway. The analysis required estimating contaminant concentration in cow milk, and was performed in a similar manner to the meat pathway analysis, as presented in Strenge-Chamberlain (Strenge-Chamberlain 1995). The contaminant-specific parameters were the soil-to-plant (animal feed) concentration ratio, the animal feed-to-milk transfer factor, and the atmospheric deposition velocity. These parameters are described in Strenge-Chamberlain (Strenge-Chamberlain 1994).

Fish Ingestion - The fish-ingestion pathway required estimating the concentration of contaminants in edible portions of fish, based on the concentration in surface water. This estimation uses the fish bioaccumulation factor, which is the ratio of contaminant concentration in fish to that in the water. This parameter is described in Strenge-Chamberlain (Strenge-Chamberlain 1994). Note that ingestion of whole fish is considered for the Native American scenario.

Swimming Water Ingestion - Inadvertently ingesting water while swimming involved direct ingestion of surface water. No contaminant-specific parameters were required.

Swimming Dermal Contact - Direct contact with surface water while swimming would result in absorption of contaminants through the skin. The absorption estimate required a value for the skin permeability constant for each contaminant. In addition, the intake estimate for chemicals must be divided by the gastrointestinal absorption factor to convert the dermal intake to an equivalent ingestion intake. The permeability constant and the gastrointestinal absorption factor are described in Strenge-Chamberlain (Strenge-Chamberlain 1994).

Shoreline Dermal Contact - All the shoreline exposure pathways required estimating the contaminant concentration in sediment based on the concentration in surface water. This transfer was estimated using the model of Soldat et al. (Soldat et al. 1974) as described in Whelan et al. (Whelan et al. 1987). This model estimates the average sediment concentration over a user-defined exposure duration. Transferring contaminants from the sediment to the individual also required a value for the skin absorption fraction for the contaminant. The skin absorption fraction is the fraction of contaminant on skin absorbed into the blood. In addition, the intake estimate for chemicals must be divided by the gastrointestinal absorption factor to convert the dermal intake to an equivalent ingestion intake. This parameter is described in Strenge-Chamberlain (Strenge-Chamberlain 1994).

Shoreline Sediment Ingestion - Inadvertently ingesting sediment while participating in shoreline recreational activities required an estimate of the shoreline sediment concentration. No other contaminant-specific consideration was required.

Soil Ingestion - Inadvertently ingesting soil would involve direct ingestion of the contaminated soil. The soil concentration is defined at the start of the exposure duration. It is necessary to account for the time variation of soil concentration due to loss by volatilization and radioactive decay. The volatilization loss was estimated using the environmental half-time parameter for soil. The time-integral of soil concentration was evaluated over the exposure duration to determine the average soil concentration present. The environmental half-time is described in Strenge-Chamberlain (Strenge-Chamberlain 1994).

Soil Dermal Contact - Contaminant-specific considerations for dermal absorption from soil involved the skin absorption fraction and the same considerations as for loss by volatilization and radioactive decay. The skin-absorption fraction gives the fraction of contaminant on the skin that is absorbed into the blood. In addition, the intake estimate for chemicals must be divided by the gastrointestinal absorption factor to convert the dermal intake to an equivalent ingestion intake. The skin-absorption fraction and the environmental half-time are described in Strenge-Chamberlain (Strenge-Chamberlain 1994).

Air Inhalation - There were no contaminant-specific parameters for inhaling air.

Soil Resuspension Inhalation - Inhaling resuspended soil involved estimating the average soil concentration present over the exposure duration. This analysis involved the same considerations as for loss by volatilization and radioactive decay. There are no other contaminant-specific considerations for this pathway. The environmental half-time is described in Strenge-Chamberlain (Strenge-Chamberlain 1994).

External Exposure from Swimming - There were no contaminant-specific considerations for external exposure to radionuclides while swimming. The water immersion external radiation dose factor was used to estimate an external slope factor for water immersion as described in Section D.2.1.3.3.

External Exposure from Boating - There were no contaminant-specific considerations for external exposure to radionuclides while boating. The water immersion external radiation dose factor was used to estimate an external slope factor for boating as described in Section D.2.1.3.3. A factor of 0.5 was applied to the water immersion external radiation dose factor to approximate the exposure geometry in a boat (half immersion).

External Exposure from Shoreline - This pathway required an estimate of the average radionuclide concentration in shoreline sediment over the exposure duration, just as for the other pathways involving shoreline sediment. There were no other contaminant-specific considerations for external exposure to radionuclides on the shoreline.

External Exposure from Soil - External exposure to radionuclides in soil required estimating the average concentration in soil over the exposure duration. There were no other contaminant-specific considerations for external exposure to radionuclides in soil.

External Exposure from Air - There were no contaminant-specific considerations for external exposure to radionuclides in air. The air immersion external radiation dose factor was used to estimate an external slope factor for air exposure as described in Section D.2.1.3.3.

Sweat Lodge Exposures for Native Americans - Exposures of Native Americans in sweat lodges are evaluated for inhalation intake and dermal contact with water. The transfer of contaminants from the water to the sweat lodge air is estimated using a "volatilization" factor, similar to the EPA/Andelman factor used for indoor inhalation of volatile organic compounds (VOCs) and radon. The steam in the sweat lodge is generated by pouring water onto heated rocks. A volatilization factor of 0.3 $L/m^3$ is used for all non-volatile contaminants, a factor of 2.5 is used for all VOCs, and a factor of 0.5 is used for radon. The dermal exposure pathway also involves use of the skin permeability factor as described for the shower dermal contact pathway. There are no other contaminant-specific parameters or considerations.

D.2.1.3.3 Unit Risk Factors

Analyzing the URFs provides estimates of health impacts per unit concentration of contaminant in a medium. The contaminants analyzed were the contaminants in the current inventories, which are

discussed in Sections D.2.1.1.1 and D.2.1.1.2. The health impact measure used for carcinogenic chemicals and radionuclides was the lifetime cancer incidence from intake received during a defined exposure duration. For noncarcinogenic chemicals, the health impact measure was the HI, which is the ratio of the average daily intake to the reference dose (RfD) (evaluated for ingestion and inhalation intake routes). For each contaminant in the current inventories, the health impacts were conservatively added across all exposure pathways for a given scenario and medium and it is assumed that all chemicals added have the same mechanism of action and affect the same target organ. The following sections describe the methods for evaluation of the URFs. The equations are from Strenge-Chamberlain (Strenge-Chamberlain 1994).

Also of concern are genetic effects from ionizing radiation. Ionizing radiation can produce submicroscopic changes in individual genes (gene mutations) and damage the chromosome structure. Damage to the genes in the germ cell of the testes or ovaries may result in the transmittal of heritable mutations. Little experimental study data exists on humans. Most of the available data are based on experimentation with animals. Within the scientific community, opinions vary about the applicability of the animal study data to humans. A study of 38,000 offspring who had at least one parent exposed to radiation at Hiroshima or Nagasaki showed no statistically substantial effects resulting from the exposure. Based on the human and animal genetic data, the number of genetic effects of an average population exposure of 1 rem per 30-year generation was calculated to be 15 to 40 additional cases of genetic disorders per million live birth offspring. This is compared to the current spontaneous incidence of about 17,300 cases per million (Zenz 1994). Assuming the conservative end of the range of 40 additional cases per million results in a dose-to-risk conversion factor of 4.0E-05 for genetic effects. By contrast, ICRP Publication 60 (ICRP 1991) recommends a dose-to-risk conversion factor for hereditary effects of 1.3E-04. Additionally, information presented in the National Council on Radiation Protection Report Number 116 (NCRP 1993) suggests that genetic effects might be greater than indicated by previous human and animal studies. Nevertheless, because the results of this assessment are intended to support comparison of the alternatives rather than to serve as a determination of absolute risk, it is considered sufficient to measure health impacts solely in terms of lifetime cancer risk. For this reason, potential genetic effects have not been calculated and are not considered further in this analysis.

**Radionuclide Unit Risk Factor Calculation**

The average daily intake and lifetime radiation doses (see Equation [1], Section D.2.1.3.1) were used to estimate the URFs for the health impact measure appropriate to the contaminant. The URFs for radionuclides were evaluated as follows for inhalation exposure pathways:

$$URF_{ih} = (Intake_{ih}) \cdot (SF_{ih})$$

The following equation was used to evaluate URFs for the ingestion exposure pathways:

$$URF_{ig} = (Intake_{ig}) \cdot (SF_{ig})$$

Where:

$URF_{ih}$ = Unit risk factor for an inhalation pathway for radionuclide i (risk per unit medium concentration)

| | | |
|---|---|---|
| $URF_{ig}$ | = | Unit risk factor for an ingestion pathway for radionuclide i (risk per unit medium concentration) |
| $Intake_{ih}$ | = | Inhalation intake for radionuclide i for the inhalation pathway of interest (pCi) |
| $Intake_{ig}$ | = | Ingestion intake for radionuclide i for the ingestion pathway of interest (pCi) |
| $SF_{ih}$ | = | Inhalation slope factor for radionuclide i (risk/pCi) |
| $SF_{ig}$ | = | Ingestion slope factor for radionuclide i (risk/pCi) |

For exposure pathways involving external radiation exposure, the URFs were evaluated as follows:

$$URF_{ix} = (Exposure_{ix}) \cdot (SF_{ix})$$

Where:

| | | |
|---|---|---|
| $URF_{ix}$ | = | Unit risk factor for an external radiation exposure pathway for radionuclide i (risk per unit medium concentration) |
| $Exposure_{ix}$ | = | Exposure time for radionuclide i for the external radiation exposure pathway of interest (hour) |
| $SF_{ix}$ | = | External exposure slope factor for radionuclide i (risk/hour per pCi/unit medium quantity) |

The external slope factors provided in HEAST (EPA 1993b) are for use with contaminated soil (pCi/g soil). For external exposure to air and water, slope factors were generated from radiation dose factors and the health effects conversion factor of 6.2E-04 risk per rem. Cancer incidence (fatal and nonfatal) is used to be consistent with EPA slope factors. The air-immersion external slope factor was evaluated as follows:

$$SF_{ia} = (6.2E\text{-}04) \cdot (DF_{ia})$$

Where:

| | | |
|---|---|---|
| $SF_{ia}$ | = | Air immersion slope factor for radionuclide i (risk/hr per $pCi/m^3$) |
| $DF_{ia}$ | = | Air immersion dose rate factor for radionuclide i (rem/hr per $pCi/m^3$) |
| 6.2E-04 | = | Cancer incidence conversion factor (risk/rem) |

For dermal exposure pathways, slope factors were generated from radiation dose factors and the health effects conversion factor of 6.2E-04 risk per rem. The dermal slope factor was evaluated as follows:

$$SF_{id} = (6.2E\text{-}04) \cdot (DF_{id})$$

Where:

| | | |
|---|---|---|
| $SF_{id}$ | = | Dermal slope factor for radionuclide i (risk/hr per pCi) |
| $DF_{id}$ | = | Dose rate factor for radionuclide i (rem/hr per pCi) |

The water immersion slope factor was evaluated as follows:

$$SF_{iw} = (6.2E\text{-}04) \cdot (DF_{iw})$$

Where:

$SF_{iw}$ = Water immersion slope factor for radionuclide i (risk/hr per pCi/L)

$DF_{iw}$ = Water immersion dose rate factor for radionuclide i (rem/hr per pCi/L)

**Chemical Unit Risk Factor Calculation**

The intake parameter for chemical exposures was the average daily intake for a chemical by either ingestion or inhalation. For carcinogenic chemicals, the intake was the average over the lifetime of the individual (70 years), and for noncarcinogenic chemicals, it was the average over the exposure duration (20 years for the industrial scenario and 30 years for other scenarios).

The lifetime risk of cancer incidence from chemical-ingestion exposures was evaluated as follows:

$$URF_{ig} = (Intake_{ig}) \cdot (Sfig)$$

Where:

$URF_{ig}$ = Unit risk factor for chemical carcinogen i from an ingestion exposure pathway g (risk/unit medium concentration)

$Intake_{ig}$ = Average daily intake of chemical i from ingestion pathway g (mg/kg/day)

$SF_{ig}$ = Ingestion slope factor for chemical i (risk per mg/kg/day).

The lifetime cancer incidence risk for inhalation was evaluated in a similar manner as follows:

$$URF_{ih} = (Intake_{ih}) \cdot (SF_{ih})$$

Where:

$URF_{ih}$ = Unit risk factor for chemical carcinogen i from an inhalation exposure pathway h (risk/unit medium concentration)

$Intake_{ih}$ = Average daily intake of chemical i from inhalation pathway h (mg/kg/day)

$SF_{ih}$ = Inhalation slope factor for chemical i (risk per mg/kg/day)

The health impact parameter for noncarcinogenic chemicals, the HI, was evaluated as follows for ingestion pathways:

$$URF_{ig} = Intake_{ig} / RfD_{ig}$$

Where:

$URF_{ig}$ = Unit risk factor for the noncarcinogenic chemical from an ingestion exposure pathway g (HI/unit medium concentration)

$Intake_{ig}$ = Average daily intake of chemical i from ingestion pathway g (mg/kg/day)

$RfD_{ig}$ = Ingestion reference dose for chemical i (mg/kg/day)

The HI for inhalation was evaluated in a similar manner as follows:

$$URF_{ih} = Intake_{ih} / RfD_{ih}$$

Where:

$URF_{ih}$ = Unit risk factor for the noncarcinogenic chemical from an inhalation exposure pathway h (HI/unit medium concentration).

$Intake_{ih}$ = Average daily intake of chemical i from inhalation pathway h (mg/kg/day).

$RfD_{ih}$ = Inhalation reference dose for chemical i (mg/kg/day).

Dermal exposures were evaluated as equivalent to ingestion exposures with a correction for the fractional absorption of the chemical in the gastrointestinal tract. This correction is discussed in Section D.2.1.3.2 in the definition of the contaminant-specific factors.

Results of the URF calculations are summarized in Tables D.2.1.15 to D.2.1.26 for the Native American, residential farmer, industrial, and recreational user (shoreline and land) scenarios. The URFs are provided for each scenario and for each of the three contaminant types: NC, CC, and RA. These summary tables present the URF values for each scenario, medium, and contaminant, summed over exposure pathways. The units for the URFs are health impacts normalized to unit medium contaminant concentration. The complete set of URFs for specific exposure pathways is provided in Strenge-Chamberlain (Strenge-Chamberlain 1994).

### D.2.1.4 Risk Module

Once the point concentration has been identified within each grid cell (based on either the current or post-remediation source), this value is multiplied by the URF. The resultant value is the risk to a receptor within this grid cell. The risk module tabulates risk for each receptor scenario across all cells.

The equations for point concentrations and total risk for each scenario are as follows:

$$C_{htm} = S_{hm} \cdot TUC_{htm} \quad (2)$$

Where:

C = Point concentration

$$R_{shtm} = \sum URF_{shm} \cdot C_{htm} \quad (3)$$

S = Source inventory

TUC = Transported unit concentration

R = Total risk

URF = Unit risk factor

The subscripts s, h, t, and m in Equation (3) represent the scenario, hazardous material, time, and media, respectively. The summation in Equation (3) represents addition of contributions from all exposure pathways associated with a particular scenario. The URF values presented in the tables of this report include the summation over the exposure pathways defined previously for each exposure scenario.

Table D.2.1.15 Native American Scenario Noncarcinogenic Chemical Unit Risk Factors

| Chemical Name | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Aluminum | 3.04E+08 | 1.07E+09 | 2.27E+01 | 5.29E+04 | 4.82E+05 |
| Arsenic | 4.16E+08 | 6.07E+09 | 3.72E+01 | 1.13E+05 | 4.14E+05 |
| Barium | 5.55E+07 | 4.84E+07 | 9.08E-01 | 1.95E+03 | 4.72E+06 |
| Beryllium | 4.70E+07 | 2.05E+08 | 6.40E+00 | 1.19E+04 | 2.10E+04 |
| Bismuth | 2.14E+06 | 2.53E+06 | 6.78E-02 | 1.57E+02 | 1.36E+05 |
| Boron | 4.21E+06 | 5.87E+06 | 2.39E+00 | 1.49E+04 | 1.05E+04 |
| Cadmium | 4.19E+08 | 7.73E+09 | 1.82E+02 | 8.75E+05 | 1.42E+06 |
| Calcium Ion | 7.46E+03 | 1.63E+04 | 4.84E-04 | 8.30E-01 | 3.35E+01 |
| Chromate Ion | 9.45E+09 | 7.22E+08 | 1.27E+02 | 2.23E+05 | 8.28E+08 |
| Chromium III | 2.48E+05 | 3.61E+06 | 2.46E-02 | 6.67E+01 | 8.25E+02 |
| Copper Ion | 9.62E+08 | 4.04E+09 | 4.79E+02 | 2.95E+06 | 1.37E+06 |
| Ferrocyanide Ion | 8.37E+05 | 1.81E+06 | 5.30E-02 | 9.10E+01 | 3.80E+03 |
| Fluoride | 1.09E+03 | 6.71E+03 | 4.90E-04 | 3.02E+00 | 1.94E+01 |
| Iron III | 7.31E+05 | 2.39E+07 | 2.14E-02 | 6.71E+01 | 5.51E+04 |
| Lead Ion | 9.93E+07 | 1.30E+09 | 7.18E+00 | 1.73E+04 | 1.20E+06 |
| Lithium Ion | 3.41E+04 | 5.97E+04 | 8.29E-03 | 4.71E+01 | 1.24E+03 |
| Magnesium Ion | 4.15E+06 | 9.16E+06 | 1.32E+00 | 7.88E+03 | 3.55E+04 |
| Manganese Ion | 6.54E+06 | 9.34E+07 | 9.93E-01 | 5.56E+03 | 3.32E+05 |
| Mercury Ion | 4.06E+09 | 5.62E+10 | 2.76E+03 | 1.75E+07 | 1.40E+07 |
| Molybdenum Ion | 3.54E+07 | 1.02E+08 | 8.34E+00 | 4.40E+04 | 1.66E+05 |
| Nickel Ion | 8.00E+06 | 9.48E+07 | 2.04E+00 | 1.07E+04 | 1.45E+04 |
| Nitrate Ion | 4.10E+07 | 1.49E+09 | 3.36E+01 | 2.17E+05 | 2.92E+03 |
| Nitrite Ion | 3.69E+06 | 7.97E+06 | 2.34E-01 | 4.01E+02 | 1.68E+04 |
| Phosphate Ion | 1.37E+07 | 2.36E+09 | 1.03E+01 | 6.65E+04 | 7.33E+04 |
| Potassium Ion | 1.28E+03 | 3.19E+04 | 8.54E-04 | 5.43E+00 | 3.35E+00 |
| Silicate Ion | 8.93E+05 | 2.70E+06 | 9.85E-02 | 1.76E+02 | 1.23E+03 |
| Silver Ion | 3.24E+07 | 7.58E+07 | 5.12E+00 | 2.34E+04 | 6.62E+05 |
| Sodium Ion | 5.11E+06 | 1.35E+08 | 0.00E+00 | 2.44E+04 | 1.50E+04 |
| Strontium Ion | 8.93E+05 | 2.41E+06 | 5.54E-01 | 3.49E+03 | 3.29E+03 |
| Sulfate Ion | 1.29E+05 | 2.18E+05 | 4.25E-02 | 2.68E+02 | 6.79E+03 |
| Uranium | 4.99E+07 | 3.65E+08 | 5.35E+00 | 1.83E+04 | 3.97E+05 |
| Vanadium Ion | 2.09E+07 | 7.34E+07 | 2.57E+00 | 6.34E+03 | 8.08E+04 |
| Zinc Ion | 1.37E+07 | 2.36E+09 | 1.03E+01 | 6.65E+04 | 7.33E+04 |

Table D.2.1.16 Native American Scenario Carcinogenic Chemical Unit Risk Factors

| Chemical Name | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Arsenic | 1.73E+05 | 2.87E+06 | 9.86E-03 | 4.31E+01 | 7.30E+03 |
| Beryllium | 7.46E+05 | 2.52E+06 | 5.33E-02 | 1.12E+02 | 4.42E+03 |
| Cadmium | 8.65E+05 | 2.15E+07 | 4.47E-01 | 2.53E+03 | 4.47E+03 |
| Chromium | 2.20E+05 | 0.00E+00 | 1.13E-03 | 1.94E+00 | 1.94E+04 |

Table D.2.1.17 Native American Scenario Radionuclide Unit Risk Factors

| Radionuclide | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Ac-225 | 6.79E+10 | 8.69E+10 | 1.55E+02 | 4.32E+05 | 3.22E+09 |
| Ac-227 | 1.12E+13 | 1.16E+13 | 4.32E+05 | 5.52E+08 | 5.44E+10 |
| Ac-228 | 1.00E+09 | 8.67E+07 | 1.64E+01 | 1.45E+04 | 2.54E+07 |
| Ag-110m | 1.18E+09 | 2.41E+10 | 9.54E+03 | 8.31E+06 | 6.63E+07 |
| Am-241 | 3.16E+12 | 6.66E+12 | 1.97E+05 | 3.32E+08 | 2.96E+10 |
| Am-243 | 3.16E+12 | 6.78E+12 | 2.12E+05 | 3.64E+08 | 2.94E+10 |
| Au-195 | 1.54E+08 | 1.02E+09 | 1.06E+02 | 9.47E+04 | 7.50E+06 |
| Ba-133 | 2.64E+08 | 4.29E+10 | 1.03E+04 | 1.12E+07 | 3.90E+06 |
| Be-10 | 2.85E+09 | 9.01E+08 | 6.18E+01 | 1.33E+05 | 1.99E+08 |
| Be-7 | 8.69E+06 | 9.13E+07 | 3.39E+01 | 2.91E+04 | 1.60E+05 |
| Bl-210 | 1.22E+09 | 3.31E+09 | 2.32E+00 | 4.56E+03 | 4.05E+07 |
| C-14 | 1.30E+09 | 1.35E+11 | 3.51E+00 | 6.01E+03 | 3.02E+07 |
| Ca-45 | 2.19E+08 | 2.42E+09 | 1.24E+01 | 3.99E+04 | 6.83E+06 |
| Cd-109 | 1.03E+09 | 4.52E+10 | 6.83E+01 | 1.61E+05 | 1.75E+07 |
| Ce-144 | 4.15E+09 | 4.12E+11 | 1.72E+02 | 1.56E+05 | 8.78E+07 |
| Cf-250 | 3.60E+12 | 2.69E+12 | 6.01E+04 | 8.98E+07 | 1.47E+11 |
| Cf-252 | 1.01E+12 | 4.38E+11 | 5.99E+03 | 5.92E+06 | 1.99E+10 |
| Cl-36 | 5.70E+11 | 5.73E+11 | 4.67E+05 | 3.00E+09 | 1.25E+07 |
| Cm-242 | 1.06E+11 | 3.00E+11 | 8.42E+02 | 1.26E+06 | 2.43E+09 |
| Cm-243 | 2.16E+12 | 3.96E+12 | 8.79E+04 | 1.18E+08 | 2.22E+10 |
| Cm-244 | 1.74E+12 | 2.99E+12 | 5.42E+04 | 6.65E+07 | 1.86E+10 |
| Cm-245 | 3.25E+12 | 7.01E+12 | 2.17E+05 | 3.77E+08 | 3.02E+10 |
| Cm-246 | 3.24E+12 | 6.90E+12 | 2.09E+05 | 3.58E+08 | 3.00E+10 |
| Cm-248 | 1.20E+13 | 2.61E+13 | 7.73E+05 | 1.33E+09 | 1.12E+11 |
| Co-56 | 1.09E+09 | 9.60E+10 | 5.17E+03 | 4.46E+06 | 3.06E+07 |
| Co-57 | 1.15E+08 | 9.40E+09 | 2.06E+02 | 1.83E+05 | 3.15E+06 |
| Co-58 | 2.97E+08 | 2.79E+10 | 9.70E+02 | 8.38E+05 | 6.45E+06 |
| Co-60 | 2.61E+09 | 3.35E+11 | 6.20E+04 | 6.03E+07 | 7.23E+07 |
| Cs-132 | 1.23E+08 | 6.88E+10 | 7.54E+01 | 6.48E+04 | 1.56E+06 |
| Cs-134 | 5.07E+09 | 2.65E+12 | 1.59E+04 | 1.51E+07 | 1.25E+08 |
| Cs-137 | 5.24E+09 | 1.86E+12 | 4.44E+04 | 6.71E+07 | 8.47E+07 |
| Es-254 | 5.26E+11 | 2.10E+11 | 4.00E+03 | 5.81E+06 | 2.30E+10 |
| Eu-152 | 2.42E+09 | 1.49E+11 | 5.37E+04 | 6.12E+07 | 6.25E+07 |
| Eu-154 | 3.21E+09 | 1.29E+11 | 4.52E+04 | 4.70E+07 | 7.30E+07 |
| Eu-155 | 5.45E+08 | 2.36E+09 | 3.70E+02 | 3.58E+05 | 1.54E+07 |
| Fe-55 | 4.03E+07 | 1.94E+10 | 6.90E-01 | 1.99E+03 | 6.27E+05 |
| Ge-68 | 1.66E+10 | 1.20E+11 | 1.07E+04 | 2.42E+07 | 3.55E+08 |
| H-3 | 9.18E+06 | 1.04E+07 | 1.55E-03 | 1.34E+00 | 3.02E+05 |
| I-129 | 3.43E+10 | 2.58E+12 | 1.43E+04 | 8.86E+07 | 8.48E+09 |
| I-131 | 3.30E+09 | 4.61E+11 | 3.83E+01 | 3.56E+04 | 5.21E+08 |
| K-40 | 1.29E+10 | 4.05E+11 | 2.95E+04 | 9.59E+07 | 3.34E+07 |
| Kr-85 | 2.75E+03 | 4.09E+08 | 0.00E+00 | 1.66E+05 | 9.32E+02 |
| Mn-52 | 5.05E+08 | 5.97E+10 | 2.94E+02 | 2.52E+05 | 4.61E+06 |
| Mn-54 | 2.01E+08 | 3.06E+10 | 3.70E+03 | 3.24E+06 | 3.55E+06 |
| Mn-56 | 7.09E+07 | 1.47E+07 | 2.74E+00 | 2.35E+03 | 9.15E+05 |

Table D.2.1.17 Native American Scenario Radionuclide Unit Risk Factors (cont'd)

| Radionuclide | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Mo-93 | 7.00E+08 | 1.26E+09 | 2.27E+02 | 1.48E+06 | 1.72E+07 |
| Na-22 | 1.36E+09 | 9.05E+10 | 2.73E+04 | 2.52E+07 | 8.05E+07 |
| Nb-93m | 2.55E+08 | 3.91E+09 | 6.32E+01 | 2.67E+05 | 9.47E+06 |
| Nb-94 | 4.18E+09 | 5.06E+11 | 2.00E+05 | 3.50E+08 | 1.28E+08 |
| Nb-95 | 7.46E+07 | 2.15E+09 | 3.81E+02 | 3.27E+05 | 3.97E+06 |
| Ni-59 | 3.12E+07 | 5.52E+08 | 1.09E+01 | 6.65E+04 | 4.04E+05 |
| Ni-63 | 8.55E+07 | 1.63E+09 | 2.74E+01 | 1.55E+05 | 1.06E+06 |
| Np-237 | 3.71E+12 | 7.59E+12 | 2.89E+05 | 5.04E+08 | 2.66E+10 |
| Np-239 | 3.55E+08 | 2.23E+10 | 2.11E+00 | 1.81E+03 | 1.96E+06 |
| P-32 | 6.80E+08 | 1.13E+13 | 4.22E+01 | 1.35E+05 | 1.51E+07 |
| Pa-231 | 8.46E+12 | 1.91E+13 | 9.71E+05 | 1.85E+09 | 1.86E+10 |
| Pa-233 | 5.19E+08 | 1.99E+09 | 4.51E+01 | 3.87E+04 | 4.12E+06 |
| Pb-210 | 7.09E+10 | 1.98E+12 | 5.38E+03 | 1.46E+07 | 1.44E+09 |
| Pb-212 | 2.15E+09 | 1.10E+10 | 1.01E+01 | 8.66E+03 | 5.75E+07 |
| Pm-147 | 3.18E+08 | 1.16E+09 | 2.40E+00 | 4.47E+03 | 6.10E+06 |
| Po-210 | 5.99E+10 | 4.51E+12 | 6.20E+01 | 1.24E+05 | 1.71E+09 |
| Pu-238 | 2.66E+12 | 5.52E+12 | 1.48E+05 | 2.32E+08 | 2.11E+10 |
| Pu-239 | 2.97E+12 | 6.55E+12 | 1.98E+05 | 3.40E+08 | 2.14E+10 |
| Pu-240 | 2.97E+12 | 6.54E+12 | 1.98E+05 | 3.39E+08 | 2.14E+10 |
| Pu-241 | 5.47E+10 | 1.47E+11 | 5.41E+03 | 9.82E+06 | 2.17E+08 |
| Pu-242 | 2.81E+12 | 6.21E+12 | 1.87E+05 | 3.21E+08 | 2.03E+10 |
| Ra-223 | 5.34E+10 | 4.45E+11 | 3.37E+01 | 2.99E+04 | 2.79E+09 |
| Ra-224 | 3.26E+10 | 2.34E+11 | 8.41E+01 | 7.22E+04 | 1.73E+09 |
| Ra-225 | 3.59E+10 | 3.03E+11 | 2.49E+02 | 6.99E+05 | 1.85E+09 |
| Ra-226 | 5.65E+10 | 1.30E+12 | 2.81E+05 | 4.95E+08 | 2.17E+09 |
| Ra-228 | 3.26E+10 | 1.20E+12 | 1.18E+05 | 1.20E+08 | 8.33E+08 |
| Re-187 | 3.66E+06 | 2.67E+07 | 2.23E+00 | 1.43E+04 | 3.52E+04 |
| Rn-222 | 8.08E+08 | 6.64E+08 | 0.00E+00 | 1.09E+05 | 6.37E+06 |
| Ru-103 | 3.05E+08 | 9.88E+09 | 2.46E+02 | 2.12E+05 | 3.99E+06 |
| Ru-106 | 1.45E+09 | 1.22E+10 | 1.00E+03 | 8.87E+05 | 8.89E+07 |
| S-35 | 7.75E+07 | 8.63E+09 | 1.85E+01 | 5.98E+04 | 2.08E+06 |
| Sb-122 | 7.30E+08 | 3.82E+10 | 1.60E+01 | 1.37E+04 | 4.40E+06 |
| Sb-124 | 9.58E+08 | 6.31E+10 | 1.62E+03 | 1.40E+06 | 1.21E+07 |
| Sb-125 | 3.02E+08 | 2.84E+10 | 4.70E+03 | 4.29E+06 | 4.74E+06 |
| Sc-46 | 6.87E+08 | 2.20E+10 | 2.45E+03 | 2.11E+06 | 1.24E+07 |
| Se-75 | 6.22E+08 | 3.20E+10 | 3.94E+02 | 3.48E+05 | 1.19E+07 |
| Se-79 | 9.63E+08 | 3.11E+10 | 2.95E+02 | 1.80E+06 | 1.44E+07 |
| Sm-147 | 5.24E+11 | 7.56E+11 | 3.37E+04 | 5.86E+07 | 5.33E+09 |
| Sm-151 | 2.63E+08 | 6.42E+08 | 1.49E+01 | 3.43E+04 | 3.67E+06 |
| Sn-113 | 4.85E+08 | 3.14E+11 | 3.33E+02 | 2.95E+05 | 1.08E+07 |
| Sn-123 | 9.13E+08 | 5.06E+11 | 2.41E+01 | 3.41E+04 | 2.75E+07 |
| Sr-85 | 1.27E+08 | 2.89E+09 | 3.71E+02 | 3.30E+05 | 1.60E+06 |
| Sr-89 | 8.76E+08 | 1.49E+10 | 2.49E+01 | 7.95E+04 | 6.86E+06 |
| Sr-90 | 2.19E+10 | 8.12E+10 | 1.51E+04 | 7.49E+07 | 6.80E+07 |
| Ta-182 | 7.23E+08 | 5.80E+12 | 1.96E+03 | 1.69E+06 | 1.40E+07 |

Table D.2.1.17 Native American Scenario Radionuclide Unit Risk Factors (cont'd)

| Radionuclide | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Tc-99 | 2.40E+09 | 3.04E+09 | 1.85E+03 | 1.19E+07 | 6.07E+06 |
| Te-125m | 2.42E+08 | 2.76E+10 | 9.58E-01 | 1.88E+03 | 2.98E+06 |
| Th-227 | 8.71E+10 | 1.21E+11 | 7.46E+01 | 6.59E+04 | 3.32E+09 |
| Th-228 | 2.26E+12 | 7.29E+11 | 3.62E+04 | 3.25E+07 | 7.25E+10 |
| Th-229 | 1.37E+13 | 2.10E+13 | 1.21E+06 | 3.26E+09 | 5.83E+10 |
| Th-230 | 2.04E+12 | 3.13E+12 | 1.40E+05 | 2.42E+08 | 1.32E+10 |
| Th-231 | 2.82E+08 | 2.72E+09 | 9.46E-02 | 1.71E+02 | 8.50E+05 |
| Th-232 | 1.06E+13 | 1.90E+13 | 1.20E+06 | 2.17E+09 | 1.48E+10 |
| Th-234 | 1.72E+09 | 5.34E+10 | 5.23E+00 | 4.50E+03 | 1.57E+07 |
| Tl-204 | 2.12E+08 | 5.68E+09 | 1.34E+01 | 3.40E+04 | 3.49E+06 |
| Tm-170 | 7.43E+08 | 5.81E+09 | 3.22E+00 | 5.21E+03 | 9.92E+06 |
| U-232 | 5.37E+11 | 2.31E+12 | 3.64E+05 | 5.91E+08 | 4.06E+10 |
| U-233 | 1.44E+11 | 1.06E+11 | 4.27E+03 | 1.57E+07 | 1.08E+10 |
| U-234 | 1.42E+11 | 7.54E+10 | 1.55E+03 | 4.83E+06 | 1.07E+10 |
| U-235 | 1.33E+11 | 1.02E+11 | 1.06E+04 | 2.09E+07 | 9.98E+09 |
| U-236 | 1.35E+11 | 7.15E+10 | 1.47E+03 | 4.57E+06 | 1.01E+10 |
| U-238 | 1.27E+11 | 7.81E+10 | 3.35E+03 | 7.85E+06 | 9.52E+09 |
| V-49 | 6.21E+06 | 1.63E+07 | 1.63E-02 | 3.91E+01 | 2.12E+05 |
| Y-88 | 2.29E+10 | 2.17E+10 | 5.31E+03 | 4.58E+06 | 1.71E+07 |
| Y-90 | 1.25E+09 | 8.98E+09 | 2.00E-01 | 1.84E+02 | 7.70E+06 |
| Zn-65 | 2.00E+09 | 6.90E+11 | 2.53E+03 | 3.43E+06 | 4.79E+07 |
| Zr-93 | 7.96E+08 | 3.99E+09 | 1.33E+02 | 7.96E+05 | 4.18E+06 |

Table D.2.1.18 Residential Farmer Scenario Noncarcinogenic Chemical Unit Risk Factors

| Chemical Name | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Aluminum | 4.04E+04 | 4.47E+04 | 5.30E-04 | 5.88E+00 | 4.48E+01 |
| Arsenic | 1.29E+08 | 2.60E+08 | 1.98E+00 | 2.57E+04 | 8.35E+04 |
| Barium | 5.77E+05 | 1.69E+06 | 2.58E-02 | 2.86E+02 | 2.47E+06 |
| Beryllium | 9.46E+06 | 1.17E+07 | 1.43E-01 | 1.33E+03 | 3.89E+03 |
| Bismuth | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Boron | 9.67E+05 | 9.73E+05 | 1.16E-01 | 3.36E+03 | 6.36E+04 |
| Cadmium | 1.05E+08 | 2.62E+08 | 6.56E+00 | 1.67E+05 | 1.33E+05 |
| Calcium Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Chromate Ion | 1.14E+07 | 2.75E+07 | 4.05E+00 | 3.36E+04 | 6.20E+08 |
| Chromium III | 5.69E+04 | 1.38E+05 | 3.87E+00 | 3.08E+04 | 6.19E+08 |
| Copper Ion | 1.89E+06 | 2.43E+06 | 1.79E-01 | 5.09E+03 | 3.04E+03 |
| Ferrocyanide Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Fluoride | 1.61E+06 | 1.68E+06 | 6.42E-02 | 1.76E+03 | 6.94E+03 |
| Iron III | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Lead Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Lithium Ion | 1.50E+07 | 1.50E+07 | 2.30E-01 | 6.40E+03 | 1.21E+05 |
| Magnesium Ion | 1.14E+04 | 1.35E+04 | 1.53E-03 | 4.50E+01 | 2.26E+01 |
| Manganese Ion | 9.61E+06 | 4.06E+07 | 5.64E-01 | 1.48E+04 | 7.01E+03 |
| Mercury Ion | 8.36E+08 | 2.13E+09 | 1.28E+02 | 3.80E+06 | 6.19E+06 |
| Molybdenum Ion | 1.05E+07 | 1.14E+07 | 3.91E-01 | 9.64E+03 | 2.05E+04 |
| Nickel Ion | 2.45E+06 | 4.41E+06 | 9.32E-02 | 2.27E+03 | 3.95E+03 |
| Nitrate Ion | 7.59E+06 | 4.38E+07 | 2.05E+00 | 6.15E+04 | 8.63E+02 |
| Nitrite Ion | 3.73E+04 | 3.78E+04 | 4.56E-04 | 3.65E+00 | 1.75E+01 |
| Phosphate Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Potassium Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Silicate Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Silver Ion | 2.83E+07 | 2.86E+07 | 4.06E-01 | 1.01E+04 | 1.95E+05 |
| Sodium Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Strontium Ion | 1.63E+05 | 1.96E+05 | 2.49E-02 | 7.29E+02 | 1.49E+02 |
| Sulfate Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Uranium | 1.41E+07 | 2.08E+07 | 2.49E-01 | 3.94E+03 | 1.55E+04 |
| Vanadium Ion | 5.37E+06 | 6.03E+06 | 8.55E-02 | 1.19E+03 | 7.83E+03 |
| Zinc Ion | 1.09E+06 | 4.31E+06 | 1.97E-01 | 5.87E+03 | 2.42E+03 |

Table D.2.1.19 Residential Farmer Scenario Carcinogenic Chemical Unit Risk Factors

| Chemical Name | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Arsenic | 2.39E+04 | 5.31E+04 | 0.000457 | 5.88 | 1.87E+03 |
| Beryllium | 7.46E+04 | 9.50E+04 | 0.00133 | 12.3 | 1.07E+03 |
| Cadmium | 0 | 0 | 4.82E-06 | 0.0386 | 771 |
| Chromium | 0 | 0 | 3.21E-05 | 0.257 | 5.14E+03 |

Table D.2.1.20 Residential Farmer Scenario Radionuclide Unit Risk Factors

| Radionuclide | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Ac-225 | 3.69E+09 | 4.69E+09 | 9.28E-01 | 1.21E+05 | 9.21E+08 |
| Ac-227 | 3.89E+11 | 5.05E+11 | 7.34E+03 | 5.15E+07 | 1.55E+10 |
| Ac-228 | 2.88E+07 | 4.43E+07 | 5.69E-03 | 1.22E+04 | 7.29E+06 |
| Ag-110m | 8.09E+08 | 8.72E+08 | 1.47E+03 | 8.30E+06 | 1.34E+07 |
| Am-241 | 1.09E+11 | 1.63E+11 | 1.91E+03 | 1.52E+07 | 8.44E+09 |
| Am-243 | 1.09E+11 | 1.63E+11 | 2.73E+03 | 2.19E+07 | 8.37E+09 |
| Au-195 | 1.92E+07 | 2.74E+07 | 1.48E+01 | 9.20E+04 | 2.11E+06 |
| Ba-133 | 6.79E+07 | 2.75E+08 | 1.55E+03 | 9.71E+06 | 1.00E+06 |
| Be-10 | 8.44E+07 | 8.82E+07 | 3.55E+00 | 3.06E+04 | 5.67E+07 |
| Be-7 | 1.98E+06 | 2.27E+06 | 2.41E+00 | 2.91E+04 | 4.58E+04 |
| Bl-210 | 1.89E+08 | 2.13E+08 | 5.75E-03 | 1.17E+03 | 1.13E+07 |
| C-14 | 6.06E+08 | 2.01E+09 | 2.01E-01 | 1.60E+03 | 3.53E+06 |
| Ca-45 | 1.21E+08 | 1.45E+08 | 5.19E-01 | 1.23E+04 | 1.26E+06 |
| Cd-109 | 2.29E+08 | 7.05E+08 | 4.98E+00 | 4.61E+04 | 4.45E+06 |
| Ce-144 | 7.25E+08 | 5.13E+09 | 2.64E+01 | 1.46E+05 | 2.41E+07 |
| Cf-250 | 9.85E+10 | 1.28E+11 | 1.19E+03 | 1.12E+07 | 4.19E+10 |
| Cf-252 | 4.65E+10 | 6.04E+10 | 1.90E+02 | 1.39E+06 | 2.51E+10 |
| Cl-36 | 4.07E+10 | 4.07E+10 | 1.11E+04 | 3.33E+08 | 1.86E+06 |
| Cm-242 | 3.52E+09 | 7.13E+09 | 6.34E+00 | 6.94E+04 | 6.93E+08 |
| Cm-243 | 7.39E+10 | 1.13E+11 | 1.44E+03 | 1.04E+07 | 6.33E+09 |
| Cm-244 | 5.93E+10 | 9.11E+10 | 7.36E+02 | 5.04E+06 | 5.33E+09 |
| Cm-245 | 1.11E+11 | 1.66E+11 | 2.17E+03 | 1.74E+07 | 8.59E+09 |
| Cm-246 | 1.11E+11 | 1.66E+11 | 1.98E+03 | 1.59E+07 | 8.55E+09 |
| Cm-248 | 4.12E+11 | 6.22E+11 | 7.32E+03 | 5.87E+07 | 3.20E+10 |
| Co-56 | 3.02E+08 | 1.23E+09 | 4.81E+02 | 4.45E+06 | 7.72E+06 |
| Co-57 | 3.37E+07 | 1.30E+08 | 3.21E+01 | 1.78E+05 | 7.57E+05 |
| Co-58 | 9.16E+07 | 3.73E+08 | 8.41E+01 | 8.35E+05 | 1.52E+06 |
| Co-60 | 6.96E+08 | 2.89E+09 | 1.07E+04 | 5.85E+07 | 1.77E+07 |
| Cs-132 | 3.98E+07 | 8.58E+08 | 8.06E-01 | 6.47E+04 | 3.80E+05 |
| Cs-134 | 2.59E+09 | 3.07E+10 | 2.84E+03 | 1.43E+07 | 2.07E+07 |
| Cs-137 | 1.90E+09 | 2.07E+10 | 5.06E+03 | 3.77E+07 | 1.39E+07 |
| Es-254 | 1.36E+10 | 1.66E+10 | 6.41E+01 | 7.35E+05 | 6.58E+09 |
| Eu-152 | 1.86E+08 | 4.66E+08 | 7.61E+03 | 4.96E+07 | 1.76E+07 |
| Eu-154 | 2.88E+08 | 5.91E+08 | 7.08E+03 | 4.27E+07 | 2.05E+07 |
| Eu-155 | 4.88E+07 | 6.56E+07 | 6.37E+01 | 3.44E+05 | 4.34E+06 |
| Fe-55 | 1.02E+07 | 2.18E+08 | 3.50E-02 | 4.80E+02 | 1.43E+05 |
| Ge-68 | 5.15E+09 | 6.18E+09 | 9.31E+02 | 8.36E+06 | 4.22E+07 |
| H-3 | 1.95E+06 | 1.98E+06 | 7.26E-05 | 7.83E-01 | 4.78E+04 |
| I-129 | 1.29E+10 | 4.01E+10 | 4.28E+02 | 1.20E+07 | 1.23E+09 |
| I-131 | 1.25E+09 | 6.61E+09 | 4.94E-01 | 3.32E+04 | 9.60E+06 |
| K-40 | 1.48E+09 | 5.23E+09 | 2.05E+03 | 2.14E+07 | 5.47E+06 |
| Kr-85 | 0.00E+00 | 6.83E+05 | 0.00E+00 | 1.43E+05 | 3.68E+02 |
| Mn-52 | 1.28E+08 | 8.43E+08 | 0.00E+00 | 2.52E+05 | 1.45E+06 |
| Mn-54 | 4.93E+07 | 3.03E+08 | 6.00E+02 | 3.22E+06 | 9.62E+05 |
| Mn-56 | 7.40E+05 | 1.03E+08 | 4.96E-04 | 2.35E+03 | 3.35E+05 |

Table D.2.1.20 Residential Farmer Scenario Radionuclide Unit Risk Factors (cont'd)

| Radionuclide | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Mo-93 | 8.52E+07 | 9.17E+07 | 5.35E+00 | 1.34E+05 | 4.70E+06 |
| Na-22 | 1.37E+09 | 1.76E+09 | 4.93E+03 | 2.47E+07 | 1.23E+07 |
| Nb-93m | 1.09E+08 | 1.48E+08 | 2.34E+00 | 5.50E+04 | 1.74E+06 |
| Nb-94 | 1.18E+09 | 2.07E+09 | 1.82E+04 | 1.47E+08 | 2.64E+07 |
| Nb-95 | 2.44E+07 | 4.05E+07 | 1.95E+01 | 3.27E+05 | 9.51E+05 |
| Ni-59 | 5.98E+06 | 1.15E+07 | 2.29E-01 | 6.16E+03 | 9.91E+04 |
| Ni-63 | 1.76E+07 | 3.40E+07 | 6.32E-01 | 1.65E+04 | 2.54E+05 |
| Np-237 | 1.29E+11 | 1.87E+11 | 5.97E+03 | 4.84E+07 | 7.56E+09 |
| Np-239 | 8.22E+07 | 3.99E+08 | 8.34E-03 | 1.80E+03 | 5.56E+05 |
| P-32 | 3.41E+08 | 1.27E+11 | 3.15E-01 | 4.32E+04 | 3.73E+06 |
| Pa-231 | 3.03E+11 | 3.92E+11 | 8.09E+03 | 7.29E+07 | 5.30E+09 |
| Pa-233 | 1.04E+08 | 1.20E+08 | 1.84E+00 | 3.87E+04 | 1.13E+06 |
| Pb-210 | 1.67E+10 | 3.68E+10 | 2.08E+02 | 2.60E+06 | 3.82E+08 |
| Pb-212 | 1.87E+08 | 7.38E+08 | 7.56E-03 | 8.66E+03 | 1.64E+07 |
| Pm-147 | 3.95E+07 | 5.14E+07 | 1.05E-01 | 9.99E+02 | 1.67E+06 |
| Po-210 | 8.44E+09 | 5.68E+10 | 2.21E+00 | 3.08E+04 | 4.77E+08 |
| Pu-238 | 9.39E+10 | 1.42E+11 | 1.54E+03 | 1.18E+07 | 6.01E+09 |
| Pu-239 | 1.05E+11 | 1.58E+11 | 1.86E+03 | 1.49E+07 | 6.09E+09 |
| Pu-240 | 1.05E+11 | 1.58E+11 | 1.86E+03 | 1.49E+07 | 6.09E+09 |
| Pu-241 | 2.00E+09 | 2.95E+09 | 4.45E+01 | 3.90E+05 | 6.17E+07 |
| Pu-242 | 9.95E+10 | 1.49E+11 | 1.77E+03 | 1.41E+07 | 5.79E+09 |
| Ra-223 | 5.28E+09 | 1.01E+10 | 6.05E-01 | 2.85E+04 | 7.93E+08 |
| Ra-224 | 2.86E+09 | 5.77E+09 | 5.13E-01 | 7.21E+04 | 4.94E+08 |
| Ra-225 | 3.65E+09 | 6.91E+09 | 2.08E+00 | 1.91E+05 | 5.24E+08 |
| Ra-226 | 7.76E+09 | 1.47E+10 | 2.53E+04 | 2.04E+08 | 6.05E+08 |
| Ra-228 | 6.40E+09 | 1.22E+10 | 1.60E+04 | 9.69E+07 | 2.26E+08 |
| Re-187 | 3.70E+05 | 6.18E+05 | 4.41E-02 | 1.30E+03 | 9.27E+03 |
| Rn-222 | 1.83E+08 | 1.85E+08 | 0.00E+00 | 1.03E+05 | 1.89E+06 |
| Ru-103 | 7.60E+07 | 1.76E+08 | 1.38E+01 | 2.11E+05 | 1.10E+06 |
| Ru-106 | 8.48E+07 | 1.94E+08 | 1.69E+02 | 8.82E+05 | 2.53E+07 |
| S-35 | 4.08E+07 | 1.33E+08 | 4.80E-01 | 1.56E+04 | 3.02E+05 |
| Sb-122 | 1.72E+08 | 6.94E+08 | 7.24E-02 | 1.37E+04 | 1.26E+06 |
| Sb-124 | 2.48E+08 | 8.92E+08 | 1.26E+02 | 1.40E+06 | 3.26E+06 |
| Sb-125 | 7.33E+07 | 2.77E+08 | 8.54E+02 | 4.27E+06 | 1.25E+06 |
| Sc-46 | 1.48E+08 | 3.35E+08 | 2.37E+02 | 2.11E+06 | 3.29E+06 |
| Se-75 | 2.58E+08 | 5.89E+08 | 4.60E+01 | 3.40E+05 | 2.21E+06 |
| Se-79 | 2.87E+08 | 6.07E+08 | 7.63E+00 | 2.05E+05 | 2.75E+06 |
| Sm-147 | 1.72E+10 | 2.24E+10 | 3.18E+02 | 2.61E+06 | 1.52E+09 |
| Sm-151 | 1.80E+07 | 2.34E+07 | 2.38E-01 | 2.96E+03 | 1.02E+06 |
| Sn-113 | 1.54E+08 | 3.53E+09 | 3.81E+01 | 2.87E+05 | 2.09E+06 |
| Sn-123 | 2.51E+08 | 5.69E+09 | 2.38E+00 | 1.99E+04 | 6.19E+06 |
| Sr-85 | 3.95E+07 | 6.27E+07 | 3.01E+01 | 3.18E+05 | 3.90E+05 |
| Sr-89 | 2.85E+08 | 4.38E+08 | 4.07E-01 | 1.88E+04 | 1.35E+06 |
| Sr-90 | 2.52E+09 | 3.14E+09 | 4.12E+02 | 1.01E+07 | 1.58E+07 |
| Ta-182 | 1.64E+08 | 6.26E+10 | 2.26E+02 | 1.69E+06 | 3.86E+06 |

Table D.2.1.20 Residential Farmer Scenario Radionuclide Unit Risk Factors (cont'd)

| Radionuclide | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Tc-99 | 2.61E+08 | 2.67E+08 | 4.79E+01 | 1.43E+06 | 1.18E+06 |
| Te-125m | 6.44E+07 | 3.62E+08 | 4.44E-02 | 7.34E+02 | 7.06E+05 |
| Th-227 | 2.47E+09 | 4.09E+09 | 1.95E+00 | 5.80E+04 | 9.46E+08 |
| Th-228 | 5.04E+10 | 6.69E+10 | 5.28E+03 | 2.62E+07 | 2.07E+10 |
| Th-229 | 4.79E+11 | 6.19E+11 | 1.51E+04 | 2.16E+08 | 1.67E+10 |
| Th-230 | 6.90E+10 | 9.04E+10 | 1.37E+03 | 1.14E+07 | 3.77E+09 |
| Th-231 | 5.36E+07 | 1.07E+08 | 2.13E-05 | 1.38E+01 | 2.43E+05 |
| Th-232 | 3.82E+11 | 4.97E+11 | 2.98E+04 | 2.97E+08 | 4.23E+09 |
| Th-234 | 4.30E+08 | 1.00E+09 | 1.91E-01 | 4.43E+03 | 4.27E+06 |
| Tl-204 | 7.87E+07 | 1.37E+08 | 1.19E+00 | 1.14E+04 | 5.59E+05 |
| Tm-170 | 1.81E+08 | 2.37E+08 | 2.70E-01 | 2.41E+03 | 2.54E+06 |
| U-232 | 3.00E+09 | 5.33E+09 | 2.71E+04 | 2.28E+08 | 1.16E+10 |
| U-233 | 1.38E+09 | 2.10E+09 | 5.64E+01 | 8.45E+05 | 3.09E+09 |
| U-234 | 1.34E+09 | 2.05E+09 | 3.87E+01 | 5.10E+05 | 3.07E+09 |
| U-235 | 1.37E+09 | 2.11E+09 | 8.34E+02 | 6.88E+06 | 2.85E+09 |
| U-236 | 1.27E+09 | 1.95E+09 | 3.66E+01 | 4.83E+05 | 2.89E+09 |
| U-238 | 1.28E+09 | 1.97E+09 | 2.09E+02 | 1.87E+06 | 2.72E+09 |
| V-49 | 1.23E+06 | 1.37E+06 | 9.64E-04 | 1.17E+01 | 5.75E+04 |
| Y-88 | 9.14E+08 | 1.22E+09 | 5.86E+02 | 4.56E+06 | 4.90E+06 |
| Y-90 | 2.92E+08 | 4.03E+08 | 8.61E-04 | 1.66E+02 | 2.18E+06 |
| Zn-65 | 8.75E+08 | 8.24E+09 | 3.27E+02 | 2.16E+06 | 7.44E+06 |
| Zr-93 | 4.57E+07 | 8.20E+07 | 1.83E+00 | 5.71E+04 | 1.16E+06 |

Table D.2.1.21 Industrial Scenario Noncarcinogenic Chemical Unit Risk Factors

| Chemical Name | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Aluminum | 9.89E+03 | 9.89E+03 | 2.43E-05 | 2.92E-01 | 0.00E+00 |
| Arsenic | 3.32E+07 | 3.32E+07 | 8.26E-02 | 9.90E+02 | 0.00E+00 |
| Barium | 1.46E+05 | 1.46E+05 | 3.74E-03 | 4.49E+01 | 1.37E+06 |
| Beryllium | 3.31E+06 | 3.31E+06 | 2.38E-02 | 2.86E+02 | 0.00E+00 |
| Bismuth | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Boron | 1.10E+05 | 1.10E+05 | 3.54E-04 | 4.23E+00 | 3.43E+04 |
| Cadmium | 2.11E+07 | 2.11E+07 | 2.38E-01 | 2.86E+03 | 0.00E+00 |
| Calcium Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Chromate Ion | 3.31E+06 | 3.31E+06 | 8.49E-01 | 1.02E+04 | 3.43E+08 |
| Chromium III | 1.65E+04 | 1.65E+04 | 8.34E-01 | 1.00E+04 | 3.43E+08 |
| Copper Ion | 2.68E+05 | 2.68E+05 | 6.70E-04 | 8.03E+00 | 0.00E+00 |
| Ferrocyanide Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Fluoride | 1.65E+05 | 1.65E+05 | 4.05E-04 | 4.86E+00 | 0.00E+00 |
| Iron III | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Lead Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Lithium Ion | 4.96E+05 | 4.96E+05 | 1.21E-03 | 1.46E+01 | 0.00E+00 |
| Magnesium Ion | 1.03E+03 | 1.03E+03 | 2.55E-06 | 3.07E-02 | 0.00E+00 |
| Manganese Ion | 2.05E+06 | 2.05E+06 | 5.71E-03 | 6.85E+01 | 0.00E+00 |
| Mercury Ion | 3.85E+07 | 3.85E+07 | 1.64E-01 | 1.97E+03 | 2.28E+06 |
| Molybdenum Ion | 2.11E+06 | 2.11E+06 | 6.66E-03 | 8.00E+01 | 0.00E+00 |
| Nickel Ion | 4.97E+05 | 4.97E+05 | 1.67E-03 | 2.00E+01 | 0.00E+00 |
| Nitrate Ion | 6.20E+03 | 6.20E+03 | 1.52E-05 | 1.83E-01 | 0.00E+00 |
| Nitrite Ion | 9.92E+03 | 9.92E+03 | 2.43E-05 | 2.92E-01 | 0.00E+00 |
| Phosphate Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Potassium Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Silicate Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Silver Ion | 2.06E+06 | 2.06E+06 | 6.66E-03 | 8.00E+01 | 0.00E+00 |
| Sodium Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Strontium Ion | 1.67E+04 | 1.67E+04 | 4.23E-05 | 5.08E-01 | 0.00E+00 |
| Sulfate Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Uranium | 3.52E+06 | 3.52E+06 | 1.11E-02 | 1.33E+02 | 0.00E+00 |
| Vanadium Ion | 1.47E+06 | 1.47E+06 | 7.94E-03 | 9.52E+01 | 0.00E+00 |
| Zinc Ion | 3.31E+04 | 3.31E+04 | 8.26E-05 | 9.90E-01 | 0.00E+00 |

Table D.2.1.22 Industrial Scenario Carcinogenic Chemical Unit Risk Factors

| Chemical Name | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Arsenic | 4.97E+03 | 4.97E+03 | 1.44E-05 | 1.73E-01 | 8.44E+02 |
| Beryllium | 2.03E+04 | 2.03E+04 | 1.47E-04 | 1.76E+00 | 4.70E+02 |
| Cadmium | 0.00E+00 | 0.00E+00 | 8.57E-07 | 1.03E-02 | 3.52E+02 |
| Chromium | 0.00E+00 | 0.00E+00 | 5.71E-06 | 6.86E-02 | 2.35E+03 |

Table D.2.1.23 Industrial Scenario Radionuclide Unit Risk Factors

| Radionuclide | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Ac-225 | 9.62E+08 | 9.62E+08 | 3.96E-02 | 3.14E+03 | 4.20E+08 |
| Ac-227 | 1.76E+11 | 1.76E+11 | 2.17E+03 | 2.39E+07 | 7.09E+09 |
| Ac-228 | 4.17E+06 | 4.17E+06 | 5.35E-04 | 1.80E+03 | 3.29E+06 |
| Ag-110m | 4.34E+07 | 4.34E+07 | 1.28E+02 | 1.11E+06 | 3.26E+06 |
| Am-241 | 4.76E+10 | 4.76E+10 | 6.64E+02 | 7.94E+06 | 3.85E+09 |
| Am-243 | 4.76E+10 | 4.76E+10 | 7.18E+02 | 8.62E+06 | 3.82E+09 |
| Au-195 | 3.90E+06 | 3.90E+06 | 1.30E+00 | 1.22E+04 | 9.51E+05 |
| Ba-133 | 1.37E+07 | 1.37E+07 | 1.08E+02 | 1.10E+06 | 4.10E+05 |
| Be-10 | 1.89E+07 | 1.89E+07 | 2.74E-01 | 3.30E+03 | 2.59E+07 |
| Be-7 | 4.40E+05 | 4.40E+05 | 2.13E-01 | 3.88E+03 | 1.87E+04 |
| Bl-210 | 3.47E+07 | 3.47E+07 | 6.33E-04 | 1.01E+02 | 5.13E+06 |
| C-14 | 5.23E+06 | 5.23E+06 | 1.47E-02 | 1.76E+02 | 7.00E+02 |
| Ca-45 | 1.03E+07 | 1.03E+07 | 1.38E-03 | 1.35E+01 | 2.51E+05 |
| Cd-109 | 4.35E+07 | 4.35E+07 | 3.52E-01 | 2.77E+03 | 1.85E+06 |
| Ce-144 | 1.63E+08 | 1.63E+08 | 2.32E+00 | 1.94E+04 | 1.08E+07 |
| Cf-250 | 3.52E+10 | 3.52E+10 | 3.26E+02 | 3.39E+06 | 1.91E+10 |
| Cf-252 | 1.64E+10 | 1.64E+10 | 6.10E+01 | 4.89E+05 | 1.15E+10 |
| Cl-36 | 1.14E+07 | 1.14E+07 | 3.51E-01 | 4.22E+03 | 1.30E+05 |
| Cm-242 | 1.39E+09 | 1.39E+09 | 2.40E+00 | 3.89E+04 | 3.16E+08 |
| Cm-243 | 3.23E+10 | 3.23E+10 | 4.11E+02 | 4.60E+06 | 2.89E+09 |
| Cm-244 | 2.59E+10 | 2.59E+10 | 2.84E+02 | 3.06E+06 | 2.43E+09 |
| Cm-245 | 4.89E+10 | 4.89E+10 | 7.03E+02 | 8.46E+06 | 3.92E+09 |
| Cm-246 | 4.89E+10 | 4.89E+10 | 6.89E+02 | 8.25E+06 | 3.90E+09 |
| Cm-248 | 1.81E+11 | 1.81E+11 | 2.54E+03 | 3.05E+07 | 1.46E+10 |
| Co-56 | 4.66E+07 | 4.66E+07 | 4.25E+01 | 5.94E+05 | 2.96E+06 |
| Co-57 | 4.91E+06 | 4.91E+06 | 2.79E+00 | 2.36E+04 | 2.90E+05 |
| Co-58 | 1.42E+07 | 1.42E+07 | 7.44E+00 | 1.11E+05 | 5.36E+05 |
| Co-60 | 9.59E+07 | 9.59E+07 | 8.18E+02 | 7.36E+06 | 6.94E+06 |
| Cs-132 | 6.63E+06 | 6.63E+06 | 7.16E-02 | 8.62E+03 | 1.03E+05 |
| Cs-134 | 2.40E+08 | 2.40E+08 | 2.37E+02 | 1.86E+06 | 2.92E+06 |
| Cs-137 | 1.60E+08 | 1.60E+08 | 3.18E+02 | 3.57E+06 | 1.92E+06 |
| Es-254 | 4.76E+09 | 4.76E+09 | 1.80E+01 | 2.31E+05 | 3.00E+09 |
| Eu-152 | 4.89E+07 | 4.89E+07 | 5.18E+02 | 5.41E+06 | 7.94E+06 |
| Eu-154 | 7.35E+07 | 7.35E+07 | 5.07E+02 | 4.99E+06 | 9.18E+06 |
| Eu-155 | 1.21E+07 | 1.21E+07 | 4.94E+00 | 4.38E+04 | 1.96E+06 |
| Fe-55 | 1.85E+06 | 1.85E+06 | 1.56E-03 | 1.26E+01 | 5.61E+04 |
| Ge-68 | 5.20E+06 | 5.20E+06 | 6.21E+01 | 5.19E+05 | 3.85E+06 |
| H-3 | 3.62E+05 | 3.62E+05 | 8.23E-06 | 1.34E-01 | 9.60E+03 |
| I-129 | 9.33E+08 | 9.33E+08 | 2.79E+00 | 3.35E+04 | 1.22E+07 |
| I-131 | 1.76E+08 | 1.76E+08 | 4.34E-02 | 4.24E+03 | 2.34E+06 |
| K-40 | 6.35E+07 | 6.35E+07 | 1.09E+02 | 1.30E+06 | 7.50E+05 |
| Kr-85 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.62E+04 | 7.52E+01 |
| Mn-52 | 2.86E+07 | 2.86E+07 | 0.00E+00 | 3.37E+04 | 5.07E+05 |
| Mn-54 | 1.00E+07 | 1.00E+07 | 5.22E+01 | 4.30E+05 | 3.85E+05 |
| Mn-56 | 1.70E+05 | 1.70E+05 | 4.41E-05 | 3.13E+02 | 8.58E+04 |

Table D.2.1.23 Industrial Scenario Radionuclide Unit Risk Factors (cont'd)

| Radionuclide | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Mo-93 | 1.05E+07 | 1.05E+07 | 1.14E-01 | 1.39E+03 | 2.08E+06 |
| Na-22 | 4.07E+07 | 4.07E+07 | 4.07E+02 | 3.26E+06 | 5.30E+05 |
| Nb-93m | 3.40E+06 | 3.40E+06 | 1.17E-02 | 1.23E+02 | 4.33E+05 |
| Nb-94 | 3.60E+07 | 3.60E+07 | 1.08E+03 | 1.30E+07 | 8.24E+06 |
| Nb-95 | 1.24E+06 | 1.24E+06 | 1.73E+00 | 4.36E+04 | 3.26E+05 |
| Ni-59 | 9.39E+05 | 9.39E+05 | 2.83E-03 | 3.39E+01 | 4.01E+04 |
| Ni-63 | 2.79E+06 | 2.79E+06 | 7.72E-03 | 9.07E+01 | 1.01E+05 |
| Np-237 | 5.74E+10 | 5.74E+10 | 1.03E+03 | 1.23E+07 | 3.45E+09 |
| Np-239 | 1.86E+07 | 1.86E+07 | 7.41E-04 | 2.40E+02 | 2.44E+05 |
| P-32 | 3.02E+07 | 3.02E+07 | 1.00E-03 | 5.66E+01 | 2.93E+05 |
| Pa-231 | 1.38E+11 | 1.38E+11 | 2.46E+03 | 3.20E+07 | 2.42E+09 |
| Pa-233 | 2.34E+07 | 2.34E+07 | 1.63E-01 | 5.16E+03 | 4.96E+05 |
| Pb-210 | 3.42E+09 | 3.42E+09 | 1.79E+01 | 1.99E+05 | 1.67E+08 |
| Pb-212 | 4.30E+07 | 4.30E+07 | 6.72E-04 | 1.15E+03 | 7.51E+06 |
| Pm-147 | 9.35E+06 | 9.35E+06 | 1.47E-02 | 1.17E+02 | 7.50E+05 |
| Po-210 | 1.88E+09 | 1.88E+09 | 2.46E-01 | 2.57E+03 | 2.14E+08 |
| Pu-238 | 4.12E+10 | 4.12E+10 | 5.49E+02 | 6.42E+06 | 2.74E+09 |
| Pu-239 | 4.63E+10 | 4.63E+10 | 6.51E+02 | 7.81E+06 | 2.78E+09 |
| Pu-240 | 4.63E+10 | 4.63E+10 | 6.50E+02 | 7.80E+06 | 2.78E+09 |
| Pu-241 | 8.83E+08 | 8.83E+08 | 1.47E+01 | 1.90E+05 | 2.81E+07 |
| Pu-242 | 4.37E+10 | 4.37E+10 | 6.14E+02 | 7.37E+06 | 2.64E+09 |
| Ra-223 | 1.16E+09 | 1.16E+09 | 5.40E-02 | 3.78E+03 | 3.61E+08 |
| Ra-224 | 6.48E+08 | 6.48E+08 | 4.56E-02 | 9.60E+03 | 2.25E+08 |
| Ra-225 | 7.88E+08 | 7.88E+08 | 8.67E-02 | 4.75E+03 | 2.38E+08 |
| Ra-226 | 1.56E+09 | 1.56E+09 | 1.51E+03 | 1.81E+07 | 2.72E+08 |
| Ra-228 | 1.31E+09 | 1.31E+09 | 1.25E+03 | 1.29E+07 | 9.95E+07 |
| Re-187 | 3.52E+04 | 3.52E+04 | 9.68E-05 | 1.16E+00 | 3.98E+03 |
| Rn-222 | 6.92E+07 | 6.92E+07 | 0.00E+00 | 1.37E+04 | 7.92E+05 |
| Ru-103 | 1.67E+07 | 1.67E+07 | 1.22E+00 | 2.81E+04 | 4.69E+05 |
| Ru-106 | 1.87E+07 | 1.87E+07 | 1.46E+01 | 1.17E+05 | 1.15E+07 |
| S-35 | 2.10E+06 | 2.10E+06 | 1.13E-04 | 1.49E+00 | 1.85E+04 |
| Sb-122 | 3.92E+07 | 3.92E+07 | 6.43E-03 | 1.83E+03 | 5.55E+05 |
| Sb-124 | 5.38E+07 | 5.38E+07 | 1.12E+01 | 1.86E+05 | 1.36E+06 |
| Sb-125 | 1.51E+07 | 1.51E+07 | 7.02E+01 | 5.66E+05 | 5.29E+05 |
| Sc-46 | 3.04E+07 | 3.04E+07 | 2.09E+01 | 2.82E+05 | 1.35E+06 |
| Se-75 | 3.31E+07 | 3.31E+07 | 4.04E+00 | 4.49E+04 | 4.99E+05 |
| Se-79 | 3.22E+07 | 3.22E+07 | 8.34E-02 | 1.00E+03 | 7.19E+05 |
| Sm-147 | 7.70E+09 | 7.70E+09 | 1.10E+02 | 1.32E+06 | 6.94E+08 |
| Sm-151 | 5.30E+06 | 5.30E+06 | 4.69E-02 | 5.49E+02 | 4.63E+05 |
| Sn-113 | 1.93E+07 | 1.93E+07 | 3.35E+00 | 3.80E+04 | 6.73E+05 |
| Sn-123 | 3.11E+07 | 3.11E+07 | 1.97E-01 | 2.12E+03 | 2.37E+06 |
| Sr-85 | 7.07E+06 | 7.07E+06 | 2.65E+00 | 4.20E+04 | 1.23E+05 |
| Sr-89 | 5.18E+07 | 5.18E+07 | 1.41E-03 | 2.67E+01 | 3.68E+05 |
| Sr-90 | 2.12E+08 | 2.12E+08 | 3.49E+00 | 3.91E+04 | 5.95E+06 |
| Ta-182 | 3.59E+07 | 3.59E+07 | 1.99E+01 | 2.26E+05 | 1.67E+06 |

Table D.2.1.23 Industrial Scenario Radionuclide Unit Risk Factors (cont'd)

| Radionuclide | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Tc-99 | 7.11E+06 | 7.11E+06 | 3.51E-02 | 4.23E+02 | 2.89E+05 |
| Te-125m | 1.28E+07 | 1.28E+07 | 3.35E-03 | 5.73E+01 | 2.85E+05 |
| Th-227 | 8.95E+08 | 8.95E+08 | 1.84E-01 | 8.08E+03 | 4.31E+08 |
| Th-228 | 2.26E+10 | 2.26E+10 | 5.05E+02 | 3.95E+06 | 9.46E+09 |
| Th-229 | 2.11E+11 | 2.11E+11 | 3.18E+03 | 3.82E+07 | 7.61E+09 |
| Th-230 | 3.12E+10 | 3.12E+10 | 4.53E+02 | 5.46E+06 | 1.72E+09 |
| Th-231 | 6.53E+06 | 6.53E+06 | 3.19E-06 | 3.81E+00 | 1.10E+05 |
| Th-232 | 1.74E+11 | 1.74E+11 | 3.60E+03 | 4.87E+07 | 1.93E+09 |
| Th-234 | 9.66E+07 | 9.66E+07 | 1.70E-02 | 5.93E+02 | 1.90E+06 |
| Tl-204 | 9.98E+06 | 9.98E+06 | 6.77E-02 | 5.72E+02 | 1.15E+05 |
| Tm-170 | 3.86E+07 | 3.86E+07 | 2.24E-02 | 2.41E+02 | 1.10E+06 |
| U-232 | 7.83E+08 | 7.83E+08 | 1.73E+03 | 2.29E+07 | 5.30E+09 |
| U-233 | 3.03E+08 | 3.03E+08 | 7.27E+00 | 9.93E+04 | 1.41E+09 |
| U-234 | 3.00E+08 | 3.00E+08 | 5.03E+00 | 6.04E+04 | 1.40E+09 |
| U-235 | 2.98E+08 | 2.98E+08 | 5.22E+01 | 6.28E+05 | 1.30E+09 |
| U-236 | 2.85E+08 | 2.85E+08 | 4.76E+00 | 5.72E+04 | 1.32E+09 |
| U-238 | 2.84E+08 | 2.84E+08 | 1.49E+01 | 1.78E+05 | 1.24E+09 |
| V-49 | 2.31E+05 | 2.31E+05 | 6.41E-05 | 5.24E-01 | 2.52E+04 |
| Y-88 | 3.93E+08 | 3.93E+08 | 5.18E+01 | 6.09E+05 | 2.10E+06 |
| Y-90 | 6.67E+07 | 6.67E+07 | 7.69E-05 | 2.19E+01 | 9.91E+05 |
| Zn-65 | 5.03E+07 | 5.03E+07 | 2.69E+01 | 2.33E+05 | 1.01E+06 |
| Zr-93 | 1.11E+07 | 1.11E+07 | 1.33E-01 | 1.61E+03 | 5.27E+05 |

Table D.2.1.24 Recreational Shoreline User and Land User Scenario Noncarcinogenic Chemical Unit Risk Factors

| Chemical Name | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Aluminum | 1.36E+03 | 6.19E+03 | 1.87E-05 | 1.73E-01 | 1.41E+00 |
| Arsenic | 4.55E+06 | 1.37E+08 | 6.48E-02 | 6.40E+02 | 6.25E+03 |
| Barium | 1.97E+04 | 1.14E+06 | 8.60E-04 | 6.90E+00 | 9.57E+04 |
| Beryllium | 3.47E+05 | 3.25E+06 | 7.02E-03 | 5.86E+01 | 1.50E+02 |
| Bismuth | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Boron | 1.51E+04 | 2.71E+04 | 3.21E-04 | 4.97E+00 | 2.41E+03 |
| Cadmium | 2.80E+06 | 1.61E+08 | 7.38E-02 | 6.93E+02 | 1.03E+03 |
| Calcium Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Chromate Ion | 3.47E+05 | 1.71E+07 | 1.55E-01 | 1.26E+03 | 2.40E+07 |
| Chromium III | 1.73E+03 | 8.56E+04 | 1.49E-01 | 1.19E+03 | 2.40E+07 |
| Copper Ion | 3.69E+04 | 5.86E+05 | 2.31E-03 | 5.88E+01 | 2.53E+02 |
| Ferrocyanide Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Fluoride | 2.27E+04 | 1.09E+05 | 2.44E-03 | 6.68E+01 | 2.34E+03 |
| Iron III | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Lead Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Lithium Ion | 6.81E+04 | 1.28E+05 | 1.28E-03 | 1.89E+01 | 4.69E+02 |
| Magnesium Ion | 1.40E+02 | 2.24E+03 | 9.11E-06 | 2.32E-01 | 4.83E-01 |
| Manganese Ion | 2.76E+05 | 3.14E+07 | 4.03E-03 | 3.97E+01 | 7.50E+01 |
| Mercury Ion | 4.85E+06 | 1.30E+09 | 4.71E+00 | 1.40E+05 | 9.40E+05 |
| Molybdenum Ion | 2.80E+05 | 1.37E+06 | 6.46E-03 | 1.09E+02 | 1.13E+03 |
| Nickel Ion | 6.82E+04 | 2.05E+06 | 1.61E-03 | 2.71E+01 | 2.81E+02 |
| Nitrate Ion | 8.52E+02 | 3.62E+07 | 3.42E-02 | 1.03E+03 | 4.40E+01 |
| Nitrite Ion | 1.36E+03 | 2.35E+03 | 1.76E-05 | 1.40E-01 | 0.00E+00 |
| Phosphate Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Potassium Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Silicate Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Silver Ion | 2.77E+05 | 7.27E+05 | 4.30E-03 | 4.39E+01 | 5.63E+02 |
| Sodium Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Strontium Ion | 2.28E+03 | 3.62E+04 | 3.99E-05 | 5.42E-01 | 4.69E-01 |
| Sulfate Ion | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Uranium | 4.66E+05 | 7.42E+06 | 6.49E-03 | 5.29E+01 | 6.25E+01 |
| Vanadium Ion | 1.72E+05 | 1.05E+06 | 3.11E-03 | 2.94E+01 | 2.40E+02 |
| Zinc Ion | 4.54E+03 | 3.22E+06 | 5.09E-03 | 1.51E+02 | 3.13E+02 |

Table D.2.1.25 Recreational Shoreline User and Land User Scenario Carcinogenic Chemical Unit Risk Factors

| Chemical Name | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Arsenic | 8.26E+02 | 3.05E+04 | 1.50E-05 | 1.48E-01 | 7.24E+01 |
| Beryllium | 2.71E+03 | 2.94E+04 | 6.49E-05 | 5.43E-01 | 4.09E+01 |
| Cadmium | 0.00E+00 | 0.00E+00 | 1.85E-07 | 1.49E-03 | 2.96E+01 |
| Chromium | 0.00E+00 | 0.00E+00 | 1.23E-06 | 9.91E-03 | 1.97E+02 |

Table D.2.1.26 Recreational Shoreline User and Land User Scenario Radionuclide Unit Risk Factors

| Radionuclide | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Ac-225 | 1.38E+08 | 1.30E+09 | 5.83E-03 | 3.06E+02 | 3.54E+07 |
| Ac-227 | 1.49E+10 | 2.29E+11 | 4.30E+02 | 3.01E+06 | 5.96E+08 |
| Ac-228 | 5.24E+05 | 2.20E+07 | 8.06E-05 | 1.72E+02 | 2.77E+05 |
| Ag-110m | 7.17E+06 | 1.28E+08 | 1.89E+01 | 1.06E+05 | 2.91E+05 |
| Am-241 | 4.14E+09 | 8.44E+10 | 1.44E+02 | 1.14E+06 | 3.24E+08 |
| Am-243 | 4.14E+09 | 8.44E+10 | 1.56E+02 | 1.24E+06 | 3.22E+08 |
| Au-195 | 6.51E+05 | 9.59E+06 | 1.90E-01 | 1.17E+03 | 8.39E+04 |
| Ba-133 | 2.28E+06 | 2.56E+08 | 1.99E+01 | 1.23E+05 | 3.48E+04 |
| Be-10 | 3.01E+06 | 8.54E+06 | 7.38E-02 | 6.32E+02 | 2.18E+06 |
| Be-7 | 7.28E+04 | 5.99E+05 | 3.09E-02 | 3.71E+02 | 1.62E+03 |
| Bl-210 | 5.76E+06 | 3.93E+07 | 1.56E-04 | 1.74E+01 | 4.32E+05 |
| C-14 | 8.70E+05 | 1.40E+09 | 6.95E-03 | 1.96E+02 | 5.09E+04 |
| Ca-45 | 1.71E+06 | 2.59E+07 | 6.43E-04 | 8.48E+00 | 2.20E+04 |
| Cd-109 | 7.00E+06 | 4.86E+08 | 5.67E-02 | 3.05E+02 | 1.59E+05 |
| Ce-144 | 2.62E+07 | 4.44E+09 | 3.48E-01 | 1.91E+03 | 9.24E+05 |
| Cf-250 | 3.61E+09 | 4.86E+10 | 6.81E+01 | 5.04E+05 | 1.62E+09 |
| Cf-252 | 1.70E+09 | 2.26E+10 | 1.06E+01 | 6.10E+04 | 9.68E+08 |
| Cl-36 | 1.88E+06 | 3.63E+07 | 2.33E+02 | 6.98E+06 | 1.39E+05 |
| Cm-242 | 1.33E+08 | 4.41E+09 | 4.72E-01 | 5.19E+03 | 2.66E+07 |
| Cm-243 | 2.82E+09 | 5.92E+10 | 8.34E+01 | 5.99E+05 | 2.43E+08 |
| Cm-244 | 2.27E+09 | 4.80E+10 | 5.55E+01 | 3.78E+05 | 2.05E+08 |
| Cm-245 | 4.25E+09 | 8.66E+10 | 1.53E+02 | 1.23E+06 | 3.30E+08 |
| Cm-246 | 4.25E+09 | 8.64E+10 | 1.50E+02 | 1.19E+06 | 3.28E+08 |
| Cm-248 | 1.57E+10 | 3.25E+11 | 5.54E+02 | 4.42E+06 | 1.23E+09 |
| Co-56 | 7.75E+06 | 9.72E+08 | 6.17E+00 | 5.68E+04 | 3.44E+05 |
| Co-57 | 8.19E+05 | 9.83E+07 | 4.13E-01 | 2.29E+03 | 3.70E+04 |
| Co-58 | 2.37E+06 | 2.90E+08 | 1.08E+00 | 1.06E+04 | 7.31E+04 |
| Co-60 | 1.59E+07 | 2.55E+09 | 1.37E+02 | 7.47E+05 | 8.51E+05 |
| Cs-132 | 1.10E+06 | 8.20E+08 | 1.03E-02 | 8.24E+02 | 9.40E+03 |
| Cs-134 | 3.99E+07 | 2.82E+10 | 3.65E+01 | 1.82E+05 | 9.01E+05 |
| Cs-137 | 2.67E+07 | 1.90E+10 | 6.51E+01 | 4.82E+05 | 6.15E+05 |
| Es-254 | 4.95E+08 | 5.57E+09 | 3.61E+00 | 3.29E+04 | 2.53E+08 |
| Eu-152 | 6.49E+06 | 5.23E+08 | 9.78E+01 | 6.32E+05 | 6.88E+05 |
| Eu-154 | 1.01E+07 | 5.44E+08 | 9.10E+01 | 5.45E+05 | 8.05E+05 |
| Eu-155 | 1.70E+06 | 2.28E+07 | 8.25E-01 | 4.44E+03 | 1.71E+05 |
| Fe-55 | 3.01E+05 | 2.08E+08 | 1.32E-03 | 1.79E+01 | 9.63E+03 |
| Ge-68 | 8.68E+05 | 1.10E+09 | 1.79E+01 | 2.29E+05 | 1.38E+07 |
| H-3 | 6.03E+04 | 8.86E+04 | 2.79E-06 | 3.01E-02 | 9.27E+02 |
| I-129 | 1.55E+08 | 2.74E+10 | 3.19E+00 | 6.74E+04 | 1.65E+07 |
| I-131 | 2.93E+07 | 5.39E+09 | 6.30E-03 | 4.08E+02 | 2.09E+05 |
| K-40 | 1.05E+07 | 3.81E+09 | 2.63E+01 | 2.69E+05 | 2.43E+05 |
| Kr-85 | 0.00E+00 | 1.36E+06 | 0.00E+00 | 1.83E+03 | 6.32E+00 |
| Mn-52 | 4.76E+06 | 7.25E+08 | 0.00E+00 | 3.22E+03 | 4.27E+04 |
| Mn-54 | 1.66E+06 | 2.78E+08 | 7.70E+00 | 4.10E+04 | 3.30E+04 |
| Mn-56 | 2.83E+04 | 1.04E+08 | 6.37E-06 | 2.99E+01 | 7.21E+03 |

Table D.2.1.26 Recreational Shoreline User and Land User Scenario Radionuclide Unit Risk Factors (cont'd)

| Radionuclide | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Mo-93 | 1.75E+06 | 9.11E+06 | 9.08E-02 | 2.38E+03 | 1.84E+05 |
| Na-22 | 6.77E+06 | 5.65E+08 | 6.33E+01 | 3.15E+05 | 3.53E+05 |
| Nb-93m | 5.64E+05 | 4.04E+07 | 7.03E-02 | 1.65E+03 | 1.56E+05 |
| Nb-94 | 5.91E+06 | 1.38E+09 | 2.35E+02 | 1.89E+06 | 1.93E+06 |
| Nb-95 | 1.98E+05 | 1.93E+07 | 2.50E-01 | 4.16E+03 | 4.71E+04 |
| Ni-59 | 1.56E+05 | 5.70E+06 | 3.15E-03 | 6.58E+01 | 4.18E+03 |
| Ni-63 | 4.64E+05 | 1.70E+07 | 8.62E-03 | 1.75E+02 | 1.09E+04 |
| Np-237 | 4.95E+09 | 9.50E+10 | 2.23E+02 | 1.78E+06 | 2.90E+08 |
| Np-239 | 3.11E+06 | 3.20E+08 | 1.07E-04 | 2.31E+01 | 2.06E+04 |
| P-32 | 5.03E+06 | 1.27E+11 | 3.51E-03 | 4.79E+02 | 1.03E+05 |
| Pa-231 | 1.16E+10 | 1.79E+11 | 5.74E+02 | 5.06E+06 | 2.04E+08 |
| Pa-233 | 3.90E+06 | 2.03E+07 | 2.36E-02 | 4.94E+02 | 4.17E+04 |
| Pb-210 | 5.69E+08 | 2.09E+10 | 6.42E+00 | 4.80E+04 | 1.42E+07 |
| Pb-212 | 7.17E+06 | 5.59E+08 | 9.72E-05 | 1.10E+02 | 6.32E+05 |
| Pm-147 | 1.38E+06 | 1.47E+07 | 4.19E-03 | 3.28E+01 | 6.80E+04 |
| Po-210 | 2.94E+08 | 4.88E+10 | 6.24E-02 | 4.56E+02 | 1.81E+07 |
| Pu-238 | 3.59E+09 | 7.37E+10 | 1.17E+02 | 8.96E+05 | 2.31E+08 |
| Pu-239 | 4.03E+09 | 8.19E+10 | 1.41E+02 | 1.13E+06 | 2.34E+08 |
| Pu-240 | 4.03E+09 | 8.18E+10 | 1.41E+02 | 1.13E+06 | 2.34E+08 |
| Pu-241 | 7.64E+07 | 1.51E+09 | 3.38E+00 | 2.94E+04 | 2.37E+06 |
| Pu-242 | 3.80E+09 | 7.75E+10 | 1.34E+02 | 1.07E+06 | 2.22E+08 |
| Ra-223 | 1.92E+08 | 5.07E+09 | 8.03E-03 | 3.72E+02 | 3.04E+07 |
| Ra-224 | 1.07E+08 | 3.02E+09 | 6.60E-03 | 9.19E+02 | 1.89E+07 |
| Ra-225 | 1.30E+08 | 3.41E+09 | 1.30E-02 | 4.73E+02 | 2.00E+07 |
| Ra-226 | 2.54E+08 | 7.95E+09 | 3.28E+02 | 2.61E+06 | 2.30E+07 |
| Ra-228 | 2.14E+08 | 6.68E+09 | 2.27E+02 | 1.36E+06 | 8.42E+06 |
| Re-187 | 5.87E+03 | 2.56E+05 | 4.38E-04 | 1.22E+01 | 3.74E+02 |
| Rn-222 | 0.00E+00 | 5.00E+06 | 0.00E+00 | 1.32E+03 | 6.66E+04 |
| Ru-103 | 2.79E+06 | 1.05E+08 | 1.77E-01 | 2.69E+03 | 4.19E+04 |
| Ru-106 | 3.02E+06 | 1.19E+08 | 2.16E+00 | 1.12E+04 | 9.73E+05 |
| S-35 | 3.50E+05 | 9.27E+07 | 1.07E-02 | 3.49E+02 | 2.37E+04 |
| Sb-122 | 6.53E+06 | 5.29E+08 | 9.30E-04 | 1.75E+02 | 4.67E+04 |
| Sb-124 | 8.97E+06 | 6.64E+08 | 1.62E+00 | 1.78E+04 | 1.19E+05 |
| Sb-125 | 2.51E+06 | 2.35E+08 | 1.10E+01 | 5.45E+04 | 4.72E+04 |
| Sc-46 | 4.93E+06 | 2.08E+08 | 3.04E+00 | 2.69E+04 | 1.58E+05 |
| Se-75 | 5.50E+06 | 3.39E+08 | 5.90E-01 | 4.34E+03 | 9.85E+04 |
| Se-79 | 5.36E+06 | 3.27E+08 | 1.38E-01 | 3.23E+03 | 1.29E+05 |
| Sm-147 | 6.58E+08 | 1.01E+10 | 2.40E+01 | 1.94E+05 | 5.85E+07 |
| Sm-151 | 6.38E+05 | 7.83E+06 | 1.28E-02 | 1.27E+02 | 4.06E+04 |
| Sn-113 | 3.20E+06 | 3.38E+09 | 4.91E-01 | 3.71E+03 | 2.31E+05 |
| Sn-123 | 5.17E+06 | 5.45E+09 | 3.46E-02 | 3.53E+02 | 4.87E+05 |
| Sr-85 | 1.17E+06 | 2.70E+07 | 3.84E-01 | 4.01E+03 | 1.06E+04 |
| Sr-89 | 8.63E+06 | 1.61E+08 | 5.20E-04 | 1.19E+01 | 3.23E+04 |
| Sr-90 | 3.49E+07 | 6.66E+08 | 1.02E+00 | 1.04E+04 | 5.09E+05 |
| Ta-182 | 5.94E+06 | 6.24E+10 | 2.90E+00 | 2.16E+04 | 1.44E+05 |

Table D.2.1.26 Recreational Shoreline User and Land User Scenario Radionuclide Unit Risk Factors (cont'd)

| Radionuclide | Unit Risk Factors Summed over Exposure Pathways for Each Medium | | | | |
|---|---|---|---|---|---|
| | Groundwater | Surfacewater | Soil (mass) | Soil (area) | Air |
| Tc-99 | 1.18E+06 | 7.99E+06 | 2.63E-01 | 7.61E+03 | 3.29E+04 |
| Te-125m | 2.11E+06 | 2.99E+08 | 6.96E-04 | 1.29E+01 | 4.13E+04 |
| Th-227 | 9.18E+07 | 2.14E+09 | 2.72E-02 | 7.93E+02 | 3.63E+07 |
| Th-228 | 1.93E+09 | 3.09E+10 | 7.70E+01 | 3.79E+05 | 7.96E+08 |
| Th-229 | 1.77E+10 | 2.77E+11 | 6.90E+02 | 5.50E+06 | 6.40E+08 |
| Th-230 | 2.64E+09 | 4.15E+10 | 9.87E+01 | 7.92E+05 | 1.45E+08 |
| Th-231 | 1.09E+06 | 5.43E+07 | 6.38E-07 | 5.48E-01 | 9.28E+03 |
| Th-232 | 1.46E+10 | 2.28E+11 | 8.62E+02 | 7.69E+06 | 1.63E+08 |
| Th-234 | 1.61E+07 | 5.89E+08 | 2.53E-03 | 5.86E+01 | 1.60E+05 |
| Tl-204 | 1.66E+06 | 6.05E+07 | 2.50E-02 | 3.01E+02 | 6.53E+04 |
| Tm-170 | 6.37E+06 | 6.34E+07 | 4.21E-03 | 3.79E+01 | 1.12E+05 |
| U-232 | 9.98E+07 | 3.54E+09 | 3.98E+02 | 3.31E+06 | 4.45E+08 |
| U-233 | 4.42E+07 | 8.21E+08 | 1.96E+00 | 1.84E+04 | 1.19E+08 |
| U-234 | 4.38E+07 | 8.10E+08 | 1.26E+00 | 1.02E+04 | 1.18E+08 |
| U-235 | 4.40E+07 | 8.58E+08 | 1.15E+01 | 9.22E+04 | 1.09E+08 |
| U-236 | 4.15E+07 | 7.68E+08 | 1.19E+00 | 9.65E+03 | 1.11E+08 |
| U-238 | 4.18E+07 | 7.88E+08 | 3.44E+00 | 2.76E+04 | 1.04E+08 |
| V-49 | 3.81E+04 | 1.80E+05 | 2.44E-05 | 1.91E-01 | 2.19E+03 |
| Y-88 | 3.49E+07 | 5.78E+08 | 7.55E+00 | 5.82E+04 | 1.78E+05 |
| Y-90 | 1.11E+07 | 1.23E+08 | 1.19E-05 | 2.25E+00 | 8.34E+04 |
| Zn-65 | 8.37E+06 | 7.38E+09 | 4.44E+00 | 3.28E+04 | 7.25E+05 |
| Zr-93 | 1.15E+06 | 4.27E+07 | 7.20E-02 | 1.86E+03 | 4.66E+04 |

To provide a visual display of the total risk, contour plots showing risk distribution across the Hanford Site were generated from the values in the risk module with the help of GIS software. Each contour line represents a discrete value of risk. Risk for these purposes is defined as the increased probability that an individual at any location along such a contour line would develop cancer (in the case of exposure to radionuclides and carcinogenic chemicals) or suffer an adverse effect (in the case of exposure to noncarcinogenic chemicals) under the particular exposure scenario. There is no universal agreement on what level of risk is considered acceptable. For purposes of this analysis, a risk of less than 1.00E-06 (one in a million) is considered low and a risk greater than 1.00E-04 (one in ten thousand) is considered high. An HI greater than 1.0 is indicative of adverse health effects. Conversely, a HI less than 1.0 suggests that no adverse health effects would be expected. The risk contour plots for each alternative are displayed in Section D.5.0. Risk from radionuclides and carcinogenic chemicals is combined and presented on one set of maps. HIs from noncarcinogenic chemicals are presented separately.

### D.2.1.5 Example Calculations

This example analysis considers the groundwater exposure pathway, the residential farmer, and the point concentration of iodine-129 (I-129) for a single source location (575000E, 137000N) at 300 years from the present resulting from a hypothetical release. The method for estimating exposure to this

receptor is summarized as follows. Also presented is a description of the URF and the risk calculations.

**Exposure**

Exposure is calculated based on the SIF value from HSRAM (DOE 1995c). The SIF is independent of the contaminant. The SIF is multiplied by contaminant-specific parameters and the initial media concentration. The equation is as follows:

$$\text{Intake or Exposure} = C_{iym}\, PF_{mix}\, SIF_{smyx}$$

Where:

Intake = Average daily intake of contaminants (Ci/kg · day) (Ci/L · day)

Exposure = Total intake or exposure received over the exposure duration (pCi or hr)

$C_{iym}$ = Concentration of contaminant i, of type y, in medium m (mg or pCi per unit quantity of medium in L, kg, $m^3$, or $m^2$)

$Pf_{mix}$ = Contaminant-specific factor for medium m, contaminant i, and exposure pathway x (units specific to analysis)

$SIF_{smyx}$ = Summary intake factor for scenario s, medium m, contaminant type y, and exposure pathway x (units specific to analysis)

The exposure is calculated from the SIF values based on the following assumptions: Media of concern (m) is groundwater; $C_{iym}$ for groundwater is one unit; and $C_{iym}$ for all other media is zero. Table D.2.1.21 presents the exposure pathways, SIF values, contaminant concentrations, and the exposure or intake for the residential farmer scenario for groundwater.

**Unit Risk Factor Calculation**

The average daily intake and lifetime radiation doses are used to estimate the URFs for the health impact measure appropriate to the contaminant. Table D.2.1.27 shows the URF calculations for the groundwater exposure pathway for I-129. The URFs for radionuclides are evaluated as follows for inhalation exposure pathways:

$$URF_{ih} = Intake_{ih}\, SF_{ih}$$

The following equation is used to evaluate URFs for the ingestion exposure pathways:

$$URF_{ig} = Intake_{ig}\, SF_{ig}$$

Where:

$URF_{ih}$ = Unit risk factor for an inhalation pathway for radionuclide i (risk per unit medium concentration)

Table D.2.1.27 Exposure Parameters and Calculations for I-129 for the Residential Farmer

| Exposure Pathway | SIF Value$_{smyx}$ | $C_{iym}$ | $PF_{mix}$ | Intake or Exposure (pCi) | Slope Factor (risk/pCi) | Unit Risk Factor |
|---|---|---|---|---|---|---|
| Water: ingestion | 2.19E+04 L | 1 pCi/L | 9.07E-01 | 1.99E+04 | 2.01E-10 | 4.00E-06 risk/pCi/L |
| Water: dermal absorption | 3.73E+04 L h/cm | 1 pCi/L h/cm | 2.10E+01 | 7.83E+05 | 8.69E-15 | 6.80E-09 risk/pCi/L |
| Shower water: ingestion | 1.12E+02 L | 1 pCi/L | 9.31E-01 | 1.04E+02 | 2.01E-10 | 2.10E-08 risk/pCi/L |
| Vegetable ingestion | 8.77E+02 kg | 1 pCi/kg | 2.15E+00 | 1.89E+03 | 2.01E-10 | 3.80E-07 risk/pCi/kg |
| Fruit ingestion | 4.60E+02 kg | 1 pCi/kg | 2.59E+00 | 1.19E+03 | 2.01E-10 | 2.40E-07 risk/pCi/kg |
| Meat ingestion | 8.22E+02 kg | 1 pCi/kg | 2.72E+00 | 2.23E+03 | 2.01E-10 | 4.50E-07 risk/pCi/kg |
| Milk ingestion | 3.29E+03 L | 1 pCi/L | 1.16E+01 | 3.82E+04 | 2.01E-10 | 7.70E-06 risk/pCi/L |
| | | | | | Total | 1.29E-05 risk/pCi/L |

$URF_{ig}$ = Unit risk factor for an ingestion pathway for radionuclide i (risk per unit medium concentration)

$Intake_{ih}$ = Inhalation intake for radionuclide i for the inhalation pathway of interest (pCi)

$Intake_{ig}$ = Ingestion intake for radionuclide i for the ingestion pathway of interest (pCi)

Sfih = Inhalation slope factor for radionuclide i (risk/pCi)

Sfig = Ingestion slope factor for radionuclide i (risk/pCi).

For exposure pathways involving external radiation exposure, the URFs are evaluated as follows:

$$URF_{ix} = Exposure_{ix} SF_{ix}$$

Where:

$URF_{ix}$ = Unit risk factor for an external radiation exposure pathway for radionuclide i (risk per unit medium concentration)

$Exposure_{ix}$ = Exposure time for radionuclide i for the external radiation exposure pathway of interest (hr)

Sfix = External exposure slope factor for radionuclide i (risk/hr per pCi/unit medium quantify).

The external slope factors provided in HEAST (EPA 1993b) are for use with contaminated soil (pCi/g soil). For external exposure to air and water, slope factors are generated from radiation dose

factors and the default health effects conversion factor of 6.2E-04 risk per rem. For example, the air-immersion effective slope factor is evaluated as follows:

$$SF_{ia} = 6.2E\text{-}04\ DF_{ia}$$

Where:

Sfia = Air immersion slope factor for radionuclide i (risk/hr per pCi/m$^3$)

$DF_{ia}$ = Air immersion dose rate factor for radionuclide i (rem/hr per pCi/m$^3$)

6.2E-04 = Cancer incidence conversion factor (risk/rem).

**Risk**

Once the point concentration has been identified within each grid cell (based on either the current or post-remediation source), this value is multiplied by the URF. The resultant value is the risk to a receptor within this grid cell. The risk module tabulates risk for each receptor scenario across all cells on the Hanford Site. Equation (3) represents total risk for each scenario.

For I-129, the concentration is 1.37E-04 g/m$^3$ of water because the concentration was given in g/m$^3$; therefore a conversion is needed to convert to Ci/mL. To convert, multiply the concentration by the specific activity of I-129 to convert to Ci/m$^3$. Next, multiply by the conversion factor 1.0E+12 to convert Ci to pCi. Then, multiply by the conversion factor 1.0E-03 to convert m$^3$ to L, assuming a density of 1. Now that the concentration units match the URF units, multiply the two numbers, which results in a risk of 3.11E-04. The calculations are as follows:

| | | |
|---|---|---|
| Concentration (g/m$^3$) | | 1.37E-04 |
| Specific activity (Ci/g) | · | 1.76E-04 |
| Concentration (Ci/m$^3$) | | 2.41E-08 |
| Conversion (Ci to pCi) | · | 1.00E+12 |
| Concentration (pCi/m$^3$) | | 2.41E+04 |
| Conversion (m$^3$ to L) | · | 1.00E-03 |
| Concentration (pCi/L) | | 2.41E+01 |
| URF | · | 1.29E-05 |
| RISK | | 3.11E-04 |

## D.2.2 REMEDIATION RISK METHODOLOGY

Remediation risk is the potential risk from exposure to toxic and radiological contaminants and direct exposure to radiation during the construction and routine operational phases of the TWRS project.

Remediation risk is expressed as the increase in probability that an individual exposed to radioactive or hazardous materials over the duration of the proposed project would contract a fatal cancer from that exposure. In the case of an exposed population, remediation risk represents the expected increase in cancer fatalities in the population at risk.

The risk endpoint for the baseline and post-remediation analyses is cancer incidence, rather than fatal cancers (see Section D.2.1.3.3.). The methodology used for those analyses employs cancer slope factors provided by the EPA (for both chemicals and radionuclides). Because those slope factors are specific to cancer incidence, it was not possible to generate estimates of cancer fatalities from them. However, the difference in cancer incidence rates versus cancer fatality rates for radionuclides is small as indicated by health effect conversion factors presented in ICRP Publication 60 (ICRP 1991). For example, the cancer fatality conversion factor for the general public is 5.0E-04 fatal cancers per rem and the corresponding cancer incidence (fatal and nonfatal cancers) conversion factor is 6.0E-04 cancers per rem. The EPA radiation slope factors give similar results for many radionuclides (e.g., Cs-137 and cobalt-60 [Co-60]) but give lower cancer incidence estimates for others (e.g., plutonium [Pu] isotopes) compared to estimates obtained by multiplying the radiation dose factor times the health effects conversion factor.

Remediation risk calculations evaluate health risk to the TWRS workers, noninvolved workers at the Hanford Site, and the general public. Potential risk to the workers would be from direct exposure to radiation and exposure to chemical emissions from remediation operations during the work day. Potential risk to the noninvolved workers would be from inhaling radioactive, toxic, and/or hazardous atmospheric emissions from tanks, process stacks, and vents. Potential risk to the general public includes both inhaling contaminants and ingesting food and water contaminated by airborne deposition.

### D.2.2.1 Source Term

The source is an estimation of the amount of a contaminant available for dispersion into the environment or the radiation field to which a receptor is directly exposed. The source term is the respirable fraction of the source released into the environment.

The source of risk for the workers is from inhalation of radiological and chemical emissions from operations and from direct exposure to radiation fields.

The source of risk for the noninvolved worker is the contaminants that could potentially reach them through dispersion of atmospheric emissions released to the environment. The atmospheric emissions could be radioactive gaseous effluents, chemical emissions, or particulates dispersed in the air. It is assumed that the emissions would be present throughout the workplace and inhaled by the noninvolved worker during the course of a normal workday. It is assumed the noninvolved worker would not ingest food products grown onsite or groundwater from nearby wells.

For the general public, the source of risk is the contaminants that could potentially reach them through atmospheric emissions released to the environment and transported offsite. Members of the general public potentially would inhale gaseous and particulate emissions; ingest vegetation, meat, and milk products contaminated by airborne deposition; and receive external exposures from submersion in a contaminated plume. Modeling codes estimate these doses based on estimates of atmospheric emissions.

### D.2.2.2 Transport

Transport refers to the movement of contaminants in the environment from the source location to the receptor. The transport analysis temporally and spatially redistributed the airborne contaminants. Transport was modeled within the site boundary and within an 80-km (50-mi) radius centered at the release point for atmospheric emissions. Transport assumptions for atmospheric emissions are described as follows for each receptor.

#### Workers

Transport was not evaluated for the worker because fixed dose values were assumed to be similar to the values previously measured for similar activities at the Hanford Site.

#### Noninvolved Workers

The noninvolved workers are assumed to be located at least 100 m (330 ft) away from the release point or area, out to the Hanford Site boundary. The computer code GENII (Napier et al. 1988) was used to calculate the atmospheric dispersion coefficient, Chi/Q, and corresponding dose for the noninvolved worker. GENII has been used routinely to support Hanford Site operations and risk assessments to calculate dose from the interaction of receptors and airborne radioactivity (DOE 1995c). GENII uses an environmental transport module linked to a human exposure/dose module. The transport module generates atmospheric dispersion coefficients (Chi/Q), which relate the concentrations released at the source to the concentrations at a receptor location. The exposure module then uses the output from the transport module to calculate the dose to a receptor under a specified exposure scenario.

The air transport model in GENII uses a Gaussian diffusion plume method to model atmospheric transport of radiological contaminants from release points or areas to receptors. GENII allows the source to be released either at ground level or at a different elevation. Hanford Site meteorological conditions are used in the analysis involving GENII.

Two types of releases were modeled for this assessment. The first type is the ground release from the tank farms. Modeling for the ground release used the 9-year average (1983 to 1991) wind data measured at a height of 10 m (33 ft) above the Hanford Meteorological Station in the 200 Areas. Table D.2.2.1 displays the meteorological data (i.e., joint frequency distribution of wind speed, wind direction, and stability category) for all stability categories (Pasquill A-G). Figure D.2.2.1 illustrates the data in Table D.2.2.1 and shows a summary of wind direction frequencies. The second release type is the elevated release, which is a release emitted from a processing plant stack. Modeling for the elevated release used the 9-year average (1983 to 1991) wind data measured at a height of 61 m (200 ft) above the Hanford Meteorological Station for stacks taller than 10 m (33 ft). Table D.2.2.2 displays the meteorological data for all stability categories (Pasquill A-G). Figure D.2.2.2 illustrates the data in Table D.2.2.2 and provides a summary of wind direction frequencies.

**General Public**

For the general public, the atmospheric transport and dispersion modeling was the same as applied for the noninvolved workers, but the distance from the release was changed to extend from the Site boundary to a distance of 80 km (50 mi).

**Air Dispersion Isopleths**

As discussed earlier, the air dispersion modeling for routine remediation was performed for two release categories: ground and elevated releases. Contour plots showing Chi/Q isopleths for these two cases are presented in Figures D.2.2.3 and D.2.2.4. These plots can be used to calculate the dose and risk to receptors at locations other than the maximally-exposed individual (MEI) locations presented in this assessment. The Chi/Q values shown were computed by GXQ Version 4 (Hey 1993 and 1994). Although the Chi/Q values used in the assessment were computed by GENII, GXQ was used for purposes of generating the contour plots because it requires less processor time than GENII. The computational methods used by GXQ are identical to those used by GENII.

**D.2.2.3 Exposure**

Exposure to the receptors for this analysis is from airborne contaminants and/or from direct exposure from gamma radiation fields. The radiological dose to a receptor would depend on the location of the receptor relative to the point of release of the radioactive material, or the shielding and distance of the receptor from the radiation field. Doses for the MEI and population were computed for each receptor class. The MEI worker is an individual that receives the highest annual exposure. The receptors are identified as follows.

- Worker population and MEI worker - These are individuals directly involved in the proposed remedial activities. They would receive exposure from inhalation and from direct exposure to gamma radiation fields during routine operation of TWRS facilities.
- Noninvolved worker population and MEI noninvolved worker - This was based on the current Hanford Site employment and assumed to be located from 100 m (330 ft) out to the Hanford Site boundary. Exposure would be by the inhalation pathway and by direct exposure from submersion in a radioactive cloud from routine air emissions during operation of TWRS facilities. The noninvolved worker population would receive a dose based on an annual average. The MEI noninvolved worker would receive the highest annual exposure.
- General public population and MEI general public - The general public population includes people located within 80-km (50-mi) of the Hanford Site boundary. They would be exposed through air dispersion of the plume, which could result in inhalation, external exposure, and exposure from ingestion of contaminated meat, dairy products, and vegetables. The MEI general public is assumed to be an individual located at the Hanford Site boundary who receives the highest annual exposure. The Site boundary is considered to be an adjusted Hanford Site boundary that excludes areas likely to be released by DOE in the near future. The Site boundary for the EIS was defined as follows:

**Figure D.2.2.1 Percent Wind Frequency for All Wind Speeds, Directions, and Pasquill Categories Measured at Height of 10 m (33 ft), Hanford Meteorological Station**

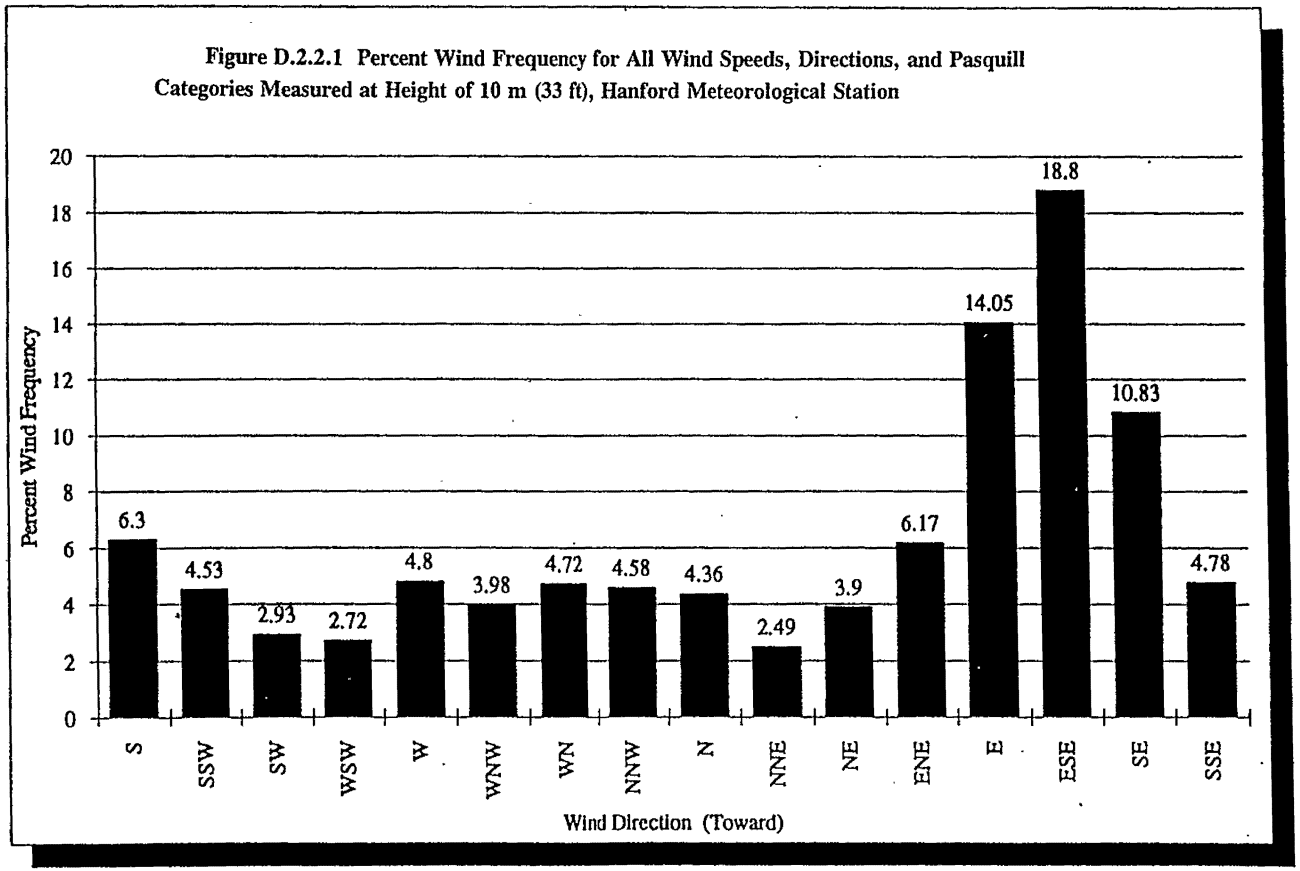


**Figure D.2.2.2 Percent Wind Frequency for All Wind Speeds, Directions, and Pasquill Categories Measured at Height of 61 m (200 ft), Hanford Meteorological Station**

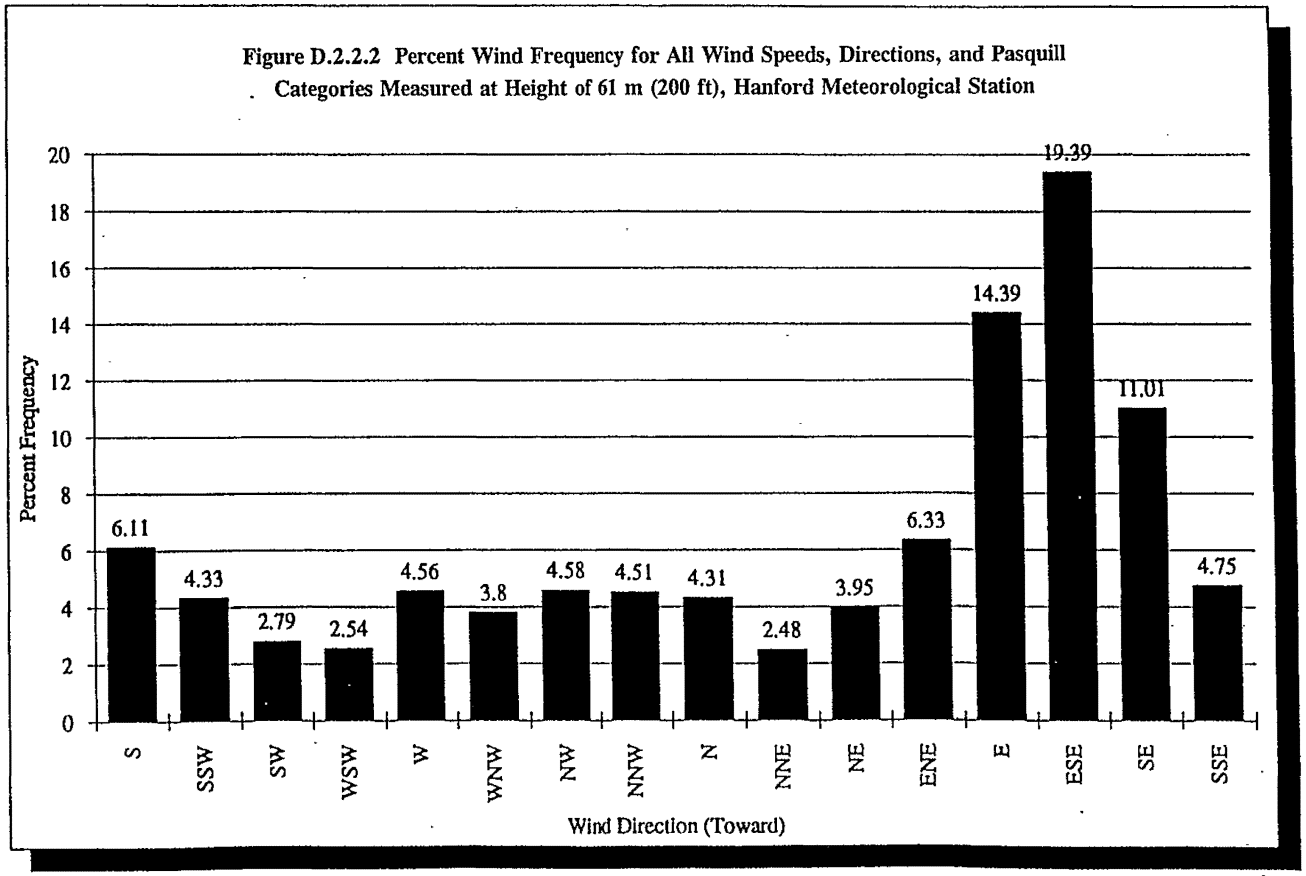


Table D.2.2.1 Joint Frequency Data[1] Collected at 10 m (33 ft) (1983 to 1991)

| WS[2] | PC[3] | S[4] | ESE | SE | SSE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.89 | A | 0.36 | 0.2 | 0.23 | 0.26 | 0.4 | 0.24 | 0.17 | 0.1 | 0.1 | 0.06 | 0.06 | 0.06 | 0.1 | 0.1 | 0.14 | 0.22 |
| 0.89 | B | 0.15 | 0.13 | 0.1 | 0.11 | 0.16 | 0.09 | 0.07 | 0.03 | 0.05 | 0.02 | 0.01 | 0.03 | 0.04 | 0.05 | 0.07 | 0.1 |
| 0.89 | C | 0.14 | 0.1 | 0.09 | 0.12 | 0.14 | 0.1 | 0.06 | 0.04 | 0.04 | 0.02 | 0.02 | 0.02 | 0.04 | 0.04 | 0.1 | 0.1 |
| 0.89 | D | 0.87 | 0.58 | 0.59 | 0.59 | 0.77 | 0.5 | 0.43 | 0.32 | 0.27 | 0.19 | 0.21 | 0.17 | 0.4 | 0.44 | 0.54 | 0.55 |
| 0.89 | E | 0.39 | 0.26 | 0.28 | 0.25 | 0.46 | 0.34 | 0.31 | 0.3 | 0.34 | 0.21 | 0.25 | 0.29 | 0.49 | 0.44 | 0.45 | 0.39 |
| 0.89 | F | 0.23 | 0.13 | 0.12 | 0.14 | 0.31 | 0.23 | 0.28 | 0.26 | 0.35 | 0.23 | 0.22 | 0.27 | 0.48 | 0.36 | 0.32 | 0.23 |
| 0.89 | G | 0.1 | 0.04 | 0.08 | 0.08 | 0.13 | 0.13 | 0.13 | 0.14 | 0.17 | 0.09 | 0.1 | 0.09 | 0.22 | 0.14 | 0.14 | 0.09 |
| | | | | | | | | | | | | | | | | | |
| 2.65 | A | 0.69 | 0.44 | 0.29 | 0.32 | 0.6 | 0.51 | 0.45 | 0.29 | 0.24 | 0.12 | 0.17 | 0.19 | 0.25 | 0.3 | 0.42 | 0.48 |
| 2.65 | B | 0.21 | 0.15 | 0.06 | 0.08 | 0.16 | 0.13 | 0.13 | 0.09 | 0.08 | 0.04 | 0.03 | 0.05 | 0.07 | 0.09 | 0.16 | 0.16 |
| 2.65 | C | 0.19 | 0.12 | 0.06 | 0.09 | 0.13 | 0.13 | 0.19 | 0.1 | 0.06 | 0.02 | 0.03 | 0.05 | 0.08 | 0.1 | 0.19 | 0.15 |
| 2.65 | D | 0.84 | 0.48 | 0.4 | 0.33 | 0.66 | 0.57 | 0.75 | 0.53 | 0.35 | 0.18 | 0.24 | 0.28 | 0.69 | 1.09 | 1.05 | 0.77 |
| 2.65 | E | 0.32 | 0.17 | 0.11 | 0.13 | 0.31 | 0.34 | 0.47 | 0.52 | 0.46 | 0.21 | 0.29 | 0.48 | 1.58 | 1.68 | 1.11 | 0.39 |
| 2.65 | F | 0.13 | 0.05 | 0.05 | 0.05 | 0.16 | 0.21 | 0.39 | 0.44 | 0.45 | 0.21 | 0.27 | 0.46 | 1.6 | 1.69 | 0.82 | 0.25 |
| 2.65 | G | 0.04 | 0.02 | 0.02 | 0.03 | 0.09 | 0.1 | 0.2 | 0.23 | 0.2 | 0.08 | 0.1 | 0.2 | 0.82 | 0.69 | 0.3 | 0.08 |
| | | | | | | | | | | | | | | | | | |
| 4.7 | A | 0.26 | 0.24 | 0.1 | 0.03 | 0.08 | 0.1 | 0.1 | 0.13 | 0.12 | 0.07 | 0.14 | 0.34 | 0.35 | 0.35 | 0.4 | 0.17 |
| 4.7 | B | 0.09 | 0.06 | 0.03 | 0.01 | 0.03 | 0.03 | 0.04 | 0.05 | 0.03 | 0.02 | 0.05 | 0.07 | 0.1 | 0.14 | 0.12 | 0.06 |
| 4.7 | C | 0.08 | 0.05 | 0.03 | 0.01 | 0.02 | 0.02 | 0.04 | 0.04 | 0.05 | 0.02 | 0.03 | 0.06 | 0.09 | 0.13 | 0.12 | 0.03 |
| 4.7 | D | 0.32 | 0.2 | 0.09 | 0.04 | 0.12 | 0.11 | 0.25 | 0.27 | 0.24 | 0.13 | 0.23 | 0.39 | 0.83 | 1.46 | 0.84 | 0.21 |
| 4.7 | E | 0.19 | 0.09 | 0.04 | 0.01 | 0.06 | 0.06 | 0.15 | 0.25 | 0.22 | 0.12 | 0.18 | 0.39 | 1.98 | 2.5 | 0.75 | 0.13 |
| 4.7 | F | 0.04 | 0.06 | 0.01 | 0.01 | 0.01 | 0.02 | 0.05 | 0.17 | 0.14 | 0.03 | 0.07 | 0.2 | 1.19 | 1.6 | 0.32 | 0.06 |
| 4.7 | G | 0.01 | 0 | 0 | 0 | 0 | 0.01 | 0.01 | 0.09 | 0.07 | 0.01 | 0.02 | 0.09 | 0.56 | 0.84 | 0.13 | 0.01 |
| | | | | | | | | | | | | | | | | | |
| 7.15 | A | 0.07 | 0.07 | 0.05 | 0.01 | 0 | 0 | 0.01 | 0.03 | 0.04 | 0.04 | 0.11 | 0.25 | 0.25 | 0.25 | 0.33 | 0.05 |
| 7.15 | B | 0.02 | 0.03 | 0.01 | 0.01 | 0 | 0 | 0 | 0.01 | 0.02 | 0.01 | 0.04 | 0.08 | 0.06 | 0.07 | 0.09 | 0.01 |
| 7.15 | C | 0.02 | 0.03 | 0.01 | 0 | 0 | 0 | 0 | 0.01 | 0.02 | 0.01 | 0.02 | 0.07 | 0.06 | 0.07 | 0.06 | 0.01 |
| 7.15 | D | 0.1 | 0.1 | 0.03 | 0.01 | 0 | 0.01 | 0.03 | 0.07 | 0.1 | 0.11 | 0.25 | 0.38 | 0.58 | 1.14 | 0.5 | 0.05 |
| 7.15 | E | 0.07 | 0.12 | 0.01 | 0 | 0 | 0 | 0.01 | 0.05 | 0.07 | 0.08 | 0.17 | 0.3 | 0.65 | 1.75 | 0.41 | 0.02 |
| 7.15 | F | 0.03 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.02 | 0 | 0.01 | 0.02 | 0.07 | 0.08 | 0.03 | 0 |
| 7.15 | G | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 |
| | | | | | | | | | | | | | | | | | |
| 9.8 | A | 0.02 | 0.02 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.01 | 0.05 | 0.16 | 0.1 | 0.11 | 0.24 | 0 |
| 9.8 | B | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0.04 | 0.02 | 0.03 | 0.06 | 0 |

Table D.2.2.1 Joint Frequency Data[1] Collected at 10 m (33 ft) (1983 to 1991) (cont'd)

| WS[2] | PC[3] | S[4] | ESE | SE | SSE | E | ESE | SE | SSE | S | SSW | SW | WSW | W | WNW | NW | NNW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9.8 | C | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0.02 | 0.05 | 0.02 | 0.03 | 0.05 | 0 |
| 9.8 | D | 0.02 | 0.04 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0.07 | 0.16 | 0.24 | 0.13 | 0.5 | 0.29 | 0.01 |
| 9.8 | E | 0.01 | 0.06 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.05 | 0.11 | 0.15 | 0.06 | 0.38 | 0.11 | 0 |
| 9.8 | F | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9.8 | G | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | | | | |
| 12.7 | A | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0.06 | 0.02 | 0.02 | 0.03 | 0 |
| 12.7 | B | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.02 | 0.01 | 0 | 0.01 | 0 |
| 12.7 | C | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0.01 | 0 | 0.01 | 0.01 | 0 |
| 12.7 | D | 0.02 | 0.03 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0.09 | 0.09 | 0.03 | 0.07 | 0.08 | 0 |
| 12.7 | E | 0.01 | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.04 | 0.02 | 0.01 | 0.05 | 0.03 | 0 |
| 12.7 | F | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12.7 | G | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | | | | |
| 15.6 | A | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0.01 | 0 |
| 15.6 | B | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15.6 | C | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 |
| 15.6 | D | 0.01 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.03 | 0.03 | 0.02 | 0 | 0 | 0 |
| 15.6 | E | 0.01 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 |
| 15.6 | F | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15.6 | G | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | | | | | |
| 19 | A | 0.02 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | B | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | C | 0.01 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | D | 0.04 | 0.07 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | E | 0.07 | 0.12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | F | 0.03 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | G | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Notes:
[1] Average wind speed and direction data collected at 10 m (33 ft) abovegrade on the Hanford Meteorological Station.
[2] Wind speed (m/sec).
[3] Pasquill categories.
[4] Downwind direction.

Table D.2.2.2 Joint Frequency Data[1] Collected at 61 m (200 ft) (1983 to 1991)

| WS[2] | PC[3] | S[4] | SSW | SW | WSW | W | WNW | NW | NNW | N | NNE | NE | ENE | E | ESE | SE | SSE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.89 | A | 0.35 | 0.18 | 0.2 | 0.24 | 0.38 | 0.23 | 0.17 | 0.09 | 0.1 | 0.06 | 0.05 | 0.06 | 0.1 | 0.1 | 0.12 | 0.18 |
| 0.89 | B | 0.12 | 0.1 | 0.09 | 0.1 | 0.13 | 0.08 | 0.06 | 0.03 | 0.05 | 0.02 | 0.01 | 0.02 | 0.04 | 0.05 | 0.06 | 0.08 |
| 0.89 | C | 0.11 | 0.08 | 0.07 | 0.1 | 0.13 | 0.09 | 0.07 | 0.04 | 0.03 | 0.02 | 0.02 | 0.03 | 0.04 | 0.03 | 0.08 | 0.08 |
| 0.89 | D | 0.62 | 0.42 | 0.39 | 0.45 | 0.6 | 0.41 | 0.36 | 0.27 | 0.21 | 0.16 | 0.17 | 0.12 | 0.26 | 0.32 | 0.42 | 0.39 |
| 0.89 | E | 0.23 | 0.16 | 0.17 | 0.15 | 0.31 | 0.26 | 0.23 | 0.27 | 0.27 | 0.16 | 0.16 | 0.19 | 0.31 | 0.28 | 0.24 | 0.22 |
| 0.89 | F | 0.13 | 0.08 | 0.08 | 0.09 | 0.19 | 0.2 | 0.28 | 0.31 | 0.33 | 0.16 | 0.16 | 0.21 | 0.4 | 0.29 | 0.23 | 0.15 |
| 0.89 | G | 0.07 | 0.03 | 0.05 | 0.05 | 0.12 | 0.11 | 0.16 | 0.21 | 0.2 | 0.09 | 0.09 | 0.1 | 0.25 | 0.14 | 0.12 | 0.07 |
| | | | | | | | | | | | | | | | | | |
| 2.65 | A | 0.6 | 0.4 | 0.29 | 0.33 | 0.59 | 0.52 | 0.42 | 0.24 | 0.2 | 0.11 | 0.14 | 0.14 | 0.2 | 0.24 | 0.35 | 0.43 |
| 2.65 | B | 0.18 | 0.13 | 0.06 | 0.09 | 0.16 | 0.12 | 0.11 | 0.07 | 0.07 | 0.03 | 0.02 | 0.04 | 0.06 | 0.07 | 0.14 | 0.13 |
| 2.65 | C | 0.18 | 0.11 | 0.06 | 0.1 | 0.13 | 0.13 | 0.15 | 0.07 | 0.05 | 0.02 | 0.02 | 0.04 | 0.05 | 0.08 | 0.16 | 0.15 |
| 2.65 | D | 0.81 | 0.42 | 0.39 | 0.32 | 0.63 | 0.5 | 0.62 | 0.37 | 0.29 | 0.13 | 0.16 | 0.22 | 0.42 | 0.59 | 0.71 | 0.68 |
| 2.65 | E | 0.26 | 0.13 | 0.14 | 0.13 | 0.27 | 0.26 | 0.25 | 0.3 | 0.32 | 0.14 | 0.21 | 0.29 | 0.58 | 0.6 | 0.57 | 0.28 |
| 2.65 | F | 0.15 | 0.06 | 0.05 | 0.04 | 0.16 | 0.12 | 0.2 | 0.2 | 0.28 | 0.16 | 0.19 | 0.26 | 0.64 | 0.57 | 0.37 | 0.17 |
| 2.65 | G | 0.04 | 0.02 | 0.03 | 0.03 | 0.07 | 0.07 | 0.1 | 0.11 | 0.11 | 0.06 | 0.07 | 0.12 | 0.46 | 0.27 | 0.14 | 0.06 |
| | | | | | | | | | | | | | | | | | |
| 4.7 | A | 0.35 | 0.27 | 0.11 | 0.05 | 0.12 | 0.1 | 0.14 | 0.15 | 0.14 | 0.07 | 0.15 | 0.29 | 0.3 | 0.31 | 0.34 | 0.22 |
| 4.7 | B | 0.11 | 0.08 | 0.03 | 0.01 | 0.04 | 0.05 | 0.06 | 0.06 | 0.03 | 0.02 | 0.05 | 0.06 | 0.08 | 0.1 | 0.11 | 0.09 |
| 4.7 | C | 0.09 | 0.06 | 0.04 | 0.02 | 0.03 | 0.02 | 0.06 | 0.05 | 0.05 | 0.02 | 0.02 | 0.03 | 0.07 | 0.08 | 0.12 | 0.05 |
| 4.7 | D | 0.38 | 0.26 | 0.14 | 0.07 | 0.17 | 0.16 | 0.27 | 0.24 | 0.2 | 0.11 | 0.19 | 0.25 | 0.61 | 0.9 | 0.79 | 0.34 |
| 4.7 | E | 0.2 | 0.11 | 0.05 | 0.04 | 0.12 | 0.13 | 0.23 | 0.23 | 0.23 | 0.11 | 0.15 | 0.31 | 1.05 | 0.95 | 0.65 | 0.25 |
| 4.7 | F | 0.08 | 0.03 | 0.02 | 0.03 | 0.05 | 0.09 | 0.11 | 0.17 | 0.19 | 0.1 | 0.13 | 0.27 | 0.89 | 0.92 | 0.44 | 0.13 |
| 4.7 | G | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.05 | 0.07 | 0.06 | 0.02 | 0.05 | 0.1 | 0.49 | 0.38 | 0.15 | 0.04 |
| | | | | | | | | | | | | | | | | | |
| 7.15 | A | 0.11 | 0.11 | 0.05 | 0.02 | 0.01 | 0.02 | 0.02 | 0.06 | 0.06 | 0.05 | 0.1 | 0.25 | 0.25 | 0.26 | 0.32 | 0.07 |
| 7.15 | B | 0.05 | 0.04 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 | 0.03 | 0.05 | 0.07 | 0.1 | 0.08 | 0.03 |
| 7.15 | C | 0.03 | 0.03 | 0.02 | 0 | 0.01 | 0 | 0.01 | 0.02 | 0.02 | 0.01 | 0.02 | 0.07 | 0.08 | 0.11 | 0.06 | 0.01 |
| 7.15 | D | 0.19 | 0.13 | 0.06 | 0.01 | 0.03 | 0.02 | 0.1 | 0.2 | 0.15 | 0.09 | 0.2 | 0.32 | 0.59 | 1.11 | 0.54 | 0.11 |
| 7.15 | E | 0.13 | 0.08 | 0.03 | 0.02 | 0.04 | 0.04 | 0.11 | 0.17 | 0.13 | 0.09 | 0.15 | 0.31 | 1.52 | 1.67 | 0.62 | 0.12 |
| 7.15 | F | 0.04 | 0.03 | 0.01 | 0.01 | 0.03 | 0.02 | 0.07 | 0.1 | 0.09 | 0.03 | 0.06 | 0.15 | 0.92 | 1.03 | 0.32 | 0.07 |
| 7.15 | G | 0.01 | 0 | 0 | 0 | 0 | 0.01 | 0.01 | 0.04 | 0.04 | 0.01 | 0.01 | 0.05 | 0.28 | 0.51 | 0.13 | 0.01 |
| | | | | | | | | | | | | | | | | | |
| 9.8 | A | 0.03 | 0.05 | 0.04 | 0 | 0 | 0 | 0 | 0.01 | 0.02 | 0.02 | 0.07 | 0.14 | 0.15 | 0.15 | 0.23 | 0.02 |
| 9.8 | B | 0.01 | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.01 | 0.03 | 0.06 | 0.05 | 0.04 | 0.06 | 0 |

Table D.2.2.2 Joint Frequency Data[1] Collected at 61 m (200 ft) 1983 to 1991) (cont'd)

| WS[2] | PC[3] | S[4] | SSW | SW | WSW | W | WNW | NW | NNW | N | NNE | NE | ENE | E | ESE | SE | SSE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9.8 | C | 0.02 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.02 | 0 | 0.01 | 0.04 | 0.04 | 0.04 | 0.05 | 0 |
| 9.8 | D | 0.06 | 0.06 | 0.01 | 0.01 | 0 | 0.01 | 0.03 | 0.06 | 0.07 | 0.08 | 0.16 | 0.29 | 0.47 | 0.81 | 0.35 | 0.04 |
| 9.8 | E | 0.09 | 0.09 | 0.01 | 0 | 0.01 | 0 | 0.06 | 0.08 | 0.08 | 0.07 | 0.13 | 0.24 | 0.99 | 1.92 | 0.41 | 0.03 |
| 9.8 | F | 0.03 | 0.03 | 0 | 0 | 0.01 | 0 | 0.02 | 0.05 | 0.04 | 0.01 | 0.02 | 0.06 | 0.45 | 0.72 | 0.13 | 0.01 |
| 9.8 | G | 0 | 0.01 | 0 | 0 | 0 | 0 | 0.01 | 0.02 | 0.01 | 0 | 0 | 0.02 | 0.13 | 0.29 | 0.04 | 0 |
| | | | | | | | | | | | | | | | | | |
| 12.7 | A | 0.01 | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.01 | 0.04 | 0.14 | 0.08 | 0.09 | 0.19 | 0 |
| 12.7 | B | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0.02 | 0.04 | 0.02 | 0.03 | 0.05 | 0 |
| 12.7 | C | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0.02 | 0.04 | 0.01 | 0.02 | 0.04 | 0 |
| 12.7 | D | 0.02 | 0.04 | 0.01 | 0.01 | 0 | 0 | 0 | 0.02 | 0.04 | 0.07 | 0.15 | 0.23 | 0.25 | 0.77 | 0.37 | 0.02 |
| 12.7 | E | 0.05 | 0.08 | 0.02 | 0 | 0 | 0 | 0.02 | 0.03 | 0.03 | 0.04 | 0.11 | 0.19 | 0.36 | 1.26 | 0.3 | 0.01 |
| 12.7 | F | 0.02 | 0.03 | 0 | 0 | 0 | 0 | 0.01 | 0.02 | 0.01 | 0 | 0.01 | 0.02 | 0.12 | 0.29 | 0.03 | 0.01 |
| 12.7 | G | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0.05 | 0.13 | 0.01 | 0 |
| | | | | | | | | | | | | | | | | | |
| 15.6 | A | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0.07 | 0.02 | 0.02 | 0.05 | 0 |
| 15.6 | B | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.02 | 0.01 | 0.01 | 0.02 | 0 |
| 15.6 | C | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0.02 | 0.01 | 0.01 | 0.02 | 0 |
| 15.6 | D | 0.01 | 0.04 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.04 | 0.13 | 0.13 | 0.04 | 0.29 | 0.14 | 0 |
| 15.6 | E | 0.01 | 0.03 | 0.01 | 0 | 0 | 0 | 0 | 0.01 | 0.01 | 0.04 | 0.07 | 0.1 | 0.06 | 0.3 | 0.1 | 0 |
| 15.6 | F | 0 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.01 | 0 | 0 | 0 | 0.01 | 0.03 | 0 | 0 |
| 15.6 | G | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.03 | 0 | 0 |
| | | | | | | | | | | | | | | | | | |
| 19 | A | 0.02 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.02 | 0 | 0.01 | 0.01 | 0 |
| 19 | B | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.01 | 0 | 0 | 0 | 0 |
| 19 | C | 0.01 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0.01 | 0 | 0 | 0 | 0 |
| 19 | D | 0.03 | 0.06 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.02 | 0.08 | 0.07 | 0.04 | 0.03 | 0.02 | 0 |
| 19 | E | 0.02 | 0.06 | 0.01 | 0 | 0 | 0 | 0 | 0.01 | 0.01 | 0.01 | 0.04 | 0.02 | 0.01 | 0.03 | 0.01 | 0 |
| 19 | F | 0.02 | 0.03 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0.01 | 0 | 0 |
| 19 | G | 0 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Notes:
[1] Average wind speed and direction data collected at 61 m (200 ft) abovegrade on the Hanford Meteorological Station.
[2] Wind speed (m/sec).
[3] Pasquill categories.
[4] Downwind direction.

**Figure D.2.2.3 Chi/Q Isopleths for Ground Releases in s/m $^{3}$**

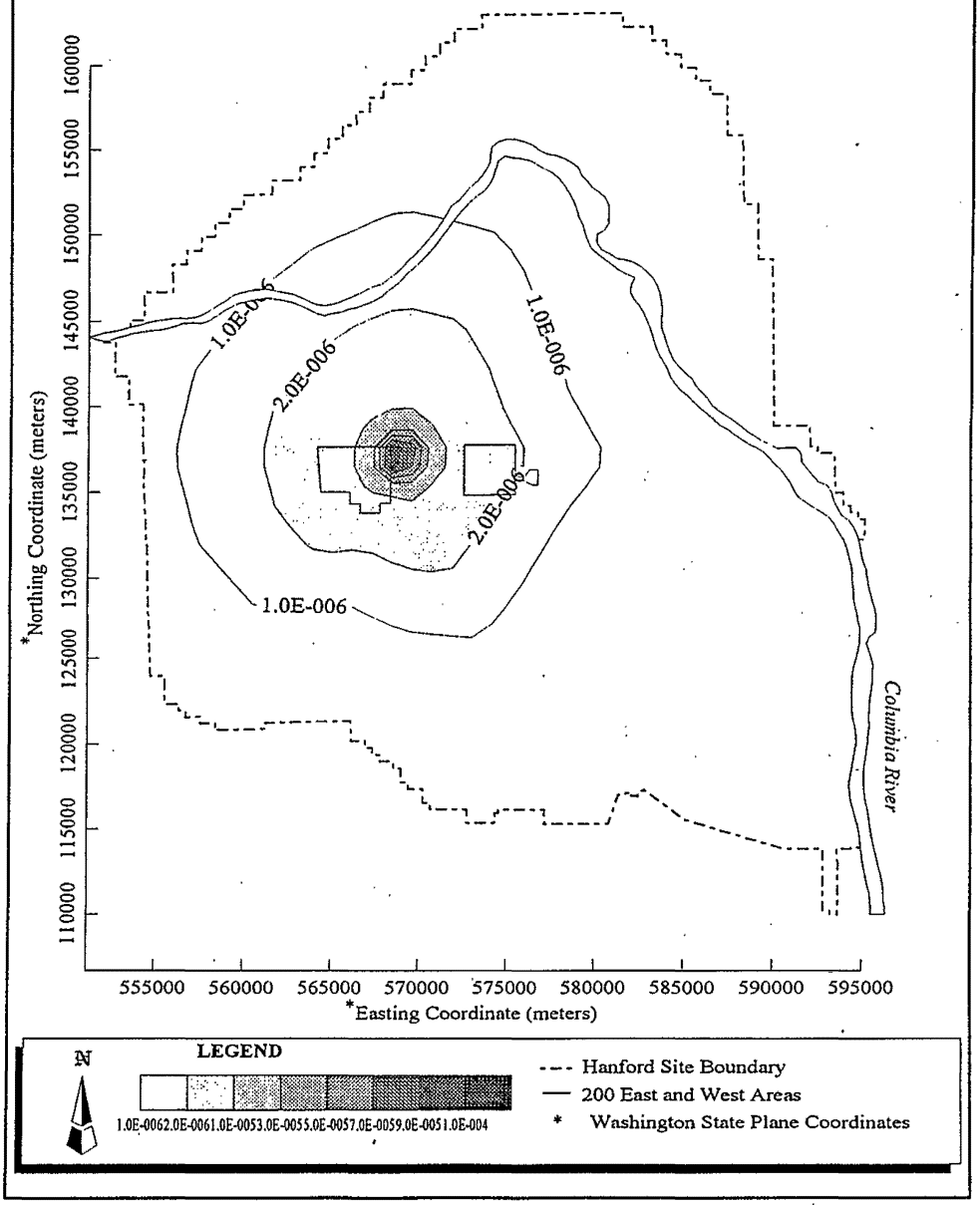
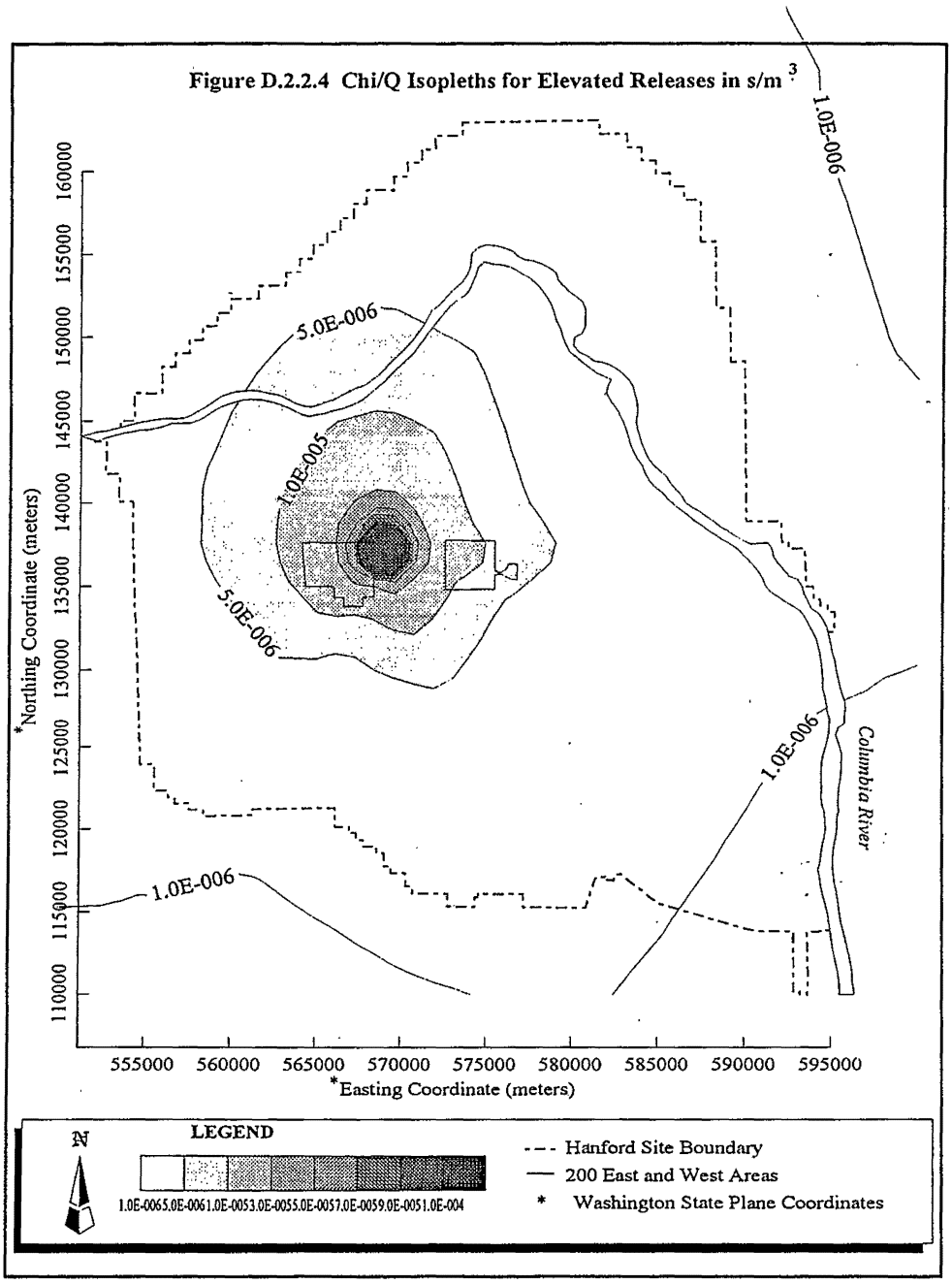


**Figure D.2.2.4 Chi/Q Isopleths for Elevated Releases in s/m $^3$**



- N. Columbia River - 0.4 km (0.25 mi) south of the south river bank;
- E. Columbia River - 0.4 km (0.25 mi) west of the west river bank;
- S. A line running west from the Columbia River, just north of the Washington Public Power Supply System leased area, through the Wye Barricade to State Route 240; and
- W. State Route 240 and State Route 24.

Potential exposure and subsequent carcinogenic risk and noncarcinogenic health hazards from chemical emissions were evaluated for the MEI worker, MEI noninvolved worker, and MEI general public receptors as described in more detail in the following text.

Radionuclide exposure estimates for the TWRS workers did not require using a computer model because fixed dose values were assumed to be similar to the values previously measured for similar activities at the Hanford Site. For exposure to nonradioactive chemical emissions, the MEI worker was evaluated using a "box" model. This model assumed that the MEI worker was located within a box 100 m long, 100 m wide, and 3 m high (330 ft long, 330 ft wide, and 10 ft high). Average wind velocity perpendicular to the side of the box was assumed to be 3.6 m/sec. Then, the Chi/Q (atmospheric dispersion coefficient) for the MEI worker was estimated using GENII as follows.

$$Chi/Q = 1 / (L) \cdot (H) \cdot (W)$$

Where:

| | | |
|---|---|---|
| Chi/Q | = | $Sec/m^3$ |
| L | = | Downwind length of the box, m |
| H | = | Height of the box, m |
| W | = | Average wind velocity, m/sec |

The estimated Chi/Q value for the MEI worker was 9.26E-04 $sec/m^3$.

For the noninvolved worker and general public, exposure was estimated through the use of the computer GENII model (Napier et al. 1988 and DOE 1995c). GENII was used to calculate doses corresponding to the Chi/Q values generated through air transport modeling. The GENII calculations were performed assuming that source term release and receptor intake end after 1 year (i.e., 8,760 hours). Doses calculated by GENII were multiplied by the duration (in years) of a particular activity to produce the total dose for that activity. The dose calculation ends after 70 years (i.e., a 70-year life expectancy is assumed).

The GENII computer program allows calculation of radiation doses to individuals or the population from airborne and waterborne radionuclide releases of radionuclides to the environment. Exposure pathways (i.e., ingestion, inhalation, and external exposure routes) are included. For the present analysis, exposure pathways are included in the dose analysis for inhalation or airborne activity, external exposure to airborne and deposited activity, and ingestion of agricultural products grown in soil contaminated from atmospheric deposition. Parameter values used in the analysis were as defined

by Schreckhise et al. (Schreckhise et al. 1993) for dose analyses performed for Hanford Site activities. The parameters used for the individual and population dose analyses generally are more conservative than those used for the baseline and post-remediation analyses. The dose estimates generated by GENII were converted to risk as described in Section D.2.2.4.

The assumptions for estimating exposures to the receptors listed previously are described in the following sections.

**Workers**

The worker exposure is a combination of exposure from inhalation and direct radiation and would depend on the activity. The historical average dose for a Hanford Site tank farm worker has been 14 millirems per year (mrem/year) (WHC 1995g and Jacobs 1996). This same average is assumed for radiation workers during construction of the transfer lines, retrieval system tie-ins, and the tank farm confinement facilities. This same dose of 14 mrem/year is also assumed for monitoring, maintenance, and closure activities. A dose of 200 mrem/year is assumed for personnel operating the evaporators, retrieval facilities, separation and treatment facilities (both in situ and ex situ), and for processing the capsules. This was based on a dose of 200 mrem/year, average whole body deep exposure to operational personnel, at the Plutonium-Uranium Extraction (PUREX) Plant during 1986 (WHC 1995g and Jacobs 1996). A dose of 200 mrem/year was assumed for capsule alternatives. The MEI dose (one worker that receives the maximum exposure permissible) was based on a current site administrative control level of 500 mrem/year per worker for each year of operation.

For nonradiological chemicals, the chemical intake (dose) was estimated for the MEI worker according to the following equation:

$$Intake_i = \frac{(Ca_i) \cdot (IR) \cdot (EF) \cdot (ED)}{(BW) \cdot (AT)}$$

Where:

| | | |
|---|---|---|
| $Intake_i$ | = | Inhalation intake of the ith chemical, mg/kg-day |
| $Ca_i$ | = | Estimated air concentration of the ith chemical, mg/m$^3$ |
| IR | = | Worker inhalation rate, 20 m$^3$/day |
| EF | = | Worker exposure frequency, 250 days/year |
| ED | = | Worker exposure duration, 30 years |
| BW | = | Worker body weight, 70 kg |
| AT | = | Averaging time, days |
| | = | (ED)(365 days/year) for noncarcinogens |
| | = | (70 years)(365 days/year) for carcinogens, (25,550 days) |

**Noninvolved Workers**

During the workday, the noninvolved workers would be exposed to contamination from atmospheric emissions released during implementation of TWRS remedial activities. The noninvolved workers are assumed to occupy an area extending from 100 m (330 ft) out to the Hanford Site boundary.

To calculate the noninvolved worker population dose, Hanford Site-specific population data were obtained from the Hanford Site phone directory and increased by 10 percent to account for uncertainties. The Hanford Site worker populations are presented in Table D.2.2.3.

The principal assumption for calculations of dose is the breathing rate, which is assumed to be 3.30E-04 $m^3$/sec (4.30E-04 $yd^3$/sec). The dose from ingesting contaminated food was not included because it was assumed that ingestion of food grown onsite would not be allowed. The duration of exposure would vary depending on the schedule for each of the TWRS alternatives being considered.

The noninvolved MEI worker was assumed to be exposed from inhalation and external radiation from the plume continuously throughout the year and from deposited activity for half of the year (4,380 hr/yr). Chemical intake (dose) was estimated for the MEI noninvolved worker according to the same equation and exposure parameters used for the MEI workers. The noninvolved worker population was assumed to be exposed from inhalation and external radiation from the plume continuously throughout the year and from deposited activity for one-third of the year (2,920 hr/yr). The dose from inhalation of resuspended activity was evaluated using the mass loading approach with a particulate air concentration of 100 mg/$m^3$ for both the maximum individual and population analyses.

**General Public**

The exposure pathways for the general public are inhalation, external exposure from submersion in a cloud, and consumption of fruits, vegetables, meat, and milk. The general public is assumed to occupy an area extending from the Hanford Site boundary to 80 km (50 mi) from the release site. Population data obtained from the 1990 Census (Beck et al. 1991) are used to calculate exposure and dose for the average member of the general public. Table D.2.2.4 displays the general public population within 80 km (50 mi) of the Hanford Site.

For radiological emissions, the assumptions for the general public (MEI and population) were the same as for the noninvolved workers, but also included ingestion of contaminated farm products. The general public MEI was assumed to ingest the following foods: leafy vegetables (82 g/day), root vegetables (600 g/day), fruit (900 g/day), grain (220 g/day), beef (220 g/day), poultry (50 g/day), milk (740 g/day), and eggs (82 g/day). The individuals in the general population each were assumed to ingest the following foods: leafy vegetables (41 g/day), root vegetables (383 g/day), fruit (175 g/day), grain (197 g/day), beef (192 g/day), poultry (23 g/day), milk (630 g/day), and eggs (55 g/day). The maximum individual exposure is based on intake assumptions that have been used historically at the Hanford Site for risk analysis intended to show protection to the public.

For nonradiological chemicals, the chemical intake (dose) was estimated for the MEI general public receptor using a lifetime average daily dose (LADD). The LADD was the combined intake over 6 years for a child and over 24 years for an adult, resulting in a residential exposure duration of 30 years. The residential or general public intake was calculated according to the following equation:

Table D.2.2.3 Onsite Population [1]

| Distance[2] (mi) | | | | | | | | | | Sector Total | Sector Direction |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 to 0.35 | 0.35 to 0.47 | 0.47 to 0.57 | 0.57 to 0.82 | 0.82 to 1.21 | 1.21 to 2.67 | 2.67 to 5.53 | 5.53 to 9.94 | 9.94 to 15.85 | 15.85 +[3] | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | S |
| 130 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 130 | SSW |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | SW |
| 50 | 0 | 0 | 0 | 0 | 0 | 317 | 0 | 0 | 0 | 367 | WSW |
| 50 | 0 | 0 | 0 | 0 | 0 | 1,626 | 0 | 0 | 0 | 1,676 | W |
| 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | WNW |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NW |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 100 | NNW |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 400 | 0 | 0 | 400 | N |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NNE |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | NE |
| 0 | 252 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 252 | ENE |
| 0 | 0 | 0 | 0 | 50 | 0 | 0 | 0 | 0 | 0 | 50 | E |
| 0 | 0 | 300 | 0 | 0 | 580 | 0 | 0 | 1,500 | 0 | 2,380 | ESE |
| 0 | 0 | 0 | 1,500 | 0 | 0 | 0 | 0 | 1,000 | 3,000 | 5,500 | SE |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | SSE |
| 280 | 252 | 300 | 1,500 | 50 | 580 | 1,943 | 500 | 2,500 | 3,000 | 10,905 | Population Total |

Notes:
[1] Source: Savino 1994.
[2] No distance information provided to the author; the numbers used were derived by splitting the distance between the midpoints.
[3] From 15.85 miles (25.50 km) to the Hanford Site Boundary.

$$Intake_i = \frac{(Ca_i) \cdot (IR) \cdot (EF) \cdot (ED)}{(BW) \cdot (AT)}$$

Where:

$Intake_i$ = Inhalation intake of the ith chemical, mg/kg-day
$Ca_i$ = Estimated air concentration of the ith chemical, mg/m$^3$

IR = Residential inhalation rate, m$^3$/day
= 20 m$^3$/day for an adult
= 10 m$^3$/day for a child

Table D.2.2.4 Offsite Population [1]

| Distance (mi) | | | | | | | | | | Sector Total | Sector Direction |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 to 1 | 1 to 2 | 2 to 3 | 3 to 4 | 4 to 5 | 5 to 10 | 10 to 20 | 20 to 30 | 30 to 40 | 40 to 50 | | |
| 0 | 0 | | 0 | 0 | 0 | 2842 | 1622 | 237 | 1144 | 5845 | S |
| 0 | 0 | 0 | 0 | 0 | 0 | 713 | 11983 | 503 | 738 | 13937 | SSW |
| 0 | 0 | 0 | 0 | 0 | 0 | 1308 | 19589 | 1132 | 637 | 22666 | SW |
| 0 | 0 | 0 | 0 | 0 | 0 | 1956 | 5406 | 16336 | 7525 | 31223 | WSW |
| 0 | 0 | 0 | 0 | 0 | 0 | 771 | 1295 | 6269 | 94203 | 102538 | W |
| 0 | 0 | 0 | 0 | 0 | 0 | 641 | 1087 | 1189 | 2375 | 5292 | WNW |
| 0 | 0 | 0 | 0 | 0 | 0 | 548 | 738 | 784 | 809 | 2879 | NW |
| 0 | 0 | 0 | 0 | 0 | 0 | 544 | 909 | 876 | 4979 | 7308 | NNW |
| 0 | 0 | 0 | 0 | 0 | 0 | 434 | 822 | 969 | 2418 | 4643 | N |
| 0 | 0 | 0 | 0 | 0 | 0 | 268 | 1030 | 5220 | 17567 | 24085 | NNE |
| 0 | 0 | 0 | 0 | 0 | 0 | 393 | 6176 | 2658 | 1145 | 10372 | NE |
| 0 | 0 | 0 | 0 | 0 | 0 | 423 | 1217 | 1652 | 664 | 3956 | ENE |
| 0 | 0 | 0 | 0 | 0 | 0 | 452 | 1373 | 1416 | 751 | 3992 | E |
| 0 | 0 | 0 | 0 | 0 | 0 | 289 | 1674 | 270 | 767 | 3000 | ESE |
| 0 | 0 | 0 | 0 | 0 | 0 | 1141 | 35519 | 73156 | 4918 | 114734 | SE |
| 0 | 0 | 0 | 0 | 0 | 0 | 2796 | 8309 | 2394 | 5891 | 19390 | SSE |
| 0 | 0 | 0 | 0 | 0 | 0 | 15519 | 98749 | 115061 | 146531 | 375860 | Population Total |

Note:
[1] Population within 80 km (50 mi) of the Hanford 200 Areas.
Source: 1990 Census (Beck et al. 1991)

EF = Residential exposure frequency, 365 days/year

ED = Residential exposure duration, years
= 24 years for an adult
= 6 years for a child

BW = Residential body weight, kg
= 70 kg for an adult
= 16 kg for a child

AT = Averaging time, days
= (ED)(365 days/year) for noncarcinogens
= (70 years)(365 days/year) for carcinogens, (25,550 days)

Noncarcinogenic health effects were evaluated for a child intake because this scenario results in a larger exposure per body weight and would be more health protective for potential sensitive members of the general population. Carcinogenic effects were evaluated using the combined LADD. Potential impacts from deposition of suspended particulate and subsequent uptake from home-grown food products are based on the magnitude of the emissions and inhalation risks/hazards for residential receptors.

### D.2.2.4 Risk

Routine risk for radionuclides is expressed in terms of latent cancer fatalities (LCFs). To estimate the number of cancer deaths that would result from exposure to low dose rates of ionizing radiation, dose-to-risk conversion factors are used to convert the calculated dose (from GENII) to a value for risk. Specific conversion factors were used that are accepted by agencies responsible for protection of human health and the environment, such as the Nuclear Regulatory Commission (NRC) (NRC 1991) and (EPA 1993a).

For radiological risk, two different conversion factors were used: one for workers and noninvolved workers and another for the general public, as recommended by the DOE Office of National Environmental Policy Act (NEPA) Oversight (DOE 1993d). The accepted dose-to-risk conversion factor for the worker is 4.0E-04 LCFs per person-rem effective dose equivalent (400 cancer deaths per million person-rem). The accepted conversion factor for the public is 5.0E-04 LCFs per person-rem effective dose equivalent (500 cancer deaths per million person-rem) (NRC 1991, ICRP 1991). The value for the public is higher because the public includes children, and children are more sensitive to radiation exposure. Assumptions for risk calculations are described in the following text.

In order to estimate the potential noncarcinogenic effects from exposure to multiple chemicals, the HI approach was used. The HI is defined as the summation of the hazard quotients (calculated dose divided by the reference dose [RfD]) for each chemical, for each route of exposure, and is represented by the following equation:

$$HI = \frac{\text{Calculated Dose}_a}{RfD_a} + \frac{\text{Calculated Dose}_b}{RfD_b} + \ldots + \frac{\text{Calculated Dose}_i}{RfD_i}$$

A total HI less than or equal to 1.0 (unity) is indicative of acceptable levels of exposure. To be truly additive in effect, chemicals must affect the same target organ system or result in the same critical toxic endpoint. Therefore, the approach listed previously is conservative and health protective in assuming that all chemical emissions are additive, and the approach provides a screening-level evaluation to potential noncarcinogenic effects.

Quantitative estimates of upper-bound incremental cancer risk (i.e., the excess cancer risk from fatal and nonfatal cancers) due to site-related chemicals were evaluated according to the following equation:

$$R_i = (q_i) \cdot (E_i)$$

Where:

$R_i$ = Estimated incremental risk of cancer associated with the chemical;
$q_i$ = Cancer slope factor for the chemical, $(mg/kg\text{-}day)^{-1}$
$E_i$ = Exposure dose for the chemical, mg/kg-day

Carcinogenic risk was assumed to be additive and was estimated by summing the upper-bound incremental cancer risk for all carcinogenic chemical emissions.

**Workers**

Worker risk was evaluated in terms of a maximum individual and collective radiation dose to the workforce. The worker risk was calculated both for each unit process and for each alternative or subalternative as a whole. The method of calculation was as follows:

$R = (DR) \cdot (W) \cdot$ (risk factor of 4.0E-04 cancer fatality/person-rem) $\cdot$ (1.0E-03 rem/mrem)

Where:

R = the number of incremental LCFs due to routine exposure
DR = is the exposure value previously discussed (i.e., 500 mrem/year for the MEI, 200 mrem/year per person, and 14 mrem/year per person)
W = the number of remediation workers exposed during processing for each alternative

For the MEI worker, the exposure assumed for the purposes of the EIS results in an annual risk of 2.0E-04 LCF (0.5 rem/year $\cdot$ 4.0E-04 LCF/rem). The risk for an entire alternative would be the product of this annual risk and the alternative's duration in years. For the worker population exposure, the exposure and resulting risk would vary by alternative and are presented in Section D.4.0.

**Noninvolved Workers**

Risk was calculated for the MEI noninvolved worker and total population of noninvolved workers. The MEI noninvolved worker is located where the dose and risk are highest. This location would change as release conditions change. The dose and risk were calculated for the Site's total noninvolved worker population of approximately 10,900.

**General Public**

The MEI member of the general public is located where the dose and risk are highest. This location would change as release locations change with the various alternatives. The population dose and risk to the general public would be the total dose and risk to the general population of approximately 376,000 within an 80-km (50-mi) radius from the release point.

### D.2.2.5 Transportation Risk

Transportation risk for routine remediation is the integrated risk from direct radiation exposure from onsite truck or rail transport of waste to and from TWRS processing facilities only. Offsite rail transport of waste to the proposed national high-level waste (HLW) repository is discussed in Volume Four, Section E.16.0.

Transportation risk has been estimated by Green (Green 1995) using the RADTRAN 4 computer code (Neuhauser and Kanipe 1986). A key variable in the code is the dose rate from the vehicle package. The radioactive shipments in this analysis were assumed to be the regulatory maximum dose rate of about 10 mrem per hour at 1 m (3.3 ft). It is likely that many of the shipments would have lower values.

For the onsite shipments, the average population density of the 200 East Area (DOE 1994) was assumed to be 264.4 persons/km$^2$ (684.7 person/mi$^2$). All onsite travel was assumed to be in a zone with this population density.

The population dose was multiplied by a dose-to-risk conversion factor to estimate the LCF. The worker conversion factor used was 4.0E-04 (400 cancer deaths per million person-rem effective dose equivalent). For the public, the conversion factor was 5.0E-04 (500 cancer deaths per million person-rem effective dose equivalent).

## D.3.0 BASELINE RISK

The baseline risk is the existing risk at any location at different times in the future in the absence of remedial activities. It would be represented by the risk from the 177 tanks, 40 inactive MUSTs, and Cs and Sr capsules at the Hanford Site if no further actions were conducted to stabilize the waste. For NEPA purposes, the baseline risk is risk from the No Action alternative.

The No Action alternative was used to approximate the baseline. The No Action alternative would involve several activities including the following.

- The SSTs would be saltwell pumped.
- Monitoring and routine maintenance would be performed.

Sections D.4.1 and D.4.11 discuss the short-term risk for the tank waste No Action alternative and capsules No Action alternative, respectively. Sections D.5.1 and D.5.11 discuss the long-term risk for the tank waste No Action alternative and the capsules No Action alternative, respectively. Section D.7.0 discusses the risk from human intrusion into the tank waste and capsules under the No Action alternatives.

## D.4.0 REMEDIATION RISK

This section presents the results of the assessment for radiological and toxicological risk during remediation to remediation workers, noninvolved workers, and the general public for each of the TWRS alternatives. The risk presented in this section was evaluated using the methodology described in Section D.2.0. Using this methodology, remediation risk to the MEIs are expressed as the probability that the individual would contract a fatal cancer as a result of exposure to a radioactive substance and/or carcinogenic chemicals during the duration of the proposed project. In the case of an exposed population, remediation risk represents the expected increase in LCFs in the population at risk of potential exposure. The toxic effects resulting from chemical exposure also are analyzed.

## D.4.1 NO ACTION ALTERNATIVE (TANK WASTE)

This section presents the anticipated remediation risk associated with the No Action alternative for tank waste, as outlined in Volume Two, Appendix B.

The radiological and toxicological risk for this alternative were based on the air emissions and direct exposure from continued operations (including tank farm and evaporator operations). There would be no construction, retrieval, pretreatment, treatment, storage, disposal, or waste transportation activities associated with this alternative; therefore, there would be no risk from these components.

### D.4.1.1 Radiological Risk

The LCF risk to the worker, noninvolved worker, and general public receptors could result from atmospheric emissions from the evaporator and tank farms. The risk was determined by analyzing the radiological source term, transport mechanism, exposure, and the risk associated with the exposure as discussed in the following subsections.

#### D.4.1.1.1 Source Term

Operating air emissions shown in Table D.4.1.1 are the evaporator and tank farm source term for the noninvolved workers and the general public (WHC 1995g and Jacobs 1996). The workers would receive a combined dose from the air emissions and from direct exposure to radiation fields associated with the evaporator and tank farm operations.

#### D.4.1.1.2 Transport

The atmospheric transport parameters for the No Action alternative are presented in Table D.4.1.2. The tank farm atmospheric radiological operating emissions were modeled as a ground release and the evaporator was modeled as an elevated release. For modeling purposes, it was assumed that the source term would be released at a point in the 200 Areas represented by the meteorological conditions at the Hanford Meteorological Station. The analysis used the Hanford Meteorological Station joint frequency data presented in Table D.2.2.1 and Figure D.2.2.1.

Table D.4.1.1 Atmospheric Radiological Emissions for the No Action Alternative (Tank Waste)

| Continued Operations | | | |
|---|---|---|---|
| Tank Farm Emissions | | Evaporator Emissions | |
| Contaminants | Ci/yr Released | Contaminants | Ci/yr Released |
| Total Alpha [1,2] | 2.88E-08 | Total Alpha [1,2] | 2.10E-05 |
| Total Beta [1,3] | 7.91E-07 | Total Beta [1,3] | 1.20E-05 |
| Sr-90 | 1.81E-05 | | |
| Cs-137 | 5.38E-05 | | |
| I-129 | 4.60E-05 | | |

Notes:
[1] These emissions were analyzed without using decay equations.
[2] Total alpha is assumed to be Pu-239.
[3] Total beta is assumed to be Sr-90.

Table D.4.1.2 Atmospheric Transport Parameters for the No Action Alternative (Tank Waste)

| | Continued Operations | |
|---|---|---|
| | Tank Farm Emissions | Evaporator Emissions |
| Stack height in m (ft) | Ground | 6.7 (22) |
| Stack radius in m (ft) | N/A | 0.53 (1.7) |
| Stack flow rate in $m^3$/sec ($ft^3$/sec) | N/A | 10 (353) |
| Stack temperature in °C (°F) | N/A | 46 (117) |
| Noninvolved worker MEI location in m (ft) ESE | 100 (328) | 200 (646) |
| Public MEI location in km (mi) ESE | 22 (14) | 22 (14) |
| Chi/Q for noninvolved worker - population in s/$m^3$ | 1.60E-03 | 4.00E-06 |
| Chi/Q for noninvolved worker - MEI in s/$m^3$ | 4.00E-04 | 2.50E-06 |
| Chi/Q for general public - population in s/$m^3$ | 2.90E-03 | 1.60E-03 |
| Chi/Q for general public - MEI in s/$m^3$ | 6.60E-08 | 3.90E-08 |

Notes:
N/A = Not applicable
ESE = East-southeast

For ground releases, dispersion in the atmosphere would cause contaminant air concentrations and exposures to decrease with increasing distance from the source. Maximum individual exposures therefore would occur at the inner boundaries (i.e., closest distance to the source) of the defined receptor occupancy zones. For the noninvolved worker, the maximum exposure would occur 100 m (330 ft) from the source (in an east-southeast direction). For the general public, the maximum exposure would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the center of the 200 East Area).

The calculated Chi/Q values for ground releases from the tank farms were calculated by the GENII computer code to be 4.00E-04 sec/$m^3$ for the noninvolved worker MEI and 6.60E-08 sec/$m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 1.60E-03 sec/$m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 2.90E-03 sec/$m^3$.

For elevated releases (stack releases), the maximum exposure would not necessarily occur at the closest distance to the source. Air transport modeling indicates that the maximum exposure for the noninvolved worker would occur 200 m (660 ft) from the source (in an east-southeast direction). The maximum exposure for a member of the general public would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the 200 East Area).

The calculated Chi/Q values for 10 years of evaporator operation were 2.50E-06 sec/$m^3$ for the noninvolved worker MEI and 3.90E-08 sec/$m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 4.00E-04 sec/$m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 1.60E-03 sec/$m^3$.

D.4.1.1.3 Exposure

The radiological exposure for the alternative is presented in Table D.4.1.3. The table shows the exposure each receptor would receive from every component. The sum of the components is shown in the last column for each population and MEI receptor except for the MEI worker. The MEI worker is not summed but is represented by the component with the highest MEI dose.

The worker population dose is dependent on the number of people in the population and the anticipated dose each individual would receive. These data were obtained from the Site maintenance and operations contractor and the TWRS EIS contractor (WHC 1995g and Jacobs 1996). The calculations for the worker exposures from continued operations are as follows:

Tank farms = (5.00E+04 person-yr) · (1.40E-02 rem/person-yr) = 7.00E+02 person-rem
Evaporator = (6.40E+02 person-yr) · (2.00E-01 rem/person-yr) = 1.28E+02 person-rem
Total = 8.28E+02 person-rem

The MEI worker was assumed to receive a dose of 500 mrem (5.00E-01 rem) per year for a maximum of 30 years.

Table D.4.1.3 Summary of Anticipated Radiological Exposure for the No Action Alternative (Tank Waste)

| | Dose (person-rem) [2] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Receptor | Construction | Continued Operations (100 yrs) [1] | Retrieval | Separations and Treatment | Storage and Disposal | Monitoring and Maintenance | Post Closure Monitoring | Total |
| Worker - Population | N/A | 8.28E+02 | N/A | N/A | N/A | N/A | N/A | 8.28E+02 |
| Worker - MEI [3] | N/A | 1.50E+01 | N/A | N/A | N/A | N/A | N/A | 1.50E+01 |
| Noninvolved Worker - Population | N/A | 2.50E-03 | N/A | N/A | N/A | N/A | N/A | 2.50E-03 |
| Noninvolved Worker - MEI | N/A | 3.90E-04 | N/A | N/A | N/A | N/A | N/A | 3.90E-04 |
| General Public - Population | N/A | 1.60E-01 | N/A | N/A | N/A | N/A | N/A | 1.60E-01 |
| General Public - MEI | N/A | 4.60E-06 | N/A | N/A | N/A | N/A | N/A | 4.60E-06 |

Notes:
[1] Continued Operations include Tank Farm and Evaporator 1.
[2] MEI receptor dose is noted in rem.
[3] Worker MEI is assumed to work for 30 years.
N/A= Not applicable

The noninvolved worker and general public receptor exposures to the atmospheric emissions (source term) were converted to a radiological dose in rem using the GENII computer code and applying the appropriate Chi/Q from Table D.4.1.2. The dose for each receptor from tank farm and evaporator operations is presented in Table D.4.1.3.

### D.4.1.1.4 Risk

The LCFs are calculated as the product of the estimated dose times the dose-to-risk conversion factor (Section D.2.2.4). The sum of the radiological dose from the evaporator and tank farms, shown in the combined dose column in Table D.4.1.4, was multiplied by the appropriate dose-to-risk conversion factor to produce the LCF risk. The LCF risk for each receptor is presented in Table D.4.1.4.

Table D.4.1.4 Summary of Anticipated Risk for the No Action Alternative (Tank Waste)

| Receptor | Combined Dose (person-rem) [1] | LCF/rem | LCF Risk |
|---|---|---|---|
| Worker - Population | 8.28E+02 | 4.00E-04 | 3.31E-01 |
| Worker - MEI | 1.50E+01 | 4.00E-04 | 6.00E-03 |
| Noninvolved Worker - Population | 2.50E-03 | 4.00E-04 | 1.00E-06 |
| Noninvolved Worker - MEI | 3.90E-04 | 4.00E-04 | 1.56E-07 |
| General Public - Population | 1.60E-01 | 5.00E-04 | 8.00E-05 |
| General Public - MEI | 4.60E-06 | 5.00E-04 | 2.30E-09 |

Notes:
[1] MEI receptor dose is noted in rem.
LCF = Latent cancer fatality

### D.4.1.2 Chemical Exposure

Potential carcinogenic risk and noncarcinogenic health hazards may result from exposure to volatile emissions from the tank farm and the evaporator for the worker, noninvolved worker, and general public. Potential carcinogenic risks and noncarcinogenic health hazards were estimated using the chemical source term, transport mechanism, exposure, and toxicological criteria as discussed in the following subsections.

#### D.4.1.2.1 Source Term

Operating air emissions from the tank farm area and the evaporator are presented in Table D.4.1.5 (WHC 1995g and Jacobs 1996). The noninvolved worker and general public would be exposed to combined emissions from the tank farm area and the evaporator. The worker would be exposed only to emissions (ground-level release) from the tank farm area because emissions from the evaporator occur through a stack-release and would not impact the onsite worker.

#### D.4.1.2.2 Transport

The tank farm chemical operating emissions were modeled as a ground release. Chemical operating emissions from the evaporator would occur from the evaporator stack and were modeled as elevated releases. Transport parameters, location of the MEI noninvolved worker and MEI general public, and Chi/Q values for the MEI noninvolved worker and MEI general public are identical to the radiological parameters presented in Table D.4.1.2.

The MEI worker was evaluated using a "box" model presented in detail in Section D.2.2.3.
The estimated Chi/Q value for the MEI worker was 9.26E-04 sec/$m^3$.

Table D.4.1.5 Chemical Emissions for the No Action Alternative (Tank Waste)

| Tank Farm Emissions | | Evaporator Emissions | |
|---|---|---|---|
| Emissions | Total (mg/sec) | Emissions | Total (mg/sec) |
| Carbon Monoxide | 1.05E+00 | Acetone | 2.30E-01 |
| Nitrogen Oxide | 1.06E-01 | Ammonia | 2.16E-01 |
| 1,3-Butadiene | 7.49E-03 | n-Butyl Alcohol | 1.73E+00 |
| 2-Hexanone | 1.37E-01 | 2-Hexanone | 8.28E-04 |
| 2-Pentanone | 2.16E-01 | Methyl Isobutyl Ketone | 1.57E-02 |
| Acetone | 2.61E+00 | | |
| Acetonitrile | 1.26E+00 | | |
| Benzene | 5.97E-02 | | |
| Heptane | 1.53E-01 | | |
| Methyl N-amyl Ketone | 1.48E-01 | | |
| N-Hexane | 1.60E-01 | | |
| Nonane | 8.32E-02 | | |
| Octane | 8.73E-02 | | |
| Toluene | 1.22E-02 | | |
| Ammonia | 7.67E+00 | | |
| Phosphoric Acid, Tributyl Ester | 1.89E-01 | | |
| Carbon Tetrachloride | 1.24E-07 | | |
| Ethyl Butyl Ketone | 4.15E-07 | | |
| Methyl Chloride | 1.83E-08 | | |
| Tetrahydrofuran | 3.20E-08 | | |

D.4.1.2.3 Exposure

**Worker**

As discussed previously in Section D.2.2.3, the MEI worker was assumed to be located within a box placed directly over the tank farm area. Exposure point concentrations of chemical emissions from the tank farm area ($mg/m^3$) were estimated by multiplying the cumulative tank farm emission rate (mg/sec) by the MEI worker Chi/Q value (9.26E-04 $sec/m^3$). Exposure point concentrations for each volatile chemical emitted from the tank farm area are summarized in Table D.4.1.6.

Estimated operating chemical emission intakes for the MEI worker were calculated according to the equation presented in Section D.2.2.3 and are presented in Table D.4.1.6.

Table D.4.1.6 No Action Alternative Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI Worker (mg/m3) | Noncarci-nogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarci-nogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 9.75E-04 | 1.91E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 9.80E-05 | 1.92E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 6.94E-06 | 1.36E-06 | 5.82E-07 | ND | 9.80E-01 | NE | 5.70E-07 |
| 2-Hexanone | 1.27E-04 | 2.48E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.00E-04 | 3.91E-05 | NC | ND | NC | NE | NC |
| Acetone | 2.41E-03 | 4.72E-04 | NC | 1.00E-01 | NC | 4.72E-03 | NC |
| Acetonitrile | 1.16E-03 | 2.27E-04 | NC | 1.40E-02 | NC | 1.62E-02 | NC |
| Benzene | 5.53E-05 | 1.08E-05 | 4.64E-06 | 1.70E-03 | 2.90E-02 | 6.36E-03 | 1.34E-07 |
| Heptane | 1.42E-04 | 2.78E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.37E-04 | 2.68E-05 | NC | 2.30E-02 | NC | 1.17E-03 | NC |
| N-hexane | 1.48E-04 | 2.90E-05 | NC | 5.70E-02 | NC | 5.09E-04 | NC |
| Nonane | 7.70E-05 | 1.51E-05 | NC | ND | NC | NE | NC |
| Octane | 8.08E-05 | 1.58E-05 | NC | ND | NC | NE | NC |
| Toluene | 1.13E-05 | 2.22E-06 | NC | 1.10E-01 | NC | 2.01E-05 | NC |
| Ammonia | 7.10E-03 | 1.39E-03 | NC | 2.90E-02 | NC | 4.79E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 1.75E-04 | 3.43E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.15E-10 | 2.25E-11 | 9.63E-12 | 5.70E-04 | 5.30E-02 | 3.94E-08 | 5.10E-13 |
| Ethyl Butyl Ketone | 3.85E-10 | 7.53E-11 | NC | 2.30E-02 | NC | 3.27E-09 | NC |
| Methyl Chloride | 1.70E-11 | 3.32E-12 | 1.42E-12 | ND | 6.30E-03 | NE | 8.97E-15 |
| Tetrahydrofuran | 2.97E-11 | 5.81E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI= 7.70E-02** | **Risk = 7.05E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

### Noninvolved Worker

The MEI noninvolved worker was assumed to be located at the point where maximum downwind air concentrations were calculated (100 m [330 ft] from the tank farm and 200 m [660 ft] from the evaporator). Exposure point concentrations ($mg/m^3$) of chemical emissions from the tank farm area and the evaporator were estimated by multiplying the cumulative tank farm and evaporator emission rates (mg/sec) by the MEI noninvolved worker Chi/Q values (4.0E-04 $sec/m^3$ for the tank farm and

2.50E-06 sec/$m^3$ for the evaporator, respectively). Exposure point concentrations for each volatile chemical emitted from the tank farm area and evaporator are summarized in Table D.4.1.7 and D.4.1.8, respectively.

Chemical intake (dose) was estimated for the MEI noninvolved worker according to the same equation and exposure parameters used for the MEI worker. Estimated operating chemical emission intakes for the MEI noninvolved worker are presented in Tables D.4.1.7 and D.4.1.8 for the tank farm area and evaporator emissions, respectively.

**General Public**

The MEI general public receptor was assumed to be located at the point where maximum air concentrations were calculated (approximately 22 km [14 mi] from both the tank farm area and the evaporator). Exposure point concentrations (mg/$m^3$) of chemical emissions from the tank farm area and the evaporator were estimated by multiplying the cumulative tank farm and evaporator emission rates (mg/sec) by the MEI general public Chi/Q values (6.60E-08 sec/$m^3$ for the tank farm and 3.90E-08 sec/$m^3$ for the evaporator), respectively. Exposure point concentrations for each volatile chemical emitted from the tank farm area and evaporator are summarized in Table D.4.1.9 and D.4.1.10, respectively.

D.4.1.2.4 Toxicity Assessment

Toxicity assessment characterizes the relationship between the exposure to a chemical and the incidence of adverse health effects in exposed populations. In a quantitative carcinogenic risk assessment, the dose-response relationship of a carcinogen is expressed in terms of a slope factor (oral) or unit risk (inhalation), which are used to estimate the probability of risk of cancer associated with a given exposure pathway. Cancer slope factors and URFs as published by EPA (IRIS and HEAST) were used in this operating chemical emission evaluation.

For noncarcinogenic effects, toxicity data developed from animal or human studies typically are used to develop noncancer acceptable levels, or RfDs. A chronic RfD is defined as an estimate of a daily exposure for the human population, including sensitive subpopulations, that is likely to be without appreciable risk of deleterious effects. Chronic RfDs, as published in IRIS or HEAST, were used in this chemical evaluation. Table D.4.1.11 summarizes the cancer slope factors, RfDs, and data sources for each volatile operating chemical emission.

D.4.1.2.5 Risk Characterization

**MEI Worker**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm are summarized in Table D.4.1.6. The total HI and cancer risk from routine tank farm emissions are 7.70E-02 and 7.05E-07, respectively.

Table D.4.1.7 No Action Alternative Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg-day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 4.21E-04 | 8.25E-05 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 4.23E-05 | 8.30E-06 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 3.00E-06 | 5.88E-07 | 2.52E-07 | ND | 9.80E-01 | NE | 2.46E-07 |
| 2-Hexanone | 5.47E-05 | 1.07E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 8.64E-05 | 1.69E-05 | NC | ND | NC | NE | NC |
| Acetone | 1.04E-03 | 2.04E-04 | NC | 1.00E-01 | NC | 2.04E-03 | NC |
| Acetonitrile | 5.02E-04 | 9.84E-05 | NC | 1.40E-02 | NC | 7.03E-03 | NC |
| Benzene | 2.39E-05 | 4.68E-06 | 2.00E-06 | 1.70E-03 | 2.90E-02 | 2.75E-03 | 5.81E-08 |
| Heptane | 6.13E-05 | 1.20E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 5.92E-05 | 1.16E-05 | NC | 2.30E-02 | NC | 5.05E-04 | NC |
| N-hexane | 6.41E-05 | 1.26E-05 | NC | 5.70E-02 | NC | 2.20E-04 | NC |
| Nonane | 3.33E-05 | 6.52E-06 | NC | ND | NC | NE | NC |
| Octane | 3.49E-05 | 6.84E-06 | NC | ND | NC | NE | NC |
| Toluene | 4.89E-06 | 9.58E-07 | NC | 1.10E-01 | NC | 8.71E-06 | NC |
| Ammonia | 3.07E-03 | 6.01E-04 | NC | 290E-02 | NC | 2.07E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 7.57E-05 | 1.48E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 4.96E-11 | 9.72E-12 | 4.16E-12 | 5.70E-04 | 5.30E-02 | 1.71E-08 | 2.21E-13 |
| Ethyl Butyl Ketone | 1.66E-10 | 3.26E-11 | NC | 2.30E-02 | NC | 1.42E-09 | NC |
| Methyl Chloride | 7.33E-12 | 1.44E-12 | 6.15E-13 | ND | 6.30E-03 | NE | 3.88E-15 |
| Tetrahydrofuran | 1.28E-11 | 2.51E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 3.33E-02** | **Risk = 3.05E-07** |

Notes:
ND = No published data
NC = Noncarcinogen
NE = Not evaluated

Table D.4.1.8 No Action Alternative (Tank Waste) Evaporator Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the Noninvolved MEI Worker (mg/m3) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Acetone | 5.75E-07 | 1.13E-07 | NC | 1.00E-01 | N/A | 1.13E-06 | NC |
| Ammonia | 5.40E-07 | 1.06E-07 | NC | 2.90E-02 | N/A | 3.65E-06 | NC |
| n-Butyl Alcohol | 4.33E-06 | 8.48E-07 | NC | 1.00E-01 | N/A | 8.48E-06 | NC |
| 2-Hexanone | 2.07E-09 | 4.06E-10 | NC | ND | N/A | NE | NC |
| Methyl Isobutyl Ketone | 3.93E-08 | 7.69E-09 | NC | 2.30E-02 | N/A | 3.34E-07 | NC |
| | | | | | | HI = 1.36E-05 | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

### MEI Noninvolved Worker

The noncarcinogenic hazards and carcinogenic risks for chemical emissions from the tank farm and evaporator are summarized in Tables D.4.1.7 and D.4.1.8, respectively. The total HI and cancer risk from combined tank farm and evaporator emissions are 3.33E-02 and 3.05E-07, respectively.

### MEI General Public

The noncarcinogenic hazards and carcinogenic risks for chemical emissions from the tank farm and evaporator are summarized in Tables D.4.1.9 and D.4.1.10, respectively. The total HI and cancer risk from combined tank farm and evaporator emissions is 1.82E-05 and 9.08E-11, respectively.

## D.4.2 LONG-TERM MANAGEMENT ALTERNATIVE

This section presents the anticipated remediation risk associated with the Long-Term Management alternative for tank waste, as outlined in Volume Two, Appendix B.

The radiological and toxicological risk for this alternative were based on the air emissions and direct exposure from construction, continued operations (including tank farm and evaporator operations), and retrieval operations. There would be no pretreatment, treatment, storage, disposal, or waste transportation activities associated with this alternative; therefore, there would be no risk from these components.

Table D.4.1.9 No Action Alternative Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI General Public ($mg/m^3$) | Noncarci-nogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarci-nogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 6.95E-08 | 4.34E-08 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 6.98E-09 | 4.36E-09 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 4.95E-10 | 3.09E-10 | 7.50E-11 | ND | 9.80E-01 | NE | 7.35E-11 |
| 2-Hexanone | 9.03E-09 | 5.64E-09 | NC | ND | NC | NE | NC |
| 2-Pentanone | 1.43E-08 | 8.91E-09 | NC | ND | NC | NE | NC |
| Acetone | 1.72E-07 | 1.08E-07 | NC | 1.00E-01 | NC | 1.08E-06 | NC |
| Acetonitrile | 8.29E-08 | 5.18E-08 | NC | 1.40E-02 | NC | 3.70E-06 | NC |
| Benzene | 3.94E-09 | 2.46E-09 | 5.97E-10 | 1.70E-03 | 2.90E-02 | 1.45E-06 | 1.73E-11 |
| Heptane | 1.01E-08 | 6.32E-09 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 9.77E-09 | 6.11E-09 | NC | 2.30E-02 | NC | 2.65E-07 | NC |
| N-hexane | 1.06E-08 | 6.61E-09 | NC | 5.70E-02 | NC | 1.16E-07 | NC |
| Nonane | 5.49E-09 | 3.43E-09 | NC | ND | NC | NE | NC |
| Octane | 5.76E-09 | 3.60E-09 | NC | ND | NC | NE | NC |
| Toluene | 8.07E-10 | 5.04E-10 | NC | 1.10E-01 | NC | 4.58E-09 | NC |
| Ammonia | 5.06E-07 | 3.16E-07 | NC | 2.90E-02 | NC | 1.09E-05 | NC |
| Phosphoric Acid, Tributyl Ester | 1.25E-08 | 7.81E-09 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 8.18E-15 | 5.11E-15 | 1.24E-15 | 5.70E-04 | 5.30E-02 | 8.97E-12 | 6.57E-17 |
| Ethyl Butyl Ketone | 2.74E-14 | 1.71E-14 | NC | 2.30E-02 | NC | 7.45E-13 | NC |
| Methyl Chloride | 1.21E-15 | 7.56E-16 | 1.83E-16 | ND | 6.30E-03 | NE | 1.16E-18 |
| Tetrahydrofuran | 2.11E-15 | 1.32E-15 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 1.75E-05** | **Risk = 9.08E-11** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.1.10 No Action Alternative (Tank Waste) Evaporator Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Acetone | 8.97E-09 | 5.61E-09 | NC | 1.00E-01 | NC | 5.61E-08 | NC |
| Ammonia | 8.42E-09 | 5.27E-09 | NC | 2.90E-02 | NC | 1.82E-07 | NC |
| n-Butyl Alcohol | 6.75E-08 | 4.22E-08 | NC | 1.00E-01 | NC | 4.22E-07 | NC |
| 2-Hexanone | 3.23E-11 | 2.02E-11 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 6.12E-10 | 3.83E-10 | NC | 2.30E-02 | NC | 1.66E-08 | NC |
| | | | | | | HI = 6.76E-07 | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

### D.4.2.1 Radiological Risk

The LCF risk to the worker, noninvolved worker, and the general public could result from direct exposure and atmospheric emissions from the evaporators and tank farms. The risk was determined by analyzing the radiological source term, the transport mechanism, exposure, and the risk associated with the exposure as discussed in the following subsections.

#### D.4.2.1.1 Source Term

Operating air emissions shown in Table D.4.2.1 are the evaporator and tank farm source terms for the noninvolved workers and the general public (WHC 1995g and Jacobs 1996). The workers would receive a combined dose from the air emissions and from direct exposure to radiation fields associated with the evaporator and tank farm operations.

#### D.4.2.1.2 Transport

The atmospheric transport parameters of the Long-Term Management alternative are presented in Table D.4.2.2. The tank farm and retrieval atmospheric radiological operating emissions were modeled as a ground release and the evaporator emissions were modeled as an elevated release. For modeling purposes, it was assumed that the source term would be released at a point in the 200 Areas represented by the meteorological conditions at the Hanford Meteorological Station. The analysis used the Hanford Meteorological Station joint frequency data from Table D.2.2.1 and Figure D.2.2.1.

Table D.4.1.11 Toxicity Criteria for Operations Chemical Emissions

| Emissions | Oral Reference Dose (mg/kg-day) | Inhalation Reference Dose (mg/kg-day) | Oral Slope Factor $(mg/kg\text{-}day)^{-1}$ | Inhalation Slope Factor $(mg/kg\text{-}day)^{-1}$ |
|---|---|---|---|---|
| Carbon Monoxide | ND | ND | NC | NC |
| Nitrogen Oxide | 1.00E+00[a] | ND | NC | NC |
| 1,3-Butadiene | ND | ND | 9.80E-01 | 9.80E-01 |
| 2-Hexanone | ND | ND | NC | NC |
| 2-Pentanone | ND | ND | NC | NC |
| Acetone | 1.00E+01[b] | 1.00E-01[c] | NC | NC |
| Acetonitrile | 6.00E-03[b] | 1.40E-02[d] | NC | NC |
| Benzene | 1.70E-03[c] | 1.70E-03[c] | NC | NC |
| Heptane | ND | ND | NC | NC |
| Methyl Isobutyl Ketone | 8.00E-02[d] | 2.30E-02[d] | NC | NC |
| Methyl N-amyl Ketone | 8.00E-02[d,f] | 2.30E-02[d,f] | NC | NC |
| n-Butyl Alcohol | 1.00E-02[b] | 1.00E-01[c] | NC | NC |
| N-hexane | 6.00E-02[d] | 5.70E-02[b] | NC | NC |
| Nonane | ND | ND | NC | NC |
| Octane | ND | ND | NC | NC |
| Toluene | 2.00E-01[b] | 1.10E-01[d] | NC | NC |
| Ammonia | ND | 2.90E-02[b] | NC | NC |
| Phosphoric Acid, Tributyl Ester | ND | ND | NC | NC |
| Carbon Tetrachloride | 7.00E-04[b] | 5.70E-04[c] | 1.30E-01[b] | 5.30E-02[b] |
| Ethyl Butyl Ketone | 8.00E+0[d,f] | 2.30E-02[d,f] | NC | NC |
| Methyl Chloride | ND | ND | 1.30E-02[d] | 6.30E-03[d] |
| Tetrahydrofuran | ND | ND | NC | NC |

Notes:
[a] Nitrogen dioxide used as a surrogate chemical, value was withdrawn from IRIS
[b] IRIS (EPA), October 1995
[c] Route-to-route extrapolation
[d] HEAST (EPA), October 1995
[e] ECAO 1995
[f] Methyl isobutyl ketone used as a surrogate chemical
NC = Noncarcinogen
ND = No data were available

Table D.4.2.1 Atmospheric Radiological Emissions for the Long-Term Management Alternative

| Continued Operations | | | | | | Retrieval Emissions | |
|---|---|---|---|---|---|---|---|
| Tank Farm Emissions | | Evaporator-1 Emissions | | Evaporator-2 Emissions [4] | | | |
| Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released |
| Total Alpha [1,2] | 2.88E-08 | Total Alpha [1,2] | 2.10E-05 | Total Alpha [1,2] | 1.41E-04 | Sr-90 | 1.00E-05 |
| Total Beta [1,3] | 7.91E-07 | Total Beta [1,3] | 1.20E-05 | Total Beta [1,3] | 8.04E-05 | Cs-137 | 7.00E-05 |
| Sr-90 | 1.81E-05 | | | | | I-129 | 1.00E-04 |
| Cs-137 | 5.38E-05 | | | | | | |
| I-129 | 4.60E-05 | | | | | | |

Notes:
[1] These emissions were analyzed without using decay equations.
[2] Total alpha is assumed to be Pu-239.
[3] Total beta is assumed to be Sr-90.
[4] Evaporator-2 is the replacement evaporator for retanking.

Table D.4.2.2 Atmospheric Transport Parameters for the Long-Term Management Alternative

| | Continued Operations | | Retrieval |
|---|---|---|---|
| | Tank Farms | Evaporators 1 and 2 | |
| Stack height in m (ft) | Ground | 6.70 (22) | Ground |
| Stack radius in m (ft) | N/A | 0.53 (1.7) | N/A |
| Stack flow rate in $m^3$/sec ($ft^3$/sec) | N/A | 10 (353) | N/A |
| Stack temperature in °C (°F) | N/A | 46 (117) | N/A |
| Noninvolved worker MEI location in m (ft) ESE | 100 (328) | 200 (656) | 100 (328) |
| Public MEI location in km (mi) ESE | 22 (14) | 22 (14) | 22 (14) |
| Chi/Q for noninvolved worker - population in s/$m^3$ | 1.60E-03 | 4.00E-04 | 1.60E-03 |
| Chi/Q for noninvolved worker - MEI in s/$m^3$ | 4.00E-04 | 2.50E-06 | 4.00E-04 |
| Chi/Q for general public - population in s/$m^3$ | 2.90E-03 | 1.60E-03 | 2.90E-03 |
| Chi/Q for general public - MEI in s/$m^3$ | 6.60E-08 | 3.90E-08 | 6.60E-08 |

Notes:
ESE = East-southeast

For ground releases, dispersion in the atmosphere would cause contaminant air concentrations and exposures to decrease with increasing distance from the source. Maximum individual exposures therefore would occur at the inner boundaries (i.e., closest distance to the source) of the defined receptor occupancy zones. For the noninvolved worker, the maximum exposure would occur 100 m (330 ft) from the source (in an east-southeast direction). For the general public, the maximum exposure would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the center of the 200 East Area).

The calculated Chi/Q values for ground releases from the tank farms were calculated by the GENII computer code to be 4.0E-04 sec/$m^3$ for the noninvolved worker MEI and 6.0E-08 sec/$m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 1.6E-03 sec/$m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 2.9E-03 sec/$m^3$.

For elevated releases (stack releases), the maximum exposure would not necessarily occur at the closest distance to the source. Air transport modeling indicates that the maximum exposure for the noninvolved worker would occur 200 m (660 ft) from the source (in an east-southeast direction). The maximum exposure for a member of the general public would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary from the 200 East Area in an east-southeast direction).

The calculated Chi/Q values for 20 years of evaporator operations were 2.50E-06 sec/$m^3$ for the noninvolved worker MEI and 3.90E-08 sec/$m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 4.0E-04 sec/$m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 1.6E-03 sec/$m^3$.

D.4.2.1.3 Exposure

The radiological exposure for the alternative is presented in Table D.4.2.3. The table shows the exposure each receptor would receive from every component. The sum of the components is shown in the last column for each population and MEI receptor except for the MEI worker. The MEI worker is not summed but is represented by the component with the highest MEI dose.

The worker population dose is dependent on the number of people in the population and the anticipated dose each individual would receive. These data were obtained from the Site maintenance and operations contractor and the TWRS EIS contractor (WHC 1995g and Jacobs 1996). The calculations for the worker exposures from construction, continued operations, and retrieval are as follows:

- Construction = (7.17E+02 person-yr) · (1.4E-02 rem/person-yr) = 1.0E+01 person-rem
- Continued Operations -
  Tank farms = (5.00E+04 person-yr) · (1.40E-02 rem/person-yr) = 7.0E+02 person-rem
  Evaporator = (7.86E+02 person-yr) · (2.00E-01 rem/person-yr) = 1.6E+02 person-rem

Table D.4.2.3 Summary of Anticipated Radiological Exposure for the Long-Term Management Alternative

| Radiological Dose (person-rem) [2] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Receptor | Construction (8 yrs) | Continued Operations [1] (100 yrs) | Retrieval (8 yrs) | Separations and Treatment | Storage and Disposal | Transportation | Monitoring and Maintenance | Post Closure Monitoring | Total |
| Worker - Population | 8.00E+00 | 8.60E+02 | 3.60E+02 | N/A | N/A | N/A | N/A | N/A | 1.23E+03 |
| Worker - MEI [3] | 4.00E+00 | 1.50E+01 | 5.00E+00 | N/A | N/A | N/A | N/A | N/A | 1.50E+01 |
| Noninvolved Worker - Population | 0.00E+00 | 8.25E-02 | 9.20E-05 | N/A | N/A | N/A | N/A | N/A | 8.26E-02 |
| Noninvolved Worker -MEI | 0.00E+00 | 8.78E-04 | 2.40E-06 | N/A | N/A | N/A | N/A | N/A | 8.78E-04 |
| General Public - Population | 0.00E+00 | 4.88E-01 | 2.30E-03 | N/A | N/A | N/A | N/A | N/A | 4.90E-01 |
| General Public - MEI | 0.00E+00 | 1.29E-05 | 7.10E-08 | N/A | N/A | N/A | N/A | N/A | 1.29E-05 |

Notes:
[1] Continued operations include tank farm and Evaporator 1 and 2.
[2] MEI receptor dose is noted in rem.
[3] Worker MEI is assumed to work for 30 years.

Total = 8.6E+02 person-rem

- Retrieval = (1.82E+03 person-yr) · (2.00E-01 rem/person-yr) = 3.6E+02 rem

The MEI worker was assumed to receive a dose of 500 mrem (5.00E-01 rem) per year for a maximum of 30 years.

The noninvolved worker and general public exposures from inhalation of the atmospheric emissions (source term) were converted to a radiological dose in rem using the GENII computer code and applying the appropriate Chi/Q.

D.4.2.1.4 Risk

The LCFs are calculated as the product of the estimated dose multiplied by the dose-to-risk conversion factor (Section D.2.2.4). The sum of the radiological dose from construction, continued operations, and retrieval, for each receptor shown in the combined dose column in Table D.4.2.4 was multiplied by the appropriate dose-to-risk conversion factor to produce the LCF risk.

### D.4.2.2 Chemical Exposure

Potential carcinogenic risk and noncarcinogenic health hazards may result from exposure to volatile emissions from the tank farm, tank waste retrieval, and evaporators for the worker, noninvolved worker, and general public. Potential carcinogenic risk and noncarcinogenic health hazards were estimated using the chemical source term, transport mechanism, exposure, and toxicological criteria as discussed in the following subsections.

#### D.4.2.2.1 Source Term

Operating air emissions from the tank farm area, tank waste retrieval, and the evaporators are presented in Table D.4.2.5 (WHC 1995g and Jacobs 1996). The noninvolved worker and general public would be exposed to combined emissions from the tank farm area, tank waste retrieval operations, and the evaporators. The worker would be exposed only to emissions (ground-level release) from the tank farm area and retrieval operations because emissions from the evaporators occur through a stack-release and would not impact the onsite worker.

#### D.4.2.2.2 Transport

The tank farm chemical operating emissions (routine emissions from the tank farm and emissions during retrieval) were modeled as a ground release. Chemical operating emissions from the evaporators would occur from the evaporator stacks and were modeled as elevated releases. Transport parameters, location of the MEI noninvolved worker and MEI general public, and Chi/Q values for the MEI noninvolved worker and MEI general public are identical to the radiological parameters presented in Table D.4.2.2.

The MEI worker was evaluated using a "box" model, as presented in detail in Section D.2.2.3. The estimated Chi/Q value for the MEI worker was 9.26E-04 sec/$m^3$.

#### D.4.2.2.3 Exposure

**Worker**

As discussed previously in Section D.4.1.2.2, the MEI worker was assumed to be located within a box placed directly over the tank farm area. Exposure point concentrations of chemical emissions (mg/$m^3$) from the tank farm area and retrieval operations were estimated by multiplying the cumulative tank farm emission rate (mg/sec) and retrieval operation emission rate (mg/sec) by the MEI worker Chi/Q value (9.26E-04 sec/$m^3$), respectively. Exposure point concentrations for each volatile chemical emitted from the tank farm area and during retrieval are summarized in Tables D.4.2.6 and D.4.2.7, respectively.

Table D.4.2.4 Summary of Anticipated Risk for the Long-Term Management Alternative

| Receptor | Combined Dose (person-rem) [1] | LCF/rem | LCF Risk |
|---|---|---|---|
| Worker - Population | 1.23E+03 | 4.0E-04 | 4.92E-01 |
| Worker - MEI | 1.50E+01 | 4.0E-04 | 6.00E-03 |
| Noninvolved Worker - Population | 8.26E-02 | 4.0E-04 | 3.30E-05 |
| Noninvolved Worker - MEI | 8.78E-04 | 4.0E-04 | 3.51E-07 |
| General Public - Population | 4.90E-01 | 5.0E-04 | 2.45E-04 |
| General Public - MEI | 1.29E-05 | 5.0E-04 | 6.45E-09 |

Notes:
[1] MEI receptor dose is noted in rem.
LCF = Latent cancer fatality

Chemical intake (dose) was estimated for the MEI worker using the same equation and exposure parameters defined in Section D.2.2.3. Estimated intakes of chemical emissions from the tank farm and retrieval operations for the MEI worker are presented in Tables D.4.2.6 and D.4.2.7, respectively.

### Noninvolved Worker

The MEI noninvolved worker was assumed to be located at the point where maximum downwind air concentrations were calculated (100 m [330 ft] from the tank farm and 200 m [660 ft] from the evaporator). Exposure point concentrations ($mg/m^3$) of chemical emissions from the tank farm, retrieval operations, and the evaporators were estimated by multiplying the cumulative tank farm, retrieval, and evaporator emission rates (mg/sec) by their respective MEI noninvolved worker Chi/Q values (4.0E-04 $sec/m^3$ for the tank farm, 4.0E-04 $sec/m^3$ for retrieval, 2.5E-06 $sec/m^3$ for the two evaporators). Exposure point concentrations for each volatile chemical emitted from the tank farm area, retrieval operations, and the evaporators are summarized in Tables D.4.2.8, and D.4.2.9, D.4.2.10, and D.4.2.11, respectively.

Chemical intake (dose) was estimated for the MEI noninvolved worker according to the same equation and exposure parameters used for the MEI worker. Estimated operating chemical emission intakes for the MEI noninvolved worker are presented in Tables D.4.2.8, D.4.2.9, D.4.2.10, and D.4.2.11 for the tank farm area, retrieval, evaporator-1, and evaporator-2 emissions, respectively.

### General Public

The MEI general public receptor was assumed to be located at the point where maximum air concentrations were calculated (approximately 22 km [14 mi] from both the tank farm area and evaporator). Exposure point concentrations ($mg/m^3$) of chemical emissions from the tank farm area, retrieval operations, evaporator-1, and evaporator-2 were estimated by multiplying the cumulative emission rates (mg/sec) of each source by their respective MEI general public Chi/Q values (6.60E-08 $sec/m^3$ for the tank farm, 6.60E-08 $sec/m^3$ for retrieval operations, 6.00E-08 $sec/m^3$ for

**Table D.4.2.5 Chemical Emissions for the Long-Term Management Alternative**

| Tank Farm Emissions | | Retrieval Emissions | | Evaporator Emissions | | DST Evaporator Emissions | |
|---|---|---|---|---|---|---|---|
| **Emissions** | **Total Tank Farm Emission Rate (mg/sec)** | **Emissions** | **Retrieval Emission Rate (mg/sec)** | **Emissions** | **Evaporator Emission Rate (mg/sec)** | **Emissions** | **DST Evaporator Emission Rate (mg/sec)** |
| Carbon Monoxide | 1.05E+00 | Carbon Monoxide | 4.91E-03 | Acetone | 2.30E-01 | Acetone | 3.06E+00 |
| Nitrogen Oxide | 1.06E-01 | Nitrogen Oxide | 1.23E-01 | Ammonia | 2.16E-01 | Ammonia | 2.89E+00 |
| 1,3-Butadiene | 7.49E-03 | 1,3-Butadiene | 8.91E-03 | n-Butyl Alcohol | 1.73E+00 | n-Butyl Alcohol | 2.30E+01 |
| 2-Hexanone | 1.37E-01 | 2-Hexanone | 1.62E-01 | 2-Hexanone | 8.28E-04 | 2-Hexanone | 1.09E-02 |
| 2-Pentanone | 2.16E-01 | 2-Pentanone | 2.57E-01 | Methyl Isobutyl Ketone | 1.57E-02 | Methyl Isobutyl Ketone | 2.09E-01 |
| Acetone | 2.61E+00 | Acetone | 3.09E+00 | | | | |
| Acetonitrile | 1.26E+00 | Acetonitrile | 1.49E+00 | | | | |
| Benzene | 5.97E-02 | Benzene | 7.07E-02 | | | | |
| Heptane | 1.53E-01 | Heptane | 1.81E-01 | | | | |
| Methyl N-amyl Ketone | 1.48E-01 | Methyl N-amyl Ketone | 1.75E-01 | | | | |
| N-Hexane | 1.60E-01 | N-Hexane | 1.89E-01 | | | | |
| Nonane | 8.32E-02 | Nonane | 9.86E-02 | | | | |
| Octane | 8.73E-02 | Octane | 1.03E-01 | | | | |
| Toluene | 1.22E-02 | Toluene | 1.44E-02 | | | | |
| Ammonia | 7.67E+00 | Ammonia | 9.16E-02 | | | | |
| Phosphoric Acid, Tributyl Ester | 1.89E-01 | Phosphoric Acid, Tributyl Ester | 4.91E-05 | | | | |
| Carbon Tetrachloride | 1.24E-07 | | | | | | |
| Ethyl Butyl Ketone | 4.15E-07 | | | | | | |
| Methyl Chloride | 1.83E-08 | | | | | | |
| Tetrahydrofuran | 3.20E-08 | | | | | | |

Table D.4.2.6 Long-Term Management Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Worker (mg/kg-day | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg-day)^{-1}$ | Noncarcinogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 9.75E-04 | 1.91E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 9.80E-05 | 1.92E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 6.94E-06 | 1.36E-06 | 5.82E-07 | ND | 9.80E-01 | NE | 5.71E-07 |
| 2-Hexanone | 1.27E-04 | 2.48E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.00E-04 | 3.92E-05 | NC | ND | NC | NE | NC |
| Acetone | 2.41E-03 | 4.73E-04 | NC | 1.00E-01 | NC | 4.73E-03 | NC |
| Acetonitrile | 1.16E-03 | 2.28E-04 | NC | 1.40E-02 | NC | 1.63E-02 | NC |
| Benzene | 5.53E-05 | 1.08E-05 | 4.64E-06 | 1.70E-03 | 2.90E-02 | 6.37E-03 | 1.34E-07 |
| Heptane | 1.42E-04 | 2.78E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.37E-04 | 2.69E-05 | NC | 2.30E-02 | NC | 1.17E.03 | NC |
| N-hexane | 1.48E-04 | 2.91E-05 | NC | 5.70E-02 | NC | 5.10E-04 | NC |
| Nonane | 7.70E-05 | 1.51E-05 | NC | ND | NC | NE | NC |
| Octane | 8.08E-05 | 1.58E-05 | NC | ND | NC | NE | NC |
| Toluene | 1.13E-05 | 2.22E-06 | NC | 1.10E-01 | NC | 2.02E-05 | NC |
| Ammonia | 7.10E-03 | 1.39E-03 | NC | 2.90E-02 | NC | 4.80E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 1.75E-04 | 3.43E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.15E-10 | 2.25E-11 | 9.63E-12 | 5.70E-04 | 5.30E-02 | 3.95E-08 | 5.11E-13 |
| Ethyl Butyl Ketone | 3.85E-10 | 7.54E-11 | NC | 2.30E-02 | NC | 3.28E-09 | NC |
| Methyl Chloride | 1.70E-11 | 3.33E-12 | 1.42E-12 | ND | 6.30E-03 | NE | 8.97E-15 |
| Tetrahydrofuran | 2.97E-11 | 5.81E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI= 7.71E-02** | **Risk = 7.05E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.2.7 Long-Term Management Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 4.55E-06 | 8.91E-07 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 1.14E-04 | 2.24E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 8.25E-06 | 1.62E-06 | 2.31E-07 | ND | 9.80E-01 | NE | 2.26E-07 |
| 2-Hexanone | 1.50E-04 | 2.94E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.38E-04 | 4.67E-05 | NC | ND | NC | NE | NC |
| Acetone | 2.86E-03 | 5.61E-04 | NC | 1.00E-01 | NC | 5.61E-03 | NC |
| Acetonitrile | 1.38E-03 | 2.70E-04 | NC | 1.40E-02 | NC | 1.93E-02 | NC |
| Benzene | 6.55E-05 | 1.28E-05 | 1.83E-06 | 1.70E-03 | 2.90E-02 | 7.55E-03 | 5.32E-08 |
| Heptane | 1.68E-04 | 3.29E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.62E-04 | 3.18E-05 | NC | 2.30E-02 | NC | 1.38E-03 | NC |
| N-hexane | 1.75E-04 | 3.43E-05 | NC | 5.70E-02 | NC | 6.02E-04 | NC |
| Nonane | 9.13E-05 | 1.79E-05 | NC | ND | NC | NE | NC |
| Octane | 9.57E-05 | 1.88E-05 | NC | ND | NC | NE | NC |
| Toluene | 1.33E-05 | 2.61E-06 | NC | 1.10E-01 | NC | 2.38E-05 | NC |
| Ammonia | 8.48E-05 | 1.66E-05 | NC | 2.90E-02 | NC | 5.73E-04 | NC |
| Phosphoric Acid, Tributyl Ester | 4.55E-08 | 8.91E-09 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 3.50E-02** | **Risk = 2.79E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

evaporator-1, and 3.90E-08 $sec/m^3$ for evaporator-2). Exposure point concentrations for each volatile chemical emitted from the tank farm area, retrieval operations, evaporator-1, and evaporator-2 are summarized in Tables D.4.2.12, D.4.2.13, D.4.2.14, and D.4.2.15, respectively.

The residential or general public intake was calculated according to the equation and exposure parameters presented in Section D.2.2.3. Estimated chemical emission intakes for the MEI general public are presented in Tables D.4.2.12, D.4.2.13, D.4.2.14, and D.4.2.15 for the tank farm area, retrieval, evaporator-1, and evaporator-2, respectively.

Table D.4.2.8 Long-Term Management Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_I$) (mg/kg-day) | Inhalation Slope Factor ($SF_I$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 4.21E-04 | 8.25E-05 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 4.23E-05 | 8.30E-06 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 3.00E-06 | 5.88E-07 | 2.52E-07 | ND | 9.80E-01 | NE | 2.46E-07 |
| 2-Hexanone | 5.47E-05 | 1.07E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 8.64E-05 | 1.69E-05 | NC | ND | NC | NE | NC |
| Acetone | 1.04E-03 | 2.04E-04 | NC | 1.00E-01 | NC | 2.04E-03 | NC |
| Acetonitrile | 5.02E-04 | 9.84E-05 | NC | 1.40E-02 | NC | 7.03E-03 | NC |
| Benzene | 2.39E-05 | 4.68E-06 | 2.00E-06 | 1.70E-03 | 2.90E-02 | 2.75E-03 | 5.81E-08 |
| Heptane | 6.13E-05 | 1.20E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 5.92E-05 | 1.16E-05 | NC | 2.30E-02 | NC | 5.05E-04 | NC |
| N-hexane | 6.41E-05 | 1.26E-05 | NC | 5.70E-02 | NC | 2.20E-04 | NC |
| Nonane | 3.33E-05 | 6.52E-06 | NC | ND | NC | NE | NC |
| Octane | 3.49E-05 | 6.84E-06 | NC | ND | NC | NE | NC |
| Toluene | 4.89E-06 | 9.58E-07 | NC | 1.10E-01 | NC | 8.71E-06 | NC |
| Ammonia | 3.07E-03 | 6.01E-04 | NC | 2.90E-02 | NC | 2.07E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 7.57E-05 | 1.48E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 4.96E-11 | 9.72E-12 | 4.16E-12 | 5.70E-04 | 5.30E-02 | 1.71E-08 | 2.21E-13 |
| Ethyl Butyl Ketone | 1.66E-10 | 3.26E-11 | NC | 2.30E-02 | 6.30E-03 | 1.42E-09 | NC |
| Methyl Chloride | 7.33E-12 | 1.44E-12 | 6.15E-13 | ND | NC | NE | 3.88E-15 |
| Tetrahydrofuran | 1.28E-11 | 2.51E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 3.33E-02** | **Risk = 3.05E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.2.9 Long-Term Management Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg-day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 1.96E-06 | 3.85E-07 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 4.94E-05 | 9.68E-06 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 3.56E-06 | 6.98E-07 | 9.98E-08 | ND | 9.80E-01 | NE | 9.78E-08 |
| 2-Hexanone | 6.49E-05 | 1.27E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 1.03E-04 | 2.02E-05 | NC | ND | NC | NE | NC |
| Acetone | 1.24E-03 | 2.42E-04 | NC | 1.00E-01 | NC | 2.42E-03 | NC |
| Acetonitrile | 5.96E-04 | 1.17E-04 | NC | 1.40E-02 | NC | 8.34E-03 | NC |
| Benzene | 2.83E-05 | 5.54E-06 | 7.92E-07 | 1.70E-03 | 2.90E-02 | 3.26E-02 | 2.30E-08 |
| Heptane | 7.25E-05 | 1.42E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 7.02E-05 | 1.38E-05 | NC | 2.30E-02 | NC | 5.98E-04 | NC |
| N-hexane | 7.56E-05 | 1.48E-05 | NC | 5.70E-02 | NC | 2.60E-04 | NC |
| Nonane | 3.94E-05 | 7.73E-06 | NC | ND | NC | NE | NC |
| Octane | 4.13E-05 | 8.10E-06 | NC | ND | NC | NE | NC |
| Toluene | 5.76E-06 | 1.13E-06 | NC | 1.10E-01 | NC | 1.03E-05 | NC |
| Ammonia | 3.66E-05 | 7.18E-06 | NC | 2.90E-02 | NC | 2.48E-04 | NC |
| Phosphoric Acid, Tributyl Ester | 1.96E-08 | 3.85E-09 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 1.51E-02** | **Risk = 1.21E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.2.10 Long-Term Management Evaporator-1 Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Acetone | 5.75E-07 | 1.13E-07 | NC | 1.00E-01 | NC | 1.13E-06 | NC |
| Ammonia | 5.40E-07 | 1.06E-07 | NC | 2.90E-02 | NC | 3.65E-06 | NC |
| n-Butyl Alcohol | 4.33E-06 | 8.48E-07 | NC | 1.00E-01 | NC | 8.48E-06 | NC |
| 2-Hexanone | 2.07E-09 | 4.06E-10 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 3.93E-08 | 7.69E-09 | NC | 2.30E-02 | NC | 3.34E-07 | NC |
| | | | | | | **HI = 1.36E-05** | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.2.11 Long-Term Management Evaporator-2 Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Acetone | 7.65E-06 | 1.50E-06 | NC | 1.00E-01 | NC | 1.50E-05 | NC |
| Ammonia | 7.23E-06 | 1.42E-06 | NC | 2.90E-02 | NC | 4.88E-05 | NC |
| n-Butyl Alcohol | 5.75E-05 | 1.13E-05 | NC | 1.00E-01 | NC | 1.13E-04 | NC |
| 2-Hexanone | 2.73E-08 | 5.34E-09 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 5.23E-07 | 1.02E-07 | NC | 2.30E-02 | NC | 4.45E-06 | NC |
| | | | | | | **HI = 1.81E-04** | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.2.12 Long-Term Management Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 6.95E-08 | 4.34E-08 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 6.98E-09 | 4.36E-09 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 4.95E-10 | 3.09E-10 | 7.50E-11 | ND | 9.80E-01 | NE | 7.35E-11 |
| 2-Hexanone | 9.03E-09 | 5.64E-09 | NC | ND | NC | NE | NC |
| 2-Pentanone | 1.43E-08 | 8.91E-09 | NC | ND | NC | NE | NC |
| Acetone | 1.72E-07 | 1.08E-07 | NC | 1.00E-01 | NC | 1.08E-06 | NC |
| Acetonitrile | 8.29E-08 | 5.18E-08 | NC | 1.40E-02 | NC | 3.70E-06 | NC |
| Benzene | 3.94E-09 | 2.46E-09 | 5.97E-10 | 1.70E-03 | 2.90E-02 | 1.45E-06 | 1.73E-11 |
| Heptane | 1.01E-08 | 6.32E-09 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 9.77E-09 | 6.11E-09 | NC | 2.30E-02 | NC | 2.65E-07 | NC |
| N-hexane | 1.06E-08 | 6.61E-09 | NC | 5.70E-02 | NC | 1.16E-07 | NC |
| Nonane | 5.49E-09 | 3.43E-09 | NC | ND | NC | NE | NC |
| Octane | 5.76E-09 | 3.60E-09 | NC | ND | NC | NE | NC |
| Toluene | 8.07E-10 | 5.04E-10 | NC | 1.10E-01 | NC | 4.58E-09 | NC |
| Ammonia | 5.06E-07 | 3.16E-07 | NC | 2.90E-02 | NC | 1.09E-05 | NC |
| Phosphoric Acid, Tributyl Ester | 1.25E-08 | 7.81E-09 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 8.18E-15 | 5.11E-15 | 1.24E-15 | 5.70E-04 | 5.30E-02 | 8.97E-12 | 6.57E-17 |
| Ethyl Butyl Ketone | 2.74E-14 | 1.71E-14 | NC | 2.30E-02 | NC | 7.45E-13 | NC |
| Methyl Chloride | 1.21E-15 | 7.56E-16 | 1.83E-16 | ND | 6.30E-03 | NE | 1.16E-18 |
| Tetrahydrofuran | 2.11E-15 | 1.32E-15 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 1.75E-05** | **Risk = 9.08E-11** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.2.13 Long-Term Management Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 3.24E-10 | 2.02E-10 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 8.15E-09 | 5.09E-09 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 5.88E-10 | 3.67E-10 | 2.97E-11 | ND | 9.80E-01 | NE | 2.91E-11 |
| 2-Hexanone | 1.07E-08 | 6.69E-09 | NC | ND | NC | NE | NC |
| 2-Pentanone | 1.70E-08 | 1.06E-08 | NC | ND | NC | NE | NC |
| Acetone | 2.04E-07 | 1.28E-07 | NC | 1.00E-01 | NC | 1.28E-06 | NC |
| Acetonitrile | 9.83E-08 | 6.14E-08 | NC | 1.40E-02 | NC | 4.39E-06 | NC |
| Benzene | 4.67E-09 | 2.92E-09 | 2.36E-10 | 1.70E-03 | 2.90E-02 | 1.72E-06 | 6.84E-12 |
| Heptane | 1.20E-08 | 7.48E-09 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.16E-08 | 7.23E-09 | NC | 2.30E-02 | NC | 3.15E-07 | NC |
| N-hexane | 1.25E-08 | 7.80E-09 | NC | 5.70E-02 | NC | 1.37E-07 | NC |
| Nonane | 6.51E-09 | 4.07E-09 | NC | ND | NC | NE | NC |
| Octane | 6.82E-09 | 4.26E-09 | NC | ND | NC | NE | NC |
| Toluene | 9.50E-10 | 5.94E-10 | NC | 1.10E-01 | NC | 5.40E-09 | NC |
| Ammonia | 6.05E-09 | 3.78E-09 | NC | 2.90E-02 | NC | 1.30E-07 | NC |
| Phosphoric Acid, Tributyl Ester | 3.24E-12 | 2.02E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 7.96E-06** | **Risk = 3.60E-11** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.2.14 Long-Term Management Evaporator-1 Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Acetone | 8.97E-09 | 5.61E-09 | NC | 1.00E-01 | NC | 5.61E-08 | NC |
| Ammonia | 8.42E-09 | 5.27E-09 | NC | 2.90E-02 | NC | 1.82E-07 | NC |
| n-Butyl Alcohol | 6.75E-08 | 4.22E-08 | NC | 1.00E-01 | NC | 4.22E-07 | NC |
| 2-Hexanone | 3.23E-11 | 2.02E-11 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 6.12E-10 | 3.38E-10 | NC | 2.30E-02 | NC | 1.66E-08 | NC |
| | | | | | | HI = 6.76E-07 | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.2.15 Long-Term Management Evaporator-2 Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Acetone | 1.19E-07 | 7.46E-08 | NC | 1.00E-01 | NC | 7.46E-07 | NC |
| Ammonia | 1.13E-07 | 7.04E-08 | NC | 2.90E-02 | NC | 2.43E-06 | NC |
| n-Butyl Alcohol | 8.97E-07 | 5.61E-07 | NC | 1.00E-01 | NC | 5.61E-06 | NC |
| 2-Hexanone | 4.25E-10 | 2.66E-10 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 8.15E-09 | 5.09E-09 | NC | 2.30E-02 | NC | 2.21E-07 | NC |
| | | | | | | HI = 9.00E-06 | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

D.4.2.2.4 Toxicity Assessment

Toxicity assessment was previously discussed in detail in Section D.4.1.2.4. Cancer slope factors, RfDs, and data sources for each volatile operating chemical emission are summarized in Table D.4.1.11.

D.4.2.2.5 Risk Characterization

**MEI Worker**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm and retrieval operations are summarized in Tables D.4.2.6 and D.4.2.7, respectively. The total HI and cancer risk from routine tank farm emissions and retrieval emissions are 1.12E-01 and 9.84E-07, respectively.

**MEI Noninvolved Worker**

The noncarcinogenic hazards and carcinogenic risks for chemical emissions from the tank farm, retrieval operations, evaporator-1, and evaporator-2 are summarized in Tables D.4.2.8, D.4.2.9, D.4.2.10, and D.4.2.11, respectively. The total HI and cancer risk from combined tank farm, retrieval, and evaporator emissions are 4.85E-02 and 4.26E-07, respectively.

**MEI General Public**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm, retrieval operations, evaporator-1, and evaporator-2 are summarized in Tables D.4.2.12, D.4.2.13, D.4.2.14, and D.4.2.15, respectively. The total HI and cancer risk from combined tank farm, retrieval, and evaporator emissions are 3.51E-05 and 1.27E-10, respectively.

## D.4.3 IN SITU FILL AND CAP ALTERNATIVE

This section presents the anticipated remediation risk associated with the In Situ Fill and Cap alternative for tank waste, as outlined in Volume Two, Appendix B.

The radiological and toxicological risk for this alternative were based on the air emissions and direct exposure from construction, continued operations (including tank farm and evaporator operations), treatment (including evaporator and gravel fill operations), and closure and monitoring. There would be no retrieval, pretreatment, storage, or waste transportation activities associated with this alternative; therefore, there would be no risk from these components.

### D.4.3.1 Radiological Risk

The LCF risk to the workers, noninvolved workers, and general public could result from direct exposure and atmospheric emissions from the components associated with this alternative. The risk was determined by analyzing the radiological source term, transport mechanism, exposure, and risk associated with the exposure as discussed in the following subsections.

D.4.3.1.1 Source Term

Source terms used for the noninvolved worker and general public are the atmospheric radiological emissions presented in Table D.4.3.1 (WHC 1995f and Jacobs 1996). The worker would receive a combined dose from the air emissions and from direct exposure from radiation fields in the work place.

D.4.3.1.2 Transport

The atmospheric transport parameters of the In Situ Fill and Cap alternative are presented in Table D.4.3.2. The tank farm and gravel fill atmospheric radiological operating emissions were modeled as a ground release, and the evaporators were modeled as an elevated release. For modeling purposes, it was assumed that the source term would be released at a point in the 200 Areas represented by the meteorological conditions at the Hanford Meteorological Station. The analysis used the Hanford Meteorological Station joint frequency data from Table D.2.2.1 and Figure D.2.2.1.

For ground releases, dispersion in the atmosphere would cause contaminant air concentrations and exposures to decrease with increasing distance from the source. Maximum individual exposures therefore would occur at the inner boundaries (i.e., closest distance to the source) of the defined receptor occupancy zones. For the noninvolved worker, the maximum exposure would occur 100 m (330 ft) from the source (in an east-southeast direction). For the general public, the maximum exposure would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the center of the 200 East Area).

The calculated Chi/Q values for ground releases from the tank farms were calculated by the GENII computer code to be 4.0E-04 sec/$m^3$ for the noninvolved worker MEI and 6.6E-08 sec/$m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 1.6E-03 sec/$m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 2.9E-03 sec/$m^3$.

For elevated releases (stack releases), the maximum exposure would not necessarily occur at the closest distance to the source. Air transport modeling indicates that the maximum exposure for the noninvolved worker would occur 200 m (660 ft) from the source (in an east-southeast direction). The maximum exposure for a member of the general public would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the 200 East Area).

The calculated Chi/Q values for the evaporator operation were 2.50E-06 sec/$m^3$ for the noninvolved worker MEI and 3.90E-08 sec/$m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 4.0E-04 sec/$m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 1.6E-03 sec/$m^3$.

Table D.4.3.1 Atmospheric Radiological Emissions for the In Situ Fill and Cap Alternative

| Continued Operations | | | | Treatment Operations | | | |
|---|---|---|---|---|---|---|---|
| Tank Farm Emissions | | Evaporator Emissions | | DST Evaporator Emissions | | Gravel Fill Emissions | |
| Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released |
| Total Alpha [1] | 2.88E-08 | Total Alpha [1] | 2.10E-05 | Total Alpha [1] | 1.41E-04 | Total Alpha [1] | 8.74E-11 |
| Total Beta [2] | 7.91E-07 | Total Beta [2] | 1.20E-05 | Total Beta [2] | 8.04E-05 | Total Beta [2] | 2.39E-09 |
| Sr-90 | 1.81E-05 | | | | | Sr-90 | 2.59E-08 |
| Cs-137 | 5.38E-05 | | | | | Cs-137 | 1.61E-07 |
| I-129 | 4.60E-05 | | | | | I-129 | 1.40E-07 |

Notes:
[1] Total alpha is assumed to be Pu-239.
[2] Total beta is assumed to be Sr-90.

Table D.4.3.2 Atmospheric Transport Parameters for the In Situ Fill and Cap Alternative

| | Continued Operations | | Treatment Operations | |
|---|---|---|---|---|
| | Tank Farms | Evaporator 1 | Evaporator 2 | In Situ Fill and Cap |
| Stack height in m (ft) | Ground | 6.70 (22) | 6.70 (22) | Ground |
| Stack radius in m (ft) | N/A | 0.53 (1.7) | 0.53 (1.7) | N/A |
| Stack flow rate in $m^3$/sec ($ft^3$/sec) | N/A | 10 (353) | 10 (353) | N/A |
| Stack temperature in °C (°F) | N/A | 46 (117) | 46 (117) | N/A |
| Noninvolved worker MEI location in m (ft) ESE | 100 (328) | 200 (656) | 200 (656) | 100 (328) |
| Public MEI location in km (mi) ESE | 22 (14) | 22 (14) | 22 (14) | 22 (14) |
| Chi/Q for noninvolved worker - population in $s/m^3$ | 1.60E-03 | 4.00E-04 | 4.00E-04 | 1.60E-03 |
| Chi/Q for noninvolved worker - MEI in $s/m^3$ | 4.00E-04 | 2.50E-06 | 2.50E-06 | 4.00E-04 |
| Chi/Q for general public - population in $s/m^3$ | 2.90E-03 | 1.60E-03 | 1.60E-03 | 2.90E-03 |
| Chi/Q for general public - MEI in $s/m^3$ | 6.60E-08 | 3.90E-08 | 3.90E-08 | 6.60E 08 |

Notes:
ESE = East-southeast

D.4.3.1.3 Exposure

The radiological exposure for the alternative is presented in Table D.4.3.3. The table shows the exposure each receptor would receive from every component. The sum of the components is shown in the last column for each population and MEI receptor except for the MEI worker. The MEI worker is not summed, but is represented by the component with the highest MEI dose.

Table D.4.3.3 Summary of Anticipated Radiological Exposure for the In Situ Fill and Cap Alternative

| Radiological Dose (person-rem) [5] | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Receptor | Construction (2 yrs) | Continued Operations [1] (12 yrs) | Retrieval | Treatment [2] (9 yrs) | Disposal | Transportation | Monitoring and Maintenance | Post Closure Monitoring (100 yrs) | Total |
| Worker - Population | 1.90E+00 | 2.97E+02 | N/A | 2.23E+02 | N/A | N/A | N/A | 1.13E+01 | 5.33E+02 |
| Worker - MEI[3, 4] | 1.00E+00 | 9.50E+00 | N/A | 4.00E+00 | N/A | N/A | N/A | 1.50E+01 | 1.50E+01 |
| Noninvolved Worker - Population | 0.00E+00 | 1.45E-03 | N/A | 4.00E-02 | N/A | N/A | N/A | 0.00E+00 | 4.15E-02 |
| Noninvolved Worker - MEI | 0.00E+00 | 7.61E-05 | N/A | 2.50E-04 | N/A | N/A | N/A | 0.00E+00 | 2.50E-04 |
| General Public - Population | 0.00E+00 | 6.90E-02 | N/A | 1.70E-01 | N/A | N/A | N/A | 0.00E+00 | 2.39E-01 |
| General Public - MEI | 0.00E+00 | 1.85E-06 | N/A | 4.10E-06 | N/A | N/A | N/A | 0.00E+00 | 4.10E-04 |

Notes:
[1] Continued operations include tank farm and Evaporator 1.
[2] Treatment includes gravel fill and Evaporator 2 .
[3] Worker MEI is assumed to work for 30 years.
[4] Total for the MEI represents the highest single exposure.
[5] MEI receptor dose noted in rem.

The worker population dose is dependent on the number of people in the population and the anticipated dose each individual would receive. These data were obtained from the Site maintenance and operations contractor and the TWRS EIS contractor (WHC 1995f and Jacobs 1996). The calculations for the worker exposures from construction, continued operations, treatment, and closure are as follows:

Construction = (1.37E+02 person-yr) · (1.4E-02 rem/person-yr) = 1.9E+00 person-rem

Continued Operations -
Tank farms = (1.21E+04 person-yr) · (1.40E-02 rem/person-yr) = 1.7E+02 person-rem
Evaporator = (6.40E+02 person-yr) · (2.00E-01 rem/person-yr) = 1.3E+02 person-rem
Total = 3.0E+02 person-rem

Treatment Operations -
Evaporator = (7.30E+01 person-yr) · (2.00E-01 rem/person-yr) = 1.5E+01 person-rem
Gravel fill = (1.04E+03 person-yr) · (2.00E-01 rem/person-yr) = 2.1E+02 person-rem
Total = 2.3E+02 person-rem

Closure -
Closure = (1.83E+02 person-yr) · (1.4E-02E-01 rem/person-yr) = 2.56E+00 person-rem
Monitoring = (6.25E+02 person-yr) · (1.4E-02 rem/person-yr) = 8.75E+00 person-rem
Total = 1.13E+01 person- rem

The MEI worker was assumed to receive a dose of 500 mrem (5.00E-01 rem) per year for a maximum of 30 years.

The noninvolved workers and general public exposures from inhalation of the atmospheric emissions (source term) were converted to a radiological dose in rem using the GENII computer code and applying the appropriate Chi/Q.

D.4.3.1.4 Risk

The LCFs are calculated as the product of the estimated dose times the dose-to-risk conversion factor (Section D.2.2.4). The sum of the radiological dose from construction, continued operations, treatment, and closure, for each receptor shown in the combined dose column in Table D.4.3.4 was multiplied by the appropriate dose-to-risk conversion factor to produce the LCF risk.

### D.4.3.2 Chemical Exposure

Potential carcinogenic risk and noncarcinogenic health hazards may result from exposure to volatile emissions from the tank farm, the evaporators, and tank filling (gravel filling) operations for the worker, noninvolved worker, and general public. Potential carcinogenic risk and noncarcinogenic health hazards were estimated using the chemical source term, transport mechanism, exposure, and toxicological criteria as discussed in the following subsections.

Table D.4.3.4 Summary of Anticipated Risk for the In Situ Fill and Cap Alternative

| Receptor | Combined Dose (person-rem) [1] | LCF/rem | LCF Risk |
|---|---|---|---|
| Worker - Population | 5.33E+02 | 4.00E-04 | 2.13E-01 |
| Worker - MEI | 1.50E+01 | 4.00E-04 | 6.00E-03 |
| Noninvolved Worker - Population | 4.15E-02 | 4.00E-04 | 1.66E-05 |
| Noninvolved Worker - MEI | 2.50E-04 | 4.00E-04 | 1.00E-07 |
| General Public - Population | 2.39E-01 | 5.00E-04 | 1.20E-04 |
| General Public - MEI | 4.10E-06 | 5.00E-04 | 2.05E-09 |

Notes:
[1] MEI receptor dose noted in rem.
LCF = Latent cancer fatality

D.4.3.2.1 Source Term

Operating air emissions from the tank farm area and the evaporators and filling the tanks with gravel are presented in Table D.4.3.5 (WHC 1995f and Jacobs 1996). The noninvolved worker and general public would be exposed to combined emissions from the tank farm area, the evaporators, and filling the tanks with gravel. The worker would be exposed only to emissions (ground-level release) from the tank farm area and filling the tanks with gravel because emissions from the evaporators occur through a stack-release and would not impact the onsite worker.

D.4.3.2.2 Transport

The tank farm chemical operating emissions (routine emissions from the tank farm and emissions during filling the tanks with gravel) were modeled as a ground release. Chemical operating emissions from the evaporators would occur from the evaporator stacks and were modeled as elevated releases. Transport parameters, location of the MEI noninvolved worker and MEI general public, and Chi/Q values for the MEI noninvolved worker and general public are identical to the radiological parameters presented in Table D.4.3.2.

The MEI worker was evaluated using a "box" model, as presented in detail in Section D.2.2.3. The estimated Chi/Q value for the MEI worker was 9.26E-04 sec/$m^3$.

D.4.3.2.3 Exposure

**Worker**

The MEI worker was assumed to be located within a box placed directly over the tank farm area. Exposure point concentrations of chemical emissions (mg/$m^3$) from the tank farm area and filling the tanks with gravel were estimated by multiplying the cumulative tank farm emission rate (mg/sec) and tank-filling emission rate (mg/sec) by the MEI worker Chi/Q value (9.26E-04 sec/$m^3$), respectively. Exposure point concentrations for each volatile chemical emitted from the tank farm area and during retrieval are summarized in Tables D.4.3.6 and D.4.3.7, respectively.

Chemical intake (dose) was estimated for the MEI worker using the same equation and exposure parameters defined in Section D.2.2.3. Estimated intakes of chemical emissions from the tank farm and tank filling operations for the MEI worker are presented in Tables D.4.3.6 and D.4.3.7, respectively.

**Noninvolved Worker**

The MEI noninvolved worker was assumed to be located at the point where maximum downwind air concentrations were calculated (100 m [330 ft] from the tank farm and 200 m [660 ft] from the evaporator). Exposure point concentrations (mg/$m^3$) of chemical emissions from the tank farm, filling the tanks with gravel, and the evaporators were estimated by multiplying the cumulative tank farm, tank-filling, and evaporator emission rates (mg/sec) by their respective MEI noninvolved worker Chi/Q values (4.0E-04 sec/$m^3$ for the tank farm, 4.0E-04 sec/$m^3$ for tank-filling, 2.50E-06 sec/$m^3$ for the evaporators).

Table D.4.3.5 Chemical Emissions for the In Situ Fill and Cap Alternative

| Tank Farm Emissions | | Tank Filling with Gravel | | Evaporator-1 Emissions | | Evaporator-2 Emissions | |
|---|---|---|---|---|---|---|---|
| Emissions | Total Tank Farm Emission Rate (mg/sec) | Emissions | Fill and Cap Emission Rate (mg/sec) | Emissions | Evaporator Emission Rate (mg/sec) | Emissions | DST Evaporator Emission Rate (mg/sec) |
| Carbon Monoxide | 1.05E+00 | Carbon Monoxide | 2.44E-02 | Acetone | 2.30E-01 | Acetone | 3.06E+00 |
| Nitrogen Oxide | 1.06E-01 | Nitrogen Oxide | 2.45E-03 | Ammonia | 2.16E-01 | Ammonia | 2.89E+00 |
| 1,3-Butadiene | 7.49E-03 | 1,3-Butadiene | 1.74E-04 | n-Butyl Alcohol | 1.73E+00 | n-Butyl Alcohol | 2.30E+-01 |
| 2-Hexanone | 1.37E-01 | 2-Hexanone | 3.17E-03 | 2-Hexanone | 8.28E-04 | 2-Hexanone | 1.09E-02 |
| 2-Pentanone | 2.16E-01 | 2-Pentanone | 5.01E-03 | Methyl Isobutyl Ketone | 1.57E-02 | Methyl Isobutyl Ketone | 2.09E-01 |
| Acetone | 2.61E+00 | Acetone | 6.05E-02 | | | | |
| Acetonitrile | 1.26E+00 | Acetonitrile | 2.91E-02 | | | | |
| Benzene | 5.97E-02 | Benzene | 1.38E-03 | | | | |
| Heptane | 1.53E-01 | Heptane | 3.56E-03 | | | | |
| Methyl N-amyl Ketone | 1.48E-01 | Methyl N-amyl Ketone | 3.43E-03 | | | | |
| N-hexane | 1.60E-01 | N-hexane | 3.72E-03 | | | | |
| Nonane | 8.32E-02 | Nonane | 1.93E-03 | | | | |
| Octane | 8.73E-02 | Octane | 2.02E-03 | | | | |
| Toluene | 1.22E-02 | Toluene | 2.84E-04 | | | | |
| Ammonia | 7.67E+00 | Ammonia | 1.78E-01 | | | | |
| Phosphoric Acid, Tributyl Ester | 1.89E-01 | Phosphoric Acid, Tributyl Ester | 4.39E-05 | | | | |
| Carbon Tetrachloride | 1.24E-07 | Carbon Tetrachloride | 2.88E-09 | | | | |
| Ethyl Butyl Ketone | 4.15E-07 | Ethyl Butyl Ketone | 9.64E-09 | | | | |
| Methyl Chloride | 1.83E-08 | Methyl Chloride | 4.25E-10 | | | | |
| Tetrahydrofuran | 3.20E-08 | Tetrahydrofuran | 7.43E-10 | | | | |

Table D.4.3.6 In Situ Fill and Cap Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 9.75E-04 | 1.91E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 9.80E-05 | 1.92E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 6.94E-06 | 1.36E-06 | 3.68E-07 | ND | 9.80E-01 | NE | 3.61E-07 |
| 2-Hexanone | 1.27E-04 | 2.48E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.00E-04 | 3.92E-05 | NC | ND | NC | NE | NC |
| Acetone | 2.41E-03 | 4.73E-04 | NC | 1.00E-01 | NC | 4.73E-03 | NC |
| Acetonitrile | 1.16E-03 | 2.28E-04 | NC | 1.40E-02 | NC | 1.63E-03 | NC |
| Benzene | 5.53E-05 | 1.08E-05 | 2.94E-06 | 1.70E-03 | 2.90E-02 | 6.37E-03 | 8.51E-08 |
| Heptane | 1.42E-04 | 2.78E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.37E-04 | 2.69E-05 | NC | 2.30E-02 | NC | 1.17E-03 | NC |
| N-hexane | 1.48E-04 | 2.91E-05 | NC | 5.70E-02 | NC | 5.10E-04 | NC |
| Nonane | 7.70E-05 | 1.51E-05 | NC | ND | NC | NE | NC |
| Octane | 8.08E-05 | 1.58E-05 | NC | ND | NC | NE | NC |
| Toluene | 1.13E-05 | 2.22E-06 | NC | 1.10E-01 | NC | 2.02E-05 | NC |
| Ammonia | 7.10E-03 | 1.39E-03 | NC | 2.90E-02 | NC | 4.80E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 1.75E-04 | 3.43E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.15E-10 | 2.25E-11 | 6.10E-12 | 5.70E-04 | 5.30E-02 | 3.95E-08 | 3.23E-13 |
| Ethyl Butyl Ketone | 3.85E-10 | 7.54E-11 | NC | 2.30E-02 | NC | 3.28E-09 | NC |
| Methyl Chloride | 1.70E-11 | 3.33E-12 | 9.01E-12 | ND | 6.30E-03 | NE | 5.68E-15 |
| Tetrahydrofuran | 2.97E-11 | 5.81E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 7.71E-02** | **Risk = 4.46E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.3.7 In Situ Fill and Cap Gravel Fill Emissions

| Emissions | Air Concentrations of Tank Filling Emissions for the MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg-day)^{-1}$ | Noncarcinogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 2.26E-05 | 4.43E-06 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 2.27E-06 | 4.46E-07 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 1.61E-07 | 3.16E-08 | 3.61E-09 | ND | 9.80E-01 | NE | 3.53E-09 |
| 2-Hexanone | 2.94E-06 | 5.76E-07 | NC | ND | NC | NE | NC |
| 2-Pentanone | 4.64E-06 | 9.09E-07 | NC | ND | NC | NE | NC |
| Acetone | 5.60E-05 | 1.10E-05 | NC | 1.00E-01 | NC | 1.10E-04 | NC |
| Acetonitrile | 2.70E-05 | 5.29E-06 | NC | 1.40E-02 | NC | 3.78E-04 | NC |
| Benzene | 1.28E-06 | 2.51E-07 | 2.87E-08 | 1.70E-03 | 2.90E-02 | 1.48E-04 | 8.33E-10 |
| Heptane | 3.29E-06 | 6.45E-07 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 3.18E-06 | 6.23E-07 | NC | 2.30E-02 | NC | 2.71E-05 | NC |
| N-hexane | 3.44E-06 | 6.74E-07 | NC | 5.70E-02 | NC | 1.18E-05 | NC |
| Nonane | 1.79E-06 | 3.50E-07 | NC | ND | NC | NE | NC |
| Octane | 1.87E-06 | 3.67E-07 | NC | ND | NC | NE | NC |
| Toluene | 2.63E-07 | 5.15E-08 | NC | 1.10E-01 | NC | 4.68E-07 | NC |
| Ammonia | 1.65E-04 | 3.23E-05 | NC | 2.90E-02 | NC | 1.11E-03 | NC |
| Phosphoric Acid, Tributyl Ester | 4.07E-06 | 7.97E-07 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 2.66E-12 | 5.22E-13 | 5.97E-14 | 5.70E-04 | 5.30E-02 | 9.16E-10 | 3.16E-15 |
| Ethyl Butyl Ketone | 8.92E-12 | 1.75E-12 | NC | 2.30E-02 | NC | 7.60E-11 | NC |
| Methyl Chloride | 3.94E-13 | 7.72E-14 | 8.82E-15 | ND | 6.30E-03 | NE | 5.56E-17 |
| Tetrahydorfuran | 6.88E-13 | 1.35E-13 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 1.79E-03** | **Risk = 4.37E-09** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Exposure point concentrations for each volatile chemical emitted from the tank farm area, tank-filling operations, and the evaporators are summarized in Tables D.4.3.8 and D.4.3.9, D.4.3.10, and D.4.3.11, respectively.

Chemical intake (dose) was estimated for the MEI noninvolved worker according to the same equation and exposure parameters used for the MEI worker. Estimated operating chemical emission intakes for the MEI noninvolved worker are presented in Tables D.4.3.8, D.4.3.9, D.4.3.10, and D.4.3.11 for the tank farm area, tank-filling, evaporator-1, and evaporator-2 emissions, respectively.

**General Public**

The MEI general public receptor was assumed to be located at the point where maximum air concentrations were calculated (approximately 22 km [14 mi] from both the tank farm area and evaporator). Exposure point concentrations ($mg/m^3$) of chemical emissions from the tank farm area, tank-filling operations, the evaporator, and the DST evaporator were estimated by multiplying the cumulative emission rates (mg/sec) of each source by their respective MEI general public Chi/Q values (6.60E-08 $sec/m^3$ for the tank farm, 6.60E-08 $sec/m^3$ for tank-filling operations, and 3.90E-08 $sec/m^3$ for the evaporators). Exposure point concentrations for each volatile chemical emitted from the tank farm area, tank-filling operations, evaporator-1, and evaporator-2 are summarized in Tables D.4.3.12, D.4.3.13, D.4.3.14, and D.4.3.15, respectively.

The residential or general public intake was calculated according to the equation and exposure parameters presented in Section D.2.2.3. Estimated chemical emission intakes for the MEI general public are presented in Tables D.4.3.12, D.4.3.13, D.4.3.14, and D.4.3.15 for the tank farm area, tank-filling operations, evaporator-1, and evaporator-2, respectively.

D.4.3.2.4 Toxicity Assessment

Toxicity assessment was previously discussed in detail in Section D.4.1.2.4. Cancer slope factors, RfDs, and data sources for each volatile operating chemical emission are summarized in Table D.4.1.11.

D.4.3.2.5 Risk Characterization

**MEI Worker**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm and tank filling operations are summarized in Tables D.4.3.6 and D.4.3.7, respectively. The total HI and cancer risk from routine tank farm emissions and tank filing emissions are 7.89E-02 and 4.50E-07, respectively.

**MEI Noninvolved Worker**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm, tank filling operations, evaporator-1, and evaporator-2 are summarized in Tables D.4.3.8, D.4.3.9, D.4.3.10, and D.4.3.11, respectively. The total HI and cancer risk from combined tank farm, tank filling, and evaporator emissions are 3.42E-02 and 1.95E-07, respectively.

Table D.4.3.8 In Situ Fill and Cap Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Nonin-volved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg-day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 4.21E-04 | 8.25E-05 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 4.23E-05 | 8.30E-06 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 3.00E-06 | 5.88E-07 | 1.59E-07 | ND | 9.80E-01 | NE | 1.56E-07 |
| 2-Hexanone | 5.47E-05 | 1.07E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 8.64E-05 | 1.69E-05 | NC | ND | NC | NE | NC |
| Acetone | 1.04E-03 | 2.04E-04 | NC | 1.00E-01 | NC | 2.04E-03 | NC |
| Acetonitrile | 5.02E-04 | 9.84E-05 | NC | 1.40E-02 | NC | 7.03E-03 | NC |
| Benzene | 2.39E-05 | 4.68E-06 | 1.27E-06 | 1.70E-03 | 2.90E-02 | 2.75E-03 | 3.68E-08 |
| Heptane | 6.13E-05 | 1.20E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 5.92E-05 | 1.16E-05 | NC | 2.30E-02 | NC | 5.05E-04 | NC |
| N-hexane | 6.41E-05 | 1.26E-05 | NC | 5.70E-02 | NC | 2.20E-04 | NC |
| Nonane | 3.33E-05 | 6.52E-06 | NC | ND | NC | NE | NC |
| Octane | 3.49E-05 | 6.84E-06 | NC | ND | NC | NE | NC |
| Toluene | 4.89E-06 | 9.58E-07 | NC | 1.10E-01 | NC | 8.71E-06 | NC |
| Ammonia | 3.07E-03 | 6.01E-04 | NC | 2.90E-02 | NC | 2.07E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 7.57E-05 | 1.48E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 4.96E-11 | 9.72E-12 | 2.63E-12 | 5.70E-04 | 5.30E-02 | 1.71E-08 | 1.40E-13 |
| Ethyl Butyl Ketone | 1.66E-10 | 3.26E-11 | NC | 2.30E-02 | NC | 1.42E-09 | NC |
| Methyl Chloride | 7.33E-12 | 1.44E-12 | 3.89E-13 | ND | 6.30E-03 | NE | 2.45E-15 |
| Tetrahydorfuran | 1.28E-11 | 2.51E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 3.33E-02** | **Risk = 1.93E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.3.9 In Situ Fill and Cap Gravel Fill Emissions

| Emissions | Air Concentrations of Tank Filling Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 9.77E-06 | 1.91E-06 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 9.82E-07 | 1.92E-07 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 6.95E-08 | 1.36E-08 | 1.56E-09 | ND | 9.80E-01 | NE | 1.53E-09 |
| 2-Hexanone | 1.27E-06 | 2.49E-07 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.00E-06 | 3.93E-07 | NC | ND | NC | NE | NC |
| Acetone | 2.42E-05 | 4.74E-06 | NC | 1.00E-01 | NC | 4.74E-05 | NC |
| Acetonitrile | 1.17E-05 | 2.28E-06 | NC | 1.40E-02 | NC | 1.63E-04 | NC |
| Benzene | 5.54E-07 | 1.09E-07 | 1.24E-08 | 1.70E-03 | 2.90E-02 | 6.39E-05 | 3.60E-10 |
| Heptane | 1.42E-06 | 2.79E-07 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.37E-06 | 2.69E-07 | NC | 2.30E-02 | NC | 1.17E-05 | NC |
| N-hexane | 1.49E-06 | 2.91E-07 | NC | 5.70E-02 | NC | 5.11E-06 | NC |
| Nonane | 7.72E-07 | 1.51E-07 | NC | ND | NC | NE | NC |
| Octane | 8.10E-07 | 1.59E-07 | NC | ND | NC | NE | NC |
| Toluene | 1.13E-07 | 2.22E-08 | NC | 1.10E-01 | NC | 2.02E-07 | NC |
| Ammonia | 7.12E-05 | 1.40E-05 | NC | 2.90E-02 | NC | 4.81E-04 | NC |
| Phosphoric Acid, Tributyl Ester | 1.76E-06 | 3.44E-07 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.15E-12 | 2.26E-13 | 2.58E-14 | 5.70E-04 | 5.30E-02 | 3.96E-10 | 1.37E-15 |
| Ethyl Butyl Ketone | 3.85E-12 | 7.56E-13 | NC | 2.30E-02 | NC | 3.29E-11 | NC |
| Methyl Chloride | 1.70E-13 | 3.33E-14 | 3.81E-15 | ND | 6.30E-03 | NE | 2.40E-17 |
| Tetrahydorfuran | 2.97E-13 | 5.83E-14 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 7.73E-04** | **Risk = 1.89E-09** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.3.10 In Situ Fill and Cap Evaporator-1 Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Acetone | 5.75E-07 | 1.13E-07 | NC | 1.00E-01 | NC | 1.13E-06 | NC |
| Ammonia | 5.40E-07 | 1.06E-07 | NC | 2.90E-02 | NC | 3.65E-06 | NC |
| n-Butyl Alcohol | 4.33E-06 | 8.48E-07 | NC | 1.00E-01 | NC | 8.48E-06 | NC |
| 2-Hexanone | 2.07E-09 | 4.06E-10 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 3.93E-08 | 7.69E-09 | NC | 2.30E-02 | NC | 3.34E-07 | NC |
| | | | | | | HI = 1.36E-05 | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.3.11 In Situ Fill and Cap Evaporator-2 Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Acetone | 7.65E-06 | 1.50E-06 | NC | 1.00E-01 | NC | 1.50E-05 | NC |
| Ammonia | 7.23E-06 | 1.42E-06 | NC | 2.90E-02 | NC | 4.88E-05 | NC |
| n-Butyl Alcohol | 5.75E-05 | 1.13E-05 | NC | 1.00E-01 | NC | 1.13E-04 | NC |
| 2-Hexanone | 2.73E-08 | 5.34E-09 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 5.23E-07 | 1.02E-07 | NC | 2.30E-02 | NC | 4.45E-06 | NC |
| | | | | | | HI = 1.81E-04 | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.3.12 In Situ Fill and Cap Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 6.95E-08 | 4.34E-08 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 6.98E-09 | 4.36E-09 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 4.95E-10 | 3.09E-10 | 4.75E-11 | ND | 9.80E-01 | NE | 4.65E-11 |
| 2-Hexanone | 9.03E-09 | 5.64E-09 | NC | ND | NC | NE | NC |
| 2-Pentanone | 1.43E-08 | 8.91E-09 | NC | ND | NC | NE | NC |
| Acetone | 1.72E-07 | 1.08E-07 | NC | 1.00E-01 | NC | 1.08E-06 | NC |
| Acetonitrile | 8.29E-08 | 5.18E-08 | NC | 1.40E-02 | NC | 3.70E-06 | NC |
| Benzene | 3.94E-09 | 2.46E-09 | 3.78E-10 | 1.70E-03 | 2.90E-02 | 1.45E-06 | 1.10E-11 |
| Heptane | 1.01E-08 | 6.32E-09 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 9.77E-09 | 6.11E-09 | NC | 2.30E-02 | NC | 2.65E-07 | NC |
| N-hexane | 1.06E-08 | 6.61E-09 | NC | 5.70E-02 | NC | 1.16E-07 | NC |
| Nonane | 5.49E-09 | 3.43E-09 | NC | ND | NC | NE | NC |
| Octane | 5.76E-09 | 3.60E-09 | NC | ND | NC | NE | NC |
| Toluene | 8.07E-10 | 5.04E-10 | NC | 1.10E-01 | NC | 4.58E-09 | NC |
| Ammonia | 5.06E-07 | 3.16E-07 | NC | 2.90E-02 | NC | 1.09E-05 | NC |
| Phosphoric Acid, Tributyl Ester | 1.25E-08 | 7.81E-09 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 8.18E-15 | 5.11E-15 | 7.86E-16 | 5.70E-04 | 5.30E-02 | 8.97E-12 | 4.16E-17 |
| Ethyl Butyl Ketone | 2.74E-14 | 1.71E-14 | NC | 2.30E-02 | NC | 7.45E-13 | NC |
| Methyl Chloride | 1.21E-15 | 7.56E-16 | 1.16E-16 | ND | 6.30E-03 | NE | 7.32E-19 |
| Tetrahydrofuran | 2.11E-15 | 1.32E-15 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 1.75E-05** | **Risk = 5.75E-11** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.3.13 In Situ Fill and Cap Gravel Fill Emissions

| Emissions | Air Concentrations of Tank Filling Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 1.47E-09 | 9.16E-10 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 1.47E-10 | 9.21E-11 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 1.04E-11 | 6.52E-12 | 4.22E-13 | ND | 9.80E-01 | NE | 4.13E-13 |
| 2-Hexanone | 1.90E-10 | 1.19E-10 | NC | ND | NC | NE | NC |
| 2-Pentanone | 3.01E-10 | 1.88E-10 | NC | ND | NC | NE | NC |
| Acetone | 3.63E-09 | 2.27E-09 | NC | 1.00E-01 | NC | 2.27E-08 | NC |
| Acetonitrile | 1.75E-09 | 1.09E-09 | NC | 1.40E-02 | NC | 7.80E-08 | NC |
| Benzene | 8.31E-11 | 5.19E-11 | 3.36E-12 | 1.70E-03 | 2.90E-02 | 3.05E-08 | 9.74E-14 |
| Heptane | 2.13E-10 | 1.33E-10 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 2.06E-10 | 1.29E-10 | NC | 2.30E-02 | NC | 5.60E-09 | NC |
| N-hexane | 2.23E-10 | 1.39E-10 | NC | 5.70E-02 | NC | 2.44E-09 | NC |
| Nonane | 1.16E-10 | 7.24E-11 | NC | ND | NC | NE | NC |
| Octane | 1.21E-10 | 7.59E-11 | NC | ND | NC | NE | NC |
| Toluene | 1.70E-11 | 1.06E-11 | NC | 1.10E-01 | NC | 9.67E-11 | NC |
| Ammonia | 1.07E-08 | 6.67E-09 | NC | 2.90E-02 | NC | 2,30E-07 | NC |
| Phosphoric Acid, Tributyl Ester | 2.63E-10 | 1.65E-10 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.73E-16 | 1.08E-16 | 6.98E-18 | 5.70E-04 | 5.30E-02 | 1.89E-13 | 3.70E-19 |
| Ethyl Butyl Ketone | 5.78E-16 | 3.61E-16 | NC | 2.30E-02 | NC | 1.57E-14 | NC |
| Methyl Chloride | 2.55E-17 | 1.59E-17 | 1.03E-18 | ND | 6.30E-03 | NE | 6.50E-21 |
| Tetrahydrofuran | 4.46E-17 | 2.79E-17 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 3.70E-07** | **Risk = 5.11E-13** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.3.14 In Situ Fill and Cap Evaporator-1 Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Acetone | 8.97E-09 | 5.61E-09 | NC | 1.00E-01 | NC | 5.61E-08 | NC |
| Ammonia | 8.42E-09 | 5.27E-09 | NC | 2.90E-02 | NC | 1.82E-07 | NC |
| n-Butyl Alcohol | 6.75E-08 | 4.22E-08 | NC | 1.00E-01 | NC | 4.22E-07 | NC |
| 2-Hexanone | 3.23E-11 | 2.02E-11 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 6.12E-10 | 3.83E-10 | NC | 2.30E-02 | NC | 1.66E-08 | NC |
| | | | | | | HI = 6.76E-07 | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.3.15 In Situ Fill and Cap Evaporator-2 Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Acetone | 1.19E-07 | 7.46E-08 | NC | 1.00E-01 | NC | 7.46E-07 | NC |
| Ammonia | 1.13E-07 | 7.04E-08 | NC | 2.90E-02 | NC | 2.43E-06 | NC |
| n-Butyl Alcohol | 8.97E-07 | 5.61E-07 | NC | 1.00E-01 | NC | 5.61E-06 | NC |
| 2-Hexanone | 4.25E-10 | 2.66E-10 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 8.15E-09 | 5.09E-09 | NC | 2.30E-02 | NC | 2.21E-07 | NC |
| | | | | | | HI = 9.00E-06 | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

**MEI General Public**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm, tank filling operations, the evaporator, and the DST evaporator are summarized in Tables D.4.3.12, D.4.3.13, D.4.3.14, and D.4.3.15, respectively. The total HI and cancer risk from combined tank farm, tank filling, and evaporator emissions are 2.75E-05 and 5.80E-11, respectively.

## D.4.4 IN SITU VITRIFICATION ALTERNATIVE

This section presents the anticipated remediation risk associated with the In Situ Vitrification alternative for tank waste as outlined in Volume Two, Appendix B.

The radiological and toxicological risk for this alternative was based on the air emissions and direct exposure from construction, continued operations (including tank farm and evaporator operations), treatment (including evaporator and in situ vitrification operations), and closure and monitoring. There would be no retrieval, pretreatment, storage, or waste transportation activities associated with this alternative; therefore, there would be no risk from these components.

### D.4.4.1 Radiological Risk

The LCF risk to the workers, noninvolved workers, and general public could result from direct exposure and atmospheric emissions from the components associated with this alternative. The risk was determined by analyzing the radiological source term, the transport mechanism, exposure, and the risk associated with the exposure as discussed in the following subsections.

#### D.4.4.1.1 Source Term

Source terms used for the noninvolved worker and general public are the atmospheric radiological emissions presented in Table D.4.4.1 (WHC 1995f and Jacobs 1996). The workers would receive a combined dose from the air emissions and from direct exposure from radiation fields in the work place.

#### D.4.4.1.2 Transport

The atmospheric transport parameters of the In Situ Vitrification alternative are presented in Table D.4.4.2. The tank farm atmospheric radiological operating emissions were modeled as a ground release, and the evaporators and in situ vitrification were modeled as an elevated release. For modeling purposes, it was assumed that the source term would be released at a point in the 200 Areas represented by the meteorological conditions at the Hanford Meteorological Station. The analysis used the Hanford Meteorological Station joint frequency data from Figure D.2.2.1 and Table D.2.2.1.

For ground releases, dispersion in the atmosphere would cause contaminant air concentrations and exposures to decrease with increasing distance from the source. Maximum individual exposures therefore would occur at the inner boundaries (i.e., closest distance to the source) of the defined receptor occupancy zones. For the noninvolved worker, the maximum exposure would occur 100 m (330 ft) from the source (in an east-southeast direction). For the general public, the maximum

Table D.4.4.1 Atmospheric Radiological Emissions for the In Situ Vitrification Alternative

| Continued Operations | | | | Treatment Operations | | | |
|---|---|---|---|---|---|---|---|
| Tank Farm Emissions | | Evaporator Emissions | | DST Evaporator Emissions | | In Situ Vitrification Emissions | |
| Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released |
| Total Alpha [1] | 2.88E-08 | Total Alpha [1] | 2.10E-05 | Total Alpha [1] | 1.41E-04 | Am-241 | 2.00E-07 |
| Total Beta [2] | 7.91E-07 | Total Beta [2] | 1.20E-05 | Total Beta [2] | 8.04E-05 | C-14 | 1.06E+03 |
| Sr-90 | 1.81E-05 | | | | | Cs-137 | 7.00E-05 |
| Cs-137 | 5.38E-05 | | | | | I-129 | 7.60E+00 |
| I-129 | 4.60E-05 | | | | | Pu-239 | 6.60E-08 |
| | | | | | | Ru-106 | 7.6E-14 |
| | | | | | | Sm-151 | 1.26E-06 |
| | | | | | | Sr-90 | 1.40E-04 |
| | | | | | | Tc-99 | 6.40E-08 |
| | | | | | | Zr-93 | 7.80E-09 |

Notes:
[1] Total alpha is assumed to be Pu-239.
[2] Total beta is assumed to be Sr-90.

Table D.4.4.2 Atmospheric Transport Parameters for the In Situ Vitrification Alternative

| | Continued Operations | | Treatment Operations | |
|---|---|---|---|---|
| | Tank Farms | Evaporator 1 | Evaporator 2 | In Situ Vitrification |
| Stack height in m (ft) | Ground | 6.70 (22) | 6.70 (22) | 30.5 (100) |
| Stack radius in m (ft) | N/A | 0.53 (1.7) | 0.53 (1.7) | 0.33 (108) |
| Stack flow rate in $m^3$/sec($ft^3$/sec) | N/A | 10 (353) | 10 (353) | 4.3 (151) |
| Stack temperature in °C (°F) | N/A | 46 (117) | 46 (117) | 93 (199) |
| Noninvolved worker MEI location in m (ft) ESE | 100 (328) | 200 (656) | 200 (656) | 300 (984) |
| Public MEI location in km (mi) ESE | 22 (14) | 22 (14) | 22 (14) | 22 (14) |
| Chi/Q for noninvolved worker - population in $s/m^3$ | 1.60E-03 | 4.00E-04 | 4.00E-04 | 2.00E-04 |
| Chi/Q for noninvolved worker - MEI in $s/m^3$ | 4.00E-04 | 2.50E-06 | 2.50E-06 | 2.30E-07 |
| Chi/Q for general public - population in $s/m^3$ | 2.90E-03 | 1.60E-03 | 1.60E-03 | 1.10E-03 |
| Chi/Q for general public - MEI in $s/m^3$ | 6.60E-08 | 3.90E-08 | 3.90E-08 | 2.40E-08 |

Notes:
ESE = East-southeast

exposure would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the center of the 200 East Area).

The calculated Chi/Q values for ground releases from the tank farms were calculated by the GENII computer code to be 4.0E-04 sec/$m^3$ for the noninvolved worker MEI and 6.6E-08 sec/$m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 1.6E-03 sec/$m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 2.9E-03 sec/$m^3$.

For elevated releases (stack releases), the maximum exposure would not necessarily occur at the closest distance to the source. Air transport modeling indicates that the maximum exposure for the noninvolved worker would occur 200 m (660 ft) from the source (in an east-southeast direction) for the evaporators and 300 m (980 ft) for vitrification. The maximum exposure for a member of the general public would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the 200 East Area).

The calculated Chi/Q values for the evaporator operation were 2.50E-06 sec/$m^3$ for the noninvolved worker MEI and 3.90E-08 sec/$m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 4.0E-04 sec/$m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 1.6E-03 sec/$m^3$. For the vitrification operation, the Chi/Q values were 2.30E-07 sec/$m^3$ for the noninvolved worker MEI, 2.4E-08 sec/$m^3$ for the general public MEI, 2.00E-04 sec/$m^3$ for the noninvolved worker population, and 1.10E-03 sec/$m^3$ for the general public population.

D.4.4.1.3 Exposure

The radiological exposure for the alternative is presented in Table D.4.4.3. The table shows the exposure each receptor would receive from every component. The sum of the components are shown in the last column for each population and MEI receptor except for the MEI worker. The MEI worker is not summed, but is represented by the component with the highest MEI dose.

The worker population dose is dependent on the number of people in the population and the anticipated dose each individual would receive. These data were obtained from the Site maintenance and operations contractor and the TWRS EIS contractor (WHC 1995f and Jacobs 1996). The calculations for the worker exposures from construction, continued operations, treatment, and closure are as follows:

Construction = (5.73E+03 person-yr) · (1.4E-02 rem/person-yr) = 8.02E+01 person-rem

**Table D.4.4.3 Summary of Anticipated Radiological Exposure for the In Situ Vitrification Alternative**

| Radiological Dose (person-rem) [5] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Receptor | Construction (17 yrs) | Continued Operations[1] (16 yrs) | Retrieval | Treatment [2] (5 yrs) | Storage and Disposal | Monitoring and Maintenance (17 yrs) | Post Closure Monitoring (100 yrs) | Total |
| Worker - Population | 8.00E+01 | 2.77E+02 | N/A | 1.19E+03 | N/A | N/A | 9.55E+00 | 1.57E+03 |
| Worker - MEI [3,4] | 9.00E+00 | 9.50E+00 | N/A | 4.50E+00 | N/A | N/A | 1.50E+01 | 1.50E+01 |
| Noninvolved Worker - Population | 0.00E+00 | 1.45E-03 | N/A | 1.35E+00 | N/A | N/A | 0.00E+00 | 1.35E+00 |
| Noninvolved Worker - MEI | 0.00E+00 | 7.61E-05 | N/A | 1.71E-04 | N/A | N/A | 0.00E+00 | 1.71E-04 |
| General Public - Population | 0.00E+00 | 6.90E-02 | N/A | 6.58E+02 | N/A | N/A | 0.00E+00 | 6.58E+02 |
| General Public - MEI | 0.00E+00 | 1.85E-06 | N/A | 2.20E-03 | N/A | N/A | 0.00E+00 | 2.20E-03 |

Notes:
[1] Continued Operations include tank farm and Evaporator 1.
[2] Treatment includes in situ vitrification and Evaporator 2.
[3] Worker MEI is assumed to work for 30 years.
[4] Total for the worker - MEI represents the highest single exposure.
[5] MEI receptor dose is noted in rem.

Continued Operations -

Tank farms = (1.06E+04 person-yr) · (1.40E-02 rem/person-yr) = 1.48E+02 person-rem
Evaporator = (6.40E+02 person-yr) · (2.00E-01 rem/person-yr) = 1.28E+02 person-rem
Total = 2.76E+02 person-rem

Treatment Operations -

Evaporator = (7.30E+01 person-yr) · (2.00E-01 rem/person-yr) = 1.46E+01 person-rem
Vitrification = (5.89E+03 person-yr) · (2.00E-01 rem/person-yr) = 1.18E+03 person-rem
Total = 1.19E+03 person-rem

Closure -

Closure = (1.82E+02 person-yr) · (1.40E-02 rem/person-yr) = 2.55E+00 person-rem
Monitoring = (5.00E+02 person-yr) · (1.40E-02 rem/person-yr) = 7.00E+00 person-rem
Total = 9.55E+00 person-rem

The MEI worker was assumed to receive a dose of 500 mrem (5.00E-01 rem) per year for a maximum of 30 years.

The noninvolved worker and general public exposures from inhalation of the atmospheric emissions (source term) were converted to a radiological dose in rem using the GENII computer code and applying the appropriate Chi/Q.

#### D.4.4.1.4 Risk

The LCFs are calculated as the product of the estimated dose times the dose-to-risk conversion factor (Section D.2.2.4). The sum of the radiological dose from construction, continued operations, treatment, and closure for each receptor shown in the combined dose column in Table D.4.4.4 was multiplied by the appropriate dose-to-risk conversion factor to produce the LCF risk.

### D.4.4.2 Chemical Exposure

Potential carcinogenic risk and noncarcinogenic health hazards may result from exposure to volatile emissions from the tank farm, the evaporators, tank filling (sand filling) operations, and vitrification of the tank contents for the worker, noninvolved worker, and general public. Potential carcinogenic risk and noncarcinogenic health hazards were estimated using the chemical source term, transport mechanism, exposure, and toxicological criteria as discussed in the following subsections.

Table D.4.4.4 Summary of Anticipated Risk for the In Situ Vitrification Alternative

| Receptor | Combined Dose (person-rem) [1] | LCF/rem | LCF Risk |
|---|---|---|---|
| Worker - Population | 1.57E+03 | 4.0E-04 | 6.28E-01 |
| Worker - MEI | 1.50E+01 | 4.0E-04 | 6.00E-03 |
| Noninvolved Worker - Population | 1.35E+00 | 4.0E-04 | 5.40E-04 |
| Noninvolved Worker - MEI | 1.71E-04 | 4.0E-04 | 6.84E-08 |
| General Public - Population | 6.58E+02 | 5.0E-04 | 3.29E-01 |
| General Public - MEI | 2.20E-03 | 5.0E-04 | 1.10E-06 |

Notes:
[1] MEI receptor dose is noted in rem.
LCF = Latent cancer fatality

#### D.4.4.2.1 Source Term

Operating air emissions from the tank farm area, filling the tanks with sand, the evaporators, and vitrification of the tank contents are presented in Table D.4.4.5 (WHC 1995f and Jacobs 1996). The noninvolved worker and general public would be exposed to combined emissions from the tank farm area, the evaporators, filling the tanks with sand, and vitrification. The worker would be exposed only to emissions (ground-level release) from the tank farm area filling the tanks with sand because emissions from the evaporators and vitrification occur through a stack-release and would not impact the onsite worker.

D.4.4.2.2 Transport

The tank farm chemical operating emissions (routine emissions from the tank farm and emissions during filling the tanks with gravel) were modeled as a ground release. Chemical operating emissions from the evaporators and vitrification operations would occur from stacks and were modeled as elevated releases. Transport parameters, location of the MEI noninvolved worker and MEI general public, and Chi/Q values for the MEI noninvolved worker and general public are identical to the radiological parameters presented in Table D.4.4.2.

The MEI worker was evaluated using a "box" model, as presented in detail in Section D.2.2.3. The estimated Chi/Q value for the MEI worker was 9.26E-04 sec/$m^3$.

D.4.4.2.3 Exposure

**Worker**

The MEI worker was assumed to be located within a box placed directly over the tank farm area. Exposure point concentrations of chemical emissions (mg/$m^3$) from the tank farm area and filling the tanks with sand were estimated by multiplying the cumulative tank farm emission rate (mg/sec) and tank-filling emission rate (mg/sec) by the MEI worker Chi/Q value (9.26E-04 sec/$m^3$), respectively. Exposure point concentrations for each volatile chemical emitted from the tank farm area and during retrieval are summarized in Tables D.4.4.6 and D.4.4.7, respectively.

Chemical intake (dose) was estimated for the MEI worker using the same equation and exposure parameters defined in Section D.2.2.3. Estimated intakes of chemical emissions from the tank farm and tank filling operations for the MEI worker are presented in Tables D.4.4.6 and D.4.4.7, respectively.

**Noninvolved Worker**

The MEI noninvolved worker was assumed to be located at the point where maximum downwind air concentrations were calculated (100 m [330 ft] from the tank farm and 200 m [660 ft] from the evaporator). Exposure point concentrations (mg/$m^3$) of chemical emissions from the tank farm, filling the tanks with sand, the evaporators, and vitrification operations were estimated by multiplying the cumulative tank farm, tank-filling, evaporator, and vitrification emission rates (mg/sec) by their respective MEI noninvolved worker Chi/Q values (4.0E-04 sec/$m^3$ for the tank farm, 4.0E-04 sec/$m^3$ for tank-filling, 2.5E-06 sec/$m^3$ for the evaporators, and 2.30E-07 sec/$m^3$ for vitrification). Exposure point concentrations for each volatile chemical emitted from the tank farm area, tank-filling operations, evaporators, and vitrification are summarized in Tables D.4.4.8 and D.4.4.9, D.4.4.10, D.4.4.11, and D.4.4.12, respectively.

Chemical intake (dose) was estimated for the MEI noninvolved worker according to the same equation and exposure parameters used for the MEI worker. Estimated operating chemical emission intakes for the MEI noninvolved worker are presented in Tables D.4.4.8, D.4.4.9, D.4.4.10, D.4.4.11, and D.4.4.12 for the tank farm area, tank-filling, evaporator-1, evaporator-2, and vitrification emissions, respectively.

Table D.4.4.5 In Situ Vitrification Source Emissions

| Tank Farm Emissions | | Retrieval Emissions | | Evaporator-1 Emissions | | Evaporator-2 Emissions | | In Situ Vitrification Emissions | |
|---|---|---|---|---|---|---|---|---|---|
| Emissions | Total Tank Farm Emission Rate (mg/sec) | Emissions | Retrieval Emission Rate (DST) (mg/sec) | Emissions | Evaporator Emission Rate (mg/sec) | Emissions | DSTS Evaporator Emission Rate (mg/sec) | Emissions | In Situ Vitrification Emission Rate (mg/sec) |
| Carbon Monoxide | 1.05E+00 | Carbon Monoxide | 2.44E-02 | Acetone | 2.30E-01 | Acetone | 3.06E+00 | Ammonia | 3.55E+02 |
| Nitrogen Oxide | 1.06E-01 | Nitrogen Oxide | 2.45E-03 | Ammonia | 2.16E-01 | Ammonia | 2.89E+00 | Nitrogen Oxide | 2.28E+03 |
| 1,3-Butadiene | 7.49E-03 | 1,3-Butadiene | 1.74E-04 | n-Butyl Alcohol | 1.73E+00 | n-Butyl Alcohol | 2.30E+01 | | |
| 2-Hexanone | 1.37E-01 | 2-Hexanone | 3.17E-03 | 2-Hexanone | 8.28E-04 | 2-Hexanone | 1.09E-02 | | |
| 2-Pentanone | 2.16E-01 | 2-Pentanone | 5.01E-03 | Methyl Isobutyl Ketone | 1.57E-02 | Methyl Isobutyl Ketone | 2.09E-01 | | |
| Acetone | 2.61E+00 | Acetone | 6.05E-02 | | | | | | |
| Acetonitrile | 1.26E+00 | Acetonitrile | 2.91E-02 | | | | | | |
| Benzene | 5.97E-02 | Benzene | 1.38E-03 | | | | | | |
| Heptane | 1.53E-01 | Heptane | 3.56E-03 | | | | | | |
| Methyl N-amyl Ketone | 1.48E-01 | Methyl N-amyl Ketone | 3.43E-03 | | | | | | |
| N-hexane | 1.60E-01 | N-hexane | 3.72E-03 | | | | | | |
| Nonane | 8.32E-02 | Nonane | 1.93E-03 | | | | | | |
| Octane | 8.73E-02 | Octane | 2.02E-03 | | | | | | |
| Toluene | 1.22E-02 | Toluene | 2.84E-04 | | | | | | |
| Ammonia | 7.67E+00 | Ammonia | 1.78E-01 | | | | | | |
| Phosphoric Acid, Tributyl Ester | 1.89E-01 | Phosphoric Acid, Tributyl Ester | 4.39E-03 | | | | | | |
| Carbon Tetrachloride | 1.24E-07 | Carbon Tetrachloride | 2.88E-09 | | | | | | |
| Ethyl Butyl Ketone | 4.15E-07 | Ethyl Butyl Ketone | 9.64E-09 | | | | | | |
| Methyl Chloride | 1.83E-08 | Methyl Chloride | 4.25E-10 | | | | | | |
| Tetrahydro-furan | 3.20E-08 | Tetrahydro-furan | 7.43E-10 | | | | | | |

Table D.4.4.6 In Situ Vitrification Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 9.75E-04 | 1.91E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 9.80E-05 | 1.92E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 6.94E-06 | 1.36E-06 | 3.68E-07 | ND | 9.80E-01 | NE | 3.61E-07 |
| 2-Hexanone | 1.27E-04 | 2.48E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.00E-04 | 3.92E-05 | NC | ND | NC | NE | NC |
| Acetone | 2.41E-03 | 4.73E-04 | NC | 1.00E-01 | NC | 4.73E-03 | NC |
| Acetonitrile | 1.16E-03 | 2.28E-04 | NC | 1.40E-02 | NC | 1.63E-03 | NC |
| Benzene | 5.53E-05 | 1.08E-05 | 2.94E-06 | 1.70E-03 | 2.90E-02 | 6.37E-03 | 8.51E-08 |
| Heptane | 1.42E-04 | 2.78E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.37E-04 | 2.69E-05 | NC | 2.30E-02 | NC | 1.17E-03 | NC |
| N-hexane | 1.48E-04 | 2.91E-05 | NC | 5.70E-02 | NC | 5.10E-04 | NC |
| Nonane | 7.70E-05 | 1.51E-05 | NC | ND | NC | NE | NC |
| Octane | 8.08E-05 | 1.58E-05 | NC | ND | NC | NE | NC |
| Toluene | 1.13E-05 | 2.22E-06 | NC | 1.10E-01 | NC | 2.02E-05 | NC |
| Ammonia | 7.10E-03 | 1.39E-03 | NC | 2.90E-02 | NC | 4.80E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 1.75E-04 | 3.43E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.15E-10 | 2.25E-11 | 6.10E-12 | 5.70E-04 | 5.30E-02 | 3.95E-08 | 3.23E-13 |
| Ethyl Butyl Ketone | 3.85E-10 | 7.54E-11 | NC | 2.30E-02 | NC | 3.28E-09 | NC |
| Methyl Chloride | 1.70E-11 | 3.33E-12 | 9.01E-13 | ND | 6.30E-03 | NE | 5.68E-15 |
| Tetrahydrofuran | 2.97E-11 | 5.81E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 7.71E-02** | **Risk = 4.46E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.4.7 In Situ Vitrification Sand Fill Emissions

| Emissions | Air Concentrations of Tank filling Emissions for the MEI Worker ($mg/m^3$) | Noncarci-nogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg-day)^{-1}$ | Noncarci-nogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 2.26E-05 | 4.43E-06 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 2.27E-06 | 4.46E-07 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 1.61E-07 | 3.16E-08 | 4.06E-09 | ND | 9.80E-01 | NE | 3.98E-09 |
| 2-Hexanone | 2.94E-06 | 5.76E-07 | NC | ND | NC | NE | NC |
| 2-Pentanone | 4.64E-06 | 9.09E-07 | NC | ND | NC | NE | NC |
| Acetone | 5.60E-05 | 1.10E-05 | NC | 1.00E-01 | NC | 1.10E-04 | NC |
| Acetonitrile | 2.70E-05 | 5.29E-06 | NC | 1.40E-02 | NC | 3.78E-04 | NC |
| Benzene | 1.28E-06 | 2.51E-07 | 3.23E-08 | 1.70E-03 | 2.90E-02 | 1.48E-04 | 9.37E-10 |
| Heptane | 3.29E-06 | 6.45E-07 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 3.18E-06 | 6.23E-07 | NC | 2.30E-02 | NC | 2.71E-05 | NC |
| N-hexane | 3.44E-06 | 6.74E-07 | NC | 5.70E-02 | NC | 1.18E-05 | NC |
| Nonane | 1.79E-06 | 3.50E-07 | NC | ND | NC | NE | NC |
| Octane | 1.87E-06 | 3.67E-07 | NC | ND | NC | NE | NC |
| Toluene | 2.63E-07 | 5.15E-08 | NC | 1.10E-01 | NC | 4.68E-07 | NC |
| Ammonia | 1.65E-04 | 3.23E-05 | NC | 2.90E-02 | NC | 1.11E-03 | NC |
| Phosphoric Acid, Tributyl Ester | 4.07E-06 | 7.97E-07 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 2.66E-12 | 5.22E-13 | 6.71E-14 | 5.70E-04 | 5.30E-02 | 9.16E-10 | 3.56E-15 |
| Ethyl Butyl Ketone | 8.92E-12 | 1.75E-12 | NC | 2.30E-02 | NC | 7.60E-11 | NC |
| Methyl Chloride | 3.94E-13 | 7.72E-14 | 9.92E-15 | ND | 6.30E-03 | NE | 6.25E-17 |
| Tetrahydrofuran | 6.88E-13 | 1.35E-13 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 1.79E-03** | **Risk = 4.91E-09** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.4.8 In Situ Vitrification Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 4.21E-04 | 8.25E-05 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 4.23E-05 | 8.30E-06 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 3.00E-06 | 5.88E-07 | 1.59E-07 | ND | 9.80E-01 | NE | 1.56E-07 |
| 2-Hexanone | 5.47E-05 | 1.07E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 8.64E-05 | 1.69E-05 | NC | ND | NC | NE | NC |
| Acetone | 1.04E-03 | 2.04E-04 | NC | 1.00E-01 | NC | 2.04E-03 | NC |
| Acetonitrile | 5.02E-04 | 9.84E-05 | NC | 1.40E-02 | NC | 7.03E-03 | NC |
| Benzene | 2.39E-05 | 4.68E-06 | 1.27E-06 | 1.70E-03 | 2.90E-02 | 2.75E-03 | 3.68E-08 |
| Heptane | 6.13E-05 | 1.20E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 5.92E-05 | 1.16E-05 | NC | 2.30E-02 | NC | 5.05E-04 | NC |
| N-hexane | 6.41E-05 | 1.26E-05 | NC | 5.70E-02 | NC | 2.20E-04 | NC |
| Nonane | 3.33E-05 | 6.52E-06 | NC | ND | NC | NE | NC |
| Octane | 3.49E-05 | 6.84E-06 | NC | ND | NC | NE | NC |
| Toluene | 4.89E-06 | 9.58E-07 | NC | 1.10E-01 | NC | 8.71E-06 | NC |
| Ammonia | 3.07E-03 | 6.01E-04 | NC | 2.90E-02 | NC | 2.07E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 7.57E-05 | 1.48E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 4.96E-11 | 9.72E-12 | 2.63E-12 | 5.70E-04 | 5.30E-02 | 1.71E-08 | 1.40E-13 |
| Ethyl Butyl Ketone | 1.66E-10 | 3.26E-11 | NC | 2.30E-02 | NC | 1.42E-09 | NC |
| Methyl Chloride | 7.33E-12 | 1.44E-12 | 3.89E-13 | ND | 6.30E-03 | NE | 2.45E-15 |
| Tetrahydrofuran | 1.28E-11 | 2.51E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 3.33E-02** | **Risk = 1.93E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.4.9 In Situ Vitrification Sand Fill Emissions

| Emissions | Air Concentrations of Tank Filling Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarci-nogen Inhalation Intake for the Noninvolved MEI Worker (mg/kd-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kd-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg-day)^{-1}$ | Noncarci-nogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 9.77E-06 | 1.91E-06 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 9.82E-07 | 1.92E-07 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 6.95E-08 | 1.36E-08 | 1.75E-09 | ND | 9.80E-01 | NE | 1.72E-09 |
| 2-Hexanone | 1.27E-06 | 2.49E-07 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.00E-06 | 3.93E-07 | NC | ND | NC | NE | NC |
| Acetone | 2.42E-05 | 4.74E-06 | NC | 1.00E-01 | NC | 4.74E-05 | NC |
| Acetonitrile | 1.17E-05 | 2.28E-06 | NC | 1.40E-02 | NC | 1.63E-04 | NC |
| Benzene | 5.54E-07 | 1.09E-07 | 1.40E-08 | 1.70E-03 | 2.90E-02 | 6.39E-05 | 4.05E-10 |
| Heptane | 1.42E-06 | 2.79E-07 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.37E-06 | 2.69E-07 | NC | 2.30E-02 | NC | 1.17E-05 | NC |
| N-hexane | 1.49E-06 | 2.91E-07 | NC | 5.70E-02 | NC | 5.11E-06 | NC |
| Nonane | 7.72E-07 | 1.51E-07 | NC | ND | NC | NE | NC |
| Octane | 8.10E-07 | 1.59E-07 | NC | ND | NC | NE | NC |
| Toluene | 1.13E-07 | 2.22E-08 | NC | 1.10E-01 | NC | 2.02E-07 | NC |
| Ammonia | 7.12E-05 | 1.40E-05 | NC | 2.90E-02 | NC | 4.81E-04 | NC |
| Phosphoric Acid, Tributyl Ester | 1.76E-06 | 3.44E-07 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.15E-12 | 2.26E-13 | 2.90E-14 | 5.70E-04 | 5.30E-02 | 3.96E-10 | 1.54E-15 |
| Ethyl Butyl Ketone | 3.85E-12 | 7.56E-13 | NC | 2.30E-02 | NC | 3.29E-11 | NC |
| Methyl Chloride | 1.70E-13 | 3.33E-14 | 4.29E-15 | ND | 6.30E-03 | NE | 2.70E-17 |
| Tetrahydrofuran | 2.97E-13 | 5.83E-14 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 7.73E-04** | **Risk = 2.12E-09** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.4.10 In Situ Vitrification Evaporator-1 Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RFD_I$) (mg/kg-day) | Inhalation Slope Factor ($SF_I$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Acetone | 5.75E-07 | 1.13E-07 | NC | 1.00E-01 | NC | 1.13E-06 | NC |
| Ammonia | 5.40E-07 | 1.06E-07 | NC | 2.90E-02 | NC | 3.65E-06 | NC |
| n-Butyl Alcohol | 4.33E-06 | 8.48E-07 | NC | 1.00E-01 | NC | 8.48E-06 | NC |
| 2-Hexanone | 2.07E-09 | 4.06E-10 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 3.93E-08 | 7.69E-09 | NC | 2.30E-02 | NC | 3.34E-07 | NC |
| | | | | | | HI = 1.36E-05 | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.4.11 In Situ Vitrification Evaporator-2 Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RFD_I$) (mg/kg-day) | Inhalation Slope Factor ($SF_I$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Acetone | 7.65E-06 | 1.50E-06 | NC | 1.00E-01 | NC | 1.50E-05 | NC |
| Ammonia | 7.23E-06 | 1.42E-06 | NC | 2.90E-02 | NC | 4.88E-05 | NC |
| n-Butyl Alcohol | 5.75E-05 | 1.13E-05 | NC | 1.00E-01 | NC | 1.13E-04 | NC |
| 2-Hexanone | 2.73E-08 | 5.34E-09 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 5.23E-07 | 1.02E-07 | NC | 2.30E-02 | NC | 4.45E-06 | NC |
| | | | | | | HI = 1.81E-04 | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.4.12 In Situ Vitrification Emissions

| Emissions | Air Concentrations of Vitrification Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarci-nogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarci-nogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Ammonia | 8.17E-05 | 1.60E-05 | NC | 2.90E-02 | NC | 5.52E-04 | NC |
| Nitrogen Oxide | 5.24E-04 | 1.03E-04 | NC | ND | NC | NE | NC |
| | | | | | | HI = 5.52E-04 | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

### General Public

The MEI general public receptor was assumed to be located at the point where maximum air concentrations were calculated (approximately 22 km [14 mi] from both the tank farm area and evaporator). Exposure point concentrations ($mg/m^3$) of chemical emissions from the tank farm area, tank-filling operations, evaporator-1, evaporator-2, and vitrification were estimated by multiplying the cumulative emission rates (mg/sec) of each source by their respective MEI general public Chi/Q values (6.60E-08 $sec/m^3$ for the tank farm, 6.60E-08 $sec/m^3$ for tank-filling operations, 3.90E-08 $sec/m^3$ for the evaporators, and 2.40E-08 $sec/m^3$ for vitrification). Exposure point concentrations for each volatile chemical emitted from the tank farm area, tank-filling operations, evaporator-1, evaporator-2, and vitrification are summarized in Tables D.4.4.13, D.4.4.14, D.4.4.15, D.4.4.16, and D.4.4.17, respectively.

The residential or general public intake was calculated according to the equation and exposure parameters presented in Section D.2.2.3. Estimated chemical emission intakes for the MEI general public are presented in Tables D.4.4.13, D.4.4.14, D.4.4.15, D.4.4.16, and D.4.4.17 for the tank farm area, tank-filling operations, evaporator-1, evaporator-2, and vitrification, respectively.

#### D.4.4.2.4 Toxicity Assessment

Toxicity assessment was previously discussed in detail in Section D.4.1.2.4. Cancer slope factors, RfDs, and data sources for each volatile operating chemical emission are summarized in Table D.4.1.11.

Table D.4.4.13 In Situ Vitrification Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 6.95E-08 | 4.34E-08 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 6.98E-09 | 4.36E-09 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 4.95E-10 | 3.09E-10 | 4.75E-11 | ND | 9.80E-01 | NE | 4.65E-11 |
| 2-Hexanone | 9.03E-09 | 5.64E-09 | NC | ND | NC | NE | NC |
| 2-Pentanone | 1.43E-08 | 8.91E-09 | NC | ND | NC | NE | NC |
| Acetone | 1.72E-07 | 1.08E-07 | NC | 1.00E-01 | NC | 1.08E-06 | NC |
| Acetonitrile | 8.29E-08 | 5.18E-08 | NC | 1.40E-02 | NC | 3.70E-06 | NC |
| Benzene | 3.94E-09 | 2.46E-09 | 3.78E-10 | 1.70E-03 | 2.90E-02 | 1.45E-06 | 1.10E-11 |
| Heptane | 1.01E-08 | 6.32E-09 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 9.77E-09 | 6.11E-09 | NC | 2.30E-02 | NC | 2.65E-07 | NC |
| N-hexane | 1.06E-08 | 6.61E-09 | NC | 5.70E-02 | NC | 1.16E-07 | NC |
| Nonane | 5.49E-09 | 3.43E-09 | NC | ND | NC | NE | NC |
| Octane | 5.76E-09 | 3.60E-09 | NC | ND | NC | NE | NC |
| Toluene | 8.07E-10 | 5.04E-10 | NC | 1.10E-01 | NC | 4.58E-09 | NC |
| Ammonia | 5.06E-07 | 3.16E-07 | NC | 2.90E-02 | NC | 1.09E-05 | NC |
| Phosphoric Acid, Tributyl Ester | 1.25E-08 | 7.81E-09 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 8.18E-15 | 5.11E-15 | 7.86E-15 | 5.70E-04 | 5.30E-02 | 8.97E-12 | 4.16E-17 |
| Ethyl Butyl Ketone | 2.74E-14 | 1.71E-14 | NC | 2.30E-02 | NC | 7.45E-13 | NC |
| Methyl Chloride | 1.21E-15 | 7.56E-16 | 1.16E-16 | ND | 6.30E-03 | NE | 7.32E-19 |
| Tetrahydrofuran | 2.11E-15 | 1.32E-15 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 1.75E-05** | **Risk = 5.75E-11** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.4.14 In Situ Vitrification Sand Fill Emissions

| Emissions | Air Concentrations of Tank Filling Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 1.47E-09 | 9.16E-10 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 1.47E-10 | 9.21E-11 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 1.04E-11 | 6.52E-12 | 4.74E-13 | ND | 9.80E-01 | NE | 4.65E-13 |
| 2-Hexanone | 1.90E-10 | 1.19E-10 | NC | ND | NC | NE | NC |
| 2-Pentanone | 3.01E-10 | 1.88E-10 | NC | ND | NC | NE | NC |
| Acetone | 3.36E-09 | 2.27E-09 | NC | 1.00E-01 | NC | 2.27E-08 | NC |
| Acetonitrile | 1.75E-09 | 1.09E-09 | NC | 1.40E-02 | NC | 7.80E-08 | NC |
| Benzene | 8.31E-11 | 5.19E-11 | 3.78E-12 | 1.70E-03 | 2.90E-02 | 3.05E-08 | 1.10E-13 |
| Heptane | 2.13E-10 | 1.33E-10 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 2.06E-10 | 1.29E-10 | NC | 2.30E-02 | NC | 5.60E-09 | NC |
| N-hexane | 2.23E-10 | 1.39E-10 | NC | 5.70E-02 | NC | 2.44E-09 | NC |
| Nonane | 1.16E-10 | 7.24E-11 | NC | ND | NC | NE | NC |
| Octane | 1.21E-10 | 7.59E-11 | NC | ND | NC | NE | NC |
| Toluene | 1.70E-11 | 1.06E-11 | NC | 1.10E-01 | NC | 9.67E-11 | NC |
| Ammonia | 1.07E-08 | 6.67E-09 | NC | 2.90E-02 | NC | 2.30E-07 | NC |
| Phosphoric Acid, Tributyl Ester | 2.63E-10 | 1.65E-10 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.73E-16 | 1.08E-16 | 7.85E-18 | 5.70E-04 | 5.30E-02 | 1.89E-13 | 4.16E-19 |
| Ethyl Butyl Ketone | 5.78E-16 | 3.61E-16 | NC | 2.30E-02 | NC | 1.57E-14 | NC |
| Methyl Chloride | 2.55E-17 | 1.59E-17 | 1.16E-18 | ND | 6.30E-03 | NE | 7.31E-21 |
| Tetrahydrofuran | 4.46E-17 | 2.79E-17 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 3.70E-07** | **Risk = 5.74E-13** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.4.15 In Situ Vitrification Evaporator-1 Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Acetone | 8.97E-09 | 5.61E-09 | NC | 1.00E-01 | NC | 5.61E-08 | NC |
| Ammonia | 8.42E-09 | 5.27E-09 | NC | 2.90E-02 | NC | 1.82E-07 | NC |
| n-Butyl Alcohol | 6.75E-08 | 4.22E-08 | NC | 1.00E-01 | NC | 4.22E-07 | NC |
| 2-Hexanone | 3.23E-11 | 2.02E-11 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 6.12E-10 | 3.83E-10 | NC | 2.30E-02 | NC | 1.66E-08 | NC |
| | | | | | | **HI = 6.76E-07** | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.4.16 In Situ Vitrification Evaporator-2 Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Acetone | 1.19E-07 | 7.46E-08 | NC | 1.00E-01 | NC | 7.46E-07 | NC |
| Ammonia | 1.13E-07 | 7.04E-08 | NC | 2.90E-02 | NC | 2.43E-06 | NC |
| n-Butyl Alcohol | 8.97E-07 | 5.61E-07 | NC | 1.00E-01 | NC | 5.61E-06 | NC |
| 2-Hexanone | 4.25E-10 | 2.66E-10 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 8.15E-09 | 5.09E-09 | NC | 2.30E-02 | NC | 2.21E-07 | NC |
| | | | | | | **HI = 9.00E-06** | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.4.17 In Situ Vitrification Emissions

| Emissions | Air Concentrations of Vitrification Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Ammonia | 8.17E-06 | 5.11E-06 | NC | 2.90E-02 | NC | 1.76E-04 | NC |
| Nitrogen Oxide | 5.24E-04 | 3.28E-05 | NC | ND | NC | NE | NC |
| | | | | | | HI = 1.76E-04 | |

Notes:
MEI = Maximally-exposed individual
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

D.4.4.2.5 Risk Characterization

**MEI Worker**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm and tank filling operations are summarized in Tables D.4.4.6 and D.4.4.7, respectively. The total HI and cancer risk from routine tank farm emissions and tank filling emissions are 7.89E-02 and 4.51E-07, respectively.

**MEI Noninvolved Worker**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm, tank filling operations, evaporator-1, evaporator-2, and vitrification are summarized in Tables D.4.4.8, D.4.4.9, D.4.4.10, D.4.4.11, and D.4.4.12, respectively. The total HI and cancer risk from combined tank farm, tank filling, evaporator, and vitrification emissions are 3.48E-02 and 1.95E-07, respectively.

**MEI General Public**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm, tank filling operations, evaporator-1, evaporator-2, and vitrification are summarized in Tables D.4.4.13, D.4.4.14, D.4.4.15, D.4.4.16, and D.4.4.17, respectively. The total HI and cancer risk from combined tank farm, tank filling, evaporator, and vitrification emissions are 2.04E-04 and 5.81E-11, respectively.

## D.4.5 EX SITU INTERMEDIATE SEPARATIONS ALTERNATIVE

This section presents the anticipated remediation risk associated with the Ex Situ Intermediate Separations alternative for tank waste, as outlined in Volume Two, Appendix B.

The radiological and toxicological risk for this alternative was based on the air emissions and direct exposure from construction, continued operations (including tank farm and evaporator operations), retrieval, separations and treatment, storage and disposal, onsite transportation of waste, monitoring and maintenance, and closure and monitoring.

### D.4.5.1 Radiological Risk

The LCF risk to the worker, noninvolved worker, and the general public could result from direct exposure and atmospheric emissions from the components associated with this alternative. The risk was determined by analyzing the radiological source term, the transport mechanism, exposure, and the risk associated with the exposure as discussed in the following subsections.

#### D.4.5.1.1 Source Term

The source term used for the noninvolved worker and general public was the atmospheric radiological emissions presented in Table D.4.5.1 (WHC 1995j and Jacobs 1996). They also would receive a direct exposure dose from the vitrified HLW as it is being transported onsite. The workers would receive a combined dose from the air emissions and from direct exposure from radiation fields in the work place.

Table D.4.5.1 Atmospheric Radiological Emissions for the Ex Situ Intermediate Separations Alternative

| Continued Operations | | | | Retrieval Emissions | | Separation and Vitrification Emissions | |
|---|---|---|---|---|---|---|---|
| Tank Farm Emissions | | Evaporator Emissions 1 | | | | | |
| Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released |
| Total Alpha [1] | 2.88E-08 | Total Alpha [1] | 2.10E-05 | Sr-90 | 5.48E-04 | Am-241 | 2.94E-03 |
| Total Beta [2] | 7.91E-07 | Total Beta [2] | 1.20E-05 | Cs-137 | 2.19E-03 | C-14 | 2.97E+02 |
| Sr-90 | 1.81E-05 | | | I-129 | 4.38E-03 | Cs-137 | 1.39E+00 |
| Cs-137 | 5.38E-05 | | | | | I-129 | 2.11E+00 |
| I-129 | 4.60E-05 | | | | | Pu-239 | 9.5E-04 |
| | | | | | | Ru-106 | 1.06E-09 |
| | | | | | | Sm-151 | 1.78E-02 |
| | | | | | | Sr-90 | 1.5E+00 |
| | | | | | | Tc-99 | 8.90E-04 |
| | | | | | | Zr-93 | 1.00E-02 |

Notes:
[1] Total alpha is assumed to be Pu-239.
[2] Total beta is assumed to be Sr-90.

#### D.4.5.1.2 Transport

The atmospheric transport parameters of the Ex Situ Intermediate Separations alternative are presented in Table D.4.5.2. The tank farm and retrieval atmospheric radiological operating emissions were modeled as a ground release, and the evaporator and the separations and vitrification were modeled as

an elevated release. For modeling purposes, it was assumed that the source term would be released at a point in the 200 Areas represented by the meteorological conditions at the Hanford Meteorological Station. The analysis used the Hanford Meteorological Station joint frequency data from Table D.2.2.1 and Figure D.2.2.1.

Table D.4.5.2 Atmospheric Transport Parameters for the Ex Situ Intermediate Separations Alternative

| Transport Parameters | Continued Operations | | Retrieval | Separations and Treatment (vitrification) |
|---|---|---|---|---|
| | Tank Farms | Evaporator 1 | | |
| Stack height in m (ft) | Ground | 6.70 (22) | Ground | 55 (180) |
| Stack radius in m (ft) | N/A | 0.53 (1.7) | N/A | 0.88 (2.9) |
| Stack flow rate in $m^3$/sec ($ft^3$/sec) | N/A | 10 (353) | N/A | 33 (1,165) |
| Stack temperature in °C (°F) | N/A | 46 (117) | N/A | 160 (320) |
| Noninvolved worker MEI location in m (ft) ESE | 100 (328) | 200 (656) | 100 (328) | 800 (2,625) |
| Public MEI location in km (mi) ESE | 22 (14) | 22 (14) | 22 (14) | 22 (14) |
| Chi/Q for noninvolved worker - population in s/$m^3$ | 1.60E-03 | 4.00E-04 | 1.60E-03 | 5.00E-05 |
| Chi/Q for noninvolved worker - MEI in s/$m^3$ | 4.00E-04 | 2.50E-06 | 4.00E-04 | 2.90E-08 |
| Chi/Q for general public - population in s/$m^3$ | 2.90E-03 | 1.60E-03 | 2.90E-03 | 5.00E-04 |
| Chi/Q for general public - MEI in s/$m^3$ | 6.60E-08 | 3.90E-08 | 6.60E-08 | 7.70E-09 |

Notes:
ESE = East-southeast

For ground releases, dispersion in the atmosphere would cause contaminant air concentrations and exposures to decrease with increasing distance from the source. Maximum individual exposures therefore would occur at the inner boundaries (i.e., closest distance to the source) of the defined receptor occupancy zones. For the noninvolved worker, the maximum exposure would occur 100 m (330 ft) from the source (in an east-southeast direction). For the general public, the maximum exposure would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the center of the 200 East Area).

The calculated Chi/Q values for ground releases from the tank farms were calculated by the GENII computer code to be 4.0E-04 sec/$m^3$ for the noninvolved worker MEI and 6.6E-08 sec/$m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 1.6E-03 sec/$m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 2.9E-03 sec/$m^3$.

For elevated releases (stack releases), the maximum exposure would not necessarily occur at the closest distance to the source. Air transport modeling indicates that the maximum exposure for the noninvolved worker would occur 200 m (660 ft) from the source (in an east-southeast direction) for the evaporator and 800 m (2,600 ft) for separations and vitrification. The maximum exposure for a member of the general public would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the 200 East Area).

The calculated Chi/Q values for the evaporator operation were 2.50E-06 sec/$m^3$ for the noninvolved worker MEI and 3.90E-08 sec/$m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 4.0E-04 sec/$m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 1.6E-03 sec/$m^3$. For the separations and vitrification operation, the Chi/Q values were 2.9E-08 sec/$m^3$ for the noninvolved worker MEI, 7.70E-09 sec/$m^3$ for the general public MEI, 5.00E-05 sec/$m^3$ for the noninvolved worker population, and 5.00E-04 sec/$m^3$ for the general public population.

D.4.5.1.3 Exposure

The radiological exposure for the alternative is presented in Table D.4.5.3. The table shows the exposure each receptor would receive from every component. The sum of the components is shown in the last column for each population and MEI receptor except for the MEI worker. The MEI worker is not summed but is represented by the component with the highest MEI dose.

The worker population dose is dependent on the number of people in the population and the anticipated dose each individual would receive. The data were obtained from the Site maintenance and operations contractor and the TWRS EIS contractor (WHC 1995j and Jacobs 1996). The calculations for the worker exposures from construction, continued operations, retrieval, separations and treatment, monitoring and maintenance, and closure are as follows:

Construction = (8.02E+02 person-yr) · (1.4E-02 rem/person-yr) = 1.12E+01 person-rem

Continued Operations -
Tank farms = (1.90E+04 person-yr) · (1.40E-02 rem/person-yr) = 2.66E+02 person-rem
Evaporator = (6.40E+02 person-yr) · (2.00E-01 rem/person-yr) = 1.28E+02 person-rem
Total = 3.94E+02 person-rem

Retrieval = (2.21E+04 person-yr) · (2.00E-01 rem/person-yr) = 4.42E+03 person-rem

Separation/Treatment = (1.49E+04 person-yr) · (2.0E-01 rem/person-yr) = 2.98E+03 person-rem

Table D.4.5.3 Summary of Anticipated Radiological Exposure for the Ex Situ Intermediate Separations Alternative

| Radiological Dose (person-rem) [2] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Receptor | Construction (19 yrs) | Continued Operations [1] (25 yrs) | Retrieval (21 yrs) | Separations and Treatment (18 yrs) | Transportation (18 yrs) | Monitoring and Maintenance (50 yrs) | Post Closure Monitoring (100 yrs) | Total |
| Worker - Population | 1.12E+01 | 3.94E+02 | 4.42E+03 | 2.98E+03 | N/A | 8.40E-01 | 1.34E+01 | 7.82E+03 |
| Worker - MEI [3,4] | 9.50E+00 | 1.45E+01 | 1.30E+01 | 1.20E+01 | N/A | 1.45E+01 | 1.50E+01 | 1.50E+01 |
| Noninvolved Worker - Population | 0.00E+00 | 1.58E-03 | 9.10E-03 | 9.10E-01 | 1.06E+00 | 0.00E+00 | 0.00E+00 | 1.98E+00 |
| Noninvolved Worker - MEI | 0.00E+00 | 7.93E-05 | 2.40E-03 | 5.30E-04 | N/A | 0.00E+00 | 0.00E+00 | 2.46E-03 |
| General Public - Population | 0.00E+00 | 8.00E-02 | 2.30E+00 | 3.10E+02 | 2.96E-01 | 0.00E+00 | 0.00E+00 | 3.12E+02 |
| General Public - MEI | 0.00E+00 | 2.19E-06 | 7.50E-05 | 6.70E-03 | N/A | 0.00E+00 | 0.00E+00 | 6.70E-03 |

Notes:
[1] Continued operations include tank farm and Evaporator 1.
[2] MEI receptor dose is noted in rem.
[3] Worker MEI is assumed to work for 30 years.
[4] Total for the MEI represents the highest single exposure.

Monitoring/Maintenance = (6.00E+01 person-yr) · (1.4E-02 rem/person-yr) = 8.40E-01 person-rem

Closure -
Closure = (2.77E+02 person-yr) · (1.40E-02 rem/person-yr) = 3.88E+00 person-rem
Monitoring = (6.77E+02 person-yr) · (1.40E-02 rem/person-yr) = 9.48E+00 person-rem
Total = 1.34E+01 person-rem

The MEI worker was assumed to receive a dose of 500 mrem (5.00E-01 rem) per year for a maximum of 30 years.

The noninvolved workers and general public exposures from inhalation of the atmospheric emissions (source term) were converted to a radiological dose in rem using the GENII computer code and applying the appropriate Chi/Q.

D.4.5.1.4 Risk

The LCFs are calculated as the product of the estimated dose times the dose-to-risk conversion factor (Section D.2.2.4). The sum of the radiological dose from construction, continued operations, retrieval,

treatment, storage and disposal, monitoring and maintenance, and closure for each receptor shown in the combined dose column in Table D.4.5.4 was multiplied by the appropriate dose-to-risk conversion factor to produce the LCF risk.

### D.4.5.2 Chemical Exposure

Potential carcinogenic risk and noncarcinogenic health hazards may result from exposure to volatile emissions from the tank farm, tank waste retrieval, the evaporator, and exposure to particulate emissions from the separation and vitrification of HLW and low-activity waste (LAW) for the worker, noninvolved worker, and the general public. Potential carcinogenic risk and noncarcinogenic health hazards were estimated using the chemical source term, transport mechanism, exposure, and toxicological criteria as discussed in the following subsections.

#### D.4.5.2.1 Source Term

Operating air emissions from the tank farm area, tank waste retrieval, the evaporator, and vitrification facilities are presented in Table D.4.5.5 (WHC 1995j and Jacobs 1996). The emission rates from the HLW and LAW vitrification facilities were combined and treated as a single-source emission. The noninvolved worker and general public would be exposed to combined emissions from the tank farm area, tank waste retrieval operations, evaporator, and vitrification facilities. The worker would be exposed only to emissions (ground-level release) from the tank farm area and retrieval operations because emissions from the evaporator and vitrification facilities occur through a stack-release and would not impact the onsite worker.

**Table D.4.5.4 Summary of Anticipated Risk for the Ex Situ Intermediate Separations Alternative**

| Receptor | Combined Dose (person-rem) [1] | LCF/rem | LCF Risk |
|---|---|---|---|
| Worker - Population | 7.82E+03 | 4.00E-04 | 3.13E+00 |
| Worker - MEI | 1.50E+01 | 4.00E-04 | 6.00E-03 |
| Noninvolved Worker - Population | 1.98E+00 | 4.00E-04 | 7.92E-04 |
| Noninvolved Worker - MEI | 2.46E-03 | 4.00E-04 | 9.84E-07 |
| General Public - Population | 3.12E+02 | 5.00E-04 | 1.56E-01 |
| General Public - MEI | 6.70E-03 | 5.00E-04 | 3.35E-06 |

Notes:
[1] MEI receptor dose is noted in rem.

Table D.4.5.5 Chemical Emissions for the Ex Situ Intermediate Separations

| Tank Farm Emissions | | Retrieval Emissions | | Evaporator Emissions | | Separations/Vitrification Emissions | |
|---|---|---|---|---|---|---|---|
| Emissions | Total Tank Farm Emission Rate (mg/sec) | Emissions | Retrieval Emission Rate (mg/sec) | Emissions | Evaporator Emission Rate (mg/sec) | Emissions | Plant Emission Rate (mg/sec) |
| Carbon Monoxide | 1.05E+00 | Carbon Monoxide | 3.16E+00 | Acetone | 2.30E-01 | Aluminum | 1.54E-02 |
| Nitrogen Oxide | 1.06E-01 | Nitrogen Oxide | 3.17E-01 | Ammonia | 2.16E-01 | Arsenic | 1.67E-06 |
| 1,3-Butadiene | 7.49E-03 | 1,3-Butadiene | 2.25E-02 | n-Butyl Alcohol | 1.73E+00 | Boron | 6.35E-04 |
| 2-Hexanone | 1.37E-01 | 2-Hexanone | 4.10E-01 | 2-Hexanone | 8.28E-04 | Barium | 4.73E-06 |
| 2-Pentanone | 2.16E-01 | 2-Pentanone | 6.48E-01 | Methyl Isobutyl Ketone | 1.57E-02 | Beryllium | 1.24E-07 |
| Acetone | 2.61E+00 | Acetone | 7.82E+00 | | | Bismuth | 3.04E-04 |
| Acetonitrile | 1.26E+00 | Acetonitrile | 3.77E+00 | | | Cadmium | 1.22E-05 |
| Benzene | 5.97E-02 | Benzene | 1.79E-01 | | | Cerium | 2.77E-04 |
| Heptane | 1.53E-01 | Heptane | 4.60E-01 | | | Chromium (+3) | 2.48E-04 |
| Methyl N-amyl Ketone | 1.48E-01 | Methyl N-amyl Ketone | 4.44E-01 | | | Copper | 1.11E-06 |
| N-hexane | 1.60E-01 | N-hexane | 4.80E-01 | | | Manganese | 1.72E-04 |
| Nonane | 8.32E-02 | Nonane | 2.50E-01 | | | Molybdenumm | 7.81E-06 |
| Octane | 8.73E-02 | Octane | 2.62E-01 | | | Nickel | 2.07E-04 |
| Toluene | 1.22E-02 | Toluene | 3.67E-02 | | | Lead | 6.56E-06 |
| Ammonia | 7.67E+00 | Ammonia | 2.30E+01 | | | Silver | 1.03E-06 |
| Phosphoric Acid, Tributyl Ester | 1.89E-01 | Phosphoric Acid, Tributyl Ester | 5.68E-01 | | | Uranium | 1.72E-03 |
| Carbon Tetrachloride | 1.24E-07 | Carbon Tetrachloride | 3.72E-07 | | | Vanadium | 3.06E-07 |
| Ethyl Butyl Ketone | 4.15E-07 | Ethyl Butyl Ketone | 1.25E-06 | | | Zinc | 6.15E-06 |
| Methyl Chloride | 1.83E-08 | Methyl Chloride | 5.50E-08 | | | | |
| Tetrahydrofuran | 3.20E-08 | Tetrahydrofuran | 9.61E-08 | | | | |

D.4.5.2.2 Transport

The tank farm chemical operating emissions (routine emissions from the tank farm and emissions during retrieval) were modeled as a ground release. Chemical operating emissions from the evaporator and vitrification facilities would occur from stack releases and were modeled as elevated releases. Transport parameters, location of the MEI noninvolved worker and MEI general public, and Chi/Q values for the MEI noninvolved worker and general public are identical to the radiological parameters presented in Table D.4.5.2.

The MEI worker (onsite worker) was evaluated using a simplified "box" model, as presented in detail in Section D.4.1.2.2. The estimated Chi/Q value for the MEI worker was 9.26E-04 sec/$m^3$.

D.4.5.2.3 Exposure

**Worker**

The MEI worker was assumed to be located within a box placed directly over the tank farm area. Exposure point concentrations of chemical emissions (mg/$m^3$) from the tank farm area and retrieval operations were estimated by multiplying the cumulative tank farm emission rate (mg/sec) and retrieval operation emission rate (mg/sec) by the MEI worker Chi/Q value (9.26E-04 sec/$m^3$), respectively.

Exposure point concentrations for each volatile chemical emitted from the tank farm area and during retrieval are summarized in Tables D.4.5.6 and D.4.5.7, respectively.

Chemical intake (dose) was estimated for the MEI worker using the same equation and exposure parameters defined in Section D.2.2.3. Estimated intakes of chemical emissions from the tank farm and retrieval operations for the MEI worker are presented in Tables D.4.5.6 and D.4.5.7, respectively.

**Noninvolved Worker**

The MEI noninvolved worker was assumed to be located at the point where maximum downwind air concentrations were calculated (100 m [330 ft] from the tank farm and 200 m [660 ft] from the evaporator). Exposure point concentrations (mg/$m^3$) of chemical emissions from the tank farm, retrieval operations, evaporator, and vitrification facilities were estimated by multiplying the cumulative tank farm, retrieval, evaporator, and plant emission rates (mg/sec) by their respective MEI noninvolved worker Chi/Q values (4.0E-04 sec/$m^3$ for the tank farm, 2.50E-06 sec/$m^3$ for the evaporator, 4.0E-04 sec/$m^3$ for retrieval, and 2.90E-08 sec/$m^3$ for the vitrification plant). Exposure point concentrations for each volatile chemical emitted from the tank farm area, the evaporator, retrieval operations, and the vitrification facility are summarized in Tables D.4.5.8, D.4.5.9, D.4.5.10, and D.4.5.11, respectively.

Chemical intake (dose) was estimated for the MEI noninvolved worker according to the same equation and exposure parameters used for the MEI worker. Estimated operating chemical emission intakes for the MEI noninvolved worker are presented in Tables D.4.5.8, D.4.5.9, D.4.5.10, and D.4.5.11 for the tank farm area, the evaporator, retrieval operations, and the vitrification facility emissions, respectively.

Table D.4.5.6 Ex Situ Intermediate Separations Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_I$) (mg/kg-day) | Inhalation Slope Factor ($SF_I$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 9.75E-04 | 1.91E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 9.80E-05 | 1.92E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 6.94E-06 | 1.36E-06 | 5.63E-07 | ND | 9.80E-01 | NE | 5.52E-07 |
| 2-Hexanone | 1.27E-04 | 2.48E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.00E-04 | 3.92E-05 | NC | ND | NC | NE | NC |
| Acetone | 2.41E-03 | 4.73E-04 | NC | 1.00E-01 | NC | 4.73E-03 | NC |
| Acetonitrile | 1.16E-03 | 2.28E-04 | NC | 1.40E-02 | NC | 1.63E-03 | NC |
| Benzene | 5.53E-05 | 1.08E-05 | 4.48E-06 | 1.70E-03 | 2.90E-02 | 6.37E-03 | 1.30E-07 |
| Heptane | 1.42E-04 | 2.78E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.37E-04 | 2.69E-05 | NC | 2.30E-02 | NC | 1.17E.03 | NC |
| N-hexane | 1.48E-04 | 2.91E-05 | NC | 5.70E-02 | NC | 5.10E-04 | NC |
| Nonane | 7.70E-05 | 1.51E-05 | NC | ND | NC | NE | NC |
| Octane | 8.08E-05 | 1.58E-05 | NC | ND | NC | NE | NC |
| Toluene | 1.13E-05 | 2.22E-06 | NC | 1.10E-01 | NC | 2.02E-05 | NC |
| Ammonia | 7.10E-03 | 1.39E-03 | NC | 2.90E-02 | NC | 4.80E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 1.75E-04 | 3.43E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.15E-10 | 2.25E-11 | 9.31E-12 | 5.70E-04 | 5.30E-02 | 3.95E-08 | 4.93E-13 |
| Ethyl Butyl Ketone | 3.85E-10 | 7.54E-11 | NC | 2.30E-02 | NC | 3.28E-09 | NC |
| Methyl Chloride | 1.70E-11 | 3.33E-12 | 1.38E-12 | ND | 6.30E-03 | NE | 8.67E-15 |
| Tetrahydrofuran | 2.97E-11 | 5.81E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 7.71E-02** | **Risk = 6.82E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.5.7 Ex Situ Intermediate Separations Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_I$) (mg/kg-day) | Inhalation Slope Factor ($SF_I$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 2.92E-03 | 5.73E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 2.94E-04 | 5.76E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 2.08E-05 | 4.08E-06 | 1.51E-06 | ND | 9.80E-01 | NE | 1.48E-06 |
| 2-Hexanone | 3.80E-04 | 7.45E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 6.00E-04 | 1.18E-04 | NC | ND | NC | NE | NC |
| Acetone | 7.24E-03 | 1.42E-03 | NC | 1.00E-01 | NC | 1.42E-02 | NC |
| Acetonitrile | 3.49E-03 | 6.84E-04 | NC | 1.40E-02 | NC | 4.88E-02 | NC |
| Benzene | 1.66E-04 | 3.25E-05 | 1.21E-05 | 1.70E-03 | 2.90E-02 | 1.91E-02 | 3.50E-07 |
| Heptane | 4.26E-04 | 8.34E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 4.11E-04 | 8.06E-05 | NC | 2.30E-02 | NC | 3.50E-03 | NC |
| N-hexane | 4.45E-04 | 8.72E-05 | NC | 5.70E-02 | NC | 1.53E-03 | NC |
| Nonane | 2.31E-04 | 4.53E-05 | NC | ND | NC | NE | NC |
| Octane | 2.42E-04 | 4.75E-05 | NC | ND | NC | NE | NC |
| Toluene | 3.40E-05 | 6.66E-06 | NC | 1.10E-01 | NC | 6.05E-05 | NC |
| Ammonia | 2.13E-02 | 4.18E-03 | NC | 2.90E-02 | NC | 1.44E-01 | NC |
| Phosphoric Acid, Tributyl Ester | 5.26E-04 | 1.03E-04 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 3.44E-10 | 6.75E-11 | 2.50E-11 | 5.70E-04 | 5.30E-02 | 1.18E-07 | 1.33E-12 |
| Ethyl Butyl Ketone | 1.15E-09 | 2.26E-10 | NC | 2.30E-02 | NC | 9.83E-09 | NC |
| Methyl Chloride | 5.09E-11 | 9.98E-12 | 3.70E-12 | ND | 6.30E-03 | NE | 2.33E-14 |
| Tetrahydrofuran | 8.90E-11 | 1.74E-11 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 2.31E-01** | **Risk = 1.83E-06** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.5.8 Ex Situ Intermediate Separations Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 4.21E-04 | 8.25E-05 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 4.23E-05 | 8.30E-06 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 3.00E-06 | 5.88E-07 | 2.43E-07 | ND | 9.80E-01 | NE | 2.38E-07 |
| 2-Hexanone | 5.47E-05 | 1.07E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 8.64E-05 | 1.69E-05 | NC | ND | NC | NE | NC |
| Acetone | 1.04E-03 | 2.04E-04 | NC | 1.00E-01 | NC | 2.04E-03 | NC |
| Acetonitrile | 5.02E-04 | 9.84E-05 | NC | 1.40E-02 | NC | 7.03E-03 | NC |
| Benzene | 2.39E-05 | 4.68E-06 | 1.94E-06 | 1.70E-03 | 2.90E-02 | 2.75E-03 | 5.62E-08 |
| Heptane | 6.13E-05 | 1.20E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 5.92E-05 | 1.16E-05 | NC | 2.30E-02 | NC | 5.05E-04 | NC |
| N-hexane | 6.41E-05 | 1.26E-05 | NC | 5.70E-02 | NC | 2.20E-04 | NC |
| Nonane | 3.33E-05 | 6.52E-06 | NC | ND | NC | NE | NC |
| Octane | 3.49E-05 | 6.84E-06 | NC | ND | NC | NE | NC |
| Toluene | 4.89E-06 | 9.58E-07 | NC | 1.10E-01 | NC | 8.71E-06 | NC |
| Ammonia | 3.07E-03 | 6.01E-04 | NC | 2.90E-02 | NC | 2.07E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 7.57E-05 | 1.48E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 4.96E-11 | 9.72E-12 | 4.02E-12 | 5.70E-04 | 5.30E-02 | 1.71E-08 | 2.13E-13 |
| Ethyl Butyl Ketone | 1.66E-10 | 3.26E-11 | NC | 2.30E-02 | NC | 1.42E-09 | NC |
| Methyl Chloride | 7.33E-12 | 1.44E-12 | 5.95E-13 | ND | 6.30E-03 | NE | 3.75E-15 |
| Tetrahydorfuran | 1.28E-11 | 2.51E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 3.33E-02** | **Risk = 2.94E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.5.9 Ex Situ Intermediate Separations Evaporator Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarci-nogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg-day)^{-1}$ | Noncarci-nogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Acetone | 5.75E-07 | 1.13E-07 | NC | 1.00E-01 | NC | 1.13E-06 | NC |
| Ammonia | 5.40E-07 | 1.06E-07 | NC | 2.90E-02 | NC | 3.65E-06 | NC |
| n-Butyl Alcohol | 4.33E-06 | 8.48E-07 | NC | 1.00E-01 | NC | 8.48E-06 | NC |
| 2-Hexanone | 2.07E-09 | 4.06E-10 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 3.93E-08 | 7.69E-09 | NC | 2.30E-02 | NC | 3.34E-07 | NC |
| | | | | | | HI = 1.36E-05 | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

### General Public

The MEI general public receptor was assumed to be located at the point where maximum air concentrations were calculated (approximately 22 km [14 mi] from both the tank farm area and evaporator). Exposure point concentrations ($mg/m^3$) of chemical emissions from the tank farm area, the evaporator, retrieval operations, and the vitrification facility were estimated by multiplying the cumulative emission rates (mg/sec) of each source by their respective MEI general public Chi/Q values (6.60E-08 $sec/m^3$ for the tank farm, 6.60E-08 $sec/m^3$ for the evaporator, 6.60E-08 $sec/m^3$ for retrieval operations, and 7.70E-09 $sec/m^3$ for the vitrification facility). Exposure point concentrations for each volatile chemical emitted from the tank farm area, the evaporator, retrieval operations, and the vitrification facility are summarized in Tables D.4.5.12, D.4.5.13, D.4.5.14, and D.4.5.15, respectively.

The residential or general public intake was calculated according to the equation and exposure parameters presented in Section D.2.2.3. Estimated chemical emission intakes for the MEI general public are presented in Tables D.4.5.12, D.4.5.13, D.4.5.14, and D.4.5.15 for the tank farm area, the evaporator, retrieval operations, and the vitrification plant, respectively.

#### D.4.5.2.4 Toxicity Assessment

Toxicity assessment was previously discussed in detail in Section D.4.1.2.4. Cancer slope factors, RfDs, and data sources for each volatile operating chemical emission are summarized in Table D.4.1.11.

Table D.4.5.10 Ex Situ Intermediate Separations Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 1.26E-03 | 2.48E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 1.27E-04 | 2.49E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 8.99E-06 | 1.76E-06 | 6.54E-07 | ND | 9.80E-01 | NE | 6.41E-07 |
| 2-Hexanone | 1.64E-04 | 3.22E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.59E-04 | 5.08E-05 | NC | ND | NC | NE | NC |
| Acetone | 3.13E-04 | 6.13E-04 | NC | 1.00E-01 | NC | 6.13E-03 | NC |
| Acetonitrile | 1.51E-03 | 2.95E-04 | NC | 1.40E-02 | NC | 2.11E-02 | NC |
| Benzene | 7.16E-05 | 1.40E-05 | 5.21E-06 | 1.70E-03 | 2.90E-02 | 8.26E-03 | 1.51E-07 |
| Heptane | 1.84E-04 | 3.60E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.78E-04 | 3.48E-05 | NC | 2.30E-02 | NC | 1.51E-03 | NC |
| N-hexane | 1.92E-04 | 3.77E-05 | NC | 5.70E-02 | NC | 6.61E-04 | NC |
| Nonane | 9.98E-05 | 1.96E-05 | NC | ND | NC | NE | NC |
| Octane | 1.05E-04 | 2.05E-05 | NC | ND | NC | NE | NC |
| Toluene | 1.47E-05 | 2.87E-06 | NC | 1.10E-01 | NC | 2.61E-05 | NC |
| Ammonia | 9.20E-03 | 1.80E-03 | NC | 2.90E-02 | NC | 6.22E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 2.27E-04 | 4.45E-05 | NC | NC | NC | NE | NC |
| Carbon Tetrachloride | 1.49E-10 | 2.92E-11 | 1.08E-11 | 5.70E-04 | 5.30E-02 | 5.12E-08 | 5.73E-13 |
| Ethyl Butyl Ketone | 4.98E-10 | 9.77E-11 | NC | 2.30E-02 | NC | 4.25E-09 | NC |
| Methyl Chloride | 2.20E-11 | 4.31E-12 | 1.60E-12 | ND | 6.30E-03 | NE | 1.01E-14 |
| Tetrahydorfuran | 3.84E-11 | 7.53E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 9.99E-02** | **Risk = 7.92E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.5.11 Ex Situ Intermediate Separations Plant Emissions

| Emissions | Air Concentrations of Vitrification Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Aluminum | 4.46E-10 | 8.75E-11 | NC | ND | NC | NE | NC |
| Arsenic | 4.83E-14 | 9.47E-15 | 3.00E-11 | ND | 1.51E+01 | NE | 4.52E-10 |
| Boron | 1.84E-11 | 3.61E-12 | NC | 5.70E-03 | NC | 6.34E-10 | NC |
| Barium | 1.37E-13 | 2.69E-14 | NC | 1.43E-04 | NC | 1.88E-10 | NC |
| Beryllium | 3.59E-15 | 7.04E-16 | 9.21E-15 | ND | 8.40E+00 | NE | 7.74E-14 |
| Bismuth | 8.83E-12 | 1.73E-12 | NC | ND | NC | NE | NC |
| Cadmium | 3.52E-13 | 6.91E-14 | 5.92E-13 | ND | 6.30E+00 | NE | 3.73E-12 |
| Cerium | 8.02E-12 | 1.57E-12 | NC | ND | NC | NE | NC |
| Chromium (+3) | 7.18E-12 | 1.41E-12 | NC | 5.71E-07 | NC | 2.47E-06 | NC |
| Copper | 3.23E-14 | 6.34E-15 | NC | ND | NC | NE | NC |
| Manganese | 5.00E-12 | 9.80E-13 | NC | ND | NC | NE | NC |
| Molybdenum | 2.27E-13 | 4.44E-14 | NC | ND | NC | NE | NC |
| Nickel | 6.01E-12 | 1.18E-12 | NC | ND | NC | NE | NC |
| Lead | 1.90E-13 | 3.73E-14 | NC | ND | NC | NE | NC |
| Silver | 2.99E-14 | 5.87E-15 | NC | ND | NC | NE | NC |
| Uranium | 5.00E-11 | 9.80E-12 | NC | ND | NC | NE | NC |
| Vanadium | 8.86E-15 | 1.74E-15 | NC | ND | NC | NE | NC |
| Zinc | 1.78E-13 | 3.49E-14 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 2.47E-06** | **Risk = 4.56E-10** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.5.12 Ex Situ Intermediate Separations Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 6.95E-08 | 4.34E-08 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 6.98E-09 | 4.36E-09 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 4.95E-10 | 3.09E-10 | 7.25E-11 | ND | 9.80E-01 | NE | 7.10E-11 |
| 2-Hexanone | 9.03E-09 | 5.64E-09 | NC | ND | NC | NE | NC |
| 2-Pentanone | 1.43E-08 | 8.91E-09 | NC | ND | NC | NE | NC |
| Acetone | 1.72E-07 | 1.08E-07 | NC | 1.00E-01 | NC | 1.08E-06 | NC |
| Acetonitrile | 8.29E-08 | 5.18E-08 | NC | 1.40E-02 | NC | 3.70E-06 | NC |
| Benzene | 3.94E-09 | 2.46E-09 | 5.77E-10 | 1.70E-03 | 2.90E-02 | 1.45E-06 | 1.67E-11 |
| Heptane | 1.01E-08 | 6.32E-09 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 9.77E-09 | 6.11E-09 | NC | 2.30E-02 | NC | 2.65E-07 | NC |
| N-hexane | 1.06E-08 | 6.61E-09 | NC | 5.70E-02 | NC | 1.16E-07 | NC |
| Nonane | 5.49E-09 | 3.43E-09 | NC | ND | NC | NE | NC |
| Octane | 5.76E-09 | 3.60E-09 | NC | ND | NC | NE | NC |
| Toluene | 8.07E-10 | 5.04E-10 | NC | 1.10E-01 | NC | 4.58E-09 | NC |
| Ammonia | 5.06E-07 | 3.16E-07 | NC | 2.90E-02 | NC | 1.09E-05 | NC |
| Phosphoric Acid, Tributyl Ester | 1.25E-08 | 7.81E-09 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 8.18E-15 | 5.11E-15 | 1.20E-15 | 5.70E-04 | 5.30E-02 | 8.97E-12 | 6.36E-17 |
| Ethyl Butyl Ketone | 2.74E-14 | 1.71E-14 | NC | 2.30E-02 | NC | 7.45E-13 | NC |
| Methyl Chloride | 1.21E-15 | 7.56E-16 | 1.77E-16 | ND | 6.30E-03 | NE | 1.12E-18 |
| Tetrahydrofuran | 2.11E-15 | 1.32E-15 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 1.75E-05** | **Risk = 8.78E-11** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.5.13 Ex Situ Intermediate Separations Evaporator Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the MEI General Public ($mg/m^3$) | Noncarci-nogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg-day)^{-1}$ | Noncarci-nogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Acetone | 8.97E-09 | 5.61E-09 | NC | 1.00E-01 | NC | 5.61E-08 | NC |
| Ammonia | 8.42E-09 | 5.27E-09 | NC | 2.90E-02 | NC | 1.82E-07 | NC |
| n-Butyl Alcohol | 6.75E-08 | 4.22E-08 | NC | 1.00E-01 | NC | 4.22E-07 | NC |
| 2-Hexanone | 3.23E-11 | 2.02E-11 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 6.12E-10 | 3.83E-10 | NC | 2.30E-02 | NC | 1.66E-08 | NC |
| | | | | | | HI = 6.76E-07 | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

### D.4.5.2.5 Risk Characterization

**MEI Worker**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm and retrieval operations are summarized in Tables D.4.5.6 and D.4.5.7, respectively. The total HI and cancer risk from routine tank farm emissions and retrieval emissions are 3.08E-01 and 2.51E-06, respectively.

**MEI Noninvolved Worker**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm, the evaporator, retrieval operations, and the vitrification facility are summarized in Tables D.4.5.8, D.4.5.9, D.4.5.10, and D.4.5.11, respectively. The total HI and cancer risk from combined tank farm, evaporator, retrieval, and plant emissions are 1.33E-01 and 1.09E-06, respectively.

**MEI General Public**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm, the evaporator, retrieval operations, and the vitrification facility are summarized in Tables D.4.5.12, D.4.5.13, D.4.5.14, and D.4.5.15, respectively. The total HI and cancer risk from combined tank farm, evaporator, retrieval, and plant emissions are 7.29E-05 and 5.43E-10, respectively.

Table D.4.5.14 Ex Situ Intermediate Separations Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg-day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 2.08E-07 | 1.30E-07 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 2.10E-08 | 1.31E-08 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 1.48E-09 | 9.27E-10 | 1.95E-10 | ND | 9.80E-01 | NE | 1.91E-10 |
| 2-Hexanone | 2.71E-08 | 1.69E-08 | NC | ND | NC | NE | NC |
| 2-Pentanone | 4.28E-08 | 2.67E-08 | NC | ND | NC | NE | NC |
| Acetone | 5.16E-07 | 3.23E-07 | NC | 1.00E-01 | NC | 3.23E-06 | NC |
| Acetonitrile | 2.49E-07 | 1.55E-07 | NC | 1.40E-02 | NC | 1.11E-05 | NC |
| Benzene | 1.18E-08 | 7.39E-09 | 1.55E-09 | 1.70E-03 | 2.90E-02 | 4.35E-06 | 4.50E-11 |
| Heptane | 3.03E-08 | 1.90E-08 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 2.93E-08 | 1.83E-08 | NC | 2.30E-02 | NC | 7.96E-07 | NC |
| N-hexane | 3.17E-08 | 1.98E-08 | NC | 5.70E-02 | NC | 3.48E-07 | NC |
| Nonane | 1.65E-08 | 1.03E-08 | NC | ND | NC | NE | NC |
| Octane | 1.73E-08 | 1.08E-08 | NC | ND | NC | NE | NC |
| Toluene | 2.42E-09 | 1.51E-09 | NC | 1.10E-01 | NC | 1.38E-08 | NC |
| Ammonia | 1.52E-06 | 9.49E-07 | NC | 2.90E-02 | NC | 3.27E-05 | NC |
| Phosphoric Acid, Tributyl Ester | 3.75E-08 | 2.34E-08 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 2.45E-14 | 1.53E-14 | 3.23E-15 | 5.70E-04 | 5.30E-02 | 2.69E-11 | 1.71E-16 |
| Ethyl Butyl Ketone | 8.22E-14 | 5.14E-14 | NC | 2.30E-02 | NC | 2.24E-12 | NC |
| Methyl Chloride | 3.63E-15 | 2.27E-15 | 4.77E-16 | ND | 6.30E-03 | NE | 3.00E-18 |
| Tetrahydrofuran | 6.34E-15 | 3.96E-15 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 5.26E-05** | **Risk = 2.36E-10** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.5.15 Ex Situ Intermediate Separations Plant Emissions

| Emissions | Air Concentrations of Vitrification Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Aluminum | 1.19E-10 | 7.41E-11 | NC | ND | NC | NE | NC |
| Arsenic | 1.28E-14 | 8.02E-15 | 1.44E-11 | ND | 1.51E+01 | NE | 2.18E-10 |
| Boron | 4.89E-12 | 3.06E-12 | NC | 5.70E-03 | NC | 5.36E-10 | NC |
| Barium | 3.65E-14 | 2.28E-14 | NC | 1.43E-04 | NC | 1.59E-10 | NC |
| Beryllium | 9.54E-16 | 5.96E-16 | 4.43E-15 | ND | 8.40E+00 | NE | 3.72E-14 |
| Bismuth | 2.34E-12 | 1.46E-12 | NC | ND | NC | NE | NC |
| Cadmium | 9.36E-14 | 5.58E-14 | 2.85E-13 | ND | 6.30E+00 | NE | 1.80E-12 |
| Cerium | 2.13E-12 | 1.33E-12 | NC | ND | NC | NE | NC |
| Chromium (+3) | 1.91E-12 | 1.19E-12 | NC | 5.71E-07 | NC | 2.09E-06 | NC |
| Copper | 8.58E-15 | 5.36E-15 | NC | ND | NC | NE | NC |
| Manganese | 1.33E-12 | 8.30E-13 | NC | ND | NC | NE | NC |
| Molybdenum | 6.02E-14 | 3.76E-14 | NC | ND | NC | NE | NC |
| Nickel | 1.60E-12 | 9.97E-13 | NC | ND | NC | NE | NC |
| Lead | 5.05E-14 | 3.16E-14 | NC | ND | NC | NE | NC |
| Silver | 7.95E-15 | 4.97E-15 | NC | ND | NC | NE | NC |
| Uranium | 1.33E-11 | 8.30E-12 | NC | ND | NC | NE | NC |
| Vanadium | 2.35E-15 | 1.47E-15 | NC | ND | NC | NE | NC |
| Zinc | 4.73E-14 | 2.96E-14 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 2.09E-06** | **Risk = 2.19E-10** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

## D.4.6 EX SITU NO SEPARATIONS ALTERNATIVE

This section presents the anticipated remediation risk associated with the Ex Situ No Separations alternative for tank waste, as outlined in Volume Two, Appendix B.

The radiological and toxicological risk for this alternative was based on the air emissions and direct exposure from construction, continued operations (including tank farm and evaporator operations),

retrieval, treatment (vitrification or calcination), storage and disposal, onsite transportation of waste, monitoring and maintenance, and closure and monitoring. There would be no pretreatment and therefore, no associated risk.

### D.4.6.1 Radiological Risk

The LCF risk to the workers, noninvolved workers, and general public could result from direct exposure and atmospheric emissions from the components associated with this alternative. The risk was determined by analyzing the radiological source term, the transport mechanism, exposure, and the risk associated with the exposure as discussed in the following subsections.

#### D.4.6.1.1 Source Term

The source term used for the noninvolved worker and general public was the atmospheric radiological emissions presented in Table D.4.6.1 (WHC 1995c and Jacobs 1996). The workers would receive a combined dose from the air emissions and from direct exposure from radiation fields in the work place.

#### D.4.6.1.2 Transport

The atmospheric transport parameters of the Ex Situ No Separations alternative are presented in Table D.4.6.2. The tank farm and retrieval atmospheric radiological operating emissions were modeled as a ground release, and the evaporator and vitrification or calcination emissions were modeled as an elevated release. For modeling purposes, it was assumed that the source term would be released at a point in the 200 Areas represented by the meteorological conditions at the Hanford Meteorological Station. The analysis used the Hanford Meteorological Station joint frequency data from Tables D.2.2.1 and D.2.2.2 and Figures D.2.2.1 and D.2.2.2.

For ground releases, dispersion in the atmosphere would cause contaminant air concentrations and exposures to decrease with increasing distance from the source. Maximum individual exposures therefore would occur at the inner boundaries (i.e., closest distance to the source) of the defined receptor occupancy zones. For the noninvolved worker, the maximum exposure would occur 100 m (330 ft) from the source (in an east-southeast direction). For the general public, the maximum exposure would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the center of the 200 East Area).

The calculated Chi/Q values for ground releases from the tank farms were calculated by the GENII computer code to be 4.0E-04 sec/$m^3$ for the noninvolved worker MEI and 6.6E-08 sec/$m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q was 1.6E-03 sec/$m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q was 2.9E-03 sec/$m^3$.

Table D.4.6.1 Atmospheric Radiological Emissions for the Ex Situ No Separations Alternative

| Continued Operations | | | | Retrieval Emissions | | Vitrification/Calcination Emissions | |
|---|---|---|---|---|---|---|---|
| Tank Farm Emissions | | Evaporator Emissions | | | | | |
| Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released |
| Total Alpha [1] | 2.88E-08 | Total Alpha [1] | 2.10E-05 | Sr-90 | 5.29E-04 | Am-241 | 3.75E-03 |
| Total Beta [2] | 7.91E-07 | Total Beta [2] | 1.20E-05 | Cs-137 | 2.12E-03 | C-14 [3] | 3.81E+02 |
| Sr-90 | 1.81E-05 | | | I-129 | 4.24E-03 | Cs-137 | 2.45E+00 |
| Cs-137 | 5.38E-05 | | | | | I-129 | 2.71E+00 |
| I-129 | 4.60E-05 | | | | | Pu-239 | 3.89E-03 |
| | | | | | | Ru-106 | 8.60E-07 |
| | | | | | | Sm-151 | 2.68E-02 |
| | | | | | | Sr-90 | 3.88E+00 |
| | | | | | | Tc-99 | 1.15E-03 |
| | | | | | | Zr-93 | 1.50E-02 |

Notes:
[1] Total alpha is assumed to be Pu-239.
[2] Total beta is assumed to be Sr-90.
[3] C-14 emissions are reduced for the calcination.

Table D.4.6.2 Atmospheric Transport Parameters for the Ex Situ No Separations Alternative

| Transport Parameters | Continued Operations | | Retrieval | Vitrification or Calcination |
|---|---|---|---|---|
| | Tank Farms | Evaporator 1 | | |
| Stack height in m (ft) | Ground | 6.70 (22) | Ground | 55 (180) |
| Stack radius in m (ft) | N/A | 0.53 (1.7) | N/A | 0.88 (2.9) |
| Stack flow rate in $m^3$/sec ($ft^3$/sec) | N/A | 10 (353) | N/A | 33 (1,165) |
| Stack temperature in °C (°F) | N/A | 46 (117) | N/A | 160 (320) |
| Noninvolved worker MEI location in m (ft) ESE | 100 (328) | 200 (656) | 100 (328) | 800 (2,625) |
| Public MEI location in km (mi) ESE | 22 (14) | 22 (14) | 22 (14) | 22 (14) |
| Chi/Q for noninvolved worker - population in s/$m^3$ | 1.60E-03 | 4.00E-04 | 1.60E-03 | 5.00E-05 |
| Chi/Q for noninvolved worker - MEI in s/$m^3$ | 4.00E-04 | 2.50E-06 | 4.00E-04 | 2.90E-08 |
| Chi/Q for general public - population in s/$m^3$ | 2.90E-03 | 1.60E-03 | 2.90E-03 | 5.00E-04 |
| Chi/Q for general public - MEI in s/$m^3$ | 6.60E-08 | 3.90E-08 | 6.60E-08 | 7.70E-09 |

Notes:
ESE = East-southeast

For elevated releases (stack releases), the maximum exposure would not necessarily occur at the closest distance to the source. Air transport modeling indicates that the maximum exposure for the noninvolved worker would occur 200 m (660 ft) from the source (in an east-southeast direction) for the evaporator and 800 m (2,625 ft) for treatment (vitrification or calcination). The maximum exposure for a member of the general public would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the 200 East Area).

The calculated Chi/Q values for the evaporator operation were 2.50E-06 sec/$m^3$ for the noninvolved worker MEI and 3.90E-08 sec/$m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 4.0E-04 sec/$m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 1.60E-03 sec/$m^3$. For the treatment (vitrification or calcination) operation, the Chi/Q values were 2.90E-08 sec/$m^3$ for the noninvolved worker MEI, 7.70E-09 sec/$m^3$ for the general public MEI, 5.00E-05 sec/$m^3$ for the noninvolved worker population, and 5.00E-04 sec/$m^3$ for the general public population.

D.4.6.1.3 Exposure

The radiological exposure for the alternative is presented in Table D.4.6.3. The table shows the exposure each receptor would receive from every component. The sum of the components are shown in the last column for each population and MEI receptor except for the MEI worker. The MEI worker is not summed but is represented by the component with the highest MEI dose.

The worker population dose is dependent on the number of people in the population and the anticipated individual dose. These data were obtained from the Site maintenance and operations contractor and the TWRS EIS contractor (WHC 1995c and Jacobs 1996). The calculations for the worker exposures from construction, continued operations, retrieval, separations and treatment, monitoring and maintenance, and closure are as follows:

Construction = (8.02E+02 person-yr) · (1.4E-02 rem/person-yr) = 1.12E+01 person-rem

Continued Operations -
Tank farms = (1.09E+04 person-yr) · (1.40E-02 rem/person-yr) = 1.53E+02 person-rem
Evaporator = (6.40E+02 person-yr) · (2.00E-01 rem/person-yr) = 1.28E+02 person-rem
Total = 2.81E+02 person-rem

Retrieval = (2.10E+04 person-yr) · (2.00E-01 rem/person-yr) = 4.20E+03 person-rem

Treatment = (1.89E+03 person-yr) · (2.00E-01 rem/person-yr) = 3.78E+02 person-rem

Table D.4.6.3 Summary of Anticipated Radiological Exposure for the Ex Situ No Separations Alternative (Vitrification)

| Radiological Dose (person-rem)[2] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Receptor | Construction (19 yrs) | Continued Operations[1] (23 yrs) | Retrieval (17 yrs) | Treatment (14 yrs) | Transportation (20 yrs) | Monitoring and Maintenance (50 yrs) | Post Closure Monitoring (100 yrs) | Total |
| Worker - Population | 1.12E+01 | 2.81E+02 | 4.20E+03 | 3.78E+02 | N/A | 7.56E+00 | 1.13E+01 | 4.89E+03 |
| Worker - MEI [3,4] | 2.50E+00 | 1.20E+01 | 9.50E+00 | 7.00E+00 | N/A | 1.50E+00 | 1.50E+01 | 1.50E+01 |
| Noninvolved Worker - Population | 0.00E+00 | 1.51E-03 | 6.70E-03 | 1.00E+00 | 1.06E+00 | 0.00E+00 | 0.00E+00 | 2.07E+00 |
| Noninvolved Worker - MEI | 0.00E+00 | 7.08E-05 | 1.70E-03 | 5.90E-04 | N/A | 0.00E+00 | 0.00E+00 | 1.70E-03 |
| General Public - Population | 0.00E+00 | 7.40E-02 | 1.70E+00 | 3.10E+02 | 2.96E-01 | 0.00E+00 | 0.00E+00 | 3.12E+02 |
| General Public - MEI | 0.00E+00 | 2.02E-06 | 5.50E-05 | 6.70E-03 | N/A | 0.00E+00 | 0.00E+00 | 6.70E-03 |

Notes:
[1] Continued operations include tank farm and Evaporator 1.
[2] MEI receptor dose is noted in rem.
[3] Worker MEI is assumed to work for 30 years.
[4] Total for the MEI represents the highest single exposure.

Monitoring/Maintenance = (5.40E+02 person-yr) · (1.4E-02 rem/person-yr) = 7.56E+00 person-rem

Closure -
Closure = (2.15E+02 person-yr) · (1.40E-02 rem/person-yr) = 3.01E+00 person-rem
Monitoring = (5.93E+02 person-yr) · (1.40E-02 rem/person-yr) = 8.30E+00 person-rem
Total = 1.13E+01 person-rem

The MEI worker was assumed to receive a dose of 500 mrem (5.00E-01 rem) per year for a maximum of 30 years.

The noninvolved workers and general public exposures from inhalation of the atmospheric emissions (source term) were converted to a radiological dose in rem using the GENII computer code and applying the appropriate Chi/Q.

D.4.6.1.4 Risk

The LCFs are calculated as the product of the estimated dose times the dose-to-risk conversion factor (Section D.2.2.4). The sum of the radiological dose from construction, continued operations, treatment, and closure, for each receptor shown in the combined dose column in Table D.4.6.4, was multiplied by the appropriate dose-to-risk conversion factor to produce the LCF risk.

### D.4.6.2 Chemical Exposure

Potential carcinogenic risk and noncarcinogenic health hazards may result from exposure to volatile emissions from the tank farm, tank waste retrieval, and the evaporator, and exposure to particulate emissions from the separation and vitrification of HLW and LAW for the worker, noninvolved worker, and the general public. Potential carcinogenic risk and noncarcinogenic health hazards were estimated using the chemical source term, transport mechanism, exposure, and toxicological criteria as discussed in the following subsections.

D.4.6.2.1 Source Term

Operating air emissions from the tank farm area, tank waste retrieval, evaporator, and vitrification facility are presented in Table D.4.6.5. The emission rates from the HLW and LAW vitrification facilities were combined and treated as a single-source emission. The noninvolved worker and the general public would be exposed to combined emissions from the tank farm area, tank waste retrieval operations, evaporator, and vitrification facilities. The worker would only be exposed to emissions (ground-level release) from the tank farm area and retrieval operations because emissions from the evaporator and vitrification facilities occur through a stack-release and would not impact the onsite worker.

Table D.4.6.4 Summary of Anticipated Risk for the Ex Situ No Separations (Vitrification) Alternative

| Receptor | Combined dose (person-rem) [1] | LCF/rem | LCF Risk |
|---|---|---|---|
| Worker - Population | 4.89E+03 | 4.00E-04 | 1.96E+00 |
| Worker - MEI | 1.50E+01 | 4.00E-04 | 6.00E-03 |
| Noninvolved Worker - Population | 2.07E+00 | 4.00E-04 | 8.28E-04 |
| Noninvolved Worker - MEI | 1.70E-03 | 4.00E-04 | 6.80E-07 |
| General Public - Population | 3.12E+02 | 5.00E-04 | 1.56E-01 |
| General Public - MEI | 6.70E-03 | 5.00E-04 | 3.35E-06 |

Notes:
[1] MEI receptor dose is noted in rem.
LCF = Latent cancer fatality

Table D.4.6.5 Chemical Emissions for the Ex Situ No Separation

| Tank Farm Emissions | | Retrieval Emissions | | Evaporator Emissions | | Separator/Vitrification Emissions | |
|---|---|---|---|---|---|---|---|
| Emissions | Total Tank Farm Emission Rate (mg/sec) | Emissions | Retrieval Emission Rate (mg/sec) | Emissions | Evaporator Emission Rate (mg/sec) | Emissions | Plant Emission Rate (mg/sec) |
| Carbon Monoxide | 1.05E+00 | Carbon Monoxide | 3.16E+00 | Acetone | 2.30E-01 | Aluminum | 9.25E-03 |
| Nitrogen Oxide | 1.06E-01 | Nitrogen Oxide | 3.17E-01 | Ammonia | 2.16E-01 | Antimony | 3.55E-06 |
| 1,3-Butadiene | 7.49E-03 | 1,3-Butadiene | 2.25E-02 | n-Butyl Alcohol | 1.73E+00 | Arsenic | 1.16E-06 |
| 2-Hexanone | 1.37E-01 | 2-Hexanone | 4.10E-01 | 2-Hexanone | 8.28E-04 | Boron | 2.33E-02 |
| 2-Pentanone | 2.16E-01 | 2-Pentanone | 6.48E-01 | Methyl Isobutyl Ketone | 1.57E-02 | Barium | 4.50E-06 |
| Acetone | 2.61E+00 | Acetone | 7.82E+00 | | | Beryllium | 1.91E-08 |
| Acetonitrile | 1.26E+00 | Acetonitrile | 3.77E+00 | | | Bismuth | 4.68E-04 |
| Benzene | 5.97E-02 | Benzene | 1.79E-01 | | | Cadmium | 2.01E-05 |
| Heptane | 1.53E-01 | Heptane | 4.60E-01 | | | Cerium | 4.51E-04 |
| Methyl N-amyl Ketone | 1.48E-01 | Methyl N-amyl Ketone | 4.44E-01 | | | Chromium (+3) | 3.15E-04 |
| N-hexane | 1.60E-01 | N-hexane | 4.80E-01 | | | Cobalt | 1.55E-06 |
| Nonane | 8.32E-02 | Nonane | 2.50E-01 | | | Copper | 1.88E-06 |
| Octane | 8.73E-02 | Octane | 2.62E-01 | | | Manganese | 2.57E-04 |
| Toluene | 1.22E-02 | Toluene | 3.67E-02 | | | Molybdenum | 1.61E-05 |
| Ammonia | 7.67E+00 | Ammonia | 2.30E+01 | | | Nickel | 3.38E-04 |
| Phosphoric Acid, Tributyl Ester | 1.89E-01 | Phosphoric Acid, Tributyl Ester | 5.68E-01 | | | Lead | 6.11E-05 |
| Carbon Tetrachloride | 1.24E-07 | Carbon Tetrachloride | 3.72E-07 | | | Selenium | 4.53E-06 |
| Ethyl Butyl Ketone | 4.15E-07 | Ethyl Butyl Ketone | 1.25E-06 | | | Silver | 4.21E-07 |
| Methyl Chloride | 1.83E-08 | Methyl Chloride | 5.50E-08 | | | Uranium | 2.59E-03 |
| Tetrahydrofuran | 3.20E-08 | Tetrahydrofuran | 9.61E-08 | | | Vanadium | 9.20E-08 |
| | | | | | | Zinc | 4.49E-06 |

D.4.6.2.2 Transport

The tank farm chemical operating emissions (routine emissions from the tank farm and emissions during retrieval) were modeled as a ground release. Chemical operating emissions from the evaporator and vitrification facilities would occur from stack releases and were modeled as elevated releases. Transport parameters, location of the MEI noninvolved worker and MEI general public, and Chi/Q values for the MEI noninvolved worker and general public are identical to the radiological parameters presented in Table D.4.6.2.

The MEI worker was evaluated using a simplified "box" model, as presented in detail in Section D.2.2.3. The estimated Chi/Q value for the MEI worker was 9.26E-04 sec/$m^3$.

D.4.6.2.3 Exposure

**Worker**

The MEI worker was assumed to be located within a box placed directly over the tank farm area. Exposure point concentrations of chemical emissions (mg/$m^3$) from the tank farm area and retrieval operations were estimated by multiplying the cumulative tank farm emission rate (mg/sec) and retrieval operation emission rate (mg/sec) by the MEI worker Chi/Q value (9.26E-04 sec/$m^3$), respectively. Exposure point concentrations for each volatile chemical emitted from the tank farm area and during retrieval are summarized in Tables D.4.6.6 and D.4.6.7, respectively.

Chemical intake (dose) was estimated for the MEI worker using the same equation and exposure parameters defined in Section D.2.2.3. Estimated intakes of chemical emissions from the tank farm and retrieval operations for the MEI worker are presented in Tables D.4.6.6 and D.4.6.7, respectively.

**Noninvolved Worker**

The MEI noninvolved worker was assumed to be located at the point where maximum downwind air concentrations were calculated (100 m [330 ft] from the tank farm and 200 m [660 ft] from the evaporator). Exposure point concentrations (mg/$m^3$) of chemical emissions from the tank farm, retrieval operations, evaporator, and vitrification facilities were estimated by multiplying the cumulative tank farm, retrieval, evaporator, and plant emission rates (mg/sec) by their respective MEI noninvolved worker Chi/Q values (4.00E-04 sec/$m^3$ for the tank farm, 2.50E-06 sec/$m^3$ for the evaporator, 4.00E-04 sec/$m^3$ for retrieval, and 2.90E-08 sec/$m^3$ for the vitrification facility). Exposure point concentrations for each volatile chemical emitted from the tank farm area, the evaporator, retrieval operations, and the vitrification facility are summarized in Tables D.4.6.8, D.4.6.9, D.4.6.10, and D.4.6.11, respectively.

Chemical intake (dose) was estimated for the MEI noninvolved worker according to the same equation and exposure parameters used for the MEI worker. Estimated operating chemical emission intakes for the MEI noninvolved worker are presented in Tables D.4.6.8, D.4.6.9, D.4.6.10 and D.4.6.11 for the tank farm area, the evaporator, retrieval operations and the vitrification facility emissions, respectively.

Table D.4.6.6 Ex Situ No Separations Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_I$) (mg/kg-day) | Inhalation Slope Factor ($SF_I$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 9.75E-04 | 1.91E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 9.80E-05 | 1.92E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 6.94E-06 | 1.36E-06 | 4.66E-07 | ND | 9.80E-01 | NE | 4.56E-07 |
| 2-Hexanone | 1.27E-04 | 2.48E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.00E-04 | 3.92E-05 | NC | ND | NC | NE | NC |
| Acetone | 2.41E-03 | 4.73E-04 | NC | 1.00E-01 | NC | 4.73E-03 | NC |
| Acetonitrile | 1.16E-03 | 2.28E-04 | NC | 1.40E-02 | NC | 1.63E-03 | NC |
| Benzene | 5.53E-05 | 1.08E-05 | 3.71E-06 | 1.70E-03 | 2.90E-02 | 6.37E-03 | 1.08E-07 |
| Heptane | 1.42E-04 | 2.78E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.37E-04 | 2.69E-05 | NC | 2.30E-02 | NC | 1.17E-03 | NC |
| N-hexane | 1.48E-04 | 2.91E-05 | NC | 5.70E-02 | NC | 5.10E-04 | NC |
| Nonane | 7.70E-05 | 1.51E-05 | NC | ND | NC | NE | NC |
| Octane | 8.08E-05 | 1.58E-05 | NC | ND | NC | NE | NC |
| Toluene | 1.13E-05 | 2.22E-06 | NC | 1.10E-01 | NC | 2.02E-05 | NC |
| Ammonia | 7.10E-03 | 1.39E-03 | NC | 2.90E-02 | NC | 4.80E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 1.75E-04 | 3.43E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.15E-10 | 2.25E-11 | 7.70E-12 | 5.70E-04 | 5.30E-02 | 3.95E-08 | 4.08E-13 |
| Ethyl Butyl Ketone | 3.85E-10 | 7.54E-11 | NC | 2.30E-02 | NC | 3.28E-09 | NC |
| Methyl Chloride | 1.70E-11 | 3.33E-12 | 1.14E-12 | ND | 6.30E-03 | NE | 7.17E-15 |
| Tetrahydrofuran | 2.97E-11 | 5.81E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 7.71E-02** | **Risk = 5.64E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.6.7 Ex Situ No Separations Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 2.92E-03 | 5.73E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 2.94E-04 | 5.76E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 2.08E-05 | 4.08E-06 | 1.11E-06 | ND | 9.80E-01 | NE | 1.08E-06 |
| 2-Hexanone | 3.80E-04 | 7.45E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 6.00E-04 | 1.18E-04 | NC | ND | NC | NE | NC |
| Acetone | 7.24E-03 | 1.42E-03 | NC | 1.00E-01 | NC | 1.42E-02 | NC |
| Acetonitrile | 3.79E-03 | 6.84E-04 | NC | 1.40E-02 | NC | 4.88E-02 | NC |
| Benzene | 1.66E-04 | 3.25E-05 | 8.81E-06 | 1.70E-03 | 2.90E-02 | 1.91E-02 | 2.55E-07 |
| Heptane | 4.26E-04 | 8.34E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 4.11E-04 | 8.06E-05 | NC | 2.30E-02 | NC | 3.50E-03 | NC |
| N-hexane | 4.45E-04 | 8.72E-05 | NC | 5.70E-02 | NC | 1.53E-03 | NC |
| Nonane | 2.31E-04 | 4.53E-05 | NC | ND | NC | NE | NC |
| Octane | 2.42E-04 | 4.75E-05 | NC | ND | NC | NE | NC |
| Toluene | 3.40E-05 | 6.66E-06 | NC | 1.10E-01 | NC | 6.05E-05 | NC |
| Ammonia | 2.13E-02 | 4.18E-03 | NC | 2.90E-02 | NC | 1.44E-01 | NC |
| Phosphoric Acid, Tributyl Ester | 5.26E-04 | 1.03E-04 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 3.44E-10 | 6.75E-11 | 1.83E-11 | 5.70E-04 | 5.30E-02 | 1.18E-07 | 9.69E-13 |
| Ethyl Butyl Ketone | 1.15E-09 | 2.26E-10 | NC | 2.30E-02 | NC | 9.83E-09 | NC |
| Methyl Chloride | 5.09E-11 | 9.98E-12 | 2.70E-12 | ND | 6.30E-03 | NE | 1.70E-14 |
| Tetrahydorfuran | 8.90E-11 | 1.74E-11 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 2.31E-01** | **Risk = 1.34E-06** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.6.8 Ex Situ No Separations Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI Noninvolved Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Noninvolved Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Noninvolved Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI Noninvolved Worker | Excess Cancer Risk for the MEI Noninvolved Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 4.21E-04 | 8.25E-05 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 4.23E-05 | 8.30E-06 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 3.00E-06 | 5.88E-07 | 2.01E-07 | ND | 9.80E-01 | NE | 1.97E-07 |
| 2-Hexanone | 5.47E-05 | 1.07E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 8.64E-05 | 1.69E-05 | NC | ND | NC | NE | NC |
| Acetone | 1.04E-03 | 2.04E-04 | NC | 1.00E-01 | NC | 2.04E-03 | NC |
| Acetonitrile | 5.02E-04 | 9.84E-05 | NC | 1.40E-02 | NC | 7.03E-03 | NC |
| Benzene | 2.39E-05 | 4.68E-06 | 1.60E-06 | 1.70E-03 | 2.90E-02 | 2.75E-03 | 4.65E-08 |
| Heptane | 6.13E-05 | 1.20E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 5.29E-05 | 1.16E-05 | NC | 2.30E-02 | NC | 5.05E-04 | NC |
| N-hexane | 6.41E-05 | 1.26E-05 | NC | 5.70E-02 | NC | 2.02E-04 | NC |
| Nonane | 3.33E-05 | 6.52E-06 | NC | ND | NC | NE | NC |
| Octane | 3.49E-05 | 6.84E-06 | NC | ND | NC | NE | NC |
| Toluene | 4.89E-06 | 9.58E-07 | NC | 1.10E-01 | NC | 8.71E-06 | NC |
| Ammonia | 3.07E-03 | 6.01E-04 | NC | 2.90E-02 | NC | 2.07E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 7.57E-05 | 1.48E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 4.96E-11 | 9.72E-12 | 3.33E-12 | 5.70E-04 | 5.30E-02 | 1.71E-08 | 1.76E-13 |
| Ethyl Butyl Ketone | 1.66E-10 | 3.26E-11 | NC | 2.30E-02 | NC | 1.42E-09 | NC |
| Methyl Chloride | 7.33E-12 | 1.44E-12 | 4.92E-13 | ND | 6.30E-03 | NE | 3.10E-15 |
| Tetrahydorfuran | 1.28E-11 | 2.51E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 3.33E-02** | **Risk = 2.44E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.6.9 Ex Situ No Separations Evaporator Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kd-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kd-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Acetone | 5.75E-07 | 1.13E-07 | NC | 1.00E-01 | NC | 1.13E-06 | NC |
| Ammonia | 5.40E-07 | 1.06E-07 | NC | 2.90E-02 | NC | 3.65E-06 | NC |
| n-Butyl Alcohol | 4.33E-06 | 8.48E-07 | NC | 1.00E-01 | NC | 8.48E-06 | NC |
| 2-Hexanone | 2.07E-09 | 4.06E-10 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 3.93E-08 | 7.69E-09 | NC | 2.30E-02 | NC | 3.34E-07 | NC |
| | | | | | | HI = 1.36E-05 | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

### General Public

The MEI general public receptor was assumed to be located at the point where maximum air concentrations were calculated (approximately 22 km [14 mi] from both the tank farm area and evaporator). Exposure point concentrations ($mg/m^3$) of chemical emissions from the tank farm area, the evaporator, retrieval operations, and the vitrification facility were estimated by multiplying the cumulative emission rates (mg/sec) of each source by their respective MEI general public Chi/Q values (6.60E-08 $sec/m^3$ for the tank farm, 3.90E-08 $sec/m^3$ for the evaporator, 6.60E-08 $sec/m^3$ for retrieval operations, and 7.70E-09 $sec/m^3$ for the vitrification facility). Exposure point concentrations for each volatile chemical emitted from the tank farm area, the evaporator, retrieval operations, and the vitrification facility are summarized in Tables D.4.6.12, D.4.6.13, D.4.6.14 and D.4.6.15, respectively.

The residential or general public intake was calculated according to the equation and exposure parameters presented in Section D.2.2.3. Estimated chemical emission intakes for the MEI general public are presented in Tables D.4.6.12, D.4.6.13, D.4.6.14, and D.4.6.15 for the tank farm area, the evaporator, retrieval operations and the vitrification facility, respectively.

#### D.4.6.2.4 Toxicity Assessment

Toxicity assessment was previously discussed in detail in Section D.4.1.2.4. Cancer slope factors, RfDs, and data sources for each volatile operating chemical emission are summarized in Table D.4.1.11.

Table D.4.6.10 Ex Situ No Separations Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_I$) (mg/kg-day) | Inhalation Slope Factor ($SF_I$) $(mg/kg-day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 1.26E-03 | 2.48E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 1.27E-04 | 2.49E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 8.99E-06 | 1.76E-06 | 4.78E-07 | ND | 9.80E-01 | NE | 4.68E-07 |
| 2-Hexanone | 1.64E-04 | 3.22E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.59E-04 | 5.08E-05 | NC | ND | NC | NE | NC |
| Acetone | 3.13E-03 | 6.13E-04 | NC | 1.00E-01 | NC | 6.13E-03 | NC |
| Acetonitrile | 1.51E-03 | 2.95E-04 | NC | 1.40E-02 | NC | 2.11E-02 | NC |
| Benzene | 7.16E-05 | 1.40E-05 | 3.80E-06 | 1.70E-03 | 2.90E-02 | 8.26E-03 | 1.10E-07 |
| Heptane | 1.84E-04 | 3.60E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.78E-04 | 3.48E-05 | NC | 2.30E-02 | NC | 1.51E-03 | NC |
| N-hexane | 1.92E-04 | 3.77E-05 | NC | 5.70E-02 | NC | 6.61E-04 | NC |
| Nonane | 9.98E-05 | 1.96E-05 | NC | ND | NC | NE | NC |
| Octane | 1.05E-04 | 2.05E-05 | NC | ND | NC | NE | NC |
| Toluene | 1.47E-05 | 2.87E-06 | NC | 1.10E-01 | NC | 2.61E-05 | NC |
| Ammonia | 9.20E-03 | 1.80E-03 | NC | 2.90E-02 | NC | 6.22E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 2.27E-04 | 4.45E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.49E-10 | 2.92E-11 | 7.90E-12 | 5.70E-04 | 5.30E-02 | 5.12E-08 | 4.19E-13 |
| Ethyl Butyl Ketone | 4.98E-10 | 9.77E-11 | NC | 2.30E-02 | NC | 4.25E-09 | NC |
| Methyl Chloride | 2.20E-11 | 4.31E-12 | 1.17E-12 | ND | 6.30E-03 | NE | 7.36E-15 |
| Tetrahydorfuran | 3.84E-11 | 7.53E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 9.99E-02** | **Risk = 5.78E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.6.11 Ex Situ No Separations Plant Emissions

| Emissions | Air Concentrations of Vitrification Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Aluminum | 2.68E-10 | 5.26E-11 | NC | ND | NC | NE | NC |
| Antimony | 1.03E-13 | 2.02E-14 | NC | | NC | NE | NC |
| Arsenic | 4.67E-14 | 9.14E-15 | 1.05E-11 | ND | 1.51E+01 | NE | 1.58E-10 |
| Boron | 6.75E-10 | 1.32E-10 | NC | 5.70E-03 | NC | 2.32E-08 | NC |
| Barium | 1.31E-13 | 2.56E-14 | NC | 1.43E-04 | NC | 1.79E-10 | NC |
| Beryllium | 5.54E-16 | 1.09E-16 | 2.64E-11 | ND | 8.40E+00 | NE | 2.22E-10 |
| Bismuth | 1.36E-11 | 2.66E-12 | NC | ND | NC | NE | NC |
| Cadmium | 5.84E-13 | 1.14E-13 | 2.17E-17 | ND | 6.30E+00 | NE | 1.36E-16 |
| Cerium | 1.31E-11 | 2.57E-12 | NC | ND | NC | NE | NC |
| Chromium (+3) | 9.13E-12 | 1.79E-12 | NC | 5.71E-07 | NC | 3.13E-06 | NC |
| Cobalt | 4.50E-14 | 8.82E-15 | NC | 2.90E-04 | NC | 3.04E-11 | NC |
| Copper | 5.44E-14 | 1.07E-14 | NC | ND | NC | NE | NC |
| Manganese | 7.45E-12 | 1.46E-12 | NC | ND | NC | NE | NC |
| Molybdenum | 4.67E-13 | 9.14E-14 | NC | ND | NC | NE | NC |
| Nickel | 9.80E-12 | 1.92E-12 | NC | ND | NC | NE | NC |
| Lead | 1.77E-12 | 3.47E-13 | NC | ND | NC | NE | NC |
| Selenium | 1.31E-13 | 2.57E-14 | NC | ND | NC | NE | NC |
| Silver | 1.22E-14 | 2.39E-15 | NC | ND | NC | NE | NC |
| Uranium | 7.52E-11 | 1.47E-11 | NC | ND | NC | NE | NC |
| Vanadium | 2.67E-15 | 5.23E-16 | NC | ND | NC | NE | NC |
| Zinc | 1.30E-13 | 2.55E-14 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 3.16E-06** | **Risk = 3.80E-10** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.6.12 Ex Situ No Separations Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 6.95E-08 | 4.34E-08 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 6.98E-09 | 4.36E-09 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 4.95E-10 | 3.09E-10 | 6.00E-11 | ND | 9.80E-01 | NE | 5.88E-11 |
| 2-Hexanone | 9.03E-09 | 5.64E-09 | NC | ND | NC | NE | NC |
| 2-Pentanone | 1.43E-08 | 8.91E-09 | NC | ND | NC | NE | NC |
| Acetone | 1.72E-07 | 1.08E-07 | NC | 1.00E-01 | NC | 1.08E-06 | NC |
| Acetonitrile | 8.29E-08 | 5.18E-08 | NC | 1.40E-02 | NC | 3.70E-06 | NC |
| Benzene | 3.94E-09 | 2.46E-09 | 4.78E-10 | 1.70E-03 | 2.90E-02 | 1.45E-06 | 1.39E-11 |
| Heptane | 1.01E-08 | 6.32E-09 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 9.77E-09 | 6.11E-09 | NC | 2.30E-02 | NC | 2.65E-07 | NC |
| N-hexane | 1.06E-08 | 6.61E-09 | NC | 5.70E-02 | NC | 1.16E-07 | NC |
| Nonane | 5.49E-09 | 3.43E-09 | NC | ND | NC | NE | NC |
| Octane | 5.76E-09 | 3.60E-09 | NC | ND | NC | NE | NC |
| Toluene | 8.07E-10 | 5.04E-10 | NC | 1.10E-01 | NC | 4.58E-09 | NC |
| Ammonia | 5.06E-07 | 3.16E-07 | NC | 2.90E-02 | NC | 1.09E-05 | NC |
| Phosphoric Acid, Tributyl Ester | 1.25E-08 | 7.81E-09 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 8.18E-15 | 5.11E-15 | 9.92E-16 | 5.70E-04 | 5.30E-02 | 8.97E-12 | 5.26E-17 |
| Ethyl Butyl Ketone | 2.74E-14 | 1.71E-14 | NC | 2.30E-02 | NC | 7.45E-13 | NC |
| Methyl Chloride | 1.21E-15 | 7.56E-16 | 1.47E-16 | ND | 6.30E-03 | NE | 9.24E-19 |
| Tetrahydrofuran | 2.11E-15 | 1.32E-15 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 1.75E-05** | **Risk = 7.26E-11** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.6.13 Ex Situ No Separations Evaporator Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Acetone | 8.97E-09 | 5.61E-09 | NC | 1.00E-01 | NC | 5.61E-08 | NC |
| Ammonia | 8.42E-09 | 5.27E-09 | NC | 2.90E-02 | NC | 1.82E-07 | NC |
| n-Butyl Alcohol | 6.75E-08 | 4.22E-08 | NC | 1.00E-01 | NC | 4.22E-07 | NC |
| 2-Hexanone | 3.23E-11 | 2.02E-11 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 6.12E-10 | 3.83E-10 | NC | 2.30E-02 | NC | 1.66E-08 | NC |
| | | | | | | HI = 6.76E-07 | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

### D.4.6.2.5 Risk Characterization

**MEI Worker**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm and retrieval operations are summarized in Tables D.4.6.6 and D.4.5.7, respectively. The total HI and cancer risk from routine tank farm emissions and retrieval emissions are 3.08E-01 and 1.90E-06, respectively.

**MEI Noninvolved Worker**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm, the evaporator, retrieval operation, and the vitrification facility are summarized in Tables D.4.6.8, D.4.6.9, D.4.6.10 and D.4.6.11, respectively. The total HI and cancer risk from combined tank farm, evaporator, retrieval, and plant emissions are 1.33E-01 and 8.22E-07, respectively.

**MEI General Public**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm, evaporator, retrieval operations, and the vitrification facility are summarized in Tables D.4.6.12, D.4.6.13, D.4.6.14 and D.4.6.15, respectively. The total HI and cancer risk from combined tank farm, evaporator, retrieval, and plant emissions are 7.34E-05 and 4.29E-10, respectively.

Table D.4.6.14 Ex Situ No Separations Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kd-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kd-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg-day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 2.08E-07 | 1.30E-07 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 2.10E-08 | 1.31E-08 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 1.48E-09 | 9.27E-10 | 1.42E-10 | ND | 9.80E-01 | NE | 1.40E-10 |
| 2-Hexanone | 2.71E-08 | 1.69E-08 | NC | ND | NC | NE | NC |
| 2-Pentanone | 4.28E-08 | 2.67E-08 | NC | ND | NC | NE | NC |
| Acetone | 5.16E-07 | 3.23E-07 | NC | 1.00E-01 | NC | 3.23E-06 | NC |
| Acetonitrile | 2.49E-07 | 1.55E-07 | NC | 1.40E-02 | NC | 1.11E-05 | NC |
| Benzene | 1.18E-08 | 7.39E-09 | 1.13E-09 | 1.70E-03 | 2.90E-02 | 4.35E-06 | 3.29E-11 |
| Heptane | 3.03E-08 | 1.90E-08 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 2.93E-08 | 1.83E-08 | NC | 2.30E-02 | NC | 7.96E-07 | NC |
| N-hexane | 3.17E-08 | 1.98E-08 | NC | 5.70E-02 | NC | 3.48E-07 | NC |
| Nonane | 1.65E-08 | 1.03E-08 | NC | ND | NC | NE | NC |
| Octane | 1.73E-08 | 1.08E-08 | NC | ND | NC | NE | NC |
| Toluene | 2.42E-09 | 1.51E-09 | NC | 1.10E-01 | NC | 1.38E-08 | NC |
| Ammonia | 1.52E-06 | 9.49E-07 | NC | 2.90E-02 | NC | 3.27E-05 | NC |
| Phosphoric Acid, Tributyl Ester | 3.75E-08 | 2.34E-08 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 2.45E-14 | 1.53E-14 | 2.36E-15 | 5.70E-04 | 5.30E-02 | 2.69E-11 | 1.25E-16 |
| Ethyl Butyl Ketone | 8.22E-14 | 5.14E-14 | NC | 2.30E-02 | NC | 2.24E-12 | NC |
| Methyl Chloride | 3.63E-15 | 2.27E-15 | 3.48E-16 | ND | 6.30E-03 | NE | 2.20E-18 |
| Tetrahydrofuran | 6.34E-15 | 3.96E-15 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 5.26E-05** | **Risk = 1.73E-10** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.6.15 Ex Situ No Separations Plant Emissions

| Emissions | Air Concentrations of Vitrification Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Aluminum | 7.12E-11 | 4.45E-11 | NC | ND | NC | NE | NC |
| Antimony | 2.74E-14 | 1.71E-14 | NC | ND | NC | NE | NC |
| Arsenic | 1.24E-14 | 7.74E-15 | 5.05E-12 | ND | 1.51E+01 | NE | 7.63E-11 |
| Boron | 1.79E-10 | 1.12E-10 | NC | 5.70E-03 | NC | 1.96E-08 | NC |
| Barium | 3.47E-14 | 2.17E-14 | NC | 1.43E-04 | NC | 1.52E-10 | NC |
| Beryllium | 1.47E-16 | 9.19E-17 | 1.27E-11 | ND | 8.40E+00 | NE | 1.07E-10 |
| Bismuth | 3.60E-12 | 2.25E-12 | NC | ND | NC | NE | NC |
| Cadmium | 1.55E-13 | 9.69E-14 | 1.04E-17 | ND | 6.30E+00 | NE | 6.57E-17 |
| Cerium | 3.48E-12 | 2.17E-12 | NC | ND | NC | NE | NC |
| Chromium (+3) | 2.42E-12 | 1.52E-12 | NC | 5.71E-07 | NC | 2.65E-06 | NC |
| Cobalt | 1.19E-14 | 7.46E-15 | NC | 2.90E-04 | NC | 2.57E-11 | NC |
| Copper | 1.44E-14 | 9.02E-15 | NC | ND | NC | NE | NC |
| Manganese | 1.98E-12 | 1.24E-12 | NC | ND | NC | NE | NC |
| Molybdenum | 1.24E-13 | 7.74E-14 | NC | ND | NC | NE | NC |
| Nickel | 2.60E-12 | 1.63E-12 | NC | ND | NC | NE | NC |
| Lead | 4.71E-13 | 2.94E-13 | NC | ND | NC | NE | NC |
| Selenium | 3.48E-14 | 2.18E-14 | NC | ND | NC | NE | NC |
| Silver | 3.24E-15 | 2.03E-15 | NC | ND | NC | NE | NC |
| Uranium | 2.00E-11 | 1.25E-11 | NC | ND | NC | NE | NC |
| Vanadium | 7.09E-16 | 4.43E-16 | NC | ND | NC | NE | NC |
| Zinc | 3.46E-14 | 2.16E-14 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 2.67E-06** | **Risk = 1.83E-10** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

### D.4.6.3 Calcination Subalternative

Calcining the tank waste rather than vitrifying it is a subalternative to the Ex Situ No Separations alternative as out lined in Volume Two, Appendix B of the EIS.

The radiological and toxicological risk for this subalternative was based on the air emissions and direct exposure from construction, continued operations (including tank farm and evaporator operations), retrieval, treatment (vitrification or calcination), storage and disposal, onsite transportation of waste, monitoring and maintenance, and closure and monitoring. There would be no pretreatment (separations); therefore, there would be no risk from pretreatment.

#### D.4.6.3.1 Radiological Risk

The LCF risk to workers, noninvolved workers, and general public could result from direct exposure and atmospheric emissions from the components associated with this alternative. The risk was determined by analyzing the radiological source term, the transport mechanism, exposure, and the risk associated with the exposure as discussed in the following subsections.

**Source Term**

The source term used for the noninvolved worker and general public was the atmospheric radiological emissions presented in Table D.4.6.1 (WHC 1995c and Jacobs 1996). The workers would receive a combined dose from the air emissions and from direct exposure from radiation fields in the work place.

**Transport**

The atmospheric transport parameters are presented in Table D.4.6.2.

**Exposure**

The radiological exposure for the Ex Situ No Separations (Calcination) alternative is presented in Table D.4.6.16. The table shows the exposure each receptor would receive from every component. The sum of the components are shown in the last column for each population and MEI receptor except for the MEI worker. The MEI worker is not summed, but is represented by the component with the highest MEI dose.

Exposure to the worker population and MEI worker was previously calculated in Section D.4.6.1.3. The noninvolved workers and general public exposures from inhalation of the atmospheric emissions (source term) were converted to a radiological dose in rem using the GENII computer code and applying the appropriate Chi/Q.

**Risk**

The LCFs are calculated as the product of the estimated dose times the dose-to-risk conversion factor (Section D.2.2.4). The sum of the radiological dose from construction, continued operations, treatment, and closure, for each receptor shown in the combined dose column in Table D.4.6.17, was multiplied by the appropriate dose-to-risk conversion factor to produce the LCF risk.

Table D.4.6.16 Summary of Anticipated Radiological Exposure for the No Separations (Calcination) Alternative

| | Radiological Dose (person-rem)[2] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Receptor | Construction (19 yrs) | Continued Operations [1] (23 yrs) | Retrieval (17 yrs) | Treatment (Calcination) (14 yrs) | Transpor-tation (20 yrs) | Monitoring and Maintenance (50 yrs) | Post Closure Monitoring (100 yrs) | Total |
| Worker - Population | 1.10E+01 | 2.81E+02 | 4.20E+03 | 3.78E+02 | N/A | 7.56E+00 | 1.13E+01 | 4.89E+03 |
| Worker - MEI[3, 4] | 2.50E+00 | 1.20E+01 | 9.50E+00 | 7.00E+00 | N/A | 1.50E+01 | 1.50E+01 | 1.50E+01 |
| Noninvolved Worker - Population | 0.00E+00 | 1.51E-03 | 6.70E-03 | 9.00E-01 | 1.06E+00 | 0.00E+00 | 0.00E+00 | 1.97E+00 |
| Noninvolved Worker - MEI | 0.00E+00 | 7.08E-05 | 1.70E-03 | 5.20E-04 | N/A | 0.00E+00 | 0.00E+00 | 1.70E-03 |
| General Public - Population | 0.00E+00 | 7.40E-02 | 1.70E+00 | 2.20E+02 | 2.96E-01 | 0.00E+00 | 0.00E+00 | 2.22E+02 |
| General Public - MEI | 0.00E+00 | 2.02E-06 | 5.50E-05 | 4.80E-03 | N/A | 0.00E+00 | 0.00E+00 | 4.80E-03 |

Notes:
[1] Continued operations include tank farm and Evaporator 1.
[2] MEI receptor dose is noted in rem.
[3] Worker MEI is assumed to work for 30 years.
[4] Total for the MEI represents the highest single exposure.

Table D.4.6.17 Summary of Anticipated Risk for the Ex Situ No Separations Alternative (Calcination)

| Receptor | Combined dose (person-rem) [1] | LCF/rem | LCF Risk |
|---|---|---|---|
| Worker - Population | 4.89E+03 | 4.00E-04 | 1.96E+00 |
| Worker - MEI | 1.50E+01 | 4.0E-04 | 6.00E-03 |
| Noninvolved Worker - Population | 1.97E+00 | 4.0E-04 | 7.88E-04 |
| Noninvolved Worker - MEI | 1.70E-03 | 4.0E-04 | 6.80E-07 |
| General Public - Population | 2.22E+02 | 5.0E-04 | 1.11E-01 |
| General Public - MEI | 4.80E-03 | 5.0E-04 | 2.40E-06 |

Notes:
[1] MEI receptor doses are noted in rem.
LCF = Latent cancer fatality

## D.4.7 EX SITU EXTENSIVE SEPARATIONS ALTERNATIVE

This section presents the anticipated remediation risk associated with the Ex Situ Extensive Separations alternative for tank waste, as outlined in Volume Two, Appendix B of the EIS.

The radiological and toxicological risk for this alternative was based on the air emissions and direct exposure from construction, continued operations (including tank farm and evaporator operations), retrieval, separations and treatment, onsite transportation of waste, monitoring and maintenance, and closure and monitoring.

### D.4.7.1 Radiological Risk

The LCF risk to the workers, noninvolved workers, and general public could result from direct exposure and atmospheric emissions from the components associated with this alternative. The risk was determined by analyzing the radiological source term, the transport mechanism, exposure, and the risk associated with the exposure as discussed in the following subsections.

#### D.4.7.1.1 Source Term

The source term used for the noninvolved worker and general public was the atmospheric radiological emissions presented in Table D.4.7.1 (WHC 1995e and Jacobs 1996). The workers would receive a combined dose from the air emissions and from direct exposure from radiation fields in the work place.

#### D.4.7.1.2 Transport

The atmospheric transport parameters of the Ex Situ Extensive Separations alternative are presented in Table D.4.7.2. The tank farm and retrieval atmospheric radiological operating emissions were modeled as a ground release and the evaporator and the separations and vitrification were modeled as an elevated release. For modeling purposes, it was assumed that the source term would be released at a point in the 200 Areas represented by the meteorological conditions at the Hanford Meteorological Station. The analysis used the Hanford Meteorological Station joint frequency data from Table D.2.2.1 and Figure D.2.2.1.

For ground releases, dispersion in the atmosphere would cause contaminant air concentrations and exposures to decrease with increasing distance from the source. Maximum individual exposures therefore would occur at the inner boundaries (i.e., closest distance to the source) of the defined receptor occupancy zones. For the noninvolved worker, the maximum exposure would occur 100 m (330 ft) from the source (in an east-southeast direction). For the general public, the maximum exposure would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the center of the 200 East Area).

Table D.4.7.1 Atmospheric Radiological Emissions for the Ex Situ Extensive Separations Alternative

| Continued Operations | | | | Retrieval Emissions | | Separation and Vitrification Emissions | |
|---|---|---|---|---|---|---|---|
| Tank Farm Emissions | | Evaporator Emissions | | | | | |
| Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released |
| Total Alpha[1] | 2.88E-08 | Total Alpha[1] | 2.10E-05 | Sr-90 | 5.95E-04 | Am-241 | 2.74E-03 |
| Total Beta[2] | 7.91E-07 | Total Beta[2] | 1.20E-05 | Cs-137 | 2.30E-03 | C-14 | 2.81E+02 |
| Cs-137 | 5.38E-05 | | | I-129 | 4.60E-03 | Cs-137 | 8.94E-01 |
| I-129 | 4.60E-05 | | | | | I-129 | 2.00E+00 |
| Sr-90 | 1.81E-05 | | | | | Pu-239 | 8.42E-04 |
| | | | | | | Ru-106 | 1.00E-09 |
| | | | | | | Sr-90 | 1.42E+00 |
| | | | | | | Tc-99 | 8.42E-04 |
| | | | | | | Zr-93 | 1.05E-04 |

Notes:
[1] Total alpha is assumed to be Pu-239.
[2] Total beta is assumed to be Sr-90.

Table D.4.7.2 Atmospheric Transport Parameters for the Ex Situ Extensive Separations Alternative

| Transport Parameters | Continued Operations | | Retrieval | Separation and Vitrification |
|---|---|---|---|---|
| | Tank Farms | Evaporator 1 | | |
| Stack height in m (ft) | Ground | 6.70 (22) | Ground | 55 (180) |
| Stack radius in m (ft) | N/A | 0.53 (1.7) | N/A | .88 (2.9) |
| Stack flow rate in $m^3$/sec ($ft^3$/sec) | N/A | 10 (353) | N/A | 33 (1,165) |
| Stack temperature in °C (°F) | N/A | 46 (117) | N/A | 160 (320) |
| Noninvolved worker MEI location in m (ft) ESE | 100 (328) | 200 (656) | 100 (328) | 800 (2,625) |
| Public MEI location in km (mi) ESE | 22 (14) | 22 (14) | 22 (14) | 22 (14) |
| Chi/Q for noninvolved worker - population in $s/m^3$ | 1.60E-03 | 4.00E-04 | 1.60E-03 | 5.00E-05 |
| Chi/Q for noninvolved worker - MEI in $s/m^3$ | 4.00E-04 | 2.50E-06 | 4.00E-04 | 2.90E-08 |
| Chi/Q for general public - population in $s/m^3$ | 2.90E-03 | 1.60E-03 | 2.90E-03 | 5.00E-04 |
| Chi/Q for general public - MEI in $s/m^3$ | 6.60E-08 | 3.90E-08 | 6.60E-08 | 7.70E-09 |

Notes:
ESE = East-southeast

The calculated Chi/Q values for ground releases from the tank farms were calculated by the GENII computer code to be 4.0E-04 sec/$m^3$ for the noninvolved worker MEI and 6.60E-08 sec/$m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 1.60E-03 sec/$m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 2.90E-03 sec/$m^3$.

For elevated releases (stack releases), the maximum exposure would not necessarily occur at the closest distance to the source. Air transport modeling indicates that the maximum exposure for the noninvolved worker would occur 200 m (660 ft) from the source (in an east-southeast direction) for the evaporator and 800 m (2,600 ft) for separations and vitrification. The maximum exposure for a member of the general public would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the 200 East Area).

The calculated Chi/Q values for the evaporator operation were 2.50E-06 sec/$m^3$ for the noninvolved worker MEI and 3.90E-08 sec/$m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 4.0E-04 sec/$m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 1.60E-03 sec/$m^3$. For the separations and vitrification operation, the Chi/Q values were 2.90E-08 sec/$m^3$ for the noninvolved worker MEI, 7.70E-09 sec/$m^3$ for the general public MEI, 5.00E-05 sec/$m^3$ for the noninvolved worker population, and 5.00E-04 sec/$m^3$ for the general public population.

D.4.7.1.3 Exposure

The radiological exposure for the alternative is presented in Table D.4.7.3. The table shows the exposure each receptor would receive from every component. The sum of the components are shown in the last column for each population and MEI receptor except for the MEI worker. The MEI worker is not summed but is represented by the component with the highest MEI dose.

The worker population dose is dependent on the number of people in the population and the anticipated dose each individual would receive. These data were obtained from the Site maintenance and operations contractor and the TWRS EIS contractor (WHC 1995e and Jacobs 1996). The calculations for the worker exposures from construction, continued operations, retrieval, separations and treatment, monitoring and maintenance, and closure are as follows:

Construction = (8.02E+02 person-yr) · (1.40E-02 rem/person-yr) = 1.12E+01 person-rem

Continued Operations -
Tank farms = (1.24E+04 person-yr) · (1.40E-02 rem/person-yr) = 1.74E+02 person-rem
Evaporator = (6.40E+02 person-yr) · (2.00E-01 rem/person-yr) = 1.28E+02 person-rem
Total = 3.02E+02 person-rem

Table D.4.7.3 Summary of Anticipated Radiological Exposure for the Ex Situ Extensive Separations Alternative

| Radiological Dose (person-rem) [2] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Receptor | Construction (18 yrs) | Continued Operations [1] (26 yrs) | Retrieval (20 yrs) | Separations and Treatment (19 yrs) | Transportation (3 yrs) | Monitoring and Maintenance (50 yrs) | Post Closure Monitoring (100 yrs) | Total |
| Worker - Population | 1.12E+01 | 3.02E+02 | 4.42E+03 | 3.26E+03 | N/A | 8.40E-01 | 1.54E+01 | 8.01E+03 |
| Worker - MEI [3, 4] | 1.00E+01 | 1.50E+01 | 1.15E+01 | 1.05E+01 | N/A | 8.00E+00 | 1.50E+01 | 1.50E+01 |
| Noninvolved Worker - Population | 0.00E+00 | 1.59E-03 | 8.10E-03 | 7.40E-01 | 1.06E+00 | 0.00E+00 | 0.00E+00 | 1.81E+00 |
| Noninvolved Worker - MEI | 0:00E+00 | 1.66E-04 | 2.10E-03 | 4.20E-04 | N/A | 0.00E+00 | 0.00E+00 | 2.10E-03 |
| General Public - Population | 0.00E+00 | 8.10E-02 | 2.10E+00 | 2.50E+02 | 2.96E-01 | 0.00E+00 | 0.00E+00 | 2.53E+02 |
| General Public - MEI | 0.00E+00 | 2.20E-06 | 6.70E-05 | 5.50E-03 | N/A | 0.00E+00 | 0.00E+00 | 5.50E-03 |

Notes:
[1] Continued operations include tank farm and Evaporator 1.
[2] MEI receptor dose is noted in rem.
[3] Worker MEI is assumed to work for 30 years.
[4] Total for the MEI represents the highest single exposure.

Retrieval = (2.21E+04 person-yr) · (2.00E-01 rem/person-yr) = 4.42E+03 person-rem

Separation/Treatment = (1.63E+04 person-yr) · (2.00E-01 rem/person-yr) = 3.26E+03 person-rem

Monitoring/Maintenance = (6.00E+01 person-yr) · (1.40E-02 rem/person-yr) = 8.40E-01 person-rem

Closure -
Closure = (2.81E+02 person-yr) · (1.40E-02 rem/person-yr) = 3.93E+00 person-rem
Monitoring = (8.20E+02 person-yr) · (1.40E-02 rem/person-yr) = 1.15E+01 person-rem
Total = 1.54E+01 person-rem

The MEI worker was assumed to receive a dose of 500 mrem (5.00E-01 rem) per year for a maximum of 30 years.

The noninvolved workers and general public exposures from inhalation of the atmospheric emissions (source term) were converted to a radiological dose in rem using the GENII computer code and applying the appropriate Chi/Q.

D.4.7.1.4 Risk

Latent cancer fatalities are calculated as the product of the estimated dose times the dose-to-risk conversion factor (Section D.2.2.4). The sum of the radiological dose from construction, continued operations, treatment, and closure, for each receptor shown in the combined dose column in Table D.4.7.4, was multiplied by the appropriate dose-to-risk conversion factor to produce the LCF risk.

Table D.4.7.4 Summary of Anticipated Risk for the Ex Situ Extensive Separations Alternative

| Receptor | Combined Dose (person-rem) [1] | LCF/rem | LCF Risk |
|---|---|---|---|
| Worker - Population | 8.01E+03 | 4.00E-04 | 3.20E+00 |
| Worker - MEI | 1.50E+01 | 4.00E-04 | 6.00E-03 |
| Noninvolved Worker - Population | 1.81E+00 | 4.00E-04 | 7.24E-04 |
| Noninvolved Worker - MEI | 2.10E-03 | 4.00E-04 | 8.40E-07 |
| General Public - Population | 2.53E+02 | 5.00E-04 | 1.26E-01 |
| General Public - MEI | 5.50E-03 | 5.00E-04 | 2.75E-06 |

Notes:
[1] MEI receptor dose is noted in rem.
LCF = Latent cancer fatality

### D.4.7.2 Chemical Exposure

Potential carcinogenic risk and noncarcinogenic health hazards may result from exposure to volatile emissions from the tank farm, tank waste retrieval, and the evaporator, and exposure to particulate emissions from the separation and vitrification of HLW and LAW for the worker, noninvolved worker, and general public. Potential carcinogenic risk and noncarcinogenic health hazards were estimated using the chemical source term, transport mechanism, exposure, and toxicological criteria as discussed in the following subsections.

D.4.7.2.1 Source Term

Operating air emissions from the tank farm area, tank waste retrieval, the evaporator and vitrification facilities are presented in Table D.4.7.5 (WHC 1995e and Jacobs 1996). The emission rates from the HLW and LAW vitrification facilities were combined and treated as a single-source emission.
The noninvolved worker and general public would be exposed to combined emissions from the tank farm area, tank waste retrieval operations, evaporator, and vitrification facilities. The worker would only be exposed to emissions (ground-level release) from the tank farm area and retrieval Operations because emissions from the evaporator and vitrification facilities occur through a stack-release and would not impact the onsite worker.

**Table D.4.7.5 Chemical Emissions for the Ex Situ Extensive Separations Alternative**

| Tank Farm Emissions | | Retrieval Emissions | | Evaporator Emissions | | Separations/Vitrification Emissions | |
|---|---|---|---|---|---|---|---|
| Emissions | Total Tank Farm Emission Rate (mg/sec) | Emissions | Retrieval Emission Rate (mg/sec) | Emissions | Evaporator Emission Rate (mg/sec) | Emissions | Plant Emission Rate (mg/sec) |
| Carbon Monoxide | 1.05E+00 | Carbon Monoxide | 3.16E+00 | Acetone | 2.30E-01 | Aluminum | 1.54E-02 |
| Nitrogen Oxide | 1.06E-01 | Nitrogen Oxide | 3.17E-01 | Ammonia | 2.16E-01 | Arsenic | 1.67E-06 |
| 1,3-Butadiene | 7.49E-03 | 1,3-Butadiene | 2.25E-02 | n-Butyl Alcohol | 1.73E+00 | Boron | 6.35E-04 |
| 2-Hexanone | 1.37E-01 | 2-Hexanone | 4.10E-01 | 2-Hexanone | 8.28E-04 | Barium | 4.73E-06 |
| 2-Pentanone | 2.16E-01 | 2-Pentanone | 6.48E-01 | Methyl Isobutyl Ketone | 1.57E-02 | Beryllium | 1.24E-07 |
| Acetone | 2.61E+00 | Acetone | 7.82E+00 | | | Bismuth | 3.04E-04 |
| Acetonitrile | 1.26E+00 | Acetonitrile | 3.77E+00 | | | Cadmium | 1.22E-05 |
| Benzene | 5.97E-02 | Benzene | 1.79E-01 | | | Cerium | 2.77E-04 |
| Heptane | 1.53E-01 | Heptane | 4.60E-01 | | | Chromium (+3) | 2.48E-04 |
| Methyl N-amyl Ketone | 1.48E-01 | Methyl N-amyl Ketone | 4.44E-01 | | | Copper | 1.11E-06 |
| N-hexane | 1.60E-01 | N-hexane | 4.80E-01 | | | Manganese | 1.72E-04 |
| Nonane | 8.32E-02 | Nonane | 2.50E-01 | | | Molybdenum | 7.81E-06 |
| Octane | 8.73E-02 | Octane | 2.62E-01 | | | Nickel | 2.07E-04 |
| Toluene | 1.22E-02 | Toluene | 3.67E-02 | | | Lead | 6.56E-06 |
| Ammonia | 7.67E+00 | Ammonia | 2.30E+01 | | | Silver | 1.03E-06 |
| Phosphoric Acid, Tributyl Ester | 1.89E-01 | Phosphoric Acid, Tributyl Ester | 5.68E-01 | | | Uranium | 1.72E-03 |
| Carbon Tetrachloride | 1.24E-07 | Carbon Tetrachloride | 3.72E-07 | | | Vanadium | 3.06E-07 |
| Ethyl Butyl Ketone | 4.15E-07 | Ethyl Butyl Ketone | 1.25E-06 | | | Zinc | 6.15E-06 |
| Methyl Chloride | 1.83E-08 | Methyl Chloride | 5.50E-08 | | | | |
| Tetrahydrofuran | 3.20E-08 | Tetrahydrofuran | 9.61E-08 | | | | |

D.4.7.2.2 Transport

The tank farm chemical operating emissions (routine emissions from the tank farm and emissions during retrieval) were modeled as a ground release. Chemical operating emissions from the evaporator and vitrification facilities would occur from stack releases and were modeled as elevated releases. Transport parameters, location of the MEI noninvolved worker and MEI general public, and Chi/Q values for the MEI noninvolved worker and general public are identical to the radiological parameters presented in Table D.4.7.2.

The MEI worker was evaluated using a simplified "box" model, as presented in detail in Section D.2.2.3. The estimated Chi/Q value for the MEI worker was 9.26E-04 sec/$m^3$.

D.4.7.2.3 Exposure

Worker

The MEI worker was assumed to be located within a box placed directly over the tank farm area. Exposure point concentrations of chemical emissions (mg/$m^3$) from the tank farm area and retrieval operations were estimated by multiplying the cumulative tank farm emission rate (mg/sec) and retrieval operation emission rate (mg/sec) by the MEI worker Chi/Q value (9.26E-04 sec/$m^3$), respectively. Exposure point concentrations for each volatile chemical emitted from the tank farm area and during retrieval are summarized in Tables D.4.7.6 and D.4.7.7, respectively.

Chemical intake (dose) was estimated for the MEI Worker using the same equation and exposure parameters defined in Section D.2.2.3.1. Estimated intakes of chemical emissions from the tank farm and retrieval operations for the MEI worker are presented in Tables D.4.7.6 and D.4.7.7, respectively.

Noninvolved Worker

The MEI noninvolved worker was assumed to be located at the point where maximum downwind air concentrations were calculated (100 m [330 ft] from the tank farm and 200 m [660 ft] from the evaporator). Exposure point concentrations (mg/$m^3$) of chemical emissions from the tank farm, retrieval operations, evaporator, and vitrification facilities were estimated by multiplying the cumulative tank farm, retrieval, evaporator and plant emission rates (mg/sec) by their respective MEI noninvolved worker Chi/Q values (4.0E-04 sec/$m^3$ for the tank farm, 2.50E-06 sec/$m^3$ for the evaporator, 4.0E-04 sec/$m^3$ for retrieval, and 2.90E-08 sec/$m^3$ for the vitrification facility). Exposure point concentrations for each chemical emitted from the tank farm area, the evaporator, retrieval operations, and the vitrification facility are summarized in Tables D.4.7.8, D.4.7.9, D.4.7.10 and D.4.7.11, respectively.

Table D.4.7.6 Ex Situ Extensive Separations Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 9.75E-04 | 1.91E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 9.80E-05 | 1.92E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 6.94E-06 | 1.36E-06 | 5.82E-07 | ND | 9.80E-01 | NE | 5.71E-07 |
| 2-Hexanone | 1.27E-04 | 2.48E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.00E-04 | 3.92E-05 | NC | ND | NC | NE | NC |
| Acetone | 2.41E-03 | 4.73E-04 | NC | 1.00E-01 | NC | 4.73E-03 | NC |
| Acetonitrile | 1.16E-03 | 2.28E-04 | NC | 1.40E-02 | NC | 1.63E-03 | NC |
| Benzene | 5.53E-05 | 1.08E-05 | 4.64E-06 | 1.70E-03 | 2.90E-02 | 6.37E-03 | 1.34E-07 |
| Heptane | 1.42E-04 | 2.78E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.37E-04 | 2.69E-05 | NC | 2.30E-02 | NC | 1.17E-03 | NC |
| N-hexane | 1.48E-04 | 2.91E-05 | NC | 5.70E-02 | NC | 5.10E-04 | NC |
| Nonane | 7.70E-05 | 1.51E-05 | NC | ND | NC | NE | NC |
| Octane | 8.08E-05 | 1.58E-05 | NC | ND | NC | NE | NC |
| Toluene | 1.13E-05 | 2.22E-06 | NC | 1.10E-01 | NC | 2.02E-05 | NC |
| Ammonia | 7.10E-03 | 1.39E-03 | NC | 2.90E-02 | NC | 4.80E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 1.75E-04 | 3.43E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.15E-10 | 2.25E-11 | 9.63E-12 | 5.70E-04 | 5.30E-02 | 3.95E-08 | 5.11E-13 |
| Ethyl Butyl Ketone | 3.85E-10 | 7.54E-11 | NC | 2.30E-02 | NC | 3.28E-09 | NC |
| Methyl Chloride | 1.70E-11 | 3.33E-12 | 1.42E-12 | ND | 6.30E-03 | NE | 8.97E-15 |
| Tetrahydrofuran | 2.97E-11 | 5.81E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 7.71E-02** | **Risk = 7.05E-07** |

Notes:
NC = Noncarcinogen
ND = No data published
NE = Not evaluated

Table D.4.7.7 Ex Situ Extensive Separations Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_I$) (mg/kg-day) | Inhalation Slope Factor ($SF_I$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 2.92E-03 | 5.73E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 2.94E-04 | 5.76E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 2.08E-05 | 4.08E-06 | 1.34E-06 | ND | 9.80E-01 | NE | 1.31E-06 |
| 2-Hexanone | 3.80E-04 | 7.45E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 6.00E-04 | 1.18E-04 | NC | ND | NC | NE | NC |
| Acetone | 7.24E-03 | 1.42E-03 | NC | 1.00E-01 | NC | 1.42E-02 | NC |
| Acetonitrile | 3.49E-03 | 6.84E-04 | NC | 1.40E-02 | NC | 4.88E-02 | NC |
| Benzene | 1.66E-04 | 3.25E-05 | 1.07E-05 | 1.70E-03 | 2.90E-02 | 1.91E-02 | 3.09E-07 |
| Heptane | 4.26E-04 | 8.34E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 4.11E-04 | 8.06E-05 | NC | 2.30E-02 | NC | 3.50E-03 | NC |
| N-hexane | 4.45E-04 | 8.72E-05 | NC | 5.70E-02 | NC | 1.53E-03 | NC |
| Nonane | 2.31E-04 | 4.53E-05 | NC | ND | NC | NE | NC |
| Octane | 2.42E-04 | 4.75E-05 | NC | ND | NC | NE | NC |
| Toluene | 3.40E-05 | 6.66E-06 | NC | 1.10E-01 | NC | 6.05E-05 | NC |
| Ammonia | 2.13E-02 | 4.18E-03 | NC | 2.90E-02 | NC | 1.44E-01 | NC |
| Phosphoric Acid, Tributyl Ester | 5.26E-04 | 1.03E-04 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 3.44E-10 | 6.75E-11 | 2.21E-11 | 5.70E-04 | 5.30E-02 | 1.18E-07 | 1.17E-12 |
| Ethyl Butyl Ketone | 1.15E-09 | 2.26E-10 | NC | 2.30E-02 | NC | 9.83E-09 | NC |
| Methyl Chloride | 5.09E-11 | 9.98E-12 | 3.27E-12 | ND | 6.30E-03 | NE | 2.06E-14 |
| Tetrahydrofuran | 8.90E-11 | 1.74E-11 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 2.31E-01** | **Risk = 1.62E-06** |

Notes:
NC = Noncarcinogen
ND = No data published
NE = Not evaluated

Table D.4.7.8 Ex Situ Extensive Separations Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 4.21E-04 | 8.25E-05 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 4.23E-05 | 8.30E-06 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 3.00E-06 | 5.88E-07 | 2.52E-07 | ND | 9.80E-01 | NE | 2.46E-07 |
| 2-Hexanone | 5.47E-05 | 1.07E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 8.64E-05 | 1.69E-05 | NC | ND | NC | NE | NC |
| Acetone | 1.04E-03 | 2.04E-04 | NC | 1.00E-01 | NC | 2.04E-03 | NC |
| Acetonitrile | 5.02E-04 | 9.84E-05 | NC | 1.40E-02 | NC | 7.03E-03 | NC |
| Benzene | 2.39E-05 | 4.68E-06 | 2.00E-06 | 1.70E-03 | 2.90E-02 | 2.75E-03 | 5.81E-08 |
| Heptane | 6.13E-05 | 1.20E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 5.92E-05 | 1.16E-05 | NC | 2.30E-02 | NC | 5.05E-04 | NC |
| N-hexane | 6.41E-05 | 1.26E-05 | NC | 5.70E-02 | NC | 2.20E-04 | NC |
| Nonane | 3.33E-05 | 6.52E-06 | NC | ND | NC | NE | NC |
| Octane | 3.49E-05 | 6.84E-06 | NC | ND | NC | NE | NC |
| Toluene | 4.89E-06 | 9.58E-07 | NC | 1.10E-01 | NC | 8.71E-06 | NC |
| Ammonia | 3.07E-03 | 6.01E-04 | NC | 2.90E-02 | NC | 2.07E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 7.57E-05 | 1.48E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 4.96E-11 | 9.72E-12 | 4.16E-12 | 5.70E-04 | 5.30E-02 | 1.71E-08 | 2.21E-13 |
| Ethyl Butyl Ketone | 1.66E-10 | 3.26E-11 | NC | 2.30E-02 | NC | 1.42E-09 | NC |
| Methyl Chloride | 7.33E-12 | 1.44E-12 | 6.15E-13 | ND | 6.30E-03 | NE | 3.88E-15 |
| Tetrahydorfuran | 1.28E-11 | 2.51E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 3.33E-02** | **Risk = 3.05E-07** |

Notes:
NC = Noncarcinogen
ND = No data published
NE = Not evaluated

Table D.4.7.9 Ex Situ Extensive Separations Evaporator Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Acetone | 5.75E-07 | 1.13E-07 | NC | 1.00E-01 | NC | 1.13E-06 | NC |
| Ammonia | 5.40E-07 | 1.06E-07 | NC | 2.90E-02 | NC | 3.65E-06 | NC |
| n-Butyl Alcohol | 4.33E-06 | 8.48E-07 | NC | 1.00E-01 | NC | 8.48E-06 | NC |
| 2-Hexanone | 2.07E-09 | 4.06E-10 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 3.93E-08 | 7.69E-09 | NC | 2.30E-02 | NC | 3.34E-07 | NC |
| | | | | | | HI = 1.36E-05 | |

Notes:
NC = Noncarcinogen
ND = No data published
NE = Not evaluated

Chemical intake (dose) was estimated for the MEI noninvolved worker according to the same equation and exposure parameters used for the MEI worker. Estimated operating chemical emission intakes for the MEI noninvolved worker are presented in Tables D.4.7.8, D.4.7.9, D.4.7.10 and D.4.7.11 for the tank farm area, the evaporator, retrieval operations, and the vitrification facility emissions, respectively.

### General Public

The MEI general public receptor was assumed to be located at the point where maximum air concentrations were calculated (approximately 22 km [14 mi] from both the tank farm area and evaporator). Exposure point concentrations ($mg/m^3$) of chemical emissions from the tank farm area, evaporator, retrieval operations, and the vitrification facility were estimated by multiplying the cumulative emission rates (mg/sec) of each source by their respective MEI general public Chi/Q values (6.60E-08 $sec/m^3$ for the tank farm, 3.90E-08 $sec/m^3$ for evaporator, 6.60E-08 $sec/m^3$ for retrieval operations, and 7.70E-09 $sec/m^3$ for the vitrification facility). Exposure point concentrations for each chemical emitted from the tank farm area, the evaporator, retrieval operations and the vitrification facility are summarized in Tables D.4.7.12, D.4.7.13, D.4.7.14 and D.4.7.15, respectively.

The residential or general public intake was calculated according to the equation and exposure parameters presented in Section D.2.2.3. Estimated chemical emission intakes for the MEI general public are presented in Tables D.4.7.12, D.4.7.13, D.4.7.14, and D.4.7.15 for the tank farm area, the evaporator, retrieval operations and the vitrification facility, respectively.

Table D.4.7.10 Ex Situ Extensive Separations Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 1.26E-03 | 2.48E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 1.27E-04 | 2.49E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 8.99E-06 | 1.76E-06 | 5.78E-07 | ND | 9.80E-01 | NE | 5.67E-07 |
| 2-Hexanone | 1.64E-04 | 3.22E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.59E-04 | 5.08E-05 | NC | ND | NC | NE | NC |
| Acetone | 3.13E-04 | 6.13E-04 | NC | 1.00E-01 | NC | 6.13E-03 | NC |
| Acetonitrile | 1.51E-03 | 2.95E-04 | NC | 1.40E-02 | NC | 2.11E-02 | NC |
| Benzene | 7.16E-05 | 1.40E-05 | 4.61E-06 | 1.70E-03 | 2.90E-02 | 8.26E-03 | 1.34E-07 |
| Heptane | 1.84E-04 | 3.60E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.78E-04 | 3.48E-05 | NC | 2.30E-02 | NC | 1.51E-03 | NC |
| N-hexane | 1.92E-04 | 3.77E-05 | NC | 5.70E-02 | NC | 6.61E-04 | NC |
| Nonane | 9.98E-05 | 1.96E-05 | NC | ND | NC | NE | NC |
| Octane | 1.05E-04 | 2.05E-05 | NC | ND | NC | NE | NC |
| Toluene | 1.47E-05 | 2.87E-06 | NC | 1.10E-01 | NC | 2.61E-05 | NC |
| Ammonia | 9.20E-03 | 1.80E-03 | NC | 2.90E-02 | NC | 6.22E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 2.27E-04 | 4.45E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.49E-10 | 2.92E-11 | 9.57E-12 | 5.70E-04 | 5.30E-02 | 5.12E-08 | 5.07E-13 |
| Ethyl Butyl Ketone | 4.98E-10 | 9.77E-11 | NC | 2.30E-02 | NC | 4.25E-09 | NC |
| Methyl Chloride | 2.20E-11 | 4.31E-12 | 1.41E-12 | ND | 6.30E-03 | NE | 8.91E-15 |
| Tetrahydorfuran | 3.84E-11 | 7.53E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 9.99E-02** | **Risk = 7.00E-07** |

Notes:
NC = Noncarcinogen
ND = No data published
NE = Not evaluated

Table D.4.7.11 Ex Situ Extensive Separations Plant Emissions

| Emissions | Air Concentrations of Vitrification Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RFD_I$) (mg/kg-day) | Inhalation Slope Factor ($SF_I$) $(mg/kg-day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Aluminum | 4.46E-10 | 8.75E-11 | NC | ND | NC | NE | NC |
| Arsenic | 4.83E-14 | 9.47E-15 | 2.62E-11 | ND | 1.51E+01 | NE | 3.96E-10 |
| Boron | 1.84E-11 | 3.61E-12 | NC | 5.70E-03 | NC | 6.34E-10 | NC |
| Barium | 1.37E-13 | 2.69E-14 | NC | 1.43E-04 | NC | 1.88E-10 | NC |
| Beryllium | 3.59E-15 | 7.04E-16 | 8.06E-15 | ND | 8.40E+00 | NE | 6.77E-14 |
| Bismuth | 8.83E-12 | 1.73E-12 | NC | ND | NC | NE | NC |
| Cadmium | 3.52E-13 | 6.91E-14 | 5.18E-13 | | 6.30E+00 | NE | 3.26E-12 |
| Cerium | 8.02E-12 | 1.57E-12 | NC | ND | NC | NE | NC |
| Chromium (+3) | 7.18E-12 | 1.41E-12 | NC | 5.71E-07 | NC | 2.47E-06 | NC |
| Copper | 3.23E-14 | 6.34E-15 | NC | ND | NC | NE | NC |
| Manganese | 5.00E-12 | 9.80E-13 | NC | ND | NC | NE | NC |
| Molybdenum | 2.27E-13 | 4.44E-14 | NC | ND | NC | NE | NC |
| Nickel | 6.01E-12 | 1.18E-12 | NC | ND | NC | NE | NC |
| Lead | 1.90E-13 | 3.73E-14 | NC | ND | NC | NE | NC |
| Silver | 2.99E-14 | 5.87E-15 | NC | ND | NC | NE | NC |
| Uranium | 5.00E-11 | 9.80E-12 | NC | ND | NC | NE | NC |
| Vanadium | 8.86E-15 | 1.74E-15 | NC | ND | NC | NE | NC |
| Zinc | 1.78E-13 | 3.49E-14 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 2.47E-06** | **Risk = 3.99E-10** |

Notes:
NC = Noncarcinogen
ND = No data published
NE = Not evaluated

Table D.4.7.12 Ex Situ Extensive Separations Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 6.95E-08 | 4.34E-08 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 6.98E-09 | 4.36E-09 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 4.95E-10 | 3.09E-10 | 7.50E-11 | ND | 9.80E-01 | NE | 7.35E-11 |
| 2-Hexanone | 9.03E-09 | 5.64E-09 | NC | ND | NC | NE | NC |
| 2-Pentanone | 1.43E-08 | 8.91E-09 | NC | ND | NC | NE | NC |
| Acetone | 1.72E-07 | 1.08E-07 | NC | 1.00E-01 | NC | 1.08E-06 | NC |
| Acetonitrile | 8.29E-08 | 5.18E-08 | NC | 1.40E-02 | NC | 3.70E-06 | NC |
| Benzene | 3.94E-09 | 2.46E-09 | 5.97E-10 | 1.70E-03 | 2.90E-02 | 1.45E-06 | 1.73E-11 |
| Heptane | 1.01E-08 | 6.32E-09 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 9.77E-09 | 6.11E-09 | NC | 2.30E-02 | NC | 2.65E-07 | NC |
| N-hexane | 1.06E-08 | 6.61E-09 | NC | 5.70E-02 | NC | 1.16E-07 | NC |
| Nonane | 5.49E-09 | 3.43E-09 | NC | ND | NC | NE | NC |
| Octane | 5.76E-09 | 3.60E-09 | NC | ND | NC | NE | NC |
| Toluene | 8.07E-10 | 5.04E-10 | NC | 1.10E-01 | NC | 4.58E-09 | NC |
| Ammonia | 5.06E-07 | 3.16E-07 | NC | 2.90E-02 | NC | 1.09E-05 | NC |
| Phosphoric Acid, Tributyl Ester | 1.25E-08 | 7.81E-09 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 8.18E-15 | 5.11E-15 | 1.24E-15 | 5.70E-04 | 5.30E-02 | 8.97E-12 | 6.57E-17 |
| Ethyl Butyl Ketone | 2.74E-14 | 1.71E-14 | NC | 2.30E-02 | NC | 7.45E-13 | NC |
| Methyl Chloride | 1.21E-15 | 7.56E-16 | 1.83E-16 | ND | 6.30E-03 | NE | 1.16E-18 |
| Tetrahydrofuran | 2.11E-15 | 1.32E-15 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 1.75E-05** | **Risk = 9.08E-11** |

Notes:
NC = Noncarcinogen
ND = No data published
NE = Not evaluated

Table D.4.7.13 Ex Situ Extensive Separations Evaporator Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Acetone | 8.97E-09 | 5.61E-09 | NC | 1.00E-01 | NC | 5.61E-08 | NC |
| Ammonia | 8.42E-09 | 5.27E-09 | NC | 2.90E-02 | NC | 1.82E-07 | NC |
| n-Butyl Alcohol | 6.75E-08 | 4.22E-08 | NC | 1.00E-01 | NC | 4.22E-07 | NC |
| 2-Hexanone | 3.23E-11 | 2.02E-11 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 6.12E-10 | 3.83E-10 | NC | 2.30E-02 | NC | 1.66E-08 | NC |
| | | | | | | HI = 6.76E-07 | |

Notes:
NC = Noncarcinogen
ND = No data published
NE = Not evaluated

D.4.7.2.4 Toxicity Assessment

Toxicity assessment was previously discussed in detail in Section D.4.1.2.4. Cancer slope factors, RfDs, and data sources for each volatile operating chemical emission are summarized in Table D.4.1.11.

D.4.7.2.5 Risk Characterization

**MEI Worker**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm and retrieval operations are summarized in Tables D.4.7.6 and D.4.7.7, respectively. The total HI and cancer risk from routine tank farm emissions and retrieval emissions are 3.08E-01 and 2.33E-06, respectively.

**MEI Noninvolved Worker**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm, evaporator, retrieval operations, and the vitrification facility are summarized in Tables D.4.7.8, D.4.7.9, D.4.7.10 and D.4.7.11, respectively. The total HI and cancer risk from combined tank farm, evaporator, retrieval, and plant emissions are 1.33E-01 and 1.01E-06, respectively.

Table D.4.7.14 Ex Situ Extensive Separations Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 2.08E-07 | 1.30E-07 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 2.10E-08 | 1.31E-08 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 1.48E-09 | 9.27E-10 | 1.72E-10 | ND | 9.80E-01 | NE | 1.69E-10 |
| 2-Hexanone | 2.71E-08 | 1.69E-08 | NC | ND | NC | NE | NC |
| 2-Pentanone | 4.28E-08 | 2.67E-08 | NC | ND | NC | NE | NC |
| Acetone | 5.16E-07 | 3.23E-07 | NC | 1.00E-01 | NC | 3.23E-06 | NC |
| Acetonitrile | 2.49E-07 | 1.55E-07 | NC | 1.40E-02 | NC | 1.11E-05 | NC |
| Benzene | 1.18E-08 | 7.39E-09 | 1.37E-09 | 1.70E-03 | 2.90E-02 | 4.35E-06 | 3.98E-11 |
| Heptane | 3.03E-08 | 1.90E-08 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 2.93E-08 | 1.83E-08 | NC | 2.30E-02 | NC | 7.96E-07 | NC |
| N-hexane | 3.17E-08 | 1.98E-08 | NC | 5.70E-02 | NC | 3.48E-07 | NC |
| Nonane | 1.65E-08 | 1.03E-08 | NC | ND | NC | NE | NC |
| Octane | 1.73E-08 | 1.08E-08 | NC | ND | NC | NE | NC |
| Toluene | 2.42E-09 | 1.51E-09 | NC | 1.10E-01 | NC | 1.38E-08 | NC |
| Ammonia | 1.52E-06 | 9.49E-07 | NC | 2.90E-02 | NC | 3.27E-05 | NC |
| Phosphoric Acid, Tributyl Ester | 3.75E-08 | 2.34E-08 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 2.45E-14 | 1.53E-14 | 2.85E-15 | 5.70E-04 | 5.30E-02 | 2.69E-11 | 1.51E-16 |
| Ethyl Butyl Ketone | 8.22E-14 | 5.14E-14 | NC | 2.30E-02 | NC | 2.24E-12 | NC |
| Methyl Chloride | 3.63E-15 | 2.27E-15 | 4.22E-16 | ND | 6.30E-03 | NE | 3.66E-18 |
| Tetrahydrofuran | 6.34E-15 | 3.96E-15 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 5.26E-05** | **Risk = 2.09E-10** |

Notes:
NC = Noncarcinogen
ND = No data published
NE = Not evaluated

Table D.4.7.15 Ex Situ Extensive Separations Plant Emissions

| Emissions | Air Concentrations of Vitrification Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Aluminum | 1.19E-10 | 7.41E-11 | NC | ND | NC | NE | NC |
| Arsenic | 1.28E-14 | 8.02E-15 | 1.26E-11 | ND | 1.51E+01 | NE | 1.90E-10 |
| Boron | 4.89E-12 | 3.06E-12 | NC | 5.70E-03 | NC | 5.36E-10 | NC |
| Barium | 3.65E-14 | 2.28E-14 | NC | 1.43E-04 | NC | 1.59E-10 | NC |
| Beryllium | 9.54E-16 | 5.96E-16 | 3.88E-15 | ND | 8.40E+00 | NE | 3.26E-14 |
| Bismuth | 2.34E-12 | 1.46E-12 | NC | ND | NC | NE | NC |
| Cadmium | 9.36E-14 | 5.58E-14 | 2.49E-13 | ND | 6.30E+00 | NE | 1.57E-12 |
| Cerium | 2.13E-12 | 1.33E-12 | NC | ND | NC | NE | NC |
| Chromium (+3) | 1.92E-12 | 1.19E-12 | NC | 5.71E-07 | NC | 2.09E-06 | NC |
| Copper | 8.58E-15 | 5.36E-15 | NC | ND | NC | NE | NC |
| Manganese | 1.33E-12 | 8.30E-13 | NC | ND | NC | NE | NC |
| Molybdenum | 6.02E-14 | 3.76E-14 | NC | ND | NC | NE | NC |
| Nickel | 1.60E-12 | 9.97E-13 | NC | ND | NC | NE | NC |
| Lead | 5.05E-14 | 3.16E-14 | NC | ND | NC | NE | NC |
| Silver | 7.95E-15 | 4.97E-15 | NC | ND | NC | NE | NC |
| Uranium | 1.33E-11 | 8.30E-12 | NC | ND | NC | NE | NC |
| Vanadium | 2.35E-15 | 1.47E-15 | NC | ND | NC | NE | NC |
| Zinc | 4.73E-14 | 2.96E-14 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 2.09E-06** | **Risk = 1.92E-10** |

Notes:
NC = Noncarcinogen
ND = No data published
NE = Not evaluated

**MEI General Public**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm, evaporator, retrieval operations, and the vitrification facility are summarized in Tables D.4.7.12, D.4.7.13, D.4.7.14 and D.4.7.15, respectively. The total HI and cancer risk from combined tank farm, evaporator, retrieval and plant emissions are 7.28E-05 and 4.92E-10, respectively.

## D.4.8 EX SITU/IN SITU COMBINATION 1 ALTERNATIVE

This section presents the anticipated remediation risk associated with the Ex Situ/In Situ Combination 1 alternative for tank waste, as outlined in Volume Two, Appendix B of the EIS.

The radiological and toxicological risk for this alternative was based on the air emissions and direct exposure from construction, continued operations (including tank farm and evaporator operations), retrieval, separations and treatment (including vitrification, evaporator, and gravel fill operations), onsite transportation of waste, storage and disposal, monitoring and maintenance, and closure and monitoring.

### D.4.8.1 Radiological Risk

The LCF risk to the workers, noninvolved workers, and general public could result from direct exposure and atmospheric emissions from the components associated with this alternative. The risk was determined by analyzing the radiological source term, the transport mechanism, exposure, and the risk associated with the exposure as discussed in the following subsections.

#### D.4.8.1.1 Source Term

The source term used for the noninvolved worker and general public was the atmospheric radiological emissions presented in Table D.4.8.1 (WHC 1995f, 1995j, and Jacobs 1996). The workers would receive a combined dose from the air emissions and from direct exposure from radiation fields in the work place.

#### D.4.8.1.2 Transport

The atmospheric transport parameters of the Ex Situ/In Situ Combination 1 alternative are presented in Table D.4.8.2. The tank farm and retrieval atmospheric radiological operating emissions were modeled as a ground release; the evaporator and the separations and vitrification were modeled as an elevated release. For modeling purposes, it was assumed that the source term would be released at a point in the 200 Areas represented by the meteorological conditions at the Hanford Meteorological Station. The analysis used the Hanford Meteorological Station joint frequency data from Table D.2.2.1 and Figure D.2.2.1.

Table D.4.8.1 Atmospheric Radiological Emissions for the Ex Situ/In Situ Combination 1 Alternative

| Continued Operations | | | | Treatment (gravel fill) | | | | Retrieval Emissions [2] | | Separation and Vitrification Emissions [4] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tank Farm Emissions [1] | | Evaporator Emissions[1] | | Evaporator Emissions | | Gravel and Fill Emissions [3] | | | | | |
| Contam-inants | Ci/yr Released | Contam-inants | Ci/yr Released | Contam-inants | Ci/yr Released | Contam-inants | Ci/yr Released | Contam-inants | Ci/yr Released | Contam-inants | Ci/yr Released |
| Total Alpha [4] | 2.88E-08 | Total Alpha [4] | 2.10E-05 | Total Alpha[4] | 1.04E-04 | Total Alpha[4] | 4.92E-11 | Sr-90 | 5.00E-04 | Am-241 | 2.26E-03 |
| Total Beta [5] | 7.91E-07 | Total Beta [5] | 1.20E-05 | Total Beta[5] | 8.04E-05 | Total Beta[5] | 1.34E-09 | Cs-137 | 2.00E-03 | C-14 | 2.67E+02 |
| Sr-90 | 1.81E-05 | | | | | Sr-90 | 1.45E-08 | I-129 | 4.00E-03 | Cs-137 | 1.22E+00 |
| Cs-137 | 5.38E-05 | | | | | Cs-137 | 9.01E-08 | | | I-129 | 1.90E+00 |
| I-129 | 4.60E-05 | | | | | I-129 | 7.85E-08 | | | Pu-239 | 5.89E-04 |
| | | | | | | | | | | Ru-106 | 3.92E-10 |
| | | | | | | | | | | Sm-151 | 1.28E-02 |
| | | | | | | | | | | Sr-90 | 1.05E+00 |
| | | | | | | | | | | Tc-99 | 8.01E-04 |
| | | | | | | | | | | Zr-93 | 6.70E-03 |

Notes:
[1] Percentage of inventory retrieved for the Ex Situ Intermediate Separations alternative.
[2] Based on the percentage of inventory times the air release.
[3] Percentage of inventory not retrieved for the Ex Situ Intermediate Separations alternative.
[4] Total alpha is assumed to be Pu-239.
[5] Total beta is assumed to be Sr-90.

For ground releases, dispersion in the atmosphere would cause contaminant air concentrations and exposures to decrease with increasing distance from the source. Maximum individual exposures therefore would occur at the inner boundaries (i.e., closest distance to the source) of the defined receptor occupancy zones. For the noninvolved worker, the maximum exposure would occur 100 m (330 ft) from the source (in an east-southeast direction). For the general public, the maximum exposure would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the center of the 200 East Area).

The calculated Chi/Q values for ground releases from the tank farms were calculated by the GENII computer code to be 4.00E-04 sec/m$^3$ for the noninvolved worker MEI and 6.60E-08 sec/m$^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 1.60E-03 sec/m$^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 2.90E-03 sec/m$^3$.

Table D.4.8.2 Atmospheric Transport Parameters for Ex Situ/In Situ Combination 1 Alternative

| Transport Parameters | Continued Operations | | Treatment (gravel fill) | | Retrieval | Separate and Vitrify |
|---|---|---|---|---|---|---|
| | Tank Farms | Evaporator 1 | Evaporator 2 | Gravel Fill | | |
| Stack height in m (ft) | Ground | 6.70 (22) | 6.70 (22) | Ground | Ground | 55 (180) |
| Stack radius in m (ft) | N/A | 0.53 (1.7) | 0.53 (1.7) | N/A | N/A | 0.88 (2.9) |
| Stack flow rate in $m^3$/sec ($ft^3$/sec) | N/A | 10 (353) | 10 (353) | N/A | N/A | 33 (1,165) |
| Stack temperature in °C (°F) | N/A | 46 (117) | 46 (117) | N/A | N/A | 160 (32) |
| Noninvolved worker MEI location in m (ft) ESE | 100 (328) | 200 (656) | 200 (656) | 100 (328) | 100 (328) | 800 (2,625) |
| Public MEI location in km (mi) ESE | 22 (14) | 22 (14) | 22 (14) | 22 (14) | 22 (14) | 22 (14) |
| Chi/Q for noninvolved worker - population in $s/m^3$ | 1.60E-03 | 4.00E-04 | 4.00E-04 | 1.60E-03 | 1.60E-03 | 5.00E-05 |
| Chi/Q for noninvolved worker - MEI in $s/m^3$ | 4.00E-04 | 2.50E-06 | 2.50E-06 | 4.00E-04 | 4.00E-04 | 2.90E-08 |
| Chi/Q for general public - population in $s/m^3$ | 2.90E-03 | 1.60E-03 | 1.60E-03 | 2.90E-03 | 2.90E-03 | 5.00E-04 |
| Chi/Q for general public - MEI in $s/m^3$ | 6.60E-08 | 3.90E-08 | 3.90E-08 | 6.60E-08 | 6.60E-08 | 7.70E-09 |

Notes:
ESE = East-southeast

For elevated releases (stack releases), the maximum exposure would not necessarily occur at the closest distance to the source. Air transport modeling indicates that the maximum exposure for the noninvolved worker would occur 200 m (660 ft) from the source (in an east-southeast direction) for the evaporator and 800 m (2,600 ft) for separations and vitrification. The maximum exposure for a member of the general public would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the 200 East Area).

The calculated Chi/Q values for the evaporator operation were 2.50E-06 $sec/m^3$ for the noninvolved worker MEI and 3.90E-08 $sec/m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 4.0E-04 $sec/m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 1.60E-03 $sec/m^3$. For the separations and vitrification operation, the Chi/Q value was 2.90E-08 $sec/m^3$ for the noninvolved worker MEI,

7.70E-09 sec/m$^3$ for the general public MEI, 5.00E-05 sec/m$^3$ for the noninvolved worker population, and 5.00E-04 sec/m$^3$ for the general public population.

D.4.8.1.3 Exposure

The radiological exposure for the alternative is presented in Table D.4.8.3. The table shows the exposure each receptor would receive from every component. The sum of the components are shown in the last column for each population and MEI receptor except for the MEI worker. The MEI worker is not summed, but is represented by the component with the highest MEI dose.

Table D.4.8.3 Summary of Anticipated Radiological Exposure for the Ex Situ/In Situ Combination 1 Alternative

| | Radiologic Dose (person-rem) [5] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Receptor | Construction (18 yrs) | Continued Operations [1] (29 yrs) | Retrieval (20 yrs) | Separations and Treatment [2] (18 yrs) | Transportation (18 yrs) | Monitoring and Maintenance (50 yrs) | Post Closure Monitoring (100 yrs) | Total |
| Worker - Population | 7.50E+00 | 3.94E+02 | 2.64E+03 | 2.00E+03 | N/A | 8.40E-01 | 1.29E+01 | 5.06E+03 |
| Worker - MEI[3, 4] | 1.00E+01 | 1.45E+01 | 1.30E+01 | 1.20E+01 | N/A | 1.50E+01 | 1.50E+01 | 1.50E+01 |
| Noninvolved Worker - Population | N/A | 1.58E-03 | 7.70E-03 | 8.20E-01 | 1.43E-01 | N/A | N/A | 9.72E-01 |
| Noninvolved Worker - MEI | N/A | 1.63E-04 | 2.10E-03 | 6.30E-04 | N/A | N/A | N/A | 2.10E-03 |
| General Public - Population | N/A | 8.00E-02 | 2.10E+00 | 2.60E+02 | 4.00E-02 | N/A | N/A | 2.62E+02 |
| General Public - MEI | N/A | 2.19E-06 | 6.80E-05 | 6.00E-03 | N/A | N/A | N/A | 6.00E-03 |

Notes:
[1] Continued operations include tank farm and Evaporator 1
[2] Separations and Treatment include Separations, Vitrification, Gravel Fill, and Evaporator 2
[3] Worker MEI is assumed to work for 30 years
[4] Total for the MEI represents the highest single exposure
[5] MEI receptor dose is noted in rem

The worker population dose is dependent on the number of people in the population and the anticipated individual dose. The data were obtained from the Site maintenance and operations contractor and the TWRS EIS contractor (WHC 1995f, j and Jacobs 1996). The calculations for the worker exposures from construction, continued operations, retrieval, separations and treatment, monitoring and maintenance, and closure are as follows:

Construction = (5.36E+02 person-yr) · (1.4E-02 rem/person-yr) = 7.50E+00 person-rem

Continued Operations -

Tank farms = (1.90E+04 person-yr) · (1.40E-02 rem/person-yr) = 2.66E+02 person-rem

Evaporator = (6.40E+02 person-yr) · (2.00E-01 rem/person-yr) = 1.28E+02 person-rem
Total = 3.94E+02 person-rem

Retrieval = (1.32E+04 person-yr) · (2.00E-01 rem/person-yr) = 2.64E+03 person-rem

Separation/Treatment = (9.98E+03 person-yr) · (2.00E-01 rem/person-yr) = 2.00E+03 person-rem

Monitoring/Maintenance = (6.00E+01 person-yr) · (1.40E-02 rem/person-yr) = 8.40E-01 person rem

Closure -
Closure = (2.44E+02 person-yr) · (1.40E-02 rem/person-yr) = 3.41E+00 person-rem
Monitoring = (6.77E+02 person-yr) · (1.40E-02 rem/person-yr) = 9.48E+00 person-rem
Total = 1.29E+01 person-rem

The MEI worker was assumed to receive a dose of 500 mrem (5.00E-01 rem) per year for a maximum of 30 years.

The noninvolved workers and general public exposures from inhalation of the atmospheric emissions (source term) were converted to a radiological dose in rem using the GENII computer code and applying the appropriate Chi/Q.

D.4.8.1.4 Risk

The LCFs are calculated as the product of the estimated dose times the dose-to-risk conversion factor (Section D.2.2.4). The sum of the radiological dose from construction, continued operations, treatment, and closure, for each receptor shown in the combined dose column in Table D.4.8.4, was multiplied by the appropriate dose-to-risk conversion factor to produce the LCF risk.

Table D.4.8.4 Summary of Anticipated Risk for the Ex Situ/In Situ Combination 1 Alternative

| Receptor | Combined Dose (person-rem) [1] | LCF/rem | LCF Risk |
|---|---|---|---|
| Worker - Population | 5.06E+03 | 4.00E-04 | 2.02E+00 |
| Worker - MEI | 1.50E+01 | 4.00E-04 | 6.00E-03 |
| Noninvolved Worker - Population | 9.72E-01 | 4.00E-04 | 3.89E-04 |
| Noninvolved Worker - MEI | 2.10E-03 | 4.00E-04 | 8.40E-07 |
| General Public - Population | 2.62E+02 | 5.00E-04 | 1.31E-01 |
| General Public - MEI | 6.00E-03 | 5.00E-04 | 3.00E-06 |

Notes:
[1]MEI receptor dose is noted in rem
LCF = Latent cancer fatality

### D.4.8.2 Chemical Exposure

Potential carcinogenic risk and noncarcinogenic health hazards may result from exposure to volatile emissions from the tank farm, the evaporators, tank filling (sand filling) operations, retrieval operations, and particulate emissions from vitrification of tank waste for the worker, noninvolved worker, and general public. Potential carcinogenic risk and noncarcinogenic health hazards were estimated using the chemical source term, transport mechanism, exposure, and toxicological criteria as discussed in the following subsections.

#### D.4.8.2.1 Source Term

Operating air emissions from the tank farm area, the evaporators, filling the tanks with sand, retrieval of the tank waste, and vitrification of tank waste are presented in Table D.4.8.5 (WHC 1995f, j and Jacobs 1996). The noninvolved worker and general public would be exposed to combined emissions from the tank farm area, the evaporators, filling the tanks with sand, retrieval operations and vitrification, while the worker would only be exposed to emissions (ground-level release) from the tank farm area, filling the tanks with sand and retrieval, because emissions from the evaporators and vitrification facility occur through a stack-release and would not impact the onsite worker.

**Table D.4.8.5 Chemical Emissions for the Ex Situ/In Situ Combination 1 Alternative**

| Tank Farm Emissions | | Retrieval Emissions | | Tank Filling with Gravel | |
|---|---|---|---|---|---|
| Emissions | Total Tank Farm Emission Rate (mg/sec) | Emissions | Retrieval Emission Rate (mg/sec) | Emissions | Fill and Cap Emission Rate (mg/sec) |
| Carbon Monoxide | 1.05E+00 | Carbon Monoxide | 3.16E+00 | Carbon Monoxide | 2.44E-02 |
| Nitrogen Oxide | 1.06E-01 | Nitrogen Oxide | 3.17E-01 | Nitrogen Oxide | 2.45E-03 |
| 1,3-Butadiene | 7.49E-03 | 1,3-Butadiene | 2.25E-02 | 1,3-Butadiene | 1.74E-04 |
| 2-Hexanone | 1.37E-01 | 2-Hexanone | 4.10E-01 | 2-Hexanone | 3.17E-03 |
| 2-Pentanone | 2.16E-01 | 2-Pentanone | 6.48E-01 | 2-Pentanone | 5.01E-03 |
| Acetone | 2.61E+00 | Acetone | 7.82E+00 | Acetone | 6.05E-02 |
| Acetonitrile | 1.26E+00 | Acetonitrile | 3.77E+00 | Acetonitrile | 2.91E-02 |
| Benzene | 5.97E-02 | Benzene | 1.79E-01 | Benzene | 1.38E-03 |
| Heptane | 1.53E-01 | Heptane | 4.60E-01 | Heptane | 3.56E-03 |
| Methyl N-amyl Ketone | 1.48E-01 | Methyl N-amyl Ketone | 4.44E-01 | Methyl N-amyl Ketone | 3.43E-03 |
| N-hexane | 1.60E-01 | N-hexane | 4.80E-01 | N-hexane | 3.72E-03 |
| Nonane | 8.32E-02 | Nonane | 2.50E-01 | Nonane | 1.93E-03 |
| Octane | 8.73E-02 | Octane | 2.62E-01 | Octane | 2.20E-03 |
| Toluene | 1.22E-02 | Toluene | 3.67E-02 | Toluene | 2.84E-04 |
| Ammonia | 7.67E+00 | Ammonia | 2.30E+01 | Ammonia | 1.78E-01 |

Table D.4.8.5 Chemical Emissions for the Ex Situ/In Situ Combination 1 Alternative (cont'd)

| Evaporator-1 Emissions | | Evaporator-2 Emissions | | Separations/Vitrification Emissions | |
|---|---|---|---|---|---|
| Emissions | Evaporator Emission Rate | Emissions | DSTs Emission Rate (mg/sec) | Emissions | Plant Emission Rate (mg/sec) |
| Phosphoric Acid, Tributyl Ester | 1.89E-01 | Phosphoric Acid, Tributyl Ester | 5.68E-01 | Phosphoric Acid, Tributyl Ester | 4.39E-03 |
| Carbon Tetrachloride | 1.24E-07 | Carbon Tetrachloride | 3.72E-07 | Carbon Tetrachloride | 2.88E-09 |
| Ethyl Butyl Ketone | 4.15E-07 | Ethyl Butyl Ketone | 1.25E-06 | Ethyl Butyl Ketone | 9.64E-09 |
| Methyl Chloride | 1.83E-08 | Methyl Chloride | 5.50E-08 | Methyl Chloride | 4.25E-10 |
| Tetrahydrofuran | 3.20E-08 | Tetrahydrofuran | 9.61E-08 | Tetrahydrofuran | 7.43E-10 |
| Acetone | 2.30E-01 | Acetone | 3.06E+00 | Aluminum | 1.54E-02 |
| Ammonia | 2.16E-01 | Ammonia | 2.89E+00 | Arsenic | 1.67E-06 |
| n-Butyl Alcohol | 1.73E+00 | n-Butyl Alcohol | 2.30E+01 | Boron | 6.35E-04 |
| 2-Hexanone | 8.28E-04 | 2-Hexanone | 1.09E-02 | Barium | 4.73E-06 |
| Methyl Isobutyl Ketone | 1.57E-02 | Methyl Isobutyl Ketone | 2.09E-01 | Beryllium | 1.24E-07 |
| | | | | Bismuth | 3.04E-04 |
| | | | | Cadmium | 1.22E-05 |
| | | | | Cerium | 2.77E-04 |
| | | | | Chromium (+3) | 2.48E-04 |
| | | | | Copper | 1.11E-06 |
| | | | | Manganese | 1.72E-04 |
| | | | | Molybdenum | 7.81E-06 |
| | | | | Nickel | 2.07E-04 |
| | | | | Lead | 6.56E-06 |
| | | | | Silver | 1.03E-06 |
| | | | | Uranium | 1.72E-03 |
| | | | | Vanadium | 3.06E-07 |
| | | | | Zinc | 6.15E-06 |

D.4.8.2.2 Transport

Chemical operating emissions from the tank farm, filling of the tanks and retrieval of tank waste were modeled as a ground release. Chemical operating emissions from the evaporators and vitrification facility would occur from the evaporator stacks and were modeled as elevated releases. Transport parameters, location of the MEI noninvolved worker and MEI general public, and Chi/Q values for the

MEI noninvolved worker and general public are identical to the radiological parameters presented in Table D.4.8.2.

The MEI worker was evaluated using a simplified "box" model, as presented in detail in Section D.4.1.2.2. The estimated Chi/Q value for the MEI worker was 9.26E-04 sec/$m^3$.

D.4.8.2.3 Exposure

**Worker**

The MEI worker was assumed to be located within a box placed directly over the tank farm area. Exposure point concentrations of chemical emissions (mg/$m^3$) from the tank farm area, filling the tanks with sand and retrieval of tank waste were estimated by multiplying each cumulative source emission rate (mg/sec) by the MEI worker Chi/Q value (9.26E-04 sec/$m^3$). Exposure point concentrations for each volatile chemical emitted from the tank farm area, retrieval operations, and filling of the tanks are summarized in Tables D.4.8.6, D.4.8.7 and D.4.8.8, respectively.

Chemical intake (dose) was estimated for the MEI worker using the same equation and exposure parameters defined in Section D.2.2.3. Estimated intakes of chemical emissions from the tank farm, retrieval operations and tank filling operations for the MEI worker are presented in Tables D.4.8.6, D.4.8.7, and D.4.8.8, respectively.

**Noninvolved Worker**

The MEI noninvolved worker was assumed to be located at the point where maximum downwind air concentrations were calculated (100 m [330 ft] from the tank farm and 200 m [660 ft] from the evaporator). Exposure point concentrations (mg/$m^3$) of chemical emissions from the tank farm, evaporators, retrieval operations, tank-filling, and vitrification were estimated by multiplying each cumulative source emission rate (mg/sec) by its respective MEI noninvolved worker Chi/Q value (4.00E-04 sec/$m^3$ for the tank farm, 4.00E-04 sec/$m^3$ for tank-filling, 2.50E-06 sec/$m^3$ for the evaporator, 4.00E-04 sec/$m^3$ for retrieval, and 2.90E-08 sec/$m^3$ for vitrification). Exposure point concentrations for each volatile chemical emitted from the tank farm area, evaporators, retrieval, tank-filling and vitrification are summarized in Tables D.4.8.9, D.4.8.10, D.4.8.11, D.4.8.12, D.4.8.13 and D.4.8.14, respectively.

Chemical intake (dose) was estimated for the MEI noninvolved worker according to the same equation and exposure parameters used for the MEI worker. Estimated operating chemical emission intakes for the MEI noninvolved worker are presented in Tables D.4.8.9, D.4.8.10, D.4.8.11, D.4.8.12, D.4.8.13 and D.4.8.14 for the tank farm area, evaporator-1, evaporator-2, retrieval operations, tank-filling, and vitrification, respectively.

Table D.4.8.6 Ex Situ/In Situ Combination 1 Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 9.75E-04 | 1.91E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 9.80E-05 | 1.92E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 6.94E-06 | 1.36E-06 | 5.63E-07 | ND | 9.80E-01 | NE | 5.52E-07 |
| 2-Hexanone | 1.27E-04 | 2.48E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.00E-04 | 3.92E-05 | NC | ND | NC | NE | NC |
| Acetone | 2.41E-03 | 4.73E-04 | NC | 1.00E-01 | NC | 4.73E-03 | NC |
| Acetonitrile | 1.16E-03 | 2.28E-04 | NC | 1.40E-02 | NC | 1.63E-03 | NC |
| Benzene | 5.53E-05 | 1.08E-05 | 4.48E-06 | 1.70E-03 | 2.90E-02 | 6.37E-03 | 1.30E-07 |
| Heptane | 1.42E-04 | 2.78E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.37E-04 | 2.69E-05 | NC | 2.30E-02 | NC | 1.17E-03 | NC |
| N-hexane | 1.48E-04 | 2.91E-05 | NC | 5.70E-02 | NC | 5.10E-04 | NC |
| Nonane | 7.70E-05 | 1.51E-05 | NC | ND | NC | NE | NC |
| Octane | 8.08E-05 | 1.58E-05 | NC | ND | NC | NE | NC |
| Toluene | 1.13E-05 | 2.22E-06 | NC | 1.10E-01 | NC | 2.02E-05 | NC |
| Ammonia | 7.10E-03 | 1.39E-03 | NC | 2.90E-02 | NC | 4.80E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 1.75E-04 | 3.43E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.15E-10 | 2.25E-11 | 9.31E-12 | 5.70E-04 | 5.30E-02 | 3.95E-08 | 4.93E-13 |
| Ethyl Butyl Ketone | 3.85E-10 | 7.54E-11 | NC | 2.30E-02 | NC | 3.28E-09 | NC |
| Methyl Chloride | 1.70E-11 | 3.33E-12 | 1.38E-12 | ND | 6.30E-03 | NE | 8.67E-15 |
| Tetrahydrofuran | 2.97E-11 | 5.81E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 7.71E-02** | **Risk = 6.82E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.8.7 Ex Situ/In Situ Combination 1 Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 2.92E-03 | 5.73E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 2.94E-04 | 5.76E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 2.08E-05 | 4.08E-06 | 1.51E-06 | ND | 9.80E-01 | NE | 1.48E-06 |
| 2-Hexanone | 3.80E-04 | 7.45E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 6.00E-04 | 1.18E-04 | NC | ND | NC | NE | NC |
| Acetone | 7.24E-03 | 1.42E-03 | NC | 1.00E-01 | NC | 1.42E-02 | NC |
| Acetonitrile | 3.49E-03 | 6.84E-04 | NC | 1.40E-02 | NC | 4.88E-02 | NC |
| Benzene | 1.66E-04 | 3.25E-05 | 1.21E-05 | 1.70E-03 | 2.90E-02 | 1.91E-02 | 3.50E-07 |
| Heptane | 4.26E-04 | 8.34E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 4.11E-04 | 8.06E-05 | NC | 2.30E-02 | NC | 3.50E-03 | NC |
| N-hexane | 4.45E-04 | 8.72E-05 | NC | 5.70E-02 | NC | 1.53E-03 | NC |
| Nonane | 2.31E-04 | 4.53E-05 | NC | ND | NC | NE | NC |
| Octane | 2.42E-04 | 4.75E-05 | NC | ND | NC | NE | NC |
| Toluene | 3.40E-05 | 6.66E-06 | NC | 1.10E-01 | NC | 6.05E-05 | NC |
| Ammonia | 2.13E-02 | 4.18E-03 | NC | 2.90E-02 | NC | 1.44E-01 | NC |
| Phosphoric Acid, Tributyl Ester | 5.26E-04 | 1.03E-04 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 3.44E-10 | 6.75E-11 | 2.50E-11 | 5.70E-04 | 5.30E-02 | 1.18E-07 | 1.33E-12 |
| Ethyl Butyl Ketone | 1.15E-09 | 2.26E-10 | NC | 2.30E-02 | NC | 9.83E-09 | NC |
| Methyl Chloride | 5.09E-11 | 9.98E-12 | 3.70E-12 | ND | 6.30E-03 | NE | 2.33E-14 |
| Tetrahydrofuran | 8.90E-11 | 1.74E-11 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 2.31E-01** | **Risk = 1.83E-06** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.8.8 Ex Situ/In Situ Combination 1 Gravel Fill Emissions

| Emissions | Air Concentrations of Tank Filling Emissions for the MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 2.26E-05 | 4.43E-06 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 2.27E-06 | 4.46E-07 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 1.16E-07 | 3.16E-08 | 3.61E-09 | ND | 9.80E-01 | NE | 3.53E-09 |
| 2-Hexanone | 2.94E-06 | 5.76E-07 | NC | ND | NC | NE | NC |
| 2-Pentanone | 4.64E-06 | 9.09E-07 | NC | ND | NC | NE | NC |
| Acetone | 5.60E-05 | 1.10E-05 | NC | 1.00E-01 | NC | 1.10E-04 | NC |
| Acetonitrile | 2.70E-05 | 5.29E-06 | NC | 1.40E-02 | NC | 3.78E-04 | NC |
| Benzene | 1.28E-06 | 2.51E-07 | 2.87E-08 | 1.70E-03 | 2.90E-02 | 1.48E-04 | 8.33E-10 |
| Heptane | 3.29E-06 | 6.45E-07 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 3.18E-06 | 6.23E-07 | NC | 2.30E-02 | NC | 2.71E-05 | NC |
| N-hexane | 3.44E-06 | 6.74E-07 | NC | 5.70E-02 | NC | 1.18E-05 | NC |
| Nonane | 1.79E-06 | 3.50E-07 | NC | ND | NC | NE | NC |
| Octane | 1.87E-06 | 3.67E-07 | NC | ND | NC | NE | NC |
| Toluene | 2.63E-07 | 5.15E-08 | NC | 1.10E-01 | NC | 4.68E-07 | NC |
| Ammonia | 1.65E-04 | 3.23E-05 | NC | 2.90E-02 | NC | 1.11E-03 | NC |
| Phosphoric Acid, Tributyl Ester | 4.07E-06 | 7.97E-07 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 2.66E-12 | 5.22E-13 | 5.97E-14 | 5.70E-04 | 5.30E-02 | 9.16E-10 | 3.16E-15 |
| Ethyl Butyl Ketone | 8.92E-12 | 1.75E-12 | NC | 2.30E-02 | NC | 7.60E-11 | NC |
| Methyl Chloride | 3.94E-13 | 7.72E-14 | 8.82E-15 | ND | 6.30E-03 | NE | 5.56E-17 |
| Tetrahydrofuran | 6.88E-13 | 1.35E-13 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 1.79E-03** | **Risk = 4.37E-09** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.8.9 Ex Situ/In Situ Combination 1 Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 4.21E-04 | 8.25E-05 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 4.23E-05 | 8.30E-06 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 3.00E-06 | 5.88E-07 | 2.43E-07 | ND | 9.80E-01 | NE | 2.38E-07 |
| 2-Hexanone | 5.47E-05 | 1.07E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 8.64E-05 | 1.69E-05 | NC | ND | NC | NE | NC |
| Acetone | 1.04E-03 | 2.04E-04 | NC | 1.00E-01 | NC | 2.04E-03 | NC |
| Acetonitrile | 5.02E-04 | 9.84E-05 | NC | 1.40E-02 | NC | 7.03E-03 | NC |
| Benzene | 2.39E-05 | 4.68E-06 | 1.94E-06 | 1.70E-03 | 2.90E-02 | 2.75E-03 | 5.62E-08 |
| Heptane | 6.13E-05 | 1.20E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 5.92E-05 | 1.16E-05 | NC | 2.30E-02 | NC | 5.05E-04 | NC |
| N-hexane | 6.41E-05 | 1.26E-05 | NC | 5.70E-02 | NC | 2.20E-04 | NC |
| Nonane | 3.33E-05 | 6.52E-06 | NC | ND | NC | NE | NC |
| Octane | 3.49E-05 | 6.84E-06 | NC | ND | NC | NE | NC |
| Toluene | 4.89E-06 | 9.58E-07 | NC | 1.10E-01 | NC | 8.71E-06 | NC |
| Ammonia | 3.07E-03 | 6.01E-04 | NC | 2.90E-02 | NC | 2.07E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 7.57E-05 | 1.48E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 4.96E-11 | 9.72E-12 | 4.02E-12 | 5.70E-04 | 5.30E-02 | 1.71E-08 | 2.13E-13 |
| Ethyl Butyl Ketone | 1.66E-10 | 3.26E-11 | NC | 2.30E-02 | NC | 1.42E-09 | NC |
| Methyl Chloride | 7.33E-12 | 1.44E-12 | 5.95E-13 | ND | 6.30E-03 | NE | 3.75E-15 |
| Tetrahydorfuran | 1.28E-11 | 2.51E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 3.33E-02** | **Risk = 2.94E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

**Table D.4.8.10 Ex Situ/In Situ Combination 1 Evaporator-1 Emissions**

| Emissions | Air Concentrations of Evaporator Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Acetone | 5.75E-07 | 1.13E-07 | NC | 1.00E-01 | NC | 1.13E-06 | NC |
| Ammonia | 5.40E-07 | 1.06E-07 | NC | 2.90E-02 | NC | 3.65E-06 | NC |
| n-Butyl Alcohol | 4.33E-06 | 8.48E-07 | NC | 1.00E-01 | NC | 8.48E-06 | NC |
| 2-Hexanone | 2.07E-09 | 4.06E-10 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 3.93E-08 | 7.69E-09 | NC | 2.30E-02 | NC | 3.34E-07 | NC |
| | | | | | | **HI = 1.36E-05** | |

Notes:
NC = Noncarcinogen
NE = Not evaluated

**Table D.4.8.11 Ex Situ/In Situ Combination 1 Evaporator-2 Emissions**

| Emissions | Air Concentrations of Evaporator Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Acetone | 7.65E-06 | 1.50E-06 | NC | 1.00E-01 | NC | 1.50E-05 | NC |
| Ammonia | 7.23E-06 | 1.42E-06 | NC | 2.90E-02 | NC | 4.88E-05 | NC |
| n-Butyl Alcohol | 5.75E-05 | 1.13E-05 | NC | 1.00E-01 | NC | 1.13E-04 | NC |
| 2-Hexanone | 2.73E-08 | 5.34E-09 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 5.23E-07 | 1.20E-07 | NC | 2.30E-02 | NC | 4.45E-06 | NC |
| | | | | | | **HI = 1.81E-04** | |

Notes:
NC = Noncarcinogen
NE = Not evaluated

Table D.4.8.12 Ex Situ/In Situ Combination 1 Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_I$) (mg/kg-day) | Inhalation Slope Factor ($SF_I$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 1.26E-03 | 2.48E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 1.27E-04 | 2.49E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 8.99E-06 | 1.76E-06 | 6.54E-07 | ND | 9.80E-01 | NE | 6.41E-07 |
| 2-Hexanone | 1.64E-04 | 3.22E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.59E-04 | 5.08E-05 | NC | ND | NC | NE | NC |
| Acetone | 3.13E-03 | 6.13E-04 | NC | 1.00E-01 | NC | 6.13E-03 | NC |
| Acetonitrile | 1.51E-03 | 2.95E-04 | NC | 1.40E-02 | NC | 2.11E-02 | NC |
| Benzene | 7.16E-05 | 1.40E-05 | 5.21E-06 | 1.70E-03 | 2.90E-02 | 8.26E-03 | 1.51E-07 |
| Heptane | 1.84E-04 | 3.60E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.78E-04 | 3.48E-05 | NC | 2.30E-02 | NC | 1.51E-03 | NC |
| N-hexane | 1.92E-04 | 3.77E-05 | NC | 5.70E-02 | NC | 6.61E-04 | NC |
| Nonane | 9.98E-05 | 1.96E-05 | NC | ND | NC | NE | NC |
| Octane | 1.05E-04 | 2.05E-05 | NC | ND | NC | NE | NC |
| Toluene | 1.47E-05 | 2.87E-06 | NC | 1.10E-01 | NC | 2.61E-05 | NC |
| Ammonia | 9.20E-03 | 1.80E-03 | NC | 2.90E-02 | NC | 6.22E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 2.27E-04 | 4.45E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.49E-10 | 2.92E-11 | 1.08E-11 | 5.70E-04 | 5.30E-02 | 5.12E-08 | 5.73E-13 |
| Ethyl Butyl Ketone | 4.98E-10 | 9.77E-11 | NC | 2.30E-02 | NC | 4.25E-09 | NC |
| Methyl Chloride | 2.20E-11 | 4.31E-12 | 1.60E-12 | ND | 6.30E-03 | NE | 1.01E-14 |
| Tetrahydorfuran | 3.84E-11 | 7.53E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 9.99E-02** | **Risk = 7.92E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.8.13 Ex Situ/In Situ Combination 1 Gravel Emissions

| Emissions | Air Concentrations of Tank Filling Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 9.77E-06 | 1.91E-06 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 9.82E-07 | 1.92E-07 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 6.95E-08 | 1.36E-08 | 1.56E-09 | ND | 9.80E-01 | NE | 1.53E-09 |
| 2-Hexanone | 1.27E-06 | 2.49E-07 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.00E-06 | 3.93E-07 | NC | ND | NC | NE | NC |
| Acetone | 2.42E-05 | 4.47E-06 | NC | 1.00E-01 | NC | 4.74E-05 | NC |
| Acetonitrile | 1.17E-05 | 2.28E-06 | NC | 1.40E-02 | NC | 1.63E-04 | NC |
| Benzene | 5.54E-07 | 1.09E-07 | 1.24E-08 | 1.70E-03 | 2.90E-02 | 6.39E-05 | 3.60E-10 |
| Heptane | 1.42E-06 | 2.79E-07 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.37E-06 | 2.69E-07 | NC | 2.30E-02 | NC | 1.17E-05 | NC |
| N-hexane | 1.49E-06 | 2.91E-07 | NC | 5.70E-02 | NC | 5.11E-06 | NC |
| Nonane | 7.72E-07 | 1.51E-07 | NC | ND | NC | NE | NC |
| Octane | 8.10E-07 | 1.59E-07 | NC | ND | NC | NE | NC |
| Toluene | 1.13E-07 | 2.22E-08 | NC | 1.10E-01 | NC | 2.02E-07 | NC |
| Ammonia | 7.12E-05 | 1.40E-05 | NC | 2.90E-02 | NC | 4.81E-04 | NC |
| Phosphoric Acid, Tributyl Ester | 1.76E-06 | 3.44E-07 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.15E-12 | 2.26E-13 | 2.58E-14 | 5.70E-04 | 5.30E-02 | 3.96E-10 | 1.37E-15 |
| Ethyl Butyl Ketone | 3.85E-12 | 7.56E-13 | NC | 2.30E-02 | NC | 3.29E-11 | NC |
| Methyl Chloride | 1.70E-13 | 3.33E-14 | 3.81E-15 | ND | 6.30E-03 | NE | 2.40E-17 |
| Tetrahydorfuran | 2.97E-13 | 5.83E-14 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 7.73E-04** | **Risk = 1.89E-09** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.8.14 Ex Situ/In Situ Combination 1 Plant Emissions

| Emissions | Air Concentrations of Vitrification Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Aluminum | 4.46E-10 | 8.75E-11 | NC | ND | NC | NE | NC |
| Arsenic | 4.83E-14 | 9.47E-15 | 3.00E-11 | ND | 1.51E+01 | NE | 4.52E-10 |
| Boron | 1.84E-11 | 3.61E-12 | NC | 5.70E-03 | NC | 6.34E-10 | NC |
| Barium | 1.37E-13 | 2.69E-14 | NC | 1.43E-04 | NC | 1.88E-10 | NC |
| Beryllium | 3.59E-15 | 7.04E-16 | 9.21E-15 | ND | 8.40E+00 | NE | 7.74E-14 |
| Bismuth | 8.83E-12 | 1.73E-12 | NC | ND | NC | NE | NC |
| Cadmium | 3.52E-13 | 6.91E-14 | 5.92E-13 | ND | 6.30E+00 | NE | 3.73E-12 |
| Cerium | 8.02E-12 | 1.57E-12 | NC | ND | NC | NE | NC |
| Chromium (+3) | 7.18E-12 | 1.41E-12 | NC | 5.71E-07 | NC | 2.47E-06 | NC |
| Copper | 3.23E-14 | 6.34E-15 | NC | ND | NC | NE | NC |
| Manganese | 5.00E-12 | 9.80E-13 | NC | ND | NC | NE | NC |
| Molybdenum | 2.27E-13 | 4.44E-14 | NC | ND | NC | NE | NC |
| Nickel | 6.01E-12 | 1.18E-12 | NC | ND | NC | NE | NC |
| Lead | 1.90E-13 | 3.73E-14 | NC | ND | NC | NE | NC |
| Silver | 2.99E-14 | 5.87E-15 | NC | ND | NC | NE | NC |
| Uranium | 5.00E-11 | 9.80E-12 | NC | ND | NC | NE | NC |
| Vanadium | 8.86E-15 | 1.74E-15 | NC | ND | NC | NE | NC |
| Zinc | 1.78E-13 | 3.49E-14 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 2.47E-06** | **Risk = 4.56E-10** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

### General Public

The MEI general public receptor was assumed to be located at the point where maximum air concentrations were calculated (approximately 22 km [14 mi] from both the tank farm area and evaporator). Exposure point concentrations ($mg/m^3$) of chemical emissions from each source were estimated by

multiplying the cumulative emission rates (mg/sec) of each source by their respective MEI general public Chi/Q values (6.60E-08 $sec/m^3$ for the tank farm, 6.60E-08 $sec/m^3$ for tank-filling operations, 3.90E-08 $sec/m^3$ for the evaporators, 6.60E-08 $sec/m^3$ for retrieval, and 7.70E-09 $sec/m^3$ for

vitrification). Exposure point concentrations for each chemical emitted from the tank farm area, evaporator-1, evaporator-2, retrieval, tank-filling, and vitrification are summarized in Tables D.4.8.15, D.4.8.16, D.4.8.17, D.4.8.18, D.4.8.19 and D.4.8.20, respectively. The residential or general public intake was calculated according to the equation and exposure parameters presented in Section D.2.2.3. Estimated chemical emission intakes for the MEI general public are presented in Tables D.4.8.15, D.4.8.16, D.4.8.17, D.4.8.18, D.4.8.19, and D.4.8.20 for the tank farm area, evaporator-1, evaporator-2, retrieval, tank-filling, and vitrification, respectively.

D.4.8.2.4 Toxicity Assessment

Toxicity assessment was previously discussed in detail in Section D.4.1.2.4. Cancer slope factors, RfDs, and data sources for each volatile operating chemical emission are summarized in Table D.4.1.11.

D.4.8.2.5 Risk Characterization

**MEI Worker**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm, retrieval and tank filling operations are summarized in Tables D.4.8.6, D.4.8.7 and D.4.8.8, respectively. The total HI and cancer risk are 3.10E-01 and 2.52E-06, respectively.

**MEI Noninvolved Worker**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm, evaporator-1, evaporator-2, retrieval, tank-filling, and vitrification are summarized in Tables D.4.8.9, D.4.8.10, D.4.8.11, D.4.8.12, D.4.8.13 and D.4.8.14, respectively. The total HI and cancer risk are 1.34E-01 and 1.09E-06, respectively.

**MEI General Public**

The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm, evaporator-1, evaporator-2, retrieval, tank-filling, and vitrification are summarized in Tables D.4.8.15, D.4.8.16, D.4.8.17, D.4.8.18, D.4.8.19 and D.4.8.20, respectively. The total HI and cancer risk are and 5.44E-10, respectively.

## D.4.9 EX SITU/IN SITU COMBINATION 2 ALTERNATIVE

This section presents the anticipated remediation risk associated with the Ex Situ/In Situ Combination 2 alternative for tank waste, as outlined in Volume Two, Appendix B of the EIS.

The radiological and toxicological risk for this alternative was based on the same factors discussed for the Ex Situ/In Situ Combination 1 alternative (Section D.4.8).

Table D.4.8.15 Ex Situ/In Situ Combination 1 Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 6.95E-08 | 4.34E-08 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 6.98E-09 | 4.36E-09 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 4.95E-10 | 3.09E-10 | 7.25E-11 | ND | 9.80E-01 | NE | 7.10E-11 |
| 2-Hexanone | 9.03E-09 | 5.64E-09 | NC | ND | NC | NE | NC |
| 2-Pentanone | 1.43E-08 | 8.91E-09 | NC | ND | NC | NE | NC |
| Acetone | 1.72E-07 | 1.08E-07 | NC | 1.00E-01 | NC | 1.08E-06 | NC |
| Acetonitrile | 8.29E-08 | 5.18E-08 | NC | 1.40E-02 | NC | 3.70E-06 | NC |
| Benzene | 3.94E-09 | 2.46E-09 | 5.77E-10 | 1.70E-03 | 2.90E-02 | 1.45E-06 | 1.67E-11 |
| Heptane | 1.01E-08 | 6.32E-09 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 9.77E-09 | 6.11E-09 | NC | 2.30E-02 | NC | 2.65E-07 | NC |
| N-hexane | 1.06E-08 | 6.61E-09 | NC | 5.70E-02 | NC | 1.16E-07 | NC |
| Nonane | 5.49E-09 | 3.43E-09 | NC | ND | NC | NE | NC |
| Octane | 5.76E-09 | 3.60E-09 | NC | ND | NC | NE | NC |
| Toluene | 8.07E-10 | 5.04E-10 | NC | 1.10E-01 | NC | 4.58E-09 | NC |
| Ammonia | 5.06E-07 | 3.16E-07 | NC | 2.90E-02 | NC | 1.09E-05 | NC |
| Phosphoric Acid, Tributyl Ester | 1.25E-08 | 7.81E-09 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 8.18E-15 | 5.11E-15 | 1.20E-15 | 5.70E-04 | 5.30E-02 | 8.97E-12 | 6.36E-17 |
| Ethyl Butyl Ketone | 2.74E-14 | 1.71E-14 | NC | 2.30E-02 | NC | 7.45E-13 | NC |
| Methyl Chloride | 1.21E-15 | 7.56E-16 | 1.77E-16 | ND | 6.30E-03 | NE | 1.12E-18 |
| Tetrahydrofuran | 2.11E-15 | 1.32E-15 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 1.75E-05** | **Risk = 8.78E-11** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.8.16 Ex Situ/In Situ Combination 1 Evaporator-1 Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Acetone | 8.97E-09 | 5.61E-09 | NC | 1.00E-01 | NC | 5.61E-08 | NC |
| Ammonia | 8.42E-09 | 5.27E-09 | NC | 2.90E-02 | NC | 1.82E-07 | NC |
| n-Butyl Alcohol | 6.75E-08 | 4.22E-08 | NC | 1.00E-01 | NC | 4.22E-07 | NC |
| 2-Hexanone | 3.23E-11 | 2.02E-11 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 6.12E-10 | 3.83E-10 | NC | 2.30E-02 | NC | 1.66E-08 | NC |
| | | | | | | **HI = 6.76E-07** | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.8.17 Ex Situ/In Situ Combination 1 Evaporator-2 Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Acetone | 1.19E-07 | 7.46E-08 | NC | 1.00E-01 | NC | 7.46E-07 | NC |
| Ammonia | 1.13E-07 | 7.04E-08 | NC | 2.90E-02 | NC | 2.43E-06 | NC |
| n-Butyl Alcohol | 8.97E-07 | 5.61E-07 | NC | 1.00E-01 | NC | 5.61E-06 | NC |
| 2-Hexanone | 4.25E-10 | 2.66E-10 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 8.15E-09 | 5.09E-09 | NC | 2.30E-02 | NC | 2.21E-07 | NC |
| | | | | | | **HI = 9.00E-06** | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.8.18 Ex Situ/In Situ Combination 1 Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg-day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 2.08E-07 | 1.30E-07 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 2.10E-08 | 1.31E-08 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 1.48E-09 | 9.27E-10 | 1.95E-10 | ND | 9.80E-01 | NE | 1.91E-10 |
| 2-Hexanone | 2.71E-08 | 1.69E-08 | NC | ND | NC | NE | NC |
| 2-Pentanone | 4.28E-08 | 2.67E-08 | NC | ND | NC | NE | NC |
| Acetone | 5.16E-07 | 3.23E-07 | NC | 1.00E-01 | NC | 3.23E-06 | NC |
| Acetonitrile | 2.49E-07 | 1.55E-07 | NC | 1.40E-02 | NC | 1.11E-05 | NC |
| Benzene | 1.18E-08 | 7.39E-09 | 1.55E-09 | 1.70E-03 | 2.90E-02 | 4.35E-06 | 4.50E-11 |
| Heptane | 3.03E-08 | 1.90E-08 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 2.93E-08 | 1.83E-08 | NC | 2.30E-02 | NC | 7.96E-07 | NC |
| N-hexane | 3.17E-08 | 1.98E-08 | NC | 5.70E-02 | NC | 3.48E-07 | NC |
| Nonane | 1.65E-08 | 1.03E-08 | NC | ND | NC | NE | NC |
| Octane | 1.73E-08 | 1.08E-08 | NC | ND | NC | NE | NC |
| Toluene | 2.42E-09 | 1.51E-09 | NC | 1.10E-01 | NC | 1.38E-08 | NC |
| Ammonia | 1.52E-06 | 9.49E-07 | NC | 2.90E-02 | NC | 3.27E-05 | NC |
| Phosphoric Acid, Tributyl Ester | 3.75E-08 | 2.34E-08 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 2.45E-14 | 1.53E-14 | 3.23E-15 | 5.70E-04 | 5.30E-02 | 2.69E-11 | 1.71E-16 |
| Ethyl Butyl Ketone | 8.22E-14 | 5.14E-14 | NC | 2.30E-02 | NC | 2.24E-12 | NC |
| Methyl Chloride | 3.63E-15 | 2.27E-15 | 4.77E-16 | ND | 6.30E-03 | NE | 3.00E-18 |
| Tetrahydrofuran | 6.34E-15 | 3.96E-15 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 5.26E-05** | **Risk = 2.36E-10** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.8.19 Ex Situ/In Situ Combination 1 Gravel Fill Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 1.47E-09 | 9.16E-10 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 1.47E-10 | 9.21E-11 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 1.04E-11 | 6.52E-12 | 4.22E-13 | ND | 9.80E-01 | NE | 4.13E-13 |
| 2-Hexanone | 1.90E-10 | 1.19E-10 | NC | ND | NC | NE | NC |
| 2-Pentanone | 3.01E-10 | 1.88E-10 | NC | ND | NC | NE | NC |
| Acetone | 3.63E-09 | 2.27E-09 | NC | 1.00E-01 | NC | 2.27E-08 | NC |
| Acetonitrile | 1.75E-09 | 1.09E-09 | NC | 1.40E-02 | NC | 7.80E-08 | NC |
| Benzene | 8.31E-11 | 5.19E-11 | 3.36E-12 | 1.70E-03 | 2.90E-02 | 3.05E-08 | 9.74E-14 |
| Heptane | 2.13E-10 | 1.33E-10 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 2.06E-10 | 1.29E-10 | NC | 2.30E-02 | NC | 5.60E-09 | NC |
| N-hexane | 2.23E-10 | 1.39E-10 | NC | 5.70E-02 | NC | 2.44E-09 | NC |
| Nonane | 1.16E-10 | 7.24E-11 | NC | ND | NC | NE | NC |
| Octane | 1.21E-10 | 7.59E-11 | NC | ND | NC | NE | NC |
| Toluene | 1.70E-11 | 1.06E-11 | NC | 1.10E-01 | NC | 9.67E-11 | NC |
| Ammonia | 1.07E-08 | 6.67E-09 | NC | 2.90E-02 | NC | 2.30E-07 | NC |
| Phosphoric Acid, Tributyl Ester | 2.63E-10 | 1.65E-10 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.73E-16 | 1.08E-16 | 6.98E-18 | 5.70E-04 | 5.30E-02 | 1.89E-13 | 3.70E-19 |
| Ethyl Butyl Ketone | 5.78E-16 | 3.61E-16 | NC | 2.30E-02 | NC | 1.57E-14 | NC |
| Methyl Chloride | 2.55E-17 | 1.59E-17 | 1.03E-18 | ND | 6.30E-03 | NE | 6.50E-21 |
| Tetrahydrofuran | 4.46E-17 | 2.79E-17 | NC | ND | NC | NE | NC |
| | | | | | | HI = 3.70E-07 | Risk = 5.11E-13 |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.8.20 Ex Situ/In Situ Combination 1 Plant Emissions

| Emissions | Air Concentrations of Vitrification Emissions for the MEI General Public ($mg/m^3$) | Noncarci-nogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarci-nogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Aluminum | 1.19E-10 | 7.41E-11 | NC | ND | NC | NE | NC |
| Arsenic | 1.28E-14 | 8.02E-15 | 1.44E-11 | ND | 1.51E+01 | NE | 2.18E-10 |
| Boron | 4.89E-12 | 3.06E-12 | NC | 5.70E-03 | NC | 5.36E-10 | NC |
| Barium | 3.65E-14 | 2.28E-14 | NC | 1.43E-04 | NC | 1.59E-10 | NC |
| Beryllium | 9.54E-16 | 5.96E-16 | 4.43E-15 | ND | 8.40E+00 | NE | 3.72E-14 |
| Bismuth | 2.34E-12 | 1.46E-12 | NC | ND | NC | NE | NC |
| Cadmium | 9.36E-14 | 5.58E-14 | 2.85E-13 | ND | 6.30E+00 | NE | 1.80E-12 |
| Cerium | 2.13E-12 | 1.33E-12 | NC | ND | NC | NE | NC |
| Chromium (+3) | 1.91E-12 | 1.19E-12 | NC | 5.71E-07 | NC | 2.09E-06 | NC |
| Copper | 8.58E-15 | 5.36E-15 | NC | ND | NC | NE | NC |
| Manganese | 1.33E-12 | 8.30E-13 | NC | ND | NC | NE | NC |
| Molybdenum | 6.02E-14 | 3.76E-14 | NC | ND | NC | NE | NC |
| Nickel | 1.60E-12 | 9.97E-13 | NC | ND | NC | NE | NC |
| Lead | 5.05E-14 | 3.16E-14 | NC | ND | NC | NE | NC |
| Silver | 7.95E-15 | 4.97E-15 | NC | ND | NC | NE | NC |
| Uranium | 1.33E-11 | 8.30E-12 | NC | ND | NC | NE | NC |
| Vanadium | 2.35E-15 | 1.47E-15 | NC | ND | NC | NE | NC |
| Zinc | 4.73E-14 | 2.96E-14 | NC | ND | NC | NE | NC |
| | | | | | | HI = 2.09E-06 | Risk = 2.19E-10 |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

### D.4.9.1 Radiological Risk

Latent cancer fatality risk to the workers, noninvolved workers, and general public could result from direct exposure and atmospheric emissions from the components associated with this alternative. The risk was determined by analyzing the radiological source term, the transport mechanism, exposure, and the risk associated with the exposure as discussed in the following subsections.

D.4.9.1.1 Source Term

The source term used for the noninvolved worker and general public was the atmospheric radiological emissions presented in Table D.4.9.1 (WHC 1995f,1995j and Jacobs 1996). The workers would receive a combined dose from the air emissions and from direct exposure from radiation fields in the work place.

D.4.9.1.2 Transport

The atmospheric transport parameters of the Ex Situ/In Situ Combination 2 alternative are identical to those presented in Table D.4.8.2 for the Ex Situ/In Situ Combination 1 alternative. The modeling assumptions and calculated Chi/Q values for the Ex Situ/In Situ Combination 2 alternative are also identical to those discussed in Section D.4.8.1.2 for the Ex Situ/In Situ Combination 1 alternative.

Table D.4.9.1 Atmospheric Radiological Emissions for the Ex Situ/In Situ Combination 2 Alternative

| Continued Operations | | | | Treatment (gravel fill) | | | | Retrieval Emissions [2] | | Separation and Vitrification Emissions [4] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tank Farm Emissions [1] | | Evaporator Emissions[1] | | Evaporator Emissions | | Gravel and Fill Emissions [3] | | | | | |
| Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released |
| Total Alpha [4] | 2.88E-08 | Total Alpha [4] | 2.10E-05 | Total Alpha[4] | 1.41E-04 | Total Alpha[4] | 5.47E-11 | Sr-90 | 5.75E-04 | Am-241 | 3.42E-03 |
| Total Beta [5] | 7.91E-07 | Total Beta [5] | 1.20E-05 | Total Beta[5] | 8.04E-05 | Total Beta[5] | 1.49E-09 | Cs-137 | 2.30E-03 | C-14 | 2.46E+02 |
| Sr-90 | 1.81E-05 | | | | | Sr-90 | 1.61E-08 | I-129 | 4.60E-03 | Cs-137 | 1.66E+00 |
| Cs-137 | 5.38E-05 | | | | | Cs-137 | 1.00E-07 | | | I-129 | 1.94E+00 |
| I-129 | 4.60E-05 | | | | | I-129 | 8.72E-08 | | | Pu-239 | 7.46E-04 |
| | | | | | | | | | | Ru-106 | 5.37E-07 |
| | | | | | | | | | | Sm-151 | 1.59E-02 |
| | | | | | | | | | | Sr-90 | 1.63E+00 |
| | | | | | | | | | | Tc-99 | 9.40E-04 |
| | | | | | | | | | | Zr-93 | 9.21E-03 |

Notes:
[1] Percentage of inventory retrieved for the Ex Situ Intermediate Separations alternative.
[2] Based on the percentage of inventory times the air release.
[3] Percentage of inventory not retrieved for the Ex Situ Intermediate Separations alternative.
[4] Total alpha is assumed to be Pu-239.
[5] Total beta is assumed to be Sr-90.

D.4.9.1.3 Exposure

The radiological exposure for the alternative is presented in Table D.4.9.2. The table shows the exposure each receptor would receive from every component. The sum of the components are shown in the last column for each population and MEI receptor except for the MEI worker. The MEI worker is not summed, but is represented by the component with the highest MEI dose.

The worker population dose is dependent on the number of people in the population and the anticipated individual dose. The data were obtained from the Site maintenance and operations contractor and the TWRS EIS contractor (WHC 1995f, j and Jacobs 1996). The calculations for the worker exposures from construction, continued operations, retrieval, separations and treatment, monitoring and maintenance, and closure are as follows:

Construction = (5.36E+02 person-yr) · (1.4E-02 rem/person-yr) = 7.50E+00 person-rem

Continued Operations -

Tank farms = (1.90E+04 person-yr) · (1.40E-02 rem/person-yr) = 2.66E+02 person-rem

Evaporator = (6.40E+02 person-yr) · (2.00E-01 rem/person-yr) = 1.28E+02 person-rem

Total = 3.94E+02 person-rem

Retrieval = (1.32E+04 person-yr) · (2.00E-01 rem/person-yr) = 2.64E+03 person-rem

Separation/Treatment = (9.98E+03 person-yr) · (2.00E-01 rem/person-yr) = 2.00E+03 person-rem

Monitoring/Maintenance = (6.00E+01 person-yr) · (1.40E-02 rem/person-yr) = 8.40E-01 person rem

Closure -

Closure = (2.44E+02 person-yr) · (1.40E-02 rem/person-yr) = 3.41E+00 person-rem

Monitoring = (6.77E+02 person-yr) · (1.40E-02 rem/person-yr) = 9.48E+00 person-rem

Total = 1.29E+01 person-rem

The MEI worker was assumed to receive a dose of 500 mrem (5.00E-01 rem) per year for a maximum of 30 years.

The noninvolved workers and general public exposures from inhalation of the atmospheric emissions (source term) were converted to a radiological dose in rem using the GENII computer code and applying the appropriate Chi/Q.

Table D.4.9.2 Summary of Anticipated Radiological Exposure for the Ex Situ/In Situ Combination 2 Alternative

| Receptor | Radiologic Dose (person-rem) [5] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Construction (18 yrs) | Continued Operations [1] (25 yrs) | Retrieval (20 yrs) | Separations and Treatment [2] (18 yrs) | Transportation (18 yrs) | Monitoring and Maintenance (50 yrs) | Post Closure Monitoring (100 yrs) | Total |
| Worker - Population | 7.50E+00 | 3.94E+02 | 2.64E+03 | 2.00E+03 | N/A | 8.40E-01 | 1.29E+01 | 5.06E+03 |
| Worker - MEI[3,4] | 9.00E+00 | 1.25E+01 | 1.00E+01 | 9.00E+00 | N/A | 1.50E+01 | 1.50E+01 | 1.50E+01 |
| Noninvolved Worker - Population | N/A | 1.58E-03 | 7.70E-03 | 5.76E-01 | 5.10E-02 | N/A | N/A | 6.36E-01 |
| Noninvolved Worker - MEI | N/A | 1.63E-04 | 2.10E-03 | 3.60E-04 | N/A | N/A | N/A | 2.10E-03 |
| General Public - Population | N/A | 8.00E-02 | 2.10E+00 | 2.16E+02 | 1.40E-02 | N/A | N/A | 2.18E+02 |
| General Public - MEI | N/A | 2.19E-06 | 6.80E-05 | 2.52E-03 | N/A | N/A | N/A | 2.52E-03 |

Notes:
[1] Continued operations include tank farm and Evaporator 1
[2] Separations and Treatment include Separations, Vitrification, Gravel Fill, and Evaporator 2
[3] Worker MEI is assumed to work for 30 years
[4] Total for the MEI represents the highest single exposure
[5] MEI receptor dose is noted in rem

### D.4.9.1.4 Risk

The LCFs are calculated as the product of the estimated dose times the dose-to-risk conversion factor (Section D.2.2.4). The sum of the radiological dose from construction, continued operations, treatment, and closure for each receptor shown in the combined dose column in Table D.4.9.3 was multiplied by the appropriate dose-to-risk conversion factor to produce the LCF risk.

Table D.4.9.3 Summary of Anticipated Risk for the Ex Situ/In Situ Combination 2 Alternative

| Receptor | Combined Dose (person-rem) [1] | LCF/rem | LCF Risk |
|---|---|---|---|
| Worker - Population | 5.06E+03 | 4.00E-04 | 2.02E+00 |
| Worker - MEI | 1.50E+01 | 4.00E-04 | 6.00E-03 |
| Noninvolved Worker - Population | 6.36E-01 | 4.00E-04 | 2.54E-04 |
| Noninvolved Worker - MEI | 2.10E-03 | 4.00E-04 | 8.40E-07 |
| General Public - Population | 2.18E+02 | 5.00E-04 | 1.09E-01 |
| General Public - MEI | 2.52E-03 | 5.00E-04 | 1.26E-06 |

Notes:
[1]MEI receptor dose is noted in rem
LCF = Latent cancer fatalities

### D.4.9.2 Chemical Exposure

The potential carcinogenic risk and noncarcinogenic health hazards resulting from implementing the Ex Situ/In Situ Combination 2 may result from exposure to volatile emissions from the tank farm, the evaporators, tank filling (sand filling) operations, retrieval operations, and particulate emissions from vitrification of tank waste for the worker, noninvolved worker, and general public. Potential carcinogenic risk and noncarcinogenic health hazards were estimated using the chemical source term, transport mechanism, exposure, and toxicological criteria as discussed in the following subsections.

#### D.4.9.2.1 Source Term

The source emissions for the Ex Situ/In Situ Combination 2 alternative are approximately the same as those of the Ex Situ/In Situ Combination 1 alternative. This is a conservative assumption based on reviewing and comparing the waste types, volumes, and activities that would take place during the operating period of the Ex Situ/In Situ Combination 2 alternative. The chemical concentration of many contaminants would be higher for the waste retrieved for the Ex Situ/In Situ Combination 2 compared to Ex Situ/In Situ Combination 1 alternative. However, the volume of waste that would be retrieved for the Ex Situ/In Situ Combination 2 alternative would be approximately 30 percent of the Ex Situ/In Situ Combination 1 alternative. The volume of vitrified waste produced would be approximately 60 percent of the Ex Situ/In Situ Combination 1 alternative. Volatile emissions from the waste treatment facilities stacks would be lower for the Ex Situ/In Situ Combination 2 alternative based on smaller treatment facilities and smaller contaminant inventories. Chemical emissions from the waste treatment facilities would be the largest component of the operating emissions. Volatile emissions from the fill and cap portion of the Ex Situ/In Situ Combination 2 alternative would be higher than those from the Ex Situ/In Situ Combination 1 alternative because more tanks would be treated in situ. The combination of these factors resulted in assessing the chemical risk using the same emissions rates for both combination alternatives.

Therefore, operating air emissions from the tank farm area, the evaporators, filling the tanks with sand, retrieval of the tank waste, and vitrification of tank waste are presented in Table D.4.8.5 (WHC 1995f, j and Jacobs 1996). The noninvolved worker and general public would be exposed to combined emissions from the tank farm area, the evaporators, filling the tanks with sand, retrieval operations and vitrification, while the worker would only be exposed to emissions (ground-level release) from the tank farm area, filling the tanks with sand and retrieval, because emissions from the evaporators and vitrification facility occur through a stack-release and would not impact the onsite worker.

#### D.4.9.2.2 Transport

Chemical transport modeling assumptions and parameters for the Ex Situ/In Situ Combination 2 alternative are identical to those presented in Table D.4.8.2 for the Ex Situ/In Situ Combination 1 alternative. The MEI worker was evaluated using a simplified "box" model, as presented in detail in Section D.4.1.2.2. The estimated Chi/Q value for the MEI worker was 9.26E-04 sec/$m^3$.

D.4.9.2.3 Exposure

The chemical exposure to each MEI receptor (i.e., worker, noninvolved worker, and general public) from volatile chemicals emitted as a result of implementing the Ex Situ/In Situ Combination 2 alternative is approximately equal to that of Ex Situ/In Situ Combination 1 alternative.

Therefore, chemical intake (dose) for each MEI receptor are presented in Section D.4.8.2.3.

D.4.9.2.4 Toxicity Assessment

Toxicity assessment was previously discussed in detail in Section D.4.1.2.4. Cancer slope factors, RfDs, and data sources for each volatile operating chemical emission are summarized in Table D.4.1.11.

D.4.9.2.5 Risk Characterization

The noncarcinogenic hazard, and carcinogenic risk to each MEI receptor (i.e., worker, noninvolved worker, and general public) resulting from implementing the Ex Situ/In Situ Combination 2 alternative are approximately equal to that of the Ex Situ/In Situ Combination 1 alternative.

The total HI and cancer risk to each MEI receptor for each scenario is presented in Section D.4.8.2.5.

## D.4.10 PHASED IMPLEMENTATION ALTERNATIVE

The Phased Implementation alternative includes remediating the tank waste in a two-phase process. The first phase would be a commercial demonstration of the separations and immobilization processes for selected tank waste. The second step would involve scaling-up the demonstration processes to treat the remaining tank waste and construction of larger treatment facilities.

### D.4.10.1 Phase 1

This section presents the anticipated remediation risk associated with Phase 1, as outlined in Volume Two, Appendix B of the EIS.

The radiological and toxicological risk for this alternative was based on the air emissions and direct exposure from construction (including construction, decontamination and decommissioning), continued operations (including tank farm and evaporator operations), retrieval, separations and treatment (including the LAW vitrification facility and the LAW/HLW vitrification facility), storage and disposal, and monitoring and maintenance.

D.4.10.1.1 Radiological Risk

Th LCF risk to the workers, noninvolved workers, and general public could result from direct exposure and atmospheric emissions from the components associated with this alternative. The risk was determined by analyzing the radiological source term, the transport mechanism, exposure, and the risk associated with the exposure as discussed in the following subsections.

### Source Term

The source term used for the noninvolved worker and general public was the atmospheric radiological emissions presented in Table D.4.10.1. The workers would receive a combined dose from the air emissions and from direct exposure from radiation fields in the workplace.

### Transport

The atmospheric transport parameters for Phase 1 are presented in Table D.4.10.2. The tank farm atmospheric radiological operating emissions were modeled as a ground release and the evaporator and the separations and vitrification were modeled as an elevated release. For modeling purposes, it was assumed that the source term would be released at a point in the 200 Areas represented by the meteorological conditions at the Hanford Meteorological Station. The analysis used the Hanford Meteorological Station joint frequency data from Table D.2.2.1 and Figure D.2.2.1.

For ground releases, dispersion in the atmosphere would cause contaminant air concentrations and exposures to decrease with increasing distance from the source. Maximum individual exposures therefore would occur at the inner boundaries (i.e., closest distance to the source) of the defined receptor occupancy zones. For the noninvolved worker, the maximum exposure would occur 100 m (330 ft) from the source (in an east-southeast direction). For the general public, the maximum exposure would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the center of the 200 East Area).

**Table D.4.10.1 Atmospheric Radiological Emissions for Phase 1**

| Continued Operations | | | | Separations and Treatment | | | |
|---|---|---|---|---|---|---|---|
| Tank Farm Emissions | | Evaporator Emissions | | Separations and LAW Vitrification | | Separations and LAW/HLW Vitrification | |
| Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released |
| Total Alpha[1] | 2.88E-08 | Total Alpha[1] | 2.10E-05 | Am-241 | 3.26E-07 | Am-241 | 2.40E-04 |
| Total Beta [2] | 7.91E-07 | Total Beta[2] | 1.20E-05 | C-14 | 4.00E+01 | C-14 | 7.00E+01 |
| I-129 | 4.60E-05 | | | Cs-137 | 1.87E-03 | Cs-137 | 1.73E-01 |
| Cs-137 | 5.38E-05 | | | Pu-239 | 7.90E-08 | Pu-239 | 2.63E-04 |
| Sr-90 | 1.81E-05 | | | Sr-90 | 7.20E-05 | Sr-90 | 1.60E-01 |
| | | | | Tc-99 | 9.83E-07 | Tc-99 | 1.65E-05 |
| | | | | I-129 | 2.20E-01 | I-129 | 2.20E-01 |

Notes:
[1] Total alpha is assumed to be Pu-239.
[2] Total beta is assumed to be Sr-90.

Table D.4.10.2 Atmospheric Transport Parameters for Phase 1

| Transport Parameters | Continued Operations | | Treatment |
|---|---|---|---|
| | Tank Farm Emissions | Evaporator Emissions | Separation and Vitrification |
| Stack height in m (ft) | Ground | 6.70 (22) | 45.7 (150) |
| Stack radius in m (ft) | N/A | 0.53 (1.7) | 0.50 (1.6) |
| Stack flow rate in $m^3$/sec ($ft^3$/sec) | N/A | 10 (353) | 10,8 (381) |
| Stack temperature in °C (°F) | N/A | 46 (117) | 65.6 (150) |
| Noninvolved worker MEI location in m (ft) ESE | 100 (328) | 200 (656) | 400 (1312) |
| Public MEI location in km (mi) ESE | 22 (14) | 22 (14) | 22 (14) |
| Chi/Q for noninvolved worker - population in $s/m^3$ | 1.60E-03 | 4.00E-04 | 1.20E-04 |
| Chi/Q for noninvolved worker - MEI in $s/m^3$ | 4.00E-04 | 2.50E-06 | 9.40E-08 |
| Chi/Q for general public - population in $s/m^3$ | 2.90E-03 | 1.60E-03 | 8.00E-04 |
| Chi/Q for general public - MEI in $s/m^3$ | 6.60E-08 | 3.90E-08 | 1.50E-08 |

Notes:
ESE = East-southeast

The calculated Chi/Q values for ground releases from the tank farms were calculated by the GENII computer code to be 4.00E-04 sec/$m^3$ for the noninvolved worker MEI and 6.60E-08 sec/$m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 1.60E-03 sec/$m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 2.9E-03 sec/$m^3$.

For elevated releases (stack releases), the maximum exposure would not necessarily occur at the closest distance to the source. Air transport modeling indicates that the maximum exposure for the noninvolved worker would occur 200 m (660 ft) from the source (in an east-southeast direction) for the evaporator and 400 m (1,300 ft) for separations and vitrification. The maximum exposure for a member of the general public would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the 200 East Area).

The calculated Chi/Q values for the evaporator operation were 2.50E-06 sec/$m^3$ for the noninvolved worker MEI and 3.90E-08 sec/$m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 4.00E-04 sec/$m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q values were 1.60E-03 sec/$m^3$. For the separations and vitrification operation, the Chi/Q values were 9.40E-08 sec/$m^3$ for the noninvolved worker MEI, 1.50E-08 sec/$m^3$ for the general public MEI, 1.20E-04 sec/$m^3$ for the noninvolved worker population, and 8.00E-04 sec/$m^3$ for the general public population.

### Exposure

The radiological exposure for the alternative is presented in Table D.4.10.3. The table shows the exposure each receptor would receive from every component. The sum of the components are shown in the last column for each population and MEI receptor except for the MEI worker. The MEI worker is not summed but is represented by the component with the highest MEI dose.

The worker population dose is dependent on the number of people in the population and the anticipated dose each individual would receive. The data were obtained from the Site maintenance and operations contractor and the TWRS EIS contractor (WHC 1995a and Jacobs 1996). The calculations for the worker exposures from construction, continued operations, retrieval, separations and treatment, monitoring and maintenance, and closure are as follows:

Construction = (5.00E-01 person-yr) · (1.40E-02 rem/person-yr) = 7.00E-03 person-rem

Continued Operations -
Tank farms = (5.00E+03 person-yr) · (1.40E-02 rem/person-yr) = 7.00E+01 person-rem
Evaporator = (6.40E+02 person-yr) · (2.00E-01 rem/person-yr) = 1.28E+02 person-rem
Total = 1.98E+02 person-rem

Retrieval = (1.00E+02 person-yr) · (2.00E-01 rem/person-yr) = 2.00E+01 person-rem

Separation/Treatment = (3.36E+03 person-yr) · (2.00E-01 rem/person-yr) = 6.72E+02 person-rem

Table D.4.10.3 Summary of Anticipated Radiological Exposure for Phase 1

| | Dose (person-rem) [2] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Receptor | Construction and D&D (4 yrs) | Continued Operations [1] (10 yrs) | Retrieval (10 yrs) | Separations and Treatment [2] (10 yrs) | Transportation | Monitoring and Maintenance (10 yrs) | Post Closure Monitoring | Total |
| Worker - Population | 7.00E-03 | 1.98E+02 | 2.00E+01 | 6.73E+02 | N/A | N/A | N/A | 8.91E+02 |
| Worker - MEI [3] | 2.50E+00 | 5.00E+00 | 5.00E+00 | 5.00E+00 | N/A | N/A | N/A | 5.00E+00 |
| Noninvolved Worker - Population | 0.00E+00 | 1.33E-03 | 0.00E+00 | 1.19E-01 | N/A | N/A | N/A | 1.20E-01 |
| Noninvolved Worker - MEI | 0.00E+00 | 1.02E-04 | 0.00E+00 | 3.71E-05 | N/A | N/A | N/A | 1.02E-04 |
| General Public - Population | 0.00E+00 | 5.90E-02 | 0.00E+00 | 5.80E+01 | N/A | N/A | N/A | 5.81E+01 |
| General Public - MEI | 0.00E+00 | 1.50E-06 | 0.00E+00 | 7.90E-04 | N/A | N/A | N/A | 7.90E-04 |

Notes:
[1] Continued Operations include Tank Farm and Eyaporator 1.
[2] MEI receptor dose is noted in rem.
[3] Worker MEI is assumed to work for 30 years maximum.

The MEI worker was assumed to receive a dose of 500 mrem (5.00E-01 rem) per year for a maximum of 30 years.

The noninvolved workers and general public exposures from inhalation of the atmospheric emissions (source term) were converted to a radiological dose in rem using the GENII computer code and applying the appropriate Chi/Q.

**Risk**

The LCFs are calculated as the product of the estimated dose times the dose-to-risk conversion factor (Section D.2.2.4). The sum of the radiological dose from construction, continued operations, treatment, and closure, for each receptor shown in the combined dose column in Table D.4.10.4, was multiplied by the appropriate dose-to-risk conversion factor to produce the LCF risk.

**Table D.4.10.4 Summary of Anticipated Risk for Phase 1**

| Receptor | Combined Dose (person-rem) [1] | LCF/rem | LCF Risk |
|---|---|---|---|
| Worker - Population | 8.91E+02 | 4.00E-04 | 3.56E-01 |
| Worker - MEI | 5.00E+00 | 4.00E-04 | 2.00E-03 |
| Noninvolved Worker - Population | 1.20E-01 | 4.00E-04 | 4.80E-05 |
| Noninvolved Worker - MEI | 1.02E-04 | 4.00E-04 | 4.08E-08 |
| General Public - Population | 5.81E+01 | 5.00E-04 | 2.91E-02 |
| General Public - MEI | 7.90E-04 | 5.00E-04 | 3.95E-07 |

Notes:
[1] MEI dose is noted in rem
LCF = Latent cancer fatality

D.4.10.1.2 Chemical Exposure

Potential carcinogenic risk and noncarcinogenic health hazards may result from exposure to volatile emissions from the tank farm, tank waste retrieval, and the evaporator, and exposure to particulate emissions from the separation and vitrification of HLW and LAW for the worker, noninvolved worker, and general public. Potential carcinogenic risk and noncarcinogenic health hazards were estimated using the chemical source term, transport mechanism, exposure, and toxicological criteria as discussed in the following subsections.

**Source Term**

Operating air emissions from the tank farm area, tank waste retrieval, evaporator and vitrification facilities are presented in Table D.4.10.5 (Jacobs 1996). The emission rates from the full-scale HLW and LAW vitrification facilities were combined and treated as a single-source emission, as discussed in Section D.4.5.2.1 for the Ex Situ Intermediate Separations alternative. This assumption is conservative and health protective as the pilot separation/vitrification facilities are scaled-down versions and would emit a fraction of the particulates emitted in this scenario. The noninvolved worker and general public would be exposed to combined emissions from the tank farm area, tank waste retrieval operations,

evaporator, and vitrification facilities. The worker would only be exposed to emissions (ground-level release) from the tank farm area and retrieval operations because emissions from the evaporator and vitrification facilities occur through a stack-release and would not impact the onsite worker.

**Table D.4.10.5 Chemical Emissions for Phase 1**

| Tank Farm Emissions | | Retrieval Emissions | | Evaporator Emissions | | Separations/Vitrification Emissions | |
|---|---|---|---|---|---|---|---|
| Emissions | Total Tank Farm Emission Rate (mg/sec) | Emissions | Retrieval Emission Rate (mg/sec) | Emissions | Evaporator Emission Rate (mg/sec) | Emissions | Plant Emission Rate (mg/sec) |
| Carbon Monoxide | 1.05E+00 | Carbon Monoxide | 4.91E-03 | Acetone | 2.30E-01 | Aluminum | 1.54E-02 |
| Nitrogen Oxide | 1.06E-01 | Nitrogen Oxide | 1.23E-01 | Ammonia | 2.16E-01 | Arsenic | 1.67E-06 |
| 1,3-Butadiene | 7.49E-03 | 1,3-Butadiene | 8.91E-03 | n-Butyl Alcohol | 1.73E+00 | Boron | 6.35E-04 |
| 2-Hexanone | 1.37E-01 | 2-Hexanone | 1.62E-01 | 2-Hexanone | 8.28E-04 | Barium | 4.73E-06 |
| 2-Pentanone | 2.16E-01 | 2-Pentanone | 2.57E-01 | Methyl Isobutyl Ketone | 1.57E-02 | Beryllium | 1.24E-07 |
| Acetone | 2.61E+00 | Acetone | 3.09E+00 | | | Bismuth | 3.04E-04 |
| Acetonitrile | 1.26E+00 | Acetonitrile | 1.49E+00 | | | Cadmium | 1.22E-05 |
| Benzene | 5.97E-02 | Benzene | 7.07E-02 | | | Cerium | 2.77E-04 |
| Heptane | 1.53E-01 | Heptane | 1.81E-01 | | | Chromium (+3) | 2.48E-04 |
| Methyl N-amyl Ketone | 1.48E-01 | Methyl N-amyl Ketone | 1.75E-01 | | | Copper | 1.11E-06 |
| N-hexane | 1.60E-01 | N-hexane | 1.89E-01 | | | Manganese | 1.72E-04 |
| Nonane | 8.32E-02 | Nonane | 9.86E-02 | | | Molybdenum | 7.81E-06 |
| Octane | 8.73E-02 | Octane | 1.03E-01 | | | Nickel | 2.07E-04 |
| Toluene | 1.22E-02 | Toluene | 1.44E-02 | | | Lead | 6.56E-06 |
| Ammonia | 7.67E+00 | Ammonia | 9.16E-02 | | | Silver | 1.03E-06 |
| Phosphoric Acid, Tributyl Ester | 1.89E-01 | Phosphoric Acid, Tributyl Ester | 4.91E-05 | | | Uranium | 1.72E-03 |
| Carbon Tetrachloride | 1.24E-07 | | | | | Vanadium | 3.06E-07 |
| Ethyl Butyl Ketone | 4.15E-07 | | | | | Zinc | 6.15E-06 |
| Methyl Chloride | 1.83E-08 | | | | | | |
| Tetrahydrofuran | 3.20E-08 | | | | | | |

### Transport

The tank farm chemical operating emissions (routine emissions from the tank farm and emissions during retrieval) were modeled as a ground release. Chemical operating emissions from the evaporator and vitrification facilities would occur from stack releases and were modeled as elevated releases. Transport parameters, location of the MEI noninvolved worker and MEI general public, and Chi/Q values for the MEI noninvolved worker and general public, are identical to the radiological parameters presented in Table D.4.10.2.

The MEI worker was evaluated using a simplified "box" model, as presented in detail in Section D.2.2.3. The estimated Chi/Q value for the MEI worker was 9.26E-04 sec/$m^3$.

### Exposure

#### Worker

The MEI worker was assumed to be located within a box placed directly over the tank farm area. Exposure point concentrations of chemical emissions (mg/$m^3$) from the tank farm area and retrieval operations were estimated by multiplying the cumulative tank farm emission rate (mg/sec) and retrieval operation emission rate (mg/sec) by the MEI worker Chi/Q value (9.26E-04 sec/$m^3$), respectively. Exposure point concentrations for each volatile chemical emitted from the tank farm area and during retrieval are summarized in Tables D.4.10.6 and D.4.10.7, respectively.

Chemical intake (dose) was estimated for the MEI worker using the same equation and exposure parameters defined in Section D.2.2.3. Estimated intakes of chemical emissions from the tank farm and retrieval operations for the MEI worker are presented in Tables D.4.10.6 and D.4.10.7, respectively.

Noninvolved Worker - The MEI noninvolved worker was assumed to be located at the point where maximum downwind air concentrations were calculated (100 m [330 ft] from the tank farm, and 200 m [660 ft] from the evaporator). Exposure point concentrations (mg/$m^3$) of chemical emissions from the tank farm, retrieval operations, evaporator, and vitrification facilities were estimated by multiplying the cumulative tank farm, retrieval, evaporator, and plant emission rates (mg/sec) by their respective MEI noninvolved worker Chi/Q values (4.00E-04 sec/$m^3$ for the tank farm, 2.50E-06 sec/$m^3$ for the evaporator, 4.00E-04 sec/$m^3$ for retrieval, and 2.90E-08 sec/$m^3$ for the vitrification facility). Exposure point concentrations for each chemical emitted from the tank farm area, the evaporator, retrieval operations and the vitrification facility are summarized in Tables D.4.10.8, D.4.10.9, D.4.10.10 and D.4.10.11, respectively.

Chemical intake (dose) was estimated for the MEI noninvolved worker according to the same equation and exposure parameters used for the MEI worker. Estimated operating chemical emission intakes for the MEI noninvolved worker are presented in Tables D.4.10.8, D.4.10.9, D.4.10.10, and D.4.10.11 for the tank farm area, the evaporator, retrieval operations, and the vitrification facility emissions, respectively.

Table D.4.10.6 Phase 1 Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg-day)^{-1}$ | Noncarcinogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 9.75E-04 | 1.91E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 9.80E-05 | 1.92E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 6.94E-06 | 1.36E-06 | 1.94E-07 | ND | 9.80E-01 | NE | 1.90E-07 |
| 2-Hexanone | 1.27E-04 | 2.48E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.00E-04 | 3.92E-05 | NC | ND | NC | NE | NC |
| Acetone | 2.41E-03 | 4.73E-04 | NC | 1.00E-01 | NC | 4.73E-03 | NC |
| Acetonitrile | 1.16E-03 | 2.28E-04 | NC | 1.40E-02 | NC | 1.63E-03 | NC |
| Benzene | 5.53E-05 | 1.08E-05 | 1.55E-06 | 1.70E-03 | 2.90E-02 | 6.37E-03 | 4.49E-08 |
| Heptane | 1.42E-04 | 2.78E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.37E-04 | 2.69E-05 | NC | 2.30E-02 | NC | 1.17E.03 | NC |
| N-hexane | 1.48E-04 | 2.91E-05 | NC | 5.70E-02 | NC | 5.10E-04 | NC |
| Nonane | 7.70E-05 | 1.51E-05 | NC | ND | NC | NE | NC |
| Octane | 8.08E-05 | 1.58E-05 | NC | ND | NC | NE | NC |
| Toluene | 1.13E-05 | 2.22E-06 | NC | 1.10E-01 | NC | 2.02E-05 | NC |
| Ammonia | 7.10E-03 | 1.39E-03 | NC | 2.90E-02 | NC | 4.80E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 1.75E-04 | 3.43E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.15E-10 | 2.25E-11 | 3.21E-12 | 5.70E-04 | 5.30E-02 | 3.95E-08 | 1.70E-13 |
| Ethyl Butyl Ketone | 3.85E-10 | 7.54E-11 | NC | 2.30E-02 | NC | 3.28E-09 | NC |
| Methyl Chloride | 1.70E-11 | 3.33E-12 | 4.75E-13 | ND | 6.30E-03 | NE | 2.99E-15 |
| Tetrahydrofuran | 2.97E-11 | 5.81E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 7.71E-02** | **Risk = 2.35E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.10.7 Phase 1 Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 4.55E-06 | 8.91E-07 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 1.14E-04 | 2.24E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 8.25E-06 | 1.62E-06 | 2.31E-07 | ND | 9.80E-01 | NE | 2.26E-07 |
| 2-Hexanone | 1.50E-04 | 2.94E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.38E-04 | 4.67E-05 | NC | ND | NC | NE | NC |
| Acetone | 2.86E-03 | 5.61E-04 | NC | 1.00E-01 | NC | 5.61E-03 | NC |
| Acetonitrile | 1.38E-03 | 2.70E-04 | NC | 1.40E-02 | NC | 1.93E-02 | NC |
| Benzene | 6.55E-05 | 1.28E-05 | 1.83E-06 | 1.70E-03 | 2.90E-02 | 7.55E-03 | 5.32E-08 |
| Heptane | 1.68E-04 | 3.29E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.62E-04 | 3.18E-05 | NC | 2.30E-02 | NC | 1.38E-03 | NC |
| N-hexane | 1.75E-04 | 3.43E-05 | NC | 5.70E-02 | NC | 6.02E-04 | NC |
| Nonane | 9.13E-05 | 1.79E-05 | NC | ND | NC | NE | NC |
| Octane | 9.57E-05 | 1.88E-05 | NC | ND | NC | NE | NC |
| Toluene | 1.33E-05 | 2.61E-06 | NC | 1.10E-01 | NC | 2.38E-05 | NC |
| Ammonia | 8.48E-05 | 1.66E-05 | NC | 2.90E-02 | NC | 5.73E-04 | NC |
| Phosphoric Acid, Tributyl Ester | 4.55E-08 | 8.91E-09 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 3.50E-02** | **Risk = 2.79E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.10.8 Phase 1 Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarci-nogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarci-nogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 4.21E-04 | 8.25E-05 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 4.23E-05 | 8.30E-06 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 3.00E-06 | 5.88E-07 | 8.39E-08 | ND | 9.80E-01 | NE | 8.23E-08 |
| 2-Hexanone | 5.47E-05 | 1.07E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 8.64E-05 | 1.69E-05 | NC | ND | NC | NE | NC |
| Acetone | 1.04E-03 | 2.04E-04 | NC | 1.00E-01 | NC | 2.04E-03 | NC |
| Acetonitrile | 5.02E-04 | 9.84E-05 | NC | 1.40E-02 | NC | 7.03E-03 | NC |
| Benzene | 2.39E-05 | 4.68E-06 | 6.69E-07 | 1.70E-03 | 2.90E-02 | 2.75E-03 | 1.94E-08 |
| Heptane | 6.13E-05 | 1.20E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 5.92E-05 | 1.16E-05 | NC | 2.30E-02 | NC | 5.05E-04 | NC |
| N-hexane | 6.41E-05 | 1.26E-05 | NC | 5.70E-02 | NC | 2.20E-04 | NC |
| Nonane | 3.33E-05 | 6.52E-06 | NC | ND | NC | NE | NC |
| Octane | 3.49E-05 | 6.84E-06 | NC | ND | NC | NE | NC |
| Toluene | 4.89E-06 | 9.58E-07 | NC | 1.10E-01 | NC | 8.71E-06 | NC |
| Ammonia | 3.07E-03 | 6.01E-04 | NC | 2.90E-02 | NC | 2.07E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 7.57E-05 | 1.48E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 4.96E-11 | 9.72E-12 | 1.39E-12 | 5.70E-04 | 5.30E-02 | 1.71E-08 | 7.36E-14 |
| Ethyl Butyl Ketone | 1.66E-10 | 3.26E-11 | NC | 2.30E-02 | NC | 1.42E-09 | NC |
| Methyl Chloride | 7.33E-12 | 1.44E-12 | 2.05E-13 | ND | 6.30E-03 | NE | 1.29E-15 |
| Tetrahydorfuran | 1.28E-11 | 2.51E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 3.33E-02** | **Risk = 1.02E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.10.9 Phase 1 Evaporator Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Acetone | 5.75E-07 | 1.13E-07 | NC | 1.00E-01 | NC | 1.13E-06 | NC |
| Ammonia | 5.40E-07 | 1.06E-07 | NC | 2.90E-02 | NC | 3.65E-06 | NC |
| n-Butyl Alcohol | 4.33E-06 | 8.48E-07 | NC | 1.00E-01 | NC | 8.48E-06 | NC |
| 2-Hexanone | 2.07E-09 | 4.06E-10 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 3.93E-08 | 7.69E-09 | NC | 2.30E-02 | NC | 3.34E-07 | NC |
| | | | | | | HI = 1.36E-05 | |

Notes:
NC = Noncarcinogen
NE = Not evaluated

General Public - The MEI general public receptor was assumed to be located at the point where maximum air concentrations were calculated (approximately 22 km [14 mi] from both the tank farm area and evaporator). Exposure point concentrations ($mg/m^3$) of chemical emissions from the tank farm area, the evaporator, retrieval operations, and the vitrification facility were estimated by multiplying the cumulative emission rates (mg/sec) of each source by their respective MEI general public Chi/Q values (6.60E-08 $sec/m^3$ for the tank farm, 3.90E-08 $sec/m^3$ for evaporator, 6.60E-08 $sec/m^3$ for retrieval operations, and 7.70E-09 $sec/m^3$ for the vitrification facility). Exposure point concentrations for each volatile chemical emitted from the tank farm area, evaporator, retrieval operations, and the vitrification facility are summarized in Tables D.4.10.12, D.4.10.13, D.4.10.14 and D.4.10.15, respectively.

The residential or general public intake was calculated according to the equation and exposure parameters presented in Section D.2.2.3. Estimated chemical emission intakes for the MEI general public are presented in Tables D.4.10.12, D.4.10.13, D.4.1.14, and D.4.10.15 for the tank farm area, the evaporator, retrieval operations and the vitrification facility, respectively.

**Toxicity Assessment**

Toxicity assessment was previously discussed in detail in Section D.4.1.2.4. Cancer slope factors, RfDs, and data sources for each volatile operating chemical emission are summarized in Table D.4.1.11.

Table D.4.10.10 Phase 1 Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarci-nogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarci-nogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 1.96E-06 | 3.85E-07 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 4.94E-05 | 9.68E-06 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 3.56E-06 | 6.98E-07 | 9.98E-08 | ND | 9.80E-01 | NE | 9.78E-08 |
| 2-Hexanone | 6.49E-05 | 1.27E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 1.03E-04 | 2.02E-05 | NC | ND | NC | NE | NC |
| Acetone | 1.24E-03 | 2.42E-04 | NC | 1.00E-01 | NC | 2.42E-03 | NC |
| Acetonitrile | 5.96E-04 | 1.17E-04 | NC | 1.40E-02 | NC | 8.34E-03 | NC |
| Benzene | 2.83E-05 | 5.54E-06 | 7.92E-07 | 1.70E-03 | 2.90E-02 | 3.26E-03 | 2.30E-08 |
| Heptane | 7.25E-05 | 1.42E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 7.02E-05 | 1.38E-05 | NC | 2.30E-02 | NC | 5.98E-04 | NC |
| N-hexane | 7.56E-05 | 1.48E-05 | NC | 5.70E-02 | NC | 2.60E-04 | NC |
| Nonane | 3.94E-05 | 7.73E-06 | NC | ND | NC | NE | NC |
| Octane | 4.13E-05 | 8.10E-06 | NC | ND | NC | NE | NC |
| Toluene | 5.76E-06 | 1.13E-06 | NC | 1.10E-01 | NC | 1.03E-05 | NC |
| Ammonia | 3.66E-05 | 7.18E-06 | NC | 2.90E-02 | NC | 2.48E-04 | NC |
| Phosphoric Acid, Tributyl Ester | 1.96E-08 | 3.85E-09 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 1.51E-02** | **Risk = 1.21E-07** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

### Risk Characterization

**MEI Worker** - The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm and retrieval operations are summarized in Tables D.4.10.6 and D.4.10.7, respectively. The total HI and cancer risk from routine tank farm emissions and retrieval emissions are 1.12E-01 and 5.14E-07, respectively.

Table D.4.10.11 Phase 1 Plant Emissions

| Emissions | Air Concentrations of Vitrification Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Aluminum | 4.46E-10 | 8.75E-11 | NC | ND | NC | NE | NC |
| Arsenic | 4.83E-14 | 9.47E-15 | 1.25E-11 | ND | 1.51E+01 | NE | 1.89E-10 |
| Boron | 1.84E-11 | 3.61E-12 | NC | 5.70E-03 | NC | 6.34E-10 | NC |
| Barium | 1.37E-13 | 2.69E-14 | NC | 1.43E-04 | NC | 1.88E-10 | NC |
| Beryllium | 3.59E-15 | 7.04E-16 | 3.84E-15 | ND | 8.40E+00 | NE | 3.23E-14 |
| Bismuth | 8.83E-12 | 1.73E-12 | NC | ND | NC | NE | NC |
| Cadmium | 3.52E-13 | 6.91E-14 | 2.47E-13 | ND | 6.30E+00 | NE | 1.56E-12 |
| Cerium | 8.02E-12 | 1.57E-12 | NC | ND | NC | NE | NC |
| Chromium (+3) | 7.18E-12 | 1.41E-12 | NC | 5.71E-07 | NC | 2.47E-06 | NC |
| Copper | 3.23E-14 | 6.34E-15 | NC | ND | NC | NE | NC |
| Manganese | 5.00E-12 | 9.80E-13 | NC | ND | NC | NE | NC |
| Molybdenum | 2.27E-13 | 4.44E-14 | NC | ND | NC | NE | NC |
| Nickel | 6.01E-12 | 1.18E-12 | NC | ND | NC | NE | NC |
| Lead | 1.90E-13 | 3.73E-14 | NC | ND | NC | NE | NC |
| Silver | 2.99E-14 | 5.87E-15 | NC | ND | NC | NE | NC |
| Uranium | 5.00E-11 | 9.80E-12 | NC | ND | NC | NE | NC |
| Vanadium | 8.86E-15 | 1.74E-15 | NC | ND | NC | NE | NC |
| Zinc | 1.78E-13 | 3.49E-14 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 2.47E-06** | **Risk = 1.90E-10** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

**MEI Noninvolved Worker** - The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm, evaporator, retrieval operations, and the vitrification facility are summarized in Tables D.4.10.8, D.4.10.9, D.4.10.10 and D.4.10.11, respectively. The total HI and cancer risk from combined tank farm, evaporator, retrieval and plant emissions are 4.84E-02 and 2.23E-07, respectively.

Table D.4.10.12 Phase 1 Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI General Public ($mg/m^3$) | Noncarci-nogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarci-nogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 6.95E-08 | 4.34E-08 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 6.98E-09 | 4.36E-09 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 4.95E-10 | 3.09E-10 | 2.50E-11 | ND | 9.80E-01 | NE | 2.45E-11 |
| 2-Hexanone | 9.03E-09 | 5.64E-09 | NC | ND | NC | NE | NC |
| 2-Pentanone | 1.43E-08 | 8.91E-09 | NC | ND | NC | NE | NC |
| Acetone | 1.72E-07 | 1.08E-07 | NC | 1.00E-01 | NC | 1.08E-06 | NC |
| Acetonitrile | 8.29E-08 | 5.18E-08 | NC | 1.40E-02 | NC | 3.70E-06 | NC |
| Benzene | 3.94E-09 | 2.46E-09 | 1.99E-10 | 1.70E-03 | 2.90E-02 | 1.45E-06 | 5.77E-12 |
| Heptane | 1.01E-08 | 6.32E-09 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 9.77E-09 | 6.11E-09 | NC | 2.30E-02 | NC | 2.65E-07 | NC |
| N-hexane | 1.06E-08 | 6.61E-09 | NC | 5.70E-02 | NC | 1.16E-07 | NC |
| Nonane | 5.49E-09 | 3.43E-09 | NC | ND | NC | NE | NC |
| Octane | 5.76E-09 | 3.60E-09 | NC | ND | NC | NE | NC |
| Toluene | 8.07E-10 | 5.04E-10 | NC | 1.10E-01 | NC | 4.58E-09 | NC |
| Ammonia | 5.06E-07 | 3.16E-07 | NC | 2.90E-02 | NC | 1.09E-05 | NC |
| Phosphoric Acid, Tributyl Ester | 1.25E-08 | 7.81E-09 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 8.18E-15 | 5.11E-15 | 4.14E-16 | 5.70E-04 | 5.30E-02 | 8.97E-12 | 2.19E-17 |
| Ethyl Butyl Ketone | 2.74E-14 | 1.71E-14 | NC | 2.30E-02 | NC | 7.45E-13 | NC |
| Methyl Chloride | 1.21E-15 | 7.56E-16 | 6.11E-17 | ND | 6.30E-03 | NE | 3.85E-19 |
| Tetrahydrofuran | 2.11E-15 | 1.32E-15 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 1.75E-05** | **Risk = 3.03E-11** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.10.13 Phase 1 Evaporator Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the MEI General Public ($mg/m^3$) | Noncarci-nogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarci-nogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Acetone | 8.97E-09 | 5.61E-09 | NC | 1.00E-01 | NC | 5.61E-08 | NC |
| Ammonia | 8.42E-09 | 5.27E-09 | NC | 2.90E-02 | NC | 1.82E-07 | NC |
| n-Butyl Alcohol | 6.75E-08 | 4.22E-08 | NC | 1.00E-01 | NC | 4.22E-07 | NC |
| 2-Hexanone | 3.23E-11 | 2.02E-11 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 6.12E-10 | 3.83E-10 | NC | 2.30E-02 | NC | 1.66E-08 | NC |
| | | | | | | HI = 6.76E-07 | |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

**MEI General Public** - The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm, evaporator, retrieval operations, and the vitrification facility are summarized in Tables D.4.10.12, D.4.10.13, D.4.10.14 and D.4.10.15, respectively. The total HI and cancer risk from combined tank farm, evaporator, retrieval and plant emissions are 2.82E-05 and 1.58E-10, respectively.

### D.4.10.2 Total Alternative

This section presents the anticipated remediation risk associated with the Total alternative for tank waste, as outlined in Volume Two, Appendix B of the EIS.

The radiological and toxicological risk for this alternative was based on the air emissions and direct exposure from construction, continued operations (including tank farm and evaporator operations), retrieval, separations and treatment (including Phase 1 and Phase 2), storage and disposal, onsite transportation of waste, monitoring and maintenance, and closure and monitoring.

#### D.4.10.2.1 Radiological Risk

The LCF risk to the workers, noninvolved workers, and general public could result from direct exposure and atmospheric emissions from the components associated with this alternative. The risk was determined by analyzing the radiological source term, the transport mechanism, exposure, and the risk associated with the exposure as discussed in the following subsections.

Table D.4.10.14 Phase 1 Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the MEI General Public ($mg/m^3$) | Noncarci-nogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_I$) (mg/kg-day) | Inhalation Slope Factor ($SF_I$) $(mg/kg\text{-}day)^{-1}$ | Noncarci-nogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 3.24E-10 | 2.02E-10 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 8.15E-09 | 5.09E-09 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 5.88E-10 | 3.67E-10 | 2.97E-11 | ND | 9.80E-01 | NE | 2.91E-11 |
| 2-Hexanone | 1.07E-08 | 6.69E-09 | NC | ND | NC | NE | NC |
| 2-Pentanone | 1.70E-08 | 1.06E-08 | NC | ND | NC | NE | NC |
| Acetone | 2.40E-07 | 1.28E-07 | NC | 1.00E-01 | NC | 1.28E-06 | NC |
| Acetonitrile | 9.83E-08 | 6.14E-08 | NC | 1.40E-02 | NC | 4.39E-06 | NC |
| Benzene | 4.67E-09 | 2.92E-09 | 2.36E-10 | 1.70E-03 | 2.90E-02 | 1.72E-06 | 6.84E-12 |
| Heptane | 1.20E-08 | 7.48E-09 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.16E-08 | 7.23E-09 | NC | 2.30E-02 | NC | 3.15E-07 | NC |
| N-hexane | 1.25E-08 | 7.80E-09 | NC | 5.70E-02 | NC | 1.37E-07 | NC |
| Nonane | 6.51E-09 | 4.07E-09 | NC | ND | NC | NE | NC |
| Octane | 6.82E-09 | 4.26E-09 | NC | ND | NC | NE | NC |
| Toluene | 9.50E-10 | 5.94E-10 | NC | 1.10E-01 | NC | 5.40E-09 | NC |
| Ammonia | 6.05E-09 | 3.78E-09 | NC | 2.90E-02 | NC | 1.30E-07 | NC |
| Phosphoric Acid, Tributyl Ester | 3.24E-12 | 2.02E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 7.96E-06** | **Risk = 3.60E-11** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.10.15 Phase 1 Plant Emissions Phase 1 Plant Emissions

| Emissions | Air Concentrations of Vitrification Emissions for the MEI General Public ($mg/m^3$) | Noncarci-nogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarci-nogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Aluminum | 1.19E-10 | 7.41E-11 | NC | ND | NC | NE | NC |
| Arsenic | 1.28E-14 | 8.02E-15 | 6.01E-12 | ND | 1.51E+01 | NE | 9.07E-11 |
| Boron | 4.89E-12 | 3.06E-12 | NC | 5.70E-03 | NC | 5.36E-10 | NC |
| Barium | 3.65E-14 | 2.28E-14 | NC | 1.43E-04 | NC | 1.59E-10 | NC |
| Beryllium | 9.54E-16 | 5.96E-16 | 1.85E-15 | ND | 8.40E+00 | NE | 1.55E-14 |
| Bismuth | 2.34E-12 | 1.46E-12 | NC | ND | NC | NE | NC |
| Cadmium | 9.36E-14 | 5.58E-14 | 1.19E-13 | ND | 6.30E+00 | NE | 7.48E-13 |
| Cerium | 2.13E-12 | 1.33E-12 | NC | ND | NC | NE | NC |
| Chromium (+3) | 1.91E-12 | 1.19E-12 | NC | 5.71E-07 | NC | 2.09E-06 | NC |
| Copper | 8.58E-15 | 5.36E-15 | NC | ND | NC | NE | NC |
| Manganese | 1.33E-12 | 8.30E-13 | NC | ND | NC | NE | NC |
| Molybdenum | 6.02E-14 | 3.76E-14 | NC | ND | NC | NE | NC |
| Nickel | 1.60E-12 | 9.97E-13 | NC | ND | NC | NE | NC |
| Lead | 5.05E-14 | 3.16E-14 | NC | ND | NC | NE | NC |
| Silver | 7.95E-15 | 4.97E-15 | NC | ND | NC | NE | NC |
| Uranium | 1.33E-11 | 8.30E-12 | NC | ND | NC | NE | NC |
| Vanadium | 2.35E-15 | 1.47E-15 | NC | ND | NC | NE | NC |
| Zinc | 4.73E-14 | 2.96E-14 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 2.09E-06** | **Risk = 9.14E-11** |

Notes:
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

**Source Term** - The source term used for the noninvolved worker and general public was the atmospheric radiological emissions presented in Table D.4.10.16 (WHC 1995j and Jacobs 1996). They would also receive a direct exposure dose from the vitrified HLW as it is being transported to a national HLW repository. The workers would receive a combined dose from the air emissions and from direct exposure from radiation fields in the work place.

**Transport** - The atmospheric transport parameters of the Total alternative are presented in Table D.4.10.17. The tank farm and retrieval atmospheric radiological operating emissions were

modeled as a ground release, and the evaporator and the separations and vitrification were modeled as elevated releases. For modeling purposes, it was assumed that the source term would be released at a point in the 200 Areas represented by the meteorological conditions at the Hanford Meteorological Station. The analysis used the Hanford Meteorological Station joint frequency data from Table D.2.2.1 and Figure D.2.2.1.

For ground releases, dispersion in the atmosphere would cause contaminant air concentrations and exposures to decrease with increasing distance from the source. Maximum individual exposures therefore would occur at the inner boundaries (i.e., closest distance to the source) of the defined receptor occupancy zones. For the noninvolved worker, the maximum exposure would occur 100 m (330 ft) from the source (in an east-southeast direction). For the general public, the maximum exposure would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the center of the 200 East Area).

**Table D.4.10.16 Atmospheric Radiological Emissions for the Total Alternative**

| Continued Operations | | | | Retrieval Emissions | | Separations and Treatment Emissions | |
|---|---|---|---|---|---|---|---|
| Tank Farm Emissions | | Evaporator Emissions 1 | | | | Phase 2 | |
| Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released | Contaminants | Ci/yr Released |
| Total Alpha[1] | 2.88E-08 | Total Alpha[1] | 2.10E-05 | Sr-90 | 5.50E-04 | Am-241 | 3.11E-03 |
| Total Beta[2] | 7.91E-07 | Total Beta[2] | 1.20E-05 | Cs-137 | 2.20E-03 | C-14 | 2.55E+02 |
| Sr-90 | 1.81E-05 | | | I-129 | 4.40E-03 | Cs-137 | 1.47E+00 |
| Cs-137 | 5.38E-05 | | | | | I-129 | 2.00E+00 |
| I-129 | 4.60E-05 | | | | | Pu-239 | 1.01E-03 |
| | | | | | | Ru-106 | 1.12E-09 |
| | | | | | | Sm-151 | 1.88E-02 |
| | | | | | | Sr-90 | 1.59E+00 |
| | | | | | | Tc-99 | 9.42E-04 |
| | | | | | | Zr-93 | 1.06E-02 |

Notes:
[1] Total alpha is assumed to be Pu-239
[2] Total beta is assumed to be Sr-90

The calculated Chi/Q values for ground releases from the tank farms were calculated by the GENII computer code to be 4.00E-04 sec/m$^3$ for the noninvolved worker MEI and 6.60E-08 sec/m$^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 1.60E-03 sec/m$^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 2.90E-03 sec/m$^3$.

For elevated releases (stack releases), the maximum exposure would not necessarily occur at the closest distance to the source. Air transport modeling indicates that the maximum exposure for the noninvolved worker would occur 200 m (660 ft) from the source (in an east-southeast direction) for the evaporator and 800 m (2,600 ft) for separations and vitrification. The maximum exposure for a member of the general public would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the 200 East Area).

**Table D.4.10.17 Atmospheric Transport Parameters for the Total Alternative**

| Transport Parameters | Continued Operations | | Retrieval | Separations and Treatment | |
|---|---|---|---|---|---|
| | Tank Farms | Evaporator 1 | | Phase 1 | Phase 2 |
| Stack height in m (ft) | Ground | 6.70 (22) | Ground | 45.7 (150) | 55 (180) |
| Stack radius in m (ft) | N/A | 0.53 (1.6) | N/A | 0.50 (1.6) | 0.88 (2.9) |
| Stack flow rate in $m^3$/sec ($ft^3$/sec) | N/A | 10 (353) | N/A | 10.8 (381) | 33 (1,165) |
| Stack temperature in °C (°F) | N/A | 46 (117) | N/A | 65.6 (150) | 160 (320) |
| Noninvolved worker MEI location in m (ft) ESE | 100 (328) | 200 (656) | 100 (328) | 400 (1,312) | 800 (2,625) |
| Public MEI location in km (mi) ESE | 22 (14) | 22 (14) | 22 (14) | 22 (14) | 22 (14) |
| Chi/Q for noninvolved worker - population in $s/m^3$ | 1.60E-03 | 4.00E-04 | 1.60E-03 | 1.20E-04 | 5.00E-05 |
| Chi/Q for noninvolved worker - MEI in $s/m^3$ | 4.00E-04 | 2.50E-06 | 4.00E-04 | 9.40E-08 | 2.90E-08 |
| Chi/Q for general public - population in $s/m^3$ | 2.90E-03 | 1.60E-03 | 2.90E-03 | 8.00E-04 | 5.00E-04 |
| Chi/Q for general public - MEI in $s/m^3$ | 6.60E-08 | 3.90E-08 | 6.60E-08 | 1.50E-08 | 7.70E-09 |

Notes:
ESE = East-southeast

The calculated Chi/Q values for the evaporator operation were 2.50E-06 $sec/m^3$ for the noninvolved worker MEI and 3.90E-08 $sec/m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q values were 4.00E-04 $sec/m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q values were 1.60E-03 $sec/m^3$. For Phase 1 separations and vitrification operation, the Chi/Q values were 9.40E-08 $sec/m^3$ for the noninvolved worker MEI, 1.50E-08 $sec/m^3$ for the general public MEI, 1.20E-04 $sec/m^3$ for the noninvolved worker population, and 8.00E-04 $sec/m^3$ for the general public population. For Phase 2 separations and vitrification operation, the Chi/Q values were 2.90E-08 $sec/m^3$ for the noninvolved worker MEI, 7.70E-09 $sec/m^3$ for the general public MEI, 5.00E-05 $sec/m^3$ for the noninvolved worker population, and 5.00E-04 $sec/m^3$ for the general public population.

**Exposure** - The radiological exposure for the alternative is presented in Table D.4.10.18. The table shows the exposure each receptor would receive from each component. The sum of the components are shown in the last column for each population and MEI receptor except for the MEI worker. The MEI worker is not summed but is represented by the component with the highest MEI dose.

**Table D.4.10.18 Summary of Anticipated Radiological Exposure for the Total Alternative**

| | Radiological Dose (person-rem) [2] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Receptor | Construction (16 yrs) | Continued Operations [1] (31 yrs) | Retrieval (20 yrs) | Separations and Treatment (17 yrs) | Transportation (18 yrs) | Monitoring and Maintenance (50 yrs) | Post Closure Monitoring (100 yrs) | Total |
| Worker - Population | 7.51E+00 | 3.94E+02 | 4.42E+03 | 3.34E+03 | N/A | 8.40E-01 | 1.34E+01 | 8.18E+03 |
| Worker - MEI[3, 4] | 1.00E+01 | 1.45E+01 | 1.30E+01 | 1.50E+01 | N/A | 1.45E+01 | 1.50E+01 | 1.50E+01 |
| Noninvolved Worker - Population | 0.00E+00 | 1.58E-03 | 9.10E-03 | 1.19E+00 | 1.06E+00 | 0.00E+00 | 0.00E+00 | 2.26E+00 |
| Noninvolved Worker - MEI | 0.00E+00 | 7.93E-05 | 2.40E-03 | 4.66E-04 | N/A | 0.00E+00 | 0.00E+00 | 2.40E-03 |
| General Public - Population | 0.00E+00 | 8.00E-02 | 2.30E+00 | 3.85E+02 | 2.96E-01 | 0.00E+00 | 0.00E+00 | 3.88E+02 |
| General Public - MEI | 0.00E+00 | 2.19E-06 | 7.50E-05 | 4.86E-03 | N/A | 0.00E+00 | 0.00E+00 | 4.86E-03 |

Notes:
[1] Continued operations include Tank Farm and Evaporator 1.
[2] MEI receptor dose is noted in rem.
[3] Worker MEI is assumed to work for 30 years.
[4] Total for the MEI represents the highest single exposure.
MEI = Maximally-exposed individual

The worker population dose is dependent on the number of people in the population and the anticipated dose each individual would receive. The data were obtained from the Site maintenance and operations contractor and the TWRS EIS contractor (WHC 1995j and Jacobs 1996). The calculations for the worker exposures from construction, continued operations, retrieval, separations and treatment, monitoring and maintenance, and closure are as follows:

Construction

Phase 1 = (5.00E-01 person-yr) · (1.40E-02 rem/person-yr) = 7.00E-03 person-rem
Phase 2 = (5.36E+02 person-yr) · (1.40E-02 rem/person-yr) = 7.50E+00 person-rem
Total = 7.51E+00 person-rem

Continued Operations - Phase 1 and Phase 2

Tank farms = (1.90E+04 person-yr) · (1.40E-02 rem/person-yr) = 2.66E+02 person-rem
Evaporator = (6.40E+02 person-yr) · (2.00E-01 rem/person-yr) = 1.28E+02 person-rem
Total = 3.94E+02 person-rem

Retrieval
Phase 1 and 2 = (2.21E+04 person-yr) · (2.00E-01 rem/person-yr) = 4.42E+03 person-rem

Separation/Treatment
Phase 1 = (6.72E+03 person-yr) · (2.0E-01 rem/person-yr) = 1.34E+03 person-rem
Phase 2 = (9.98E+03 person-yr) · (2.0E-01 rem/person-yr) = 2.00E+03 person-rem
Total = 3.34E+03 person-rem

Monitoring and Maintenance.
Phase 1 and 2 = (6.00E+01 person-yr) · (1.40E-02 rem/person-yr) = 8.40E-01 person-rem

Closure - Phase 1 and Phase 2
Closure = (2.77E+02 person-yr) · (1.40E-02 rem/person-yr) = 3.88E+00 person-rem
Monitoring = (6.77E+02 person-yr) · (1.40E-02 rem/person-yr) = 9.48E+00 person-rem
Total = 1.34E+01 person-rem

The MEI worker was assumed to receive a dose of 500 mrem (5.00E-01 rem) per year for a maximum of 30 years.

The noninvolved workers and general public exposures from inhalation of the atmospheric emissions (source term) were converted to a radiological dose in rem using the GENII computer code and applying the appropriate Chi/Q value.

**Risk** - The LCFs are calculated as the product of the estimated dose times the dose-to-risk conversion factor (Section D.2.2.4). The sum of the radiological dose from construction, continued operations, retrieval, treatment, storage and disposal, monitoring and maintenance, and closure for each receptor shown in the combined dose column in Table D.4.10.19, was multiplied by the appropriate dose-to-risk conversion factor to produce the LCF risk.

**Table D.4.10.19 Summary of Anticipated Risk for the Total Alternative**

| Receptor | Combined Dose (person-rem) [1] | LCF/rem | LCF Risk |
|---|---|---|---|
| Worker - Population | 8.18E+03 | 4.00E-04 | 3.27E+00 |
| Worker - MEI | 1.50E+01 | 4.00E-04 | 6.00E-03 |
| Noninvolved worker - Population | 2.26E+00 | 4.00E-04 | 9.04E-04 |
| Noninvolved worker - MEI | 2.40E-03 | 4.00E-04 | 9.60E-07 |
| General public - Population | 3.88E+02 | 5.00E-04 | 1.94E-01 |
| General public - MEI | 4.86E-03 | 5.00E-04 | 2.43E-06 |

Notes:
[1] MEI receptor dose is noted in rem.
LCF = Latent cancer fatality

D.4.10.2.2 Chemical Exposure

Potential carcinogenic risk and noncarcinogenic health hazards may result from exposure to volatile emissions from the tank farm, tank waste retrieval, the evaporator, and exposure to particulate emissions from the separation and vitrification of HLW and LAW for the worker, noninvolved worker, and general public. Potential carcinogenic risk and noncarcinogenic health hazards were estimated using the chemical source term, transport mechanism, exposure, and toxicological criteria as discussed in the following subsections.

**Source Term** - Operating air emissions from the tank farm area, tank waste retrieval, evaporator, and vitrification facilities are presented in Table D.4.10.20 (WHC 1995j and Jacobs 1996). The emission rates from the HLW and LAW vitrification facilities were combined and treated as a single-source emission for both Phase 1 and Phase 2. The noninvolved worker and general public would be exposed to combined emissions from the tank farm area, tank waste retrieval operations, evaporator, and Phase 1 and Phase 2 vitrification facilities. The worker only would be exposed to emissions (ground-level release) from the tank farm area and retrieval operations because emissions from the evaporator and vitrification facilities occur through a stack-release and would not impact the onsite worker.

**Transport** - The tank farm chemical operating emissions (routine emissions from the tank farm and emissions during retrieval) were modeled as a ground release. Chemical operating emissions from the evaporator and vitrification facilities would occur from stack releases and were modeled as elevated releases. Transport parameters, location of the MEI noninvolved worker and MEI general public, and Chi/Q values for the MEI noninvolved worker and general public are identical to the radiological parameters presented in Table D.4.10.17.

The MEI worker (onsite worker) was evaluated using a simplified box model, as presented in detail in Section D.4.1.2.2. The estimated Chi/Q value for the MEI worker was 9.26E-04 sec/$m^3$.

**Exposure**

Worker - The MEI worker was assumed to be located within a box placed directly over the tank farm area. Exposure point concentrations of chemical emissions (mg/$m^3$) from the tank farm area and retrieval operations were estimated by multiplying the cumulative tank farm emission rate (mg/sec) and retrieval operation emission rate (mg/sec) by the MEI worker Chi/Q value (9.26E-04 sec/$m^3$), respectively. Exposure point concentrations for each volatile chemical emitted from the tank farm area and during retrieval are summarized in Tables D.4.10.21 and D.4.10.22 respectively.

Chemical intake (dose) was estimated for the MEI worker using the same equation and exposure parameters defined in Section D.2.2.3. Estimated intakes of chemical emissions from the tank farm and retrieval operations for the MEI worker are presented in Tables D.4.10.21 and D.4.10.22, respectively.

Table D.4.10.20 Chemical Emissions for the Total Alternative

| Tank Farm Emissions | | Retrieval Emissions | | Evaporator Emissions | | Separations/Vitrification Emissions | |
|---|---|---|---|---|---|---|---|
| Emissions | Total Tank Farm Emission Rate (mg/sec) | Emissions | Retrieval Emission Rate (mg/sec) | Emissions | Evaporator Emission Rate (mg/sec) | Emissions | Plant Emission Rate (mg/sec) |
| Carbon Monoxide | 1.05E+00 | Carbon Monoxide | 3.16E+00 | Acetone | 2.30E-01 | Aluminum | 1.54E-02 |
| Nitrogen Oxide | 1.06E-01 | Nitrogen Oxide | 3.17E-01 | Ammonia | 2.16E-01 | Arsenic | 1.67E-06 |
| 1,3-Butadiene | 7.49E-03 | 1,3-Butadiene | 2.25E-02 | n-Butyl Alcohol | 1.73E+00 | Boron | 6.35E-04 |
| 2-Hexanone | 1.37E-01 | 2-Hexanone | 4.10E-01 | 2-Hexanone | 8.28E-04 | Barium | 4.73E-06 |
| 2-Pentanone | 2.16E-01 | 2-Pentanone | 6.48E-01 | Methyl Isobutyl Ketone | 1.57E-02 | Beryllium | 1.24E-07 |
| Acetone | 2.61E+00 | Acetone | 7.82E+00 | | | Bismuth | 3.04E-04 |
| Acetonitrile | 1.26E+00 | Acetonitrile | 3.77E+00 | | | Cadmium | 1.22E-05 |
| Benzene | 5.97E-02 | Benzene | 1.79E-01 | | | Cerium | 2.77E-04 |
| Heptane | 1.53E-01 | Heptane | 4.60E-01 | | | Chromium (+3) | 2.48E-04 |
| Methyl N-amyl Ketone | 1.48E-01 | Methyl N-amyl Ketone | 4.44E-01 | | | Copper | 1.11E-06 |
| N-hexane | 1.60E-01 | N-hexane | 4.80E-01 | | | Manganese | 1.72E-04 |
| Nonane | 8.32E-02 | Nonane | 2.50E-01 | | | Molybdenumm | 7.81E-06 |
| Octane | 8.73E-02 | Octane | 2.62E-01 | | | Nickel | 2.07E-04 |
| Toluene | 1.22E-02 | Toluene | 3.67E-02 | | | Lead | 6.56E-06 |
| Ammonia | 7.67E+00 | Ammonia | 2.30E+01 | | | Silver | 1.03E-06 |
| Phosphoric Acid, Tributyl Ester | 1.89E-01 | Phosphoric Acid, Tributyl Ester | 5.68E-01 | | | Uranium | 1.72E-03 |
| Carbon Tetrachloride | 1.24E-07 | Carbon Tetrachloride | 3.72E-07 | | | Vanadium | 3.06E-07 |
| Ethyl Butyl Ketone | 4.15E-07 | Ethyl Butyl Ketone | 1.25E-06 | | | Zinc | 6.15E-06 |
| Methyl Chloride | 1.83E-08 | Methyl Chloride | 5.50E-08 | | | | |
| Tetrahydrofuran | 3.20E-08 | Tetrahydrofuran | 9.61E-08 | | | | |

Table D.4.10.21 Total Alternative Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 9.75E-04 | 1.91E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 9.80E-05 | 1.92E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 6.94E-06 | 1.36E-06 | 5.63E-07 | ND | 9.80E-01 | NE | 3.52E-07 |
| 2-Hexanone | 1.27E-04 | 2.48E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.00E-04 | 3.92E-05 | NC | ND | NC | NE | NC |
| Acetone | 2.41E-03 | 4.73E-04 | NC | 1.00E-01 | NC | 4.73E-03 | NC |
| Acetonitrile | 1.16E-03 | 2.28E-04 | NC | 1.40E-02 | NC | 1.63E-03 | NC |
| Benzene | 5.53E-05 | 1.08E-05 | 4.48E-06 | 1.70E-03 | 2.90E-02 | 6.37E-03 | 1.30E-07 |
| Heptane | 1.42E-04 | 2.78E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.37E-04 | 2.69E-05 | NC | 2.30E-02 | NC | 1.17E-03 | NC |
| N-Hexane | 1.48E-04 | 2.91E-05 | NC | 5.70E-02 | NC | 5.10E-04 | NC |
| Nonane | 7.70E-05 | 1.51E-05 | NC | ND | NC | NE | NC |
| Octane | 8.08E-05 | 1.58E-05 | NC | ND | NC | NE | NC |
| Toluene | 1.13E-05 | 2.22E-06 | NC | 1.10E-01 | NC | 2.02E-05 | NC |
| Ammonia | 7.10E-03 | 1.39E-03 | NC | 2.90E-02 | NC | 4.80E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 1.75E-04 | 3.43E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 1.15E-10 | 2.25E-11 | 9.31E-12 | 5.70E-04 | 5.30E-02 | 3.95E-08 | 4.93E-13 |
| Ethyl Butyl Ketone | 3.85E-10 | 7.54E-11 | NC | 2.30E-02 | NC | 3.28E-09 | NC |
| Methyl Chloride | 1.70E-11 | 3.33E-12 | 1.38E-12 | ND | 6.30E-03 | NE | 8.67E-15 |
| Tetrahydrofuran | 2.97E-11 | 5.81E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 7.71E-02** | **Risk = 6.82E-07** |

Notes:
HI = Hazard index
NC = Noncarcinogen
ND = No published data
NE = Not evaluated
MEI = Maximally-exposed individual

Table D.4.10.22 Total Alternative Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI Worker | Excess Cancer Risk for the MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 2.92E-03 | 5.73E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 2.94E-04 | 5.76E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 2.08E-05 | 4.08E-06 | 1.51E-06 | ND | 9.80E-01 | NE | 1.48E-06 |
| 2-Hexanone | 3.80E-04 | 7.45E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 6.00E-04 | 1.18E-04 | NC | ND | NC | NE | NC |
| Acetone | 7.24E-03 | 1.42E-03 | NC | 1.00E-01 | NC | 1.42E-02 | NC |
| Acetonitrile | 3.49E-03 | 6.84E-04 | NC | 1.40E-02 | NC | 4.88E-02 | NC |
| Benzene | 1.66E-04 | 3.25E-05 | 1.21E-05 | 1.70E-03 | 2.90E-02 | 1.91E-02 | 3.50E-07 |
| Heptane | 4.26E-04 | 8.34E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 4.11E-04 | 8.06E-05 | NC | 2.30E-02 | NC | 3.50E-03 | NC |
| N-hexane | 4.45E-04 | 8.72E-05 | NC | 5.70E-02 | NC | 1.53E-03 | NC |
| Nonane | 2.31E-04 | 4.53E-05 | NC | ND | NC | NE | NC |
| Octane | 2.42E-04 | 4.75E-05 | NC | ND | NC | NE | NC |
| Toluene | 3.40E-05 | 6.66E-06 | NC | 1.10E-01 | NC | 6.05E-05 | NC |
| Ammonia | 2.13E-02 | 4.18E-03 | NC | 2.90E-02 | NC | 1.44E-01 | NC |
| Phosphoric Acid, Tributyl Ester | 5.26E-04 | 1.03E-04 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 3.44E-10 | 6.75E-11 | 2.50E-11 | 5.70E-04 | 5.30E-02 | 1.18E-07 | 1.33E-12 |
| Ethyl Butyl Ketone | 1.15E-09 | 2.26E-10 | NC | 2.30E-02 | NC | 9.83E-09 | NC |
| Methyl Chloride | 5.09E-11 | 9.98E-12 | 3.70E-12 | ND | 6.30E-03 | NE | 2.33E-14 |
| Tetrahydrofuran | 8.90E-11 | 1.74E-11 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 2.31E-01** | **Risk = 1.83E-06** |

Notes:
HI = Hazard index
MEI = Maximally-exposed individual
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Noninvolved Worker - The MEI noninvolved worker was assumed to be located at the point where maximum downwind air concentrations were calculated (100 m [330 ft] from the tank farm and 200 m [660 ft] from the evaporator). Exposure point concentrations ($mg/m^3$) of chemical emissions from the tank farm, retrieval operations, evaporator, and vitrification facilities were estimated by multiplying the cumulative tank farm, retrieval, evaporator, and plant emission rates (mg/sec) by their respective MEI noninvolved worker Chi/Q values (4.00E-04 $sec/m^3$ for the tank farm, 2.50E-06 $sec/m^3$ for the evaporator, 4.00E-04 $sec/m^3$ for retrieval, 9.40E-08 $sec/m^3$ for Phase 1 vitrification, and 2.90E-08 $sec/m^3$ for Phase 2 vitrification). Exposure point concentrations for each volatile chemical emitted from the tank farm area, the evaporator, retrieval operations, and the Phase 1 and Phase 2 vitrification facility are summarized in Tables D.4.10.23, D.4.10.24, D.4.10.25, D.4.10.26, and D.4.10.27 respectively.

Chemical intake (dose) was estimated for the MEI noninvolved worker according to the same equation and exposure parameters used for the MEI worker. Estimated operating chemical emission intakes for the MEI noninvolved worker are presented in Tables D.4.10.23, D.4.10.24, D.4.10.25, D.4.10.26, and D.4.10.27 for the tank farm area, evaporator, retrieval operations, and the Phase 1 and Phase 2 vitrification facilities emissions, respectively.

General Public - The MEI general public receptor was assumed to be located at the point where maximum air concentrations were calculated (approximately 22 km [14 mi] from both the tank farm area and evaporator). Exposure point concentrations ($mg/m^3$) of chemical emissions from the tank farm area, the evaporator, retrieval operations, and the vitrification facilities were estimated by multiplying the cumulative emission rates (mg/sec) of each source by their respective MEI general public Chi/Q values (6.60E-08 $sec/m^3$ for the tank farm, 6.60E-08 $sec/m^3$ for the evaporator, 6.60E-08 $sec/m^3$ for retrieval operations, 1.50E-08 $sec/m^3$ for Phase 1 vitrification, and 7.70E-09 $sec/m^3$ for Phase 2 vitrification). Exposure point concentrations for each volatile chemical emitted from the tank farm area, evaporator, retrieval operations, and the Phase 1 and Phase 2 vitrification facilities are summarized in Tables D.4.10.28, D.4.10.29, D.4.10.30, D.4.10.31, and D.4.10.32, respectively.

The residential or general public intake was calculated according to the equation and exposure parameters presented in Section D.2.2.3. Estimated chemical emission intakes for the MEI general public are presented in Tables D.4.10.28, D.4.10.29, D.4.10.30, D.4.10.31, and D.4.10.32 for the tank farm area, the evaporator, retrieval operations, and the Phase 1 and Phase 2 vitrification facilities, respectively.

**Toxicity Assessment**

Toxicity assessment was previously discussed in detail in Section D.4.1.2.4. Cancer slope factors, RfDs, and data sources for each volatile operating chemical emission are summarized in Table D.4.1.11.

Table D.4.10.23 Total Alternative Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 4.21E-04 | 8.25E-05 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 4.23E-05 | 8.30E-06 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 3.00E-06 | 5.88E-07 | 2.43E-07 | ND | 9.80E-01 | NE | 2.38E-07 |
| 2-Hexanone | 5.47E-05 | 1.07E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 8.64E-05 | 1.69E-05 | NC | ND | NC | NE | NC |
| Acetone | 1.04E-03 | 2.04E-04 | NC | 1.00E-01 | NC | 2.04E-03 | NC |
| Acetonitrile | 5.02E-04 | 9.84E-05 | NC | 1.40E-02 | NC | 7.03E-03 | NC |
| Benzene | 2.39E-05 | 4.68E-06 | 1.94E-06 | 1.70E-03 | 2.90E-02 | 2.75E-03 | 5.62E-08 |
| Heptane | 6.13E-05 | 1.20E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 5.92E-05 | 1.16E-05 | NC | 2.30E-02 | NC | 5.05E-04 | NC |
| N-hexane | 6.41E-05 | 1.26E-05 | NC | 5.70E-02 | NC | 2.20E-04 | NC |
| Nonane | 3.33E-05 | 6.52E-06 | NC | ND | NC | NE | NC |
| Octane | 3.49E-05 | 6.84E-06 | NC | ND | NC | NE | NC |
| Toluene | 4.89E-06 | 9.58E-07 | NC | 1.10E-01 | NC | 8.71E-06 | NC |
| Ammonia | 3.07E-03 | 6.01E-04 | NC | 2.90E-02 | NC | 2.07E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 7.57E-05 | 1.48E-05 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 4.96E-11 | 9.72E-12 | 4.02E-12 | 5.70E-04 | 5.30E-02 | 1.71E-08 | 2.13E-13 |
| Ethyl Butyl Ketone | 1.66E-10 | 3.26E-11 | NC | 2.30E-02 | NC | 1.42E-09 | NC |
| Methyl Chloride | 7.33E-12 | 1.44E-12 | 5.95E-13 | ND | 6.30E-03 | NE | 3.75E-15 |
| Tetrahydorfuran | 1.28E-11 | 2.51E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 3.33E-02** | **Risk = 2.94E-07** |

Notes:
HI = Hazard index
MEI = Maximally-exposed individual
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.10.24 Total Alternative Evaporator Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarci-nogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg-day)^{-1}$ | Noncarci-nogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Acetone | 5.75E-07 | 1.13E-07 | NC | 1.00E-01 | NC | 1.13E-06 | NC |
| Ammonia | 5.40E-07 | 1.06E-07 | NC | 2.90E-02 | NC | 3.65E-06 | NC |
| n-Butyl Alcohol | 4.33E-06 | 8.48E-07 | NC | 1.00E-01 | NC | 8.48E-06 | NC |
| 2-Hexanone | 2.07E-09 | 4.06E-10 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 3.93E-08 | 7.69E-09 | NC | 2.30E-02 | NC | 3.34E-07 | NC |
| | | | | | | HI = 1.36E-05 | |

Notes:
HI = Hazard index
MEI= Maximally-exposed individual
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

### Risk Characterization

MEI Worker - The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm and retrieval operations are summarized in Tables D.4.10.21 and D.4.10.22, respectively. The total HI and cancer risk from routine tank farm emissions and retrieval emissions combined are 3.08E-01 and 2.51E-06, respectively.

MEI Noninvolved Worker - The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farms, the evaporator, retrieval operations, and Phase 1 and 2 vitrification facilities are summarized in Tables D.4.10.23, D.4.10.24, D.4.10.25, D.4.10.26, and D.4.10.27, respectively. The total HI and cancer risk from combined tank farm, evaporator, retrieval, and vitrification emissions are 1.33E-01 and 1.09E-06, respectively.

MEI General Public - The noncarcinogenic hazards and carcinogenic risk for chemical emissions from the tank farm, evaporator, retrieval operations, and the Phase 1 and Phase 2 vitrification facilities are summarized in Tables D.4.10.28, D.4.10.29, D.4.10.30, D.4.10.31, and D.4.10.32, respectively. The total HI and cancer risk from combined tank farm, evaporator, retrieval, and vitrification emissions are 7.50E-05 and 6.35E-10, respectively.

Table D.4.10.25 Total Alternative Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day | Inhalation Reference Dose ($RfD_I$) (mg/kg-day) | Inhalation Slope Factor ($SF_I$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 1.26E-03 | 2.48E-04 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 1.27E-04 | 2.49E-05 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 8.99E-06 | 1.76E-06 | 6.54E-07 | ND | 9.80E-01 | NE | 6.41E-07 |
| 2-Hexanone | 1.64E-04 | 3.22E-05 | NC | ND | NC | NE | NC |
| 2-Pentanone | 2.59E-04 | 5.08E-05 | NC | ND | NC | NE | NC |
| Acetone | 3.13E-04 | 6.13E-04 | NC | 1.00E-01 | NC | 6.13E-03 | NC |
| Acetonitrile | 1.51E-03 | 2.95E-04 | NC | 1.40E-02 | NC | 2.11E-02 | NC |
| Benzene | 7.16E-05 | 1.40E-05 | 5.21E-06 | 1.70E-03 | 2.90E-02 | 8.26E-03 | 1.51E-07 |
| Heptane | 1.84E-04 | 3.60E-05 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 1.78E-04 | 3.48E-05 | NC | 2.30E-02 | NC | 1.51E-03 | NC |
| N-hexane | 1.92E-04 | 3.77E-05 | NC | 5.70E-02 | NC | 6.61E-04 | NC |
| Nonane | 9.98E-05 | 1.96E-05 | NC | ND | NC | NE | NC |
| Octane | 1.05E-04 | 2.05E-05 | NC | ND | NC | NE | NC |
| Toluene | 1.47E-05 | 2.87E-06 | NC | 1.10E-01 | NC | 2.61E-05 | NC |
| Ammonia | 9.20E-03 | 1.80E-03 | NC | 2.90E-02 | NC | 6.22E-02 | NC |
| Phosphoric Acid, Tributyl Ester | 2.27E-04 | 4.45E-05 | NC | NC | NC | NE | NC |
| Carbon Tetrachloride | 1.49E-10 | 2.92E-11 | 1.08E-11 | 5.70E-04 | 5.30E-02 | 5.12E-08 | 5.73E-13 |
| Ethyl Butyl Ketone | 4.98E-10 | 9.77E-11 | NC | 2.30E-02 | NC | 4.25E-09 | NC |
| Methyl Chloride | 2.20E-11 | 4.31E-12 | 1.60E-12 | ND | 6.30E-03 | NE | 1.01E-14 |
| Tetrahydorfuran | 3.84E-11 | 7.53E-12 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 9.99E-02** | **Risk = 7.92E-07** |

Notes:
HI = Hazard index
MEI= Maximally-exposed individual
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.10.26 Total Alternative Phase 1 Plant Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Aluminum | 4.46E-10 | 8.75E-11 | NC | ND | NC | NE | NC |
| Arsenic | 4.83E-14 | 9.47E-15 | 1.25E-11 | ND | 1.51E+01 | NE | 1.89E-10 |
| Boron | 1.84E-11 | 3.61E-12 | NC | 5.70E-03 | NC | 6.34E-10 | NC |
| Barium | 1.37E-13 | 2.69E-14 | NC | 1.43E-04 | NC | 1.88E-10 | NC |
| Beryllium | 3.59E-15 | 7.04E-16 | 3.84E-15 | ND | 8.40E+00 | NE | 3.23E-14 |
| Bismuth | 8.83E-12 | 1.73E-12 | NC | ND | NC | NE | NC |
| Cadmium | 3.52E-13 | 6.91E-14 | 2.47E-13 | ND | 6.30E+00 | NE | 1.56E-12 |
| Cerium | 8.02E-12 | 1.57E-12 | NC | ND | NC | NE | NC |
| Chromium (+3) | 7.18E-12 | 1.41E-12 | NC | 5.71E-07 | NC | 2.47E-06 | NC |
| Copper | 3.23E-14 | 6.34E-15 | NC | ND | NC | NE | NC |
| Manganese | 5.00E-12 | 9.80E-13 | NC | ND | NC | NE | NC |
| Molybdenum | 2.27E-13 | 4.44E-14 | NC | ND | NC | NE | NC |
| Nickel | 6.01E-12 | 1.18E-12 | NC | ND | NC | NE | NC |
| Lead | 1.90E-13 | 3.73E-14 | NC | ND | NC | NE | NC |
| Silver | 2.99E-14 | 5.87E-15 | NC | ND | NC | NE | NC |
| Uranium | 5.00E-11 | 9.80E-12 | NC | ND | NC | NE | NC |
| Vanadium | 8.86E-15 | 1.74E-15 | NC | ND | NC | NE | NC |
| Zinc | 1.78E-13 | 3.49E-14 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 2.47E-06** | **Risk = 1.91E-10** |

Notes:
HI = Hazard index
MEI= Maximally-exposed individual
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.10.27 Total Alternative Phase 2 Plant Emissions

| Emissions | Air Concentrations of Vitrification Emissions for the Noninvolved MEI Worker ($mg/m^3$) | Noncarcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Carcinogen Inhalation Intake for the Noninvolved MEI Worker (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the Noninvolved MEI Worker | Excess Cancer Risk for the Noninvolved MEI Worker |
|---|---|---|---|---|---|---|---|
| Aluminum | 4.46E-10 | 8.75E-11 | NC | ND | NC | NE | NC |
| Arsenic | 4.83E-14 | 9.47E-15 | 3.00E-11 | ND | 1.51E+01 | NE | 4.52E-10 |
| Boron | 1.84E-11 | 3.61E-12 | NC | 5.70E-03 | NC | 6.34E-10 | NC |
| Barium | 1.37E-13 | 2.69E-14 | NC | 1.43E-04 | NC | 1.88E-10 | NC |
| Beryllium | 3.59E-15 | 7.04E-16 | 9.21E-15 | ND | 8.40E+00 | NE | 7.74E-14 |
| Bismuth | 8.83E-12 | 1.73E-12 | NC | ND | NC | NE | NC |
| Cadmium | 3.52E-13 | 6.91E-14 | 5.92E-13 | ND | 6.30E+00 | NE | 3.73E-12 |
| Cerium | 8.02E-12 | 1.57E-12 | NC | ND | NC | NE | NC |
| Chromium (+3) | 7.18E-12 | 1.41E-12 | NC | 5.71E-07 | NC | 2.47E-06 | NC |
| Copper | 3.23E-14 | 6.34E-15 | NC | ND | NC | NE | NC |
| Manganese | 5.00E-12 | 9.80E-13 | NC | ND | NC | NE | NC |
| Molybdenum | 2.27E-13 | 4.44E-14 | NC | ND | NC | NE | NC |
| Nickel | 6.01E-12 | 1.18E-12 | NC | ND | NC | NE | NC |
| Lead | 1.90E-13 | 3.73E-14 | NC | ND | NC | NE | NC |
| Silver | 2.99E-14 | 5.87E-15 | NC | ND | NC | NE | NC |
| Uranium | 5.00E-11 | 9.80E-12 | NC | ND | NC | NE | NC |
| Vanadium | 8.86E-15 | 1.74E-15 | NC | ND | NC | NE | NC |
| Zinc | 1.78E-13 | 3.49E-14 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 2.47E-06** | **Risk = 4.56E-10** |

Notes:
HI = Hazard index
MEI = Maximally-exposed individual
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

## D.4.11 NO ACTION ALTERNATIVE (CAPSULES)

This section presents the anticipated remediation risk associated with the No Action alternative for Cs and Sr capsules, as outlined in Volume Two, Appendix B of the EIS.

The radiological risk for this alternative was based on the air emissions and direct exposure from storage operations at WESF. No nonradiological chemical (toxicological) emissions were associated with the capsules.

Table D.4.10.28 Total Alternative Tank Farm Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 6.95E-08 | 4.34E-08 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 6.98E-09 | 4.36E-09 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 4.95E-10 | 3.09E-10 | 7.25E-11 | ND | 9.80E-01 | NE | 7.10E-11 |
| 2-Hexanone | 9.03E-09 | 5.64E-09 | NC | ND | NC | NE | NC |
| 2-Pentanone | 1.43E-08 | 8.91E-09 | NC | ND | NC | NE | NC |
| Acetone | 1.72E-07 | 1.08E-07 | NC | 1.00E-01 | NC | 1.08E-06 | NC |
| Acetonitrile | 8.29E-08 | 5.18E-08 | NC | 1.40E-02 | NC | 3.70E-06 | NC |
| Benzene | 3.94E-09 | 2.46E-09 | 5.77E-10 | 1.70E-03 | 2.90E-02 | 1.45E-06 | 1.67E-11 |
| Heptane | 1.01E-08 | 6.32E-09 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 9.77E-09 | 6.11E-09 | NC | 2.30E-02 | NC | 2.65E-07 | NC |
| N-hexane | 1.06E-08 | 6.61E-09 | NC | 5.70E-02 | NC | 1.16E-07 | NC |
| Nonane | 5.49E-09 | 3.43E-09 | NC | ND | NC | NE | NC |
| Octane | 5.76E-09 | 3.60E-09 | NC | ND | NC | NE | NC |
| Toluene | 8.07E-10 | 5.04E-10 | NC | 1.10E-01 | NC | 4.58E-09 | NC |
| Ammonia | 5.06E-07 | 3.16E-07 | NC | 2.90E-02 | NC | 1.09E-05 | NC |
| Phosphoric Acid, Tributyl Ester | 1.25E-08 | 7.81E-09 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 8.18E-15 | 5.11E-15 | 1.20E-15 | 5.70E-04 | 5.30E-02 | 8.97E-12 | 6.36E-17 |
| Ethyl Butyl Ketone | 2.74E-14 | 1.71E-14 | NC | 2.30E-02 | NC | 7.45E-13 | NC |
| Methyl Chloride | 1.21E-15 | 7.56E-16 | 1.77E-16 | ND | 6.30E-03 | NE | 1.12E-18 |
| Tetrahydrofuran | 2.11E-15 | 1.32E-15 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 1.75E-05** | **Risk = 8.78E-11** |

Notes:
HI = Hazard index
MEI= Maximally-exposed individual
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.10.29 Total Alternative Evaporator Emissions

| Emissions | Air Concentrations of Evaporator Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg-day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Acetone | 8.97E-09 | 5.61E-09 | NC | 1.00E-01 | NC | 5.61E-08 | NC |
| Ammonia | 8.42E-09 | 5.27E-09 | NC | 2.90E-02 | NC | 1.82E-07 | NC |
| n-Butyl Alcohol | 6.75E-08 | 4.22E-08 | NC | 1.00E-01 | NC | 4.22E-07 | NC |
| 2-Hexanone | 3.23E-11 | 2.02E-11 | NC | ND | NC | NE | NC |
| Methyl Isobutyl Ketone | 6.12E-10 | 3.83E-10 | NC | 2.30E-02 | NC | 1.66E-08 | NC |
| | | | | | | HI = 6.76E-07 | |

Notes:
HI = Hazard index
MEI = Maximally-exposed individual
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

### D.4.11.1 Radiological Risk

The LCF risk to the workers, noninvolved workers, and general public could result from direct exposure and atmospheric emissions from the components associated with this alternative. The risk was determined by analyzing the radiological source term, the transport mechanism, exposure, and the risk associated with the exposure as discussed in the following subsections.

#### D.4.11.1.1 Source Term

The source term used for the noninvolved worker and general public was the atmospheric radiological emissions presented in Table D.4.11.1 (WHC 1995h and Jacobs 1996). The workers would receive a combined dose from the air emissions and from direct exposure from radiation fields in the workplace.

#### D.4.11.1.2 Transport

The atmospheric transport parameters of the No Action Capsules alternative are presented in Table D.4.11.2. The atmospheric radiological operating emissions were modeled as an elevated release. For modeling purposes, it was assumed that the source term would be released at a point in the 200 Areas represented by the meteorological conditions at the Hanford Meteorological Station. The analysis used the Hanford Meteorological Station joint frequency data from Table D.2.2.1 and Figure D.2.2.1.

Table D.4.10.30 Total Alternative Retrieval Emissions

| Emissions | Air Concentrations of Retrieval Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RfD_I$) (mg/kg-day) | Inhalation Slope Factor ($SF_I$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Carbon Monoxide | 2.08E-07 | 1.30E-07 | NC | ND | NC | NE | NC |
| Nitrogen Oxide | 2.10E-08 | 1.31E-08 | NC | ND | NC | NE | NC |
| 1,3-Butadiene | 1.48E-09 | 9.27E-10 | 1.95E-10 | ND | 9.80E-01 | NE | 1.91E-10 |
| 2-Hexanone | 2.71E-08 | 1.69E-08 | NC | ND | NC | NE | NC |
| 2-Pentanone | 4.28E-08 | 2.67E-08 | NC | ND | NC | NE | NC |
| Acetone | 5.16E-07 | 3.23E-07 | NC | 1.00E-01 | NC | 3.23E-06 | NC |
| Acetonitrile | 2.49E-07 | 1.55E-07 | NC | 1.40E-02 | NC | 1.11E-05 | NC |
| Benzene | 1.18E-08 | 7.39E-09 | 1.55E-09 | 1.70E-03 | 2.90E-02 | 4.35E-06 | 4.50E-11 |
| Heptane | 3.03E-08 | 1.90E-08 | NC | ND | NC | NE | NC |
| Methyl N-amyl Ketone | 2.93E-08 | 1.83E-08 | NC | 2.30E-02 | NC | 7.96E-07 | NC |
| N-hexane | 3.17E-08 | 1.98E-08 | NC | 5.70E-02 | NC | 3.48E-07 | NC |
| Nonane | 1.65E-08 | 1.03E-08 | NC | ND | NC | NE | NC |
| Octane | 1.73E-08 | 1.08E-08 | NC | ND | NC | NE | NC |
| Toluene | 2.42E-09 | 1.51E-09 | NC | 1.10E-01 | NC | 1.38E-08 | NC |
| Ammonia | 1.52E-06 | 9.49E-07 | NC | 2.90E-02 | NC | 3.27E-05 | NC |
| Phosphoric Acid, Tributyl Ester | 3.75E-08 | 2.34E-08 | NC | ND | NC | NE | NC |
| Carbon Tetrachloride | 2.45E-14 | 1.53E-14 | 3.23E-15 | 5.70E-04 | 5.30E-02 | 2.69E-11 | 1.71E-16 |
| Ethyl Butyl Ketone | 8.22E-14 | 5.14E-14 | NC | 2.30E-02 | NC | 2.24E-12 | NC |
| Methyl Chloride | 3.63E-15 | 2.27E-15 | 4.77E-16 | ND | 6.30E-03 | NE | 3.00E-18 |
| Tetrahydrofuran | 6.34E-15 | 3.96E-15 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 5.26E-05** | **Risk = 2.36E-10** |

Notes:
HI = Hazard index
MEI = Maximally-exposed individual
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.10.31 Total Alternative Phase 1 Plant Emissions

| Emissions | Air Concentrations of Tank Farm Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Aluminum | 1.19E-10 | 7.41E-11 | NC | ND | NC | NE | NC |
| Arsenic | 1.28E-14 | 8.02E-15 | 6.01E-12 | ND | 1.51E+01 | NE | 9.07E-11 |
| Boron | 4.89E-12 | 3.06E-12 | NC | 5.70E-03 | NC | 5.36E-10 | NC |
| Barium | 3.65E-14 | 2.28E-14 | NC | 1.43E-04 | NC | 1.59E-10 | NC |
| Beryllium | 9.54E-16 | 5.96E-16 | 1.85E-15 | ND | 8.40E+00 | NE | 1.55E-14 |
| Bismuth | 2.34E-12 | 1.46E-12 | NC | ND | NC | NE | NC |
| Cadmium | 9.36E-14 | 5.58E-14 | 1.19E-13 | ND | 6.30E+00 | NE | 7.48E-13 |
| Cerium | 2.13E-12 | 1.33E-12 | NC | ND | NC | NE | NC |
| Chromium (+3) | 1.91E-12 | 1.19E-12 | NC | 5.71E-07 | NC | 2.09E-06 | NC |
| Copper | 8.58E-15 | 5.36E-15 | NC | ND | NC | NE | NC |
| Manganese | 1.33E-12 | 8.30E-13 | NC | ND | NC | NE | NC |
| Molybdenum | 6.02E-14 | 3.76E-14 | NC | ND | NC | NE | NC |
| Nickel | 1.60E-12 | 9.97E-13 | NC | ND | NC | NE | NC |
| Lead | 5.05E-14 | 3.16E-14 | NC | ND | NC | NE | NC |
| Silver | 7.95E-15 | 4.97E-15 | NC | ND | NC | NE | NC |
| Uranium | 1.33E-11 | 8.30E-12 | NC | ND | NC | NE | NC |
| Vanadium | 2.35E-15 | 1.47E-15 | NC | ND | NC | NE | NC |
| Zinc | 4.73E-14 | 2.96E-14 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 2.09E-06** | **Risk = 9.14E-11** |

Notes:
HI = Hazard index
MEI = Maximally-exposed individual
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

Table D.4.10.32 Total Alternative Phase 2 Plant Emissions

| Emissions | Air Concentrations of Vitrification Emissions for the MEI General Public ($mg/m^3$) | Noncarcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Carcinogen Inhalation Intake for the MEI General Public (mg/kg-day) | Inhalation Reference Dose ($RFD_i$) (mg/kg-day) | Inhalation Slope Factor ($SF_i$) $(mg/kg\text{-}day)^{-1}$ | Noncarcinogenic Hazard for the MEI General Public | Excess Cancer Risk for the MEI General Public |
|---|---|---|---|---|---|---|---|
| Aluminum | 1.19E-10 | 7.41E-11 | NC | ND | NC | NE | NC |
| Arsenic | 1.28E-14 | 8.02E-15 | 1.44E-11 | ND | 1.51E+01 | NE | 2.18E-10 |
| Boron | 4.89E-12 | 3.06E-12 | NC | 5.70E-03 | NC | 5.36E-10 | NC |
| Barium | 3.65E-14 | 2.28E-14 | NC | 1.43E-04 | NC | 1.59E-10 | NC |
| Beryllium | 9.54E-16 | 5.96E-16 | 4.43E-15 | ND | 8.40E+00 | NE | 3.72E-14 |
| Bismuth | 2.34E-12 | 1.46E-12 | NC | ND | NC | NE | NC |
| Cadmium | 9.36E-14 | 5.58E-14 | 2.85E-13 | ND | 6.30E+00 | NE | 1.80E-12 |
| Cerium | 2.13E-12 | 1.33E-12 | NC | ND | NC | NE | NC |
| Chromium (+3) | 1.91E-12 | 1.19E-12 | NC | 5.71E-07 | NC | 2.09E-06 | NC |
| Copper | 8.58E-15 | 5.36E-15 | NC | ND | NC | NE | NC |
| Manganese | 1.33E-12 | 8.30E-13 | NC | ND | NC | NE | NC |
| Molybdenum | 6.02E-14 | 3.76E-14 | NC | ND | NC | NE | NC |
| Nickel | 1.60E-12 | 9.97E-13 | NC | ND | NC | NE | NC |
| Lead | 5.05E-14 | 3.16E-14 | NC | ND | NC | NE | NC |
| Silver | 7.95E-15 | 4.97E-15 | NC | ND | NC | NE | NC |
| Uranium | 1.33E-11 | 8.30E-12 | NC | ND | NC | NE | NC |
| Vanadium | 2.35E-15 | 1.47E-15 | NC | ND | NC | NE | NC |
| Zinc | 4.73E-14 | 2.96E-14 | NC | ND | NC | NE | NC |
| | | | | | | **HI = 2.09E-06** | **Risk = 2.19E-10** |

Notes:
HI = Hazard index
MEI = Maximally-exposed individual
NC = Noncarcinogen
ND = No published data
NE = Not evaluated

For elevated releases (stack releases), the maximum exposure would not necessarily occur at the closest distance to the source. Air transport modeling indicates that the maximum exposure for the noninvolved worker would occur 200 m (660 ft) from the source (in an east-southeast direction). The maximum exposure for a member of the general public would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the 200 East Area).

Table D.4.11.1 Atmospheric Radiological Emissions for the No Action Alternative (Capsules)

| WESF Operating Emissions | |
|---|---|
| Contaminants | Ci/yr Released |
| Total Beta | 4.70E-09 |
| Sr-90 | 5.10E-06 |
| Cs-137 | 2.60E-06 |
| Pu-239, -240 | 2.40E-07 |

Table D.4.11.2 Atmospheric Transport Parameters for the No Action Alternative (Capsules)

| Transport Parameter | WESF Operations |
|---|---|
| Stack height in m (ft) | 21 (70) |
| Stack radius in m (ft) | 0.53 (1.7) |
| Stack flow rate in $m^3$/sec ($ft^3$/sec) | 9.2 (325) |
| Stack temperature in °C (°F) | 20 (68) |
| Noninvolved worker MEI location in m (ft) ESE | 200 (656) |
| Public MEI location in km (mi) ESE | 22 (14) |
| Chi/Q for noninvolved worker - population in $s/m^3$ | 3.70E-04 |
| Chi/Q for noninvolved worker - MEI in $s/m^3$ | 5.40E-07 |
| Chi/Q for general public - population in $s/m^3$ | 1.70E-03 |
| Chi/Q for general public - MEI in $s/m^3$ | 3.40E-08 |

Notes:
ESE = East-southeast

The calculated Chi/Q values were 5.40E-07 $sec/m^3$ for the noninvolved worker MEI and 3.40E-08 $sec/m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 3.70E-04 $sec/m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 1.70E-03 $sec/m^3$.

D.4.11.1.3 Exposure

The radiological exposure for the alternative is presented in Table D.4.11.3. The table shows the exposure each receptor would receive.

Table D.4.11.3 Summary of Anticipated Exposure and Risk for the No Action Alternative (Capsules)

| Receptor | Dose (person-rem)[1] | LCF/rem | LCF Risk |
|---|---|---|---|
| Worker - Population | 1.50E+02 | 4.00E-04 | 6.10E-02 |
| Worker - MEI | 5.00E+00 | 4.00E-04 | 2.00E-03 |
| Noninvolved Worker - Population | 1.30E-04 | 4.00E-04 | 5.20E-08 |
| Noninvolved Worker - MEI | 1.90E-07 | 4.00E-04 | 7.60E-11 |
| General Public - Population | 6.30E-04 | 5.00E-04 | 3.20E-07 |
| General Public - MEI | 1.30E-08 | 5.00E-04 | 6.50E-12 |

Notes:
[1]MEI receptor dose is noted in rem.

The worker population dose is dependent on the number of people in the population and the anticipated dose each individual would receive. The data were obtained from the Site maintenance and operations contractor and the TWRS EIS contractor (WHC 1995h and Jacobs 1996). The calculations for the worker exposures from storage operations are as follows:

$$\text{Storage} = (7.61\text{E}{+}02 \text{ person-yr}) \cdot (2.00\text{E-}01 \text{ rem/person-yr}) = 1.52\text{E}{+}02 \text{ person-rem}$$

The MEI worker was assumed to receive a dose of 500 mrem (5.00E-01 rem) per year for a duration of the alternative (not exceed 30 years).

The noninvolved workers and general public exposures from inhalation of the atmospheric emissions (source term) were converted to a radiological dose in rem using the GENII computer code and applying the appropriate Chi/Q value.

D.4.11.1.4 Risk

The LCFs are calculated as the product of the estimated dose times the dose-to-risk conversion factor (Section D.2.2.4). The dose-to-risk conversion factors used were 4.00E-04 LCFs per person-rem for workers and noninvolved workers and 5.00E-04 LCFs per person-rem for the general public.

The radiological dose for each receptor shown in the dose column in Table D.4.11.3 was multiplied by the appropriate dose-to-risk conversion factor to produce the LCF risk.

## D.4.12 ONSITE DISPOSAL ALTERNATIVE

This section presents the anticipated remediation risk associated with the Onsite Disposal alternative for Cs and Sr capsules, as outlined in Volume Two, Appendix B of the EIS.

The radiological risk for this alternative was based on the air emissions and direct exposure from storage and packaging operations at WESF. No nonradiological chemical (toxicological) emissions were associated with the capsules.

### D.4.12.1 Radiological Risk

The LCF risk to the workers, noninvolved workers, and general public could result from direct exposure and atmospheric emissions from the components associated with this alternative. The risk was determined by analyzing the radiological source term, the transport mechanism, exposure, and the risk associated with the exposure as discussed in the following subsections.

#### D.4.12.1.1 Source Term

The source term used for the noninvolved worker and general public was the atmospheric radiological emissions presented in Table D.4.12.1 (WHC 1995h and Jacobs 1996). The workers would receive a combined dose from the air emissions and from direct exposure from radiation fields in the workplace.

**Table D.4.12.1 Atmospheric Radiological Emissions for the Onsite Disposal Alternative**

| WESF Operating Emissions | |
|---|---|
| Contaminants | Ci/yr Released |
| Total Beta | 4.70E-09 |
| Sr-90 | 5.10E-06 |
| Cs-137 | 2.60E-06 |
| Pu-239, -240 | 2.40E-07 |

#### D.4.12.1.2 Transport

The atmospheric transport parameters of the Onsite Disposal alternative are presented in Table D.4.12.2. The atmospheric radiological operating emissions were modeled as an elevated release. For modeling purposes, it was assumed that the source term would be released at a point in the 200 Areas represented by the meteorological conditions at the Hanford Meteorological Station. The analysis used the Hanford Meteorological Station joint frequency data from Table D.2.2.1 and Figure D.2.2.1.

**Table D.4.12.2 Atmospheric Transport Parameters for the Onsite Disposal Alternative**

| WESF Operations | |
|---|---|
| Stack height in m (ft) | 21 (70) |
| Stack radius in m (ft) | 0.53 (1.7) |
| Stack flow rate in $m^3$/sec ($ft^3$/sec) | 9.2 (325) |
| Stack temperature in °C (°F) | 20 (68) |
| Noninvolved worker MEI location in m (ft) ESE | 200 (656) |
| Public MEI location in km (mi) ESE | 22 (14) |
| Chi/Q for noninvolved worker - population in $s/m^3$ | 3.70E-04 |
| Chi/Q for noninvolved worker - MEI in $s/m^3$ | 5.40E-07 |
| Chi/Q for general public - population in $s/m^3$ | 1.70E-03 |
| Chi/Q for general public - MEI in $s/m^3$ | 3.40E-08 |

Notes:
ESE = East-southeast

For elevated releases (stack releases), the maximum exposure would not necessarily occur at the closest distance to the source. Air transport modeling indicates that the maximum exposure for the noninvolved worker would occur 200 m (660 ft) from the source (in an east-southeast direction). The maximum exposure for a member of the general public would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the 200 East Area).

The calculated Chi/Q values were 5.40E-07 sec/$m^3$ for the noninvolved worker MEI and 3.40E-08 sec/$m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 3.70E-04 sec/$m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 1.70E-03 sec/$m^3$.

D.4.12.1.3 Exposure

The radiological exposure for the alternative is presented in Table D.4.12.3. The table shows the exposure each receptor would receive.

Table D.4.12.3 Summary of Anticipated Radiological Exposure for the On Site Disposal Alternative

| Receptor | Onsite Dry Storage Dose (person-rem) [1] (19 yrs) | Transportation Dose (person-rem) [1] | Total Dose (person-rem) [1] |
|---|---|---|---|
| Worker - Population | 1.74E+02 | N/A | 1.74E+02 |
| Worker - MEI | 9.50E+00 | N/A | 9.50E+00 |
| Noninvolved Worker - Population | 2.50E-04 | 5.48E-02 | 5.51E-02 |
| Noninvolved Worker - MEI | 3.60E-07 | N/A | 3.60E-07 |
| General Public - Population | 1.20E-03 | 1.63E-02 | 1.75E-02 |
| General Public - MEI | 2.50E-08 | N/A | 2.50E-08 |

Notes:
[1] MEI receptor dose is noted in rem.

The worker population dose is dependent on the number of people in the population and the anticipated dose each individual would receive. The data were obtained from the Site maintenance and operations contractor and the TWRS EIS contractor (WHC 1995h and Jacobs 1996). The calculations for the worker exposures from storage and packaging are as follows:

Storage/Packaging = (8.40E+02 person-yr) · (2.00E-01 rem/yr) = 1.68E+02 person-rem

Dry storage monitoring = (4.40E+02 person-yr) · (1.40E-01 rem/yr) = 6.16E+00 person-rem

The MEI worker was assumed to receive a dose of 500 mrem (5.00E-01 rem) per year for the duration of the alternative (not exceeding 30 years).

The noninvolved workers and general public exposures from inhalation of the atmospheric emissions (source term) were converted to a radiological dose in rem using the GENII computer code and applying the appropriate Chi/Q value.

#### D.4.12.1.4 Risk

The LCFs are calculated as the product of the estimated dose times the dose-to-risk conversion factor (Section D.2.2.4). The radiological dose for each receptor shown in the combined dose column in Table D.4.12.4 was multiplied by the appropriate dose-to-risk conversion factor to produce the LCF risk.

Table D.4.12.4 Summary of Anticipated Risk for the Onsite Disposal Alternative

| Receptor | Combined Dose (person-rem) [1] | LCF/rem | LCF Risk |
|---|---|---|---|
| Worker - Population | 1.74E+02 | 4.00E-04 | 6.96E-02 |
| Worker - MEI | 9.50E+00 | 4.00E-04 | 3.80E-03 |
| Noninvolved Worker - Population | 5.51E-02 | 4.00E-04 | 2.20E-05 |
| Noninvolved Worker - MEI | 3.60E-07 | 4.00E-04 | 1.44E-10 |
| General Public - Population | 1.75E-02 | 5.00E-04 | 8.75E-06 |
| General Public - MEI | 2.50E-08 | 5.00E-04 | 1.25E-11 |

Notes:
[1] MEI receptor dose is noted in rem.

### D.4.13 OVERPACK AND SHIP ALTERNATIVE

This section presents the anticipated remediation risk associated with the Overpack and Ship alternative for Cs and Sr capsules, as outlined in Volume Two, Appendix B of the EIS.

The radiological risk for this alternative was based on the air emissions and direct exposure from storage and overpacking at WESF, and transporting capsules onsite. No nonradiological chemical (toxicological) emissions were associated with the capsules.

#### D.4.13.1 Radiological Risk

The LCF risk to the workers, noninvolved workers, and general public could result from direct exposure and atmospheric emissions from the components associated with this alternative. The risk was determined by analyzing the radiological source term, the transport mechanism, exposure, and the risk associated with the exposure as discussed in the following subsections.

#### D.4.13.1.1 Source Term

The source term used for the noninvolved worker and general public was the atmospheric radiological emissions presented in Table D.4.13.1 (WHC 1995h and Jacobs 1996). The workers would receive a combined dose from the air emissions and from direct exposure from radiation fields in the work place.

D.4.13.1.2 Transport

The atmospheric transport parameters of the Overpack and Ship alternative are presented in Table D.4.13.2. The atmospheric radiological operating emissions were modeled as an elevated release. For modeling purposes, it was assumed that the source term would be released at a point in the 200 Areas represented by the meteorological conditions at the Hanford Meteorological Station. The analysis used the Hanford Meteorological Station joint frequency data from Table D.2.2.1 and Figure D.2.2.1.

Table D.4.13.1 Atmospheric Radiological Emissions for the Overpack and Ship Alternative

| WESF Operating Emissions | |
|---|---|
| Contaminants | Ci/yr Released |
| Total Beta | 4.70E-09 |
| Sr-90 | 5.10E-06 |
| Cs-137 | 2.60E-06 |
| Pu-239, 240 | 2.40E-07 |

Table D.4.13.2 Atmospheric Transport Parameters for the Overpack and Ship Alternative

| Transport Parameters | WESF Operations |
|---|---|
| Stack height in m (ft) | 21 (70) |
| Stack radius in m (ft) | 0.53 (1.7) |
| Stack flow rate in $m^3$/sec ($ft^3$/sec) | 9.2 (325) |
| Stack temperature in °C (°F) | 20 (68) |
| Noninvolved worker MEI location in m (ft) ESE | 200 (656) |
| Public MEI location in km (mi) ESE | 22 (14) |
| Chi/Q for noninvolved worker - population in s/$m^3$ | 3.70E-04 |
| Chi/Q for noninvolved worker - MEI in s/$m^3$ | 5.40E-07 |
| Chi/Q for general public - population in s/$m^3$ | 1.70E-03 |
| Chi/Q for general public - MEI in s/$m^3$ | 3.40E-08 |

Notes:
ESE = East-southeast

For elevated releases (stack releases), the maximum exposure would not necessarily occur at the closest distance to the source. Air transport modeling indicates that the maximum exposure for the noninvolved worker would occur 200 m (660 ft) from the source (in an east-southeast direction). The maximum exposure for a member of the general public would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the 200 East Area).

The calculated Chi/Q values were 5.40E-07 sec/$m^3$ for the noninvolved worker MEI and 3.40E-08 sec/$m^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 3.70E-04 sec/$m^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 1.70E-03 sec/$m^3$.

D.4.13.1.3 Exposure

The radiological exposure for the alternative is presented in Table D.4.13.3. The table shows the exposure each receptor would receive.

Table D.4.13.3 Summary of Anticipated Radiological Exposure for the Overpack and Ship Alternative

| | Dose (person-rem) [1] | | |
|---|---|---|---|
| Receptor | Overpack and Ship (18 yrs) | Transportation (1 yr) | Total |
| Worker - Population | 2.80E+01 | N/A | 2.80E+01 |
| Worker - MEI | 9.50E+00 | N/A | 9.50E+00 |
| Noninvolved Worker - Population | 2.50E-04 | 4.39E+01 | 4.39E+01 |
| Noninvolved Worker - MEI | 3.60E-07 | N/A | 3.60E-07 |
| General Public - Population | 1.20E-03 | 2.13E+00 | 2.13E+00 |
| General Public - MEI | 2.50E-08 | N/A | 2.50E-08 |

Notes:
[1] MEI receptor dose are noted in rem.

The worker population dose is dependent on the number of people in the population and the anticipated individual dose. The data were obtained from the Site maintenance and operations contractor and the TWRS EIS contractor (WHC 1995h and Jacobs 1996). The calculations for the worker exposures from storage and overpacking operations are as follows:

Storage/Overpacking = (1.48E+02 person-yr) · (2.00E-01 rem/person-yr) = 2.84E+01 person-rem

The MEI worker was assumed to receive a dose of 500 mrem (5.00E-01 rem) per year for the duration of the alternative (not exceeding 30 years).

The noninvolved workers and general public exposures from inhalation of the atmospheric emissions (source term) were converted to a radiological dose in rem using the GENII computer code and applying the appropriate Chi/Q.

D.4.13.1.4 Risk

The LCFs are calculated as the product of the estimated dose times the dose-to-risk conversion factor (Section D.2.2.4). The dose-to-risk conversion factors used were 4.00E-04 LCFs per person-rem for workers and noninvolved workers and 5.00E-04 LCFs per person-rem for the general public.

The radiological dose for each receptor shown in the combined dose column in Table D.4.13.4 was multiplied by the appropriate dose-to-risk conversion factor to produce the LCF risk.

Table D.4.13.4 Summary of Anticipated Risk for the Overpack and Ship Alternative

| Receptor | Combined Dose (person-rem) [1] | LCF/rem | LCF Risk |
|---|---|---|---|
| Worker - Population | 2.80E+01 | 4.00E-04 | 1.12E-02 |
| Worker - MEI | 9.50E+00 | 4.00E-04 | 3.80E-03 |
| Noninvolved Worker - Population | 4.39E+01 | 4.00E-04 | 1.76E-02 |
| Noninvolved Worker - MEI | 3.60E-07 | 4.00E-04 | 1.44E-10 |
| General Public - Population | 2.13E+00 | 5.00E-04 | 1.07E-03 |
| General Public - MEI | 2.50E-08 | 5.00E-04 | 1.25E-11 |

Notes:
[1] MEI receptor dose is noted in rem.

## D.4.14 VITRIFY WITH TANK WASTE ALTERNATIVE

This section presents the anticipated remediation risk associated with the Vitrify With Tank Waste alternative for Cs and Sr capsules, as outlined in Volume Two, Appendix B of the EIS.

The radiological risk for this alternative was based on the air emissions and direct exposure from storage and overpacking operations in WESF, and transporting the overpacked capsules to the vitrification facility. No nonradiological chemical (toxicological) emissions were associated with the capsules.

### D.4.14.1 Radiological Risk

The LCF risk to the workers, noninvolved workers, and general public could result from direct exposure and atmospheric emissions from the components associated with this alternative. The risk was determined by analyzing the radiological source term, the transport mechanism, exposure, and the risk associated with the exposure as discussed in the following subsections.

D.4.14.1.1 Source Term

The source term used for the noninvolved worker and general public was the atmospheric radiological emissions presented in Table D.4.14.1 (WHC 1995h and Jacobs 1996). The workers would receive a combined dose from the air emissions and from direct exposure from radiation fields in the workplace.

D.4.14.1.2 Transport

The atmospheric transport parameters of the Vitrify with Tank Waste alternative are presented in Table D.4.14.2. The atmospheric radiological operating emissions were modeled as an elevated release. For modeling purposes, it was assumed that the source term would be released at a point in the 200 Areas represented by the meteorological conditions at the Hanford Meteorological Station. The analysis used the Hanford Meteorological Station joint frequency data from Table D.2.2.1 and Figure D.2.2.1.

**Table D.4.14.1 Atmospheric Radiological Emissions for the Vitrify with Tank Waste Alternative**

| WESF Operating Emissions | |
|---|---|
| Contaminants | Ci/yr Released |
| Total Beta | 4.70E-09 |
| Sr-90 | 5.10E-06 |
| Cs-137 | 2.60E-06 |
| Pu-239, -240 | 2.40E-07 |

**Table D.4.14.2 Atmospheric Transport Parameters for the Vitrify with Tank Waste Alternative**

| | WESF Operations |
|---|---|
| Stack height in m (ft) | 21 (70) |
| Stack radius in m (ft) | 0.53 (1.7) |
| Stack flow rate in $m^3$/sec ($ft^3$/sec) | 9.2 (325) |
| Stack temperature in °C (°F) | 20 (68) |
| Noninvolved worker MEI location in m (ft) ESE | 200 (656) |
| Public MEI location in km (mi) ESE | 22 (14) |
| Chi/Q for noninvolved worker - population in $s/m^3$ | 3.70E-04 |
| Chi/Q for noninvolved worker - MEI in $s/m^3$ | 5.40E-07 |
| Chi/Q for general public - population in $s/m^3$ | 1.70E-03 |
| Chi/Q for general public - MEI in $s/m^3$ | 3.40E-08 |

Notes:
ESE = East-southeast

For elevated releases (stack releases), the maximum exposure would not necessarily occur at the closest distance to the source. Air transport modeling indicates that the maximum exposure for the noninvolved worker would occur 200 m (660 ft) from the source (in an east-southeast direction). The maximum exposure for a member of the general public would occur 22 km (14 mi) from the source (i.e., the distance to the Hanford Site boundary in an east-southeast direction from the 200 East Area).

The calculated Chi/Q values were 5.40E-07 sec/m$^3$ for the noninvolved worker MEI and 3.40E-08 sec/m$^3$ for the general public MEI. For the noninvolved worker population of 10,900 occupying an area between 100 m (330 ft) from the source and the Hanford Site boundary, the population-weighted Chi/Q value was 3.70E-04 sec/m$^3$. For the general public population of 376,000 occupying an area outside the Hanford Site boundary within an 80-km (50-mi) radius centered on the 200 Areas, the population-weighted Chi/Q value was 1.70E-03 sec/m$^3$.

D.4.14.1.3 Exposure

The radiological exposure for the alternative is presented in Table D.4.14.3. The table shows the exposure each receptor would receive.

Table D.4.14.3 Summary of Anticipated Radiological Exposure for the Vitrify with Tank Waste Alternative

| Receptor | Dose (person-rem) [1] | | |
|---|---|---|---|
| | Storage/Overpack (19 yrs) | Transportation | Total |
| Worker - Population | 2.80E+01 | N/A | 2.80E+01 |
| Worker - MEI | 9.50E+00 | N/A | 9.50E+00 |
| Noninvolved Worker - Population | 2.50E-04 | 1.98E+01 | 1.98E+01 |
| Noninvolved Worker - MEI | 3.60E-07 | N/A | 3.60E-07 |
| General Public - Population | 1.20E-03 | 9.62E-01 | 9.63E-01 |
| General Public -MEI | 2.50E-08 | N/A | 2.50E-08 |

Notes:
[1] MEI receptor dose is noted in rem.

The worker population dose is dependent on the number of people in the population and the anticipated individual dose. The data were obtained from the Site maintenance and operations contractor and the TWRS EIS contractor (WHC 1995h and Jacobs 1996). The calculations for the worker exposures from storage and overpacking operations are as follows:

Storage/Overpack = (1.40E+02 person-yr) · (2.00E-01 rem/person-yr) = 2.8E+01 person-rem

The MEI worker was assumed to receive a dose of 500 mrem (5.00E-01 rem) per year for a duration of the alternative (not exceeding 30 years).

The noninvolved workers and general public exposures from inhalation of the atmospheric emissions (source term) were converted to a radiological dose in rem using the GENII computer code and applying the appropriate Chi/Q.

D.4.14.1.4 Risk

The LCFs are calculated as the product of the estimated dose times the dose-to-risk conversion factor (Section D.2.2.4). The dose-to-risk conversion factors used were 4.00E-04 LCFs per person-rem for workers and noninvolved workers and 5.00E-04 LCFs per person-rem for the general public.

The radiological dose for each receptor shown in the combined dose column in Table D.4.13.4 was multiplied by the appropriate dose-to-risk conversion factor to produce the LCF risk.

Table D.4.14.4 Summary of Anticipated Risk for the Vitrify with Tank Waste Alternative

| Receptor | Combined Dose (person-rem) [1] | LCF/rem | LCF Risk |
|---|---|---|---|
| Worker - Population | 2.80E+01 | 4.00E-04 | 1.12E-02 |
| Worker - MEI | 9.50E+00 | 4.00E-04 | 3.80E-03 |
| Noninvolved Worker - Population | 1.98E+01 | 4.00E-04 | 7.92E-03 |
| Noninvolved Worker - MEI | 3.60E-07 | 4.00E-04 | 1.44E-10 |
| General Public - Population | 9.63E+01 | 5.00E-04 | 4.82E-04 |
| General Public - MEI | 2.50E-08 | 5.00E-04 | 1.25E-11 |

Notes:
[1] MEI receptor dose is noted in rem.

## D.4.15 REMEDIATION RISK SUMMARY

This section summarizes the results of the remediation risk assessment presented in Sections D.4.1 to D.4.14 for each of the alternatives. Separate summaries are presented for radiological risk and chemical risk.

### D.4.15.1 Radiological Risk

Table D.4.15.1 summarizes the calculated LCF risk associated with radiological exposures for each alternative. Risks are summarized for the workers, noninvolved workers, and the general public. Risks are also summarized for the MEI from each of these receptor groups. The table presents both remediation risk and total risk for each receptor and alternative. The total risk includes the risk from remediation activities plus the risk from post-closure monitoring.

### D.4.15.2 Chemical Risk

Tables D.4.15.2 and D.4.15.3 summarize the calculated noncarcinogenic health hazard and carcinogenic risk associated with chemical air emissions for each tank waste alternative. Capsule alternatives are not shown because chemical emissions are not associated with any of these alternatives. Table D.4.15.2 summarizes the nonradiological health hazard (expressed as a HI) for the MEI worker,

**Table D.4.15.1 Comparison of Radiological Consequences from Remediation Operations Under Normal Conditions**

| Alternative | Latent Cancer Fatalities | | | | | |
|---|---|---|---|---|---|---|
| | Workers | | Noninvolved Workers | | General Public | |
| | Population | MEI | Population | MEI | Population | MEI |
| Tank Waste | | | | | | |
| No Action (Section D.4.1.1.4) | 3.31E-01 | 6.00E-03 | 1.00E-06 | 1.56E-07 | 8.00E-05 | 2.30E-09 |
| Long-Term Management Remediation (Section D.4.2.1.4) | 4.92E-01 | 6.00E-03 | 3.30E-05 | 3.51E-07 | 2.45E-04 | 6.45E-09 |
| In Situ Fill and Cap | | | | | | |
| Remediation (Section D.4.3.1.4) | 2.09E-01 | 3.80E-03 | 1.66E-05 | 1.00E-07 | 1.20E-04 | 2.05E-09 |
| Total Alternative [1] | 2.13E-01 | 6.00E-03 | 1.66E-05 | 1.00E-07 | 1.20E-04 | 2.05E-09 |
| In Situ Vitrification (Section D.4.4.1.4) | | | | | | |
| Remediation | 6.24E-01 | 3.80E-02 | 5.40E-04 | 6.48E-08 | 3.29E-01 | 1.10E-06 |
| Total Alternative[1] | 6.28E-01 | 6.00E-03 | 5.40E-04 | 6.48E-08 | 3.29E-01 | 1.10E-06 |
| Ex Situ Intermediate Separations (Section D.4.5.1.4) | | | | | | |
| Remediation | 3.12E+00 | 5.80E-03 | 7.92E-04 | 9.84E-07 | 1.56E-01 | 3.35E-06 |
| Total Alternative [1] | 3.13E+00 | 6.00E-03 | 7.92E-04 | 9.84E-07 | 1.56E-01 | 3.35E-06 |
| Ex Situ No Separations (Section D.4.6.1.4) | | | | | | |
| Vitrification - Remediation | 1.50E+00 | 4.80E-03 | 8.28E-04 | 6.80E-07 | 1.56E-01 | 3.35E-06 |
| Total Alternative [1] | 1.96E+00 | 6.00E-03 | 8.28E-04 | 6.80E-07 | 1.56E-01 | 3.35E-06 |
| Calcination - Remediation | 1.95E+00 | 6.00E-03 | 7.88E-04 | 6.80E-07 | 1.11E-01 | 2.40E-06 |
| Total Alternative [1] | 1.96E+00 | 6.00E-03 | 7.88E-04 | 6.80E-07 | 1.11E-01 | 2.40E-06 |
| Ex Situ Extensive Separations (Section D.4.7.1.4) | | | | | | |
| Remediation | 3.19E+00 | 6.00E-03 | 7.24E-04 | 8.40E-07 | 1.26E-01 | 2.75E-06 |
| Total Alternative [1] | 3.20E+00 | 6.00E-03 | 7.24E-04 | 8.40E-07 | 1.26E-01 | 2.75E-06 |
| Ex Situ/In Situ Combination 1 (Section D.4.8.1.4) | | | | | | |
| Remediation | 2.02E+00 | 6.00E-03 | 3.89E-04 | 8.40E-07 | 1.31E-01 | 3.00E-06 |
| Total Alternative [1] | 2.02E+00 | 6.00E-03 | 3.89E-04 | 8.40E-07 | 1.31E-01 | 3.00E-06 |
| Ex Situ/In Situ Combination 2 (Section D.4.9.1.4) | | | | | | |
| Remediation | 2.02E+00 | 6.00E-03 | 2.54E-04 | 8.40E-07 | 1.09E-01 | 1.26E-06 |
| Total Alternative [1] | 2.02E+00 | 6.00E-03 | 2.54E-04 | 8.40E-07 | 1.09E-01 | 1.26E.06 |
| Phased Implementation (Section D.4.10.1.4) | | | | | | |
| Remediation | 3.27E+00 | 6.00E-03 | 9.04E-04 | 9.60E-07 | 1.94E-01 | 2.43E-06 |
| Total Alternative[1] | 3.27E+00 | 6.00E-03 | 9.04E-04 | 9.60E-07 | 1.94E-01 | 2.43E-06 |

Table D.4.15.1 Comparison of Radiological Consequences from Remediation Operations Under Normal Conditions (cont'd)

| Alternative | Latent Cancer Fatalities | | | | | |
|---|---|---|---|---|---|---|
| | Workers | | Noninvolved Workers | | General Public | |
| | Population | MEI | Population | MEI | Population | MEI |
| Capsules | | | | | | |
| No Action (Section D.4.11.1.4) | 6.10E-02 | 2.00E-03 | 5.20E-08 | 7.60E-11 | 3.20E-07 | 6.50E-12 |
| Onsite Disposal (Section D.4.12.1.4) Remediation | 6.96E-02 | 3.80E-03 | 2.20E-05 | 1.44E-10 | 8.75E-06 | 1.25E-11 |
| Overpack and Ship (Section D.4.13.1.4) Remediation | 1.12E-02 | 3.80E-03 | 1.76E-02 | 1.44E-10 | 1.07E-03 | 1.25E-11 |
| Vitrify with Tank Waste (Section D.4.14.1.4) Remediation | 1.12E-02 | 3.80E-03 | 7.92E-03 | 1.44E-10 | 4.82E-04 | 1.25E-11 |

Notes:
[1] Includes remediation and closure.
MEI = Maximally-exposed individual

Table D.4.15.2 Comparison of Nonradiological Chemical Hazards from Remediation Operations

| Alternative | Nonradiological Health Hazards | | |
|---|---|---|---|
| | MEI Involved Worker Hazard Index | MEI Noninvolved Worker Hazard Index | MEI General Public Hazard Index |
| No Action (Section D.4.1.2.5) | 7.70E-02 | 3.33E-02 | 1.82E-05 |
| Long-Term Management (Section D.4.2.2.5) | 1.12E-01 | 4.86E-02 | 3.51E-05 |
| In Situ Fill and Cap (Section D.4.3.2.5) | 7.89E-02 | 3.43E-02 | 2.75E-05 |
| In Situ Vitrification (Section D.4.4.2.5) | 7.89E-02 | 3.48E-02 | 2.04E-04 |
| Ex Situ Intermediate Separations (Section D.4.5.2.5) | 3.08E-01 | 1.33E-01 | 7.29E-05 |
| Ex Situ No Separations (Section D.4.6.2.5) | 3.08E-01 | 1.33E-01 | 7.34E-05 |
| Ex Situ Extensive Separations (Section D.4.7.2.5) | 3.08E-01 | 1.33E-01 | 7.29E-05 |
| Ex Situ/In Situ Combination 1 (Section D.4.8.2.5) | 3.10E-01 | 1.34E-01 | 8.22E-05 |
| Ex Situ/In Situ Combination 2 (Section D.4.9.2.5) | 3.10E-01 | 1.34E-01 | 8.22E-05 |
| Phased Implementation (Section D.4.10.2.5) | 3.08E-01 | 1.33E-01 | 7.50E-05 |

Notes:
MEI = Maximally-exposed individual

Table D.4.15.3 Comparison of Nonradiological Chemical Cancer Risks from Remediation Operations

| Alternative | Chemical Incremental Lifetime Cancer Risks | | |
|---|---|---|---|
| | MEI Involved Worker Cancer Risk | MEI Noninvolved Worker Cancer Risk | MEI General Public Cancer Risk |
| No Action (Section D.4.1.2.5) | 7.05E-07 | 3.05E-07 | 9.08E-11 |
| Long-Term Management (Section D.4.2.2.5) | 9.84E-07 | 4.26E-07 | 1.27E-10 |
| In Situ Fill and Cap (Section D.4.3.2.5) | 4.50E-07 | 1.95E-07 | 5.80E-11 |
| In Situ Vitrification (Section D.4.4.2.5) | 4.51E-07 | 1.95E-07 | 5.81E-11 |
| Ex Situ Intermediate Separations (Section D.4.5.2.5) | 2.51E-06 | 1.09E-06 | 5.43E-10 |
| Ex Situ No Separations (Section D.4.6.2.5) | 1.90E-06 | 8.22E-07 | 4.29E-10 |
| Ex Situ Extensive Separations (Section D.4.7.2.5) | 2.33E-06 | 1.01E-06 | 4.92E-10 |
| Ex Situ/In Situ Combination 1 (Section D.4.8.2.5) | 2.52E-06 | 1.09E-06 | 5.43E-10 |
| Ex Situ/In Situ Combination 2 (Section D.4.9.2.5) | 2.52E-06 | 1.09E-06 | 5.43E-10 |
| Phased Implementation (Section D.4.10.2.5) | 2.51E-06 | 1.09E-06 | 6.34E-10 |

Notes:
MEI = Maximally-exposed individual

MEI noninvolved worker, and MEI general public for each alternative. Table D.4.15.3 summarizes the nonradiological cancer risk for the MEI worker, MEI noninvolved worker, and MEI general public for each alternative.

## D.4.16 UNCERTAINTY

The uncertainties in the risk assessment for tank waste remediation are associated with the source data and source term, transport, exposure pathway, and dose to risk conversion factors. By far the greatest uncertainty is associated with the source data, which are based on the estimated inventory and source terms (e.g., the amount of chemicals and radionuclides released into the environment). The uncertainties associated with the source and source terms are discussed in detail in Volume Five, Appendix K. Other contributors to the routine risk assessment uncertainty are the airborne transport of the released chemicals and radionuclides, accumulation of contaminants in food products, production and distribution of food products, lifestyle and diet of specific individuals or food consumption rates, and dose conversion factors of the contaminants. A detailed discussion of the uncertainties in the remediation risk assessment is presented in Volume Five, Appendix K.

## D.5.0 ANTICIPATED POST-REMEDIATION RISK

This section presents the results of the assessment of anticipated post-remediation risk for each of the TWRS EIS alternatives. Post-remediation risk is the risk to a future land user from exposure to residual contamination after the TWRS mission has been completed. Anticipated risk was evaluated for five exposure scenarios: 1) the Native American; 2) the residential farmer; 3) the industrial worker; 4) the recreational shoreline user; and 5) the recreational land user. These scenarios were selected to represent a range of possible land uses that could occur at the Hanford Site in the future.

The risk presented in this section was evaluated using the modular risk assessment methodology described in Section D.2.1. The modular approach separates the four basic components of the risk assessment process (i.e., source, transport, exposure, and risk) into discrete modules that can be assessed independently and then combined.

The following sections discuss the source, transport, exposure, and risk modules developed for each of the TWRS EIS alternatives. Due to their length, the supporting tables and graphs are presented at the end of this section.

## D.5.1 NO ACTION ALTERNATIVE (TANK WASTE) (BASELINE RISK ASSESSMENT)

This section presents the anticipated post-remediation risk associated with the No Action alternative for tank waste. Post remediation for this alternative refers to risk remaining after tank farm operational activities and 100 years institutional controls (40 CFR 191) are discontinued.

### D.5.1.1 Source

Post-remediation contamination sources under the No Action alternative would consist of the current inventories in the SSTs, DSTs, and MUSTs (Jacobs 1996). Additional discussion of contaminant source inventories is provided in Volume Two, Appendix A.

### D.5.1.2 Transport

Post remediation contaminant releases would be from the tanks to the soil. Contaminants released to the soil would migrate to groundwater in proportion to their ionic mobility. Air emissions from all sources were assumed to be zero. Thus, groundwater transport (i.e., transport in the vadose zone and aquifer) was the only transport pathway considered for this assessment. The point concentrations used for the risk calculations (i.e., future concentrations at a given receptor originating from a particular source) were generated through groundwater transport modeling and are discussed briefly in the following text. A detailed discussion of groundwater modeling is provided in Volume Four, Appendix F.

Groundwater modeling predicts that contaminants released from the tanks would be present in groundwater beneath the Hanford Site for all periods of interest [i.e., 300, 500, 2,000, 5,000, and 10,000 years from the present (40 CFR 191)]. Calculated groundwater contaminant concentrations and spatial distributions are discussed in Volume Four, Appendix F.

Example point concentrations for one constituent (I-129) are displayed in Table D.5.1.1. The table shows calculated groundwater concentrations by grid cell for the periods of interest. Similar data have been tabulated for the other constituents calculated to reach groundwater but are not presented here in the interest of brevity.

Contaminated groundwater would eventually discharge to the Columbia River where it would be rapidly diluted by mixing with the river flow. The contaminant mass entering the river would cause the recreational shoreline user to receive small exposures from surface water activities. To evaluate an upper bound for these exposures, conservative surface water concentrations were calculated for five mobile constituents of concern (C-14, I-129, Tc-99, U-238, and nitrate) by applying a dilution factor to the maximum calculated groundwater concentration given in Volume Four, Appendix F for each constituent in each time period. The resultant river water concentrations were then conservatively assumed to be present uniformly in the surface water used by the recreational shoreline user.

The dilution factor was determined by using results from the surface water impacts analysis described in Section 5.2.2. In that analysis, a mixing calculation indicated that the concentration of nitrate in the Columbia River would reach a maximum of 0.177 mg/L under the Long-Term Management alternative at 300 years from 1995. This concentration (0.177 mg/L) is approximately 0.12 mg/L above the river's 0.05 mg/L background nitrate concentration and resulted from the discharge of groundwater with a maximum calculated nitrate concentration of 1.05E+03 mg/L. Using these results, the ratio of surface water concentration (0.177-0.05=0.127 mg/L) to groundwater concentration (1.05E+03 mg/L) yields a dilution factor for nitrate of 0.127/1.05E+03=1.21E-04. For the risk analysis, the maximum calculated groundwater concentrations for the constituents of concern were multiplied by the dilution factor to produce maximum surface water concentrations. Applying the nitrate dilution factor to the other four constituents is considered appropriate because these constituents have approximately the same groundwater mobility (i.e., the same $K_d$) as nitrate.

### D.5.1.3 Exposure

Exposure is quantified using a URF. A URF is the risk associated with exposure to a unit concentration of a given contaminant under one of five exposure scenarios (i.e., Native American, residential farmer, industrial, recreational shoreline user, and recreational land user). URFs were developed for the appropriate exposure pathway (i.e., ingestion, inhalation, and direct contact) for each applicable exposure scenario. URFs are discussed and presented in Section D.2.1.3.

Exposure would occur as the result of direct or indirect exposure to groundwater and, for the recreational shoreline user, to surface water. The recreational land user scenario assumes no use of groundwater; thus there is no complete exposure pathway. Therefore, there is no risk associated with this scenario and it is not discussed further. Because the Native American, residential farmer, industrial, and recreational shoreline user scenarios included groundwater use, these receptors have complete exposure pathways and receive direct exposure. These receptors would have the potential to receive indirect exposures through the pathways shown in Section D.2.1.3.

### D.5.1.4 Risk

The anticipated risk to a receptor within a grid cell was calculated as the product of the point concentration and the URF (Section D.2.1.4). The risk module calculates risk for each exposure scenario, source, and period of interest across all grid cells on the Hanford Site. To visually display the anticipated risk, GIS software was used to generate contour maps illustrating potential risk to a receptor at various locations across the Hanford Site. Each area defined by contour lines represents a zone with a discrete value of risk. Risk from radionuclides and carcinogenic chemicals was combined and presented on one set of maps. HIs from noncarcinogenic chemicals are presented on a separate set of maps.

For radionuclides and carcinogenic chemicals, the risk is defined as the increased probability that an individual at any location along a contour line would develop cancer under the defined conditions of the exposure scenario. Human health risk is defined in terms of the incremental lifetime cancer risk (ILCR). Although there is no universally accepted standard for the level of risk considered acceptable, for purposes of this analysis risk of 1.00E-06 (one in one million) is considered to be low and risk greater than 1.00E-04 (one in ten thousand) is considered high. An ILCR of 1 means that an individual's lifetime probability of developing cancer approaches 100 percent.

For noncarcinogenic chemicals, the HI is the ratio of chemical intake to a reference dose below which no toxic effects are expected. Where the HI is less than 1.0, no toxic effects are expected. Where it is greater than 1, toxic effects are expected. Contour maps for the HI are constructed in the same way as for the cancer risk.

On certain contour maps, white areas with risk values less than the minimum value contoured (i.e., less than 1.0E-06) appear as "holes" in the risk distributions. One such set of "holes" trending in a northwest-to-southeast direction north of the 200 Areas represents areas where basalt occurs above the water table, preventing the influx of contaminated water into these areas. Another such set underlying the 200 West Area represents conditions of groundwater mounding created by liquid discharges from Hanford Site facilities. The roughness associated with the contour lines is a function of the resolution of the analysis (i.e., 1 by 1 km [0.6 by 0.6 mi] grid size).

The risk calculation for the No Action alternative combines the risk contributed by the SSTs and DSTs into a single risk value for each grid cell. Risk calculations were performed for all five periods of interest. Risk contour maps are presented for all scenarios and time periods except in cases where the maximum combined risk from radionuclides and carcinogenic chemicals is below 1.00E-06, or the maximum hazard from noncarcinogenic chemicals is less than an HI of 1.0. No maps are presented in these latter cases.

Contour maps depicting the risk from radionuclides and carcinogenic chemicals in tank waste are presented in Figures D.5.1.1 to D.5.1.5 for the Native American scenario, Figures D.5.1.6 to D.5.1.9 for the residential farmer scenario, Figures D.5.1.10 to D.5.1.13 for the industrial worker scenario, and Figures D.5.1.14 to D.5.1.16 for the recreational shoreline user scenario. Contour maps depicting

the HI from noncarcinogenic chemicals in tank waste are presented in Figures D.5.1.17 to D.5.1.19 for the Native American scenario, Figures D.5.1.20 to D.5.1.22 for the residential farmer scenario, and Figure D.5.1.23 for the industrial worker scenario. No HI maps are presented for the recreational shoreline user scenario because the maximum HI did not exceed 1.0.

Note that the contour maps depicting risk (ILCR) to the recreational shoreline user include a contribution from C-14, I-129, Tc-99, and U-238 in surface water. A summary of the surface water contributions for the recreational shoreline user scenario is shown in Table D.5.1.2 for each alternative and time period. These contributions are quite small and in the case of the residential farmer scenario would be even smaller because the residential farmer scenario involves substantially less surface water activity. For this reason, surface water contributions for the residential farmer scenario are disregarded for this and all other TWRS alternatives. For the Native American scenario, surface water pathways are integrated into the groundwater pathways for all alternatives.

## D.5.2 LONG-TERM MANAGEMENT ALTERNATIVE

This section presents the anticipated post-remediation risk associated with the Long-Term Management alternative for tank waste. Post remediation for this alternative refers to the risk remaining after operation of the tank farms (i.e., institutional controls) is discontinued (assumed to be 100 years from 1995 for the purpose of this EIS). Over the 100-year period, the SSTs would continue to be stabilized and isolated to prevent liquid infiltration and the DSTs would undergo two tanking campaigns.

### D.5.2.1 Source

Under the Long-Term Management alternative, the post-remediation source for SSTs would consist of the current SST farms. The source for the DSTs would consist of the current DST farms (containing 1 percent residual) and the replacement DST farms (containing the remaining 99 percent of the inventory) (WHC 1995g and Jacobs 1996). Additional discussion of source inventories is provided in Volume Four, Appendix F.

### D.5.2.2 Transport

Post-remediation contaminant releases would be to the soil below the tanks. Contaminants released to the soil would migrate to groundwater in proportion to their ionic mobility. Groundwater modeling predicts that contaminants released from the tanks would be present in groundwater beneath the Hanford Site for all periods of interest (i.e. 300, 500, 2,000, 5,000, and 10,000 years from the present). Calculated groundwater contaminant concentrations and distributions are discussed in Volume Four, Appendix F.

To evaluate surface water exposures for the recreational shoreline user scenario, surface water concentrations resulting from groundwater discharge to the Columbia River were conservatively calculated using a dilution factor approach as described for the No Action alternative in Section D.5.1.2.

### D.5.2.3 Exposure

Exposure for the Long-Term Management alternative was analyzed using the same URF methods and factors used for the No Action alternative (Section D.5.1.3). URFs are presented in Section D.2.1.3.

### D.5.2.4 Risk

Risk for the Long-Term Management alternative is calculated using the same approach used for the No Action alternative (Section D.5.1.4). The risk calculation combines the risk contributed by the SSTs, original DSTs, and the replacement DST groups into a single risk value for each grid cell.

Contour maps depicting the risk from radionuclides and carcinogenic chemicals in tank waste are presented in Figures D.5.2.1 to D.5.2.5 for the Native American scenario, Figures D.5.2.6 to D.5.2.9 for the residential farmer scenario, Figures D.5.2.10 to D.5.2.13 for the industrial scenario, and Figures D.5.2.14 to D.5.2.16 for the recreational shoreline user scenario. Contour maps depicting the HI from noncarcinogenic chemicals in tank waste are presented in Figures D.5.2.17 to D.5.2.19 for the Native American scenario, Figures D.5.2.20 to D.5.2.22 for the residential farmer scenario, and Figure D.5.2.23 for the industrial scenario. No HI maps are presented for the recreational shoreline user scenario because the maximum HI did not exceed 1.0.

## D.5.3 IN SITU FILL AND CAP ALTERNATIVE

This section presents the anticipated post-remediation risk associated with the In Situ Fill and Cap alternative. Implementing this alternative would involve leaving radioactive waste in the existing tanks. DST liquid would be pumped to the evaporator and the concentrated waste returned to the DST Farms. The tanks would then be filled with gravel and capped with Hanford Barriers (WHC 1995f and Jacobs 1996).

### D.5.3.1 Source

Post-remediation contamination sources under this alternative would consist of the current tank inventory as described in Volume Four, Appendix F.

### D.5.3.2 Transport

Transport for the In Situ Fill and Cap alternative was analyzed using the same approach used for the No Action alternative (Section D.5.1.2) except that under the In Situ Fill and Cap alternative a Hanford Barrier would be placed over the tanks to reduce the infiltration of precipitation. This barrier would slow the process of leaching contaminants from the waste.

Groundwater modeling predicts that contaminants released from the fill and cap residuals would not reach groundwater during the first 500 years. Point concentrations are therefore zero for all constituents for the 300- and 500-year periods. During the latter three periods of interest (i.e., 2,500, 5,000, and 10,000 years from the present), modeling predicts that contaminants released from the in situ fill and cap residuals would be present in groundwater. Predicated groundwater contaminant concentrations and distributions during each time period are discussed in Volume Four, Appendix F.

To evaluate surface water exposures for the recreational shoreline user scenario, surface water concentrations resulting from groundwater discharge to the Columbia River were conservatively calculated using a dilution factor approach as described for the No Action alternative in Section D.5.1.2.

### D.5.3.3 Exposure

Exposure for the In Situ Fill and Cap alternative was analyzed using the same URF methods and factors as used for the No Action alternative (Section D.5.1.3). URFs are presented in Section D.2.1.3.

### D.5.3.4 Risk

Risk for the In Situ Fill and Cap alternative was calculated using the same approach as used for the No Action alternative (Section D.5.1.4). Because all tank constituents are calculated to have groundwater concentrations of zero within all cells for the 300- and 500-year periods, no risk calculations were performed for those periods.

Contour maps depicting the risk from radionuclides and carcinogenic chemicals for the In Situ Fill and Cap alternative are presented in Figures D.5.3.1 and D.5.3.2 for the Native American scenario; Figures D.5.3.3 and D.5.3.4 for the residential farmer scenario; Figures D.5.3.5 and D.5.3.6 for the industrial worker scenario; and Figures D.5.3.7 and D.5.3.8 for the recreational shoreline user scenario. Contour maps depicting the HI from noncarcinogenic chemicals are presented in Figures D.5.3.9 and D.5.3.10 for the Native American scenario, and Figures D.5.3.11 and D.5.3.12 for the residential farmer scenario. No HI maps are presented for the industrial worker or recreational shoreline user scenarios because the maximum HI from noncarcinogenic chemicals does not exceed 1.0.

## D.5.4 IN SITU VITRIFICATION ALTERNATIVE

This section presents the anticipated post-remediation risk associated with the In Situ Vitrification alternative. This alternative would involve melting the tank waste and tanks into a glass monolith. Implementing this alternative would involve 1) sending all pumpable liquid from the DSTs to the evaporator for removing excess water; 2) constructing tank farm confinement facilities; 3) filling tank voids with Hanford Site sand; 4) vitrifying, using joule heating, to melt the tank waste and tanks in place into a single block of glass; and 5) installing Hanford Barriers over the vitrified site.

### D.5.4.1 Source

Post-remediation contamination sources under the In Situ Vitrification alternative would consist of the current tank inventory (minus volatiles) but in a vitrified form that would release contaminants very slowly (WHC 1995f and Jacobs 1996). Additional discussion of contaminant source inventories is provided in Volume Four, Appendix F.

### D.5.4.2 Transport

Post-remediation contaminant releases would be to the soil below the vitrified tanks. Contaminants released to the soil would migrate to groundwater in proportion to their ionic mobility. Groundwater

modeling predicts that contaminants released from the vitrified tanks would not reach groundwater during the first 500 years. Point concentrations are therefore zero for all constituents for the first two periods of interest (i.e., 300 and 500 years from the present). During the latter three periods of interest (i.e., 2,500, 5,000, and 10,000 years from the present), modeling predicts that contaminants released would be present in groundwater. Predicated groundwater contaminant concentrations and distributions are discussed in Volume Four, Appendix F.

To evaluate surface water exposures for the recreational shoreline user scenario, surface water concentrations resulting from groundwater discharge to the Columbia River were conservatively calculated using a dilution factor approach as described for the No Action alternative in Section D.5.1.2.

### D.5.4.3 Exposure

Exposure for the In Situ Vitrification alternative was analyzed using the same URF methods and factors used for the No Action alternative (Section D.5.1.3). URFs are presented in Section D.2.1.3.

### D.5.4.4 Risk

The risk is calculated using the same approach used for the No Action alternative (Section D.5.1.4). Because all constituents in the vitrified tanks are calculated to have groundwater concentrations of zero within all cells for the 300- and 500-year periods, no risk calculations were performed for those periods.

Contour maps depicting the risk from radionuclides and carcinogenic chemicals in the vitrified tanks are presented in Figures D.5.4.1 and D.5.4.2 for the Native American scenario, Figures D.5.4.3 and D.5.4.4 for the residential farmer scenario, and Figures D.5.4.5 and D.5.4.6 for the industrial worker scenario. The maximum risk (ILCR) from radionuclides and carcinogenic chemicals did not exceed 1.00E-06 for the recreational shoreline user scenario; therefore, no risk contour maps are presented. The maximum HI from noncarcinogenic chemicals did not exceed 1.0 for any scenario or time period; therefore, no maps are presented for the HI.

## D.5.5 EX SITU INTERMEDIATE SEPARATIONS ALTERNATIVE

This section presents the anticipated post-remediation risk associated with the Ex Situ Intermediate Separations alternative. Implementing this alternative would involve retrieving tank waste, separating the HLW and LAW fractions, treating/immobilizing both fractions by converting them to glass, and disposing of the final glass waste forms. The vitrified LAW would be disposed of in onsite vaults. The vitrified HLW would be shipped to the proposed national HLW repository.

### D.5.5.1 Source

Post-remediation contamination sources under the Ex Situ Intermediate Separations alternative would consist of tank residuals and the LAW disposal vaults. Tank waste retrieval efficiency is assumed to be 99 percent (WHC 1995f and Jacobs 1996). The contaminant inventory in tank residuals was therefore assumed to be 1 percent of the current inventory discussed in Volume Two, Appendix A. The LAW

vaults would contain the contaminant inventory remaining in the LAW fractions following pretreatment and vitrification. Additional discussion of the inventory for the LAW vaults is presented in Volume Four, Appendix F.

### D.5.5.2 Transport

Post-remediation contaminant releases were assumed to be to the soil below the tanks and the LAW vaults. Contaminants released to the soil would migrate to groundwater in proportion to their ionic mobility.

Groundwater modeling predicts that contaminants released from tank residuals would not reach groundwater during the first 500 years. Point concentrations are therefore zero for all constituents at periods of 300 and 500 years. During the latter three periods of interest (i.e., 2,500, 5,000, and 10,000 years from the present), modeling predicts that contaminants released from tank residuals would be present in groundwater beneath the Hanford Site.

Groundwater modeling predicts that contaminants leached from the LAW vaults would not reach groundwater during the first 2,500 years. Point concentrations are therefore zero for all constituents at periods of 300, 500, and 2,500 years. During the latter two periods of interest (i.e., 5,000 and 10,000 years from the present), modeling predicts that contaminants released from the LAW vaults would be present in groundwater beneath the Hanford Site. Calculated groundwater contaminant concentrations and distributions are discussed in Volume Four, Appendix F.

To evaluate surface water exposures for the recreational shoreline user scenario, surface water concentrations resulting from groundwater discharge to the Columbia River were conservatively calculated using a dilution factor approach, as described for the No Action alternative in Section D.5.1.2.

### D.5.5.3 Exposure

Exposure for the Ex Situ Intermediate Separations alternative was analyzed using the same URF methods and factors used for the No Action alternative (Section D.5.1.3). URFs are presented in Section D.2.1.3.

### D.5.5.4 Risk

Risk for the Ex Situ Intermediate Separations alternative is calculated using the same approach used for the No Action alternative (Section D.5.1.4). Risk calculations were performed separately for the tank residuals, LAW vaults, and residuals and vaults combined.

Contaminants released from tank residuals are calculated to have groundwater concentrations of zero in all cells at periods of 300 and 500 years from the present. Risk calculations were therefore performed only for periods 2,500, 5,000, and 10,000 years from the present. Contour maps depicting the risk from radionuclides and carcinogenic chemicals in tank residuals are presented in Figures D.5.5.1 and D.5.5.2 for the Native American scenario, Figures D.5.5.3 and D.5.5.4 for the residential farmer

scenario, Figures D.5.5.5 and D.5.5.6 for the industrial scenario, and Figure D.5.5.7 for the recreational shoreline user scenario. Maps depicting the HI from noncarcinogenic chemicals in tank residuals are presented in Figures D.5.5.8 for the Native American scenario and Figure D.5.5.9 for the residential farmer scenario. No HI maps are presented for the industrial or recreational shoreline user scenarios because the maximum HI did not exceed 1.0 for either scenario.

Contaminants released from LAW vaults are calculated to have groundwater concentrations of zero in all cells at periods of 300, 500, and 2,500 years from the present. Risk calculations were therefore performed only for periods of 5,000 and 10,000 years from the present. Contour maps depicting the risk from radionuclides and carcinogenic chemicals in LAW vaults are presented in Figures D.5.5.10 and D.5.5.11 for the Native American scenario, Figures D.5.5.12 and D.5.5.13 for the residential farmer scenario, and in Figures D.5.5.14 and D.5.5.15 for the industrial scenario. No risk maps are presented for the recreational shoreline user scenario because the maximum risk (ILCR) from radionuclides and carcinogenic chemicals in LAW vaults did not exceed 1.00E-06. No HI maps are presented because the maximum HI from noncarcinogenic chemicals in the LAW vaults did not exceed 1.0 for any scenario.

Risk calculations for the combined tank residuals and LAW vaults were performed only for periods of 2,500, 5,000, and 10,000 years from the present (contaminants would not reach groundwater during the 300- and 500-year periods). Contour maps depicting the combined risk from radionuclides and carcinogenic chemicals in tank residuals and LAW vaults are presented in Figures D.5.5.16 to D.5.5.18 for the Native American scenario, Figures D.5.5.19 to D.5.5.21 for the residential farmer scenario, Figures D.5.5.22 to D.5.5.24 for the industrial scenario, and Figure D.5.5.25 for the recreational shoreline user scenario. Maps depicting the combined HI from noncarcinogenic chemicals in tank residuals and LAW vaults are presented in Figure D.5.5.26 for the Native American scenario and Figure D.5.5.27 for the residential farmer scenario. No HI maps are presented for the industrial scenario or recreational shoreline user scenario because the maximum combined HI did not exceed 1.0 for either scenario.

### D.5.6 EX SITU NO SEPARATIONS ALTERNATIVE

This section presents the anticipated post-remediation risk associated with the Ex Situ No Separations alternative. Under this alternative, tank waste would be retrieved and vitrified or calcined. The retrieved waste would not be separated into HLW and LAW waste streams. Waste from SSTs and DSTs would be blended as necessary and vitrified into a HLW glass or calcined and put into canisters. The HLW glass or the calcined waste would be shipped offsite to the proposed national HLW repository (WHC 1995c and Jacobs 1996).

#### D.5.6.1 Source

Post-remediation contamination sources under the Ex Situ No Separations alternative would consist of tank residuals. Since tank waste retrieval would be conducted in the same manner as for the Ex Situ Intermediate Separations alternative (i.e., 99 percent retrieval efficiency), the contaminant inventory in the tank residuals would be the same.

### D.5.6.2 Transport

Because the contaminant inventory in tank residuals was the same as for the Ex Situ Intermediate Separations alternative, a separate groundwater transport modeling analysis was not required. Modeling results for the Ex Situ No Separations alternative would be the same as the results for the tank residuals for the Ex Situ Intermediate Separations alternative (Section D.5.5.2).

### D.5.6.3 Exposure

Because the contaminant inventory in the tank residuals would be the same as for the Ex Situ Intermediate Separations alternative, exposures would be the same.

### D.5.6.4 Risk

Risk and HI contours for the tank residuals in the Ex Situ No Separations alternative would be the same as for the tank residuals in the Ex Situ Intermediate Separations alternative (Section D.5.5.4, Figures D.5.5.1 to D.5.5.9).

## D.5.7 EX SITU EXTENSIVE SEPARATIONS ALTERNATIVE

This section presents the anticipated post-remediation risk associated with the Ex Situ Extensive Separations alternative. This alternative would involve implementing the same basic operations described for the Ex Situ Intermediate Separations alternative but would involve conducting a more complex waste separation operation. Fifteen processing systems (12 more than for the Ex Situ Intermediate Separations alternative) would be used to reduce the volume of HLW and to reduce the amount of radioactive contaminants in the LAW (WHC 1995e and Jacobs 1996).

### D.5.7.1 Source

Post-remediation contamination sources under the Ex Situ Separations alternative would consist of tank residuals and LAW vaults. Because tank waste retrieval would be conducted in the same manner as for the Ex Situ Intermediate Separations alternative (i.e., 99 percent retrieval efficiency), the contaminant inventory in the tank residuals would be the same. As in the Ex Situ Intermediate Separations alternative, the LAW vaults would contain the contaminant inventory remaining in the LAW following separation and treatment. Additional discussion of the inventory for the LAW vaults is presented in Volume Four, Appendix F.

### D.5.7.2 Transport

Because the contaminant inventory in tank residuals would be the same as for the Ex Situ Intermediate Separations alternative, a separate groundwater transport modeling analysis was not required. Modeling results for tank residuals for the Ex Situ Intermediate Separations alternative (Section D.5.5.2) apply to the Ex Situ Extensive Separations alternative as well.

Groundwater modeling predicts that contaminants leached from the LAW vaults would not reach groundwater during the first 2,500 years. Point concentrations are therefore zero for all constituents at periods of 300, 500, and 2,500 years. During the latter two periods of interest (i.e., 5,000 and 10,000 years from the present), modeling predicts that contaminants released from the LAW vaults would be

present in groundwater beneath the Hanford Site. Calculated groundwater contaminant concentrations and distributions are discussed in Volume Four, Appendix F.

To evaluate surface water exposures for the recreational shoreline user scenario, surface water concentrations resulting from groundwater discharge to the Columbia River were conservatively calculated using a dilution factor approach as described for the No Action alternative in Section D.5.1.2.

### D.5.7.3 Exposure

Because the contaminant inventory in tank residuals would be the same as for the Ex Situ Intermediate Separations Alternative, exposure would be the same. Exposures for the LAW vaults were analyzed using the same URF methods and factors used for the No Action alternative (Section D.5.1.3). URFs are presented in Section D.2.1.3.

### D.5.7.4 Risk

As in the Ex Situ Intermediate Separations alternative, risk calculations were performed separately for tank residuals, LAW vaults, and residuals and vaults combined.

Risk for the tank residuals in the Ex Situ Extensive Separations alternative would be the same as for the tank residuals in the Ex Situ Intermediate Separations alternative (Section D.5.5.4, Figure D.5.5.1 to D.5.5.9).

Because constituents released from LAW vaults would not reach groundwater for 2,500 years, risk calculations were performed only for periods of 5,000 and 10,000 years. Contour maps depicting the risk from radionuclides and carcinogenic chemicals in LAW vaults are presented in Figures D.5.7.1 and D.5.7.2 for the Native American scenario, Figures D.5.7.3 and D.5.7.4 for the residential farmer scenario, and Figure D.5.7.5 for the industrial scenario. No risk maps are presented for the recreational shoreline user scenario because the maximum risk (ILCR) from radionuclides and carcinogenic chemicals in LAW vaults did not exceed 1.00E-06. No HI maps are presented because the maximum HI from noncarcinogenic chemicals in LAW vaults did not exceed 1.0 for any scenario.

Although the risk for tank residuals would be the same as for the Ex Situ Intermediate Separations alternative, the risk for LAW vaults would be different; therefore, the combined risk from residuals and vaults would be different. Risk calculations for the combined tank residuals and LAW vaults were performed only for periods of 2,500, 5,000, and 10,000 years from the present (contaminants would not reach groundwater during the 300- and 500-year periods). Contour maps depicting the combined risk from radionuclides and carcinogenic chemicals in tank residuals and LAW vaults are presented in Figures D.5.7.6 and D.5.7.7 for the Native American scenario, Figures D.5.7.8 and D.5.7.9 for the residential farmer scenario, Figures D.5.7.10 and D.5.7.11 for the industrial scenario, and Figure D.5.7.12 for the recreational shoreline user scenario. Maps depicting the combined HI from noncarcinogenic chemicals in tank residuals and LAW vaults are presented in Figure D.5.7.13 for the Native American scenario and Figure D.5.7.14 for the residential farmer scenario. No HI maps are

presented for the industrial or recreational shoreline user scenarios because the maximum combined HI did not exceed 1.0 for either scenario.

### D.5.8 EX SITU/IN SITU COMBINATION 1 ALTERNATIVE

This section presents the anticipated post-remediation risk associated with the Ex Situ/In Situ Combination 1 alternative for tank waste. This alternative would involve a combination of the Ex Situ Intermediate Separations alternative (Section D.5.5) and the In Situ Fill and Cap alternative (Section D.5.3). Tanks with the highest content of mobile constituents of concern (i.e., uranium isotopes, Tc-99, I-129, and C-14) would be remediated in accordance with the Ex Situ Intermediate Separations alternative. Tanks with a low content of these constituents would be remediated in accordance with the In Situ Fill and Cap alternative.

This EIS examines a tank selection process based on recovering 90 percent of the constituents that contribute to post-remediation risk. Implementing this process would remove approximately 50 percent of the tank waste by volume and result in ex situ remediation of approximately 70 of the 177 tanks; the remaining tanks (approximately 107) would be remediated as described under the In Situ Fill and Cap alternative. Further details of the tank selection process are provided in Volume Two, Appendix B.

#### D.5.8.1 Source

For the ex situ portion of this alternative, post-remediation contamination sources would be the same type but of lesser quantity than those described in Section D.5.5.1 for the Ex Situ Intermediate Separations alternative (i.e., tank residuals and LAW disposal vaults). For the in situ portion, post-remediation sources would be the same type but of lesser quantity than those described in Section D.5.3.1 for the In Situ Fill and Cap alternative (i.e., tank residuals). Additional discussion of contaminant source inventories is provided in Volume Four; Appendix F.

#### D.5.8.2 Transport

Post-remediation contaminant releases would be to the soil below the tanks and LAW vaults. Contaminants released to the soil would migrate to groundwater in proportion to their ionic mobility.

Groundwater modeling predicts that contaminants released from the tank residuals (both ex situ and in situ) would not reach groundwater during the first 500 years. Point concentrations are therefore zero for all constituents at periods of 300 and 500 years. During the latter three periods of interest (i.e., 2,500, 5,000, and 10,000 years from the present) modeling predicts that contaminants released from tank residuals would be present in groundwater beneath the Hanford Site.

Groundwater modeling predicts that contaminants leached from the LAW vaults would not reach groundwater during the first 2,500 years. Point concentrations are therefore zero for all constituents at periods of 300, 500, and 2,500 years. During the latter two periods of interest (i.e., 5,000 and 10,000 years from the present), modeling predicts that contaminants released from the LAW vaults would be present in groundwater beneath the Hanford Site. Calculated groundwater contaminant concentrations and distributions are discussed in Volume Four, Appendix F.

To evaluate surface water exposures for the recreational shoreline user scenario, surface water concentrations resulting from groundwater discharge to the Columbia River were conservatively calculated using a dilution factor approach as described for the No Action alternative in Section D.5.1.2.

### D.5.8.3 Exposure

Exposures for the Ex Situ/In Situ Combination 1 alternative were analyzed using the same URF methods and factors as used for the No Action alternative (Section D.5.1.3). URFs are presented in Section D.2.1.3.

### D.5.8.4 Risk

Risk for the Ex Situ/In Situ Combination 1 alternative is calculated using the same approach used for the No Action alternative (Section D.5.1.4). Risk calculations were performed separately for the tank residuals (both ex situ and in situ), LAW vaults, and residuals and vaults combined.

Contaminants released from the ex situ tank residuals are calculated to have groundwater concentrations of zero in all cells at periods of 300 and 500 years from the present. Risk calculations were therefore performed only for periods of 2,500, 5,000, and 10,000 years from the present. Contour maps depicting risk from radionuclides and carcinogenic chemicals in ex situ residuals are presented in Figures D.5.8.1 and D.5.8.2 for the Native American scenario, Figures D.5.8.3 and D.5.8.4 for the residential farmer scenario, and Figures D.5.8.5 and D.5.8.6 for the industrial scenario. No risk maps are presented for the recreational shoreline user scenario because the maximum risk (ILCR) did not exceed 1.00E-06. A map depicting the HI from noncarcinogenic chemicals in ex situ tank residuals is presented in Figure D.5.8.7 for the Native American scenario. No HI maps are presented for the residential farmer, industrial, or recreational shoreline user scenarios because the maximum HI did not exceed 1.0 for these scenarios.

Contaminants released from the in situ tank residuals are calculated to have groundwater concentrations of zero in all cells at periods of 300 and 500 years from the present. Risk calculations were therefore performed only for periods of 2,500, 5,000, and 10,000 years from the present. Contour maps depicting the risk from radionuclides and carcinogenic chemicals in the in situ tank residuals are presented in Figures D.5.8.8 and D.5.8.9 for the Native American scenario, Figures D.5.8.10 and D.5.8.11 for the residential farmer scenario, Figures D.5.8.12 and D.5.8.13 for the industrial scenario, and Figures D.5.8.14 and D.5.8.15 for the recreational shoreline user scenario. Maps depicting the HI from noncarcinogenic chemicals in the in situ tank residuals are presented in Figures D.5.8.16 and D.5.8.17 for the Native American scenario and Figures D.5.8.18 and D.5.8.19 for the residential farmer scenario. No HI maps are presented for the industrial or recreational shoreline user scenarios because the maximum HI did not exceed 1.0 for either scenario.

Contaminants released from LAW vaults are calculated to have groundwater concentrations of zero in all cells at periods of 300, 500, and 2,500 years from the present. Risk calculations were therefore performed only for periods of 5,000 and 10,000 years from the present. Contour maps depicting the

risk from radionuclides and carcinogenic chemicals in LAW vaults are presented in Figures D.5.8.20 and D.5.8.21 for the Native American scenario, Figures D.5.8.22 and D.5.8.23 for the residential farmer scenario, and Figures D.5.8.24 and D.5.8.25 for the industrial scenario. No risk maps are presented for the recreational shoreline user scenario because the maximum risk (ILCR) did not exceed 1.00E-06. No HI maps are presented because the maximum HI from noncarcinogenic chemicals in the LAW vaults did not exceed 1.0 for any scenario.

Risk calculations for the tank residuals (ex situ and in situ) in combination with the LAW vaults were performed only for periods of 2,500, 5,000, and 10,000 years from the present (contaminants would not reach groundwater during the 300- and 500-year periods). Contour maps depicting the combined risk from radionuclides and carcinogenic chemicals in tank residuals (ex situ and in situ) and LAW vaults are presented in Figures D.5.8.26 to D.5.8.28 for the Native American scenario, Figures D.5.8.29 to D.5.8.31 for the residential farmer scenario, Figures D.5.8.32 to D.5.8.34 for the industrial scenario, and Figures D.5.8.35 and D.5.8.36 for the recreational shoreline user scenario. Maps depicting the combined HI from noncarcinogenic chemicals in tank residuals (ex situ and in situ) and LAW vaults are presented in Figures D.5.8.37 and D.5.8.38 for the Native American scenario and Figures D.5.8.39 and D.5.8.40 for the residential farmer scenario. No HI maps are presented for the industrial or recreational shoreline user scenarios because the maximum combined HI did not exceed 1.0 for either scenario.

## D.5.9 EX SITU/IN SITU COMBINATION 2 ALTERNATIVE

This section presents the anticipated post-remediation risk associated with the Ex Situ/In Situ Combination 2 alternative for tank waste. This variation of the Ex Situ/In Situ Combination 1 alternative would use modified tank selection criteria to provide for ex situ treatment of the largest contributors to long-term risk (i.e., uranium isotopes, Tc-99, I-129, and C-14) while limiting the volume of waste to be processed. Under this variation, approximately 25 tanks instead of 70 tanks would be remediated as described for the Ex Situ Intermediate Separations alternative, while the remaining tanks would be remediated as described for the In Situ Fill and Cap alternative. Further details of the tank selection process are provided in Volume Two, Appendix B.

### D.5.9.1 Source

Post-remediation contamination sources for the ex situ portion of this alternative would be of the same type as those described for the Ex Situ/In Situ Combination 1 alternative (i.e., tank residuals and LAW vaults). However, under this alternative these sources would contain less contamination because less waste would be retrieved. Post-remediation sources for the in situ portion of this alternative would also be of the same type as those described for the Ex Situ/In Situ Combination 1 alternative (i.e., tank residuals). However, under this alternative these sources would contain more contamination because more waste would be left in place.

### D.5.9.2 Transport

Post-remediation contamination releases would be to the soil below the tanks and LAW vaults. Contaminants released to the soil would migrate to groundwater in proportion to their ionic mobility.

Groundwater modeling calculates that contaminants released from the tank residuals (both ex situ and in situ) would not reach groundwater during the first 500 years. Point concentrations are therefore zero for all constituents at periods of 300 and 500 years. During the latter three periods of interest (i.e., 2,500, 5,000, and 10,000 years from the present), modeling calculates that contaminants released from tank residuals would be present in groundwater beneath the Hanford Site.

Groundwater modeling calculates that contaminants leached from the LAW vaults would not reach groundwater during the first 2,500 years. Point concentrations are therefore zero for all constituents at periods of 300, 500, and 2,500 years. During the latter two periods of interest (i.e., 5,000 and 10,000 years from the present), modeling calculates that contaminants released from the LAW vaults would be present in groundwater beneath the Hanford Site. Calculated groundwater contaminant concentrations and distributions are discussed in Volume Four, Appendix F.

To evaluate surface water exposures for the recreational shoreline user scenario, surface water concentrations resulting from groundwater discharge to the Columbia River were conservatively calculated using a dilution factor approach as described for the No Action alternative in Section D.5.1.2.

### D.5.9.3 Exposure

Exposures for the Ex Situ/In Situ Combination 2 alternative were analyzed using the same URF methods and factors as used for the No Action alternative (Section D.5.1.3). URFs are presented in Section D.2.1.3.

### D.5.9.4 Risk

Risk for the Ex Situ/In Situ Combination 2 alternative is calculated using the same approach used for the No Action alternative (Section D.5.1.4). Risk calculations were performed separately for the tank residuals (both ex situ and in situ), LAW vaults, and residuals and vaults combined.

Contaminants released from the ex situ tank residuals are calculated to have groundwater concentrations of zero in all cells at periods of 300 and 500 years from the present. Risk calculations were therefore performed only for periods of 2,500, 5,000, and 10,000 years from the present. Contour maps depicting risk from radionuclides and carcinogenic chemicals in ex situ residuals are presented in Figures D.5.9.1 and D.5.9.2 for the Native American scenario, Figures D.5.9.3 and D.5.9.4 for the residential farmer scenario, and Figure D.5.9.5 for the industrial scenario. No risk maps are presented for the recreational shoreline user scenario because the maximum risk (ILCR) did not exceed 1.00E-06. No HI maps are presented because the maximum HI did not exceed 1.0 for any scenario.

Contaminants released from the in situ tank residuals are calculated to have groundwater concentrations of zero in all cells at periods of 300 and 500 years from the present. Risk calculations were therefore performed only for periods of 2,500, 5,000, and 10,000 years from the present. Contour maps depicting risk from radionuclides and carcinogenic chemicals in the in situ residuals are presented in

Figures D.5.9.6 and D.5.9.7 for the Native American scenario, Figures D.5.9.8 and D.5.9.9 for the residential farmer scenario, Figures D.5.9.10 and D.5.9.11 for the industrial scenario, and Figures D.5.9.12 and D.5.9.13 for the recreational shoreline user scenario. Maps depicting the HI from noncarcinogenic chemicals in the in situ tank residuals are presented in Figures D.5.9.14 and D.5.9.15 for the Native American scenario and Figures D.5.9.16 and D.5.9.17 for the residential farmer scenario. No HI maps are presented for the industrial or recreational shoreline user scenarios because the maximum HI did not exceed 1.0 for either scenario.

Contaminants released from the LAW vaults are calculated to have groundwater concentrations of zero in all cells at periods of 300, 500, and 2,500 years from the present. Risk calculations were therefore performed only for periods of 5,000 and 10,000 years from the present. Contour maps depicting risk from radionuclides and carcinogenic chemicals in LAW vaults are presented in Figures D.5.9.18 and D.5.9.19 for the Native American scenario, Figures D.5.9.20 and D.5.9.21 for the residential farmer scenario, and Figures D.5.9.22 and D.5.9.23 for the industrial scenario. No risk maps are presented for the recreational shoreline user scenarios because the maximum risk (ILCR) did not exceed 1.00E-06. No HI maps are presented because the maximum HI from noncarcinogenic chemicals in the LAW vaults did not exceed 1.0 for any scenario.

Risk calculations for the tank residuals (ex situ and in situ) in combination with the LAW vaults were performed only for periods of 2,500, 5,000, and 10,000 years from the present (contaminants would not reach groundwater during the 300- and 500-year periods). Contour maps depicting the combined risk from radionuclides and carcinogenic chemicals in tank residuals (ex situ and in situ) and LAW vaults are presented in Figures D.5.9.24 to D.5.9.26 for the Native American scenario, Figures D.5.9.27 to D.5.9.29 for the residential farmer scenario, Figures D.5.9.30 and D.5.9.31 for the industrial scenario, and Figures D.5.9.32 and D.5.9.33 for the recreational shoreline user scenario. Maps depicting the combined HI from noncarcinogenic chemicals in tank residuals (ex situ and in situ) and LAW vaults are presented in Figures D.5.9.34 and D.5.9.35 for the Native American scenario and Figures D.5.9.36 and D.5.9.37 for the residential farmer scenario. No HI maps are presented for the industrial or recreational shoreline user scenarios because the maximum HI did not exceed 1.0 for either scenario.

### D.5.10 PHASED IMPLEMENTATION ALTERNATIVE

This section presents the anticipated post-remediation risk associated with the Total alternative. Implementing this alternative would involve retrieving tank waste, separating the HLW and LAW fractions, treating/immobilizing both fractions by converting them to glass, and disposing of the final glass waste forms. The vitrified LAW would be disposed of in onsite vaults. The vitrified HLW would be shipped to the proposed national HLW repository.

#### D.5.10.1 Source

Post-remediation contamination sources under the Total alternative would consist of tank residuals and the LAW disposal vaults. Tank waste retrieval efficiency is assumed to be 99 percent (WHC 1995f and Jacobs 1996). The contaminant inventory in tank residuals was therefore assumed to be 1 percent of

the current inventory discussed in Volume Two, Appendix A. The LAW vaults would contain the contaminant inventory remaining in the LAW fractions following pretreatment and vitrification. Additional discussion of the inventory for the LAW vaults is presented in Appendix F.

### D.5.10.2 Transport

Post-remediation contaminant releases were assumed to be to the soil below the tanks and the LAW vaults. Contaminants released to the soil would migrate to groundwater in proportion to their ionic mobility.

Groundwater modeling predicts that contaminants released from tank residuals would not reach groundwater during the first 500 years. Point concentrations are therefore zero for all constituents at periods of 300 and 500 years. During the latter three periods of interest (i.e., 2,500, 5,000, and 10,000 years from the present), modeling predicts that contaminants released from tank residuals would be present in groundwater beneath the Hanford Site.

Groundwater modeling predicts that contaminants leached from the LAW vaults would not reach groundwater during the first 2,500 years. Point concentrations are therefore zero for all constituents at periods of 300, 500, and 2,500 years. During the latter two periods of interest (i.e., 5,000 and 10,000 years from the present), modeling predicts that contaminants released from the LAW vaults would be present in groundwater beneath the Hanford Site.

### D.5.10.3 Exposure

Exposure for the Total alternative was analyzed using the same URF methods and factors used for the No Action alternative (Section D.5.1.3). URFs are presented in Section D.2.1.3.

### D.5.10.4 Risk

Risk for the Total alternative is calculated using the same approach used for the No Action alternative (Section D.5.1.4). Risk calculations were performed separately for the tank residuals, LAW vaults, and residuals and vaults combined.

Contaminants released from tank residuals are calculated to have groundwater concentrations of zero in all cells at periods of 300 and 500 years from the present. Risk calculations were therefore performed only for periods 2,500, 5,000, and 10,000 years from the present. Contour maps depicting the risk from radionuclides and carcinogenic chemicals in tank residuals are presented in Figures D.5.10.1 and D.5.10.2 for the Native American scenario, Figures D.5.10.3 and D.5.10.4 for the residential farmer scenario, Figures D.5.10.5 and D.5.10.6 for the industrial scenario, and Figure D.5.10.7 for the recreational shoreline user scenario. Maps depicting the HI from noncarcinogenic chemicals in tank residuals are presented in Figure D.5.10.8 for the Native American scenario and Figure D.5.10.9 for the residential farmer scenario. No HI maps are presented for the industrial or recreational shoreline user scenario because the maximum HI did not exceed 1.0 for either scenario.

Contaminants released from LAW vaults are calculated to have groundwater concentrations of zero in all cells at periods of 300, 500, and 2,500 years from the present. Risk calculations were therefore performed only for periods of 5,000 and 10,000 years from the present. Contour maps depicting the risk from radionuclides and carcinogenic chemicals in LAW vaults are presented in Figures D.5.10.10 and D.5.10.11 for the Native American scenario, Figures D.5.10.12 and D.5.10.13 for the residential farmer scenario, and Figures D.5.10.14 and D.5.10.15 for the industrial scenario. No risk maps are presented for the recreational shoreline user scenario because the maximum risk (ILCR) from radionuclides and carcinogenic chemicals in LAW vaults did not exceed 1.00E-06. No HI maps are presented because the maximum HI from noncarcinogenic chemicals in the LAW vaults did not exceed 1.0 for any scenario.

Risk calculations for the combined tank residuals and LAW vaults were performed only for periods of 2,500, 5,000, and 10,000 years from the present (contaminants would not reach groundwater during the 300- and 500-years periods). Contour maps depicting the combined risk from radionuclides and carcinogenic chemicals in tanks residuals and LAW vaults are presented in Figures D.5.10.16 to D.5.10.18 for the Native American scenario, Figures D.5.10.19 to D.5.10.21 for the residential farmer scenario, Figures D.5.10.22 to D.5.10.24 for the industrial scenario, and Figure D.5.10.25 for the recreational shoreline user scenario. Maps depicting the combined HI from noncarcinogenic chemicals in tank residuals and LAW vaults are presented in Figure D.5.10.26 for the Native American scenario and Figure D.5.10.27 for the residential farmer scenario. No HI maps are presented for the industrial scenario or recreational shoreline user because the maximum combined HI did not exceed 1.0 for either scenario.

### D.5.11 NO ACTION ALTERNATIVE (CAPSULES)

Post-remediation is not included in this alternative. This alternative does not remediate the waste. After 10 years, a remediation decision would be made (Jacobs 1996).

### D.5.12 CAPSULES ONSITE DISPOSAL ALTERNATIVE

This section presents the anticipated post-remediation risk associated with the Onsite Disposal alternative for the capsules. Implementing this alternative would involve retrieving capsules from WESF, placing capsules in Overpack canisters, and transferring the canisters to an onsite drywell disposal facility where they would be stored indefinitely (WHC 1995h and Jacobs 1996).

#### D.5.12.1 Source

The inventory of cesium and strontium in drywell disposal would be the same as the cesium and strontium inventory given in Section D.2.1.1.2.

### D.5.12.2 Transport

The radioisotopes Cs-137 and Sr-90 (half lives of 30.2 and 28.6 years, respectively) will eventually decay to their stable progeny (Ba-137 and Zr-90, respectively). Groundwater transport modeling for tank waste indicates that neither Cs-137, Sr-90, nor their progeny would reach groundwater before 1,200 years (Volume Four, Appendix F), and the Cs-137 and Sr-90 would have nearly completely decayed to their stable progeny products within this time period. Therefore, only minute quantities of Cs-137 and Sr-90 would reach the groundwater.

The Cs-137 and Sr-90 daughter products (elements Ba-137 and Zr-90) are not carcinogenic, but are known to cause toxic effects at intakes greater than their respective reference doses. A rigorous groundwater transport analysis would only be needed if the estimated concentration of these stable daughters in groundwater resulted in intakes that exceed the reference doses within the 10,000-year period of interest. The following calculations show that intakes based on estimated future aquifer concentrations would be at least one order of magnitude below the reference doses. In this calculation, it was conservatively assumed that the mass of the stable daughters in the aquifer would be equal to the current mass of the parent radionuclides.

Cs-137 Case

**Data**

| | | |
|---|---|---|
| Current Cs-137 inventory | = | 5.30E+07 Ci |
| Cs-137 specific activity | = | 8.70E+01 Ci/g |
| Standard human weight | = | 70 kg |
| Standard human consumption | = | 2 L/day |
| | = | 2,000 $cm^3$/day |
| Aquifer volume | = | 1,000 m · 1,000 m · 10 m |
| | | 1.00E+07 $m^3$ |
| | | 1.00E+13 $cm^3$ (assumed) |

**Calculation**

| | | |
|---|---|---|
| Total mass of Ba-137 | = | 5.30E+07 Ci ÷ 8.7E+01 Ci/g |
| | = | 6.10E+05 g |
| Ba-137 concentration in aquifer | = | 6.10E+05 g ÷ 1.0E+13 $cm^3$ |
| | = | 6.10E-08 g/$cm^3$ |
| Intake for standard human | = | 2.00E+03 $cm^3$/day · 6.1E-08 g/$cm^3$ ÷ 70 kg |
| | = | 1.80E-06 g/kg/day |
| | = | 1.80E-03 mg/kg/day |

**Conclusion**

The reference dose for Ba-137 ingestion from HEAST (EPA 1993) is 3.50E-02 mg/kg/day. Comparing the calculated intake to the reference dose indicates that there would be no expected toxic effects from Ba-137 (i.e., 1.80E-03 mg/kg/day is less than 3.50E-02 mg/kg/day).

Sr-90 Case

Data

| | | |
|---|---|---|
| Current Sr-90 inventory | = | 2.30E+07 Ci |
| Sr-90 specific activity | = | 1.40E+02 Ci/g |
| Standard human weight | = | 70 kg |
| Standard human consumption | = | 2 L/day |
| | = | 2,000 $cm^3$/day |
| Aquifer volume | = | 1,000 m · 1,000 m · 10 m |
| | | 1.00E+07 $m^3$ |
| | | 1.00E+13 $cm^3$ (assumed) |

Calculation

| | | |
|---|---|---|
| Total mass of Zr-90 | = | 2.30E+07 Ci ÷ 1.4E+02 Ci/g |
| | = | 1.70E+05 grams |
| Zr-90 concentration in aquifer | = | 1.70E+05 grams ÷ 1.0E+13 $cm^3$ |
| | = | 1.70E-08 $g/cm^3$ |
| Intake for standard human | = | 2.00E+03 $cm^3$/day · 1.7E-08 $g/cm^3$ ÷ 70 kg |
| | = | 4.80E-07 g/kg/day |
| | = | 4.80E-04 mg/kg/day |

Conclusion

The reference dose for Zr-90 ingestion from HEAST (EPA 1993) is 7.00E-02 mg/kg/day. Comparing the calculated intake to the reference dose indicates that there would be no expected toxic effects from Zr-90 (i.e., 4.80E-04 mg/kg/day is less than 7.00E-02 mg/kg/day).

Because there would be no exposure under this alternative, there would be no anticipated risk associated with the Cs and Sr capsules under the Onsite Disposal alternative.

### D.5.13 OVERPACK AND SHIP ALTERNATIVE

Implementing this alternative would involve retrieving capsules from WESF, placing capsules in overpack canisters, and transporting the canisters offsite for disposal in a geologic repository (WHC 1995b and Jacobs 1996). Because all the capsules would be removed from the Hanford Site, there would be no post-remediation risk.

### D.5.14 CAPSULES VITRIFY WITH TANK WASTE ALTERNATIVE

Implementing this alternative would involve 1) retrieving capsules from WESF; 2) decladding the capsules and removing their contents; 3) combining the cesium and strontium with HLW from the SSTs and DSTs; 4) vitrifying the HLW into a glass; 5) placing the HLW glass into onsite interim storage; and 6) transporting the HLW glass offsite for disposal in a geologic repository (WHC 1995h and Jacobs 1996). Because all the capsule contents would be removed from the Hanford Site as part of the HLW glass, there would be no post-remediation risk.

## D.5.15 TOTAL HEALTH IMPACTS

### D.5.15.1 Total Health Impacts for Hanford Site Users

This section discusses the calculation of the total or integrated post-remediation risk over the 10,000-year period of interest. This risk has been calculated for each alternative and for four types of receptors: the Native American, the residential farmer, the industrial worker, and the recreational shoreline user. The exposure scenarios are described in Section D.2.1.3 and assume a hypothetical post-remediation use scenario under which onsite controls are not maintained.

The total risk is expressed as the total cancer incidence and cancer fatalities over the 10,000-year period for each receptor group. It is calculated by multiplying the ILCR for each receptor group (as presented in Figures D.5.1.1 through D.5.10.27) by the population for that group. Note that the risk contours shown in Figures D.5.1.1 through D.5.10.27 give the ILCR for an individual. For example, an isopleth with a value of 1.0E-03 indicates that an individual located along that contour line has a 0.001 chance of developing cancer, or that one person out of 1,000 will develop cancer. By making assumptions regarding populations, individual risks are used to calculate total risks, which indicate the number of individuals in each receptor group that may contract cancer or die from cancer over the 10,000-year period of interest.

The method used to calculate total risk uses the areas described by the individual risk contours shown in Figures D.5.1.1 through D.5.10.27. These areas were calculated using computer contouring software for periods of 300, 500, 2,500, 5,000, and 10,000 years from the present for each receptor and alternative. The number of individuals exposed in each contour area during each time interval was calculated using assumed values for population density or total population and the duration of active land use for each receptor group. The corresponding cancer incidence and cancer fatalities were obtained by multiplying the number of exposed individuals by the risk value (ILCR) for the given contour area. The total risk for each receptor is the sum of all the cancer incidences and fatalities for each contour area during each time interval.

Assumptions were made for such factors as the duration of exposure, the population affected, and the lifespan or duration of active use for a generation.

For the Native American scenario, the following assumptions were used.

- The duration of each generation is 70 years of continuous occupancy.
- The population density is 1.91 persons/km$^2$. This value is based on an assumed population of 1,500 individuals occupying 785 km$^2$ (303 mi$^2$) of the total area of the Hanford Site. This value is similar to the population density of the Umatilla Indian Reservation, which is 2.08 persons/km$^2$ based on information presented in the Comprehensive Plan of the Confederated Tribes of the Umatilla Indian Reservation (CTUIR 1995).

Consequently, the number of Native Americans at any given time is 1,500 (1.91 · 785). During a 10,000-year time span, there would be 143 generations (10,000 ÷ 70), or a total of 2.1E+05 (143 · 1,500) receptors for the Native American scenario.

For the residential farmer scenario, the following assumptions were used.

- The duration of each generation is 70 years of continuous farming.
- The population density is 4.97 persons/km$^2$ (WSDFM 1994). This population density is similar to the present (1990's) farming area surrounding the Site.
- Farming will occupy 785 km$^2$ (303 mi$^2$) of the total area of the Hanford Site.

Consequently, the number of farming individuals at any given time is 3,900 (4.97 · 785). During a 10,000-year time span, there would be 143 generations (10,000 ÷ 70), or a total of 5.6E+05 (143 · 3,900) receptors for the residential farmer scenario.

For the industrial worker scenario, the following assumptions were used.

- A workforce of 2,200 would occupy the Site. Previous estimates have indicated a large industrial complex at the Site would have a workforce of 1,700 (TRIDEC 1993).
- The duration of each worker's employment would be 30 continuous years; 30 years is assumed to be one generation or occupation period for the industrial worker.
- The calculated worker population would remain constant as a function of time.
- The worker population would not be uniformly distributed throughout the Site as for the Native American and residential farmer scenarios. Instead, the workers would occupy an industrial complex assumed to be located in the risk contour area with the highest probability of occurrence. Probability of occurrence for this assessment was calculated by dividing the areas for the individual contours by the total area of 785 km$^2$ (303 mi$^2$).

During a 10,000-year period, the net result would be 333 generations (10,000 ÷ 30) of industrial workers or a total population of 7.3E+05 receptors (333 · 2,200).

For the recreational shoreline user scenario, the following assumptions were used.

- The duration of active use of the area for recreation is 30 years per person (DOE 1995c), usage is for 14 days per year, and 30 years is assumed to be one recreational generation.
- During the period of interest there would be 40,000 one-day visits to the shoreline (NPS 1994). This would be equivalent to 2,857 visits of 14 days per visit. For use in calculations, it is assumed that 1,950 visits of 14 days each that result in exposure would occur in shoreline areas.

Consequently, during a 10,000-year period there would be 333 generations (10,000 ÷ 30), or a total of 6.5E+05 receptors (333 · 1,950) for the recreational shoreline scenario.

The results of calculating total or integrated risk for the Native American, residential farmer, industrial worker, and recreational shoreline user for all alternatives are shown in Table D.5.15.1. This table shows the total calculated cancer incidence and cancer fatalities for each group of receptors and for each alternative over the entire 10,000 years.

**Example Calculation for Total Risk**

Given a set of risk contours at 500 years, the total risk to the residential farmer based on 2 risk contours with areas of 47 $km^2$ (18 $mi^2$) and 64 $km^2$ (24 $mi^2$) and ILCR values of 0.05 and 0.001, respectively, is calculated as follows.

The risk contours at 500 years must be used to represent the next 2,000 years of exposure because the next risk contour available is for 2,500 years from the present time. During this 2,000-year period there will be 28.57 generations of residential farmers (2,000 ÷ 70) occupying the land with a population density of 4.97 persons per $km^2$. The cancer incidence, R(1), over this period for the 47 $km^2$ area with an ILCR of 0.05 is:

$R(1) = 47 \cdot 4.97 \cdot 28.57 \cdot 0.05 = 333.7$ cancer incidences

The cancer fatalities corresponding to this cancer incidence are 333.7 ÷ 1.2 = 278 fatalities. This conversion is based on the ratio of the dose to risk conversion factors for cancer incidence and cancer fatalities (6.0E-04 ÷ 5.0E-04 = 1.2) given in the ICRP (ICRP 1991).

Using the same method, the cancer incidence, R(2), over this period for the 64 $km^2$ (24 $mi^2$) area with an ILCR of 0.001 is:

$R(2) = 64 \cdot 4.97 \cdot 28.57 \cdot 0.001 = 9.0$ cancer incidences.
The corresponding cancer fatalities are 9.0 ÷ 1.2 = 7.6 fatalities.

The total risk is the sum of R(1) and R(2), that is:

$R(total) = R(1) + R(2) = 333.7 + 9.0 = 342.7 = 343$ cancer incidences.
The corresponding cancer fatalities are 343 ÷ 1.2 = 285.6 = 286 fatalities.

The above total risk is calculated by assuming that the two isopleths with risk levels of 0.05 and 0.001 have the same risk magnitude for the entire 2,000 year duration of the calculation. In reality, as time increases, the risk level decreases because of radioactive decay and the transport and dilution of contaminants in the aquifer. To make the adjustment for this, it is assumed that one-half of the risk level at the start of the period would be the risk for the entire duration. Therefore, the total cancer incidence would be one-half of 343, or 172, and the total cancer fatalities would be one-half of 286, or 143.

A high degree of uncertainty is associated with calculating cancer incidence and cancer fatalities over 10,000 years. Changes in population density, climate, use restrictions, and many other factors can affect these calculations. Therefore, the total cancer incidence and cancer fatalities should be considered rough approximations only and have been rounded to one significant digit in the text and Summary of this EIS.

### D.5.15.2 Total Health Impacts Along the Columbia River

Different contaminants will enter the groundwater and reach the Columbia River at varying times in the future. The contaminant's time of first arrival at the Columbia River, the time that peak concentration is reached, and the time of final arrival of a contaminant are dependent not only on the transport properties of the contaminant, but also on the alternative under consideration. Transport of contaminants through the groundwater is described in detail in Volume Four, Appendix F. A summary of first arrival times, times of peak concentration, and times of final arrival is shown in Table D.5.15.2 for C-14, I-129, Tc-99, U-238, and Np-237. This table also shows the total inventory in curies for each radionuclide, taking into account radioactive decay from the present until the time of peak concentration.

Total cancer fatalities are calculated using factors that relate the number of fatal cancers to the curies of each contaminant that is released to the river. These factors are calculated by using a computer program for calculating population dose integrated over 10,000 years, which estimates the time integral of collective dose over a period of up to 10,000 years for time variant radionuclide releases to surface waters, such as rivers (DOE 1987).

For long-term releases of radionuclides to the Columbia River, estimated downriver population totals are needed. For purposes of the TWRS EIS it is assumed that the potentially affected downriver population is 500,000, a number that has been used previously (DOE 1987).

A summary of the calculation results for total fatalities, population dose in person-rem, and the maximum incremental dose in mrem is shown in Table D.5.15.3.

## D.5.16 RISK RANGE

The post-remediation risk calculations presented in Section D.5.0 contain a number of conservative assumptions designed to ensure that the results provide an upper bound of the long-term risk associated with the TWRS alternatives. For comparison purposes, a nominal case has also been evaluated. The nominal case is based on most likely rather than conservative assumptions. Evaluation methods for the nominal case were identical to the bounding case. This section presents the risk range for the bounding and nominal cases. Risk range refers to the difference between the risk values for the bounding case and the corresponding values for the nominal case.

### D.5.16.1 Maximum Risk Range

Tables D.5.16.1 and D.5.16.2 show the maximum calculated values for ILCR and noncarcinogenic chemical hazard for the bounding case and nominal case, respectively. Values shown on these tables

are the highest values calculated for each exposure scenario and time period under each alternative. The risk range can be determined by comparing values on the bounding case table with their corresponding values on the nominal case table. For example, under the bounding case the post-remediation risk to the residential farmer at 300 years for the No Action alternative is calculated to be 4.58E-01 (Table D.5.16.1). Under the nominal case, this risk is calculated to be 1.92E-01. (Table D.5.16.2).

### D.5.16.2 Total Health Impacts Range

Table D.5.16.3 shows the total post-remediation cancer incidence and fatalities calculated over a 10,000-year period for the nominal case. The corresponding values for the bounding case are shown in Table D.5.15.1. The risk range can be determined in the same manner as discussed above for the maximum risk range. For example, under the bounding case for the No Action alternative, the total cancer incidence for the residential farmer over 10,000 years is calculated to be 759 (Table D.5.15.1). Under the nominal case, the corresponding cancer incidence is calculated to be 626 (Table D.5.16.3).

## D.5.17 UNCERTAINTY

The uncertainty analyses for post-remediation risk assessment are based on the HSRAM uncertainty analysis. The carcinogenic and noncarcinogenic risk presented in the post-remediation risk evaluation are estimates given multiple assumptions about exposures, toxicity, and other variables. The uncertainties are inherent (e.g., toxicity values, default exposure parameters) or specific (e.g., data evaluation, contaminant identification) in the risk assessment process. Specific considerations in evaluating uncertainty are Site-specific factors, exposure assessment factors, toxicity assessment factors, and risk characterization factors. A detailed discussion of uncertainty in the post-remediation risk assessment is provided in Volume Five, Appendix K.

**Figure D.5.1.1 No Action Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals at 300 Years from Present**

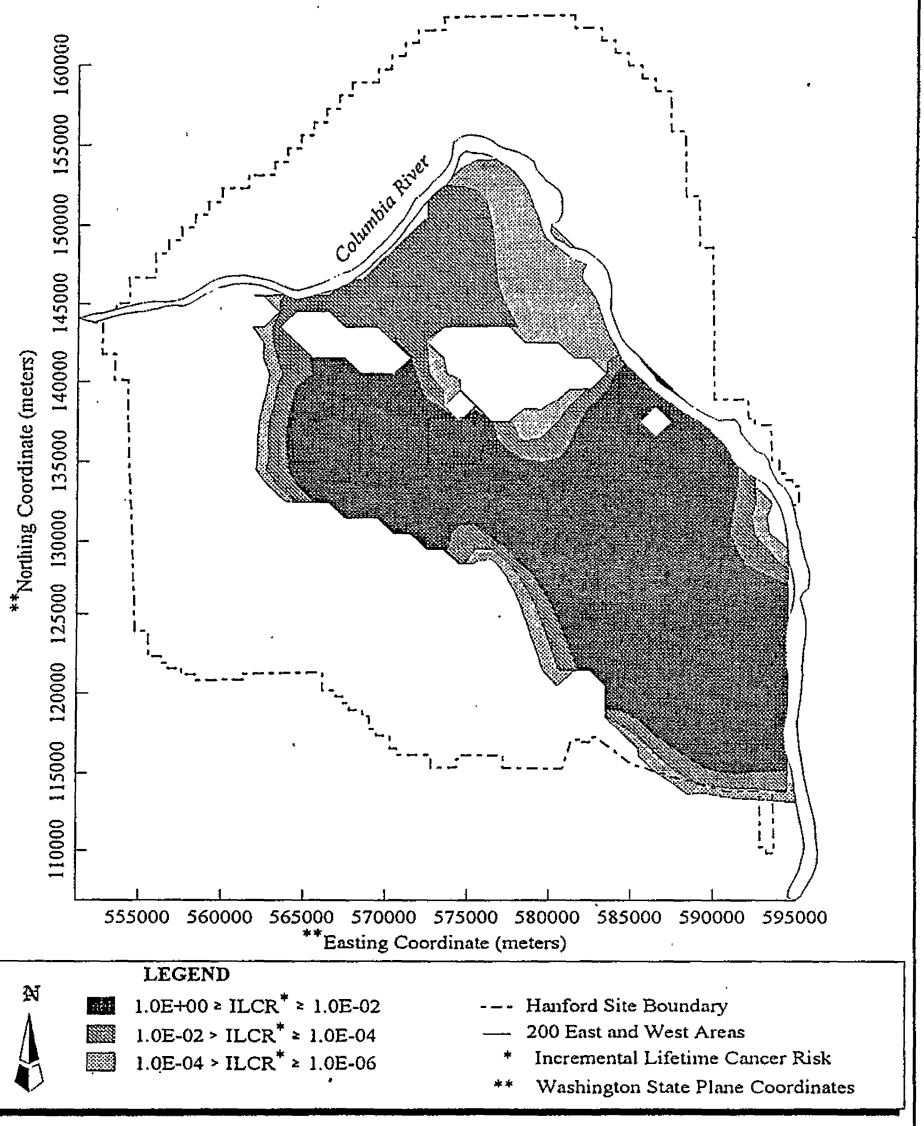


**Figure D.5.1.2 .No Action Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals at 500 Years from Present**

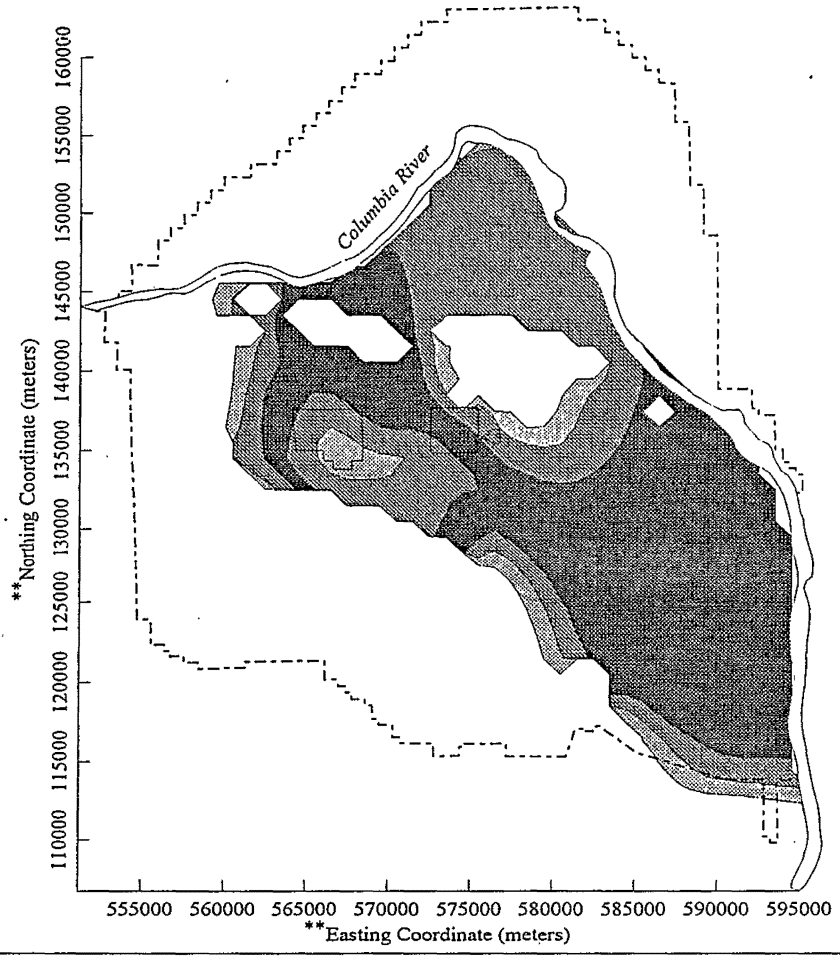


**Figure D.5.1.3 No Action Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals at 2,500 Years from Present**

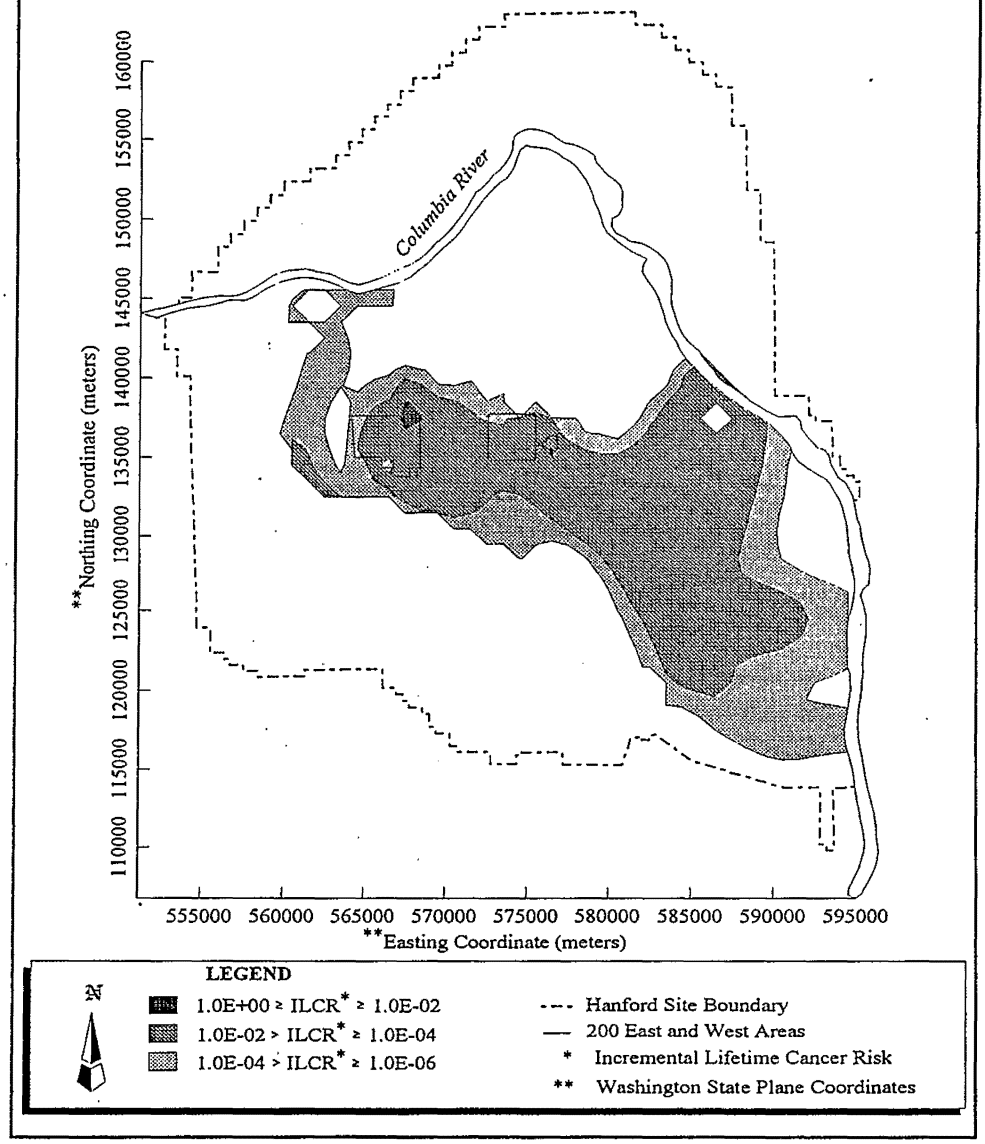


**Figure D.5.1.4 No Action Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

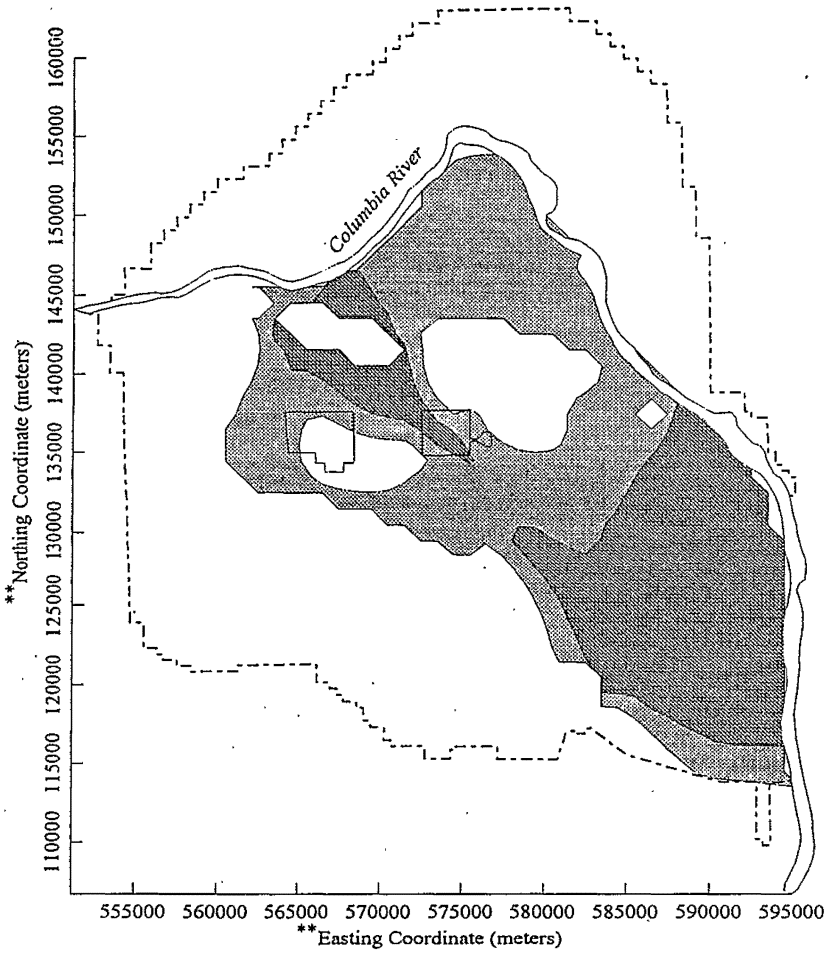


**Figure D.5.1.5 No Action Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals at 10,000 Years from Present**

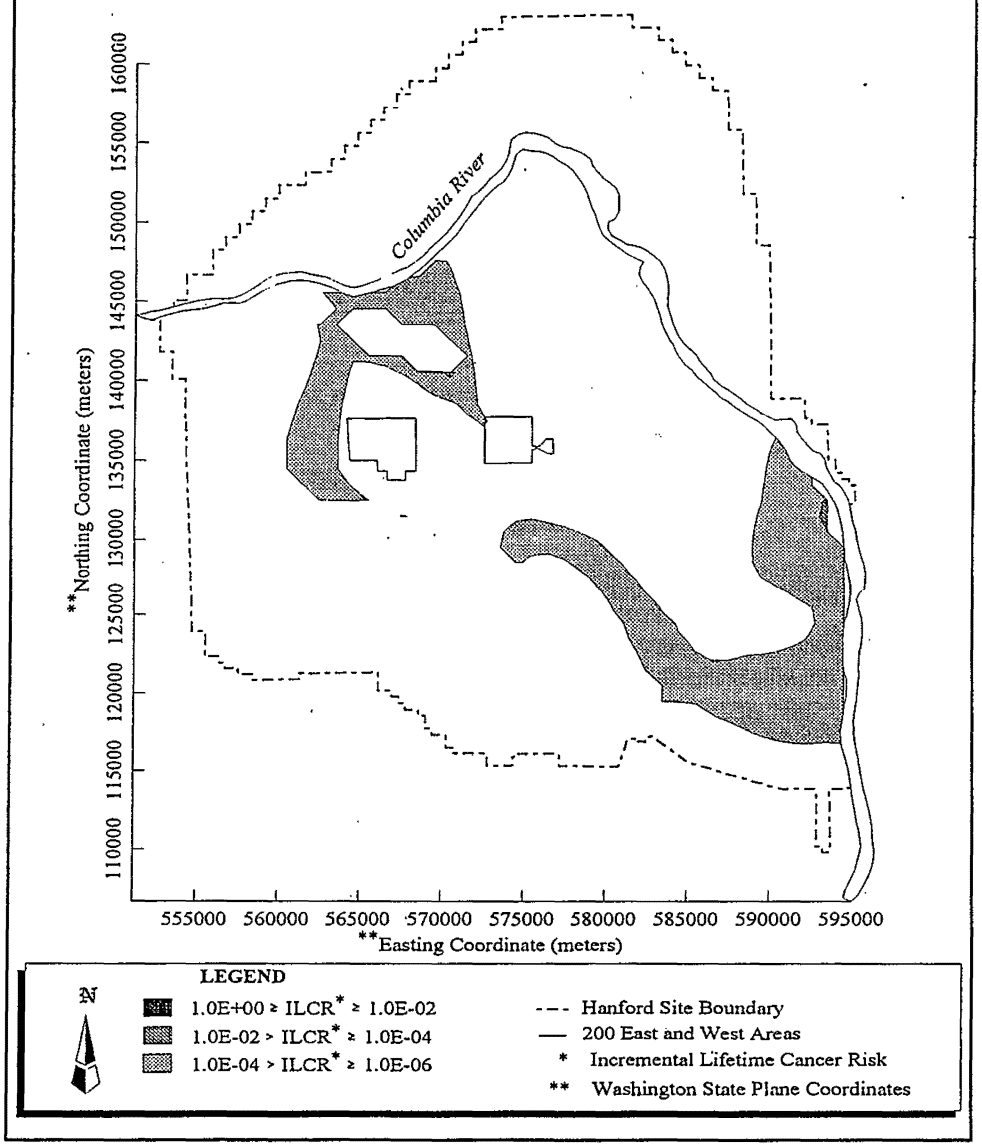


**Figure D.5.1.6 No Action Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals at 300 Years from Present**

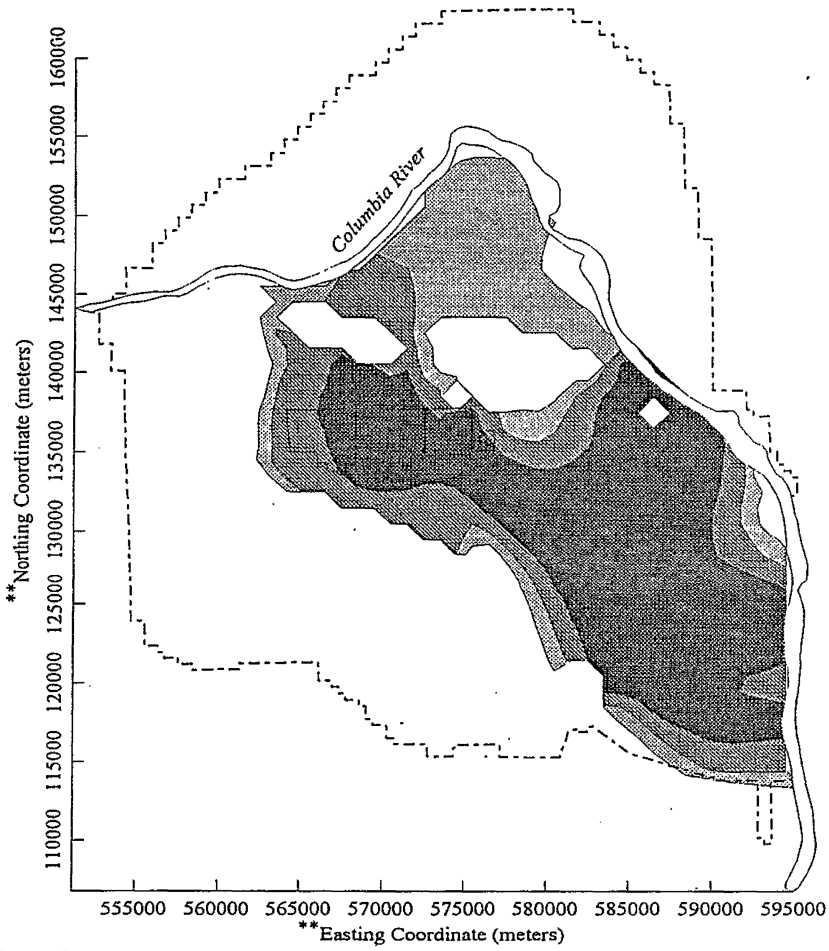


**Figure D.5.1.7 No Action Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals at 500 Years from Present**

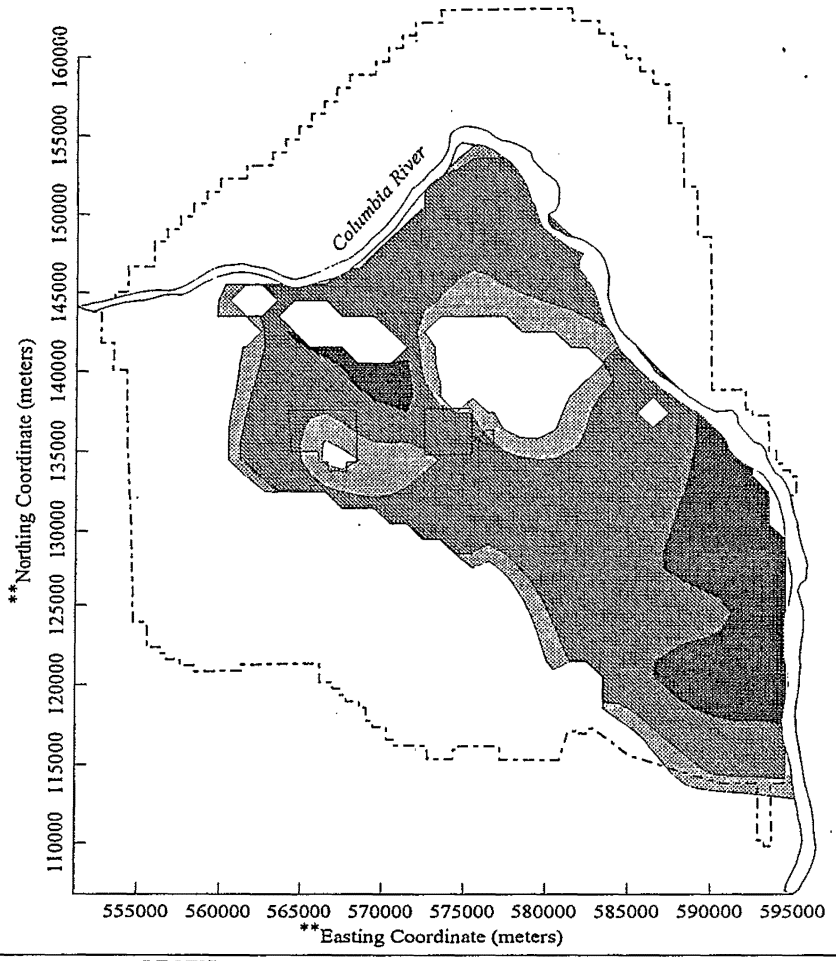


**Figure D.5.1.8 No Action Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals at 2,500 Years from Present**

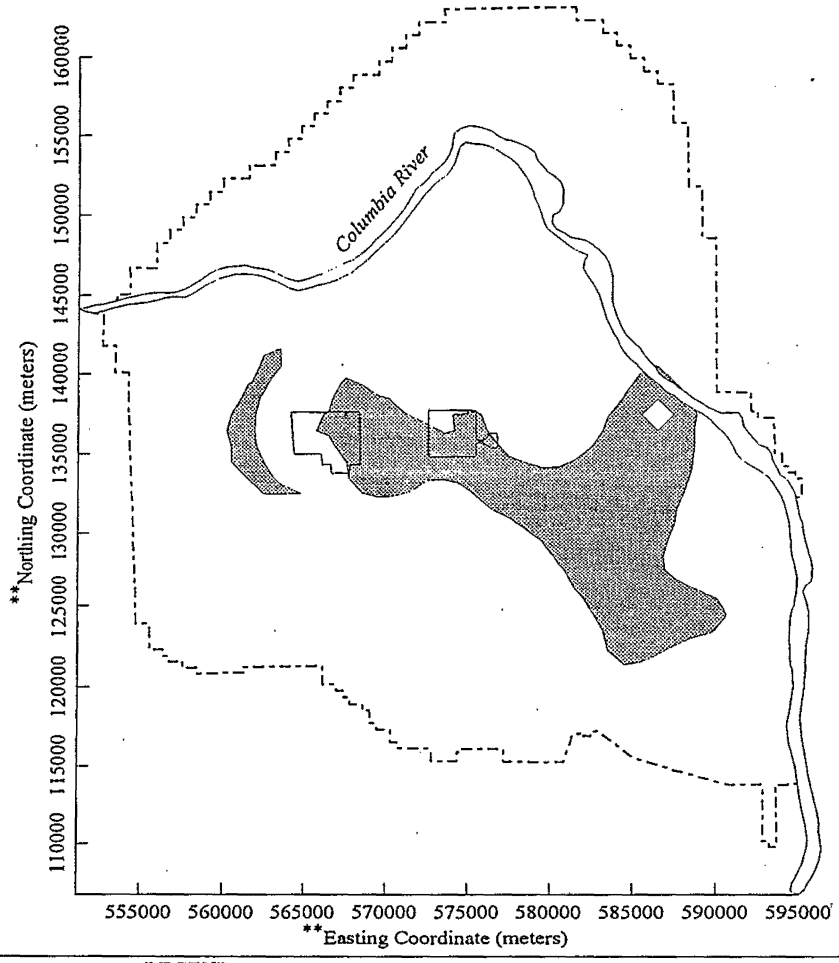


**Figure D.5.1.9 No Action Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

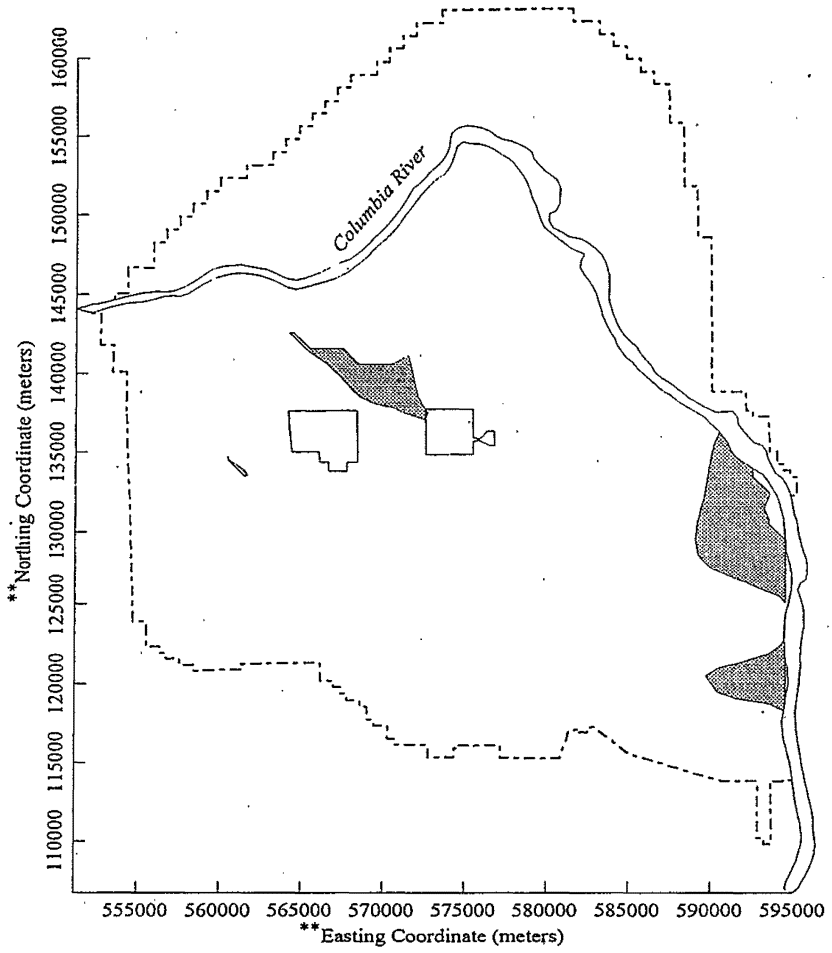


**Figure D.5.1.10 No Action Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals at 300 Years from Present**

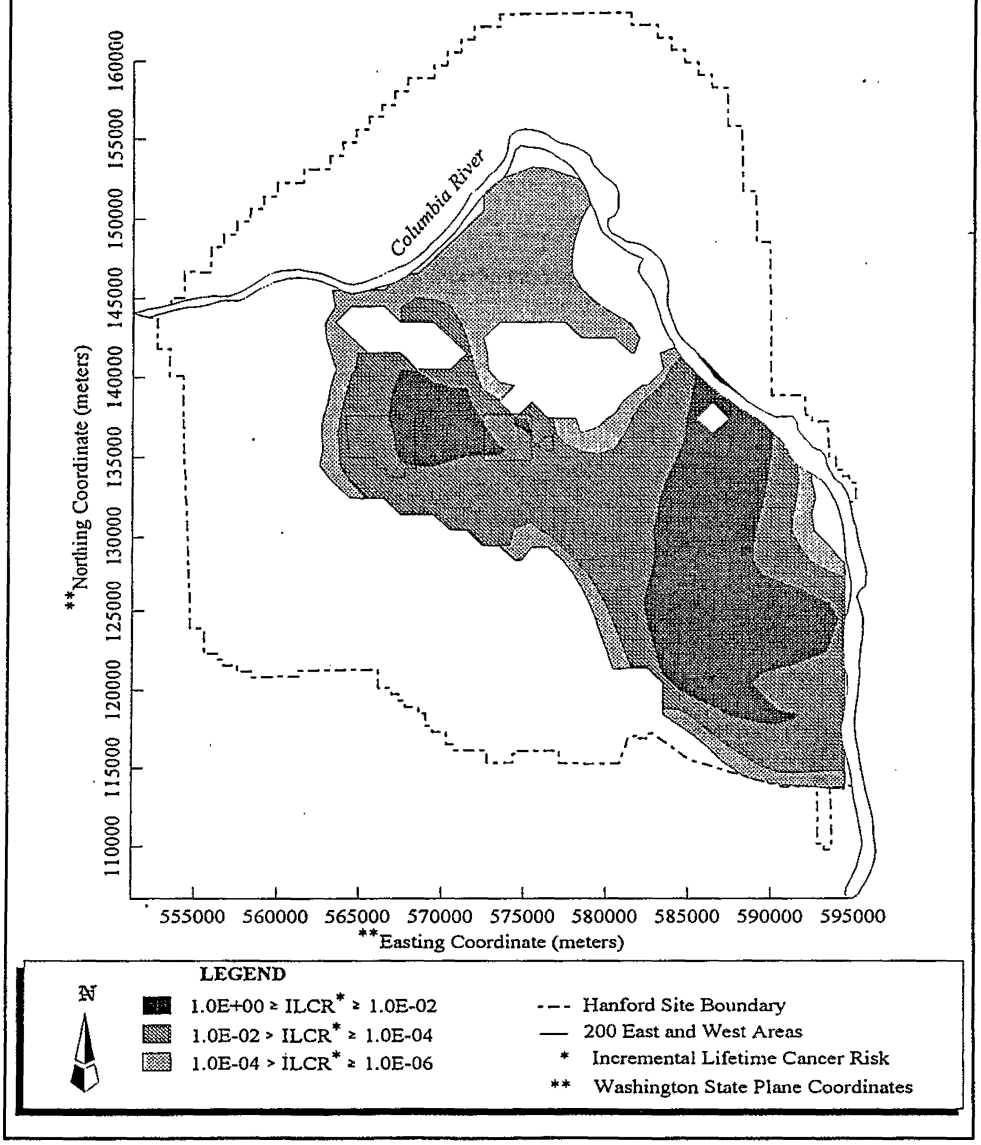


**Figure D.5.1.11 No Action Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals at 500 Years from Present**

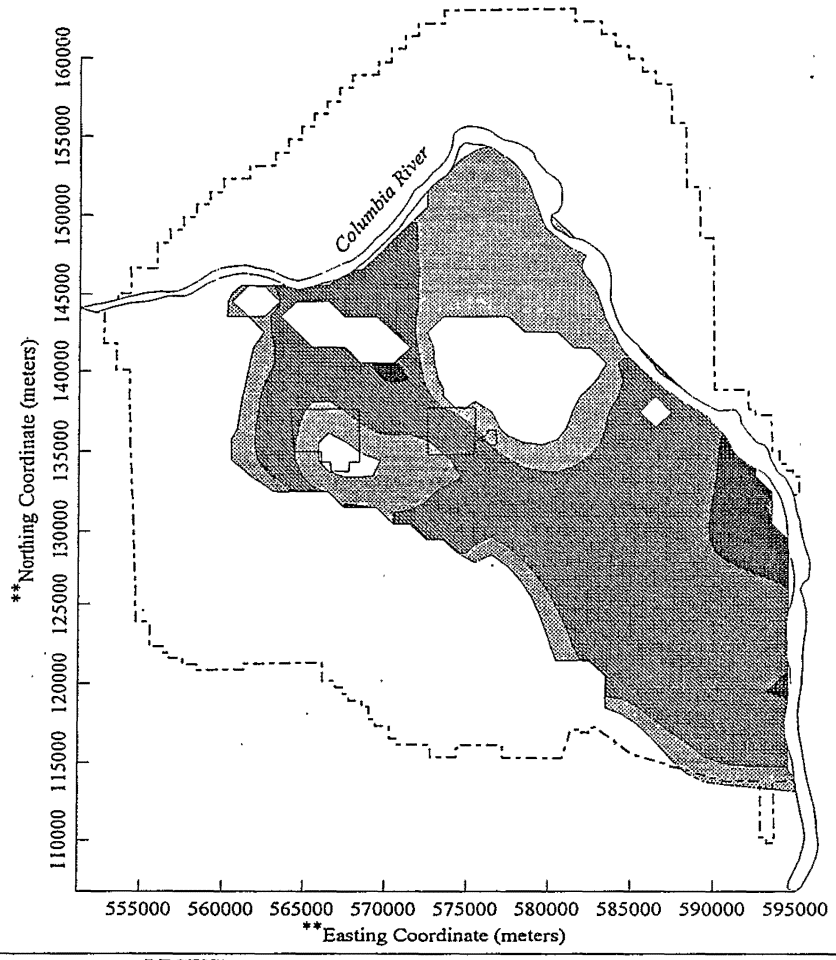


**Figure D.5.1.12 No Action Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals at 2,500 Years from Present**

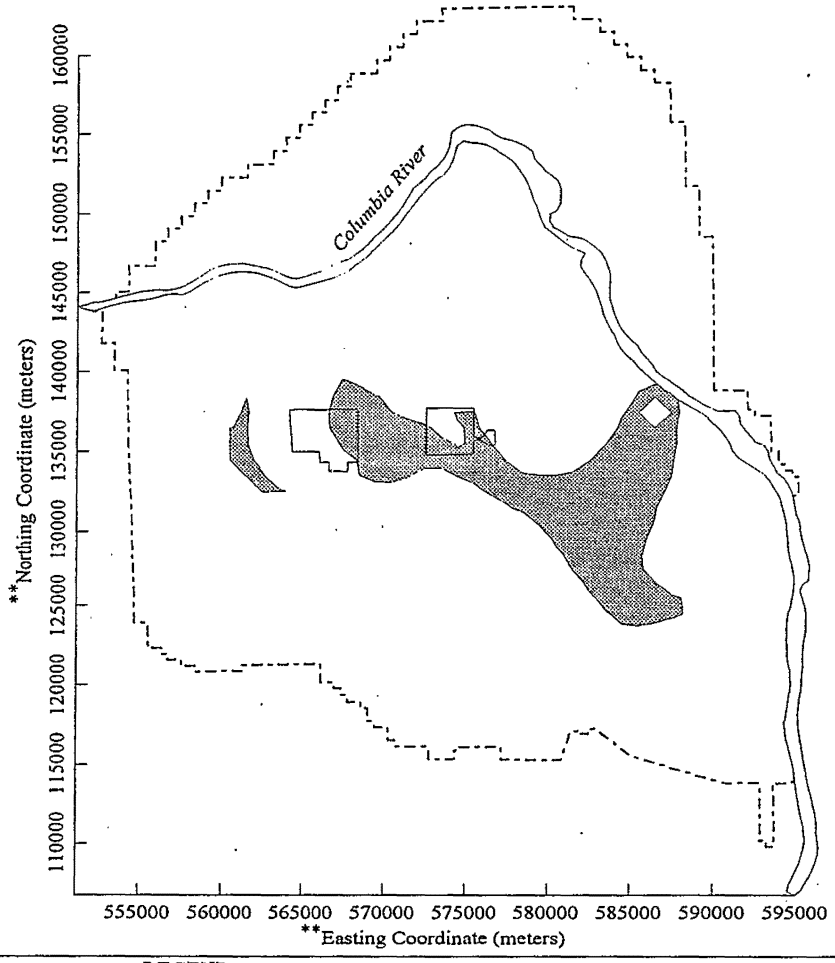


**Figure D.5.1.13 No Action Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

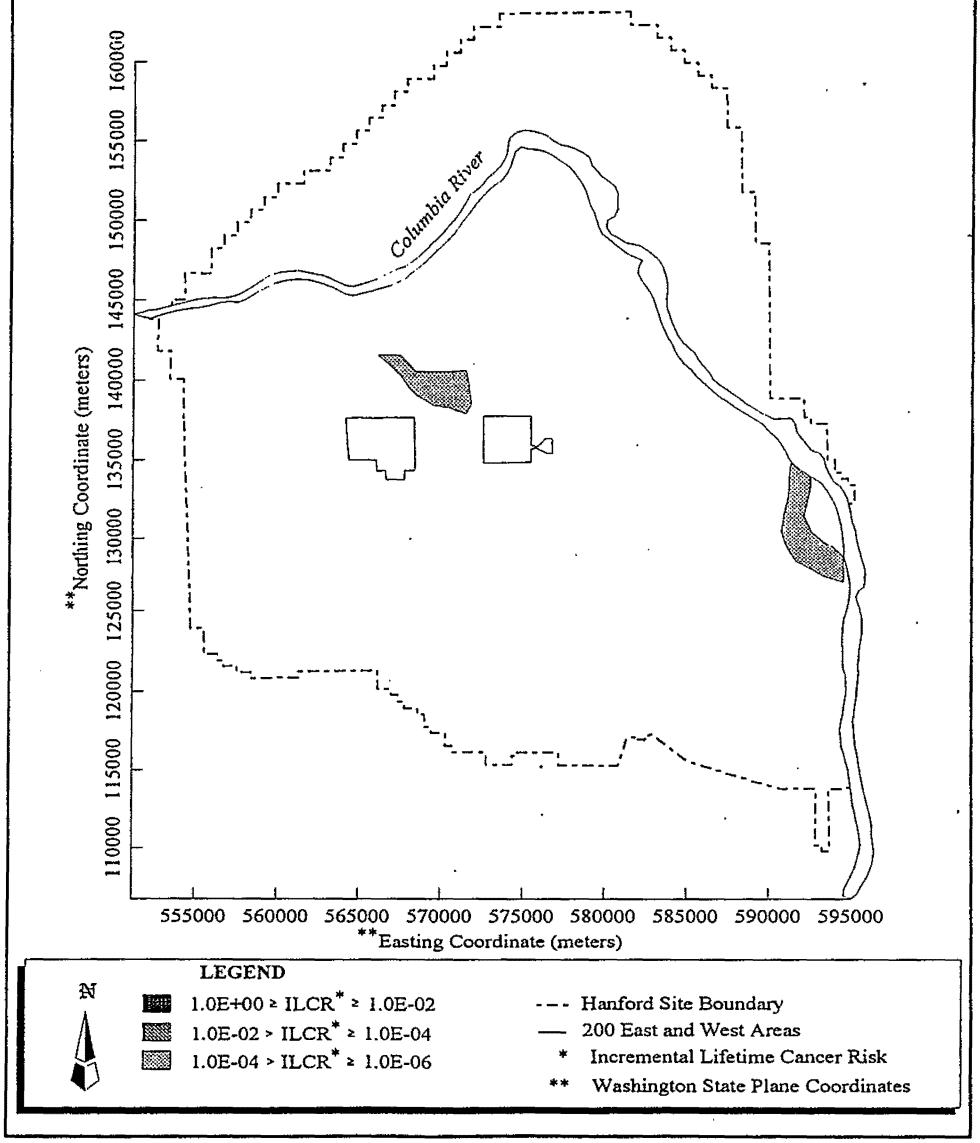


**Figure D.5.1.14 No Action Alternative, Recreational River User Scenario, Post Remediation Risk from Tank Residuals at 300 Years from Present**

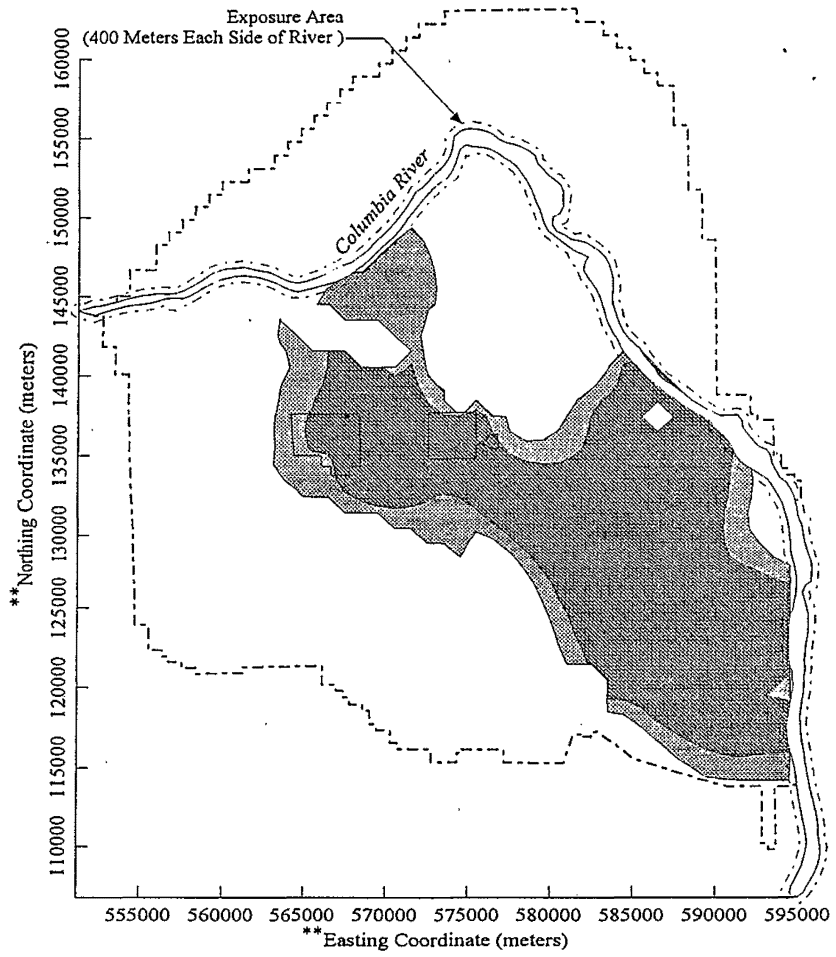


**Figure D.5.1.15 No Action Alternative, Recreational River User Scenario, Post Remediation Risk from Tank Residuals at 500 Years from Present**

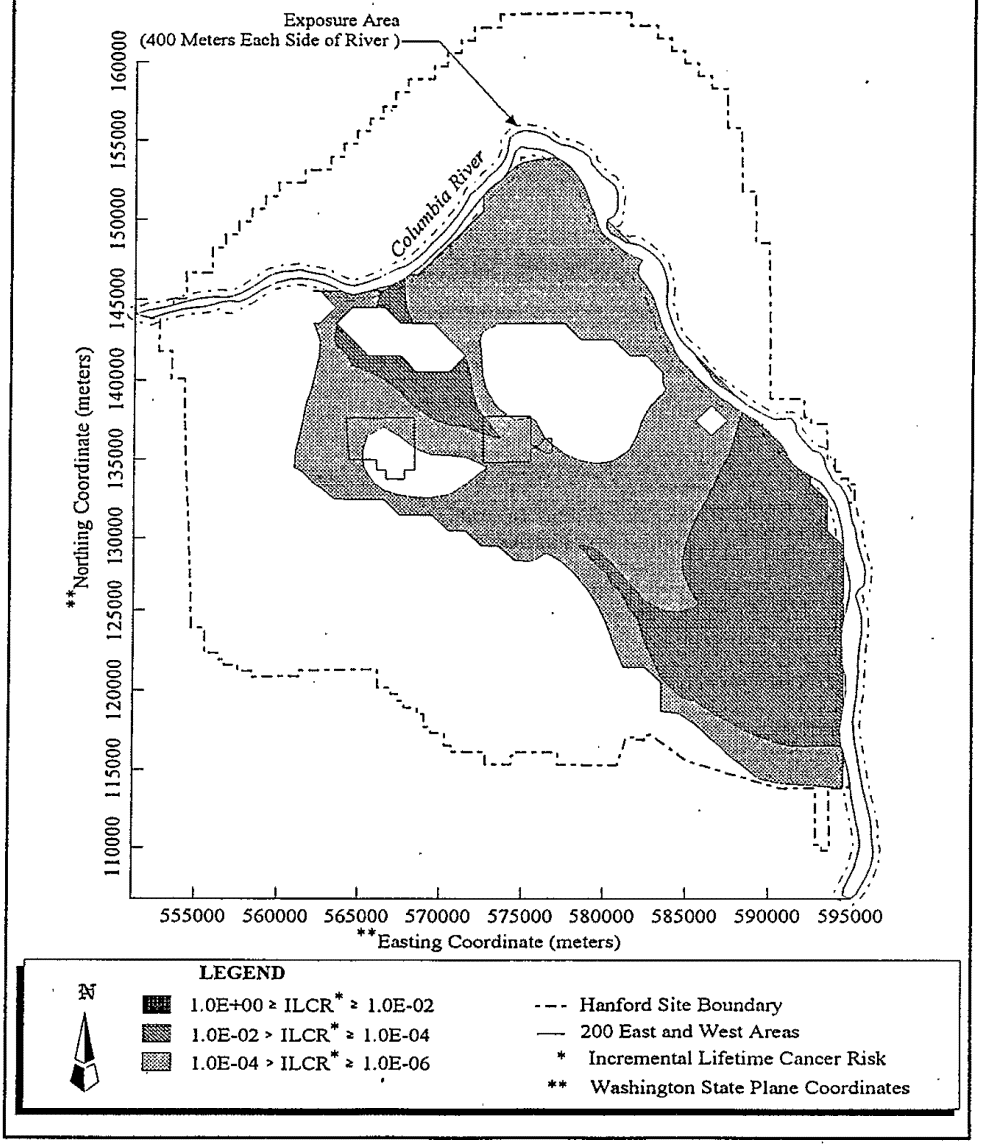


**Figure D.5.1.16 No Action Alternative, Recreational River User Scenario, Post Remediation Risk from Tank Residuals at 2,500 Years from Present**

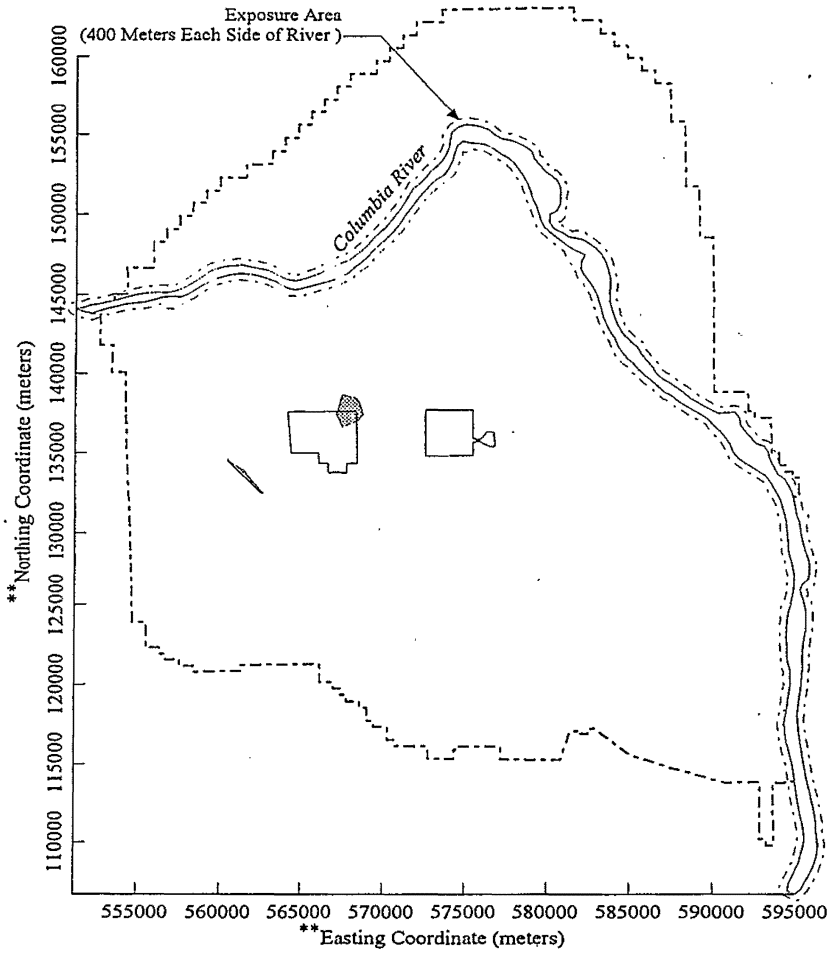


**Figure D.5.1.17 No Action Alternative, Native American Scenario, Post Remediation Hazard Index from Tank Residuals at 300 Years from Present**

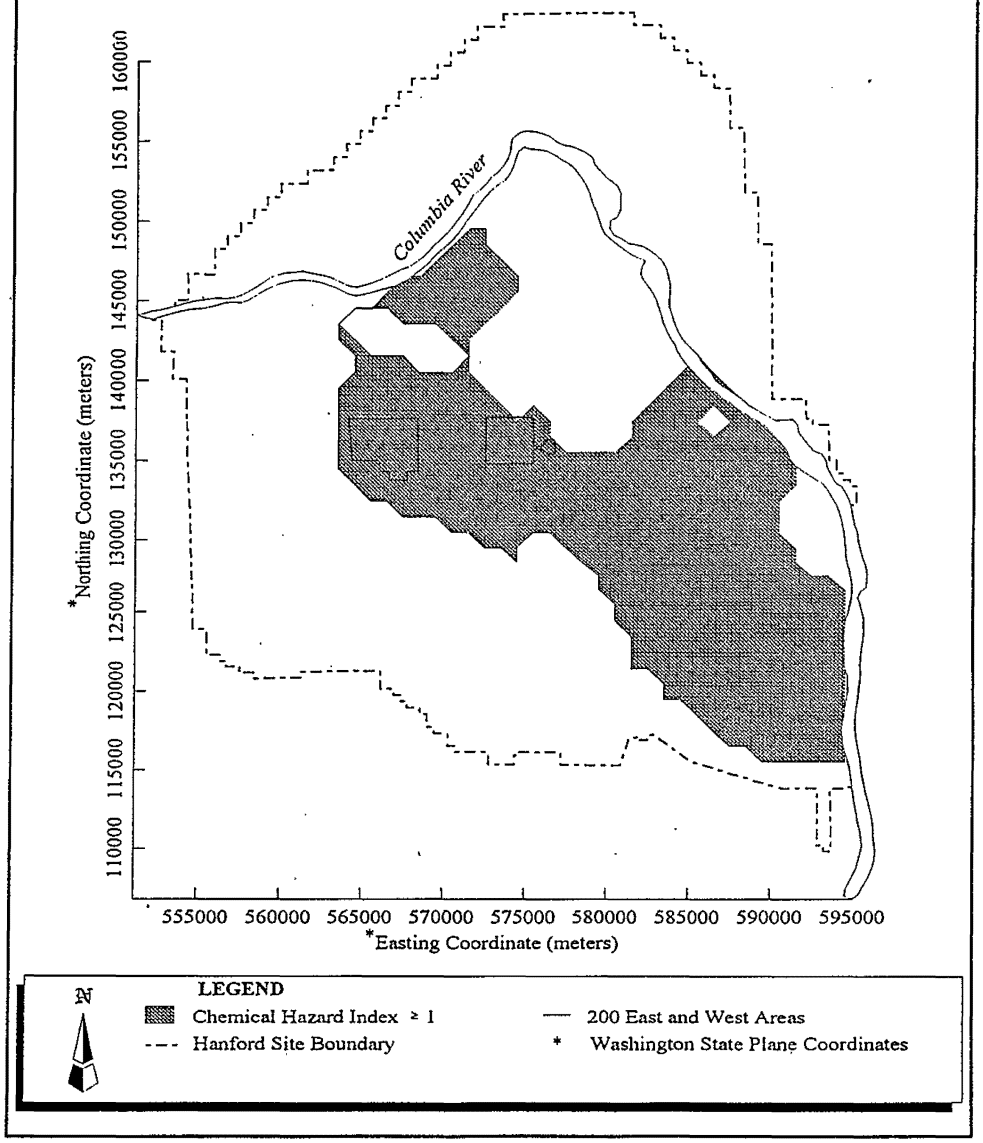


**Figure D.5.1.18 No Action Alternative, Native American Scenario, Post Remediation Hazard Index from Tank Residuals at 500 Years from Present**

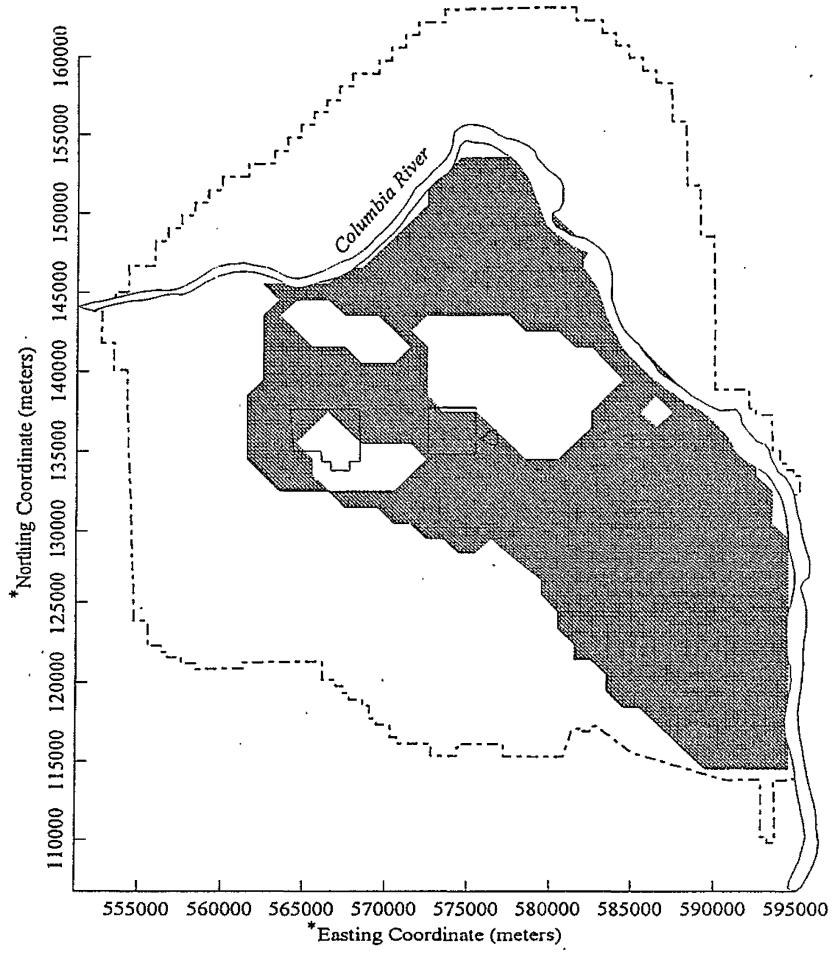


**Figure D.5.1.19 No Action Alternative, Native American Scenario, Post Remediation Hazard Index from Tank Residuals at 2,500 Years from Present**

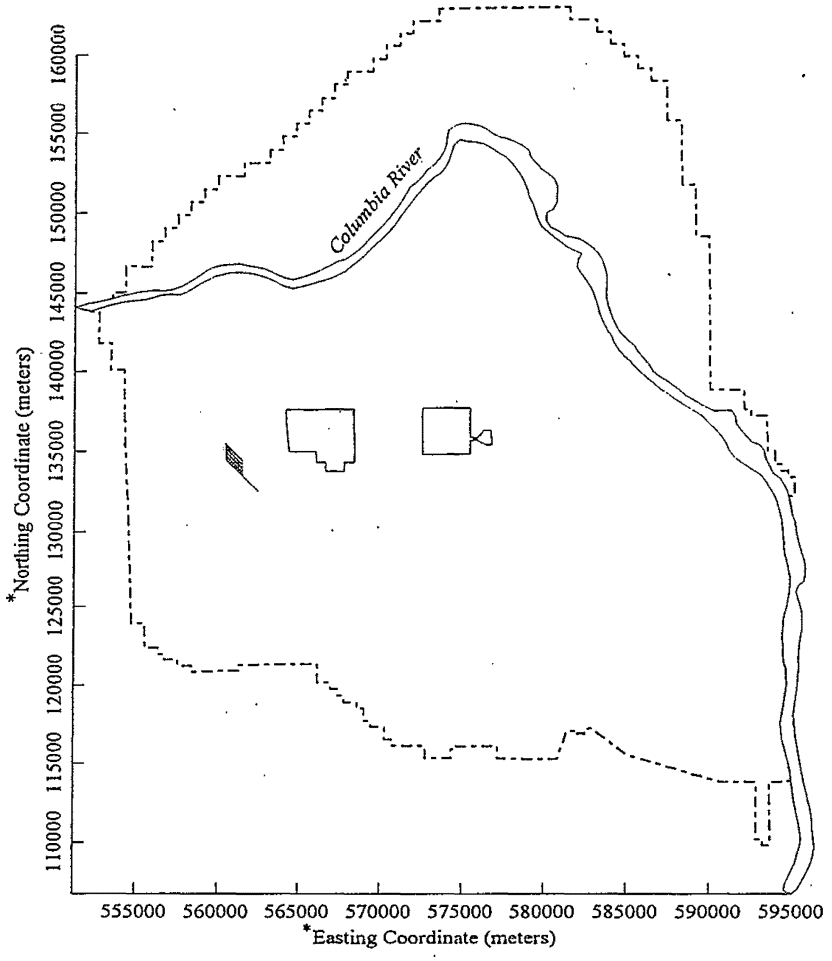


**Figure D.5.1.20 No Action Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from Tank Residuals at 300 Years from Present**

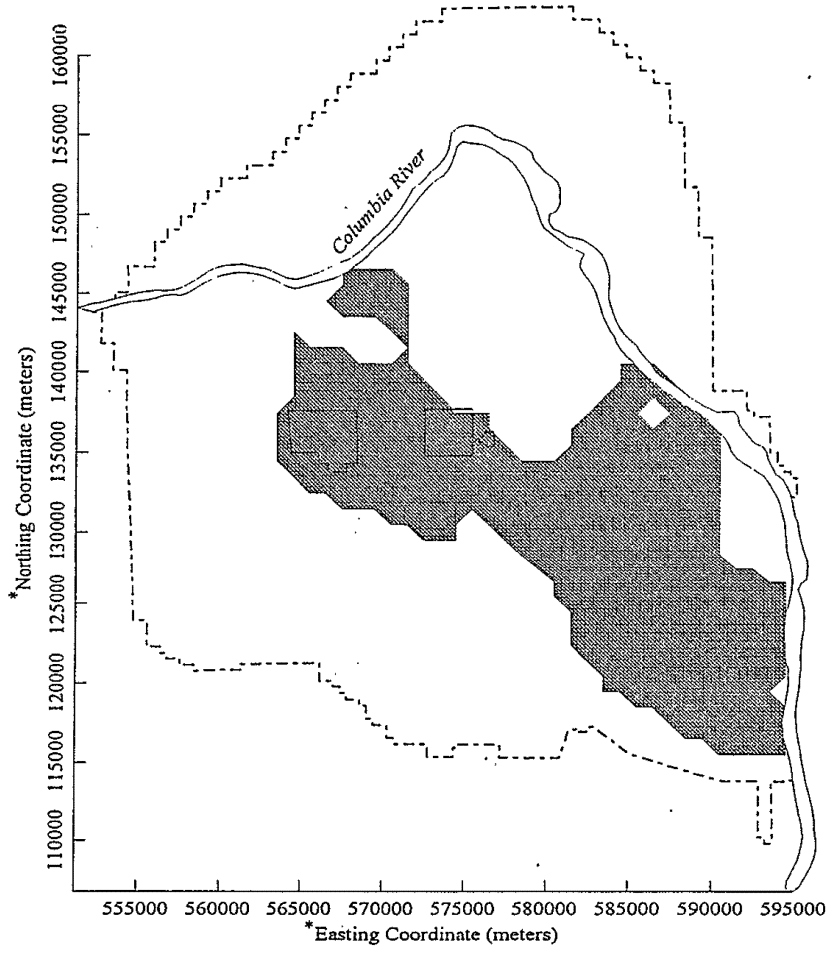


Figure D.5.1.21 No Action Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from Tank Residuals at 500 Years from Present

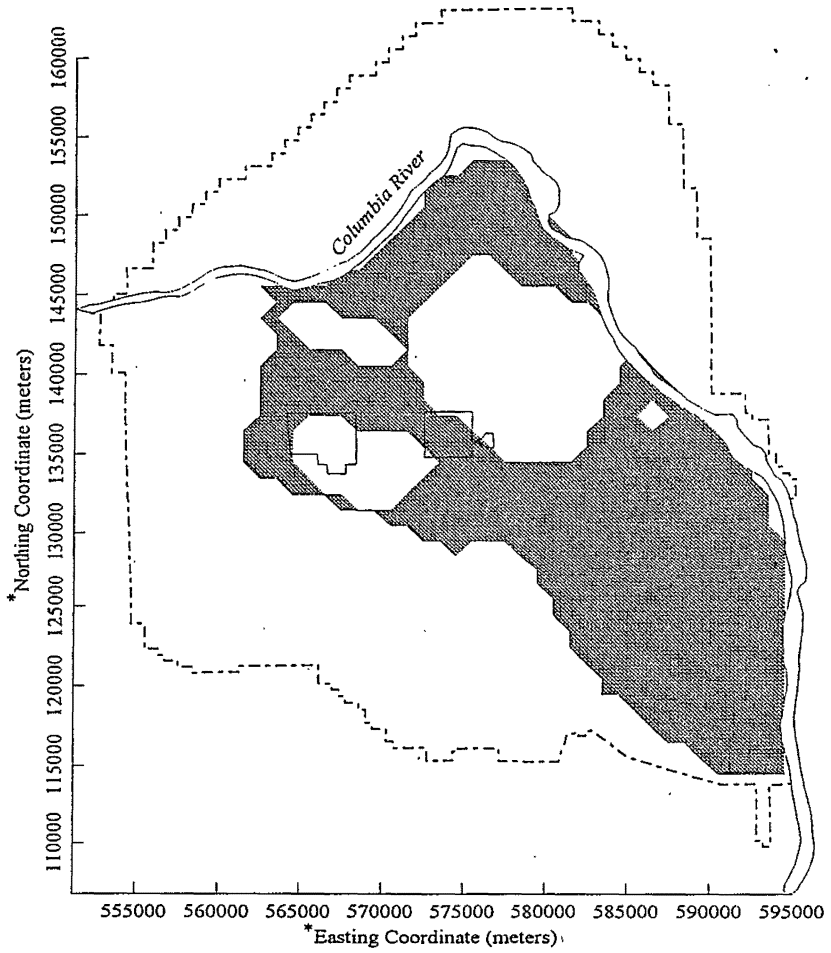


**Figure D.5.1.22 No Action Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from Tank Residuals at 2,500 Years from Present**

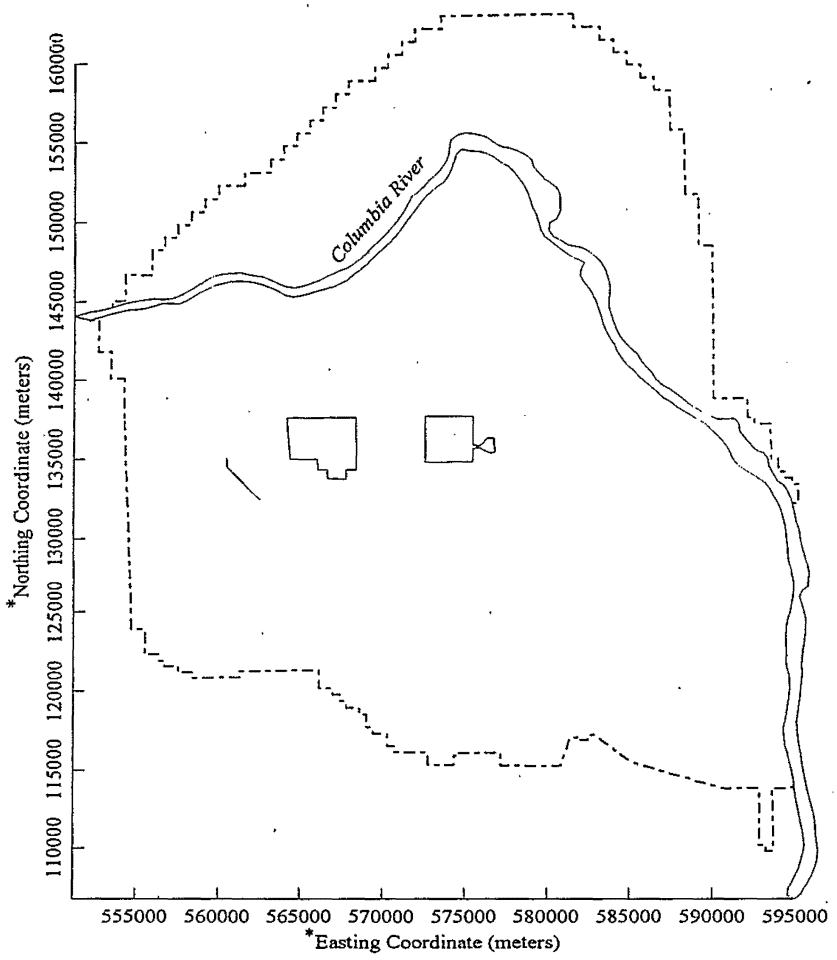


**Figure D.5.1.23 No Action Alternative, Industrial Worker Scenario, Post Remediation Hazard Index from Tank Residuals at 300 Years from Present**

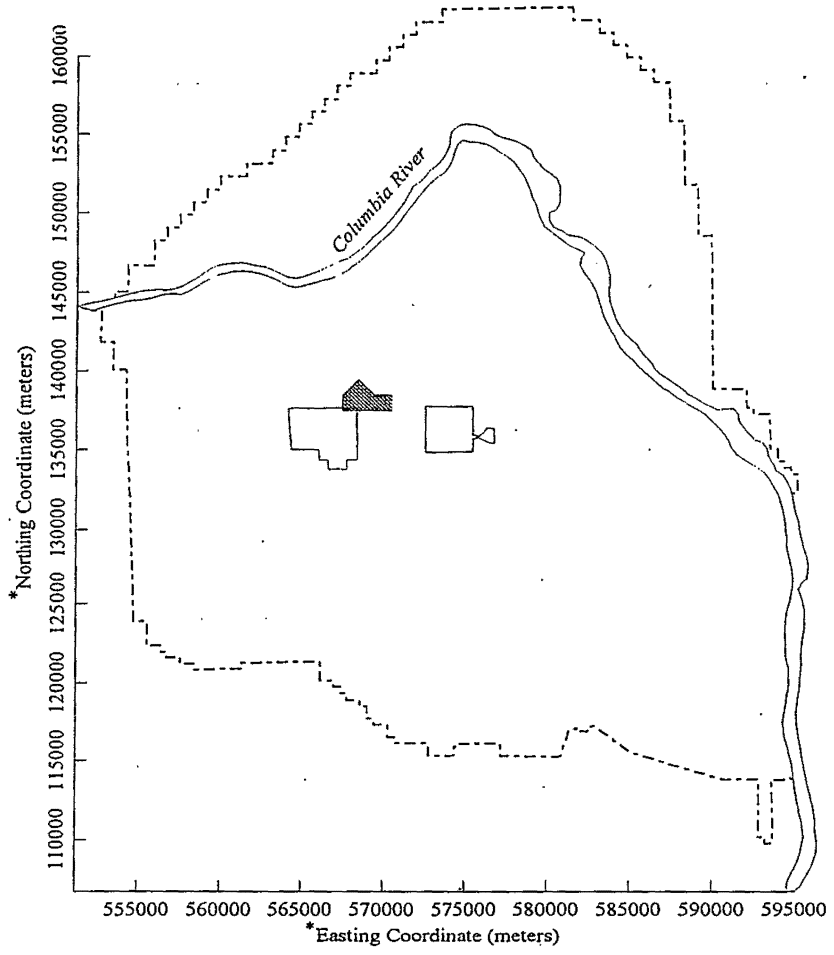


**Figure D.5.2.1 Long-Term Management Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals at 300 Years from Present**

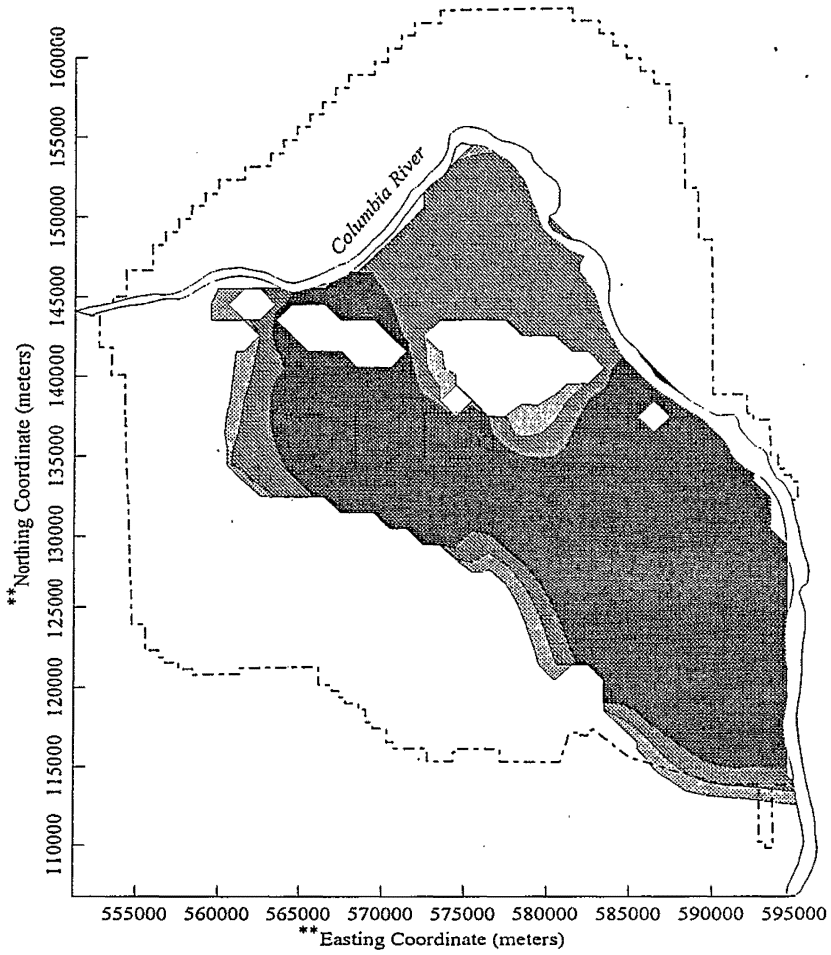


**Figure D.5.2.2 Long-Term Management Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals at 500 Years from Present**

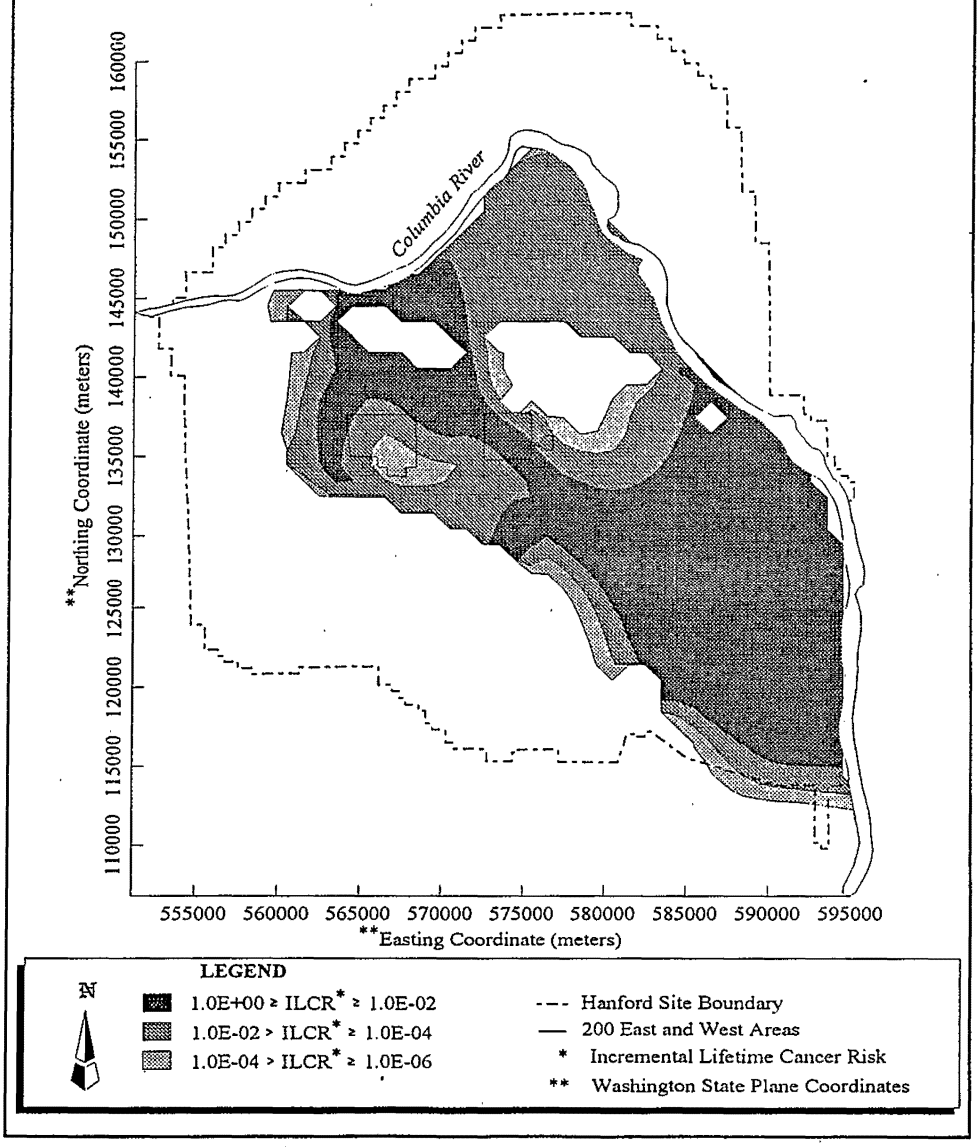


**Figure D.5.2.3 Long-Term Management Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals at 2,500 Years from Present**

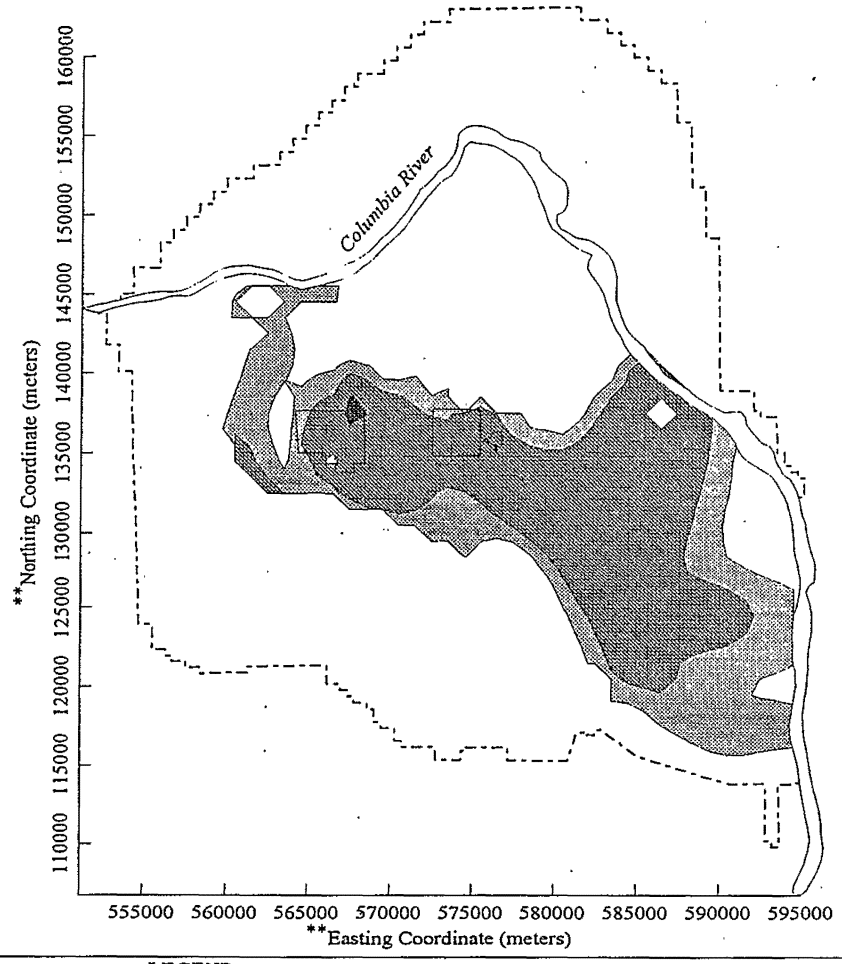


**Figure D.5.2.4 Long-Term Management Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

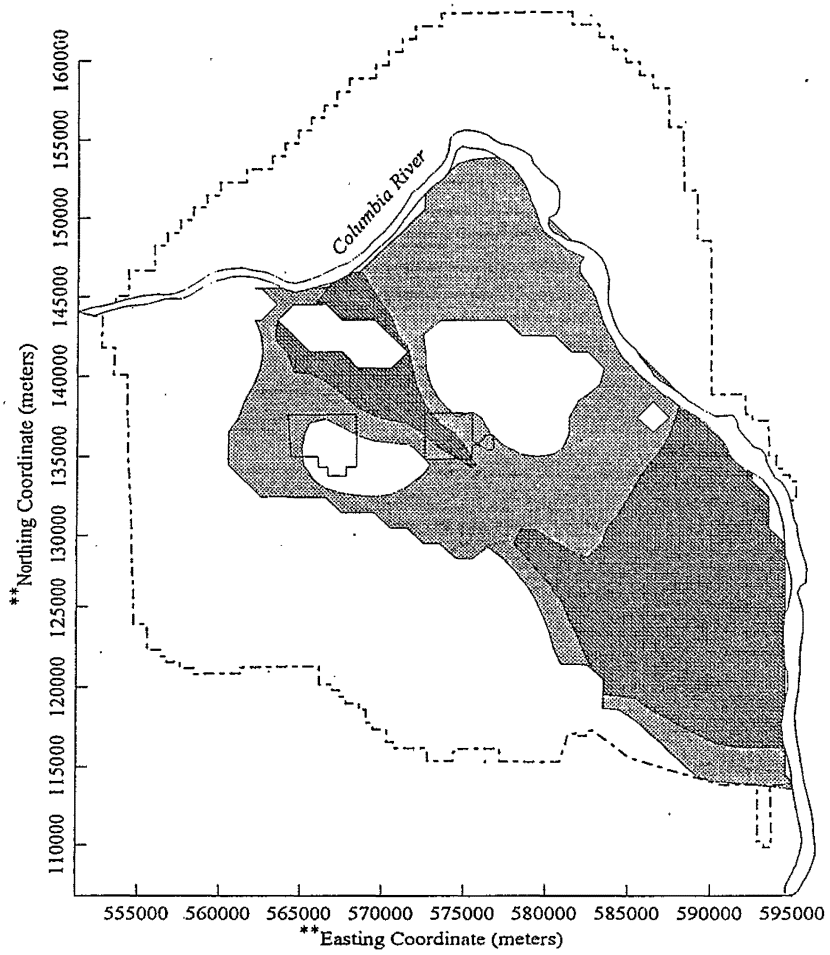


**Figure D.5.2.5 Long-Term Management Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals at 10,000 Years from Present**

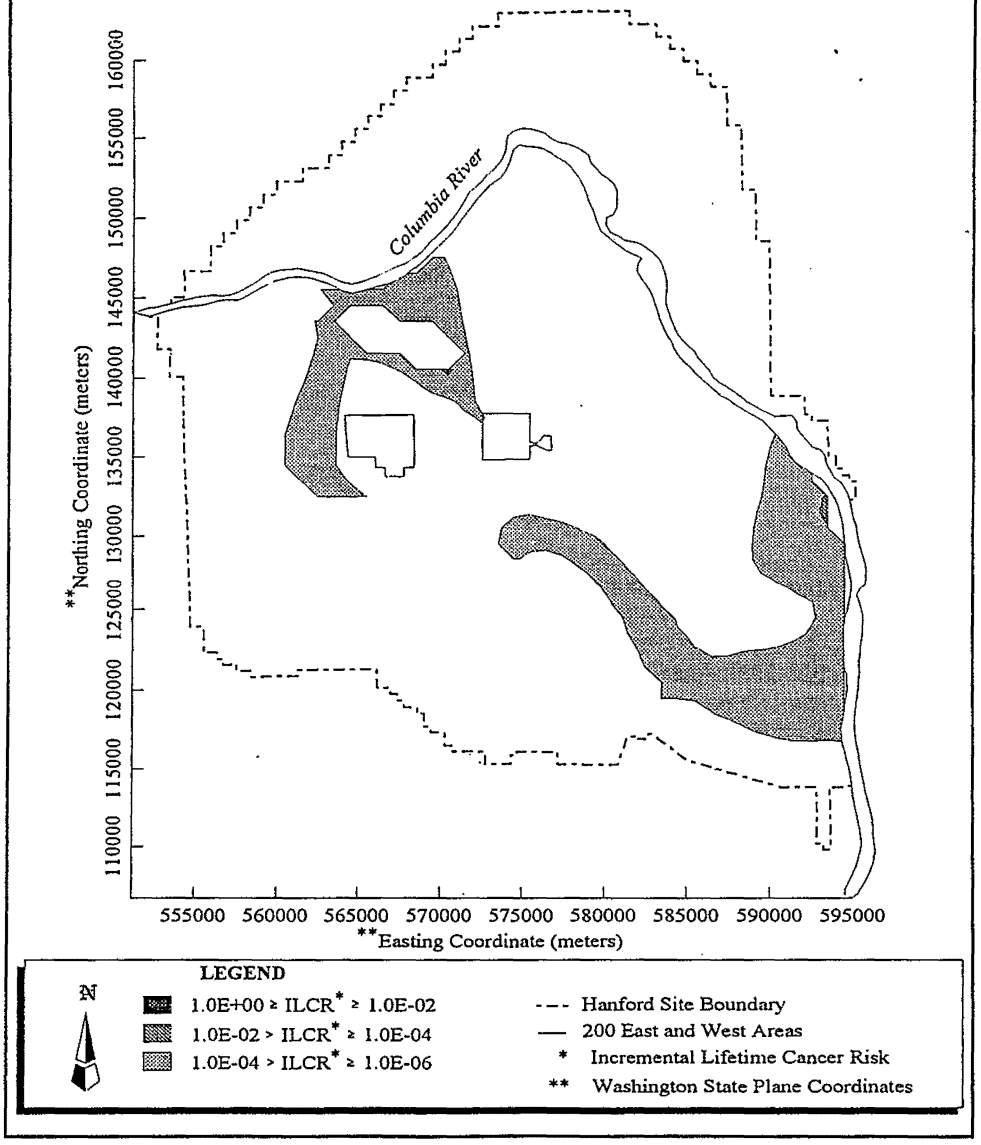


**Figure D.5.2.6 Long-Term Management Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals at 300 Years from Present**

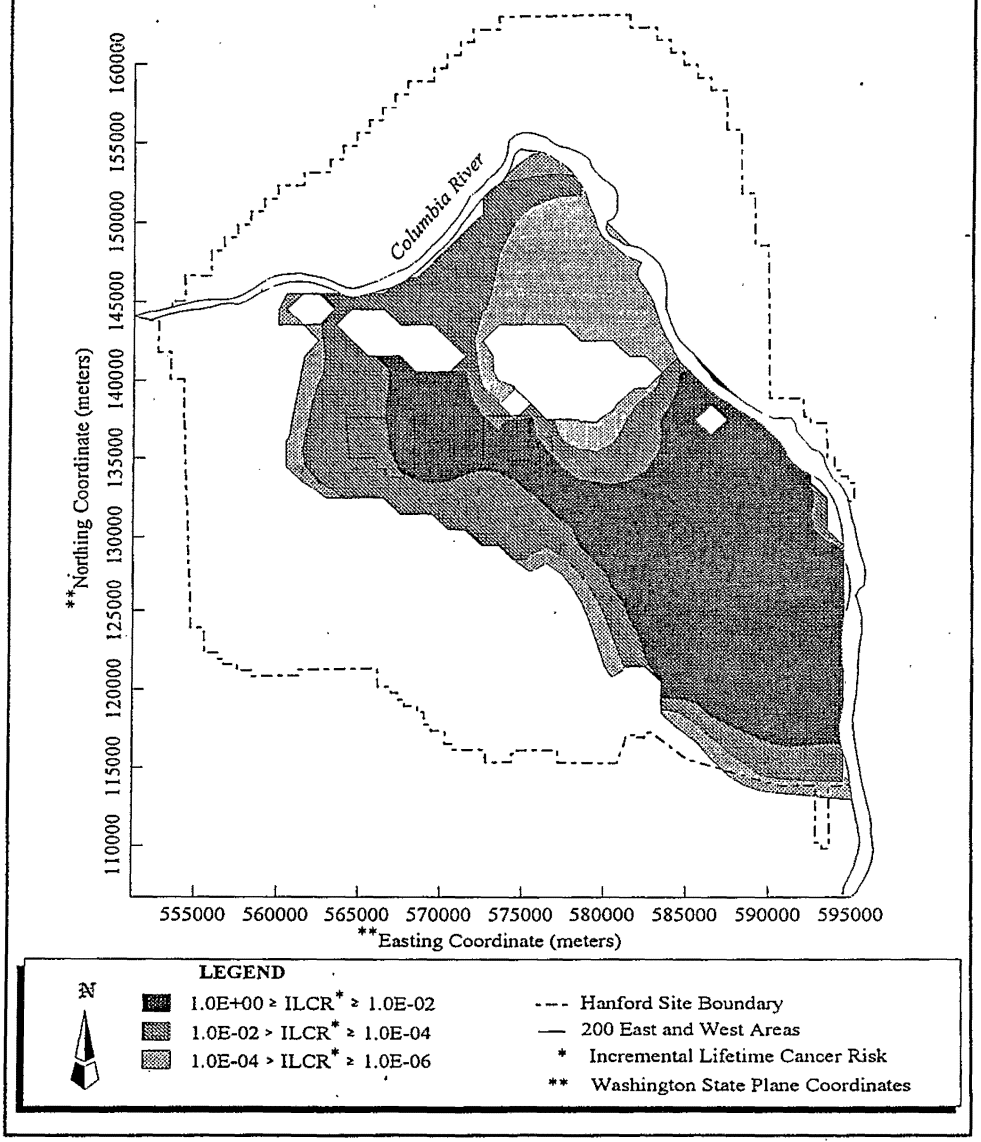


**Figure D.5.2.7 Long-Term Management Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals at 500 Years from Present**

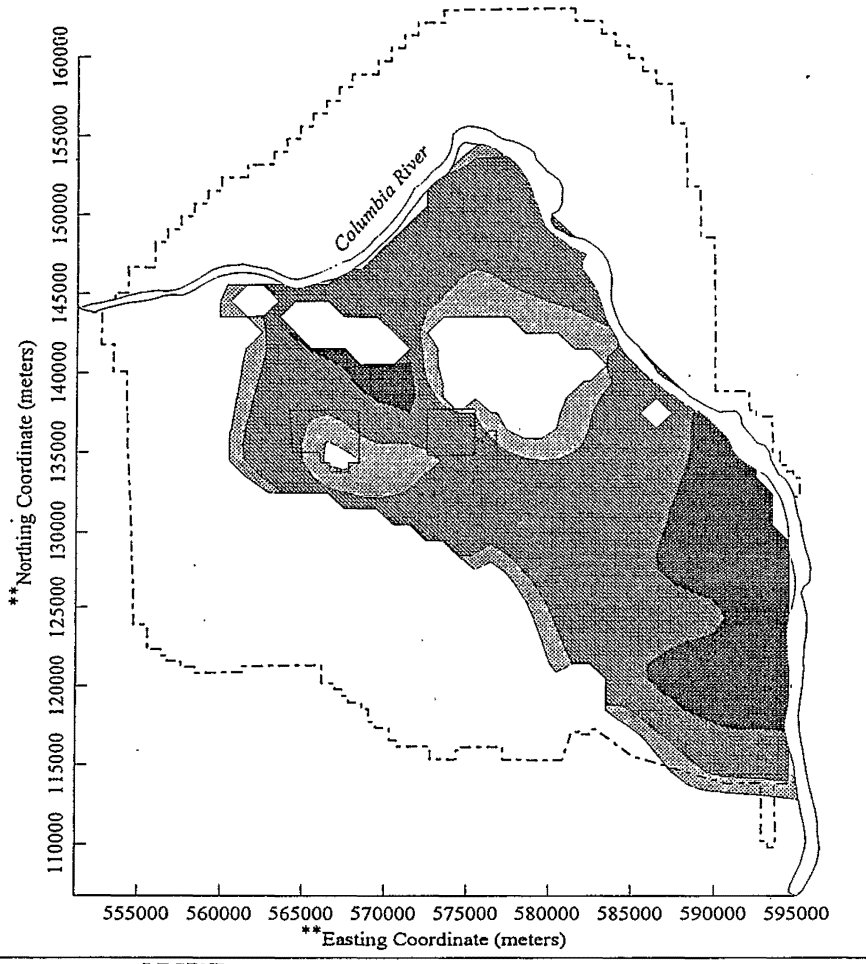


**Figure D.5.2.8 Long-Term Management Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals at 2,500 Years from Present**

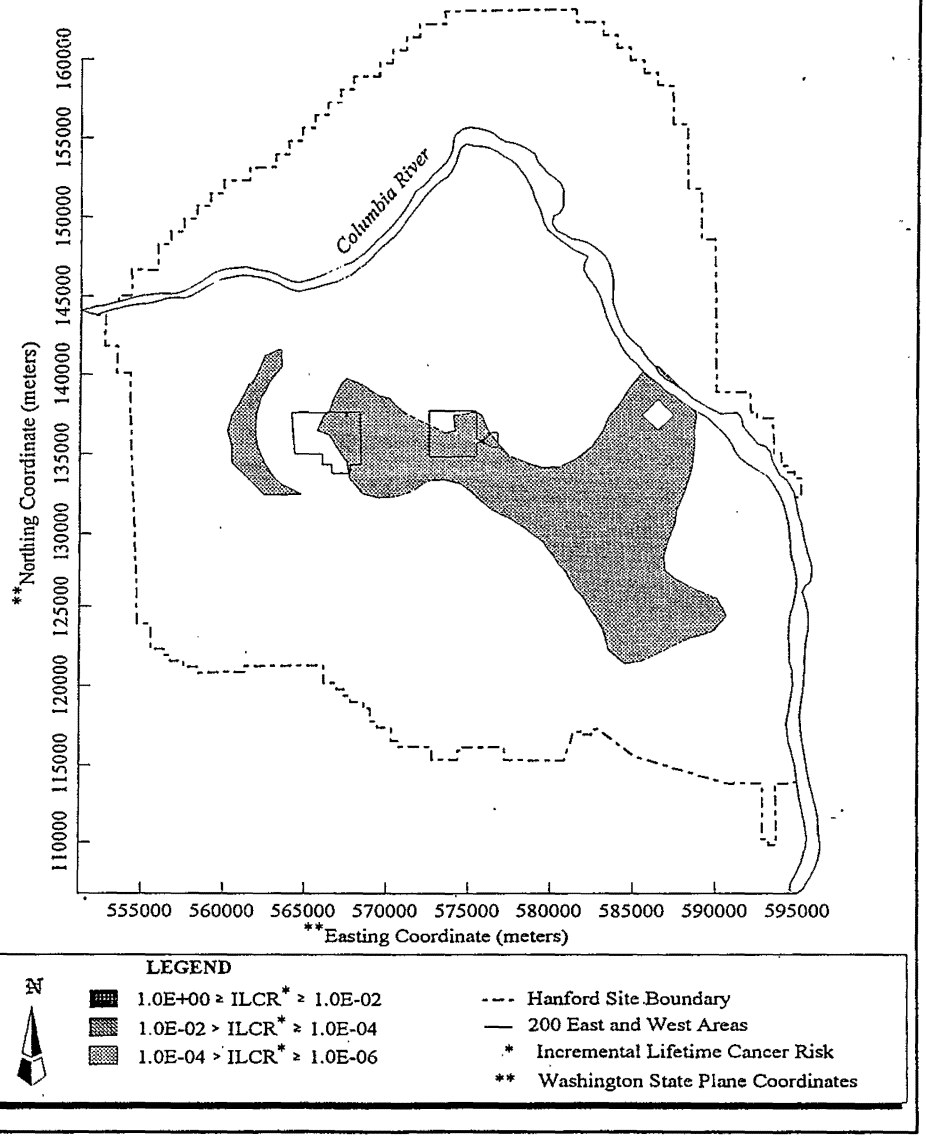


**Figure D.5.2.9 Long-Term Management Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

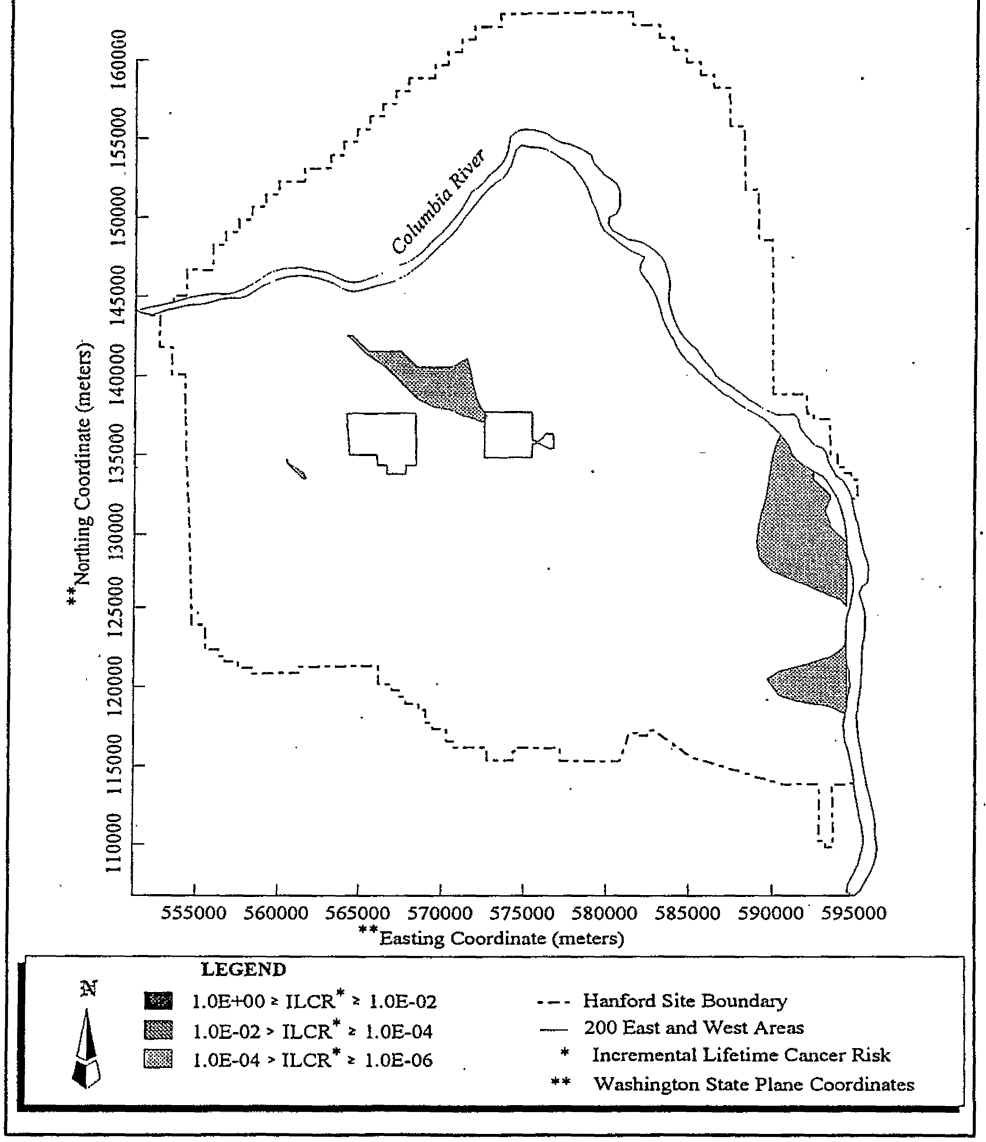


**Figure D.5.2.10 Long-Term Management Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals at 300 Years from Present**

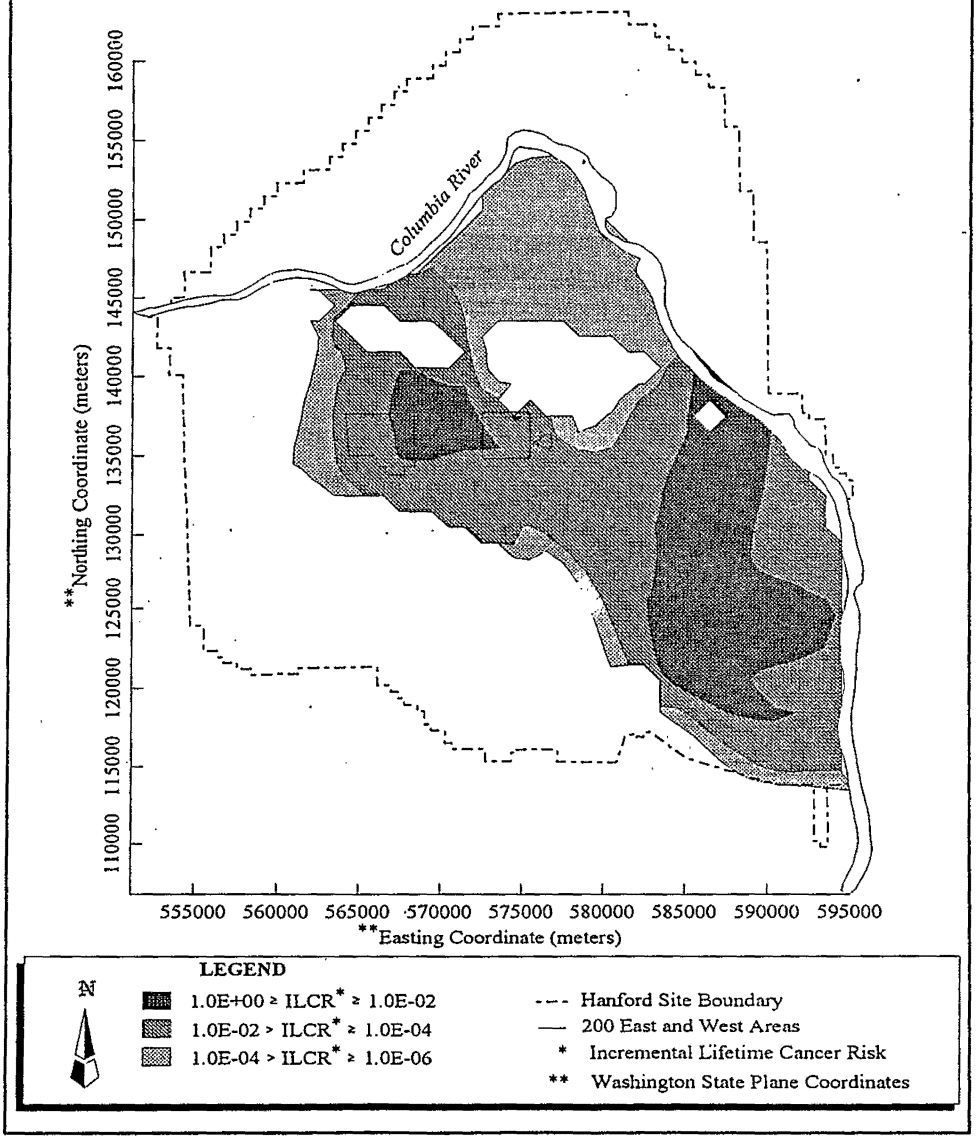


**Figure D.5.2.11 Long-Term Management Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals at 500 Years from Present**

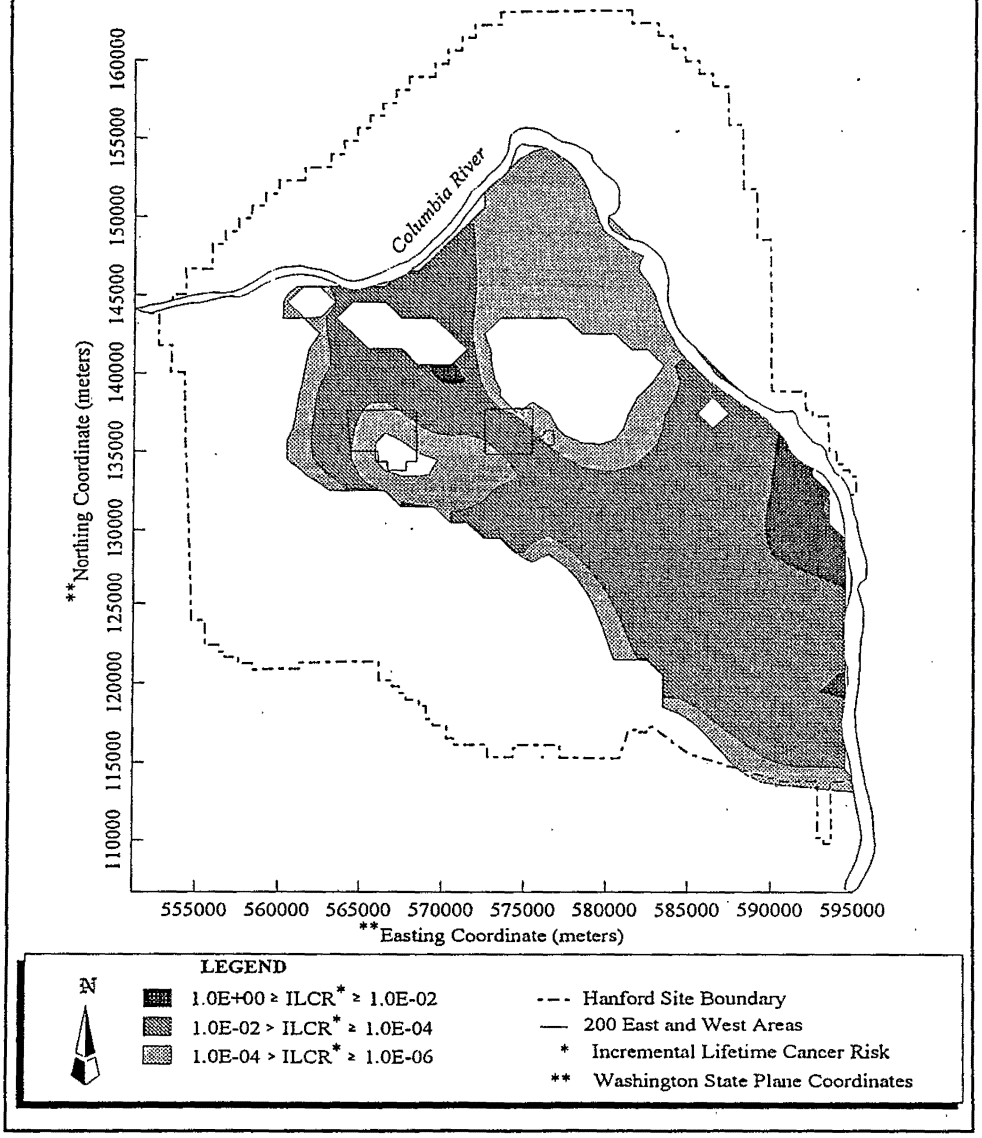


**Figure D.5.2.12 Long-Term Management Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals at 2,500 Years from Present**

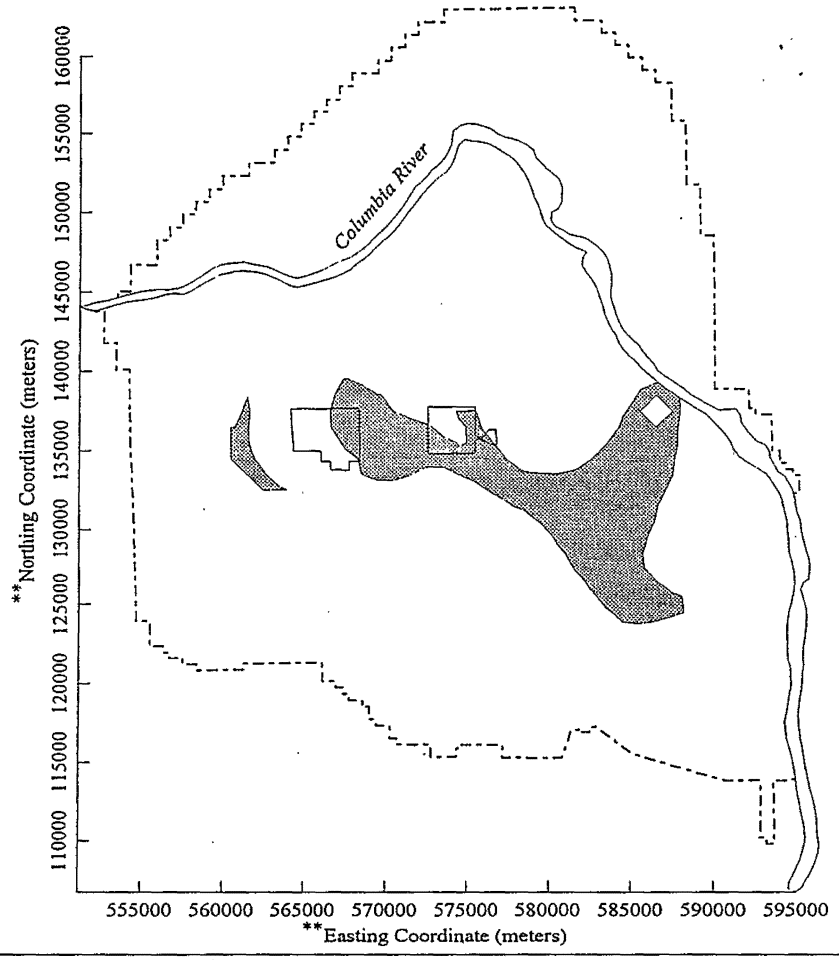


**Figure D.5.2.13 Long-Term Management Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

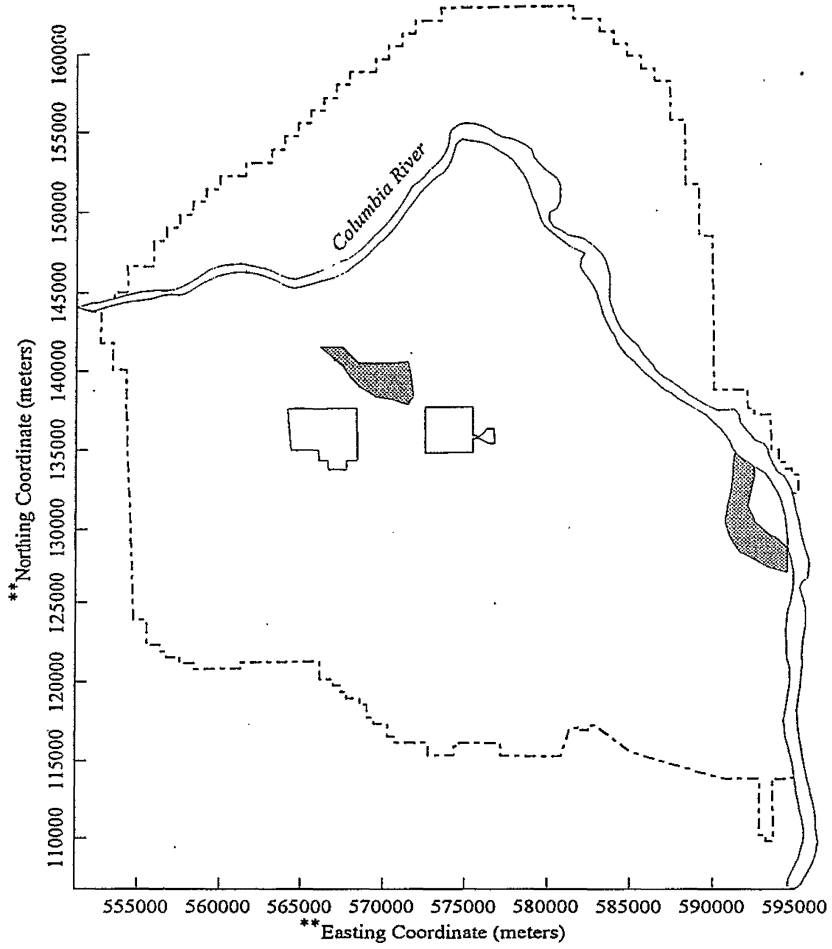


**Figure D.5.2.14 Long-Term Management Alternative, Recreational River User Scenario, Post Remediation Risk from Tank Residuals at 300 Years from Present**

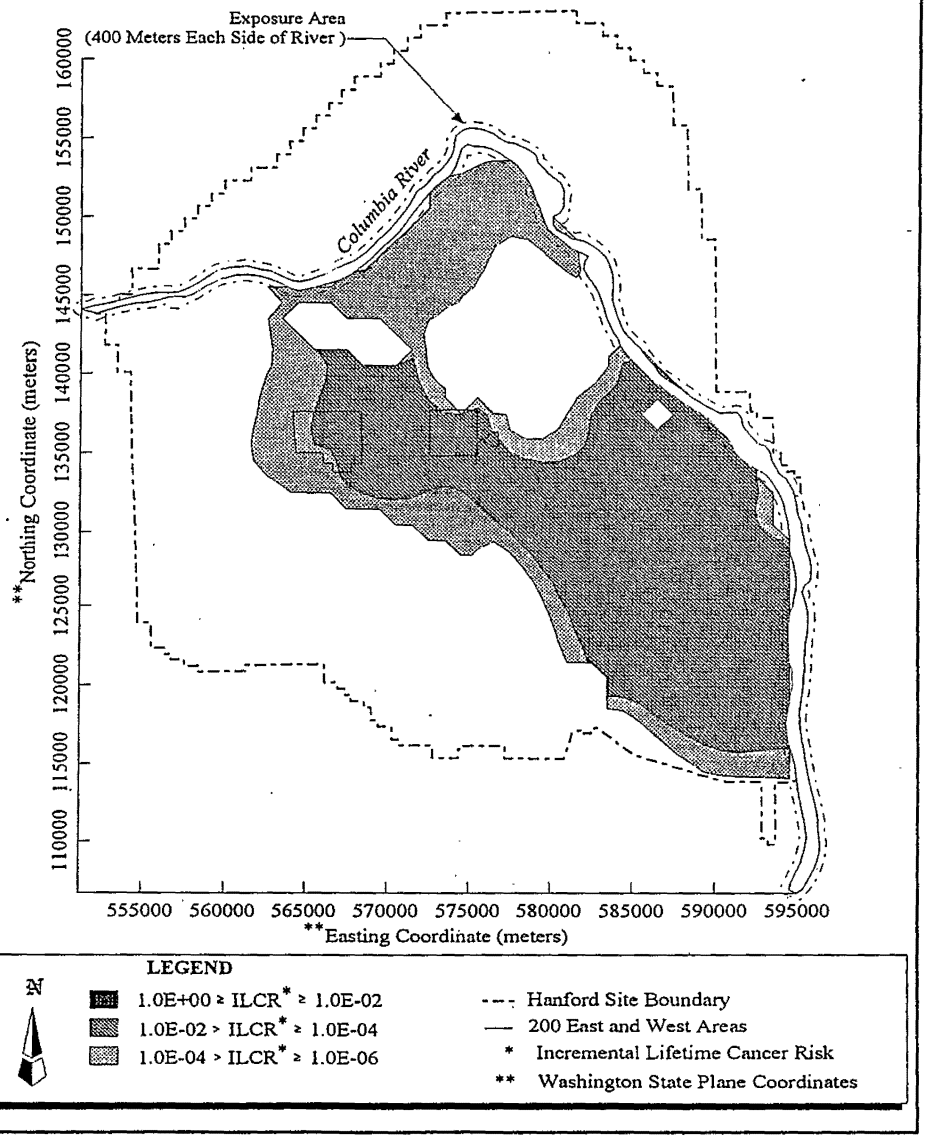


**Figure D.5.2.15 Long-Term Management Alternative, Recreational River User Scenario, Post Remediation Risk from Tank Residuals at 500 Years from Present**

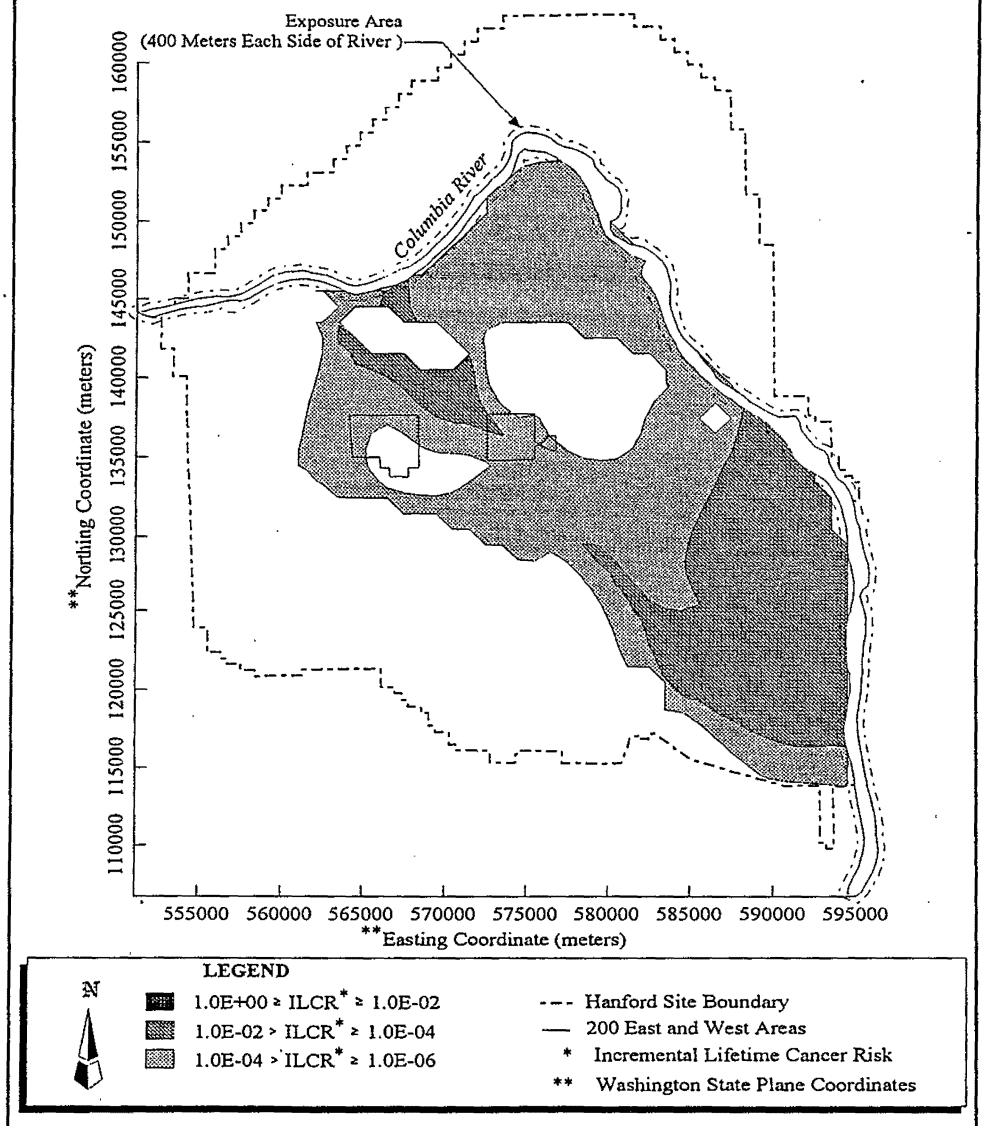


**Figure D.5.2.16 Long-Term Management Alternative, Recreational River User Scenario, Post Remediation Risk from Tank Residuals at 2,500 Years from Present**

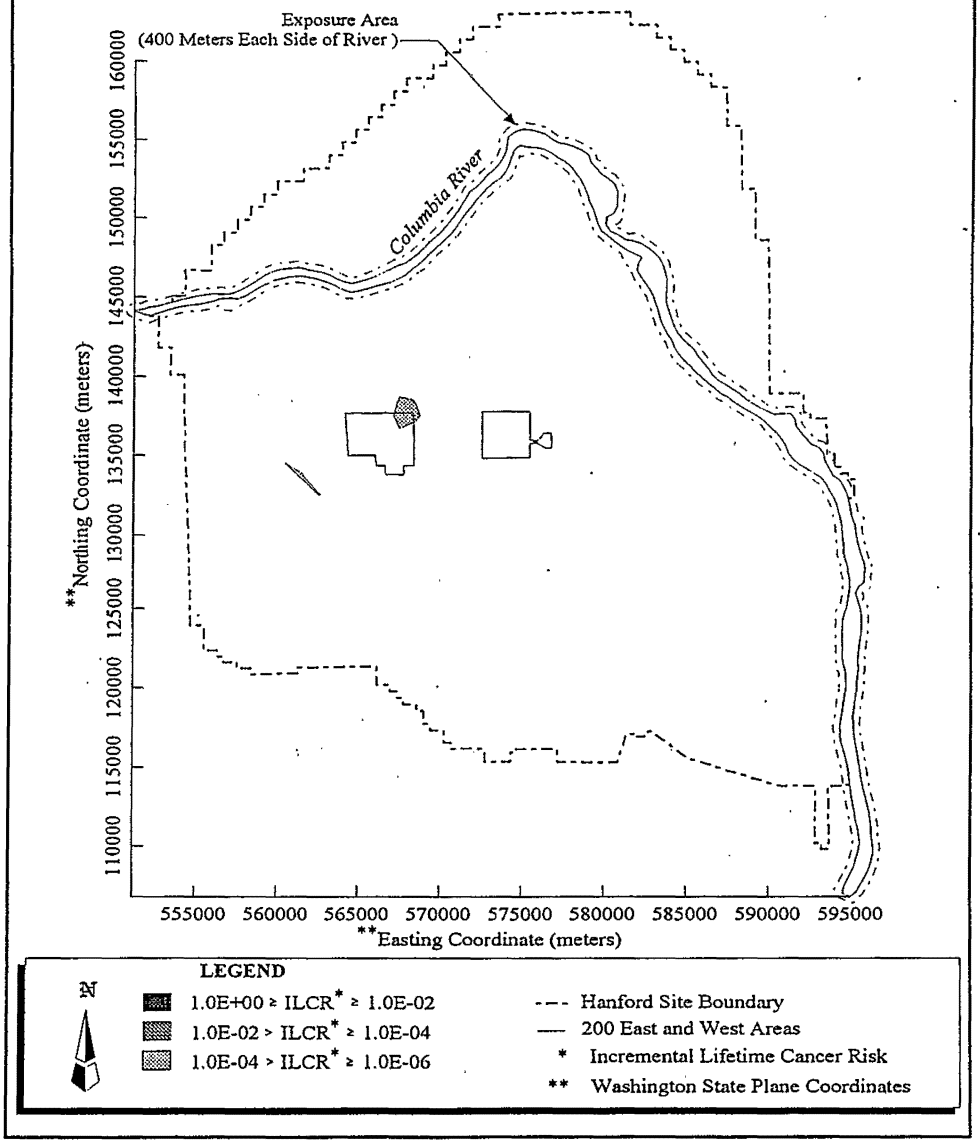


**Figure D.5.2.17 Long-Term Management Alternative, Native American Scenario, Post Remediation Hazard Index from Tank Residuals at 300 Years from Present**

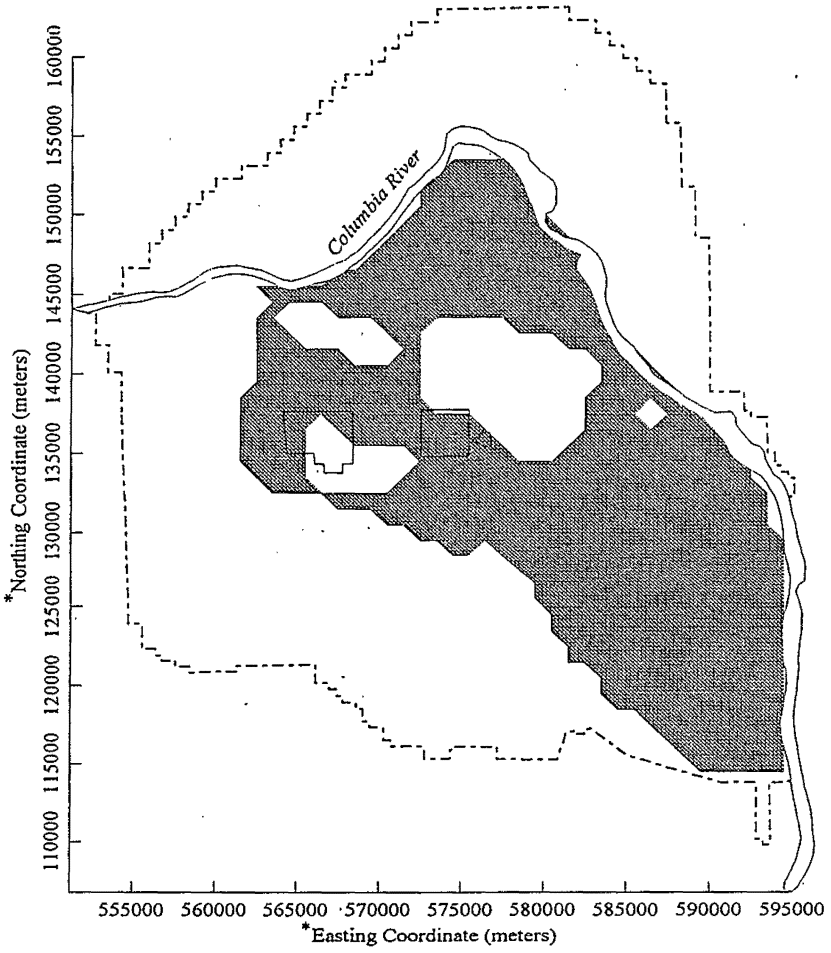


**Figure D.5.2.18 Long-Term Management Alternative, Native American Scenario, Post Remediation Hazard Index from Tank Residuals at 500 Years from Present**

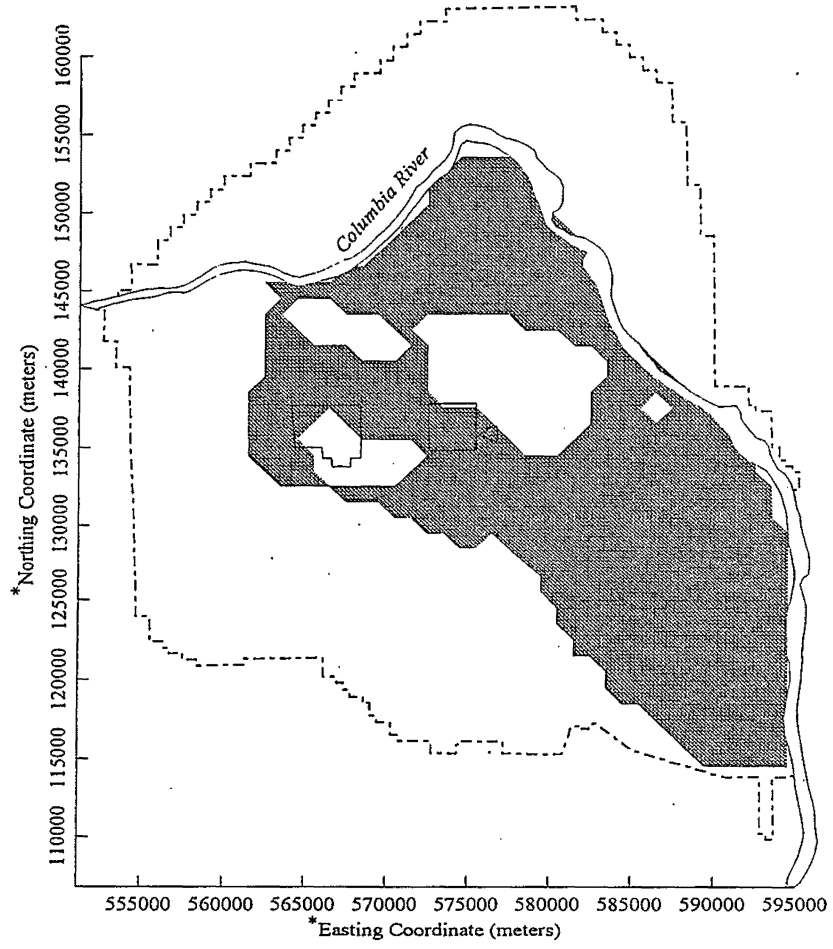


**Figure D.5.2.19 Long-Term Management Alternative, Native American Scenario, Post Remediation Hazard Index from Tank Residuals at 2,500 Years from Present**

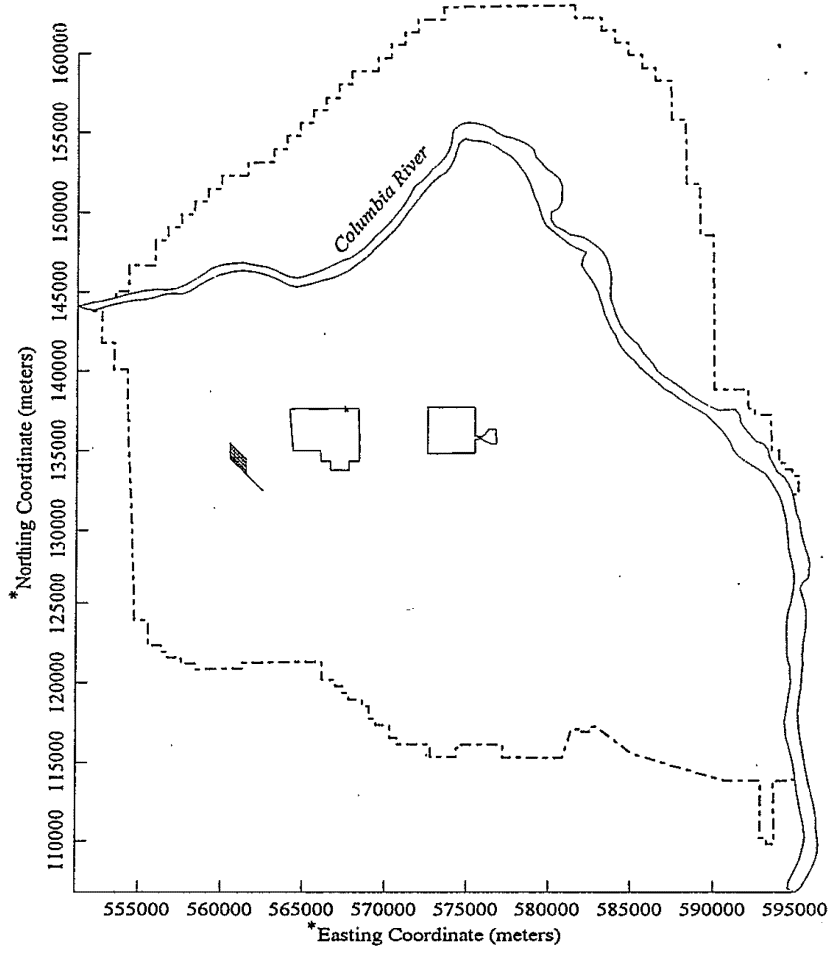


**Figure D.5.2.20 Long-Term Management Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from Tank Residuals at 300 Years from Present**

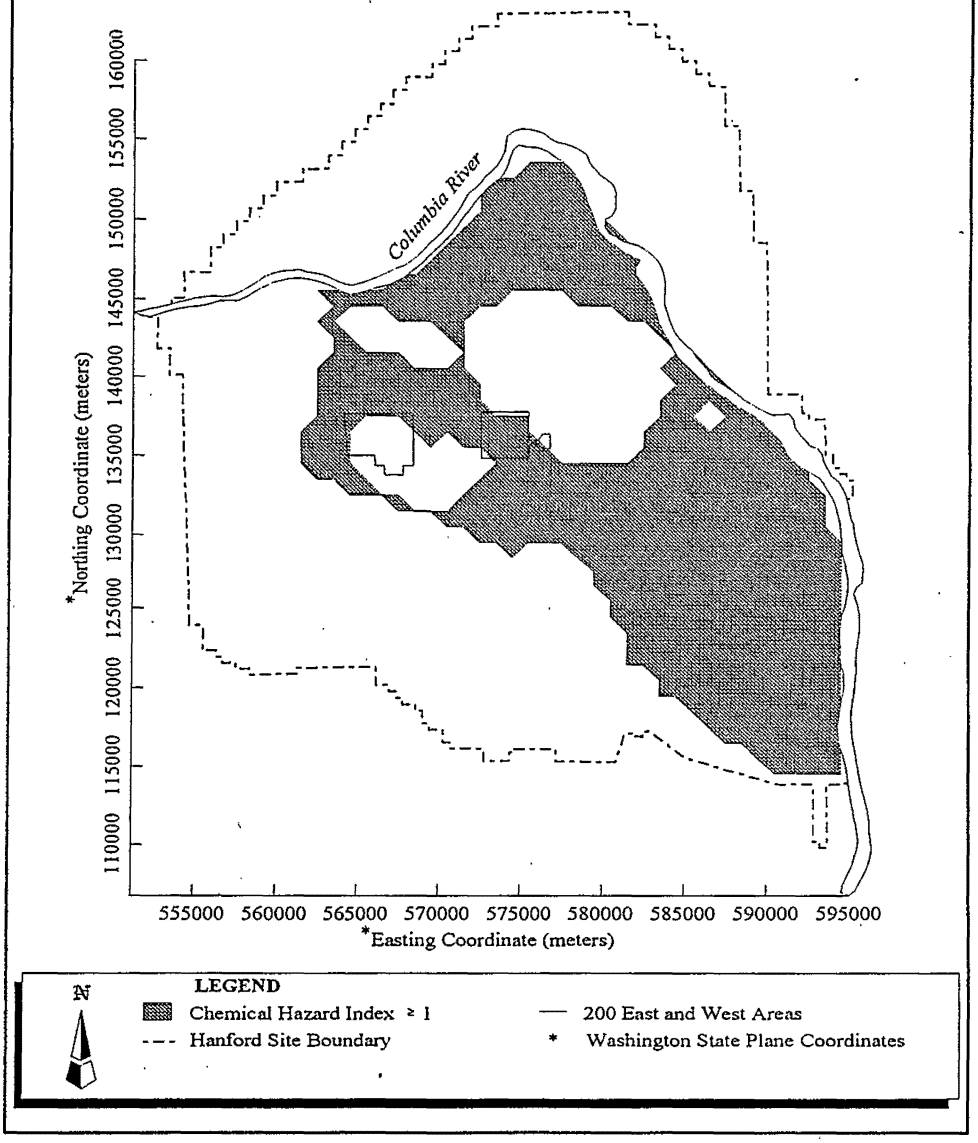


**Figure D.5.2.21 Long-Term Management Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from Tank Residuals at 500 Years from Present**

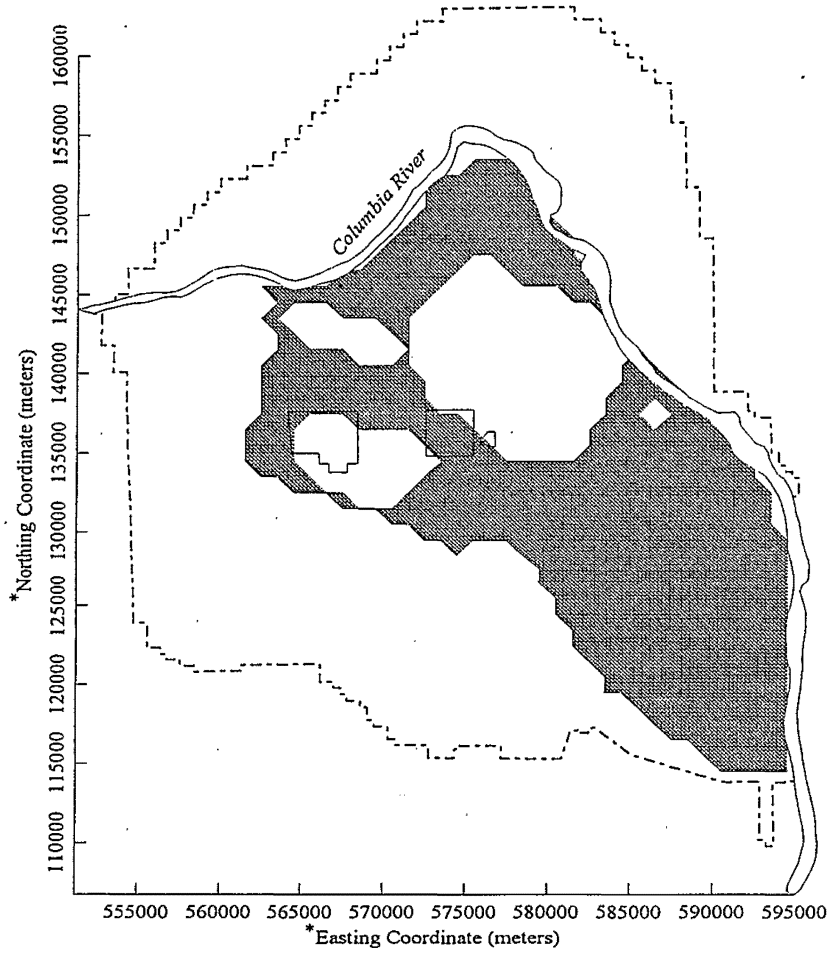


**Figure D.5.2.22 Long-Term Management Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from Tank Residuals at 2,500 Years from Present**

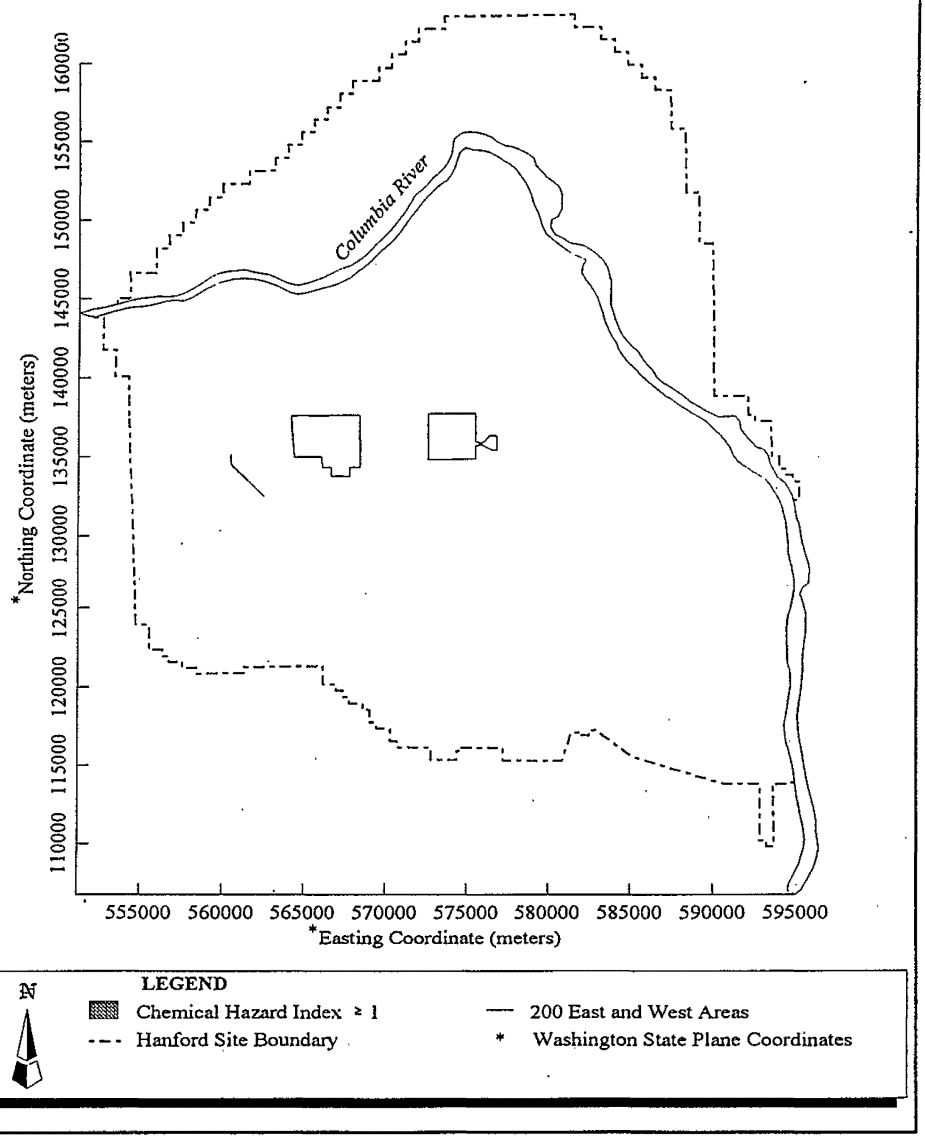


**Figure D.5.2.23 Long-Term Management Alternative, Industrial Worker Scenario, Post Remediation Hazard Index from Tank Residuals at 300 Years from Present**

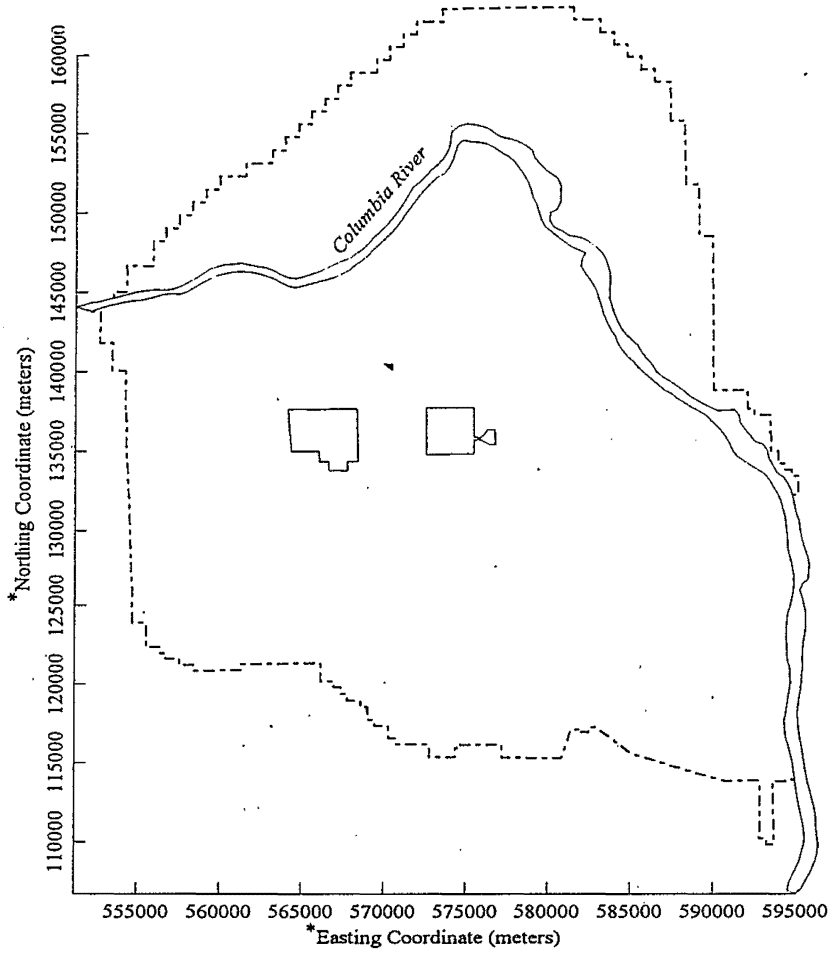


**Figure D.5.3.1 In Situ Fill and Cap Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

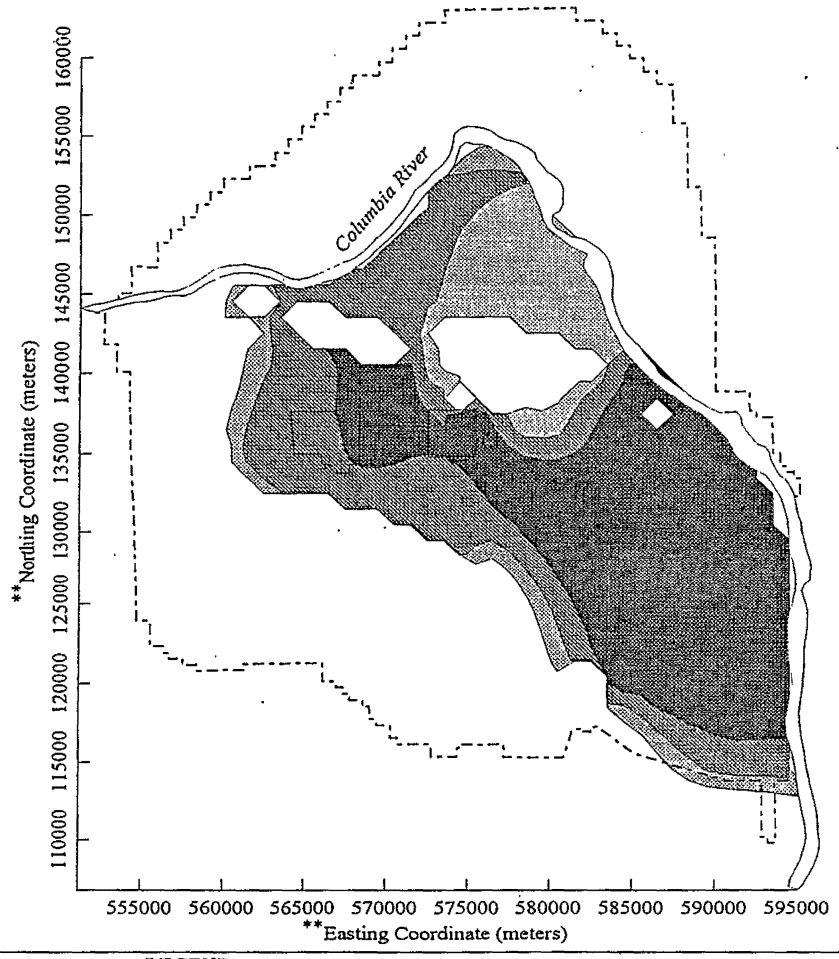


**Figure D.5.3.2 In Situ Fill and Cap Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals at 10,000 Years from Present**

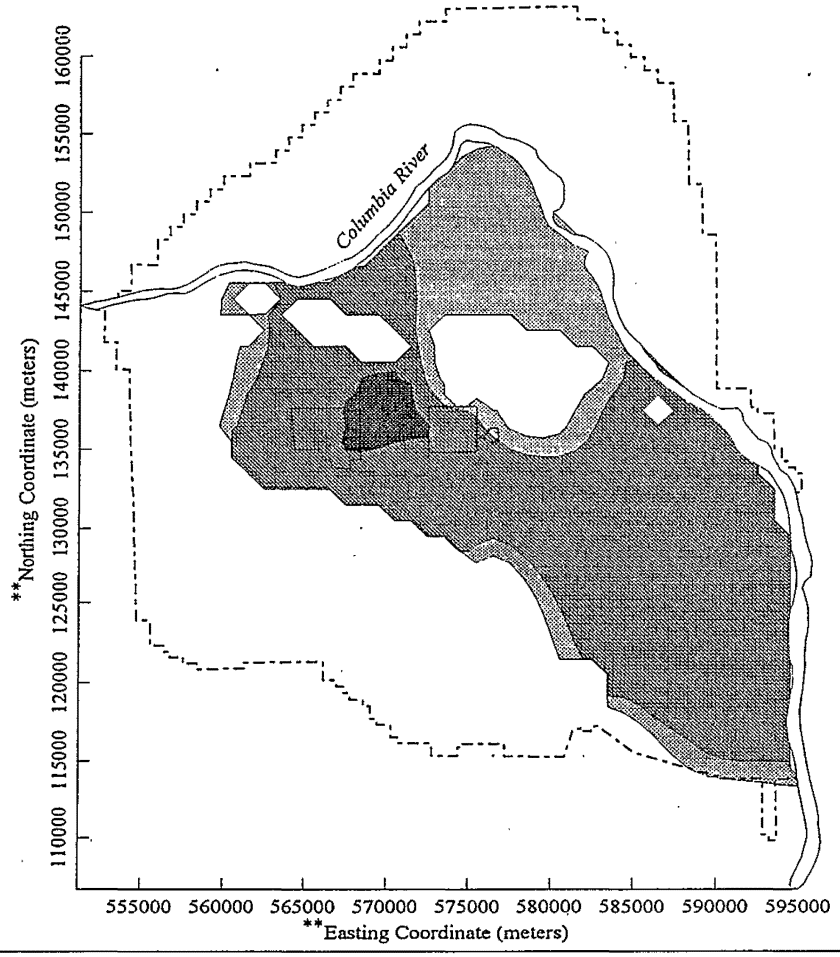


**Figure D.5.3.3 In Situ Fill and Cap Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

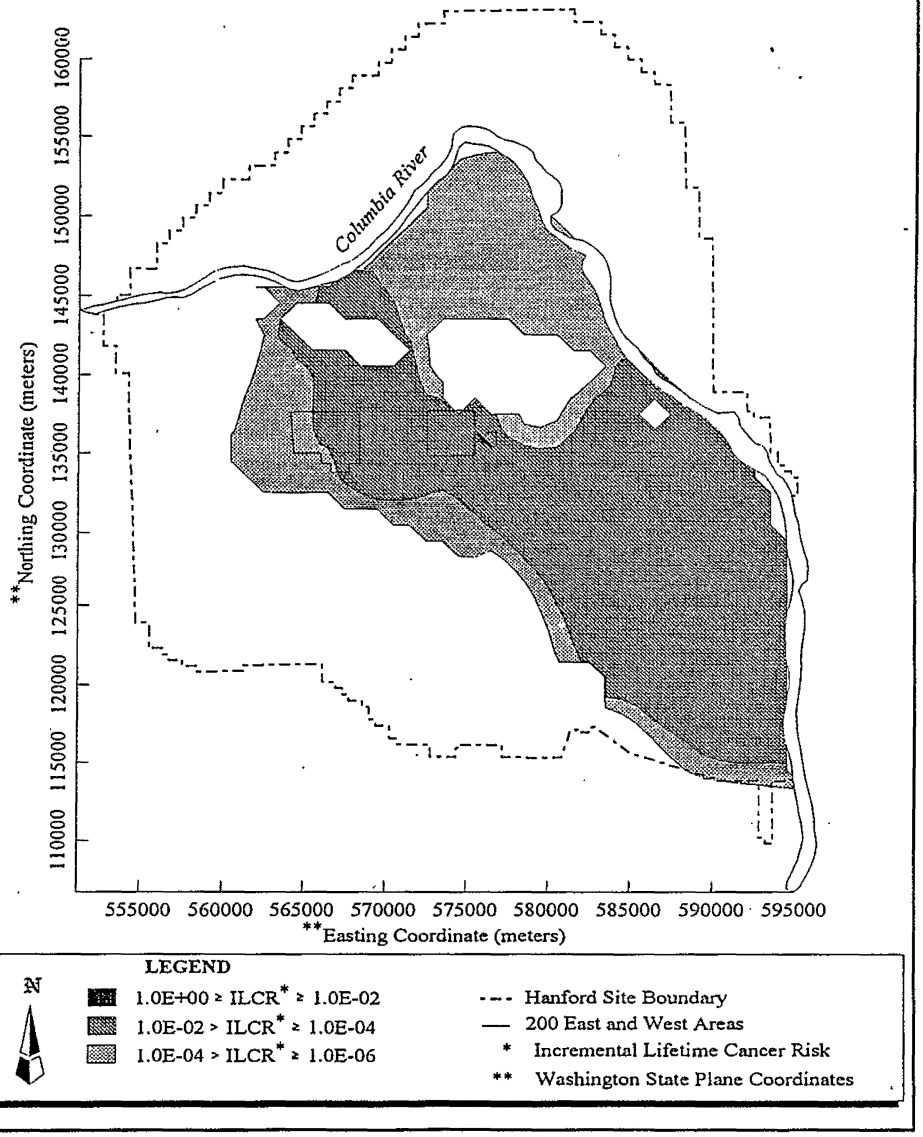


**Figure D.5.3.4 In Situ Fill and Cap Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals at 10,000 Years from Present**

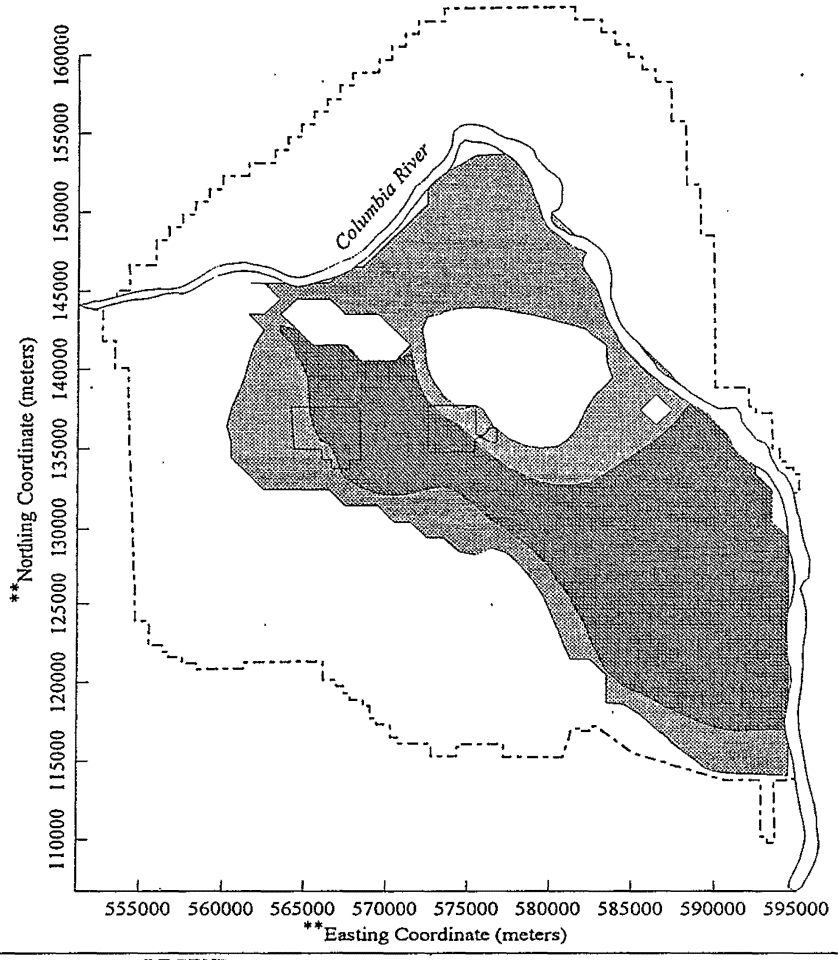


**Figure D.5.3.5 In Situ Fill and Cap Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

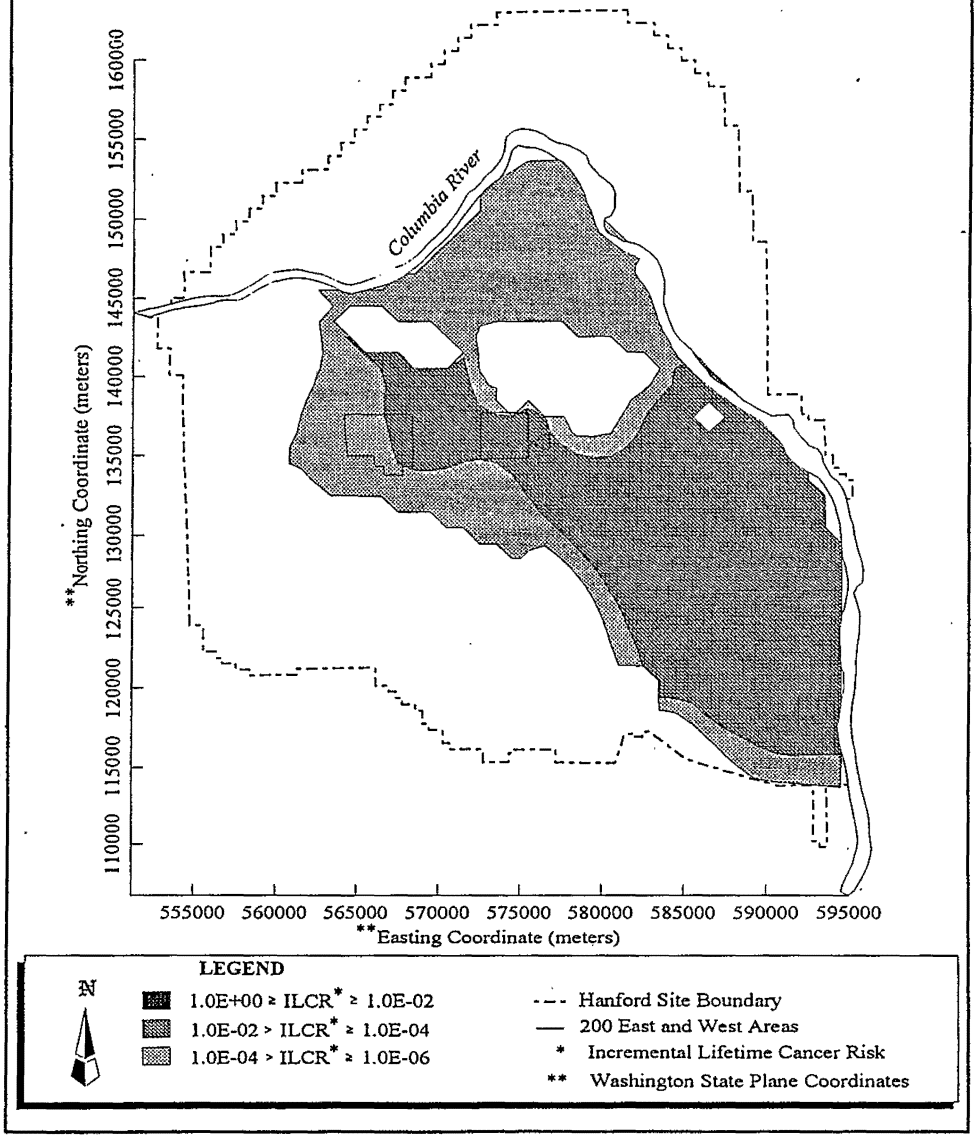


**Figure D.5.3.6 In Situ Fill and Cap Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals at 10,000 Years from Present**

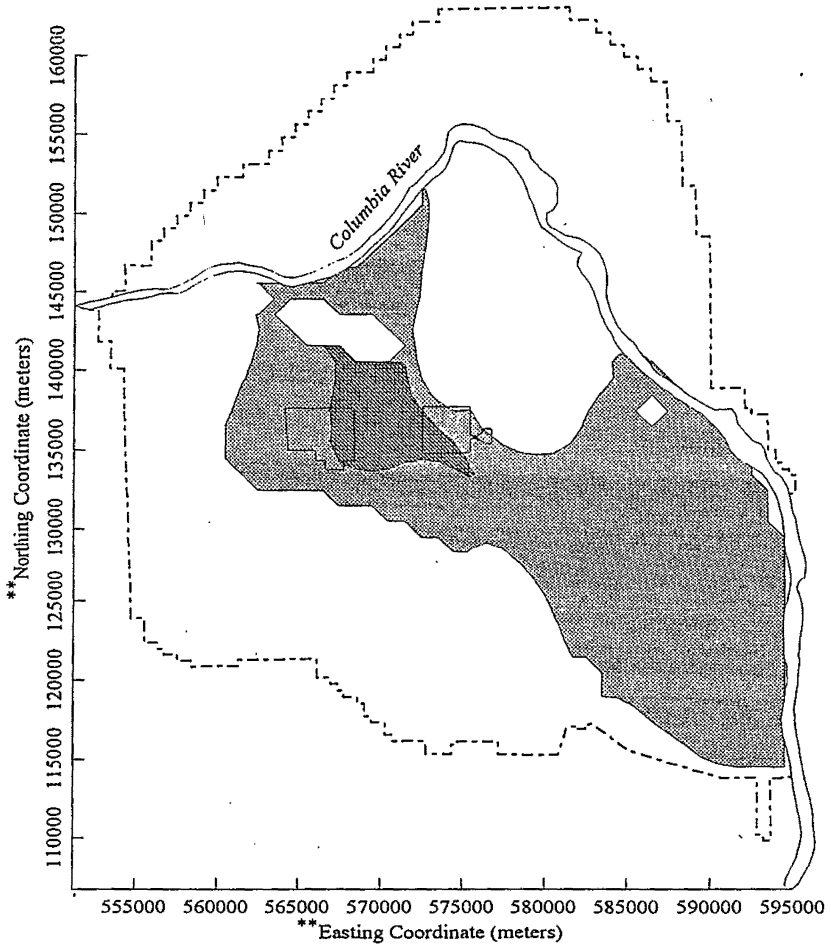


**Figure D.5.3.7 In Situ Fill and Cap Alternative, Recreational River User Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

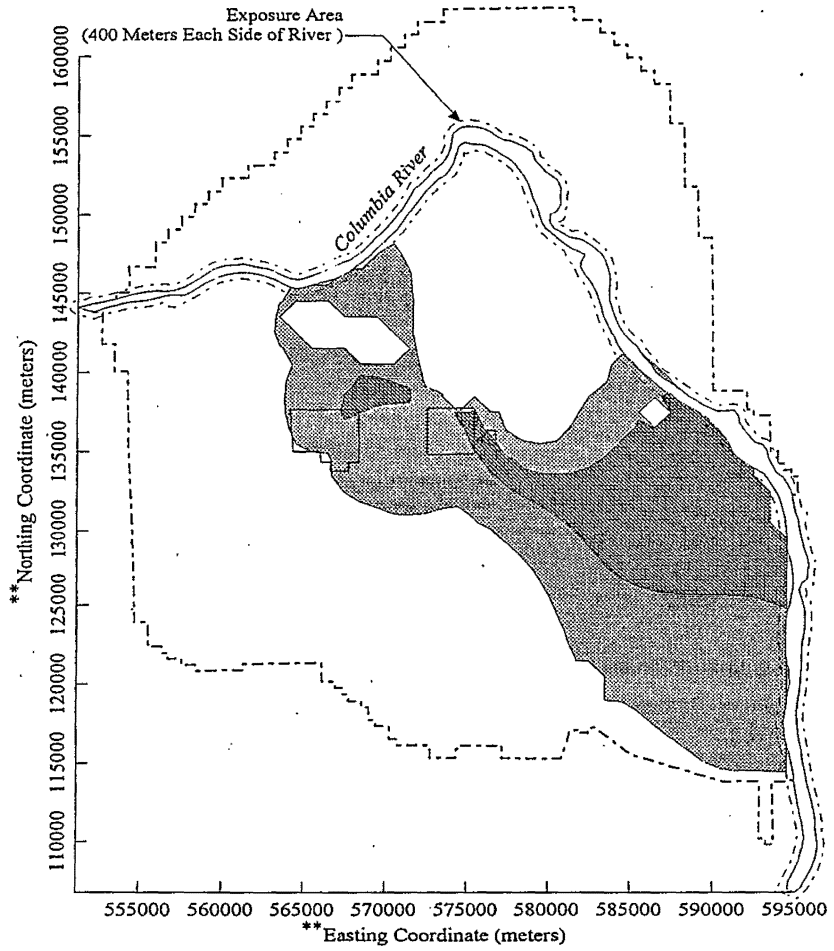


**Figure D.5.3.8 In Situ Fill and Cap Alternative, Recreational River User Scenario, Post Remediation Risk from Tank Residuals at 10,000 Years from Present**

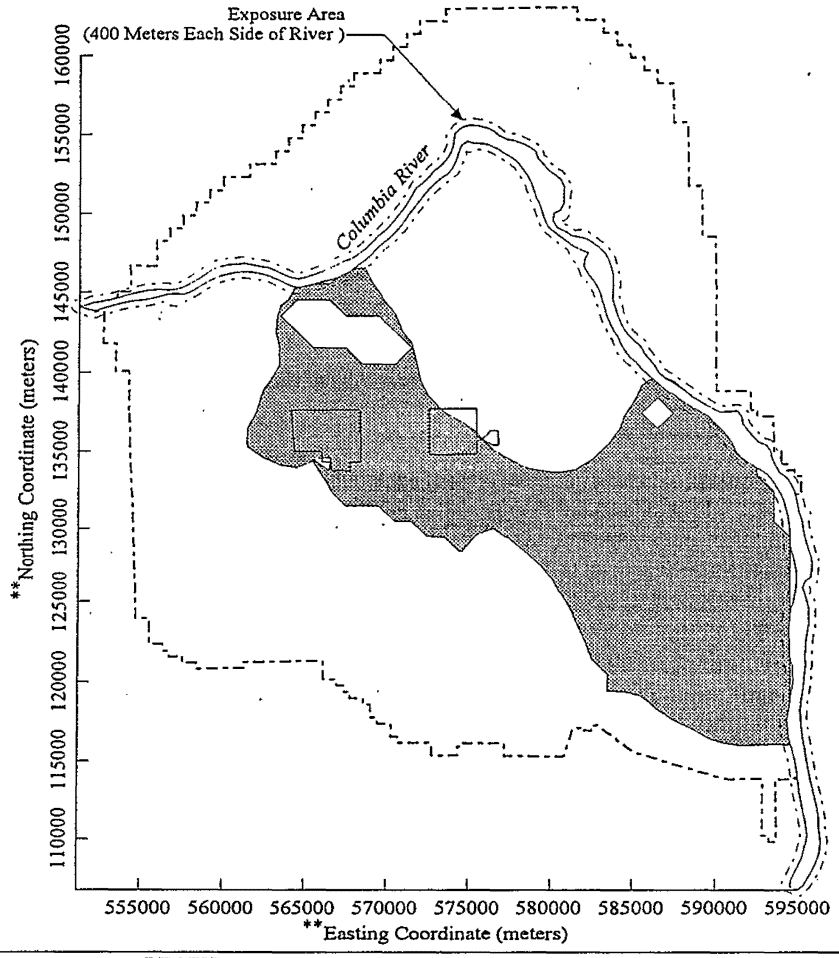


**Figure D.5.3.9 In Situ Fill and Cap Alternative, Native American Scenario, Post Remediation Hazard Index from Tank Residuals at 5,000 Years from Present**

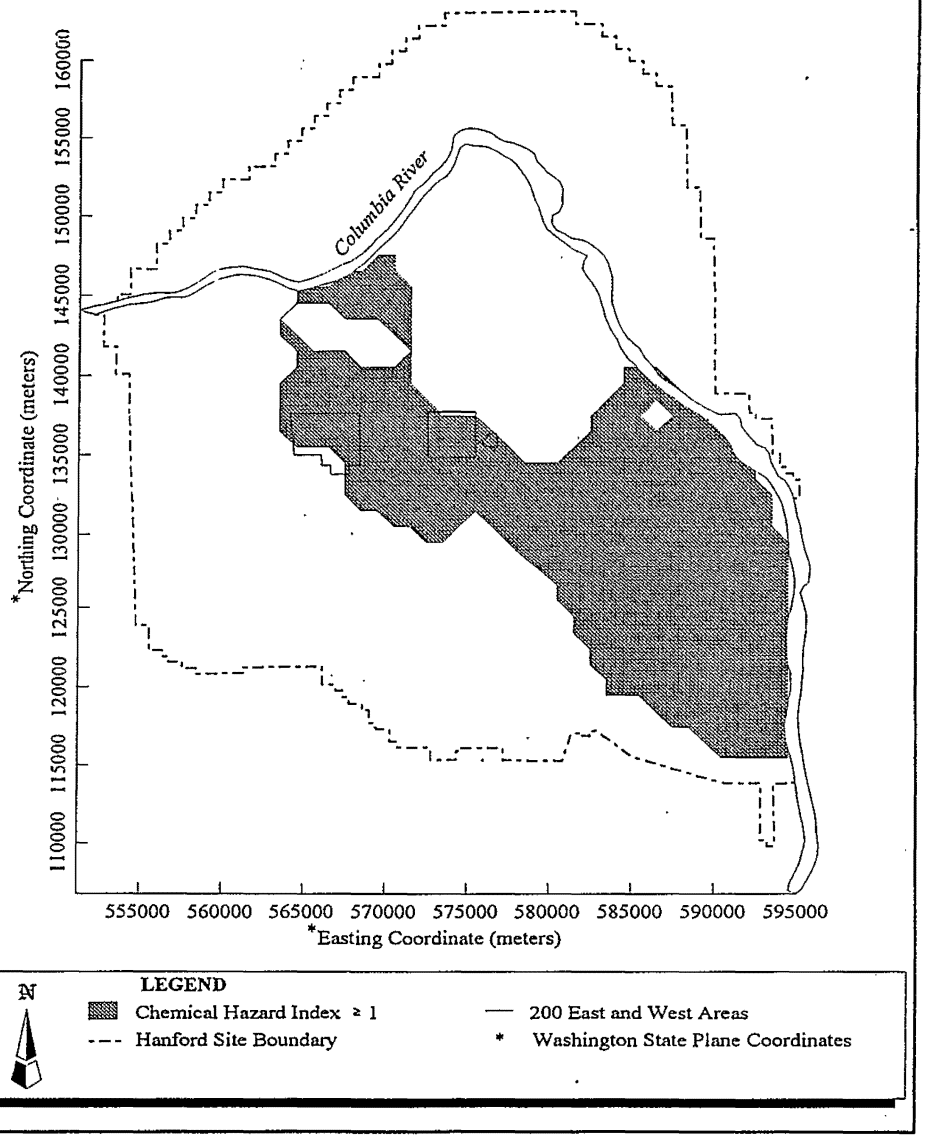


**Figure D.5.3.10 In Situ Fill and Cap Alternative, Native American Scenario, Post Remediation Hazard Index from Tank Residuals at 10,000 Years from Present**

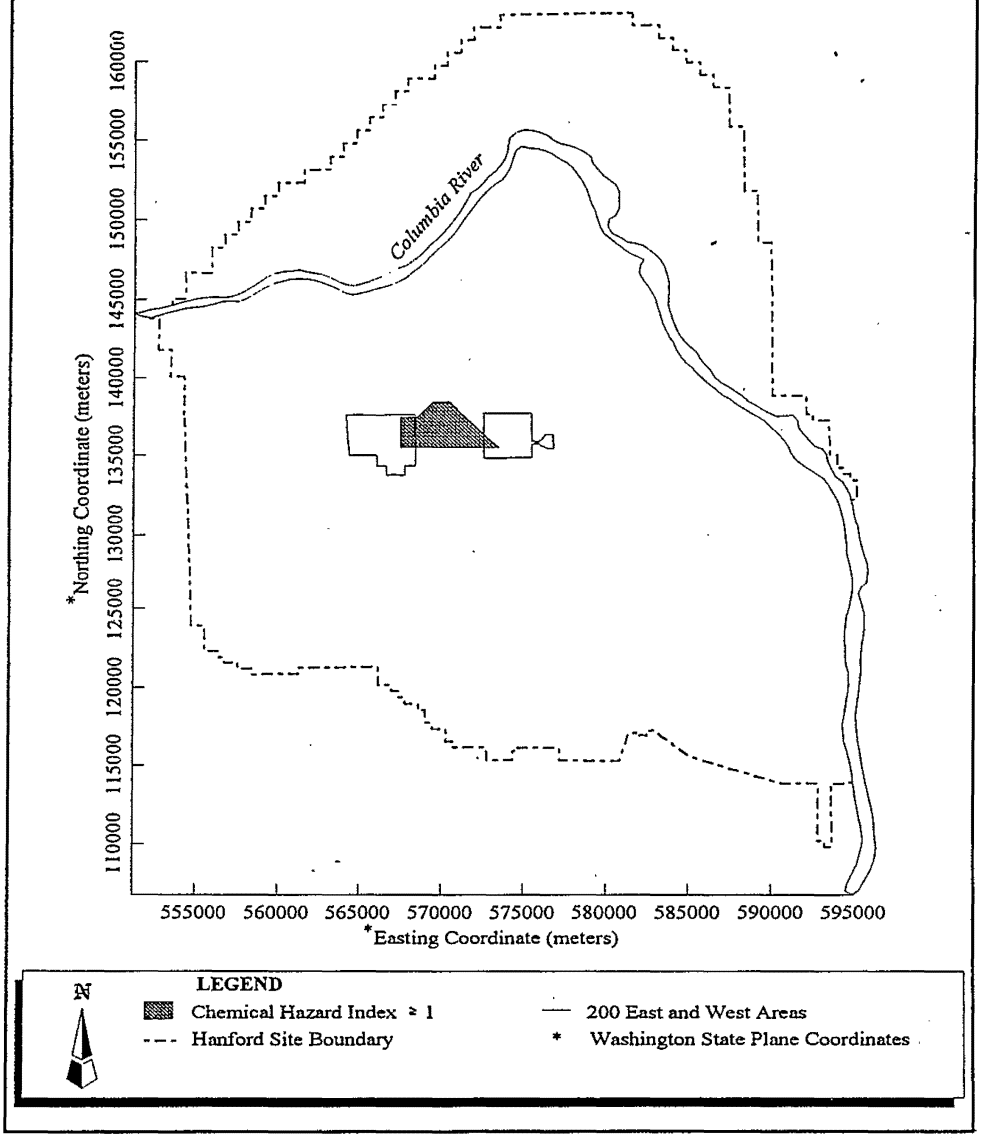


**Figure D.5.3.11 In Situ Fill and Cap Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from Tank Residuals at 5,000 Years from Present**

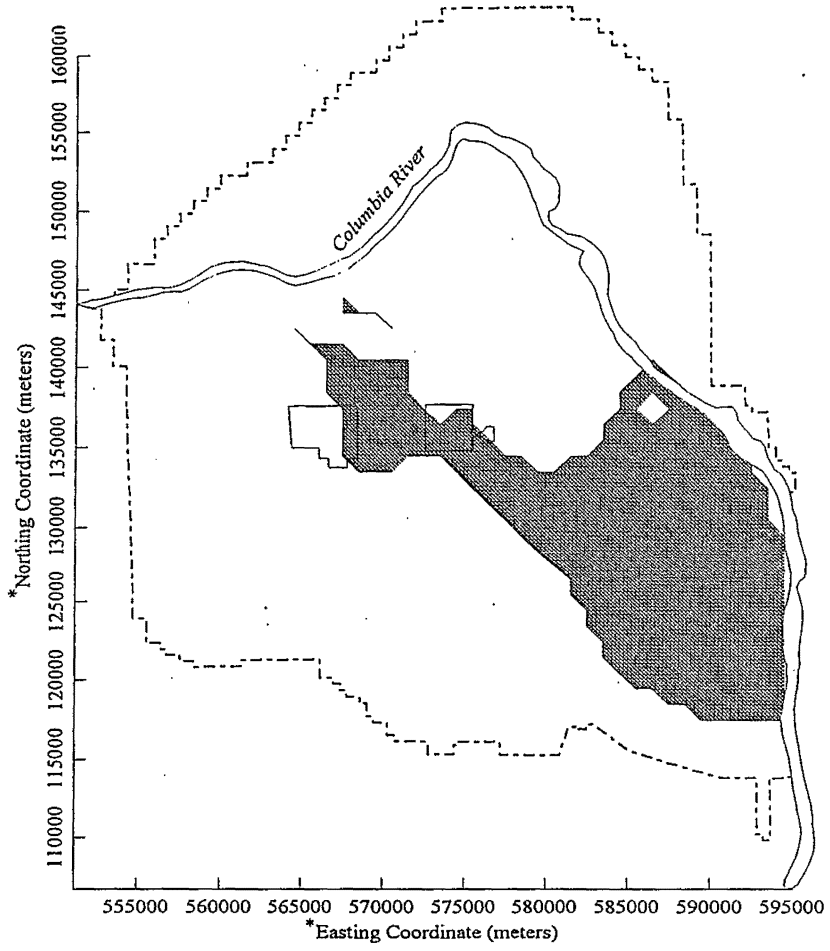


**Figure D.5.3.12 In Situ Fill and Cap Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from Tank Residuals at 10,000 Years from Present**

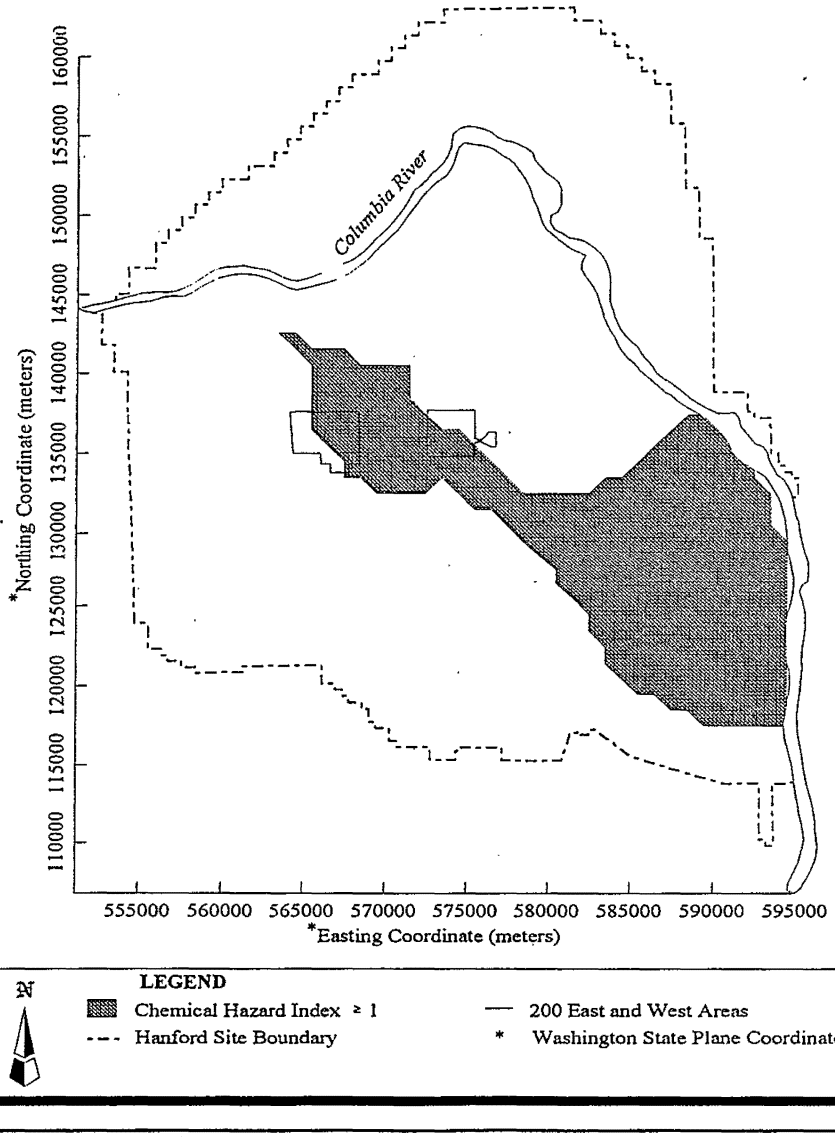


**Figure D.5.4.1 In Situ Vitrification Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

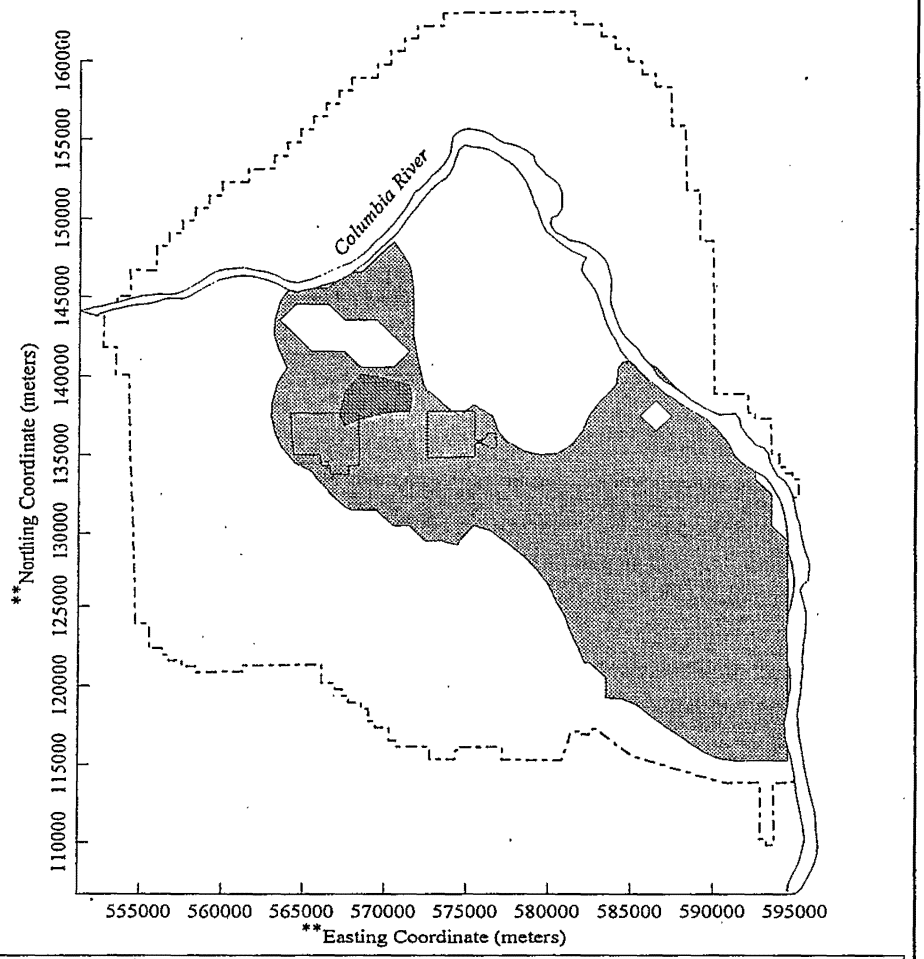


**Figure D.5.4.2 In Situ Vitrification Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals at 10,000 Years from Present**

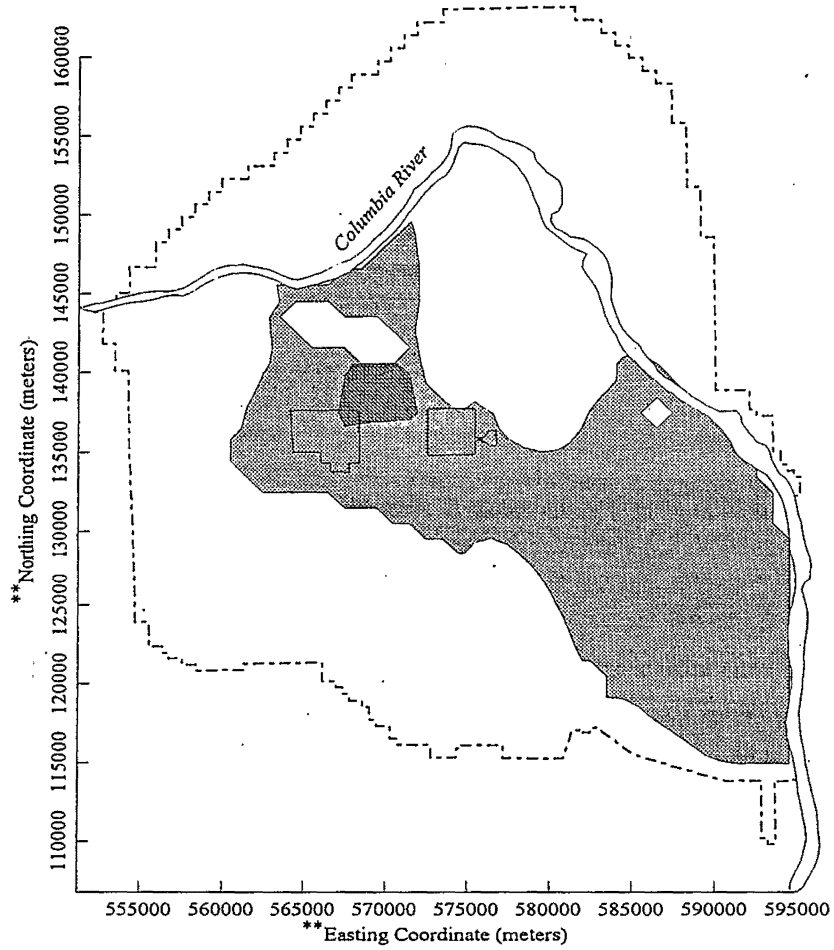


**Figure D.5.4.3 In Situ Vitrification Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

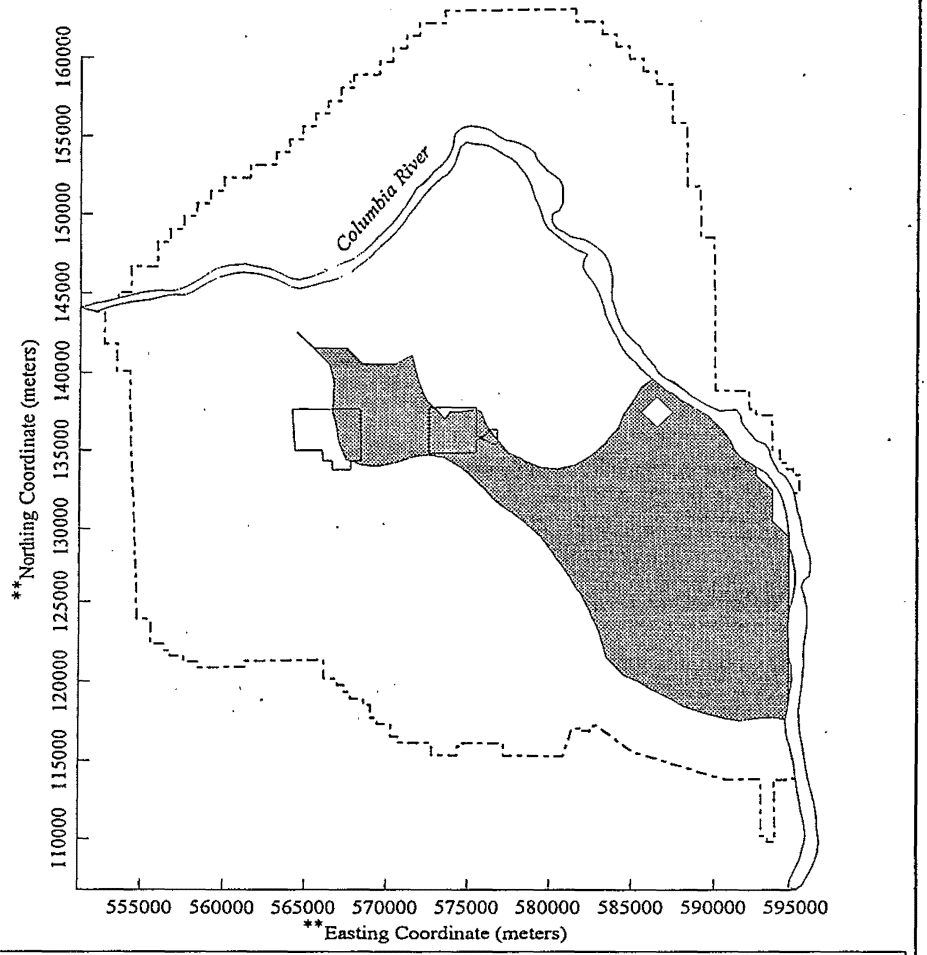


**Figure D.5.4.4 In Situ Vitrification Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals at 10,000 Years from Present**

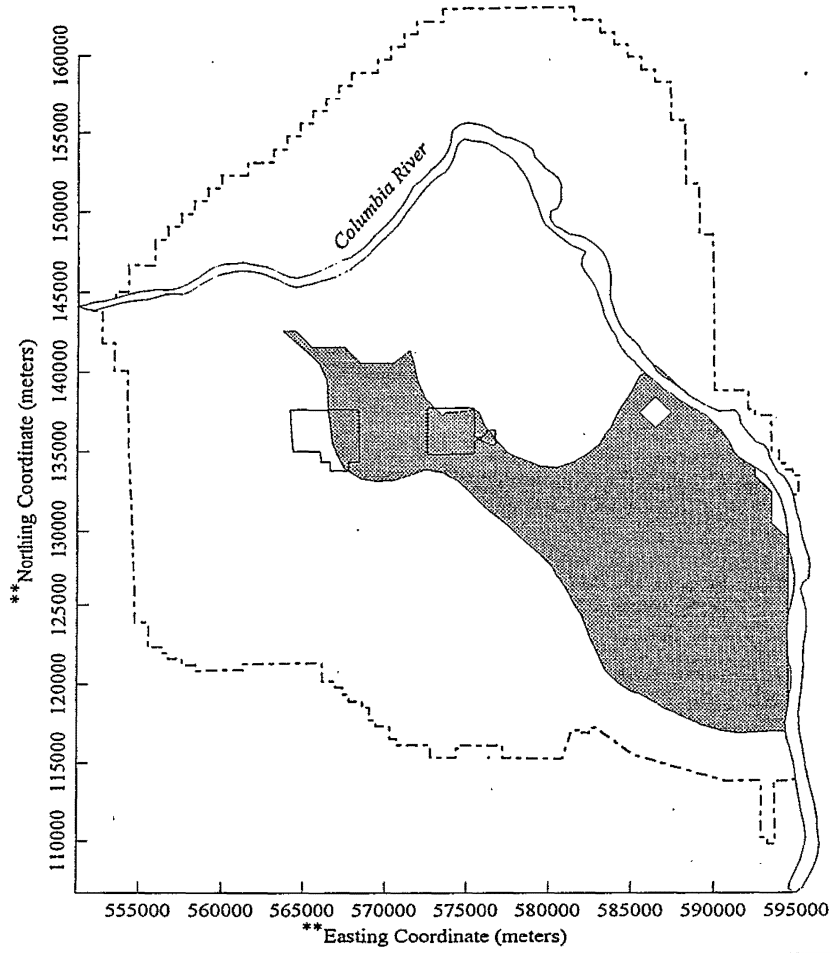


**Figure D.5.4.5 In Situ Vitrification Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

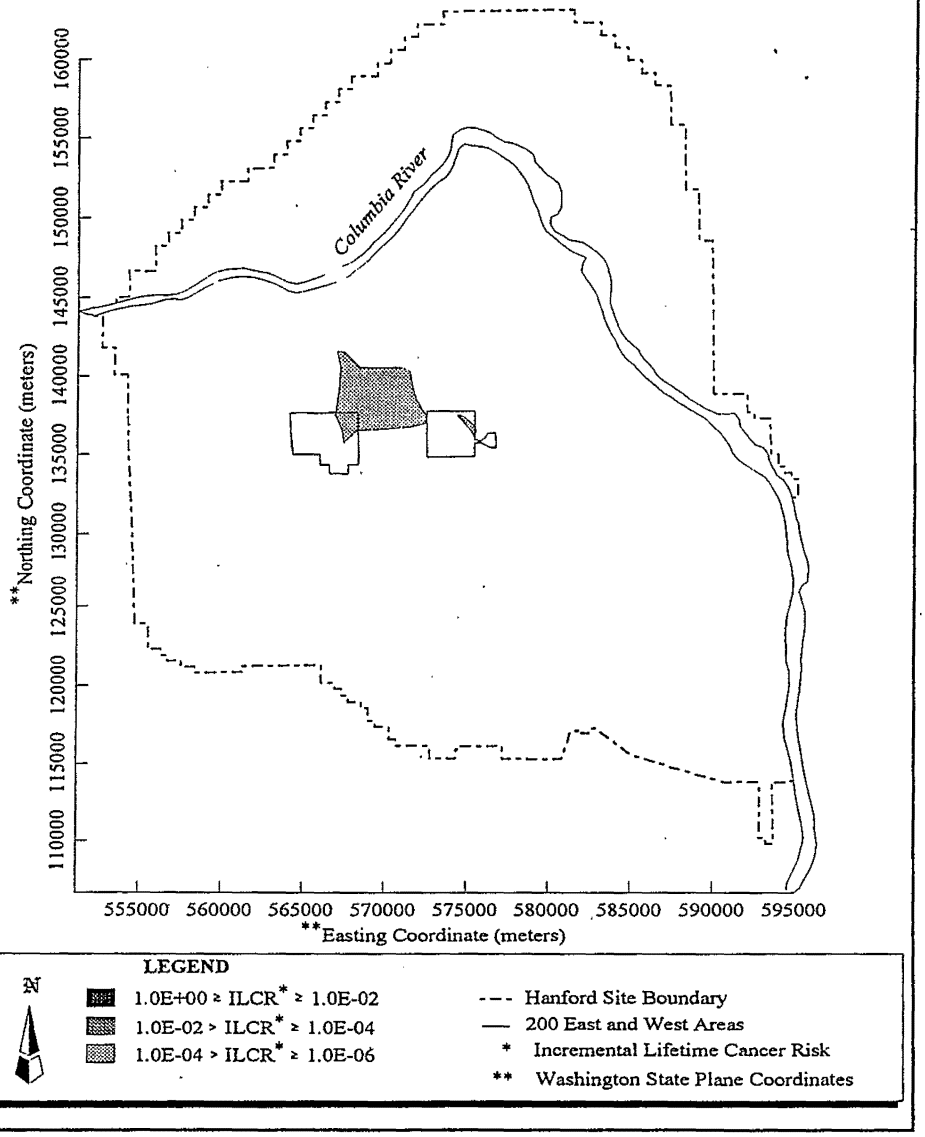


**Figure D.5.4.6 In Situ Vitrification Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals at 10,000 Years from Present**

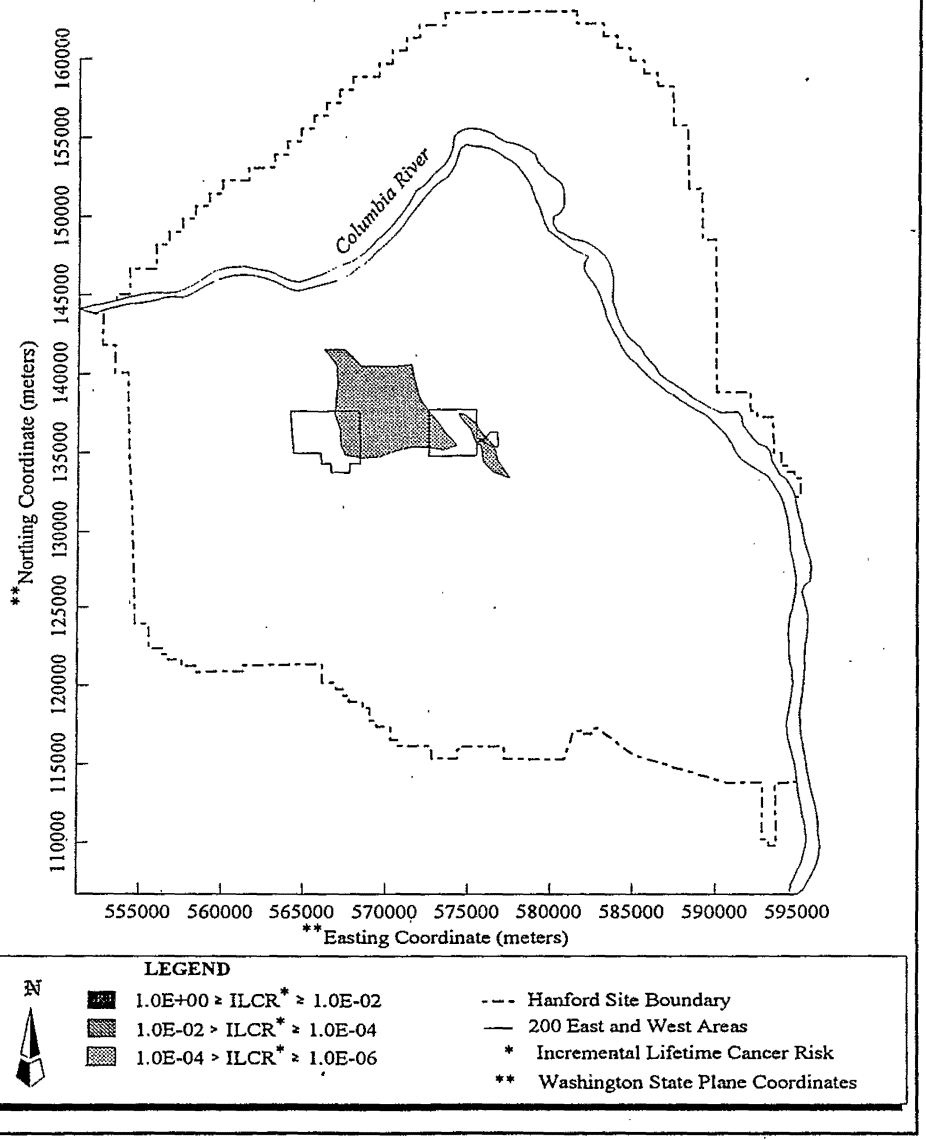


**Figure D.5.5.1 Ex Situ Intermediate Separations Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals at 2,500 Years from Present**

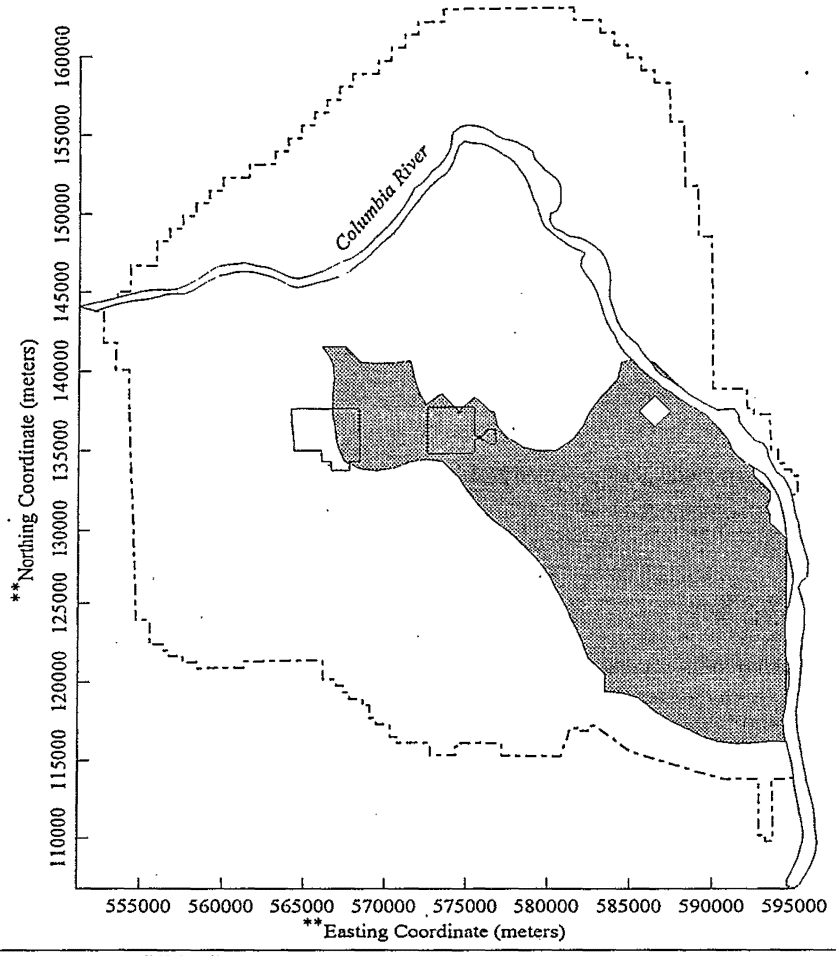


**Figure D.5.5.2 Ex Situ Intermediate Separations Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

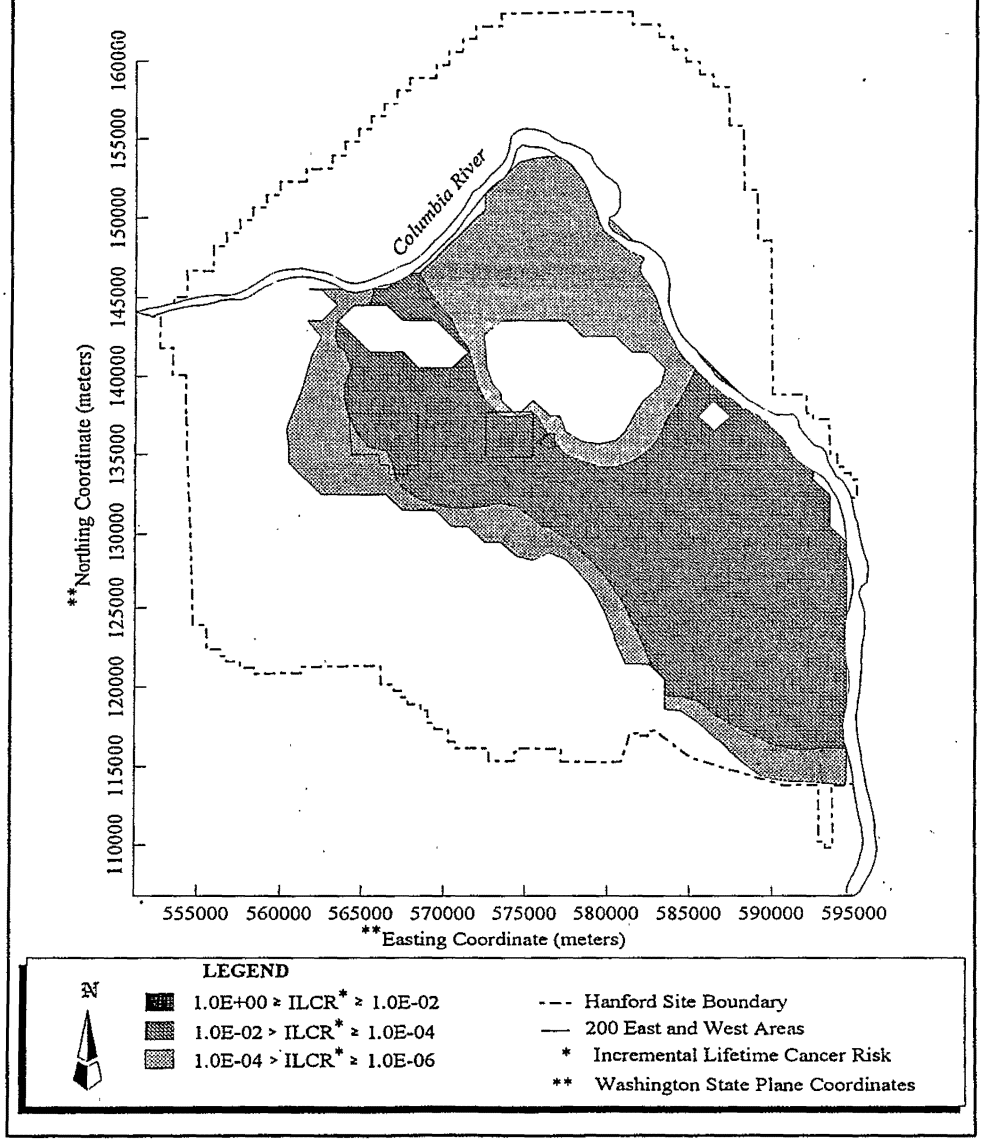


**Figure D.5.5.3 Ex Situ Intermediate Separations Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals at 2,500 Years from Present**

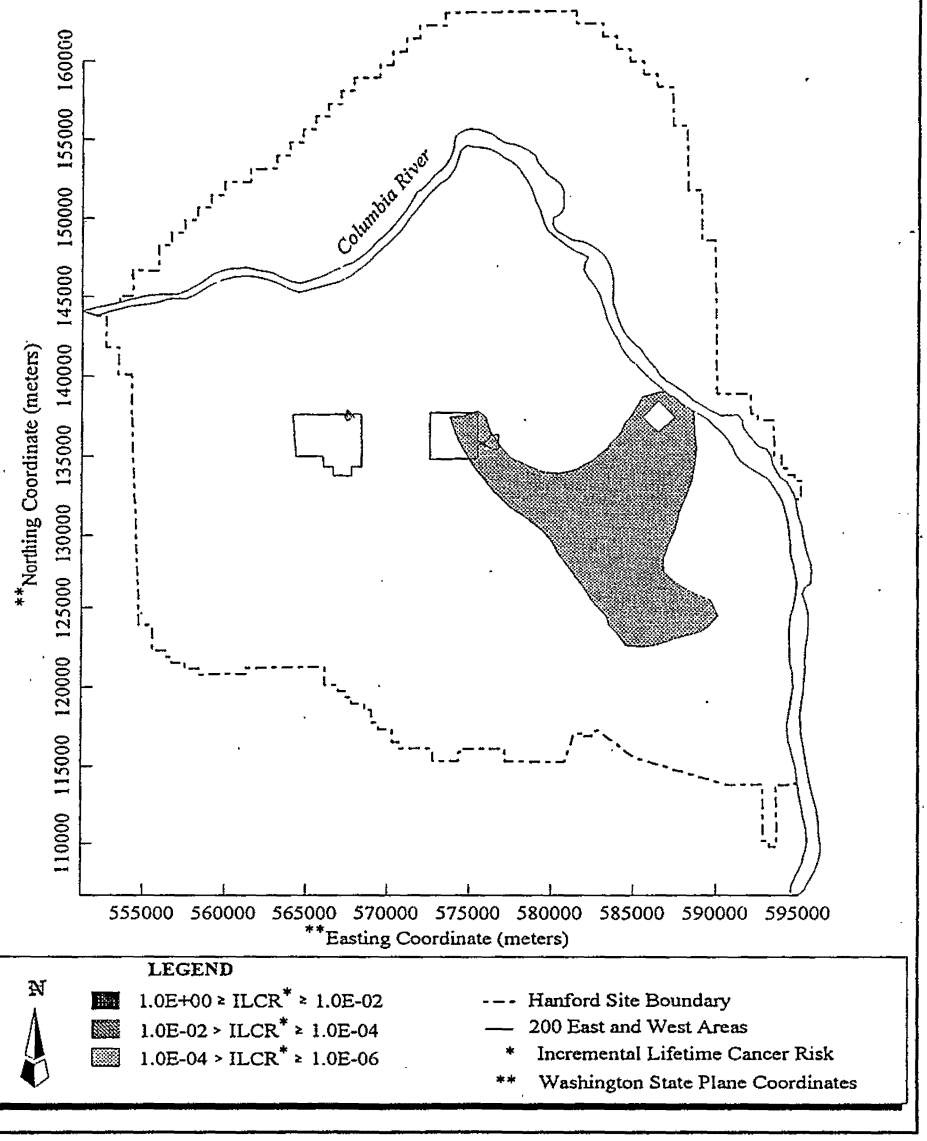


**Figure D.5.5.4 Ex Situ Intermediate Separations Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

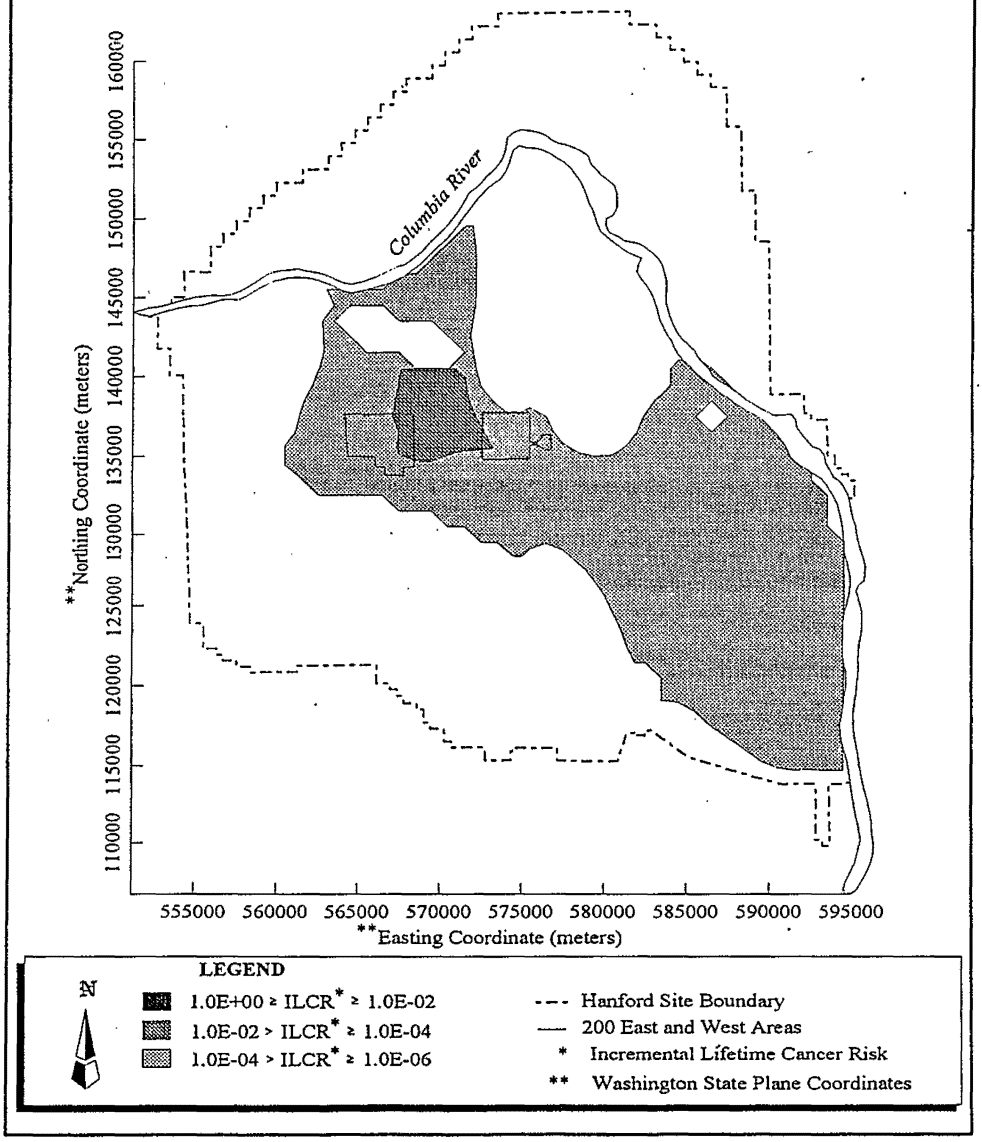


**Figure D.5.5.5 Ex Situ Intermediate Separations Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals at 2,500 Years from Present**

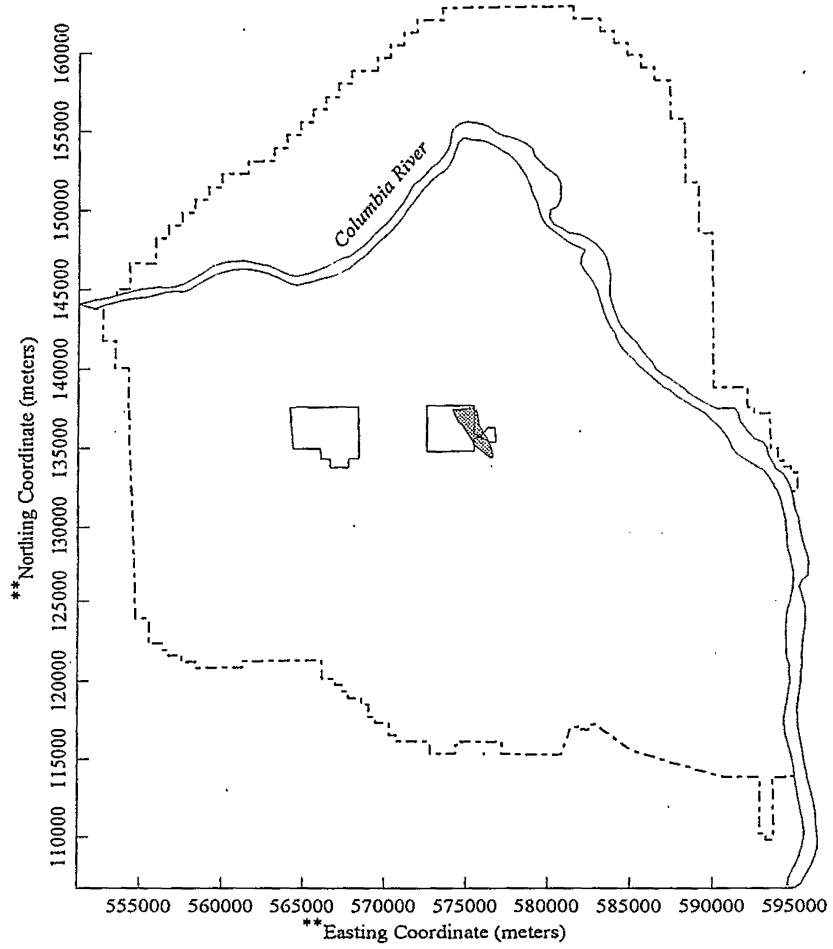


**Figure D.5.5.6 Ex Situ Intermediate Separations Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

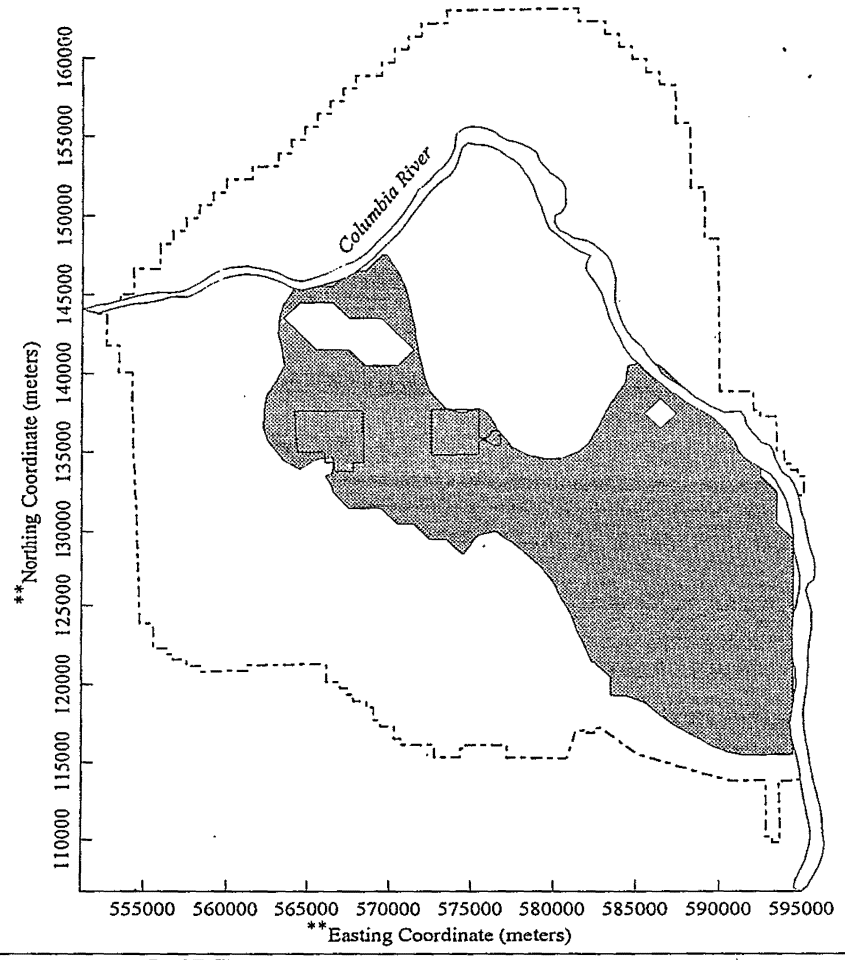


**Figure D.5.5.7 Ex Situ Intermediate Separations Alternative, Recreational River User Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

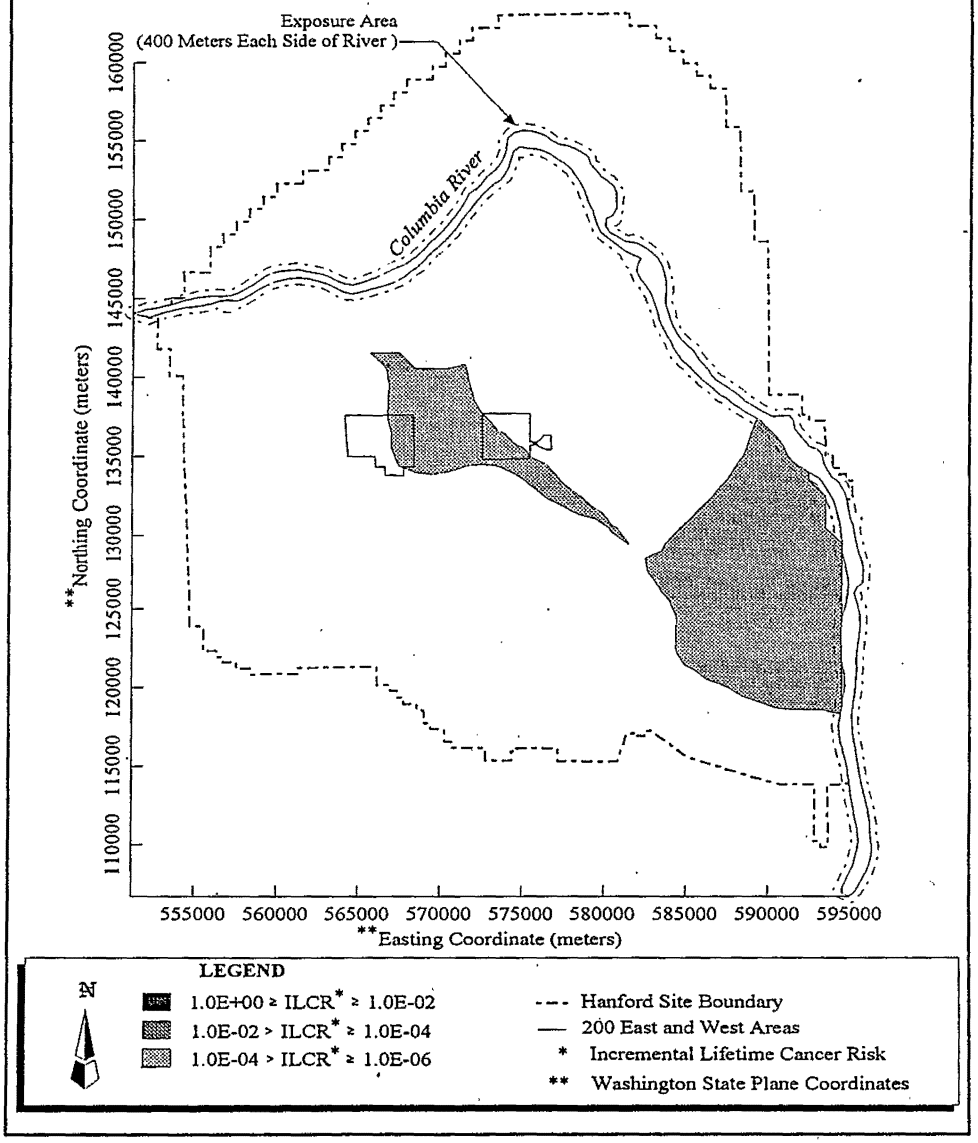


**Figure D.5.5.8 Ex Situ Intermediate Separations Alternative, Native American Scenario, Post Remediation Hazard Index from Tank Residuals at 5,000 Years from Present**

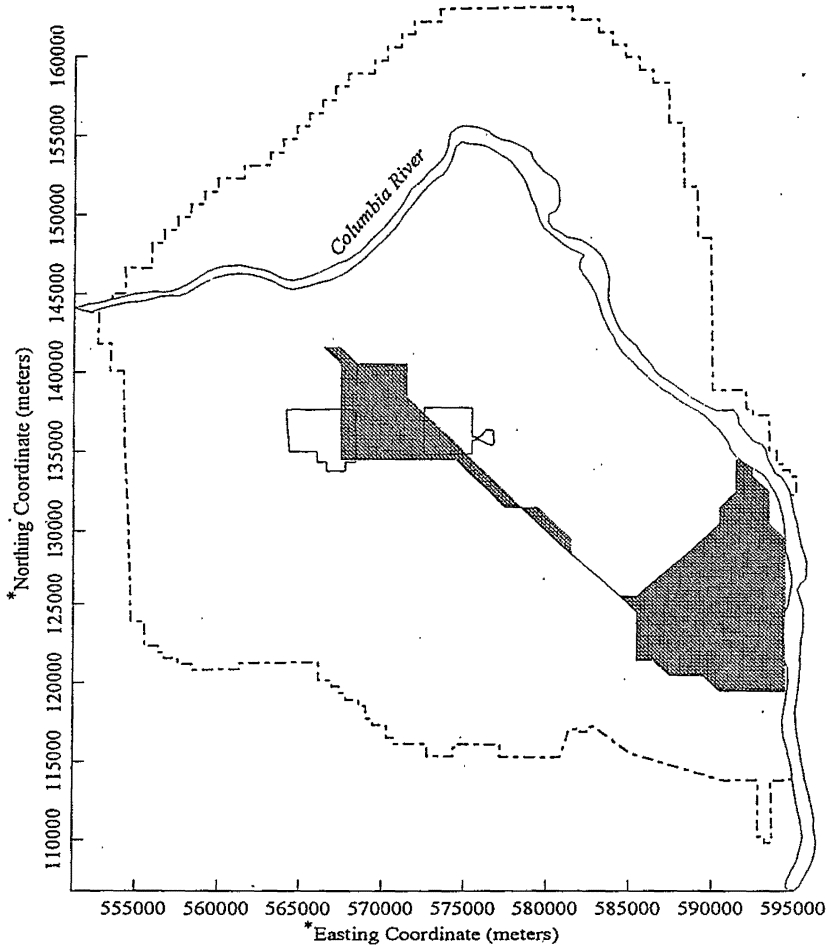


**Figure D.5.5.9 Ex Situ Intermediate Separations Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from Tank Residuals at 5,000 Years from Present**

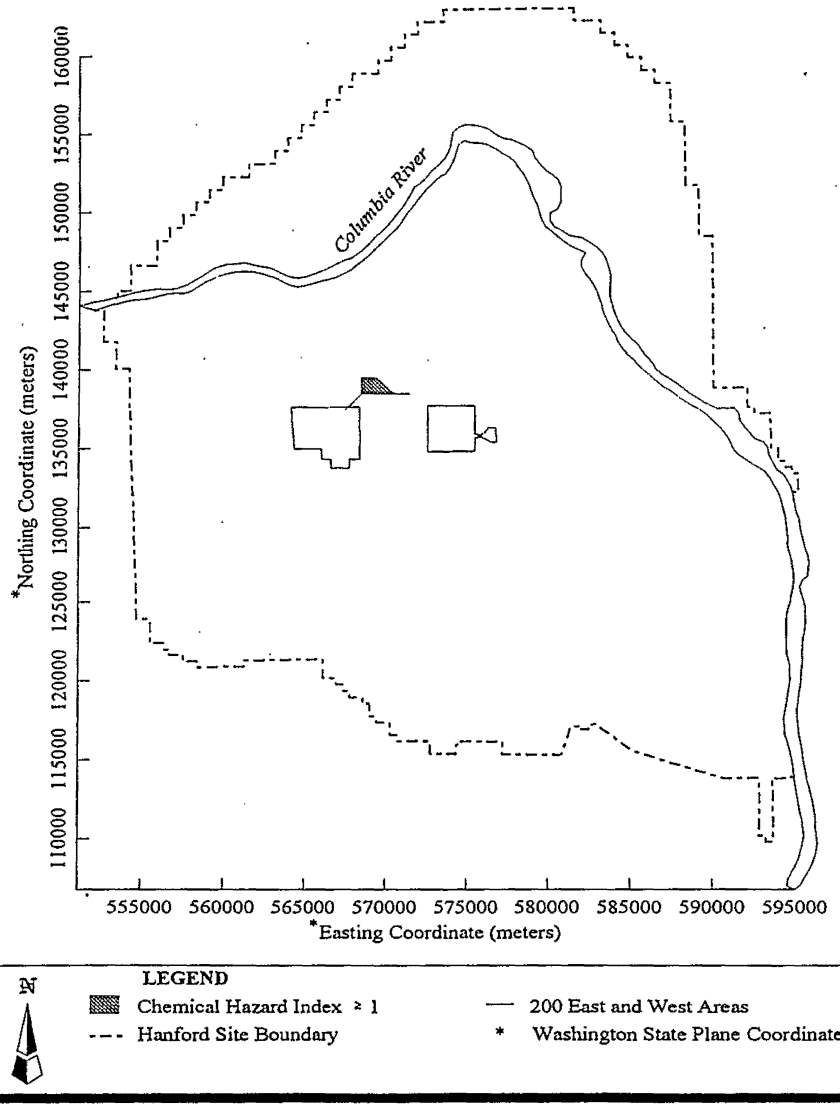


**Figure D.5.5.10 Ex Situ Intermediate Separations Alternative, Native American Scenario, Post Remediation Risk from LAW Vaults at 5,000 Years from Present**

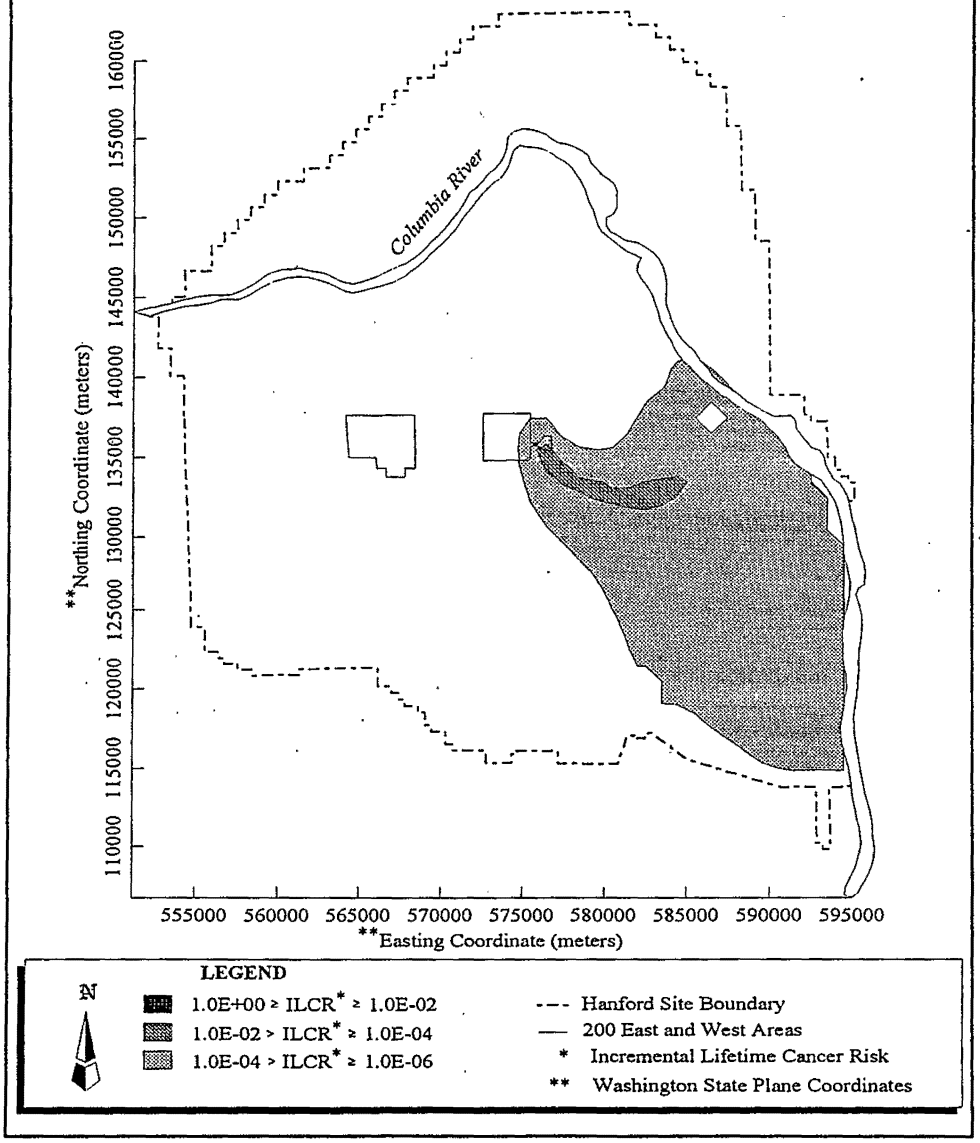


**Figure D.5.5.11 Ex Situ Intermediate Separations Alternative, Native American Scenario, Post Remediation Risk from LAW Vaults at 10,000 Years from Present**

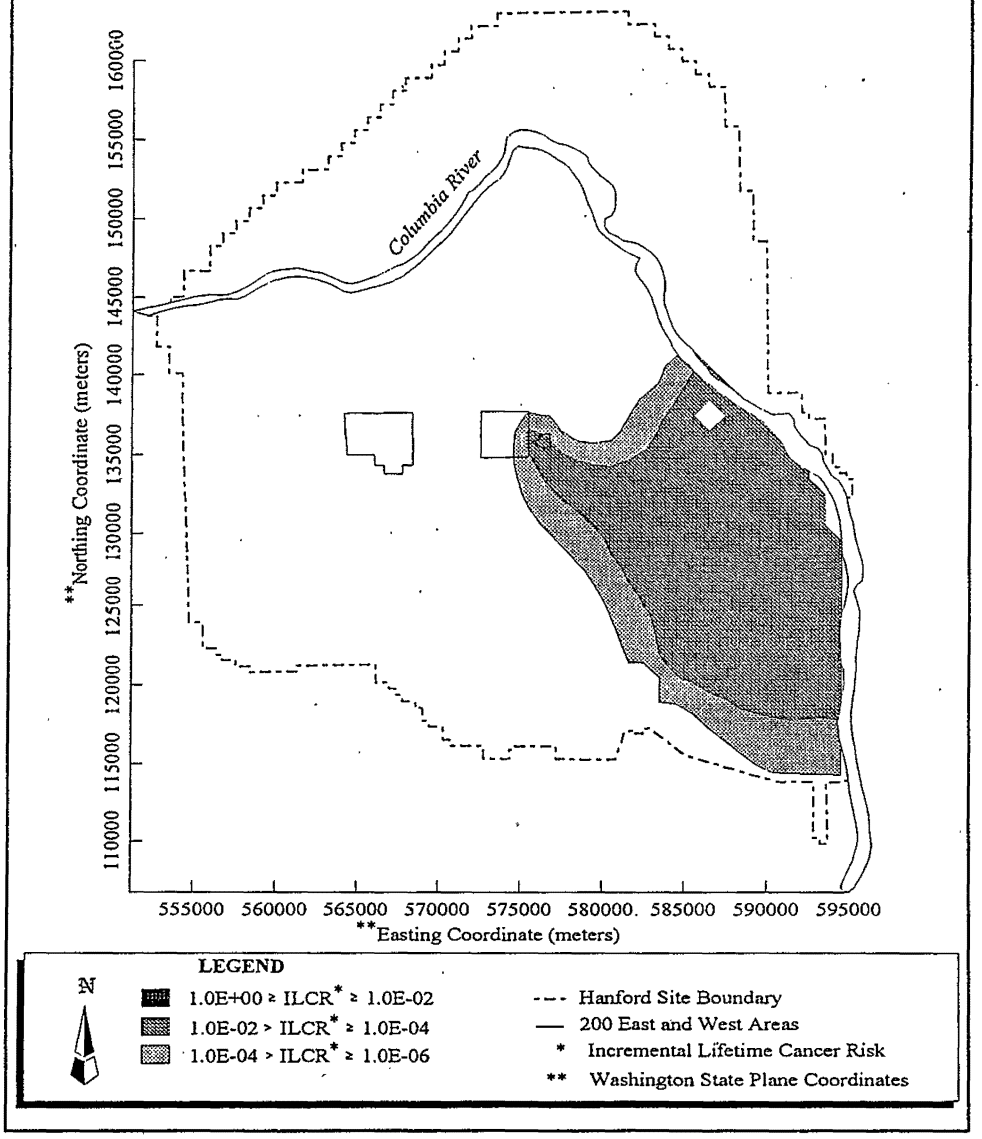


**Figure D.5.5.12 Ex Situ Intermediate Separations Alternative, Residential Farmer Scenario, Post Remediation Risk from LAW Vaults at 5,000 Years from Present**

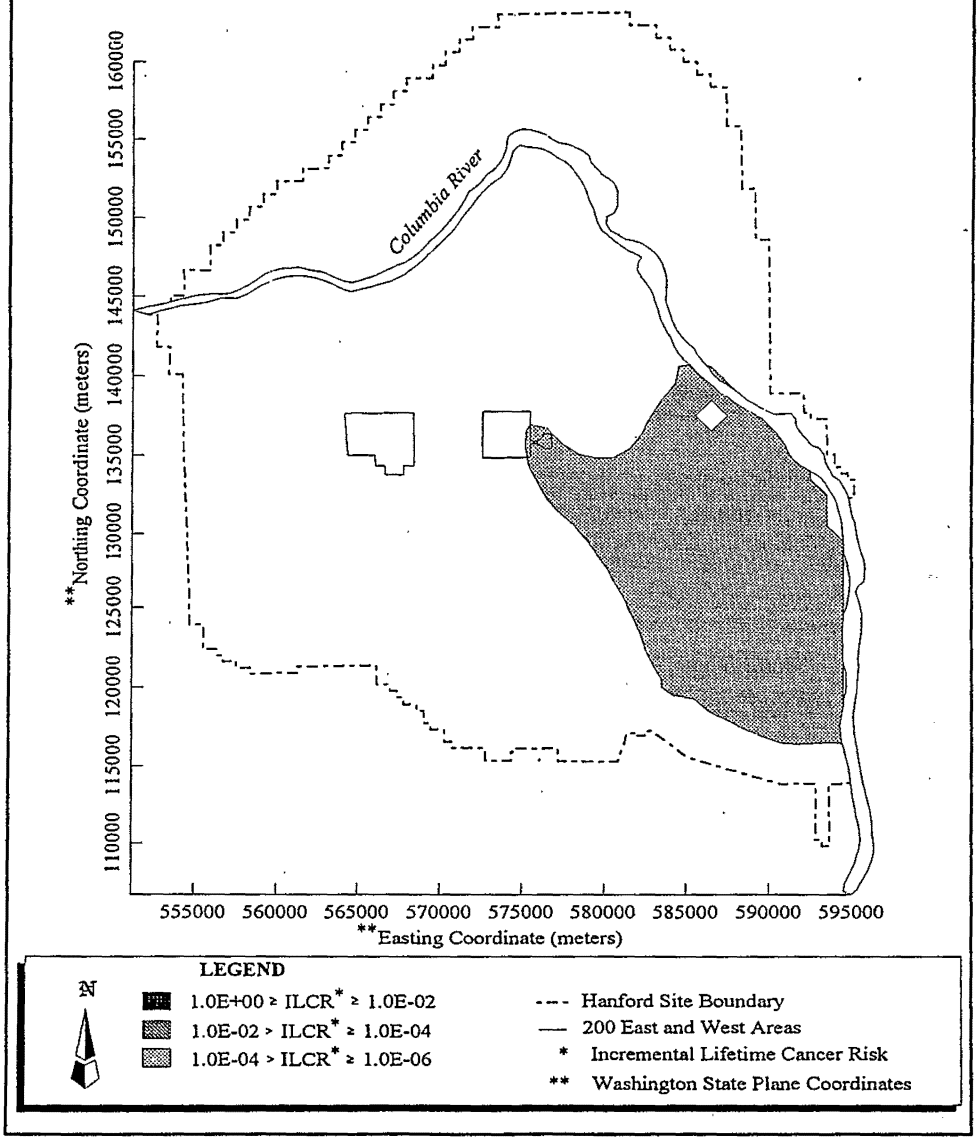


**Figure D.5.5.13 Ex Situ Intermediate Separations Alternative, Residential Farmer Scenario, Post Remediation Risk from LAW Vaults at 10,000 Years from Present**

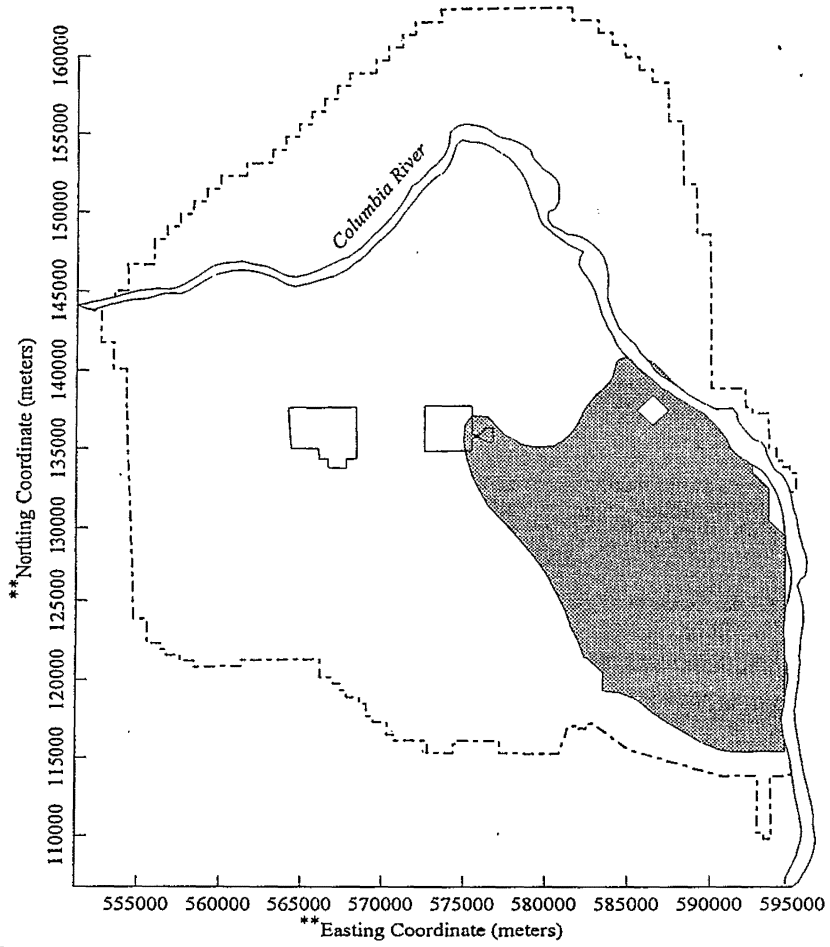


**Figure D.5.5.14 Ex Situ Intermediate Separations Alternative, Industrial Worker Scenario, Post Remediation Risk from LAW Vaults at 5,000 Years from Present**

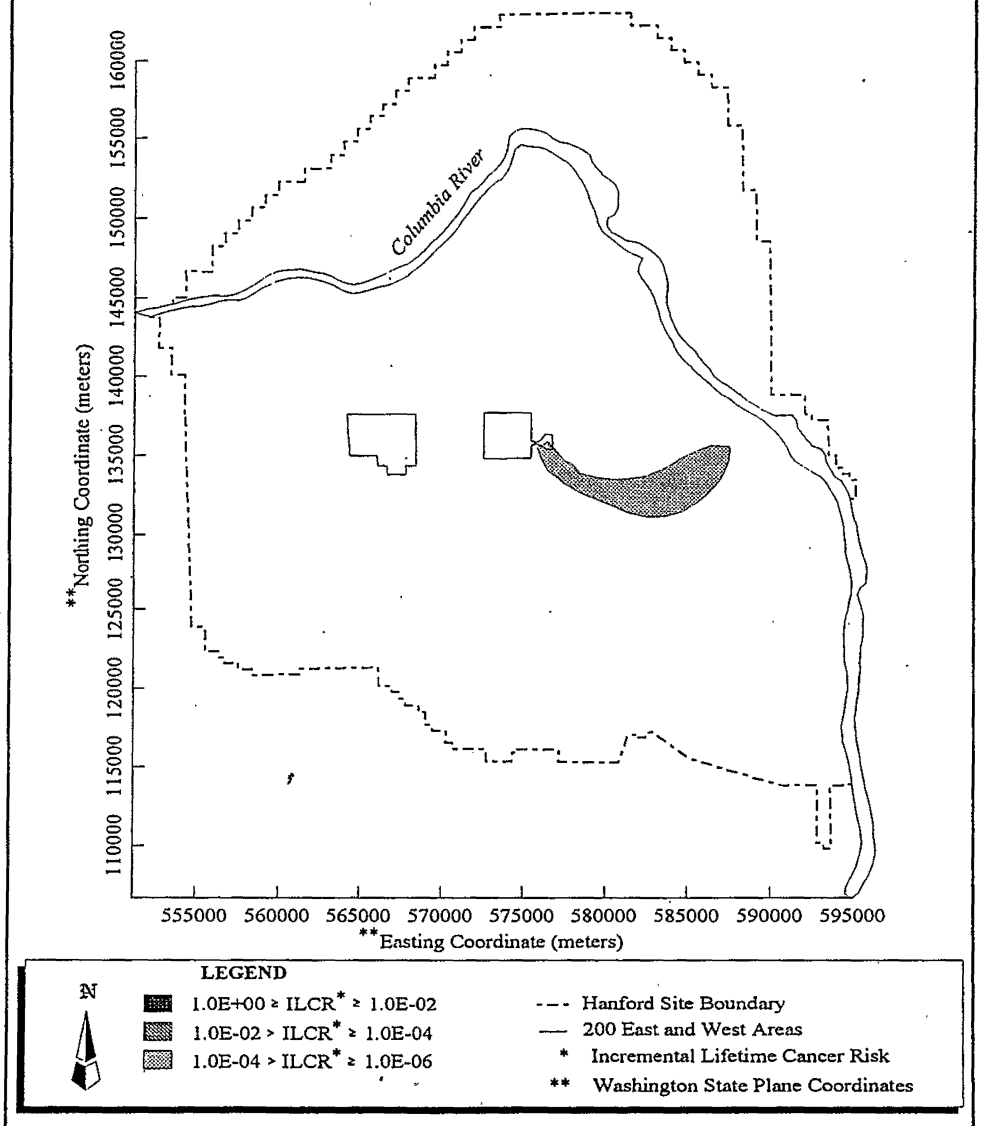


**Figure D.5.5.15 Ex Situ Intermediate Separations Alternative, Industrial Worker Scenario, Post Remediation Risk from LAW Vaults at 10,000 Years from Present**

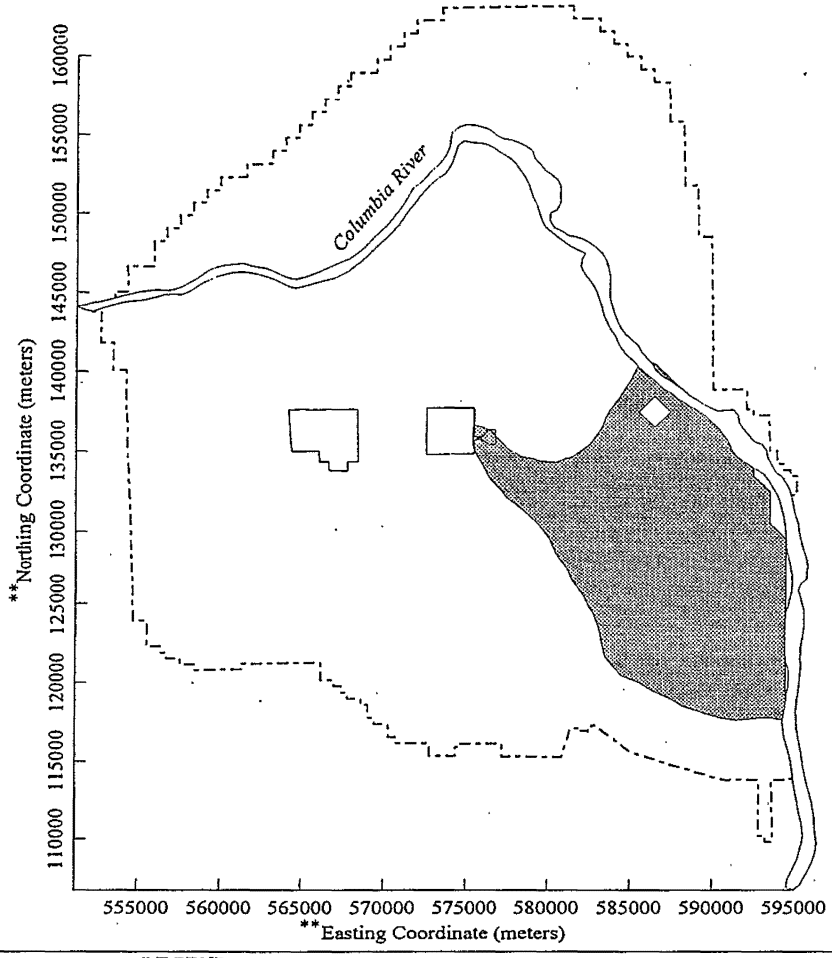


**Figure D.5.5.16 Ex Situ Intermediate Separations Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 2,500 Years from Present**

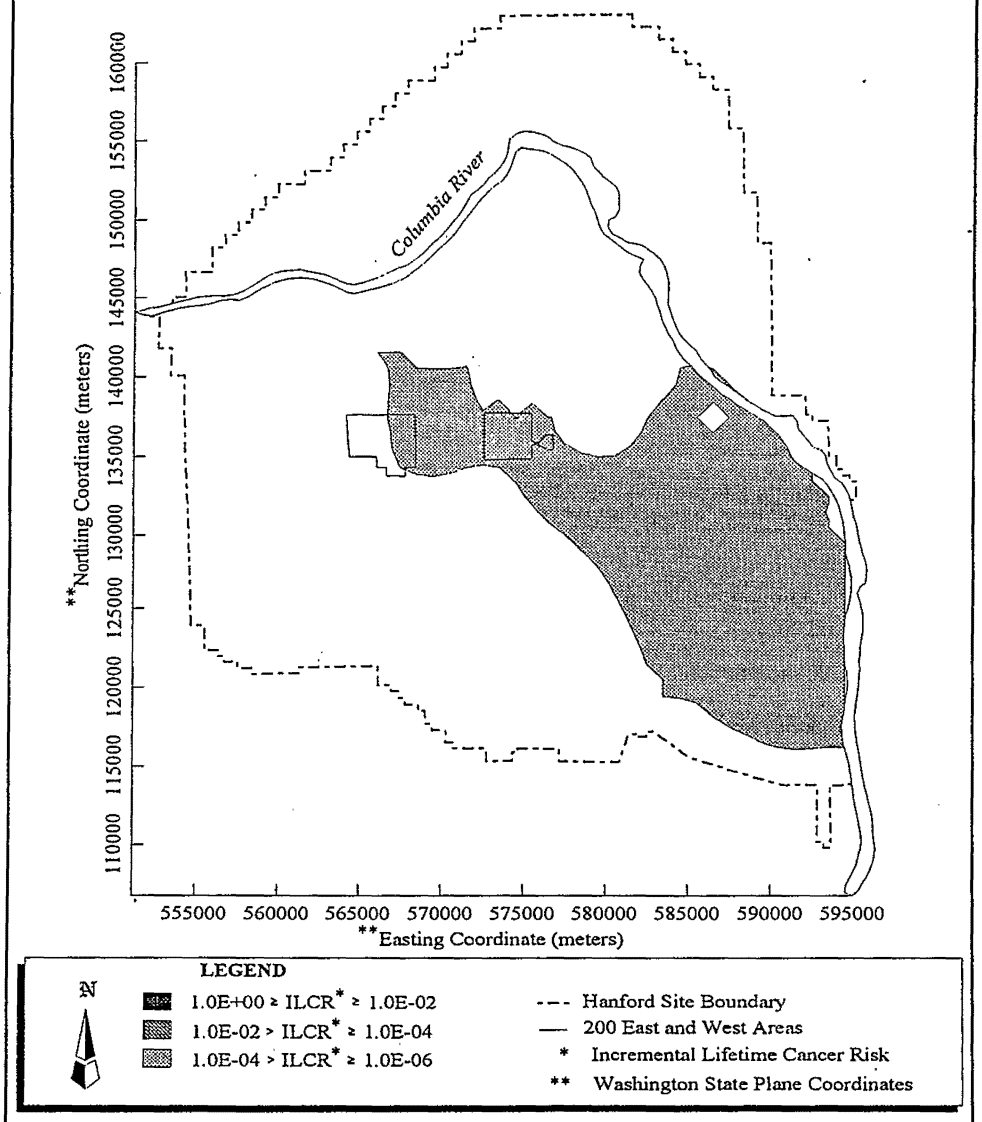


**Figure D.5.5.17 Ex Situ Intermediate Separations Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

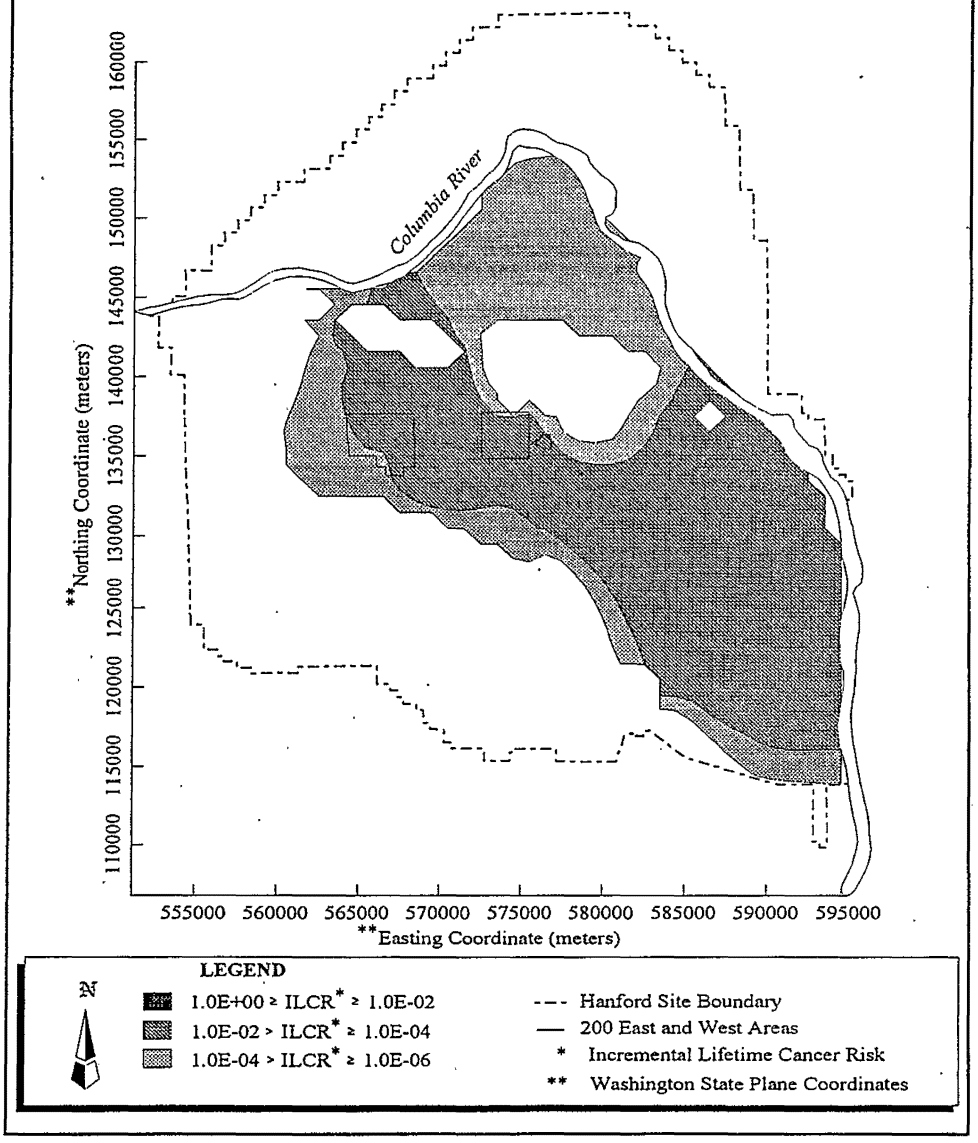


**Figure D.5.5.18 Ex Situ Intermediate Separations Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 10,000 Years from Present**

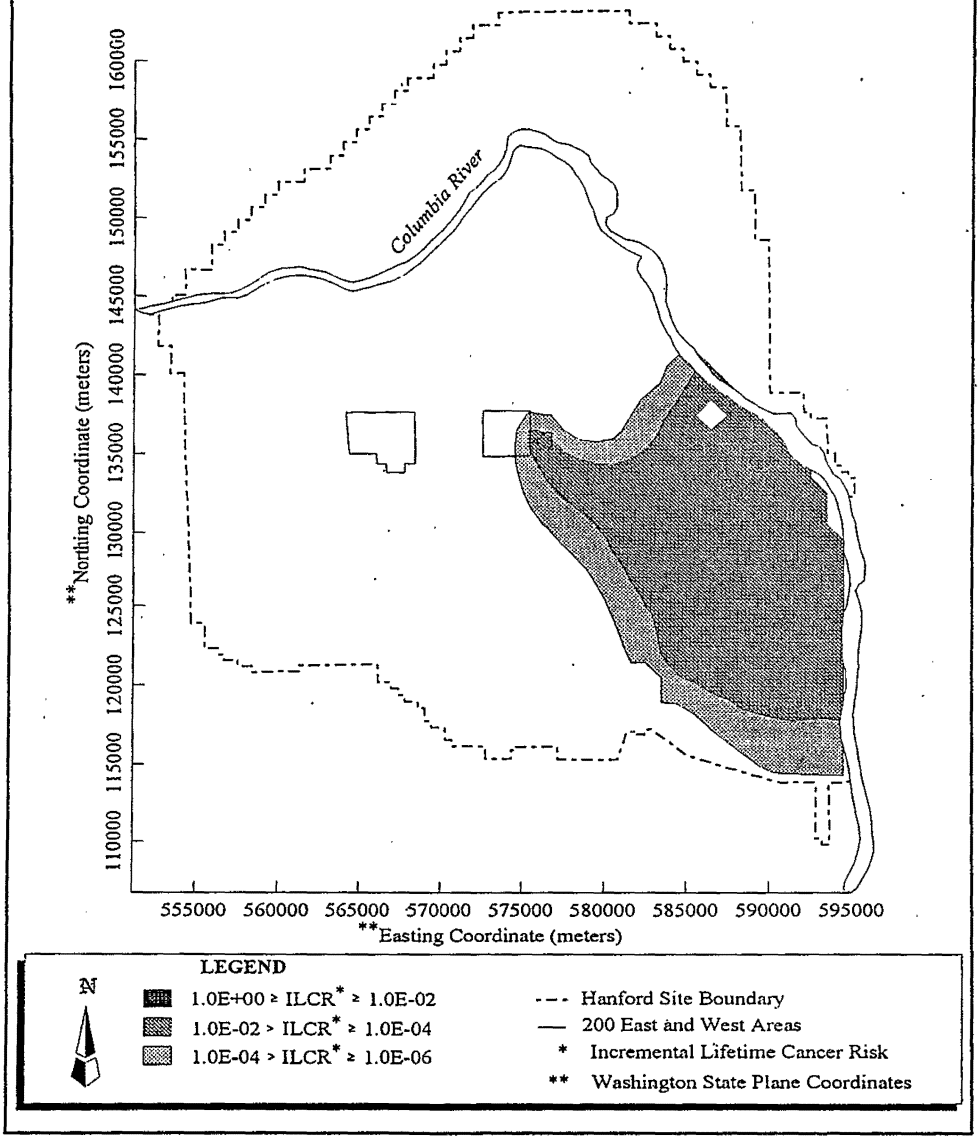


**Figure D.5.5.19 Ex Situ Intermediate Separations Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 2,500 Years from Present**

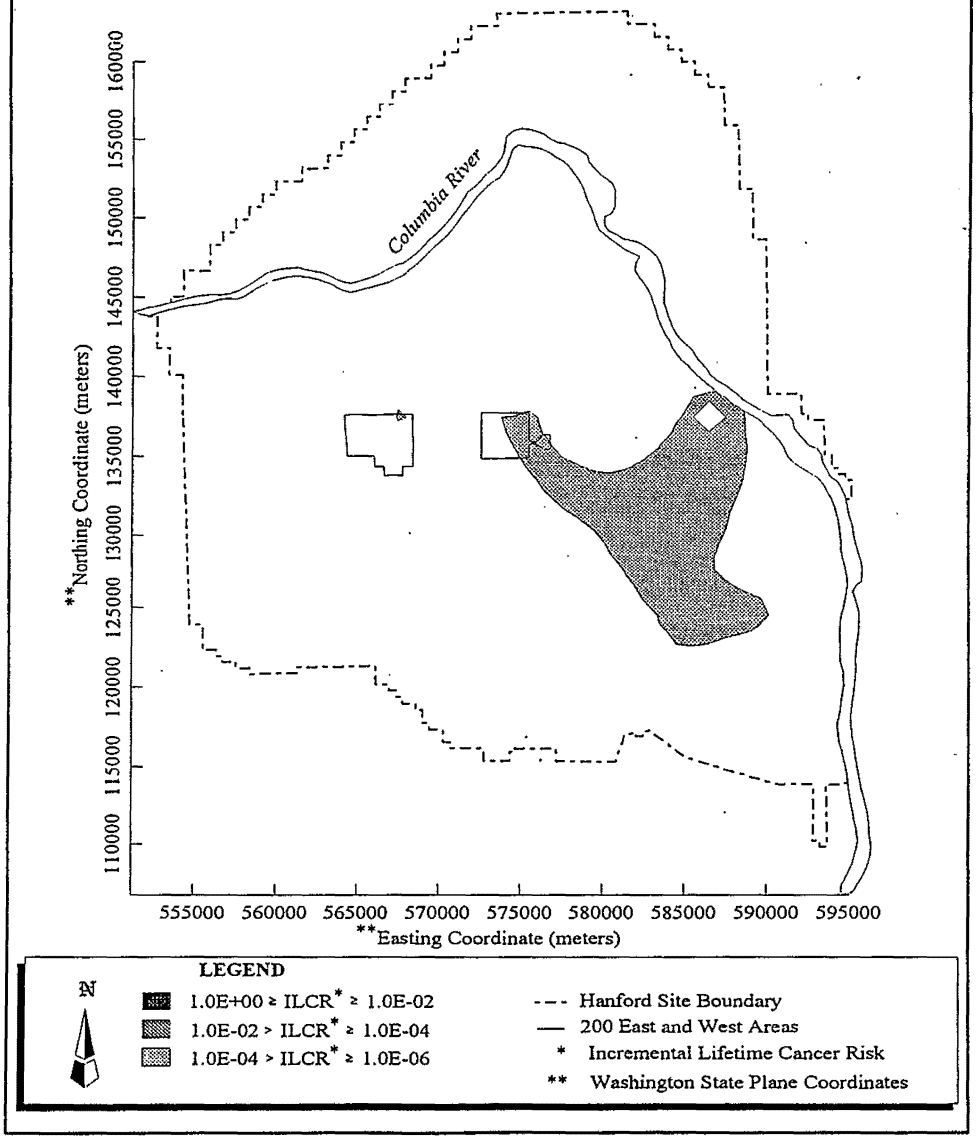


**Figure D.5.5.20 Ex Situ Intermediate Separations Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

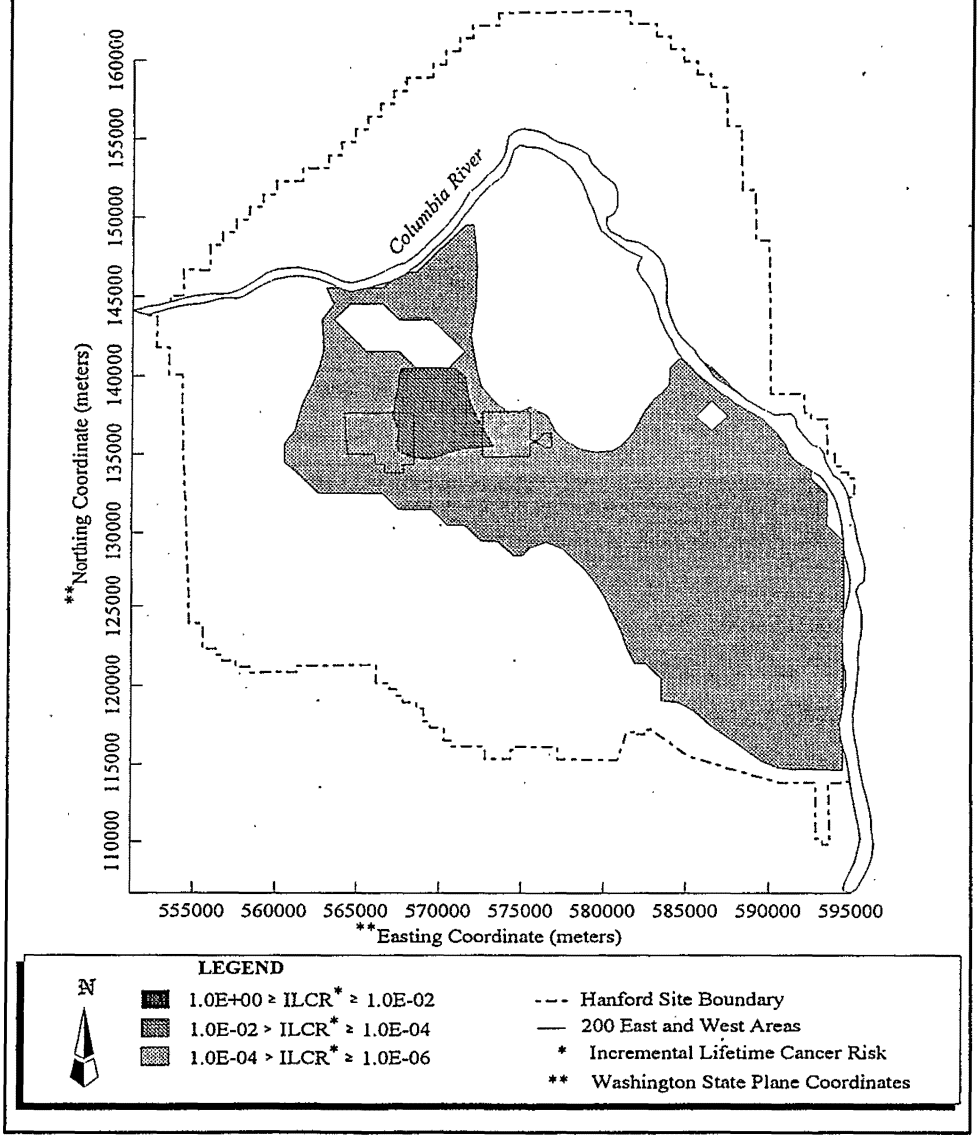


**Figure D.5.5.21 Ex Situ Intermediate Separations Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 10,000 Years from Present**

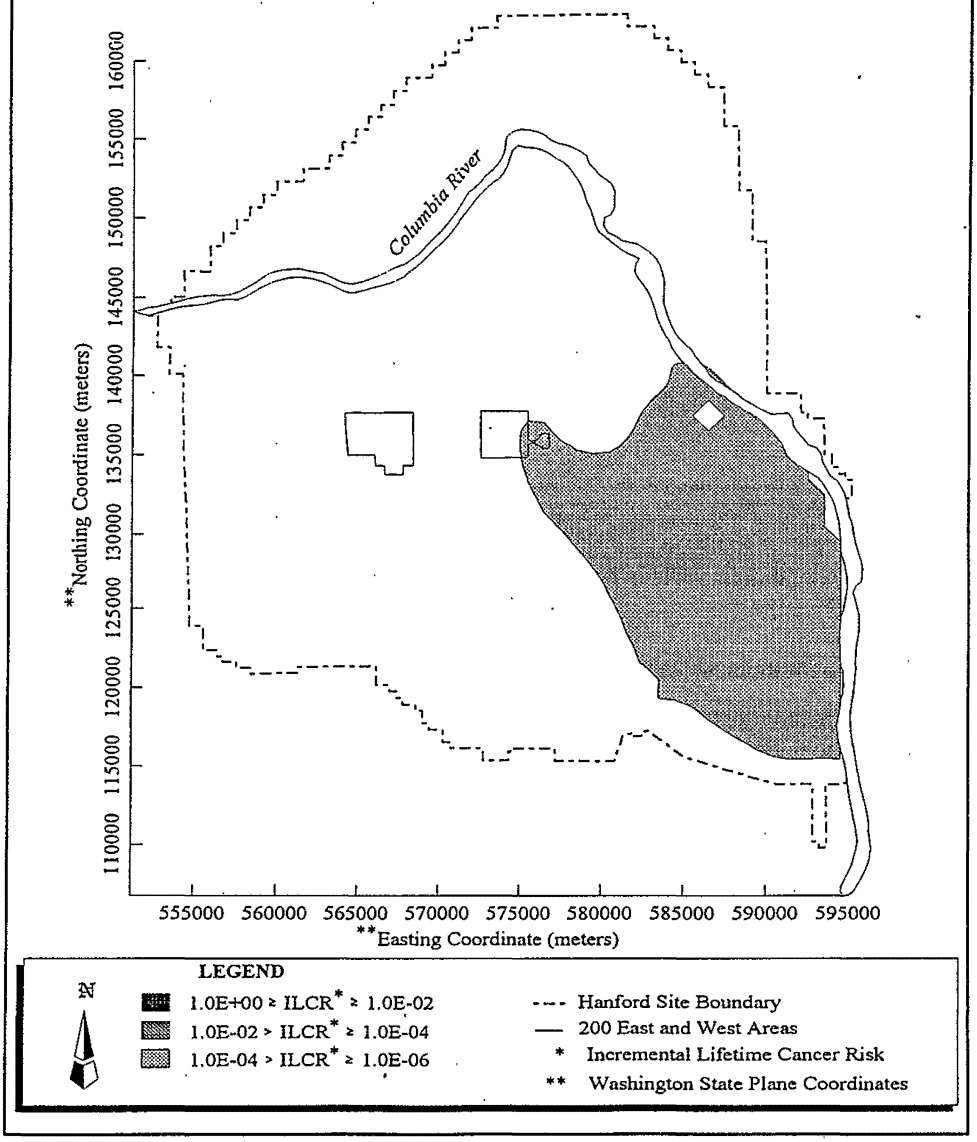


**Figure D.5.5.22 Ex Situ Intermediate Separations Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 2,500 Years from Present**

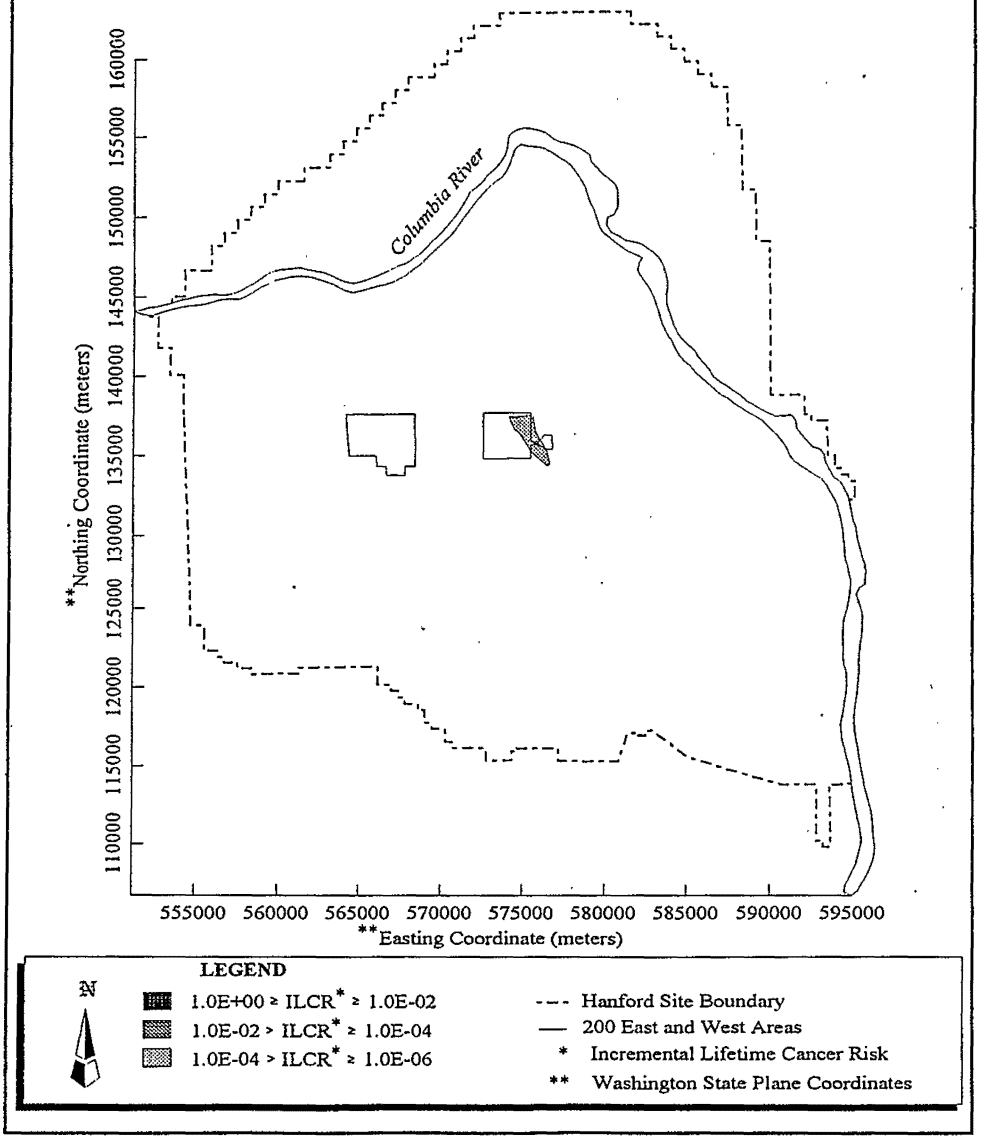


**Figure D.5.5.23 Ex Situ Intermediate Separations Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

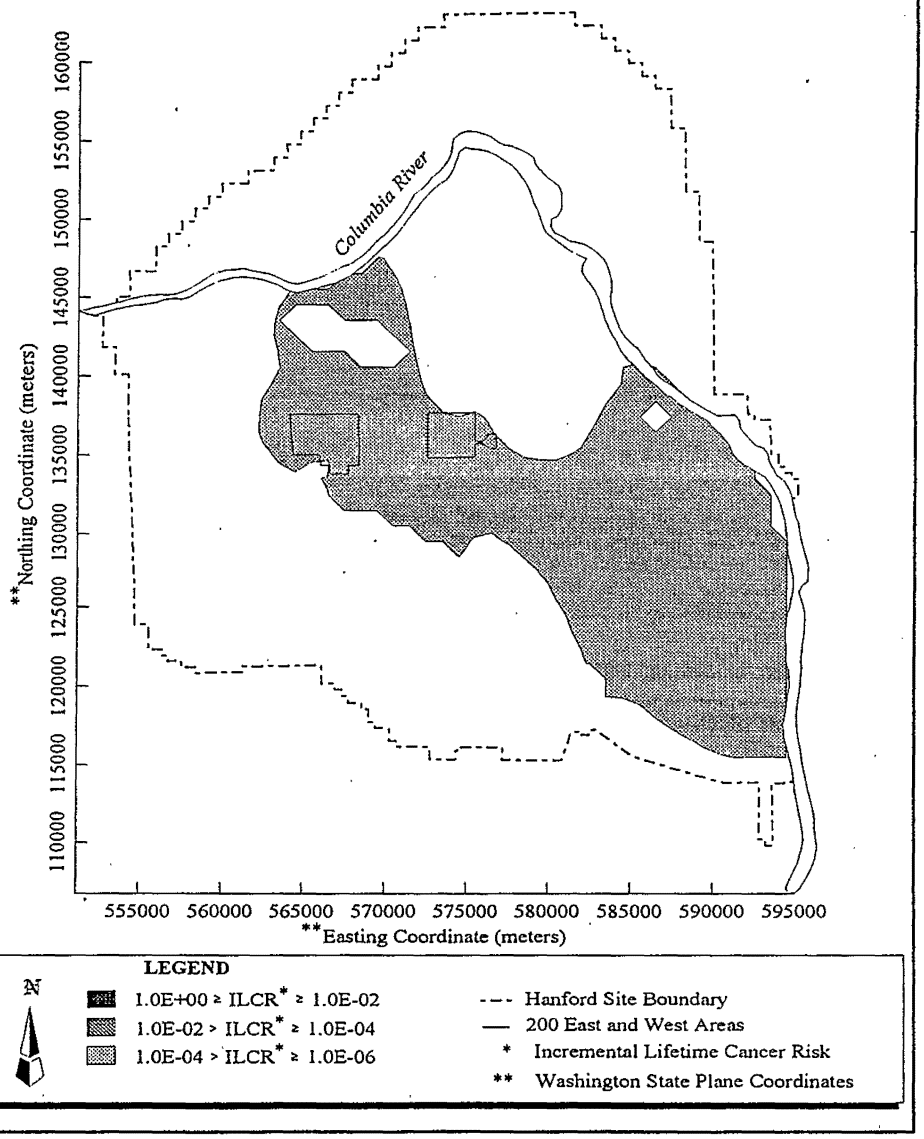


**Figure D.5.5.24 Ex Situ Intermediate Separations Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 10,000 Years from Present**

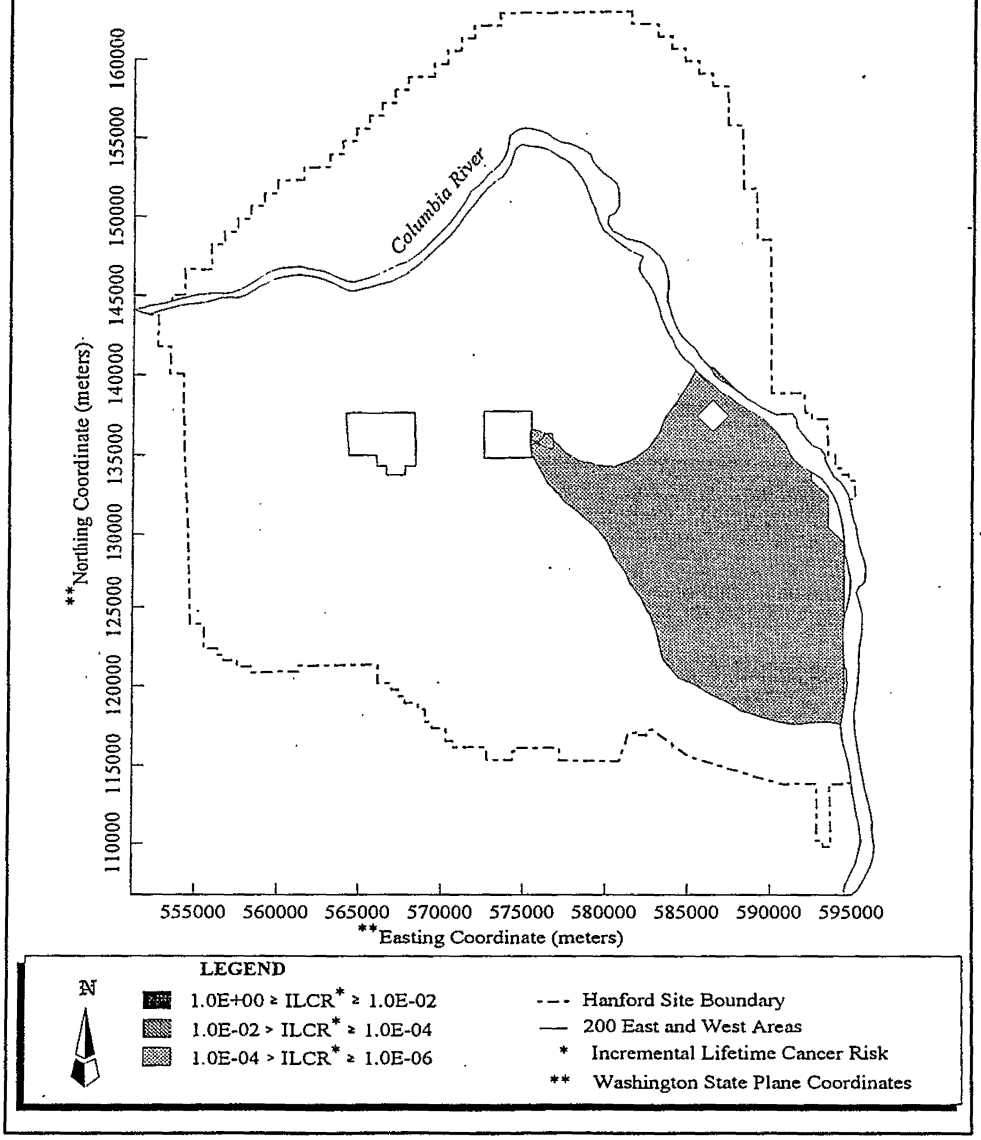


**Figure D.5.5.25 Ex Situ Intermediate Separations Alternative, Recreational River User Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

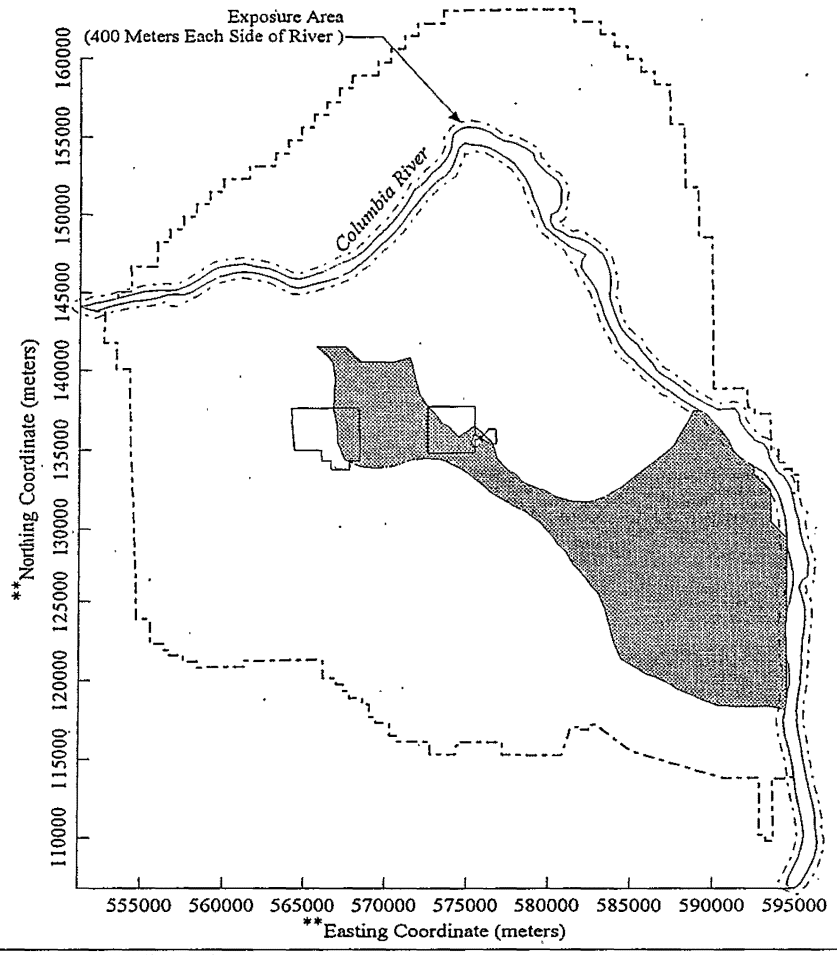


**Figure D.5.5.26 Ex Situ Intermediate Separations Alternative, Native American Scenario, Post Remediation Hazard Index from Tank Residuals and LAW Vaults at 5,000 Years from Present**

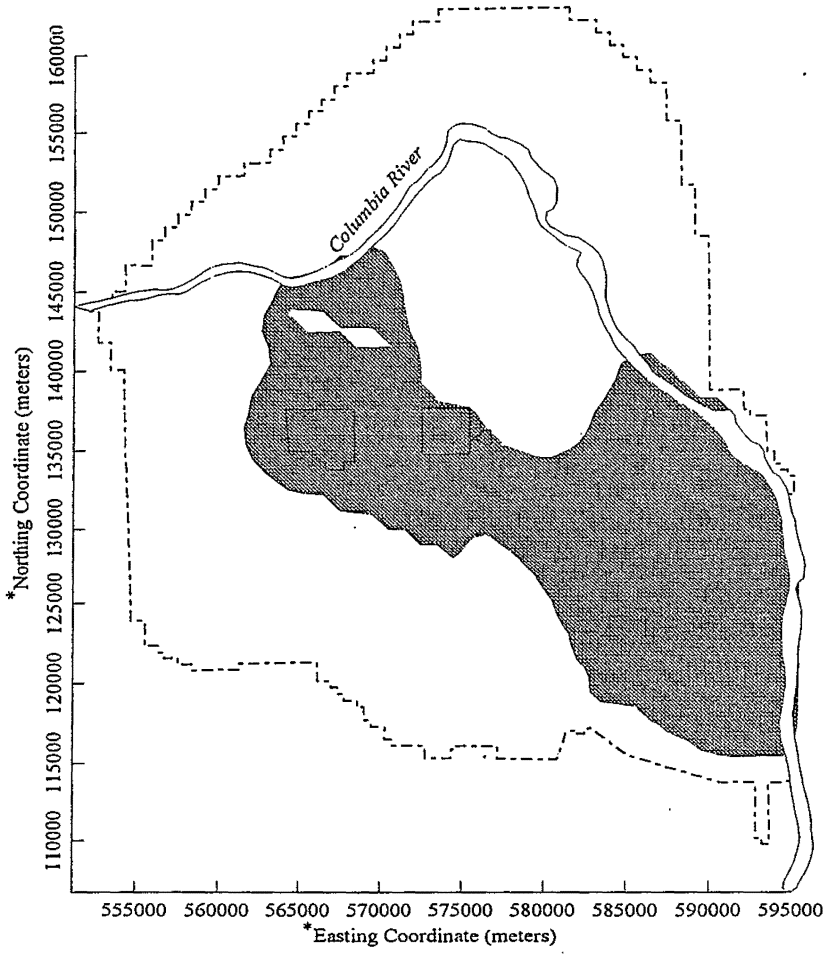


**Figure D.5.5.27 Ex Situ Intermediate Separations Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from Tank Residuals and LAW Vaults at 5,000 Years from Present**

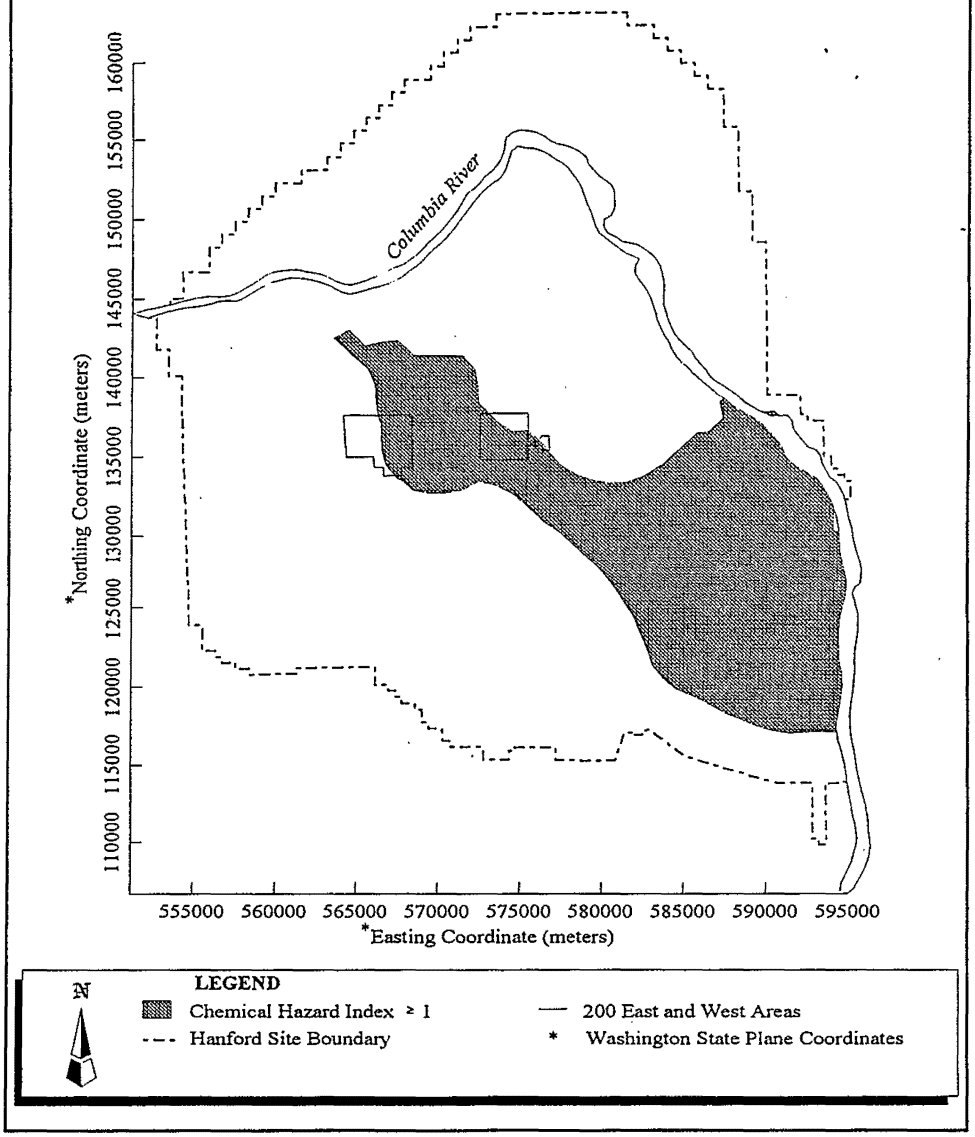


**Figure D.5.7.1 Ex Situ Extensive Separations Alternative, Native American Scenario, Post Remediation Risk from LAW Vaults at 5,000 Years from Present**

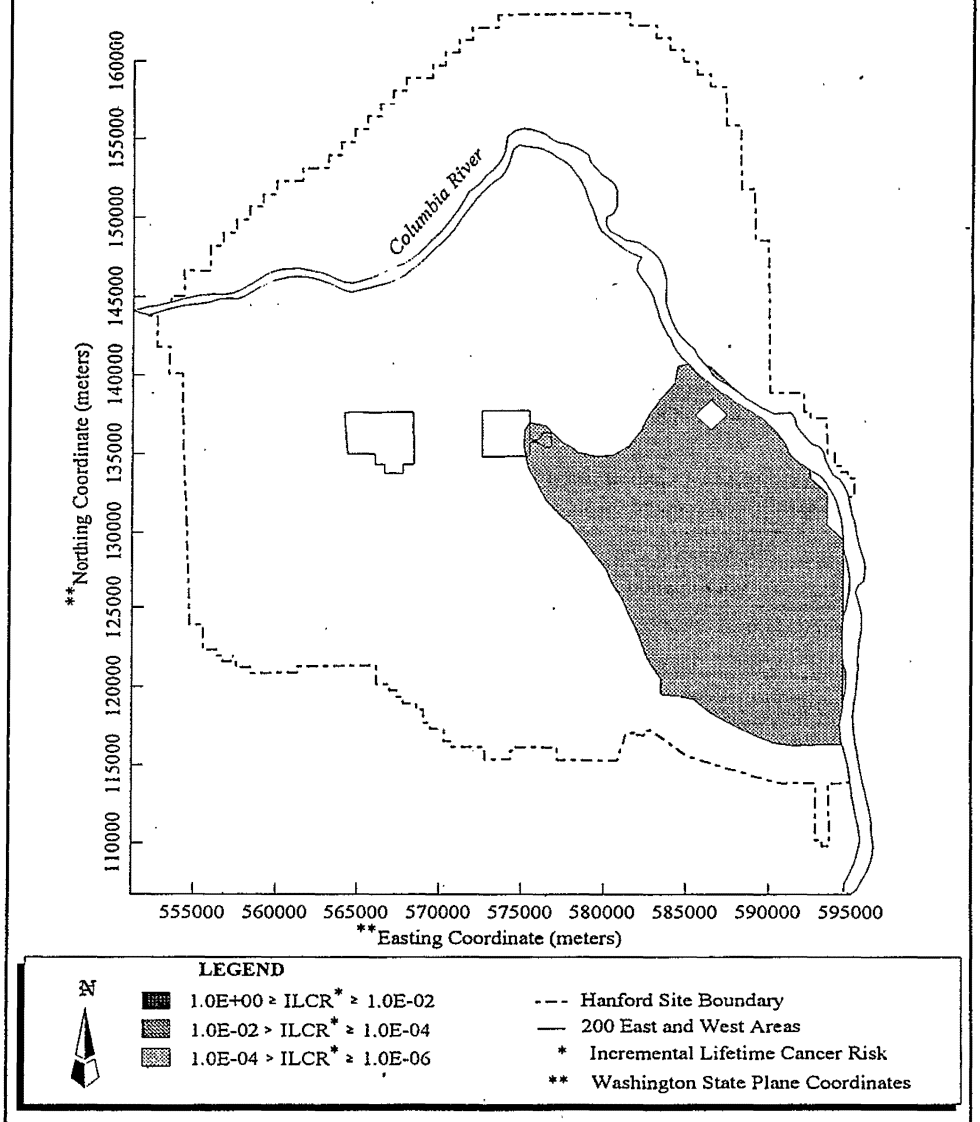


**Figure D.5.7,2 Ex Situ Extensive Separations Alternative, Native American Scenario, Post Remediation Risk from LAW Vaults at 10,000 Years from Present**

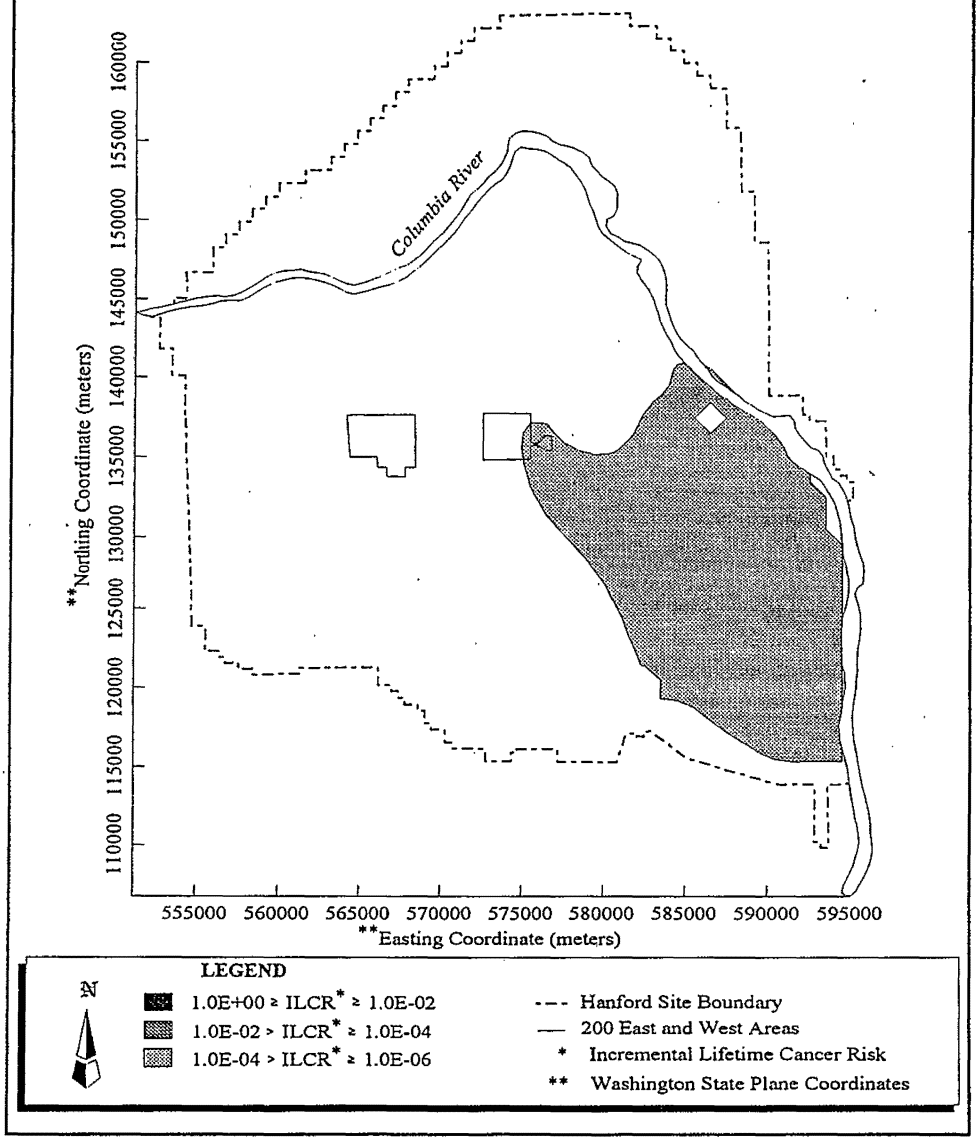


**Figure D.5.7.3 Ex Situ Extensive Separations Alternative, Residential Farmer Scenario, Post Remediation Risk from LAW Vaults at 5,000 Years from Present**

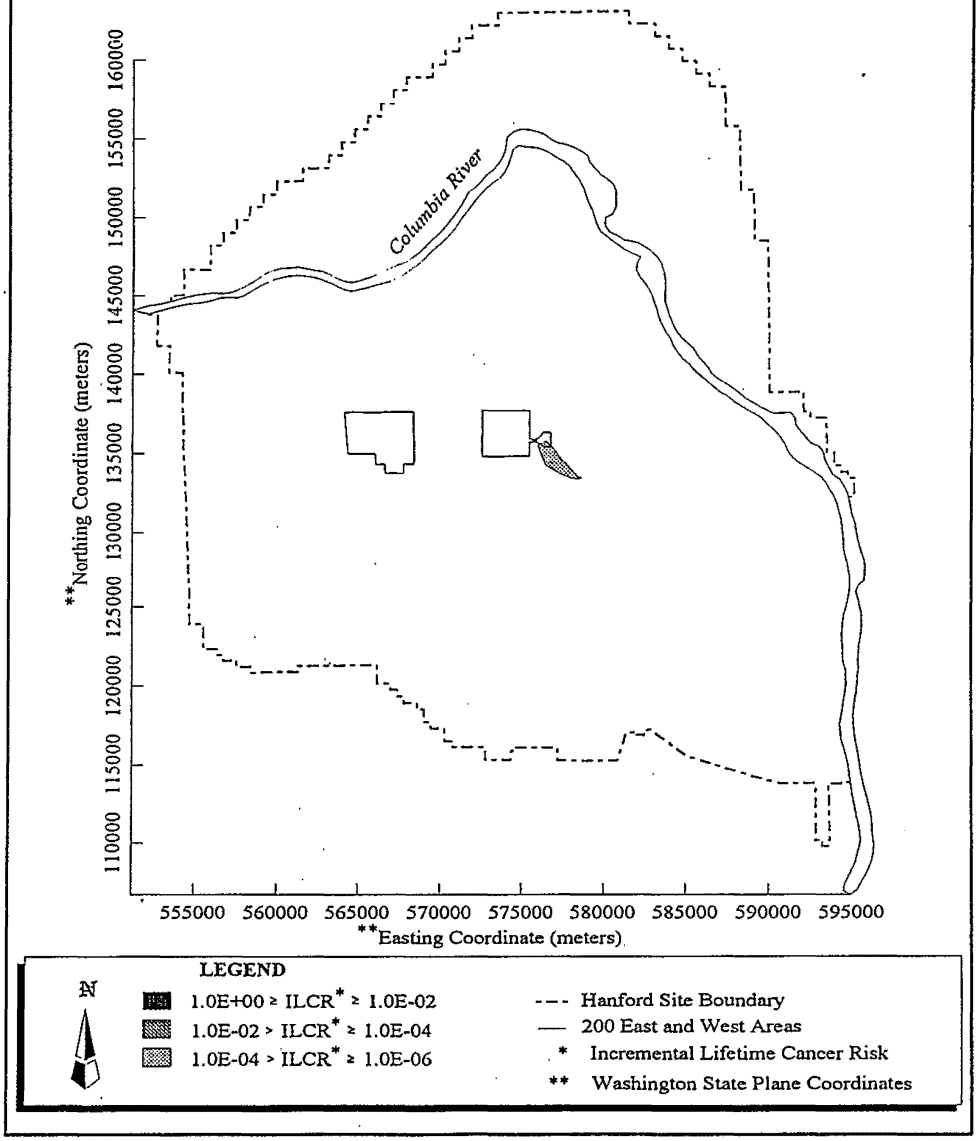


**Figure D.5.7.4 Ex Situ Extensive Separations Alternative, Residential Farmer Scenario, Post Remediation Risk from LAW Vaults at 10,000 Years from Present**

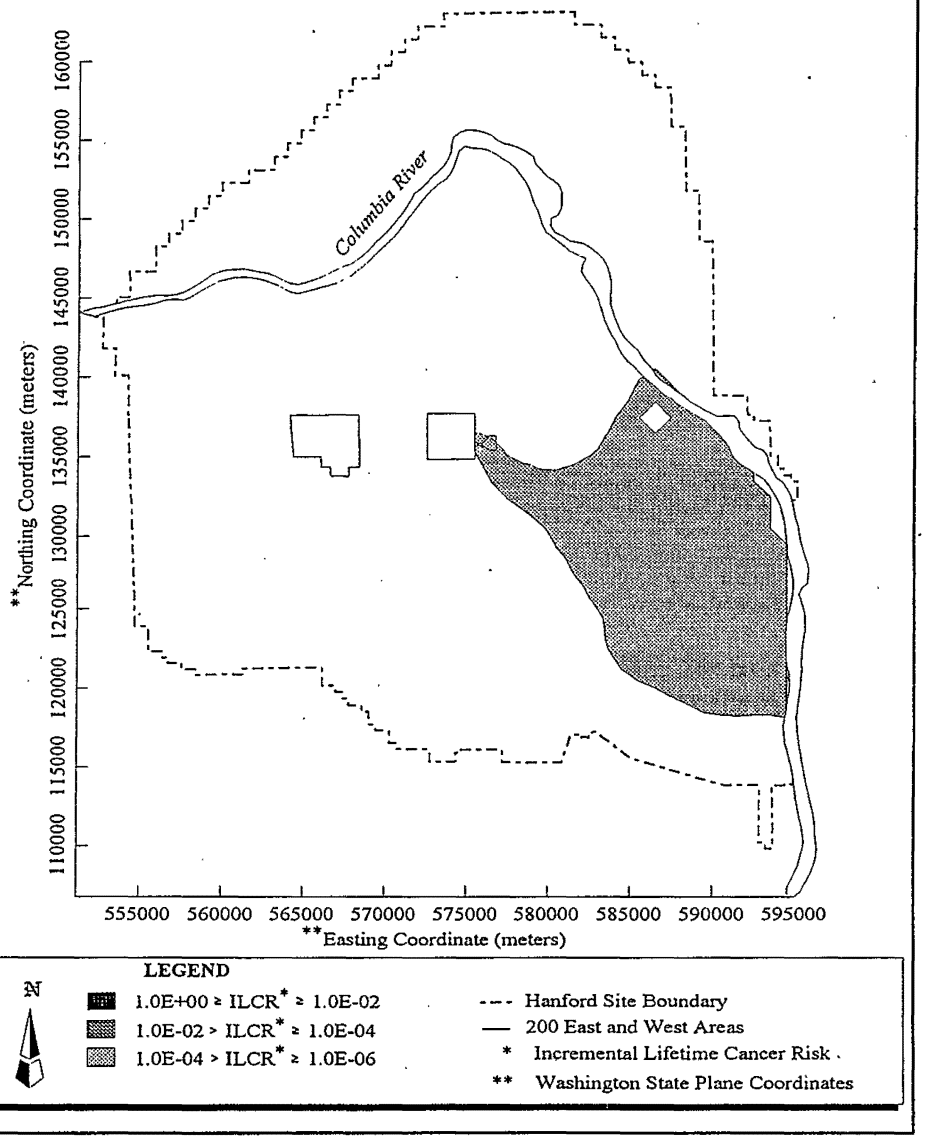


**Figure D.5.7.5 Ex Situ Extensive Separations Alternative, Industrial Worker Scenario, Post Remediation Risk from LAW Vaults at 10,000 Years from Present**

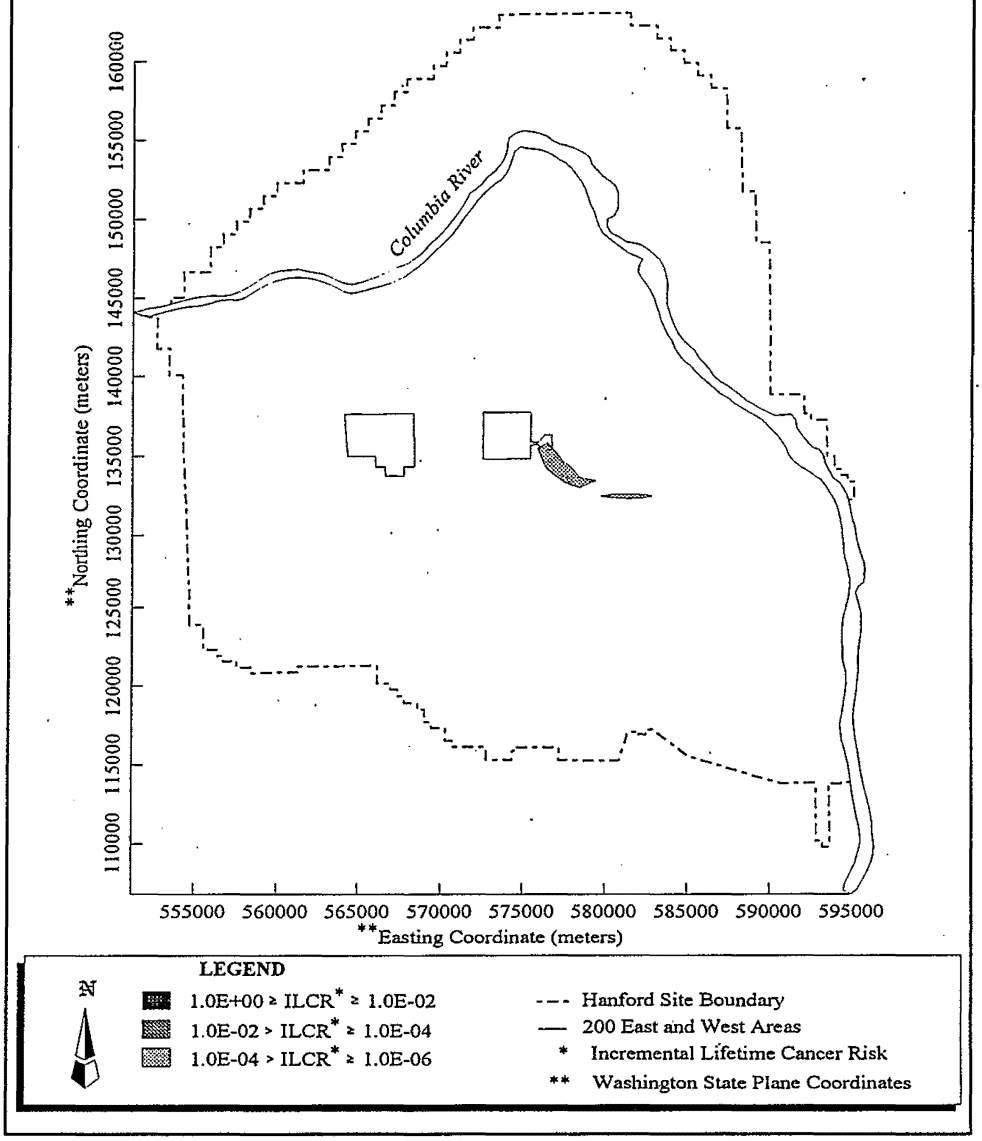


**Figure D.5.7.6 Ex Situ Extensive Separations Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 2,500 Years from Present**

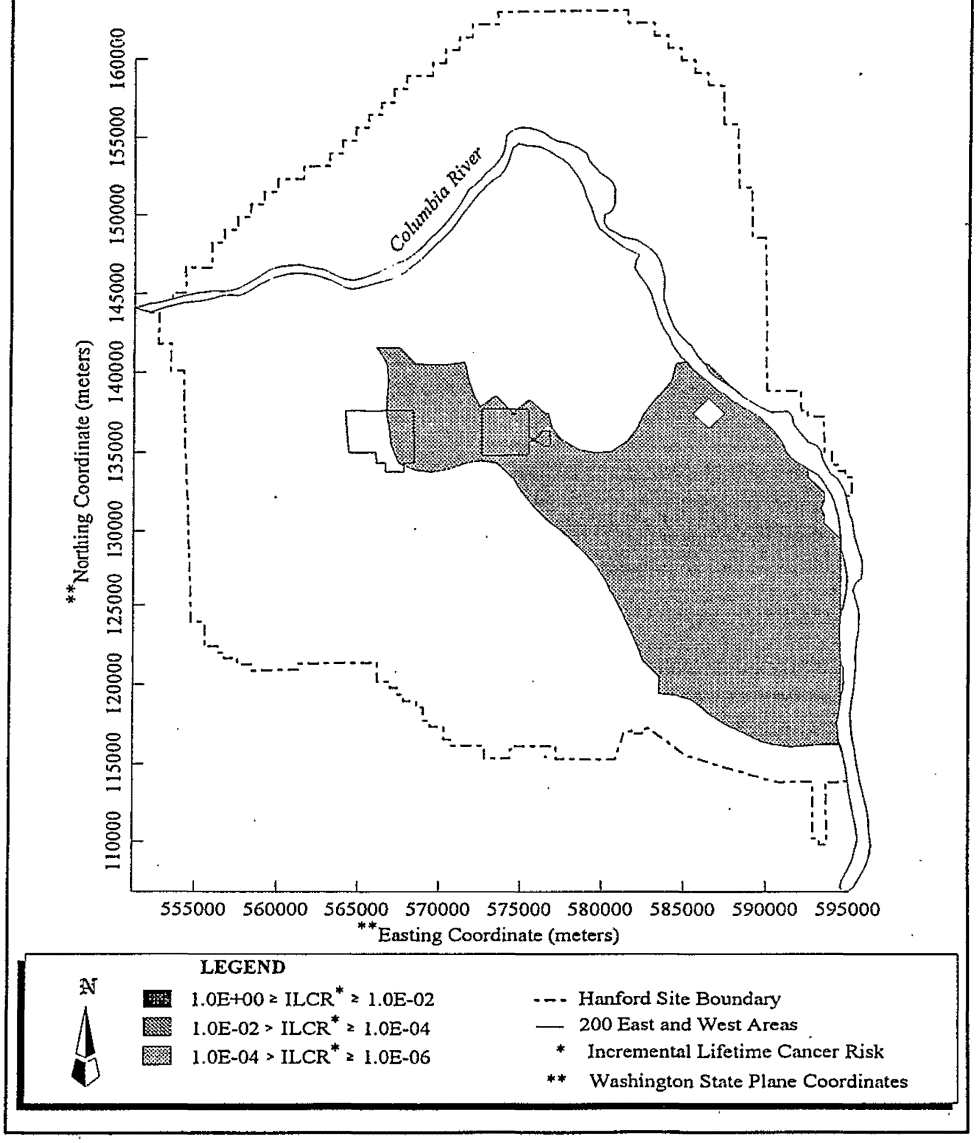


**Figure D.5.7.7 Ex Situ Extensive Separations Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

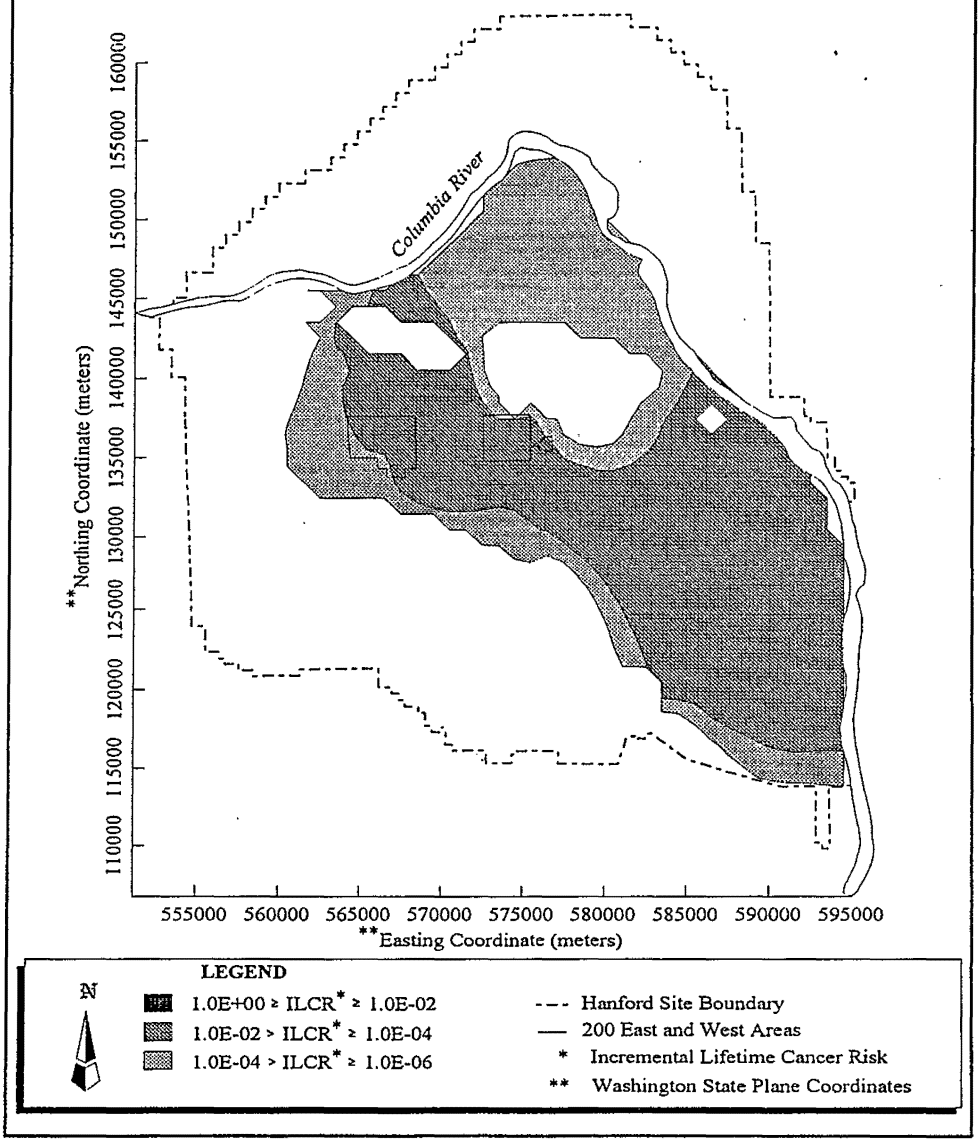


**Figure D.5.7.8 Ex Situ Extensive Separations Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 2,500 Years from Present**

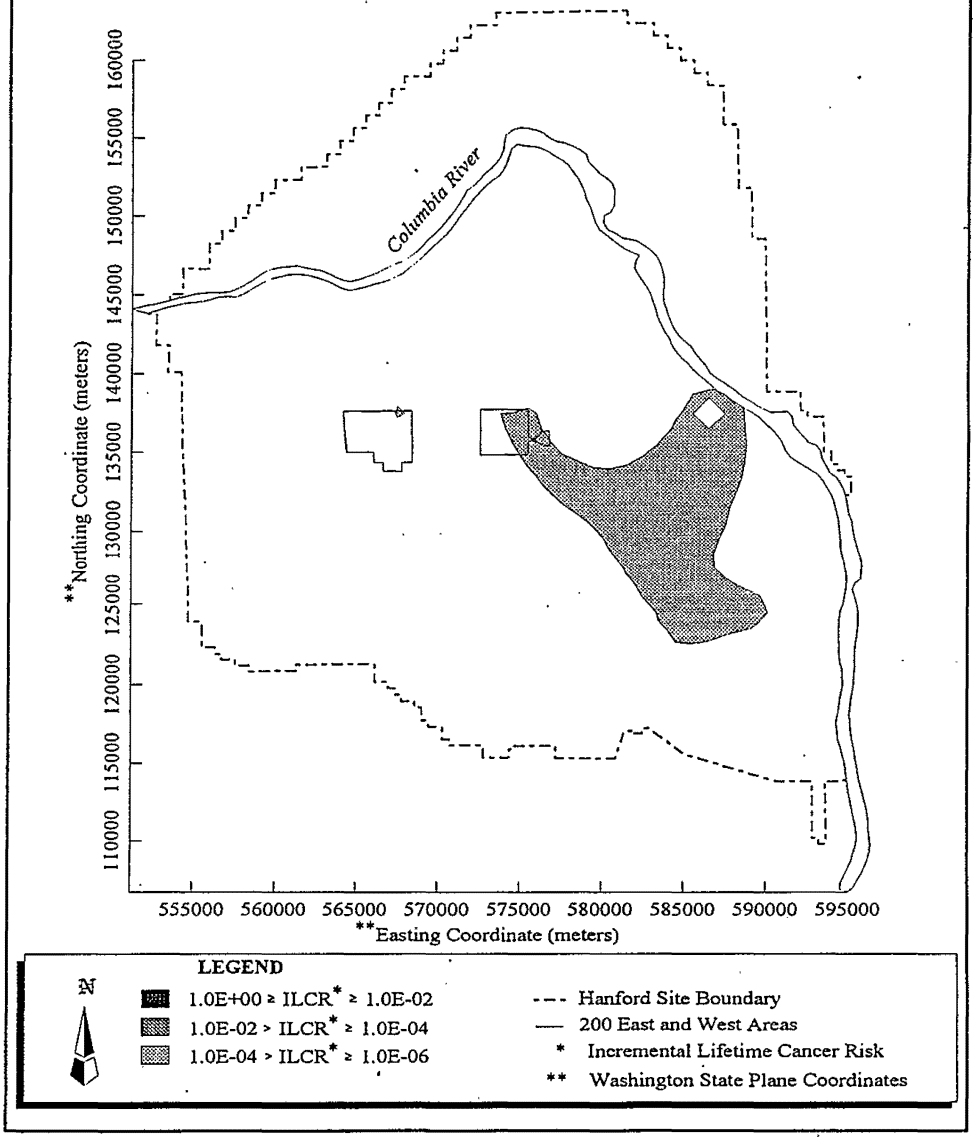


**Figure D.5.7.9 Ex Situ Extensive Separations Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

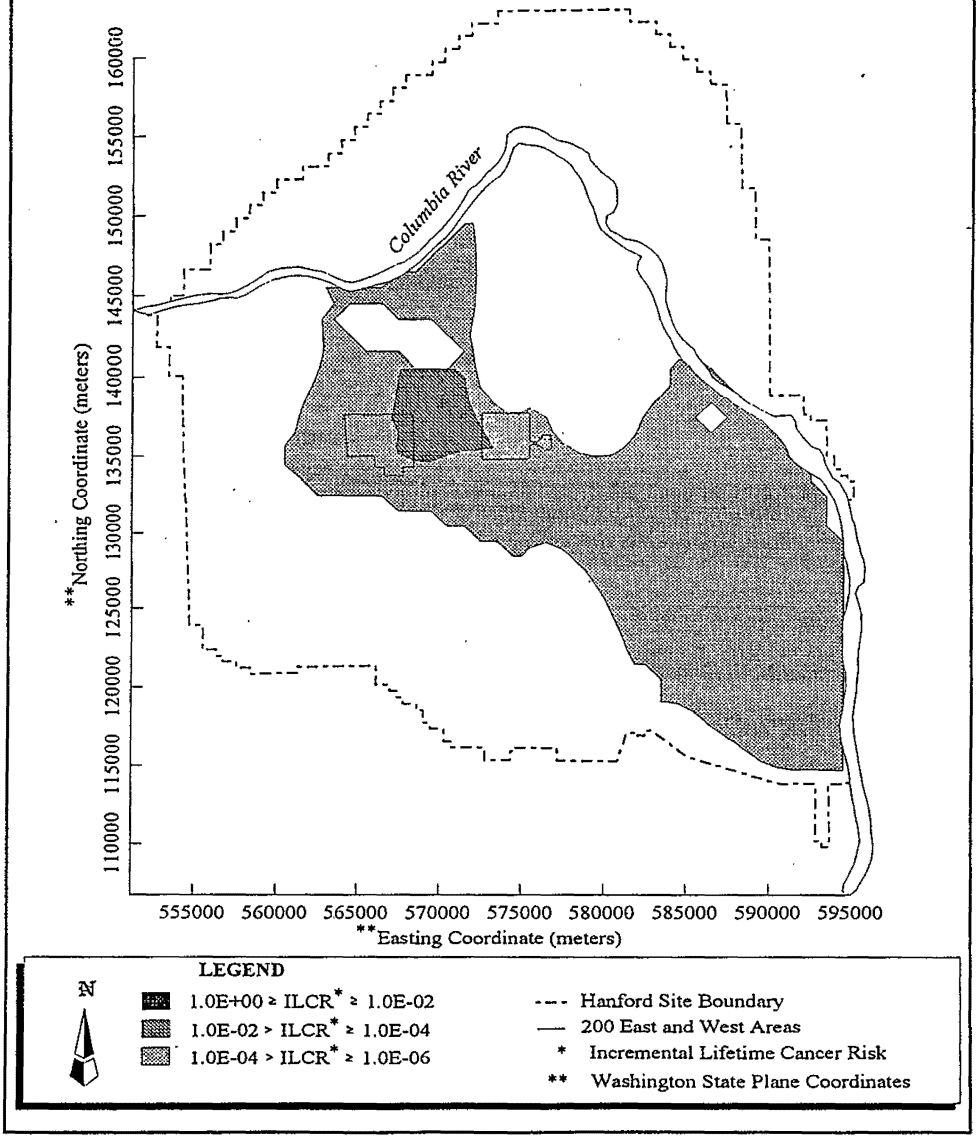


**Figure D.5.7.10 Ex Situ Extensive Separations Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 2,500 Years from Present**

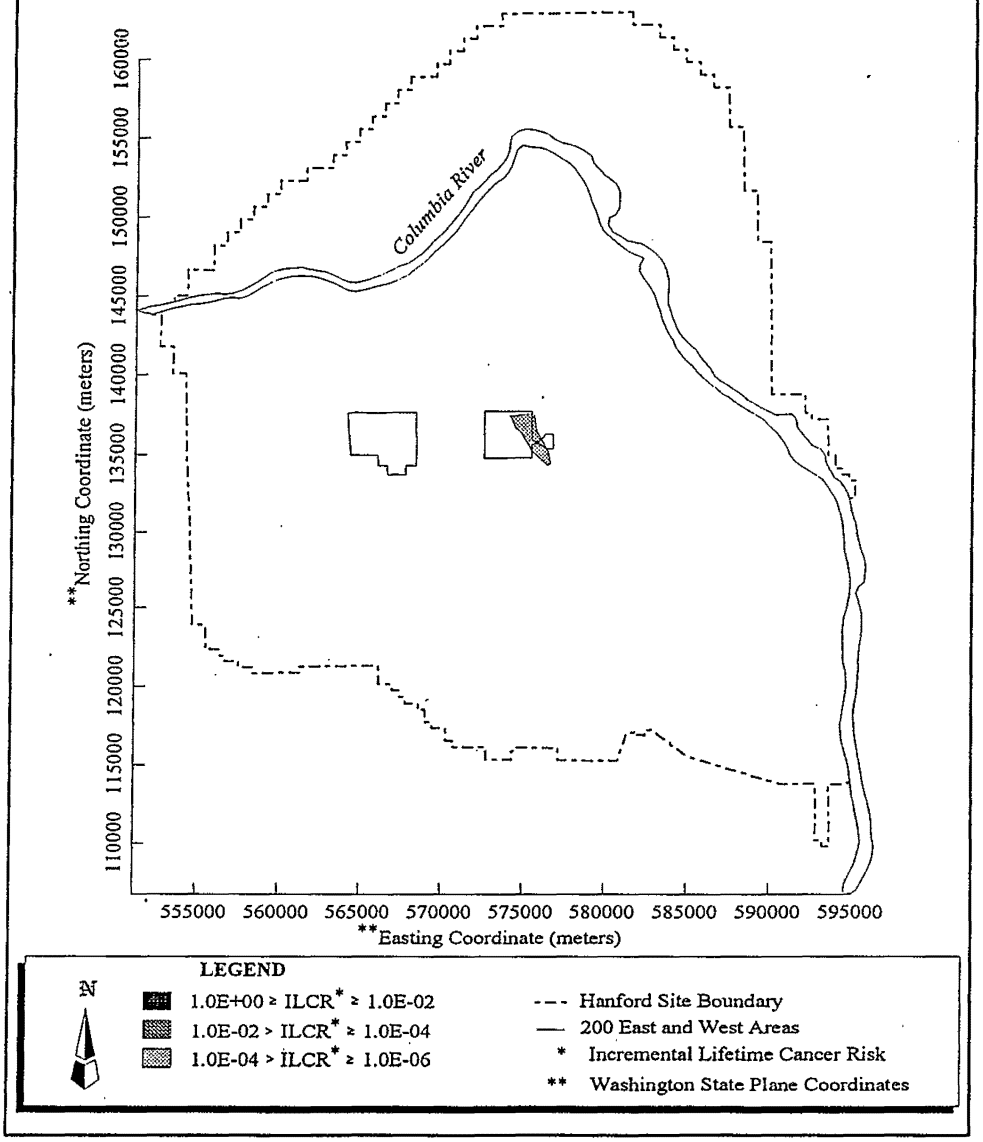


**Figure D.5.7.11 Ex Situ Extensive Separations Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

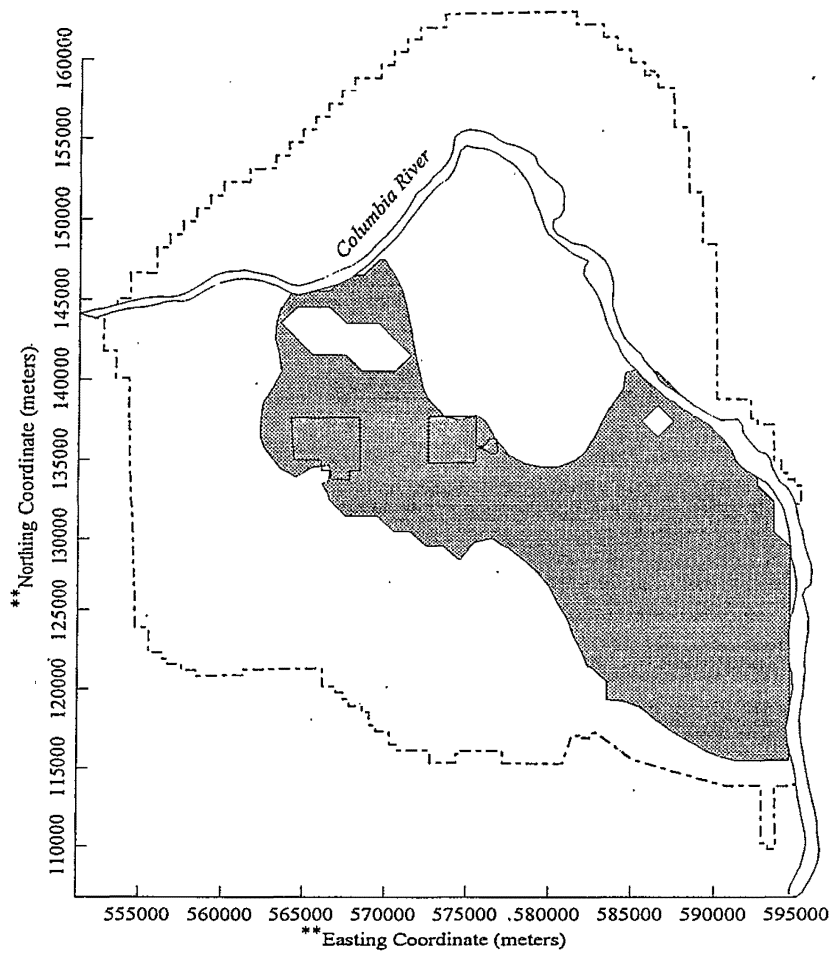


**Figure D.5.7.12 Ex Situ Extensive Separations Alternative, Recreational River User Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

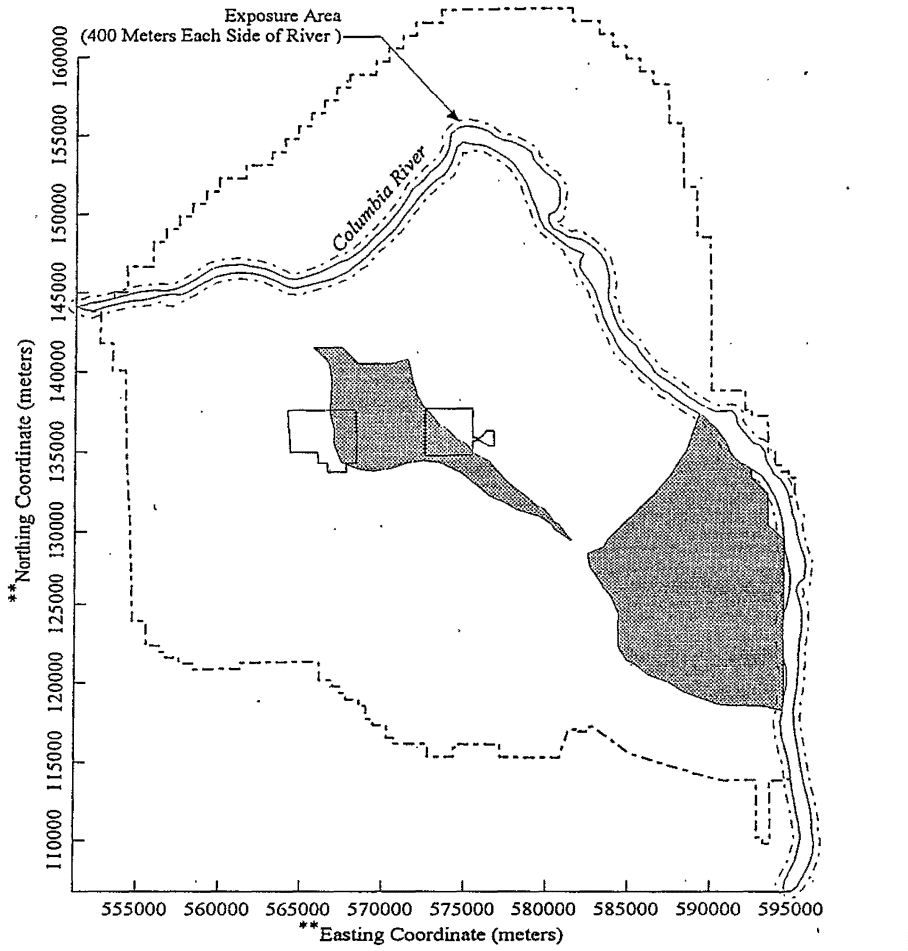


**Figure D.5.7.13 Ex Situ Extensive Separations Alternative, Native American Scenario, Post Remediation Hazard Index from Tank Residuals and LAW Vaults at 5,000 Years from Present**

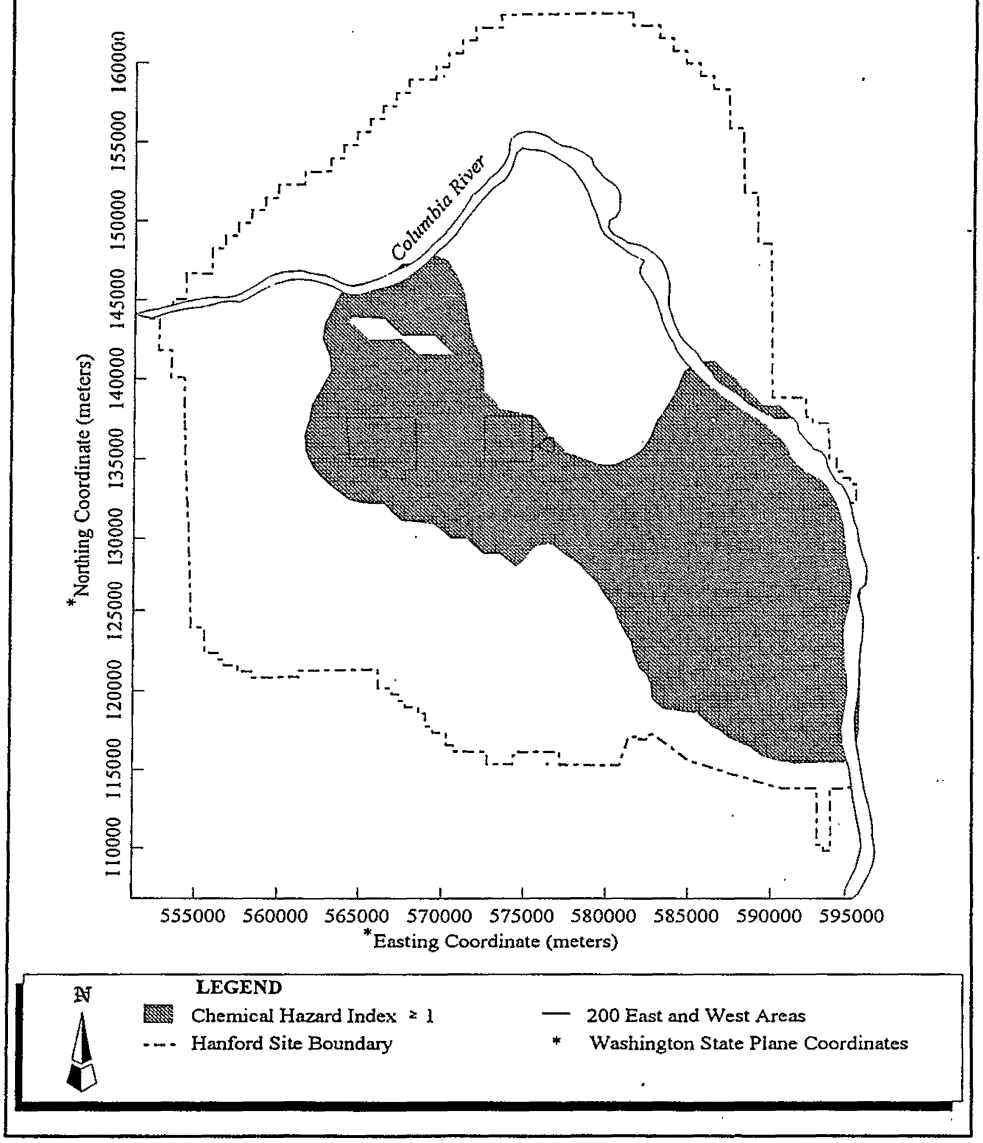


**Figure D.5.7.14 Ex Situ Extensive Separations Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from Tank Residuals and LAW Vaults at 5,000 Years from Present**

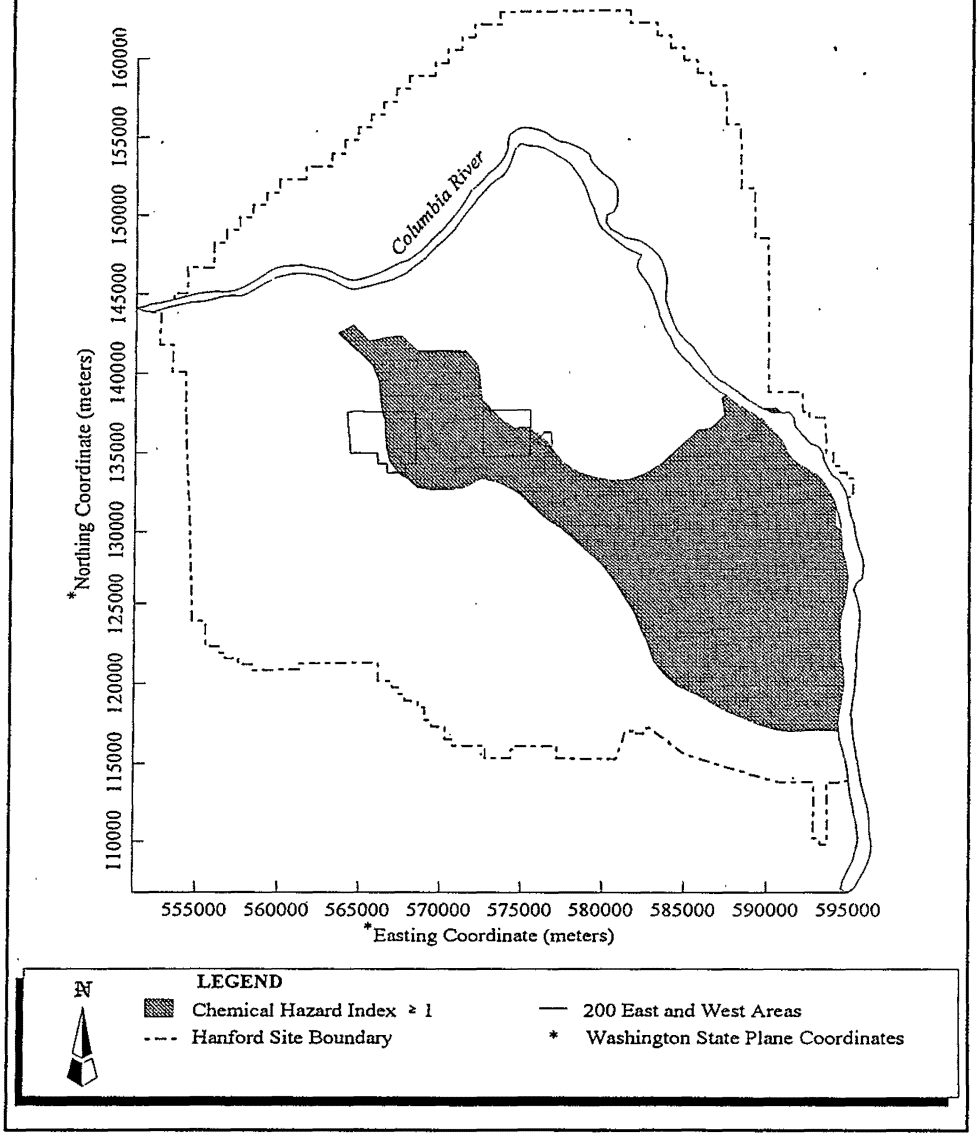


**Figure D.5.8.1 Ex Situ/In Situ Combination 1 Alternative, Native American Scenario, Post Remediation Risk from Ex Situ Tank Residuals at 2,500 Years from Present**

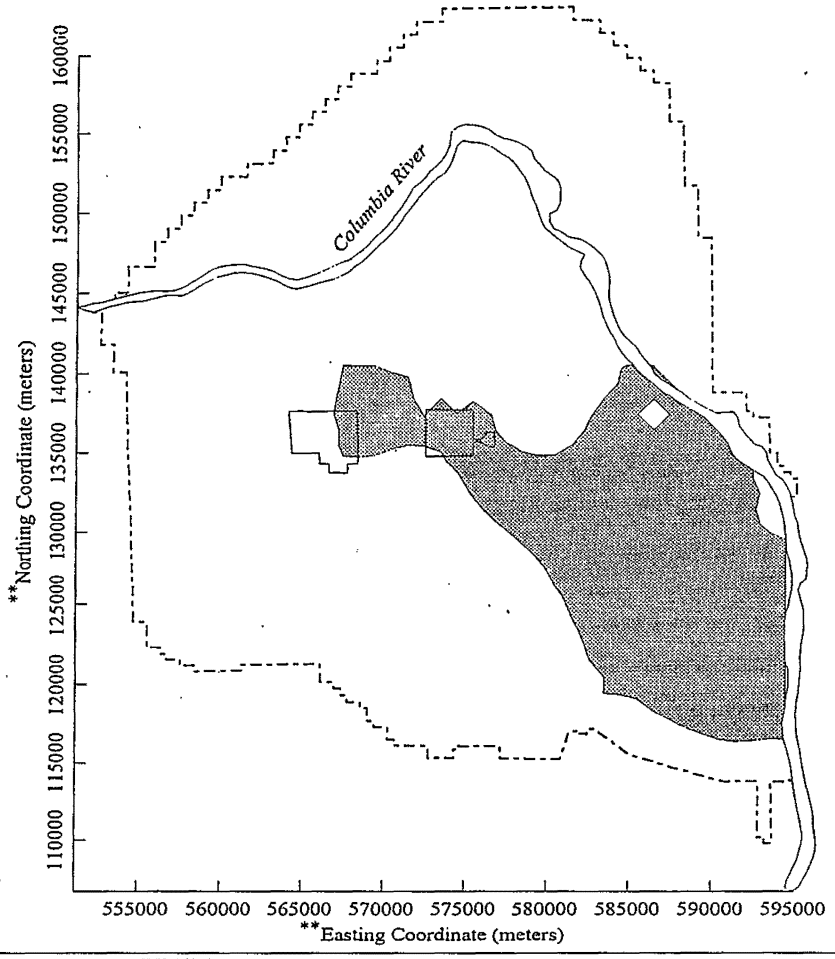


**Figure D.5.8.2 Ex Situ/In Situ Combination 1 Alternative, Native American Scenario, Post Remediation Risk from Ex Situ Tank Residuals at 5,000 Years from Present**

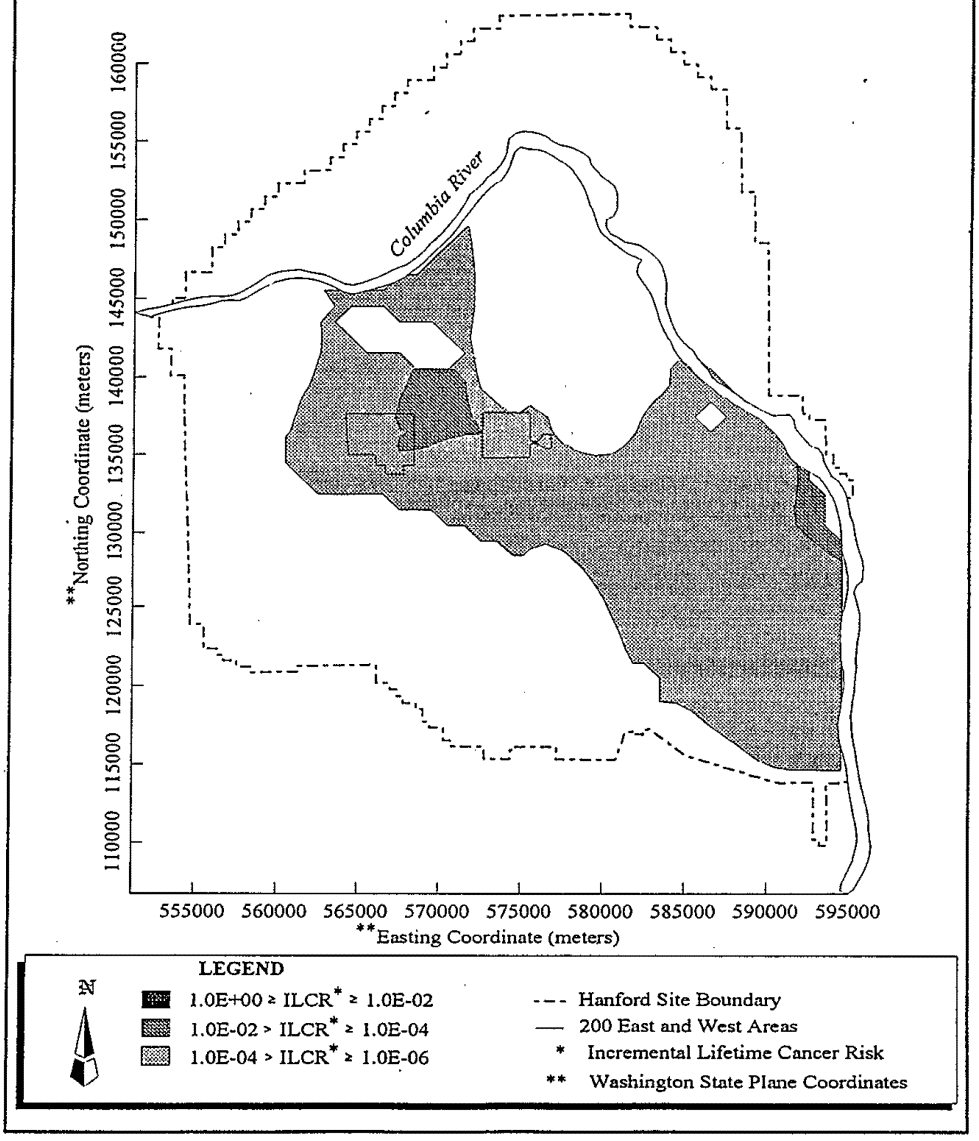


**Figure D.5.8.3 Ex Situ/In Situ Combination 1 Alternative, Residential Farmer Scenario, Post Remediation Risk from Ex Situ Tank Residuals at 2,500 Years from Present**

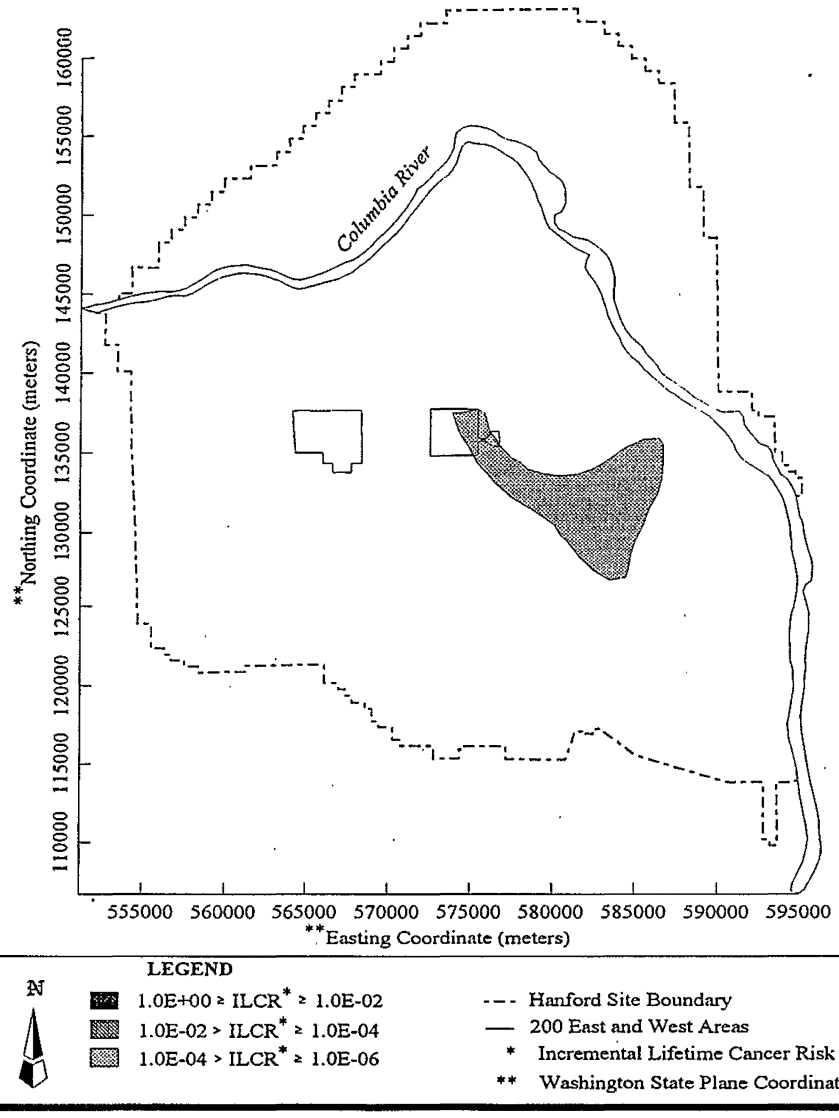


**Figure D.5.8.4 Ex Situ/In Situ Combination 1 Alternative, Residential Farmer Scenario, Post Remediation Risk from Ex Situ Tank Residuals at 5,000 Years from Present**

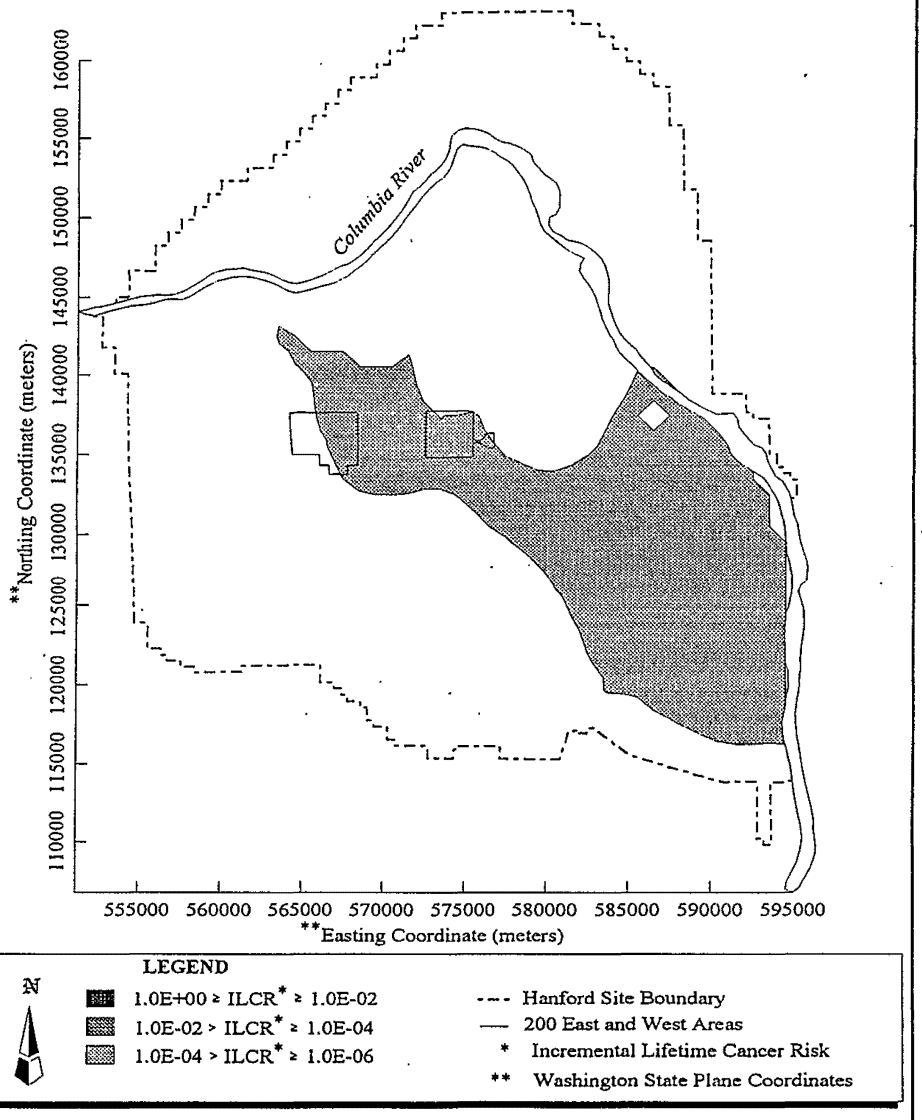


**Figure D.5.8.5 Ex Situ/In Situ Combination 1 Alternative, Industrial Worker Scenario, Post Remediation Risk from Ex Situ Tank Residuals at 2,500 Years from Present**

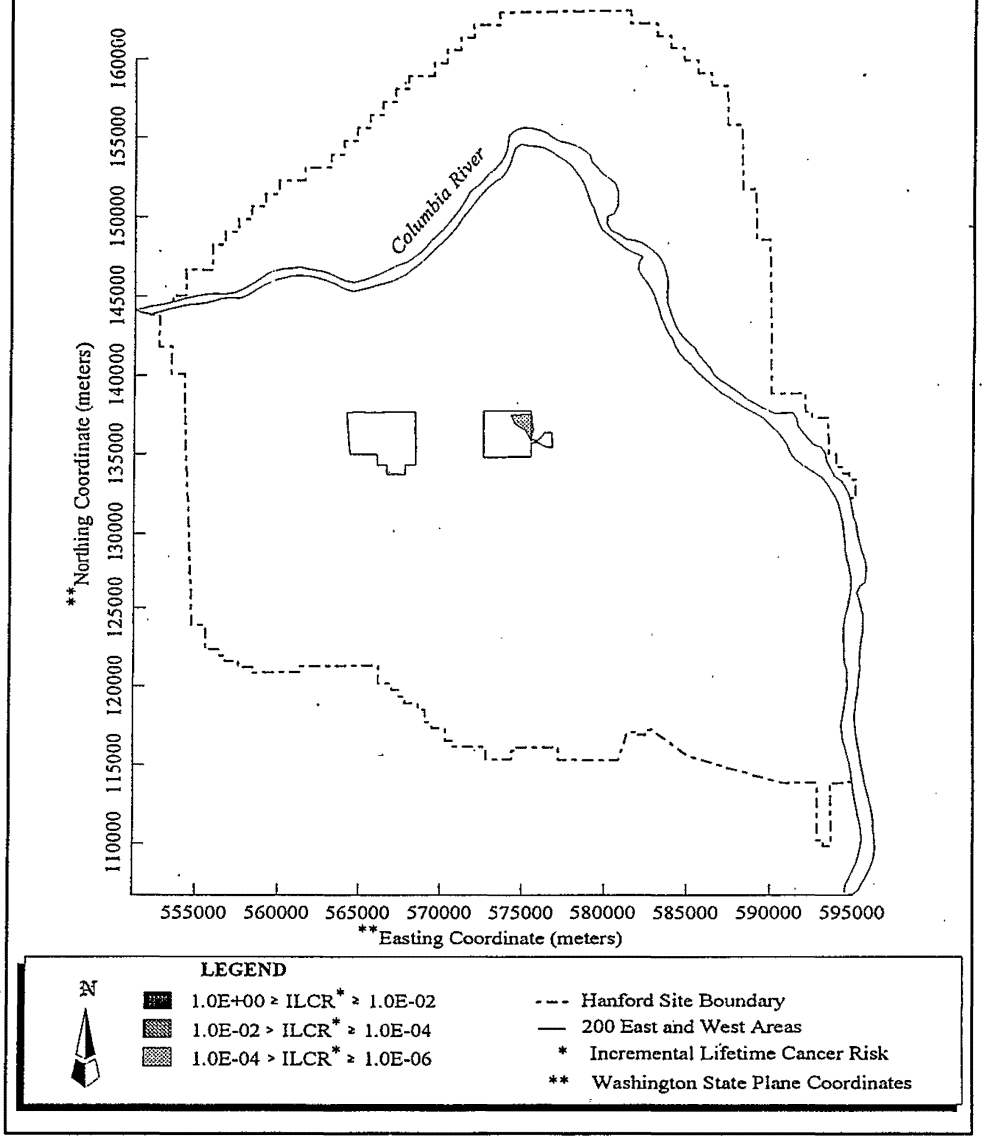


**Figure D.5.8.6 Ex Situ/In Situ Combination 1 Alternative, Industrial Worker Scenario, Post Remediation Risk from Ex Situ Tank Residuals at 5,000 Years from Present**

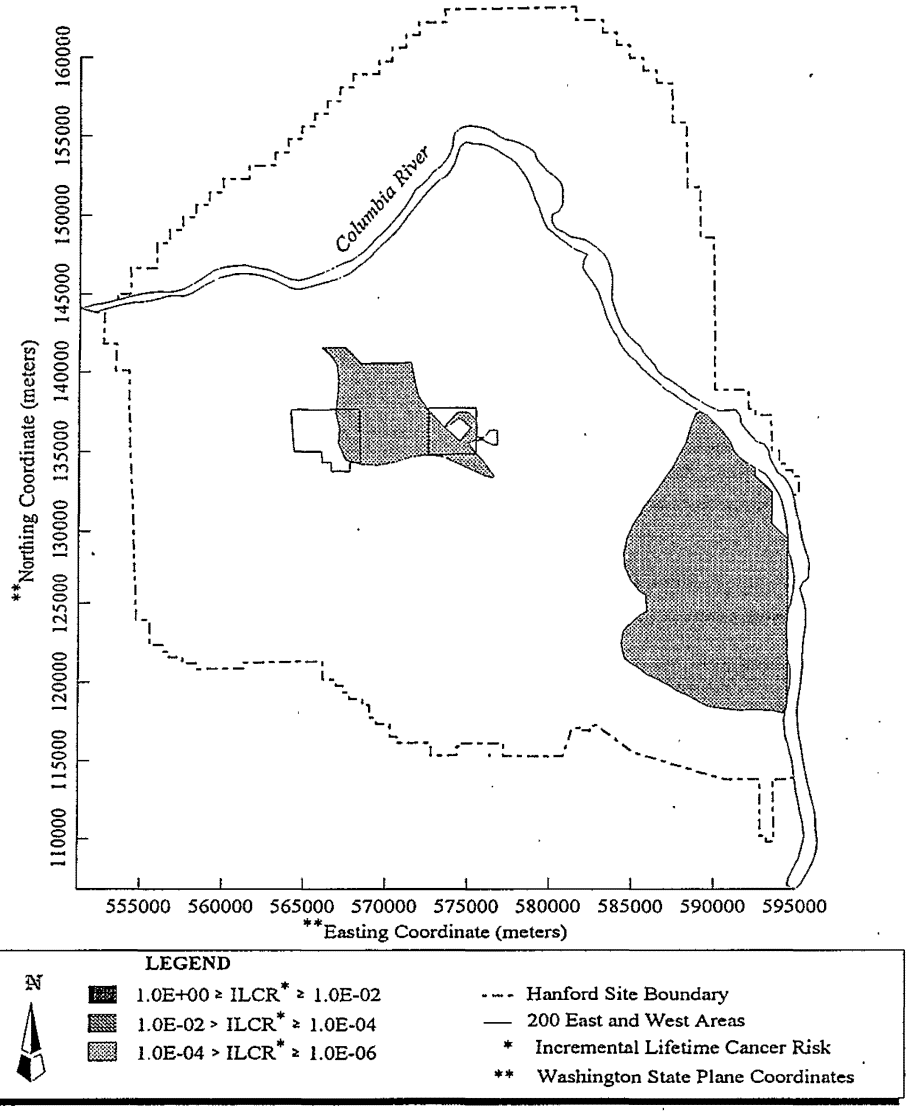
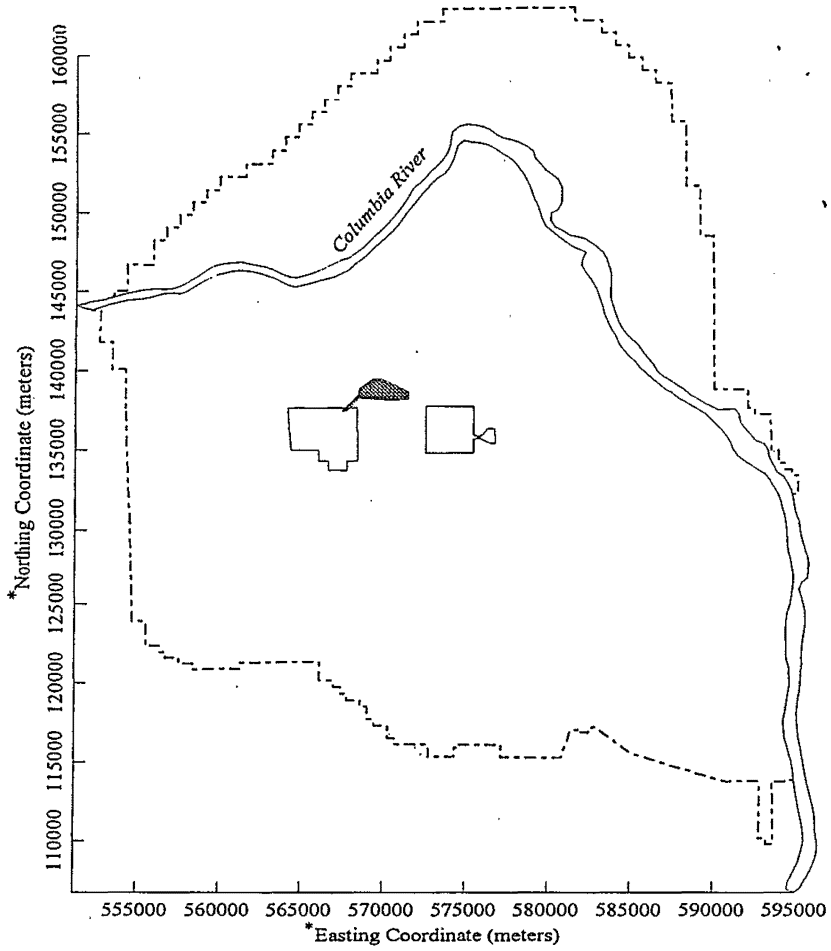


**Figure D.5.8.7 Ex Situ/In Situ Combination 1 Alternative, Native American Scenario, Post Remediation Hazard Index from Ex Situ Tank Residuals at 5,000 Years from Present**



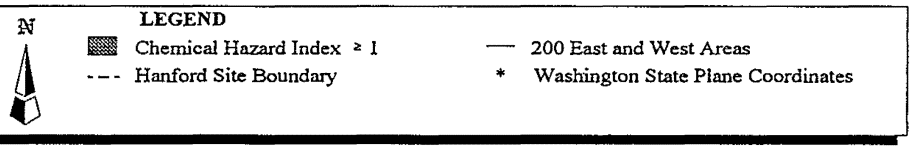



**Figure D.5.8.8 Ex Situ/In Situ Combination 1 Alternative, Native American Scenario, Post Remediation Risk from In Situ Tank Residuals at 5,000 Years from Present**

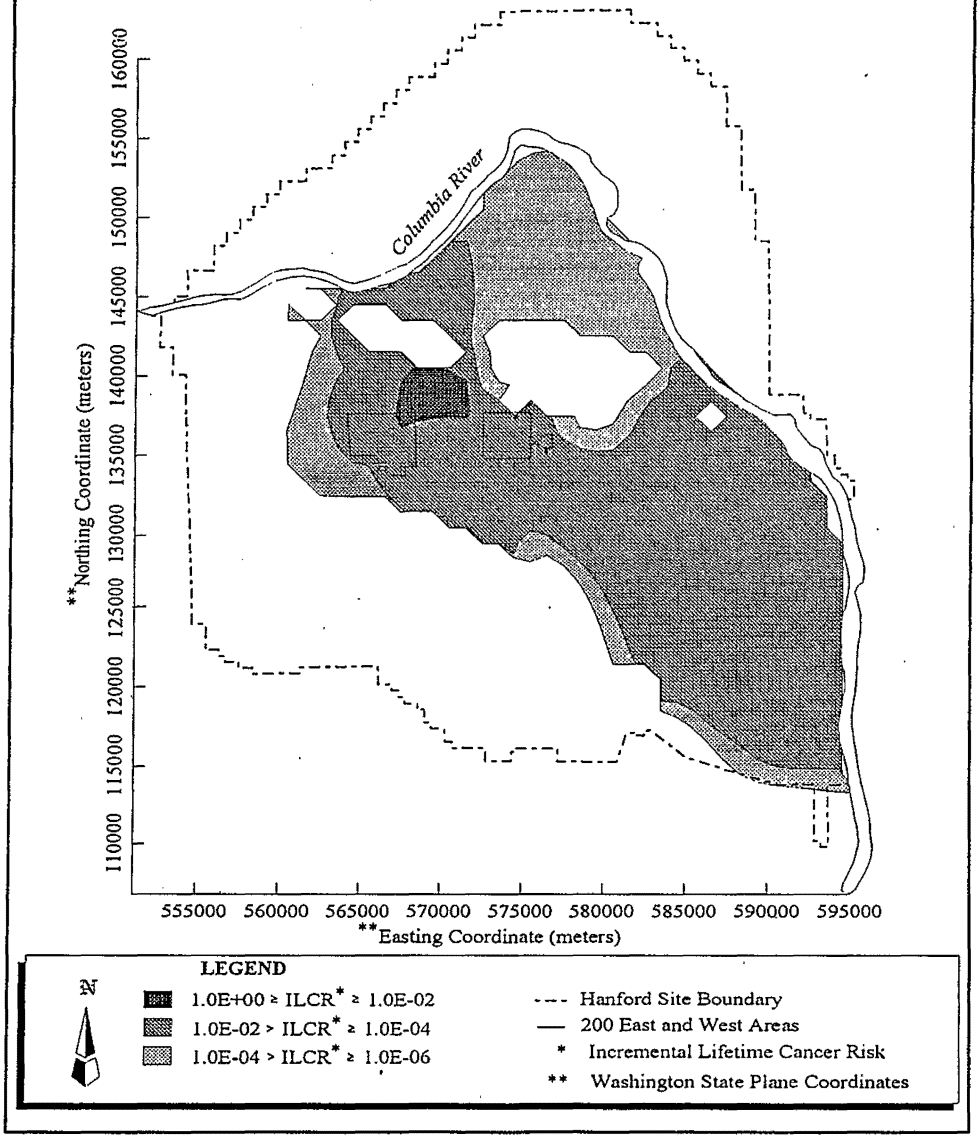


**Figure D.5.8.9 Ex Situ/In Situ Combination 1 Alternative, Native American Scenario, Post Remediation Risk from In Situ Tank Residuals at 10,000 Years from Present**

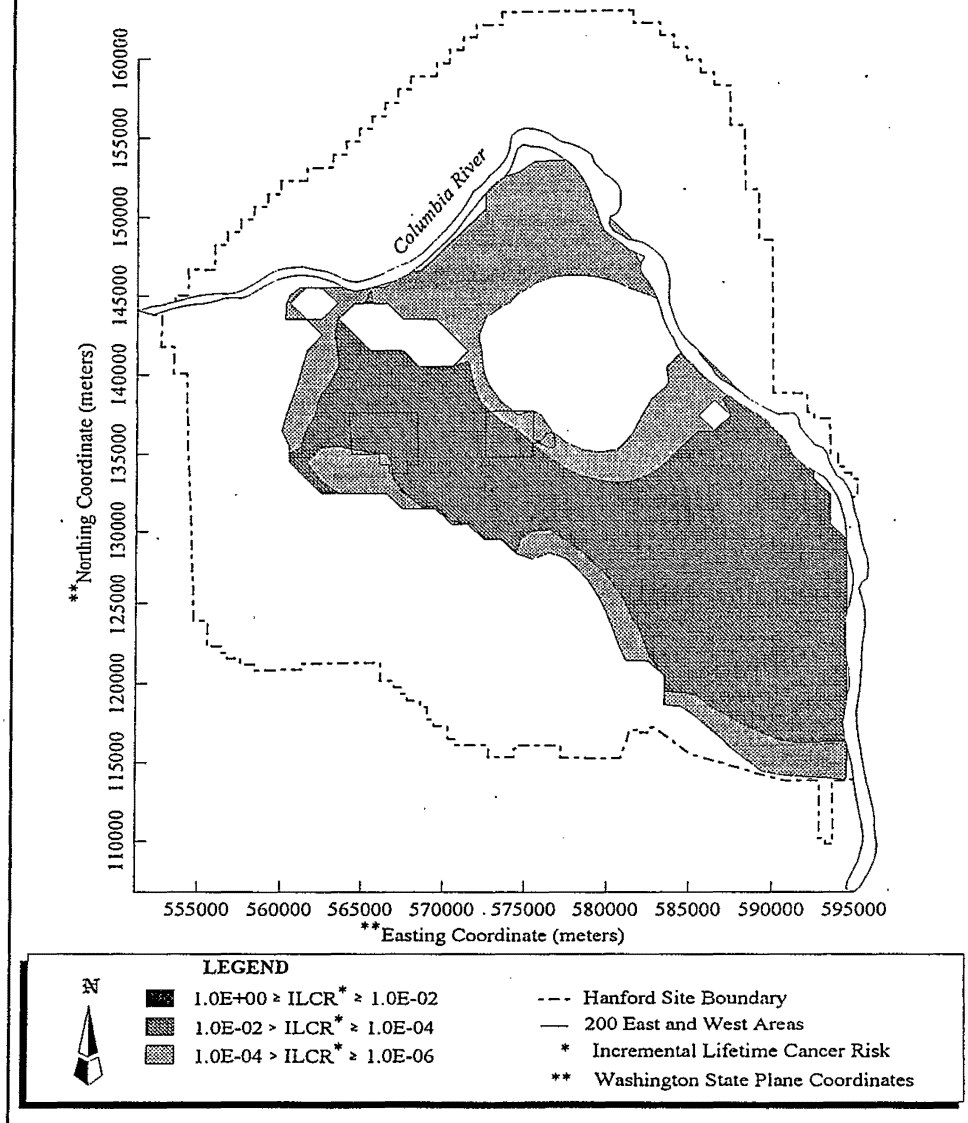


**Figure D.5.8.10 Ex Situ/In Situ Combination 1 Alternative, Residential Farmer Scenario, Post Remediation Risk from In Situ Tank Residuals at 5,000 Years from Present**

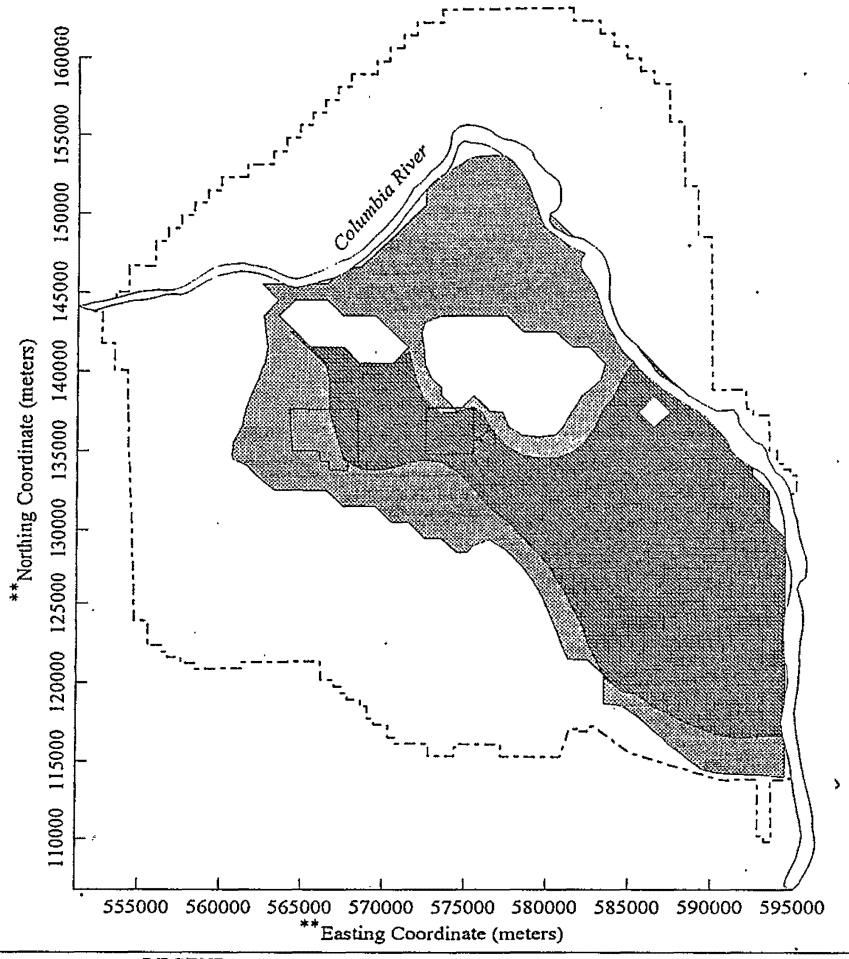


**Figure D.5.8.11 Ex Situ/In Situ Combination 1 Alternative, Residential Farmer Scenario, Post Remediation Risk from In Situ Tank Residuals at 10,000 Years from Present**

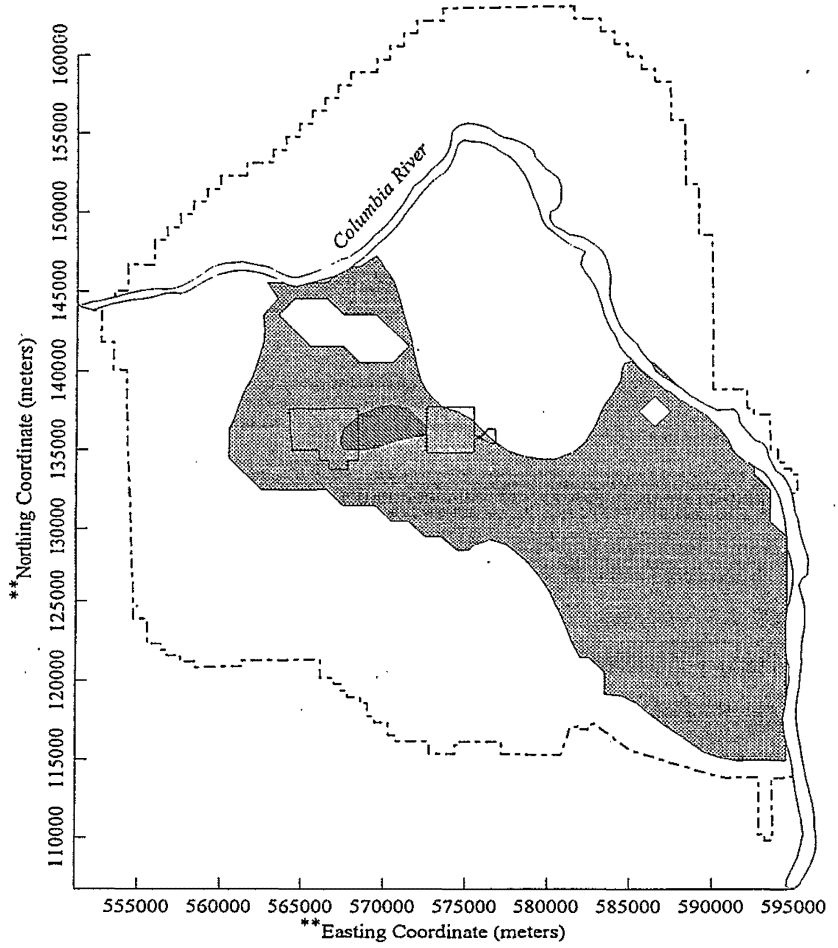


**Figure D.5.8.12 Ex Situ/In Situ Combination 1 Alternative, Industrial Worker Scenario, Post Remediation Risk from In Situ Tank Residuals at 5,000 Years from Present**

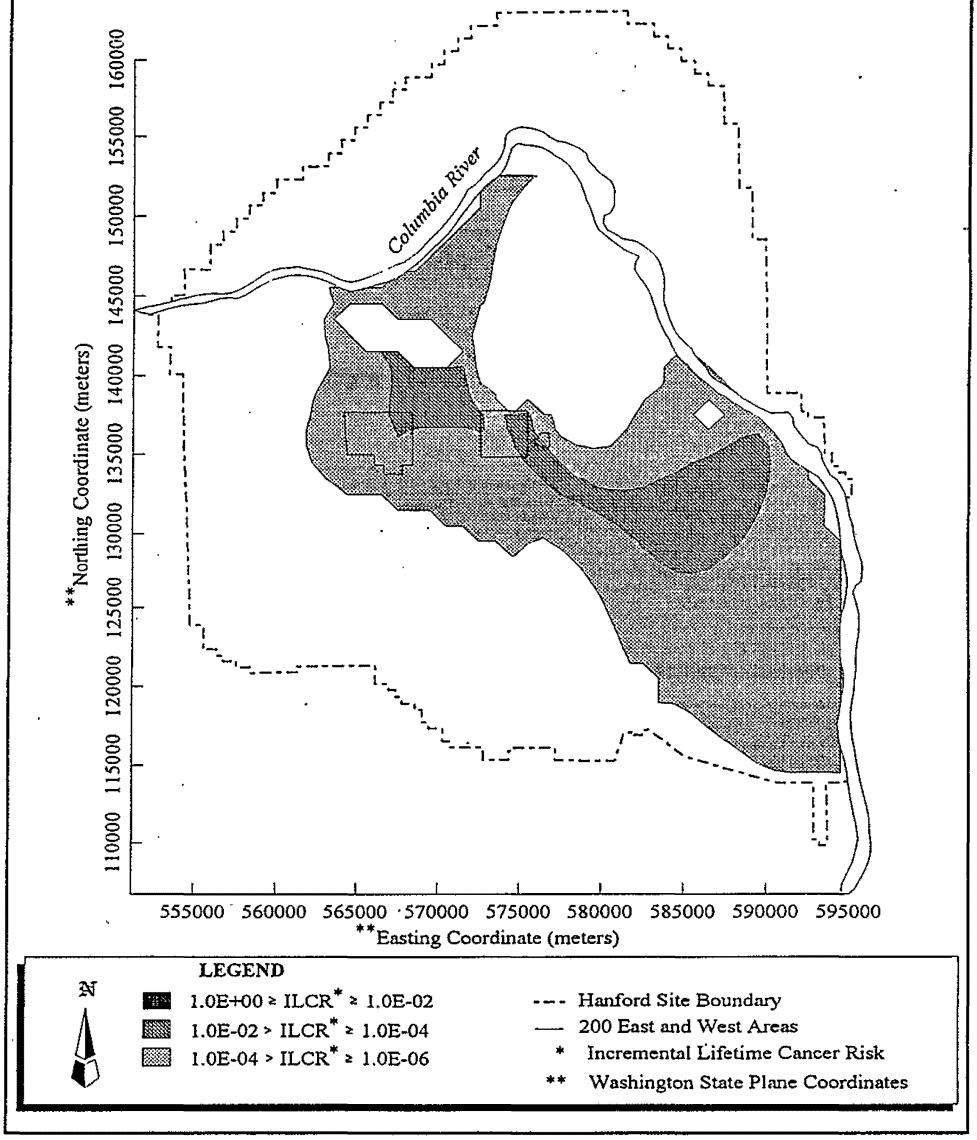


**Figure D.5.8.13 Ex Situ/In Situ Combination 1 Alternative, Industrial Worker Scenario, Post Remediation Risk from In Situ Tank Residuals at 10,000 Years from Present**

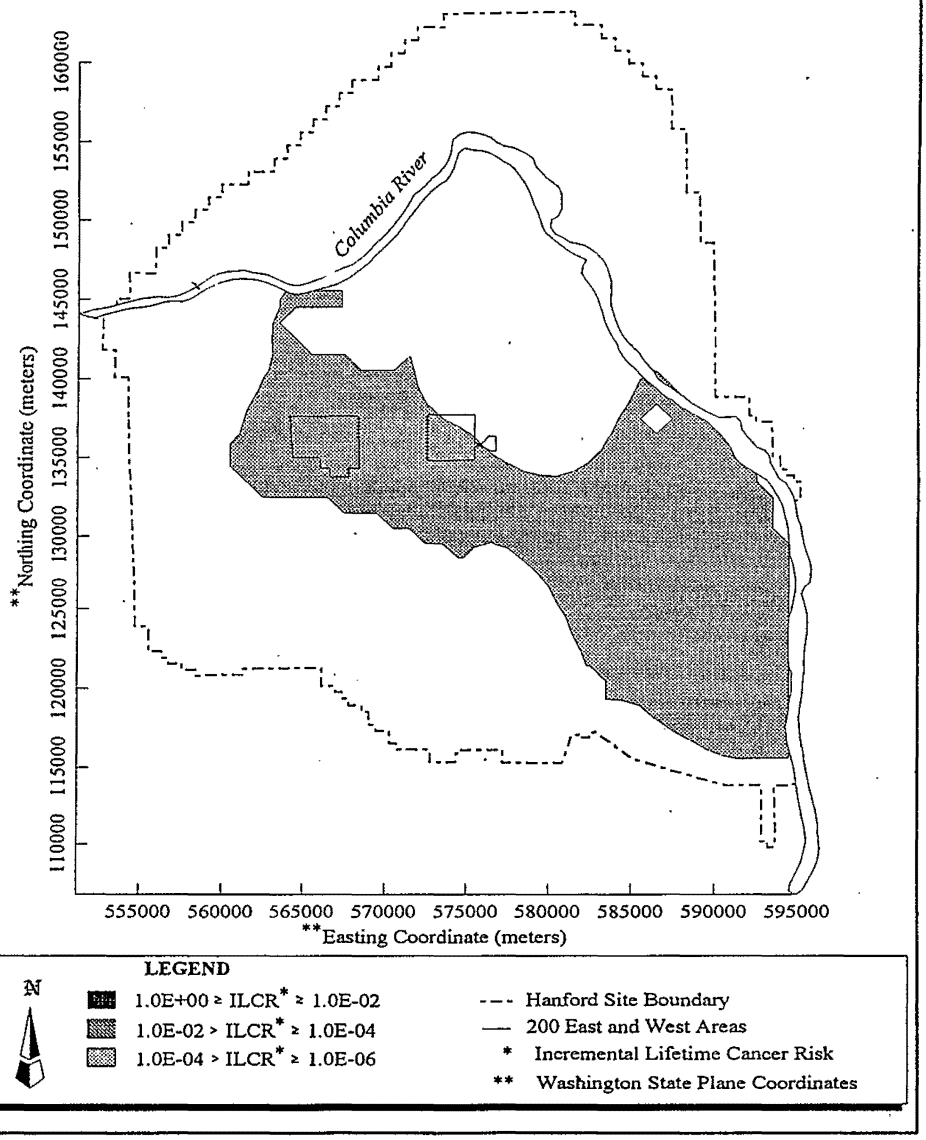


**Figure D.5.8.14 Ex Situ/In Situ Combination 1 Alternative, Recreational River User Scenario, Post Remediation Risk from In Situ Tank Residuals at 5,000 Years from Present**

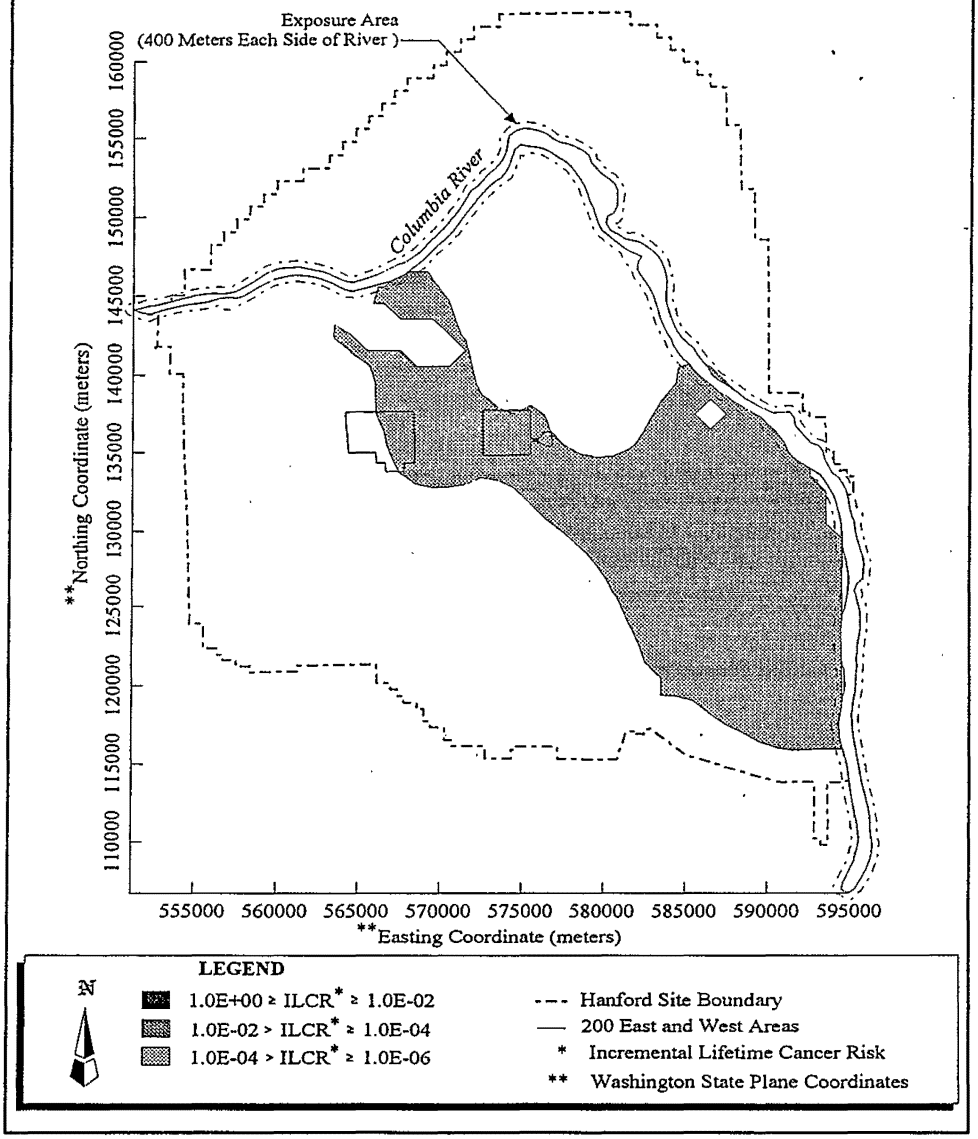


**Figure D.5.8.15 Ex Situ/In Situ Combination 1 Alternative, Recreational River User Scenario, Post Remediation Risk from In Situ Tank Residuals at 10,000 Years from Present**

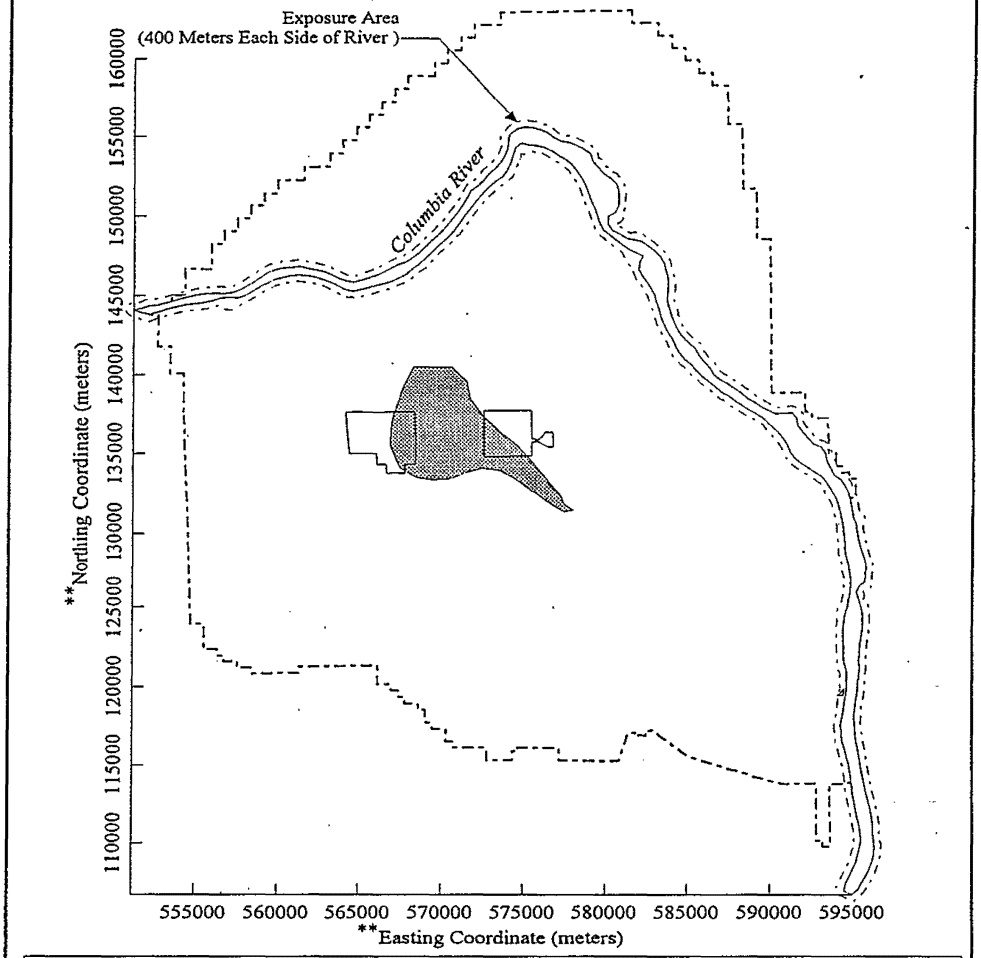


**Figure D.5.8.16 Ex Situ/In Situ Combination 1 Alternative, Native American Scenario, Post Remediation Hazard Index from In Situ Tank Residuals at 5,000 Years from Present**

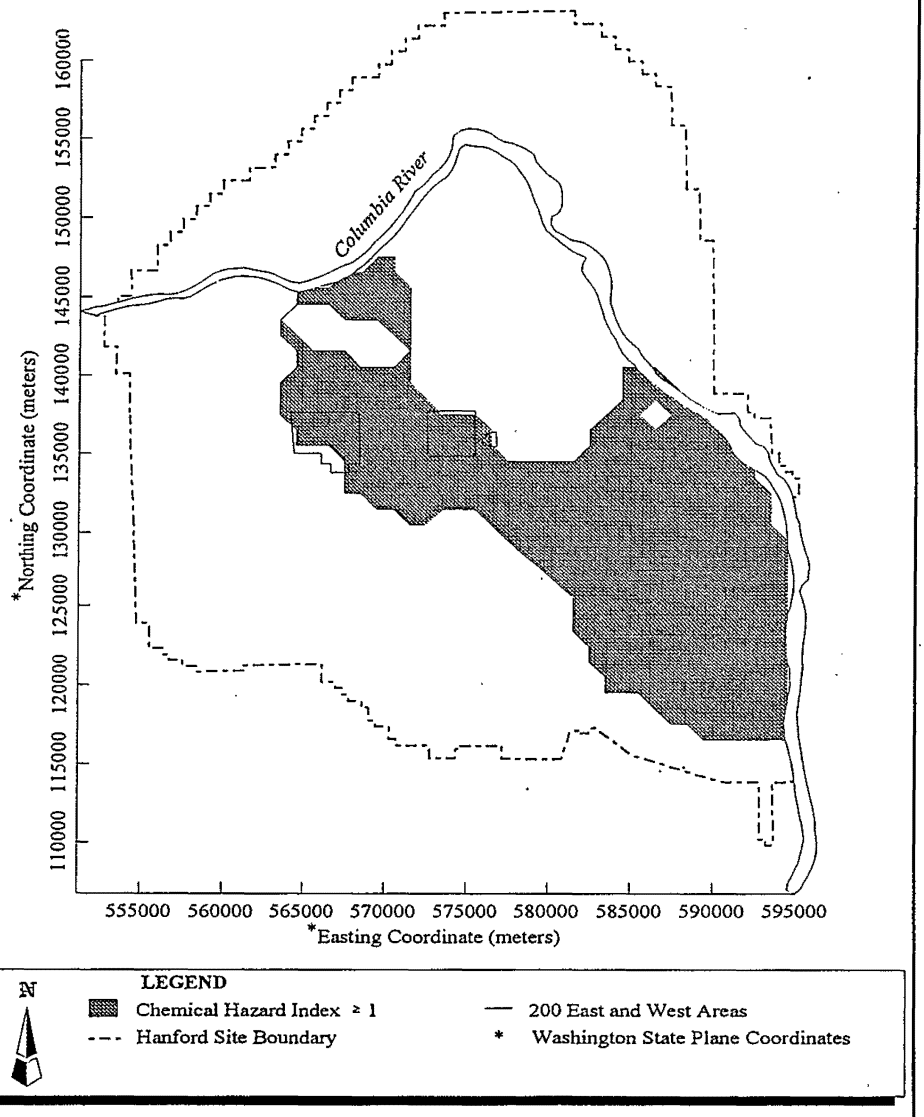


**Figure D.5.8.17 Ex Situ/In Situ Combination 1 Alternative, Native American Scenario, Post Remediation Hazard Index from In Situ Tank Residuals at 10,000 Years from Present**

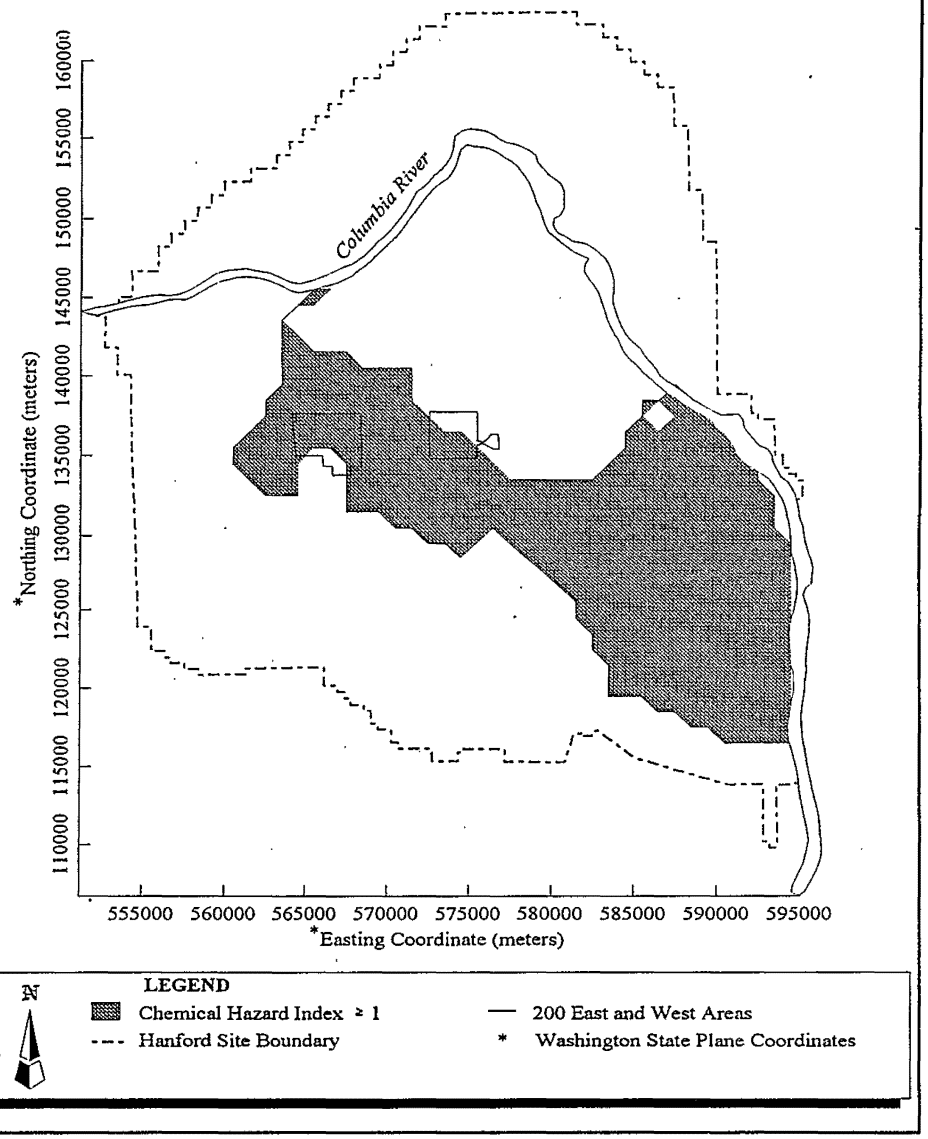


**Figure D.5.8.18 Ex Situ/In Situ Combination 1 Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from In Situ Tank Residuals at 5,000 Years from Present**

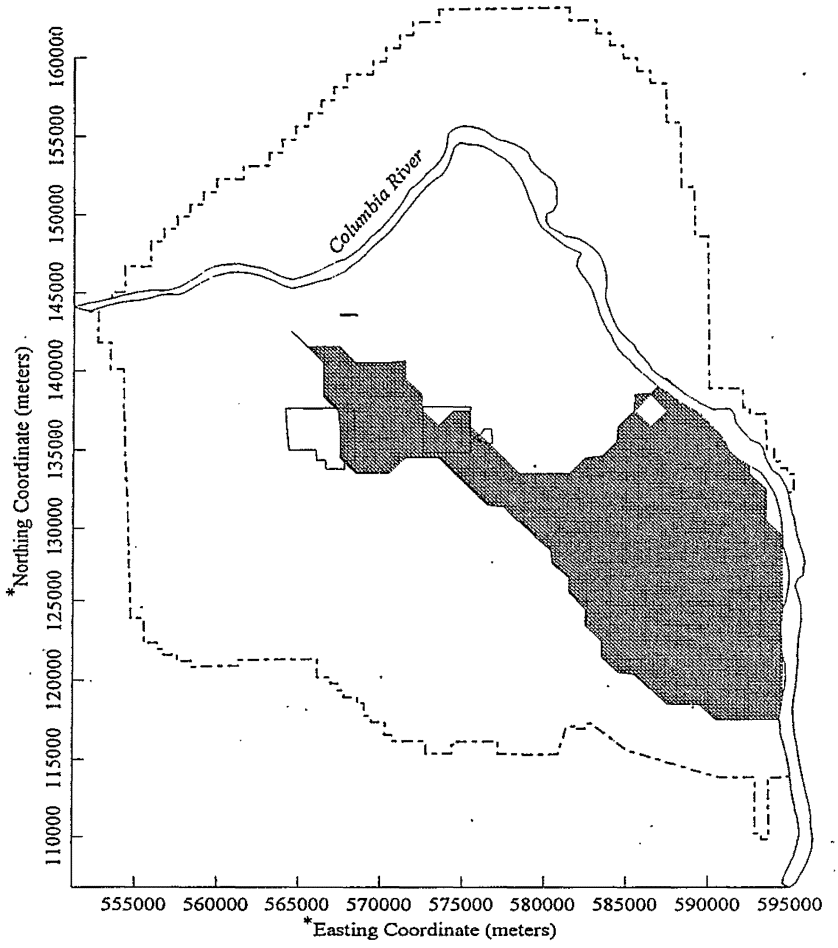


**Figure D.5.8.19 Ex Situ/In Situ Combination 1 Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from In Situ Tank Residuals at 10,000 Years from Present**

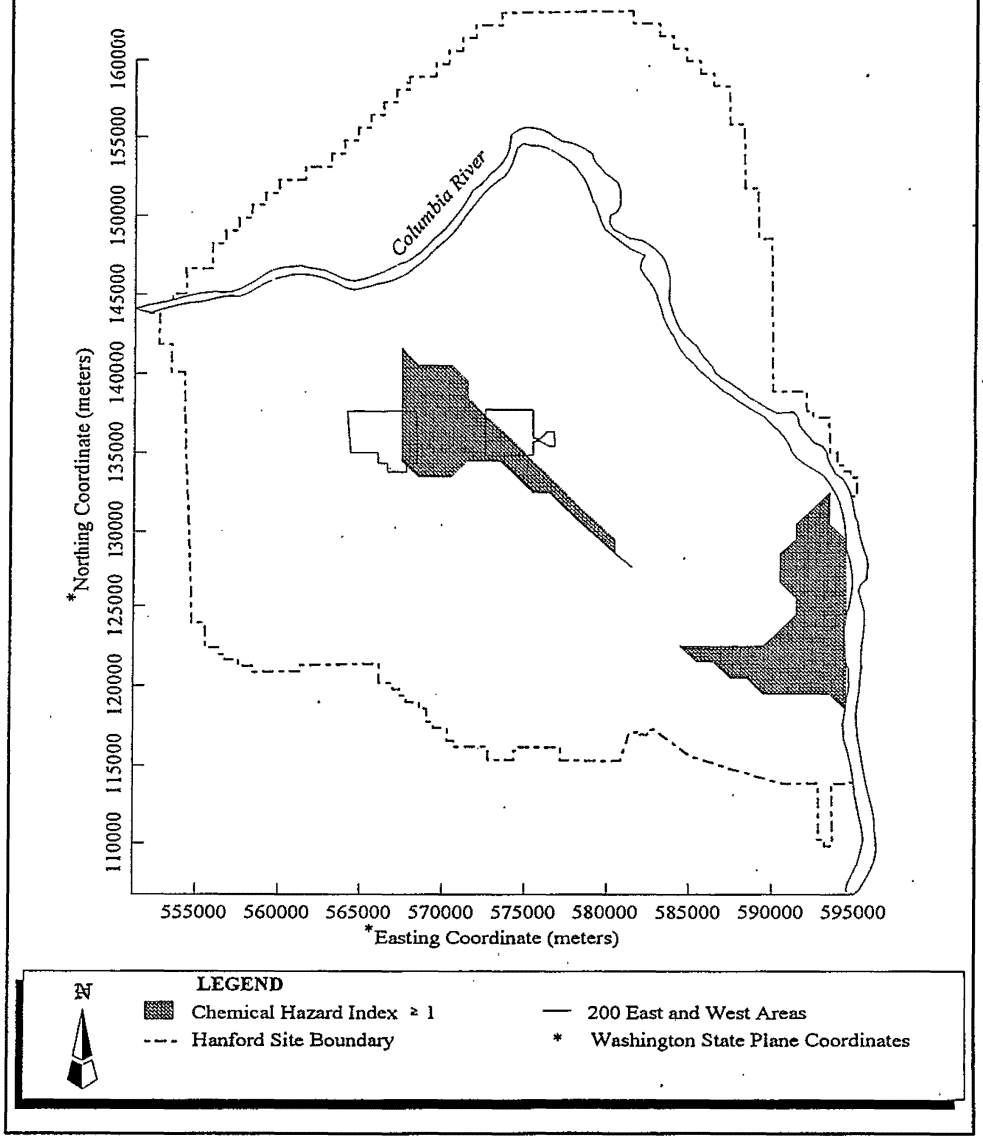


**Figure D.5.8.20 Ex Situ/In Situ Combination 1 Alternative, Native American Scenario, Post Remediation Risk from LAW Vaults at 5,000 Years from Present**

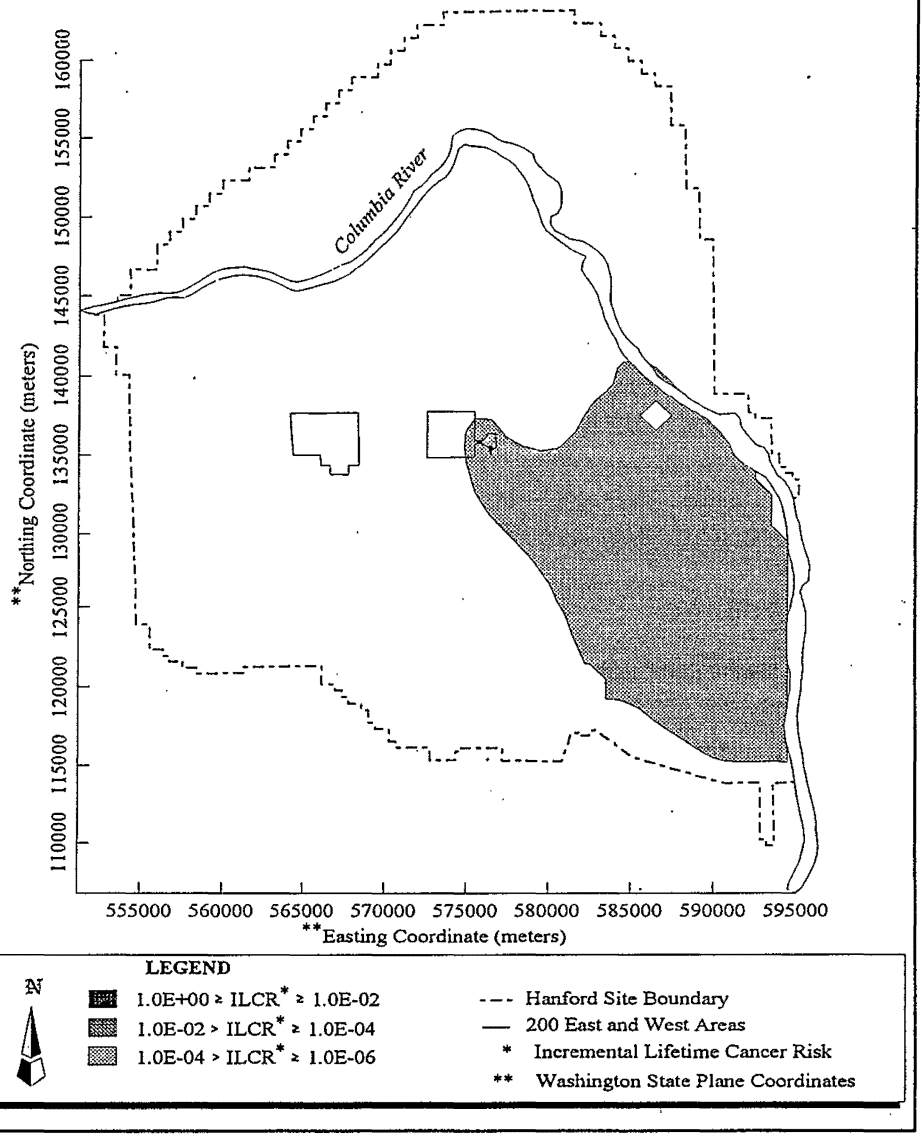


**Figure D.5.8.21 Ex Situ/In Situ Combination 1 Alternative, Native American Scenario, Post Remediation Risk from LAW Vaults at 10,000 Years from Present**

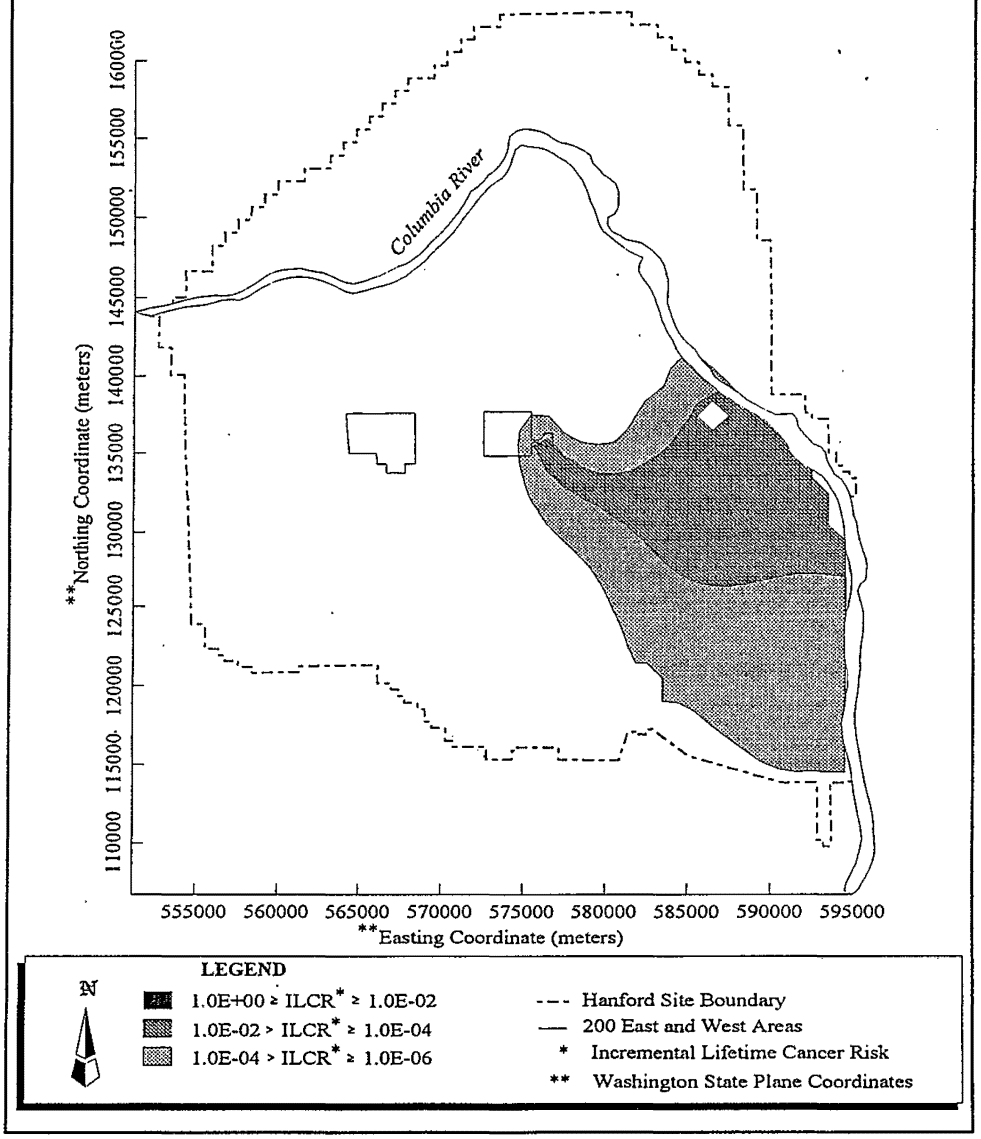


**Figure D.5.8.22 Ex Situ/In Situ Combination 1 Alternative, Residential Farmer Scenario, Post Remediation Risk from LAW Vaults at 5,000 Years from Present**

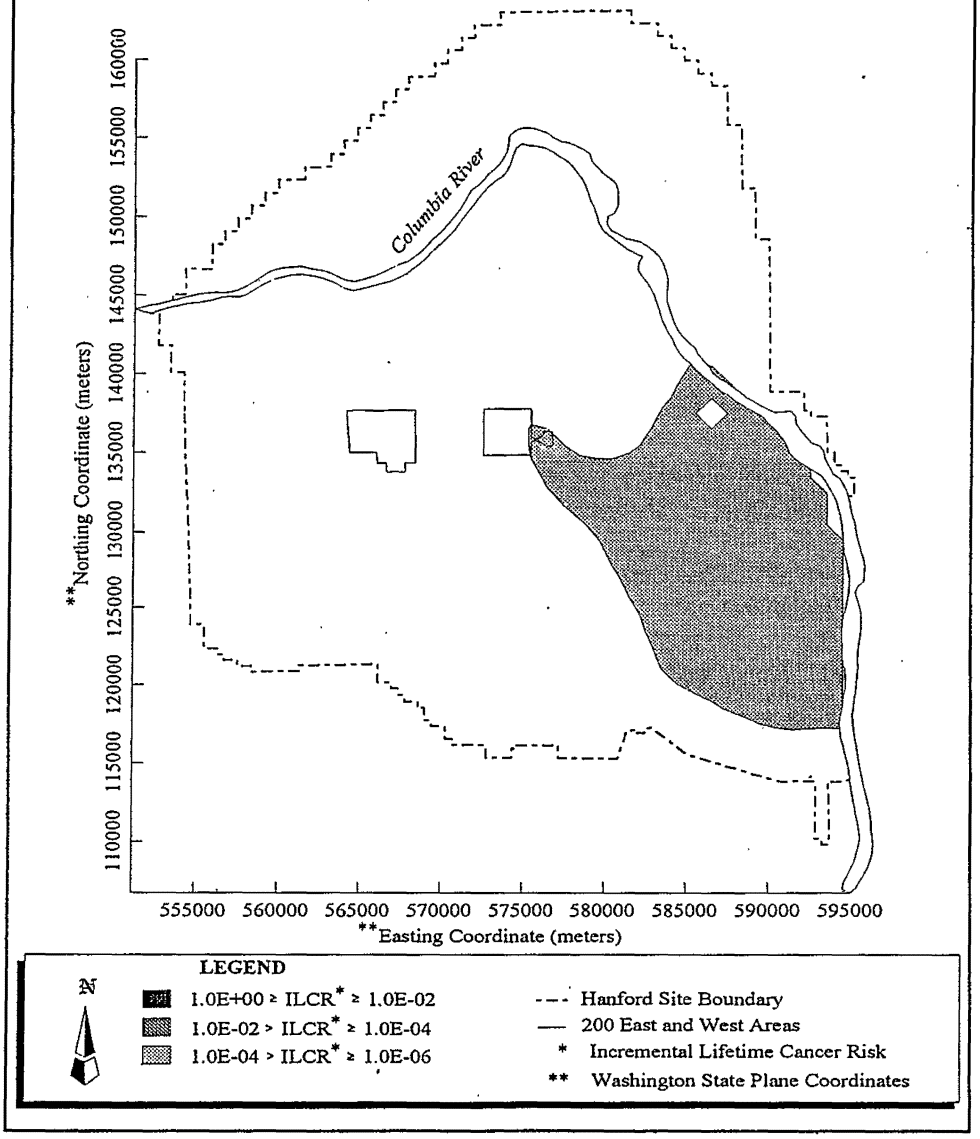


**Figure D.5.8.23 Ex Situ/In Situ Combination 1 Alternative, Residential Farmer Scenario, Post Remediation Risk from LAW Vaults at 10,000 Years from Present**

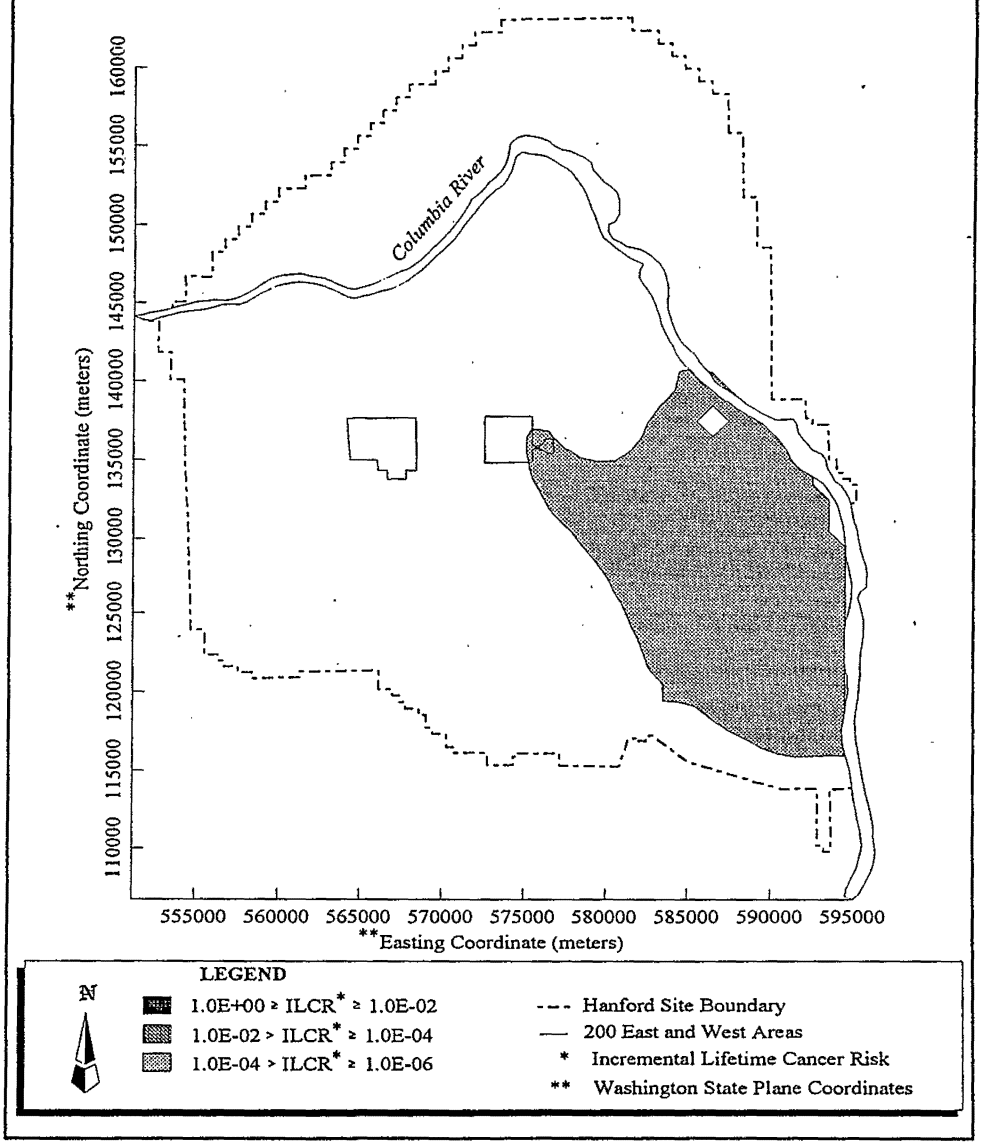


**Figure D.5.8.24 Ex Situ/In Situ Combination 1 Alternative, Industrial Worker Scenario, Post Remediation Risk from LAW Vaults at 5,000 Years from Present**

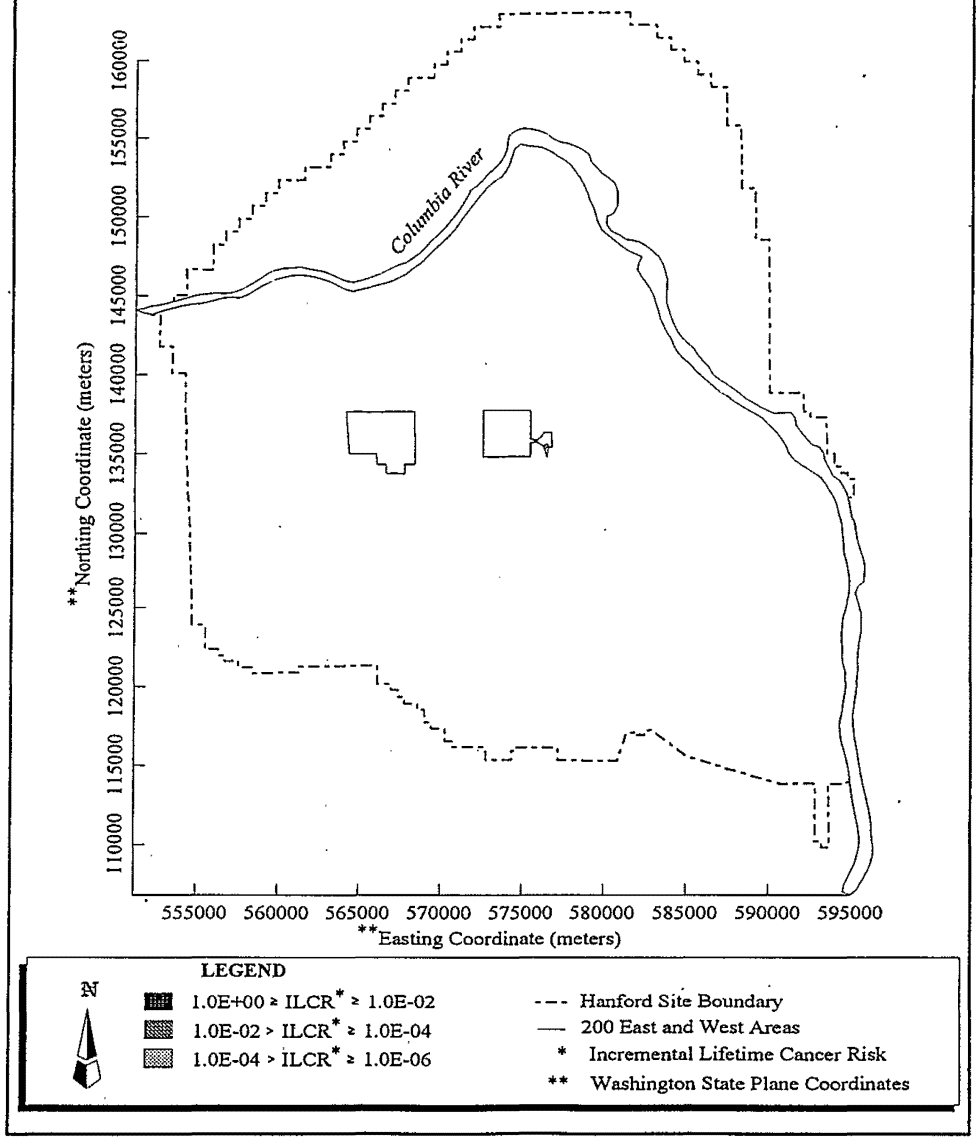


**Figure D.5.8.25 Ex Situ/In Situ Combination 1 Alternative, Industrial Worker Scenario, Post Remediation Risk from LAW Vaults at 10,000 Years from Present**

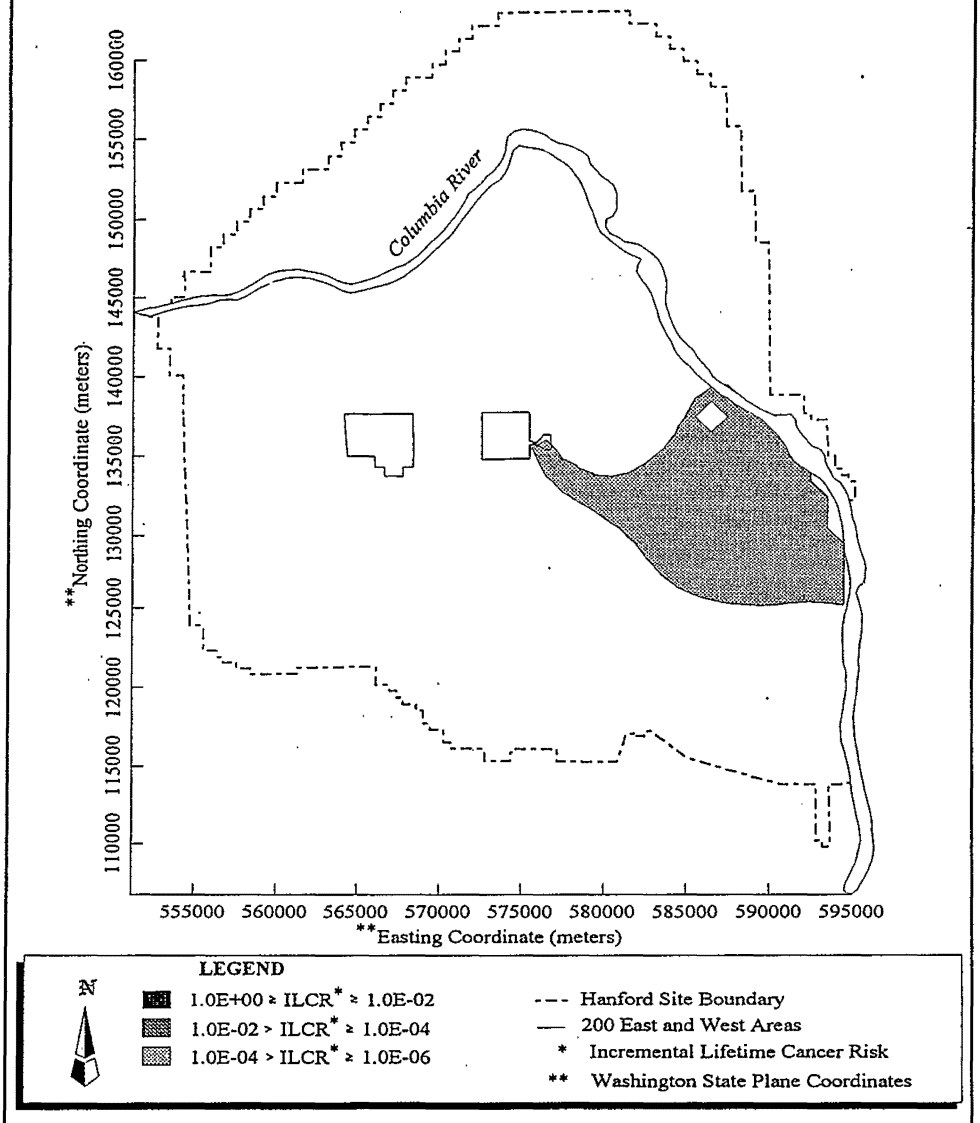


**Figure D.5.8.26 Ex Situ/In Situ Combination 1 Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 2,500 Years from Present**

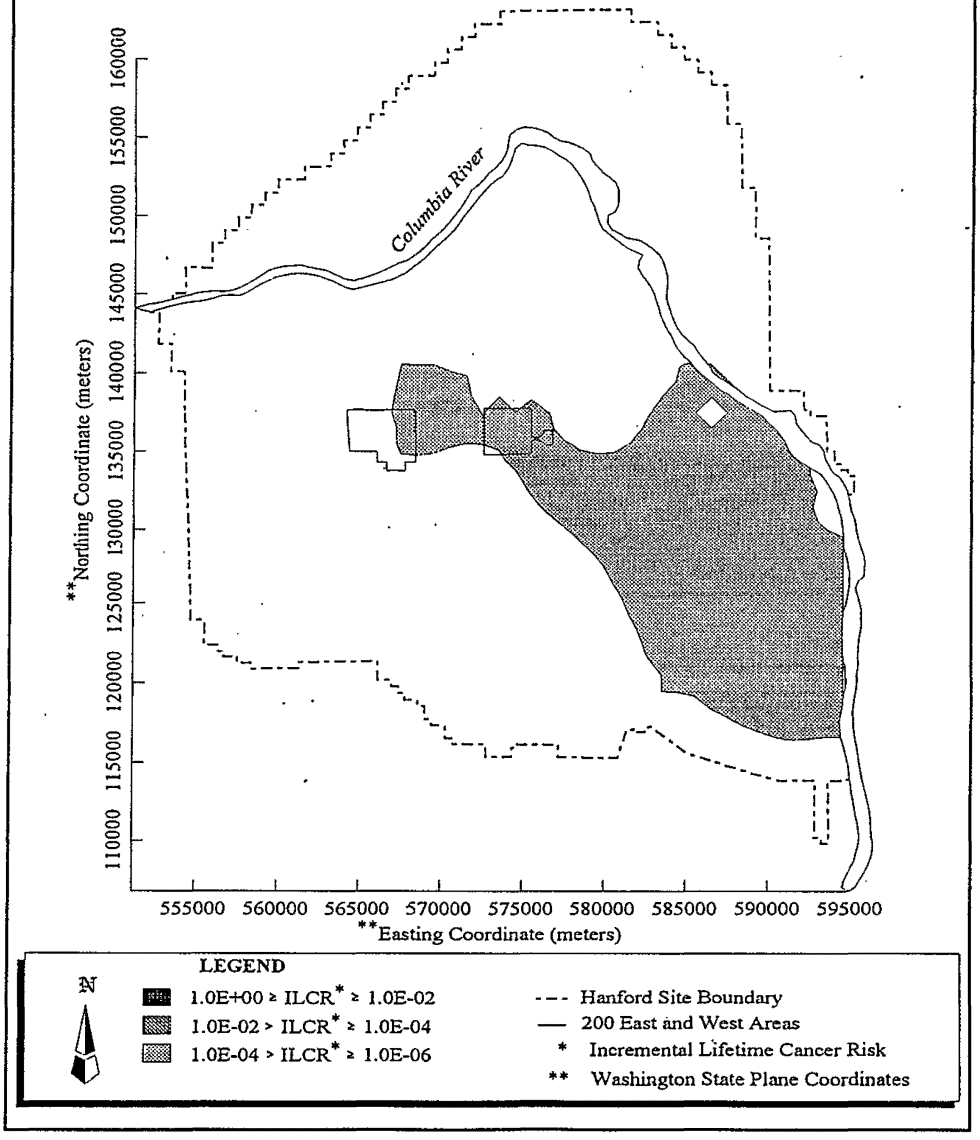


**Figure D.5.8.27 Ex Situ/In Situ Combination 1 Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

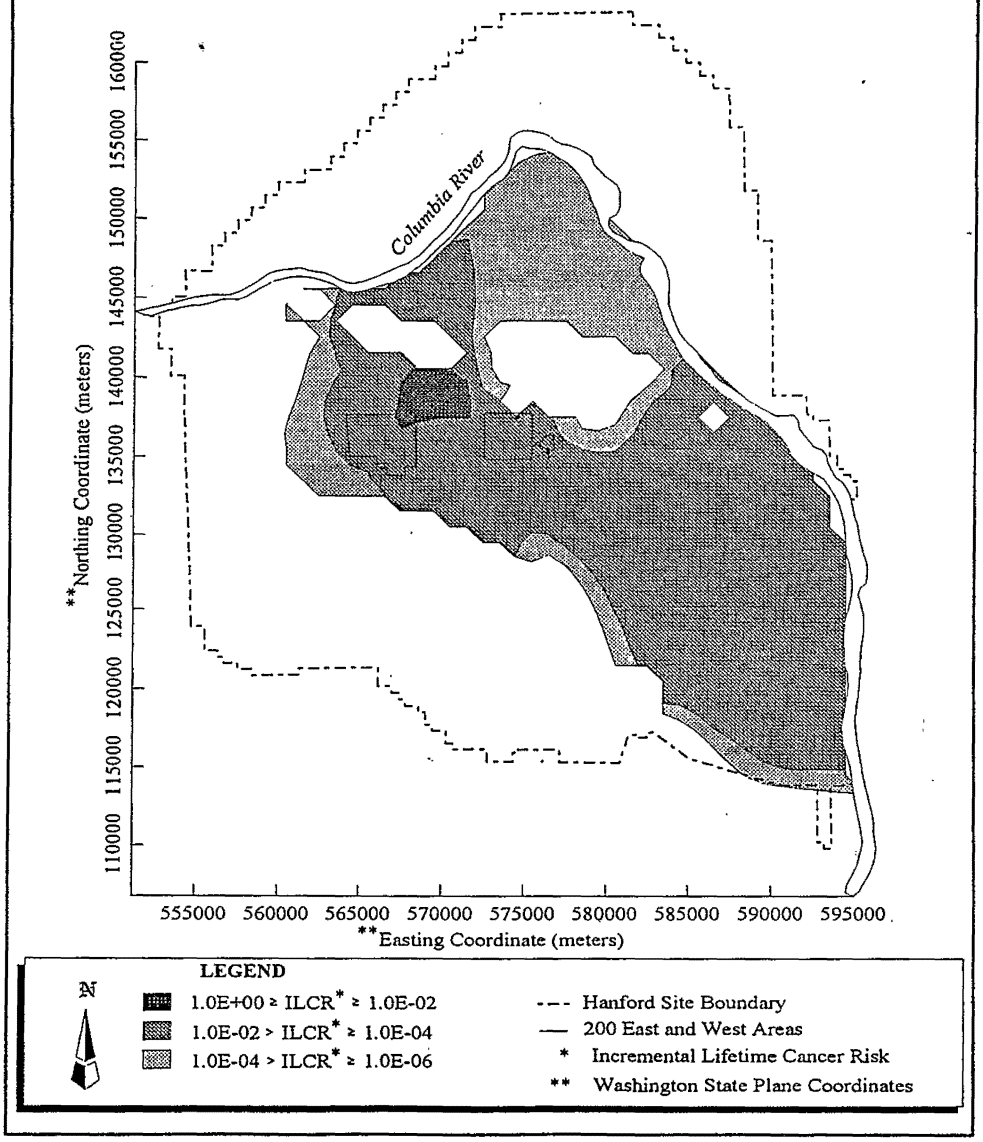


**Figure D.5.8.28 Ex Situ/In Situ Combination 1 Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 10,000 Years from Present**

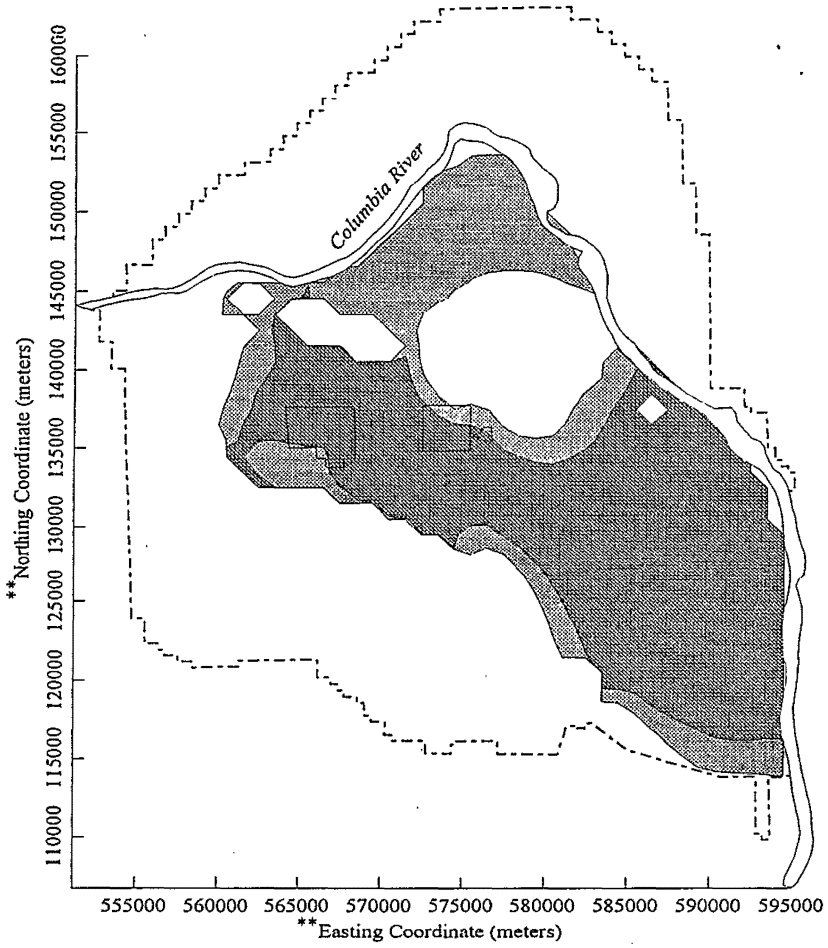


**Figure D.5.8.29 Ex Situ/In Situ Combination 1 Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 2,500 Years from Present**

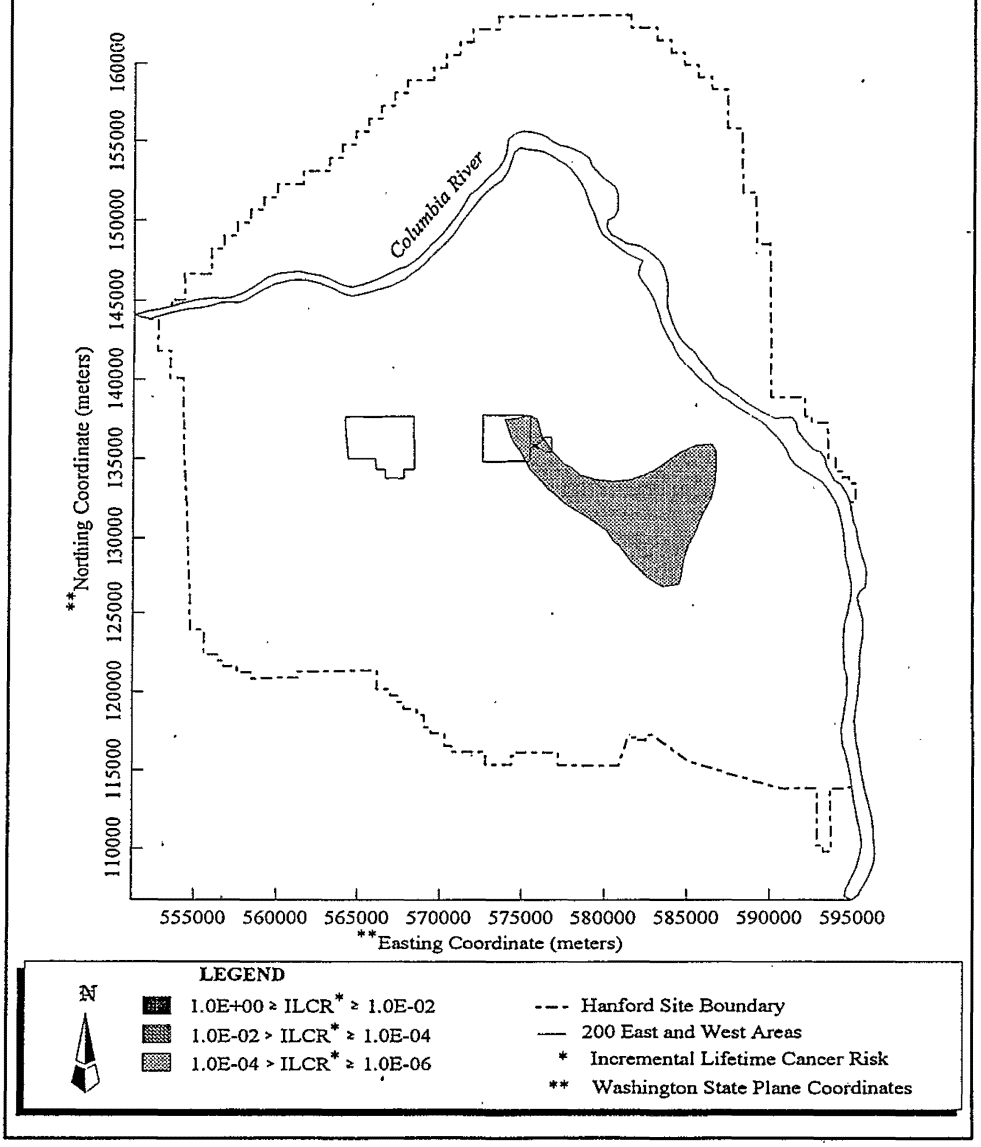


**Figure D.5.8.30 Ex Situ/In Situ Combination 1 Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

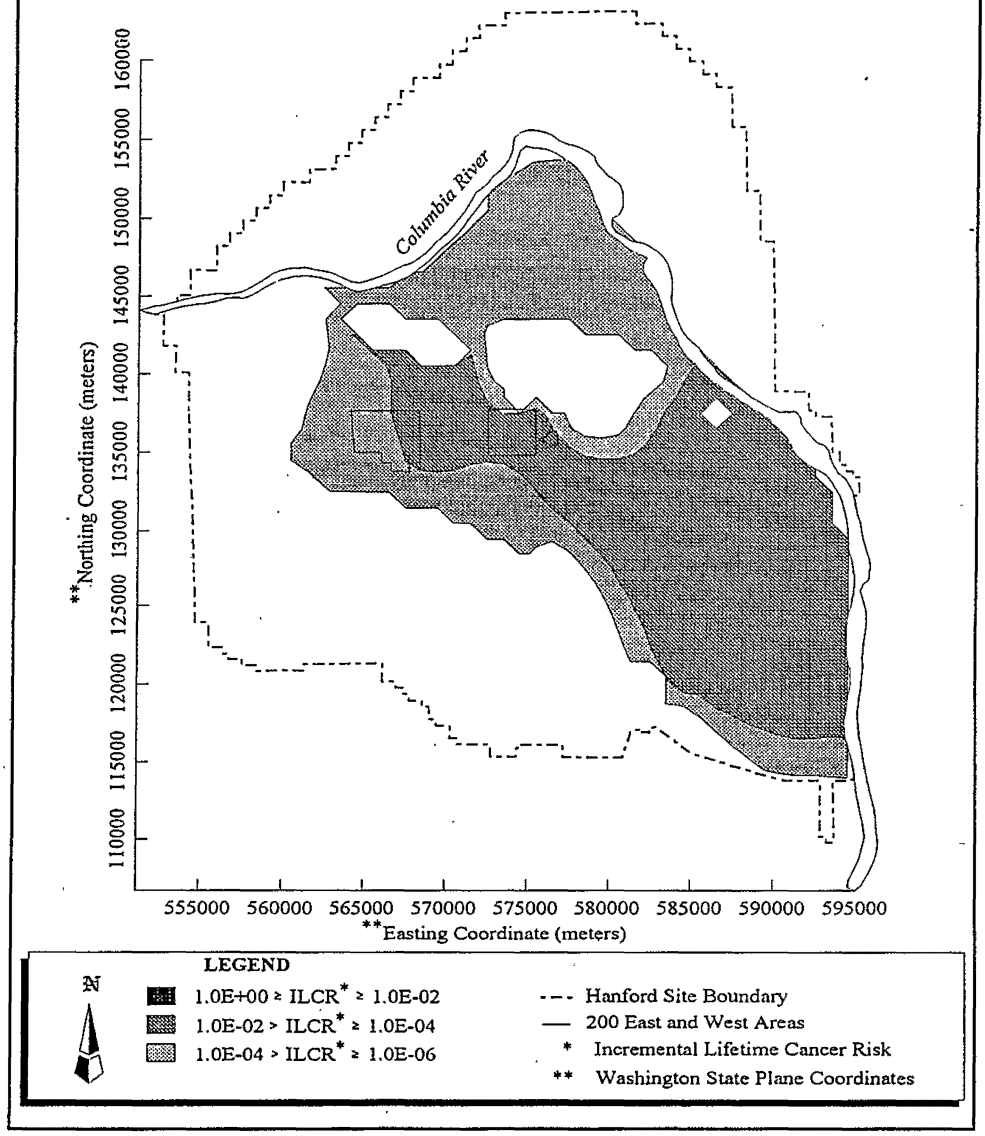


**Figure D.5.8.31 Ex Situ/In Situ Combination 1 Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 10,000 Years from Present**

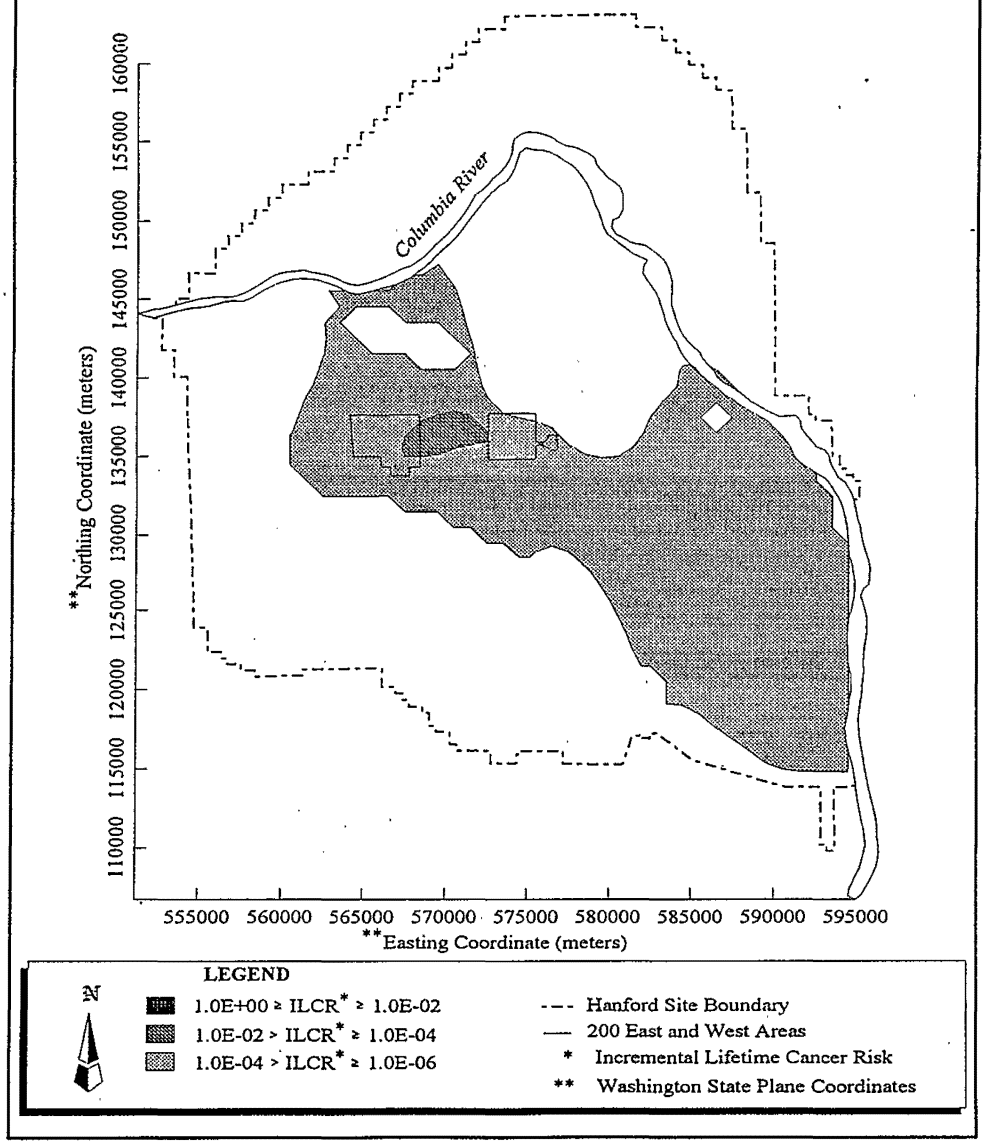


**Figure D.5.8.32 Ex Situ/In Situ Combination 1 Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 2,500 Years from Present**

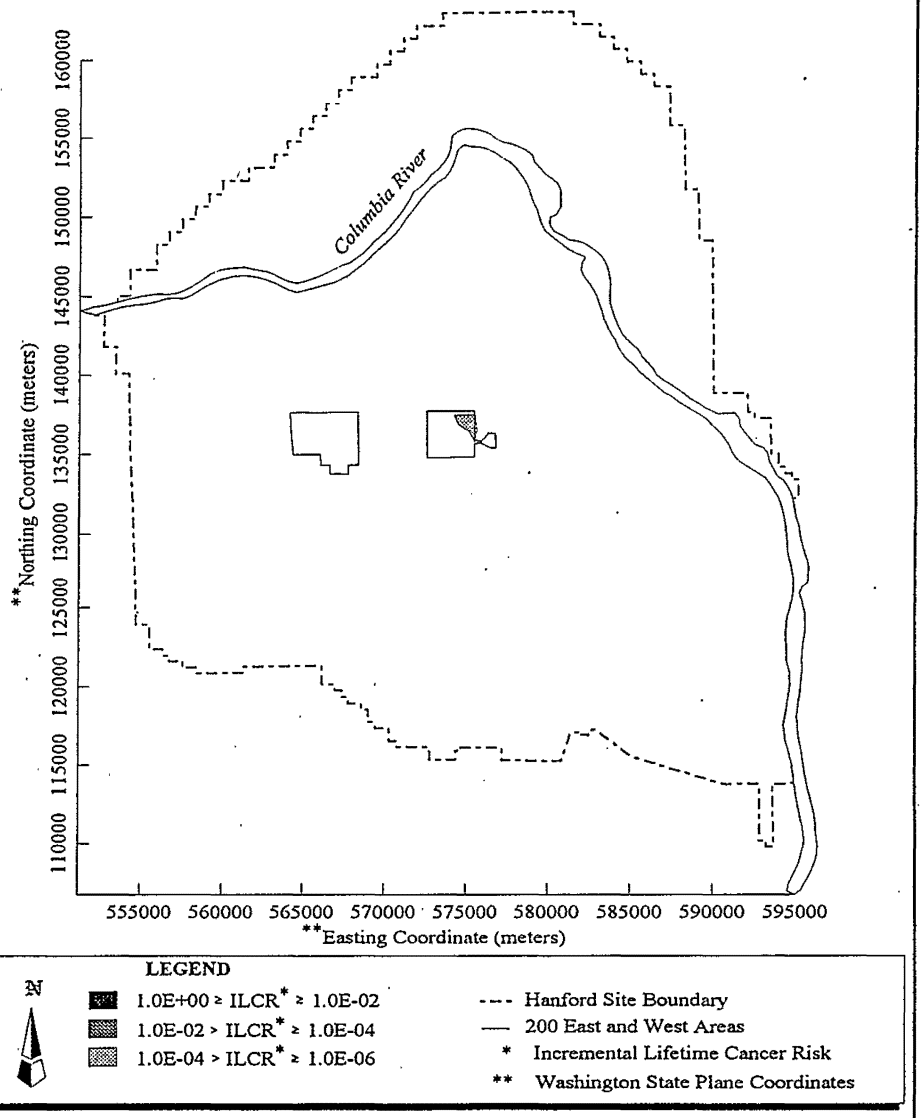


**Figure D.5.8.33 Ex Situ/In Situ Combination 1 Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

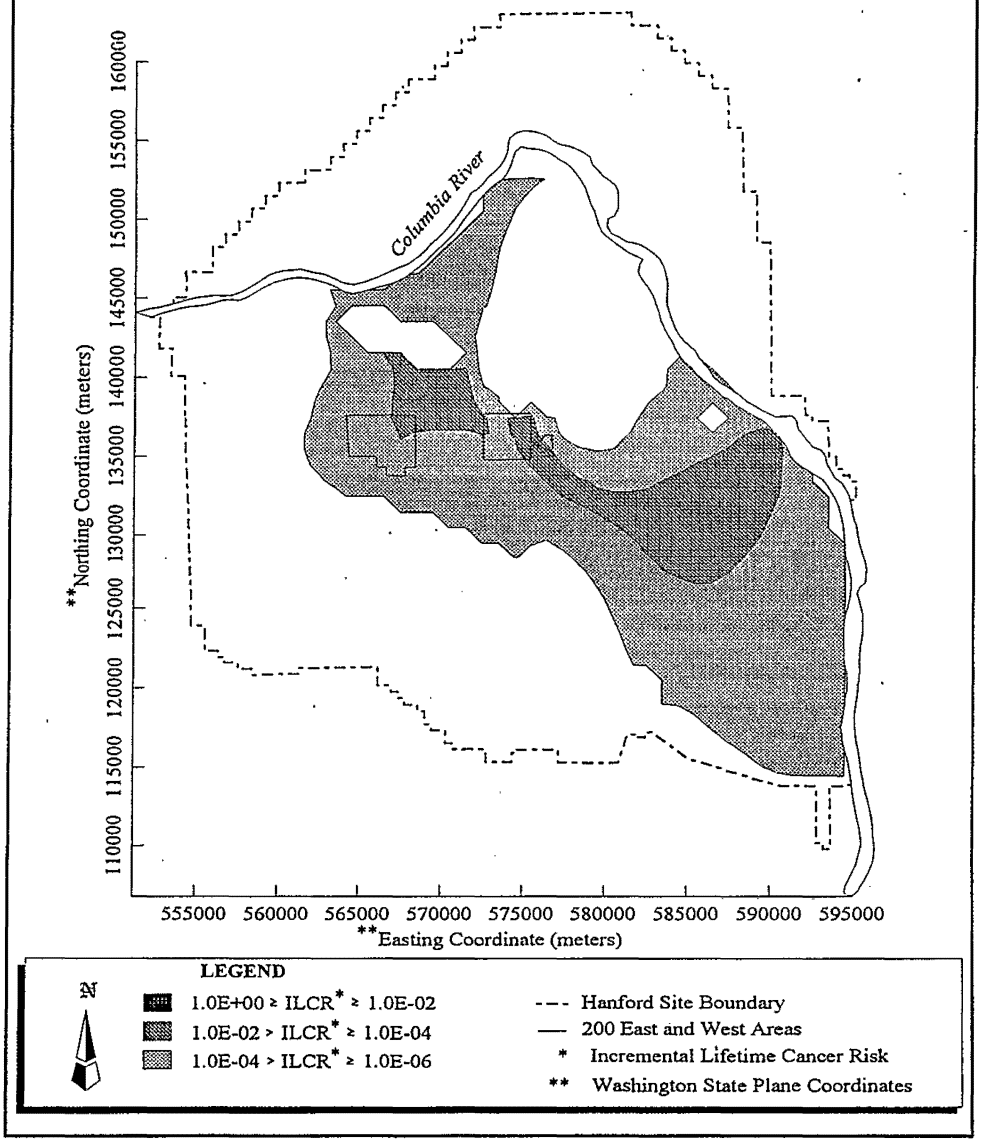


**Figure D.5.8.34 Ex Situ/In Situ Combination 1 Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 10,000 Years from Present**

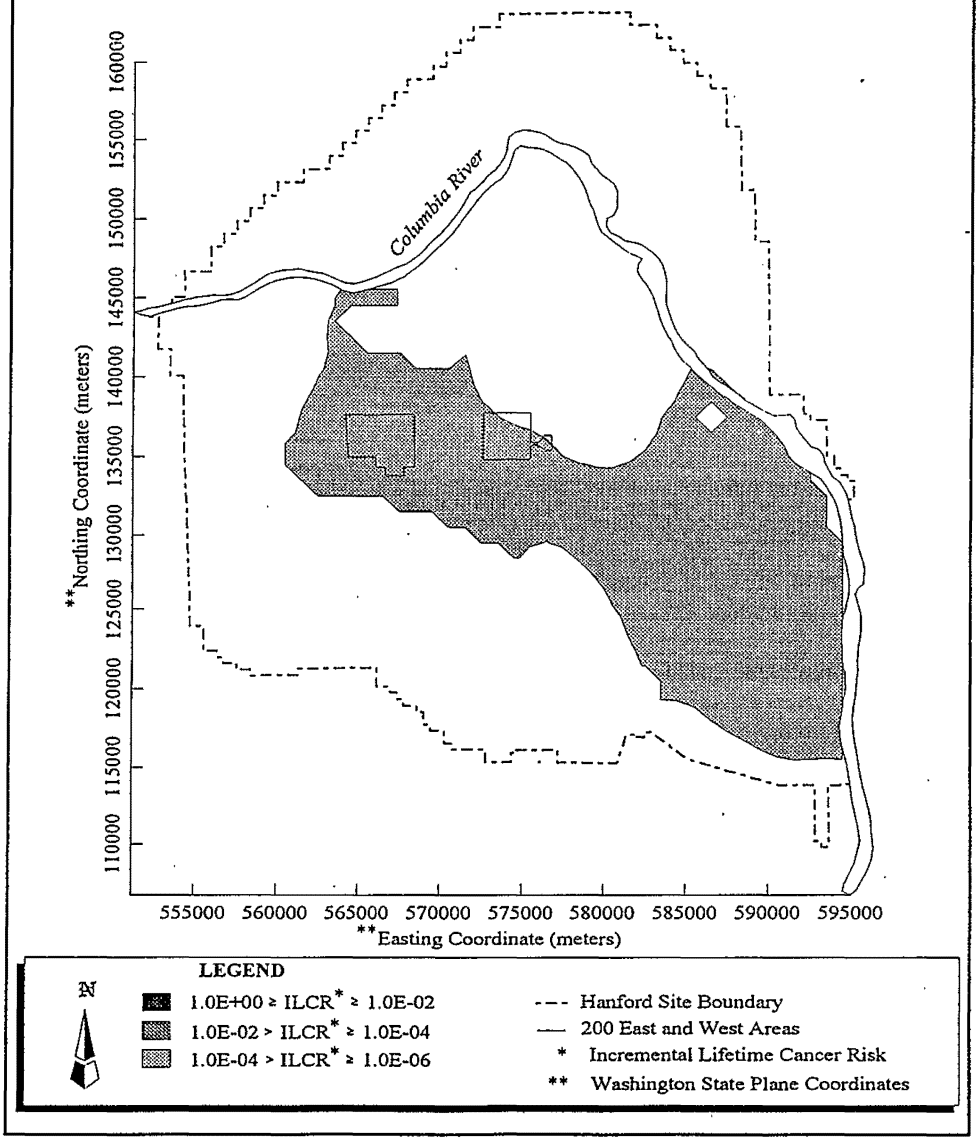


**Figure D.5.8.35 Ex Situ/In Situ Combination 1 Alternative, Recreational River User Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

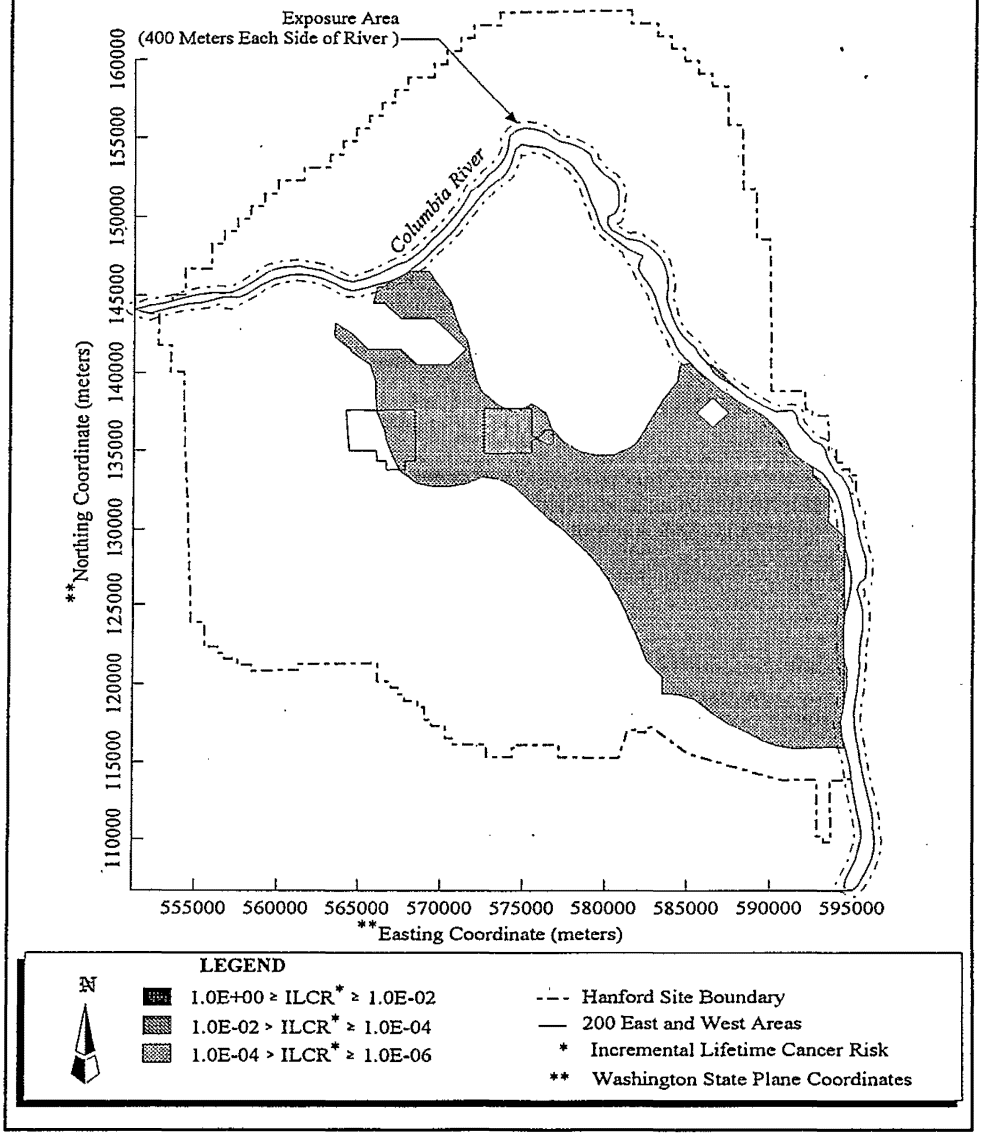


**Figure D.5.8.36 Ex Situ/In Situ Combination 1 Alternative, Recreational River User Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 10,000 Years from Present**

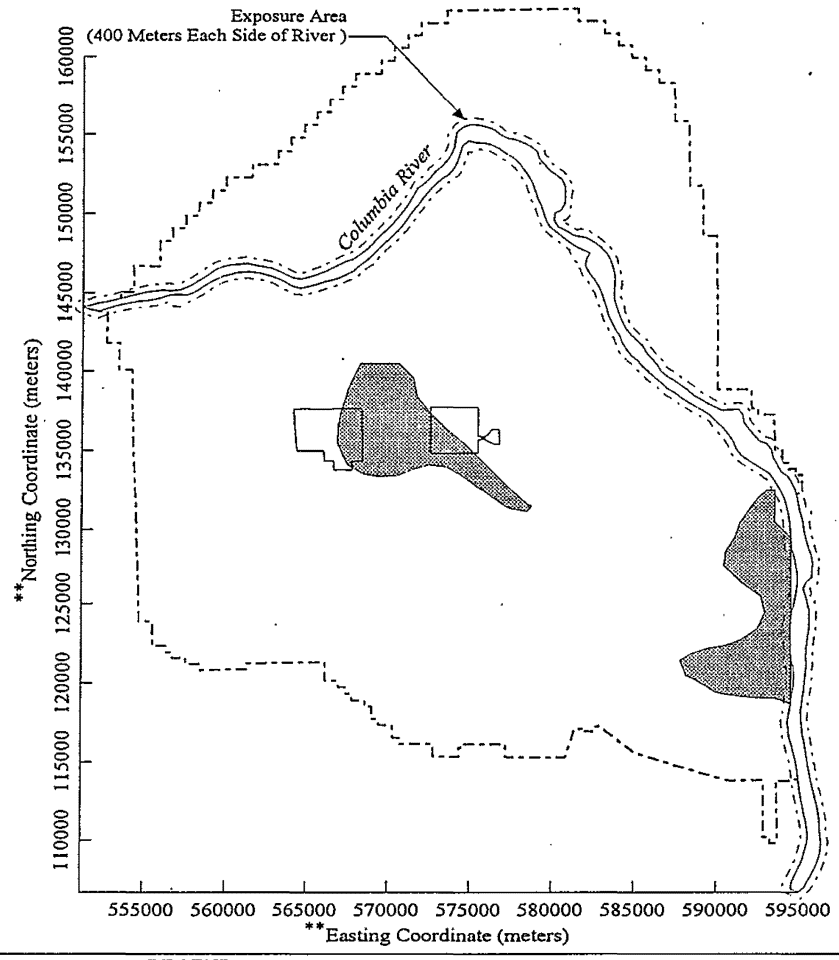


**Figure D.5.8.37 Ex Situ/In Situ Combination 1 Alternative, Native American Scenario, Post Remediation Hazard Index from Tank Residuals and LAW Vaults at 5,000 Years from Present**

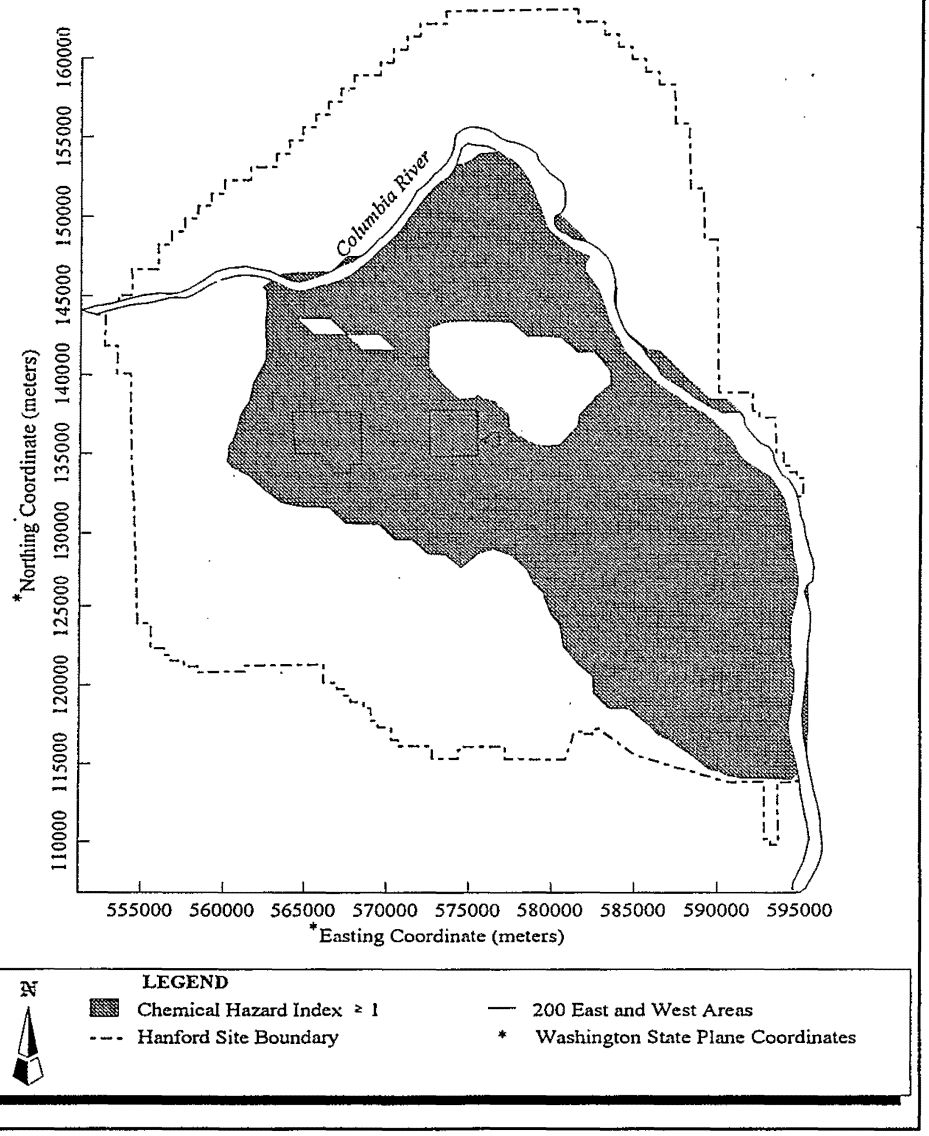


**Figure D.5.8.38 Ex Situ/In Situ Combination 1 Alternative, Native American Scenario, Post Remediation Hazard Index from Tank Residuals and LAW Vaults at 10,000 Years from Present**

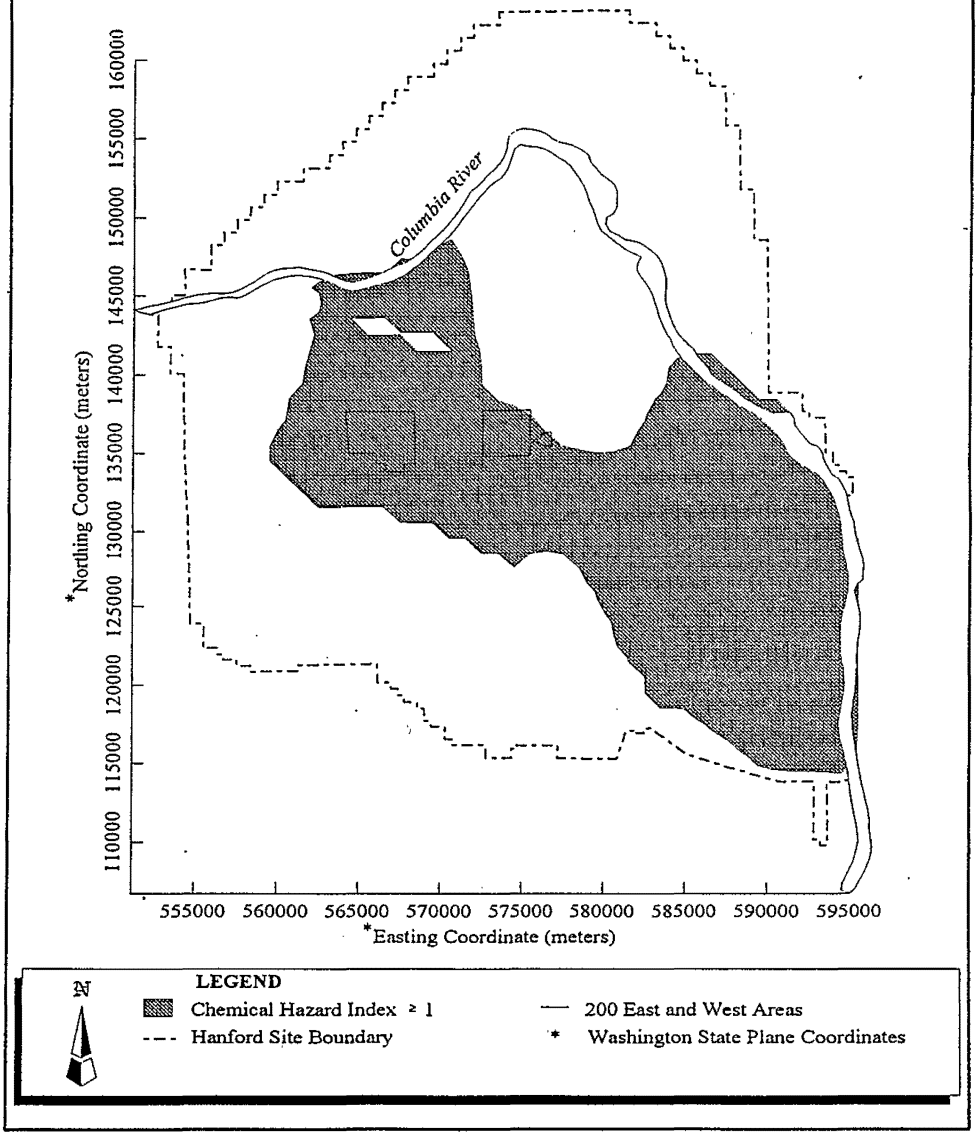


**Figure D.5.8.39 Ex Situ/In Situ Combination 1 Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from Tank Residuals and LAW Vaults at 5,000 Years from Present**

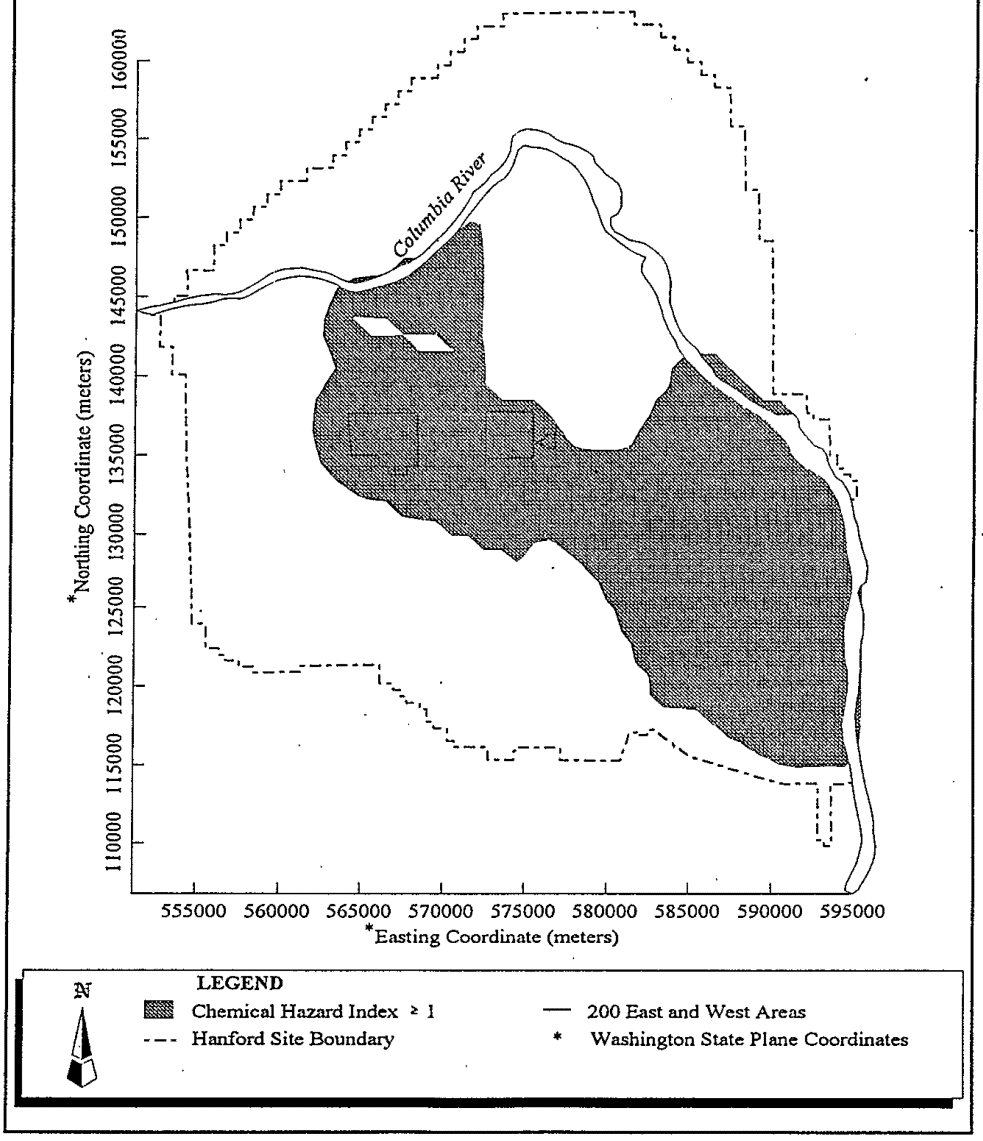


**Figure D.5.8.40 Ex Situ/In Situ Combination 1 Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from Tank Residuals and LAW Vaults at 10,000 Years from Present**

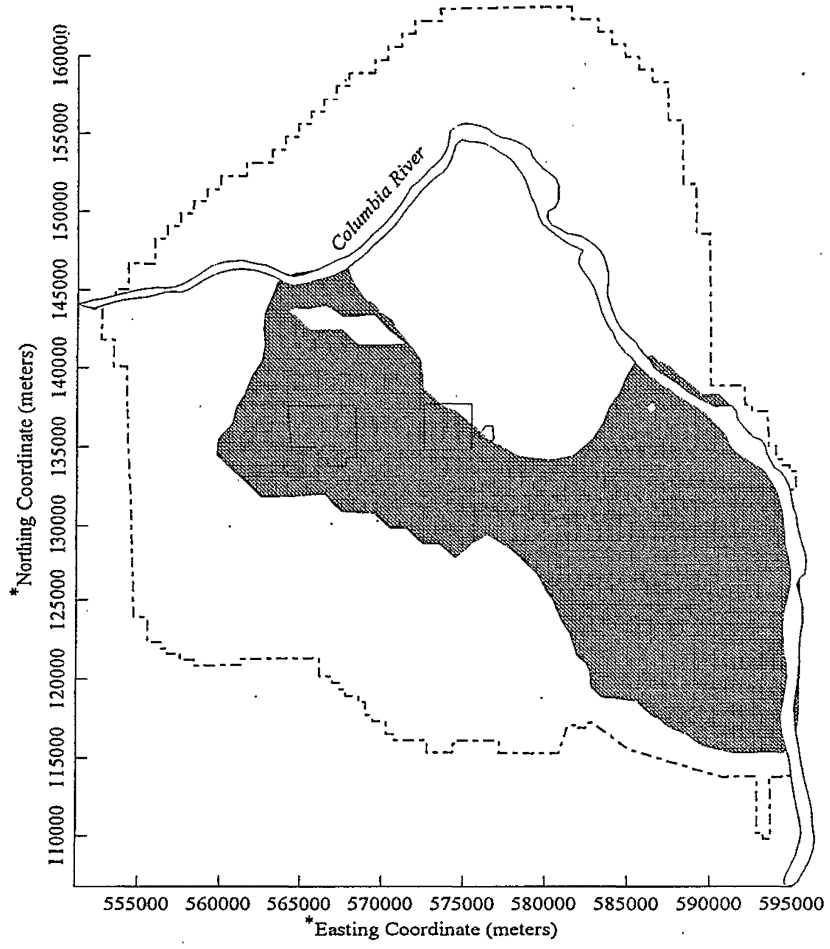


**Figure D.5.9.1 Ex Situ/In Situ Combination 2 Alternative, Native American Scenario, Post Remediation Risk from Ex Situ Tank Residuals at 2,500 Years from Present**

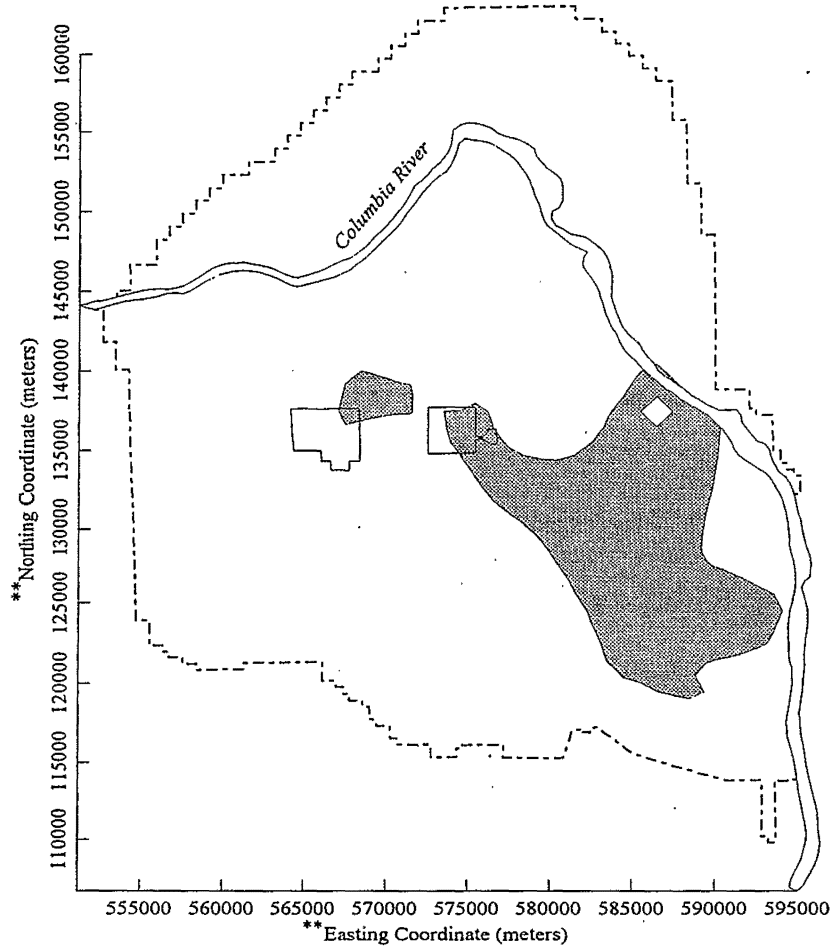


**Figure D.5.9.2 Ex Situ/In Situ Combination 2 Alternative, Native American Scenario, Post Remediation Risk from Ex Situ Tank Residuals at 5,000 Years from Present**

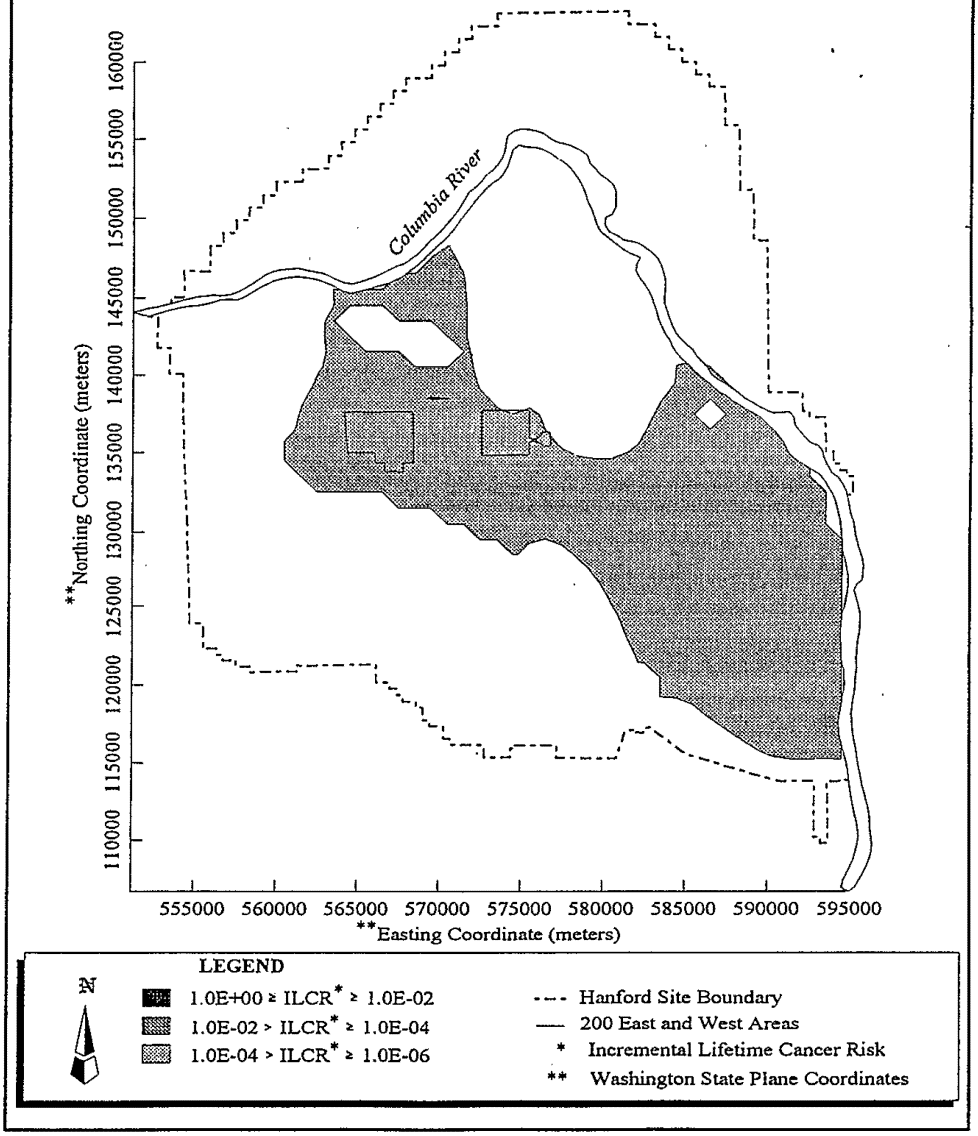


**Figure D.5.9.3 Ex Situ/In Situ Combination 2 Alternative, Residential Farmer Scenario, Post Remediation Risk from Ex Situ Tank Residuals at 2,500 Years from Present**

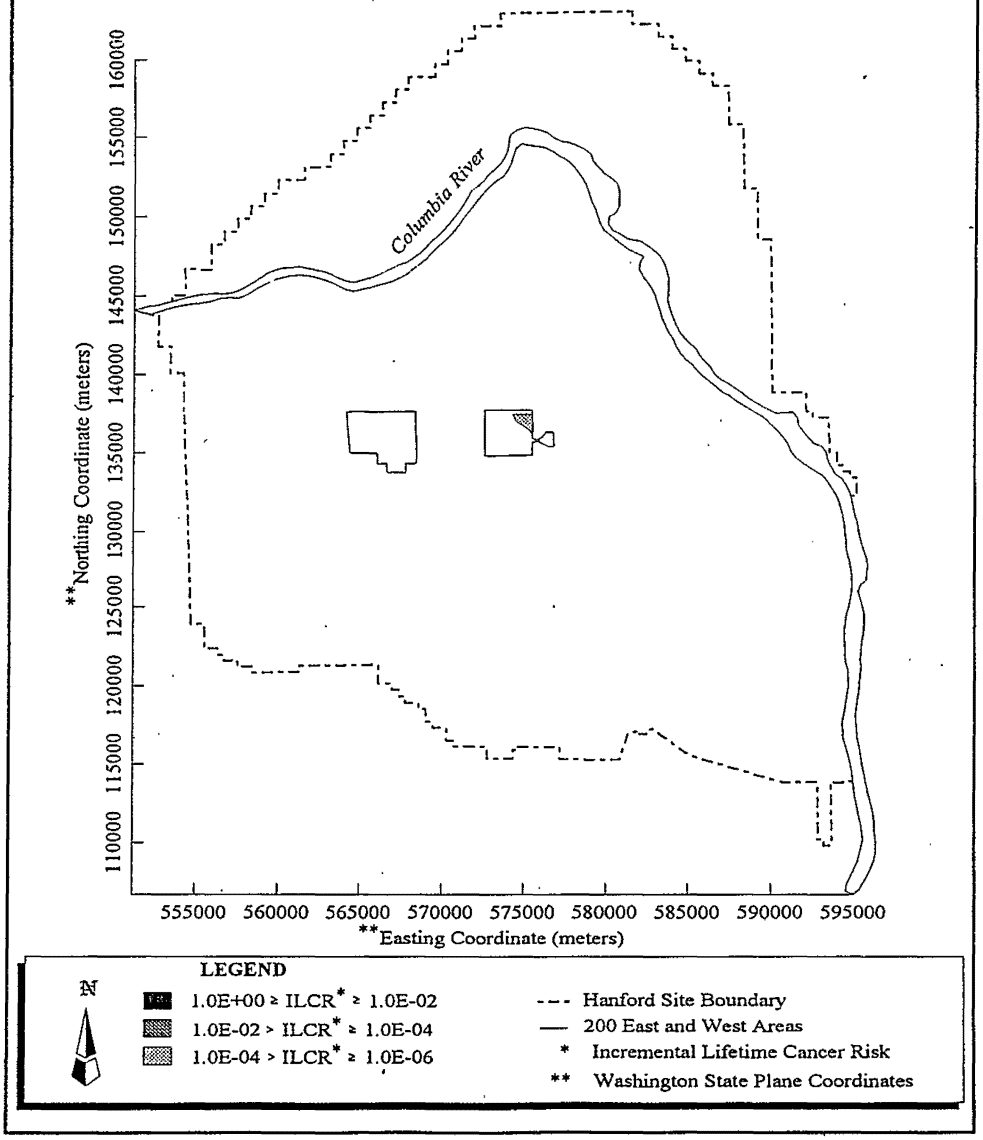


**Figure D.5.9.4 Ex Situ/In Situ Combination 2 Alternative, Residential Farmer Scenario, Post Remediation Risk from Ex Situ Tank Residuals at 5,000 Years from Present**

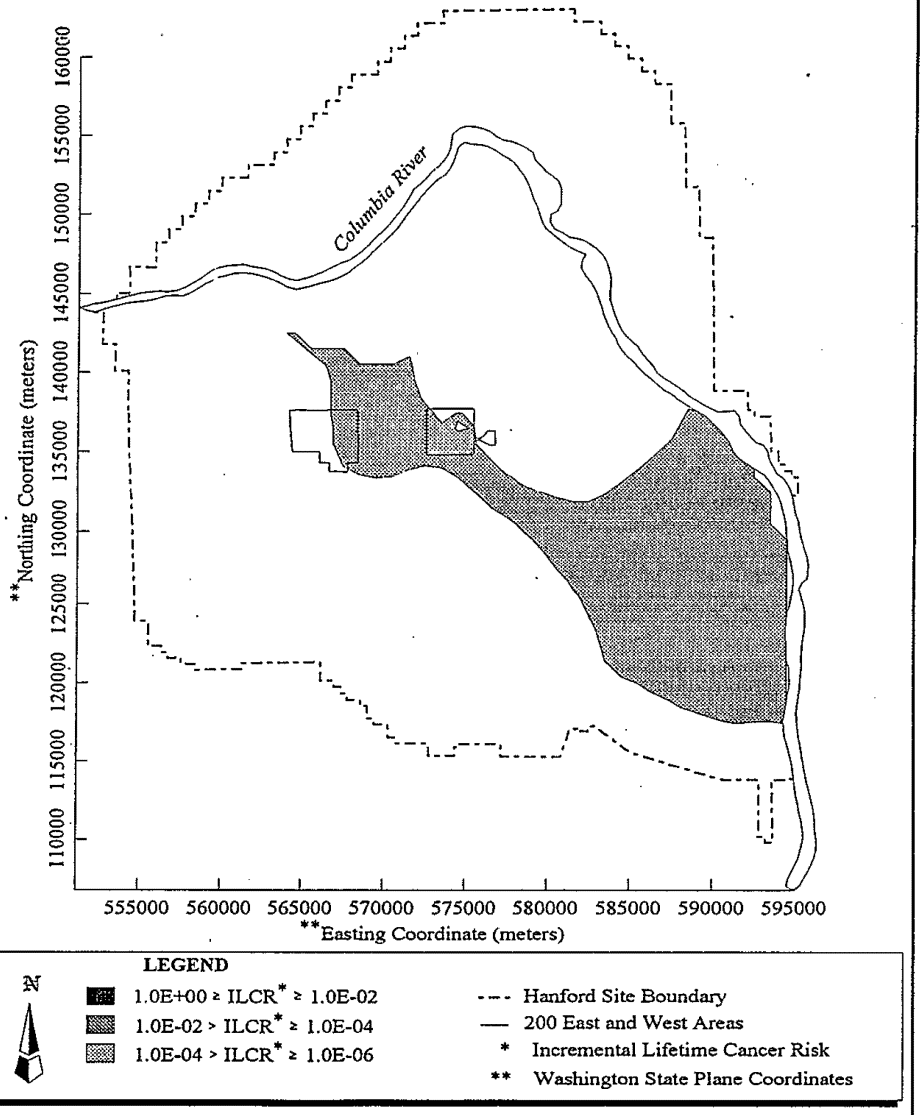


**Figure D.5.9.5 Ex Situ/In Situ Combination 2 Alternative, Industrial Worker Scenario, Post Remediation Risk from Ex Situ Tank Residuals at 5,000 Years from Present**

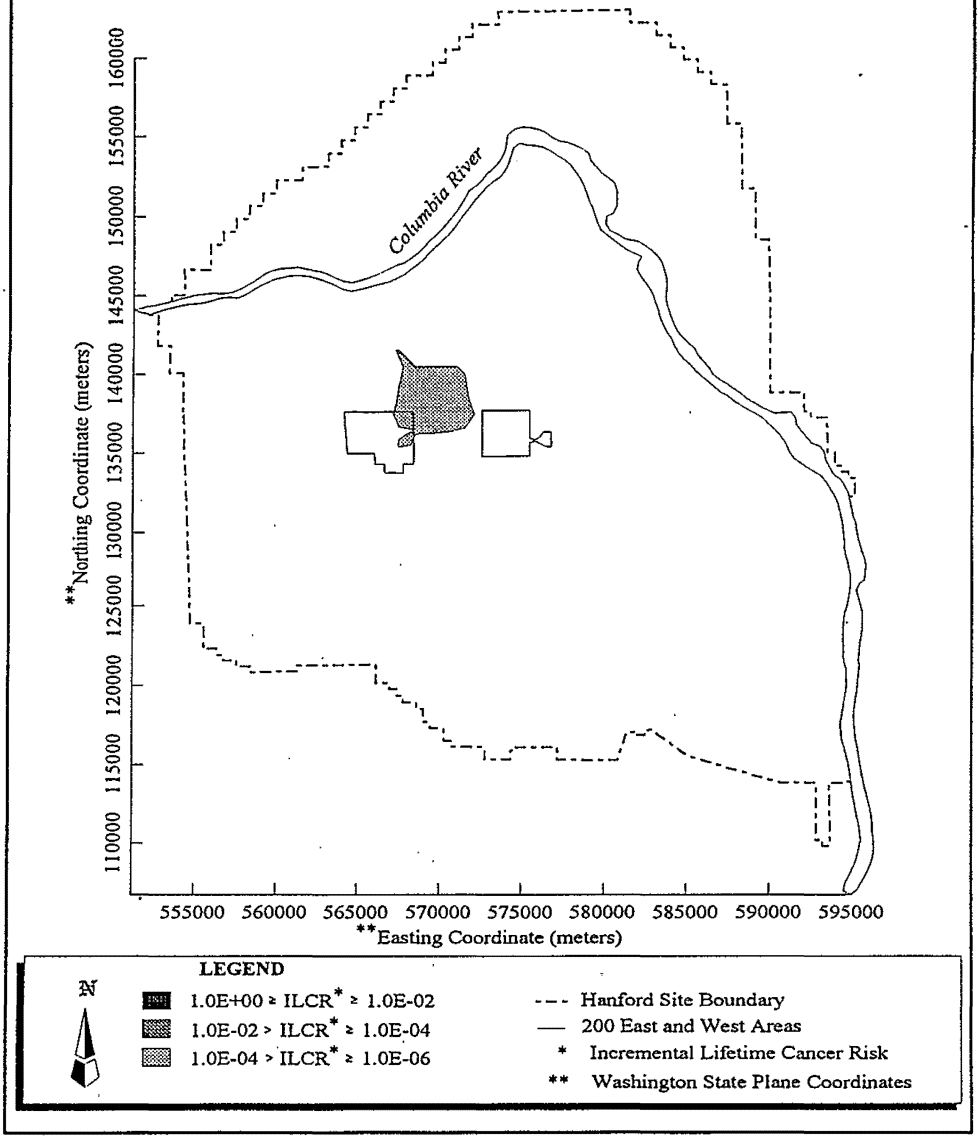


**Figure D.5.9.6 Ex Situ/In Situ Combination 2 Alternative, Native American Scenario, Post Remediation Risk from In Situ Tank Residuals at 5,000 Years from Present**

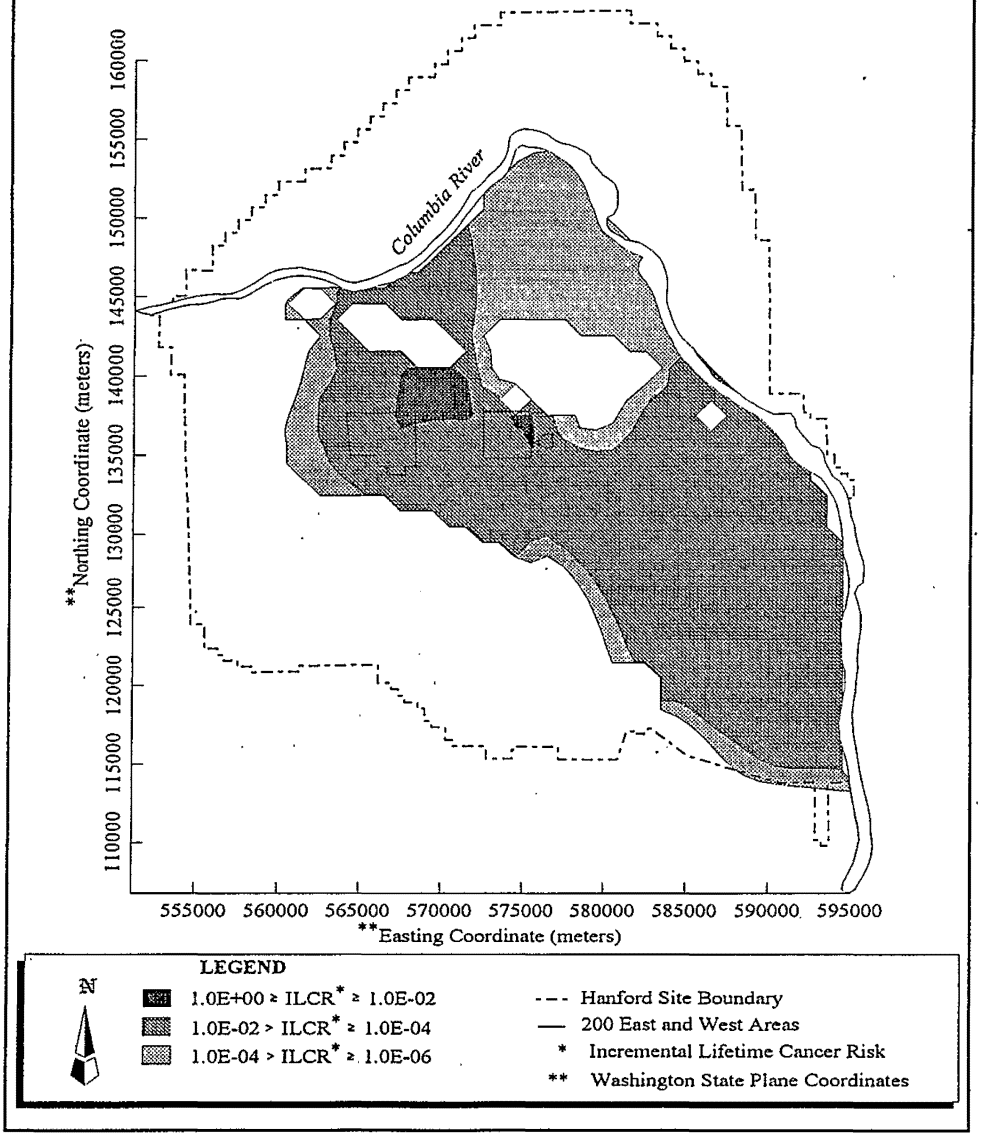


**Figure D.5.9.7 Ex Situ/In Situ Combination 2 Alternative, Native American Scenario, Post Remediation Risk from In Situ Tank Residuals at 10,000 Years from Present**

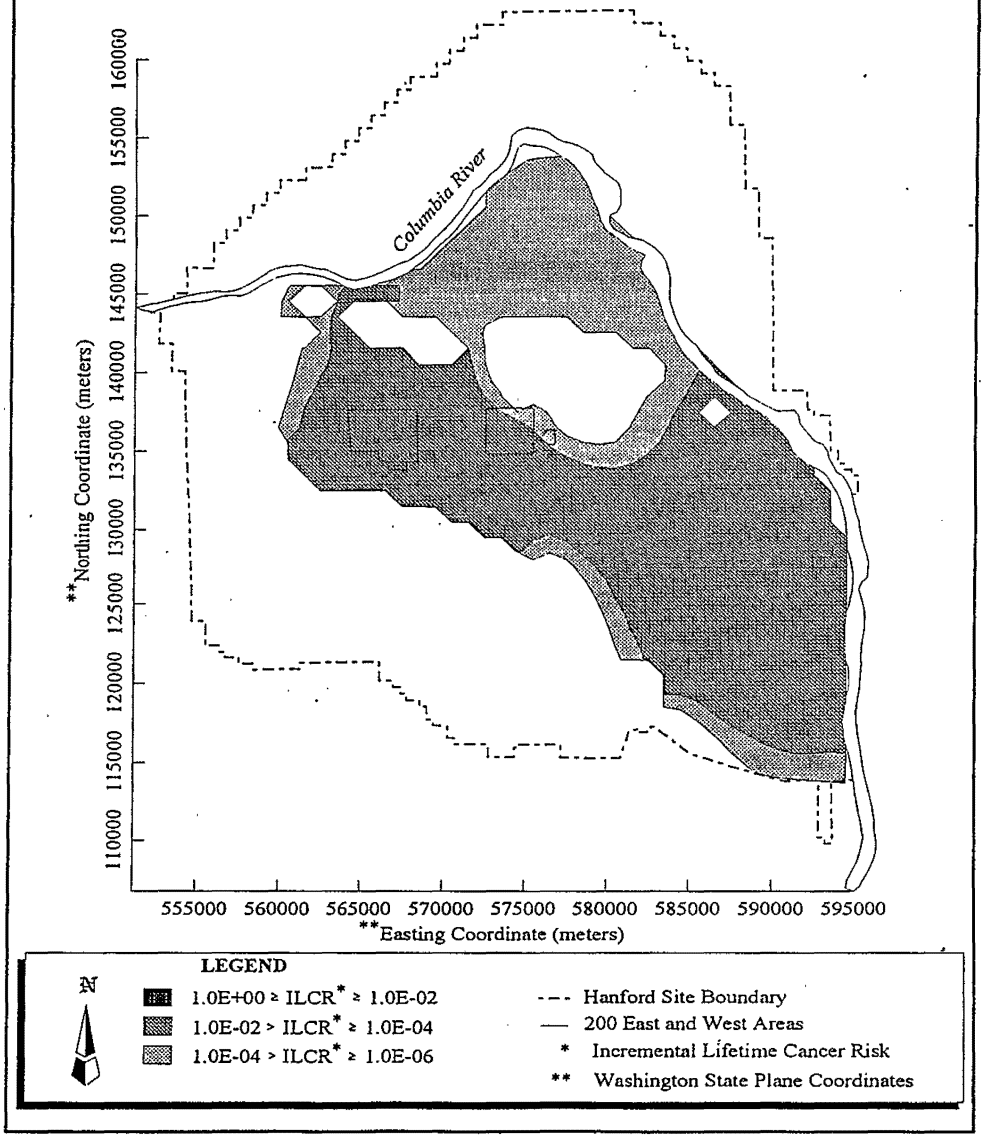


**Figure D.5.9.8 Ex Situ/In Situ Combination 2 Alternative, Residential Farmer Scenario, Post Remediation Risk from In Situ Tank Residuals at 5,000 Years from Present**

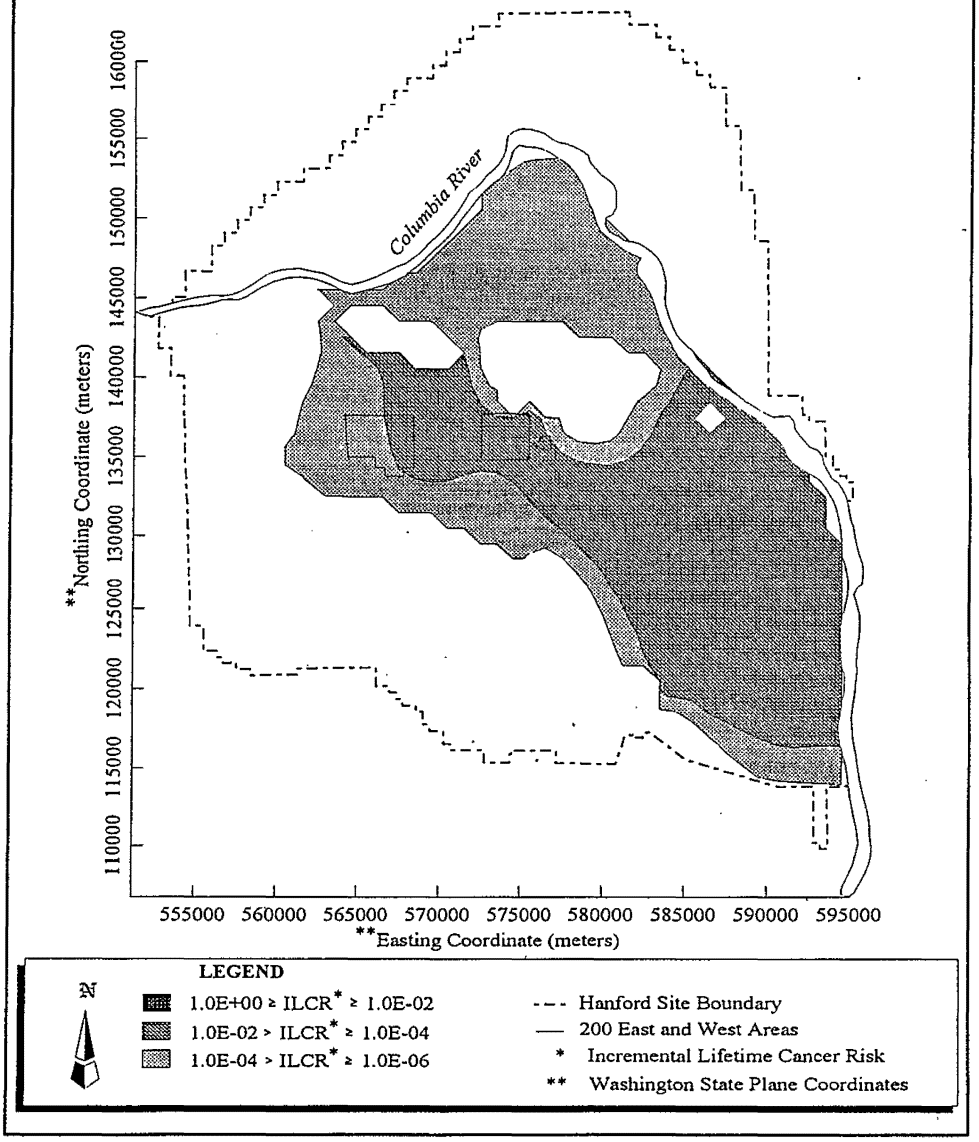


**Figure D.5.9.9 Ex Situ/In Situ Combination 2 Alternative, Residential Farmer Scenario, Post Remediation Risk from In Situ Tank Residuals at 10,000 Years from Present**

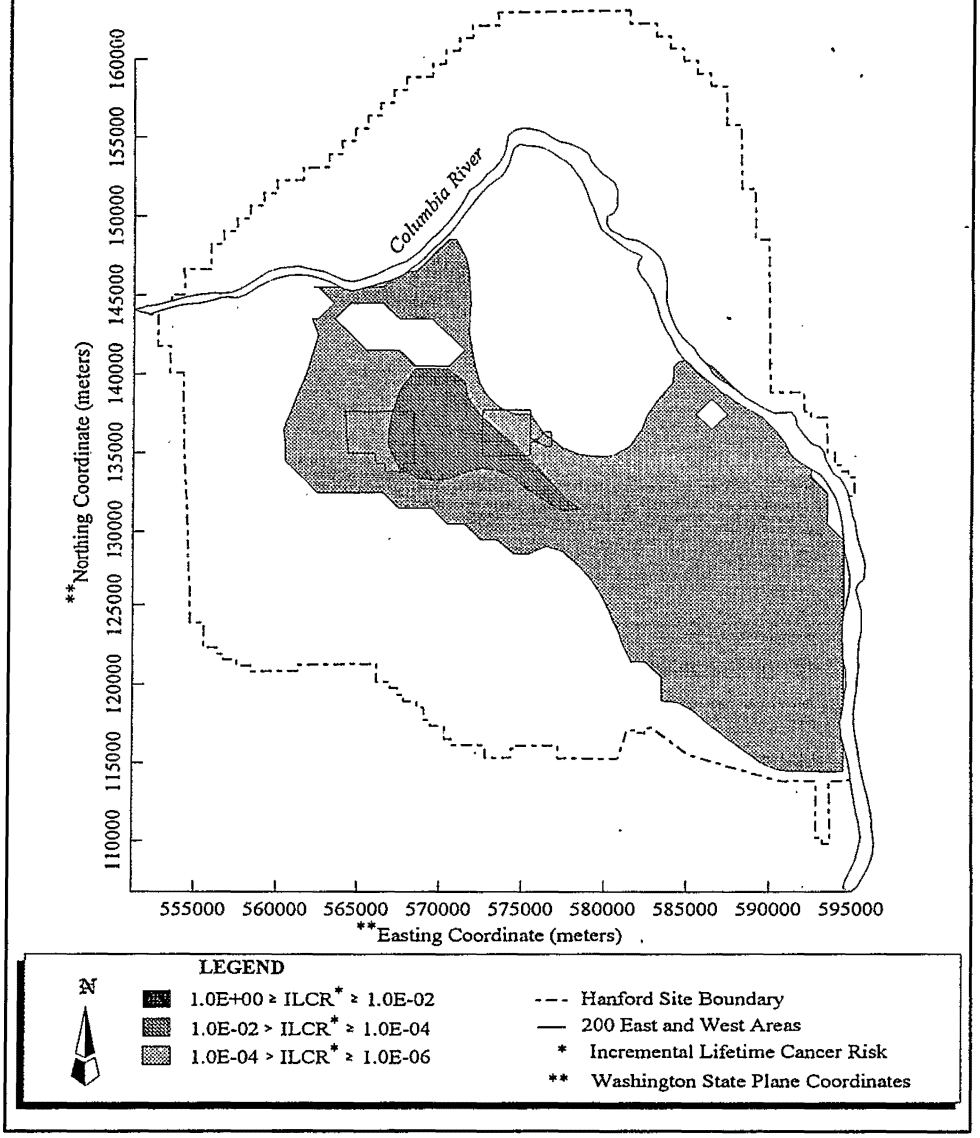


**Figure D.5.9.10 Ex Situ/In Situ Combination 2 Alternative, Industrial Worker Scenario, Post Remediation Risk from In Situ Tank Residuals at 5,000 Years from Present**

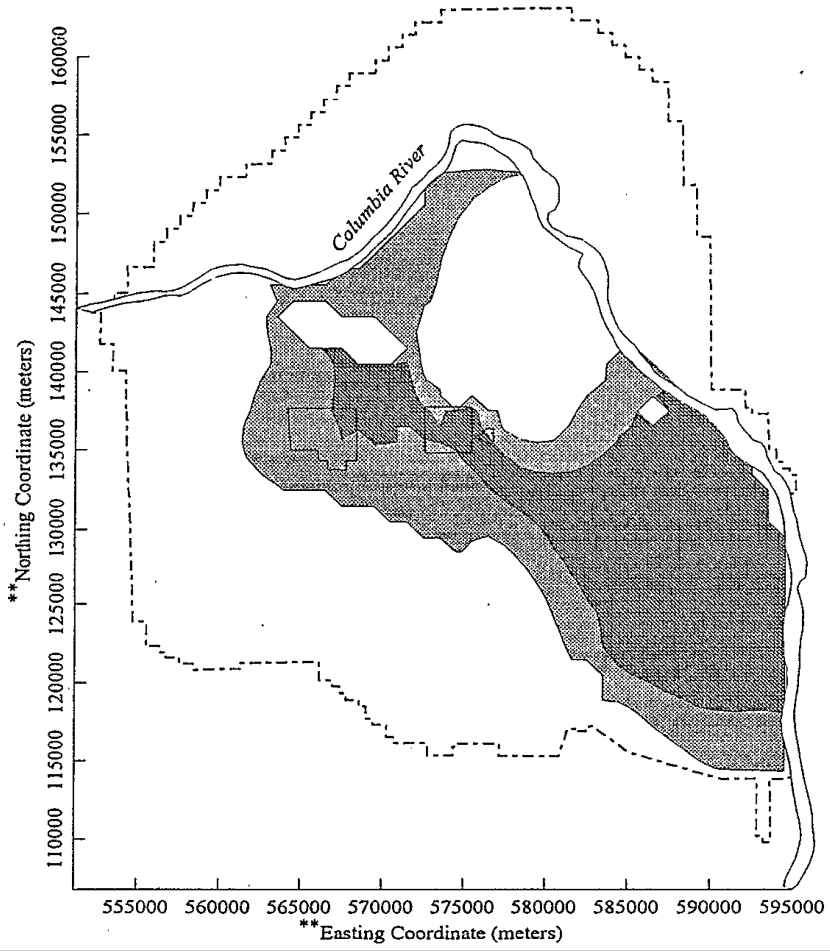


**Figure D.5.9.11 Ex Situ/In Situ Combination 2 Alternative, Industrial Worker Scenario, Post Remediation Risk from In Situ Tank Residuals at 10,000 Years from Present**

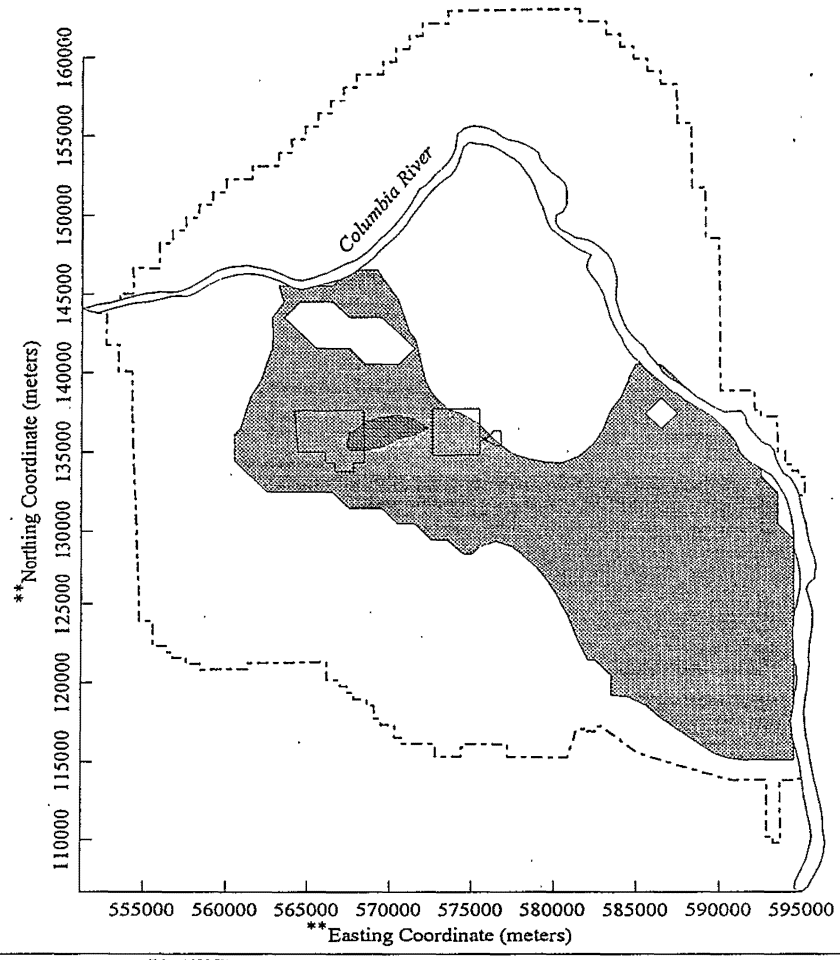


**Figure D.5.9.12 Ex Situ/In Situ Combination 2 Alternative, Recreational River User Scenario, Post Remediation Risk from In Situ Tank Residuals at 5,000 Years from Present**

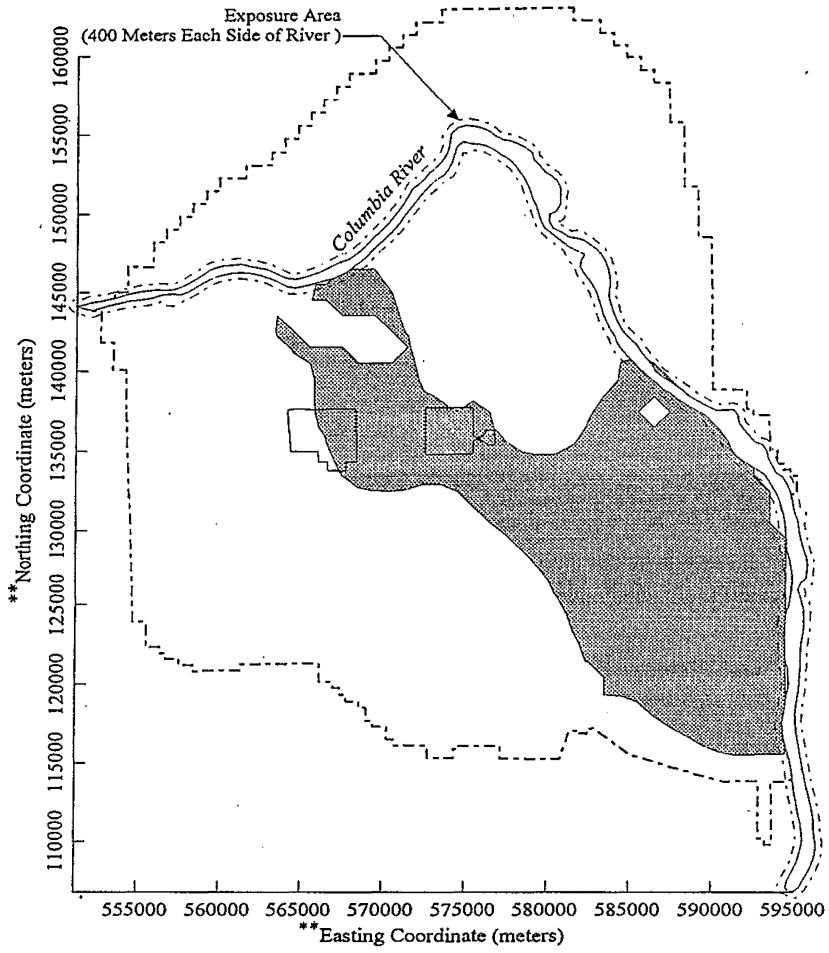


**Figure D.5.9.13 Ex Situ/In Situ Combination 2 Alternative, Recreational River User Scenario, Post Remediation Risk from In Situ Tank Residuals at 10,000 Years from Present**

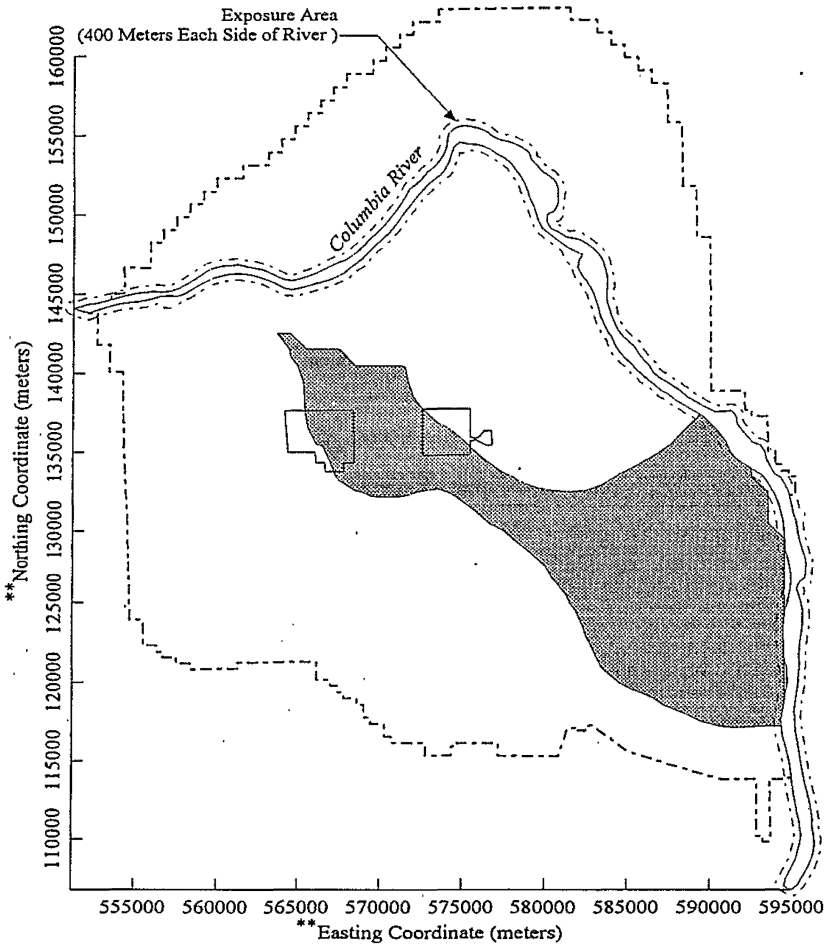


**Figure D.5.9.14 Ex Situ/In Situ Combination 2 Alternative, Native American Scenario, Post Remediation Hazard Index from In Situ Tank Residuals at 5,000 Years from Present**

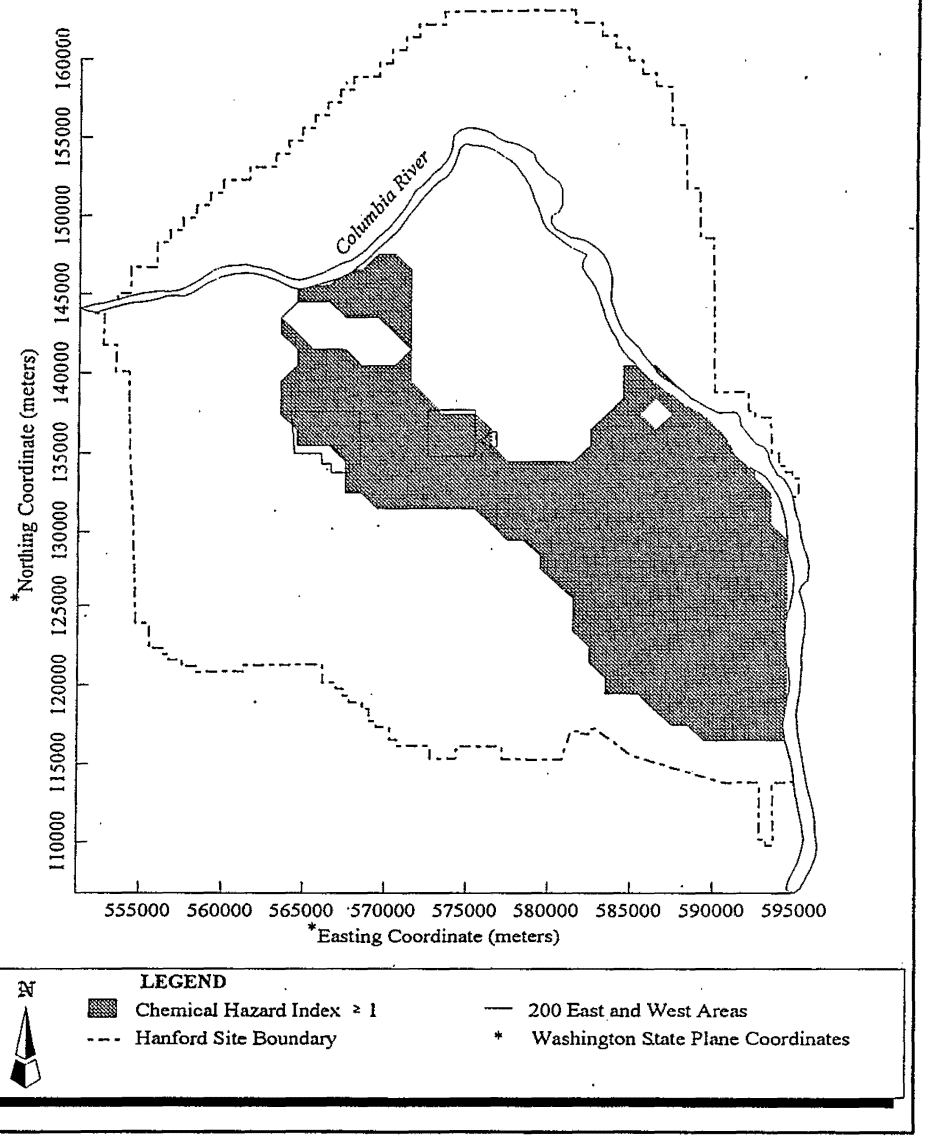


**Figure D.5.9.15 Ex Situ/In Situ Combination 2 Alternative, Native American Scenario, Post Remediation Hazard Index from In Situ Tank Residuals at 10,000 Years from Present**

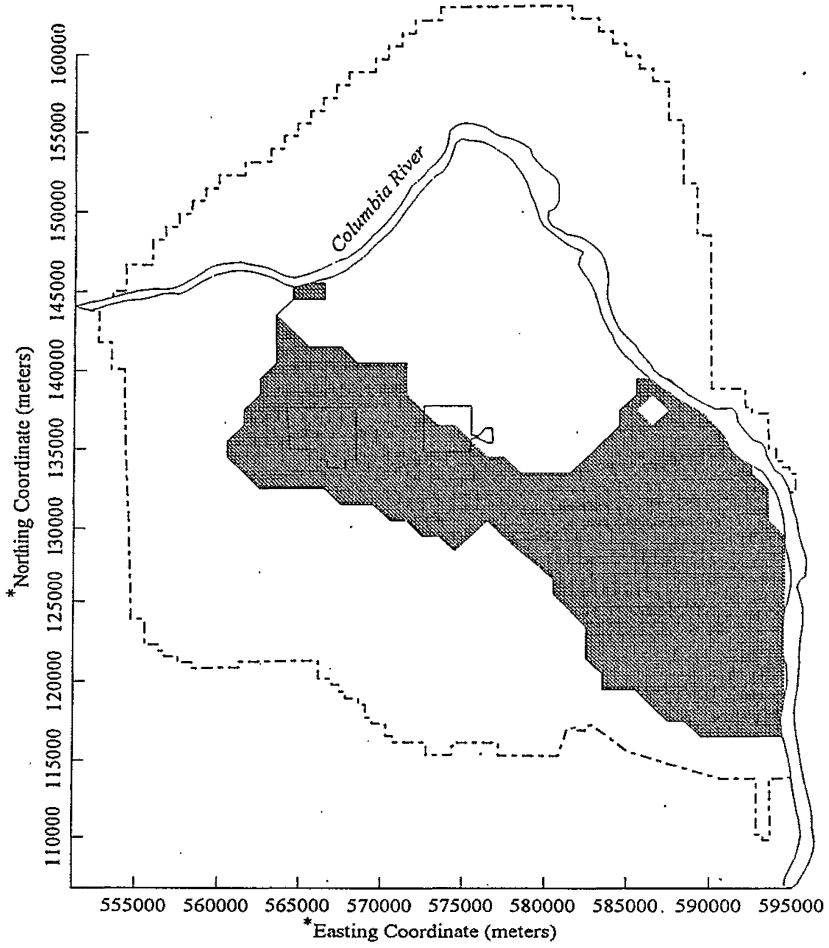


**Figure D.5.9.16 Ex Situ/In Situ Combination 2 Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from In Situ Tank Residuals at 5,000 Years from Present**

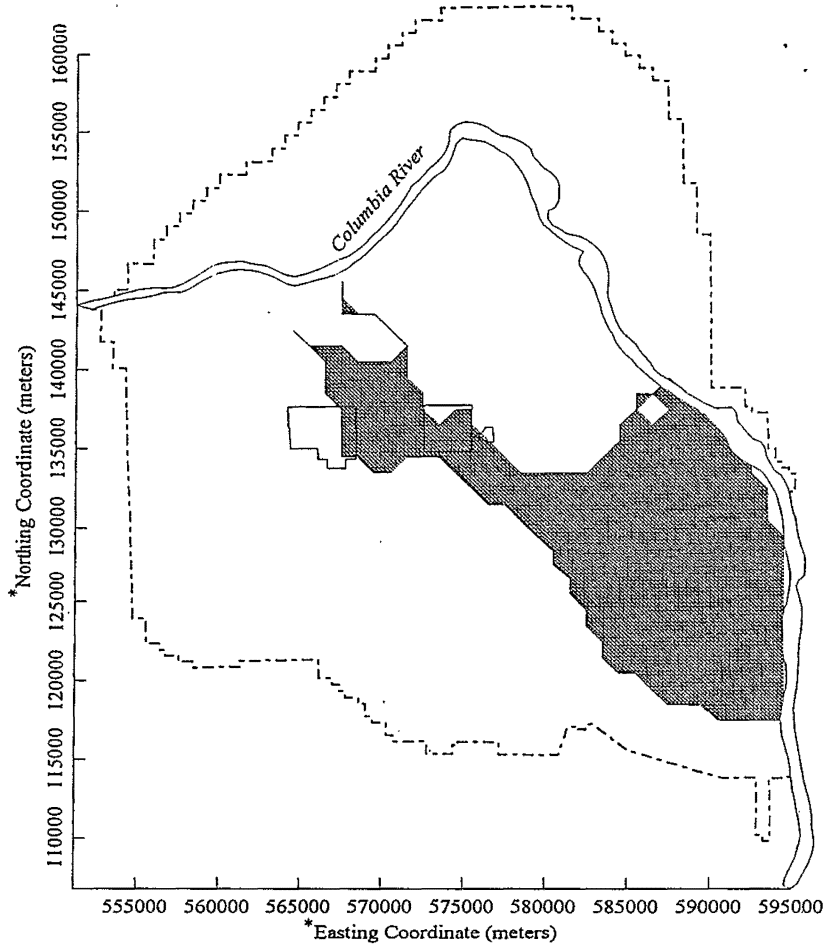


**Figure D.5.9.17 Ex Situ/In Situ Combination 2 Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from In Situ Tank Residuals at 10,000 Years from Present**

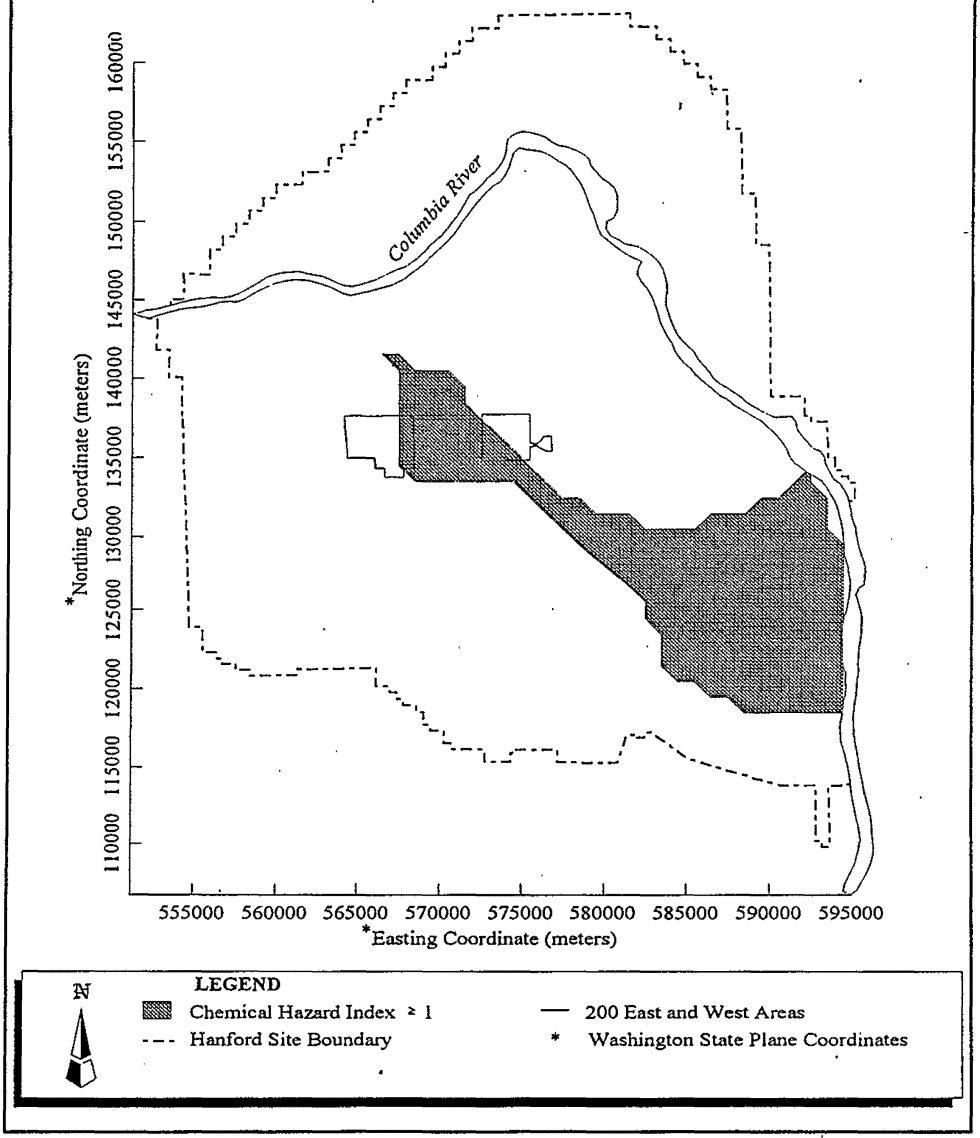


**Figure D.5.9.18 Ex Situ/In Situ Combination 2 Alternative, Native American Scenario, Post Remediation Risk from LAW Vaults at 5,000 Years from Present**

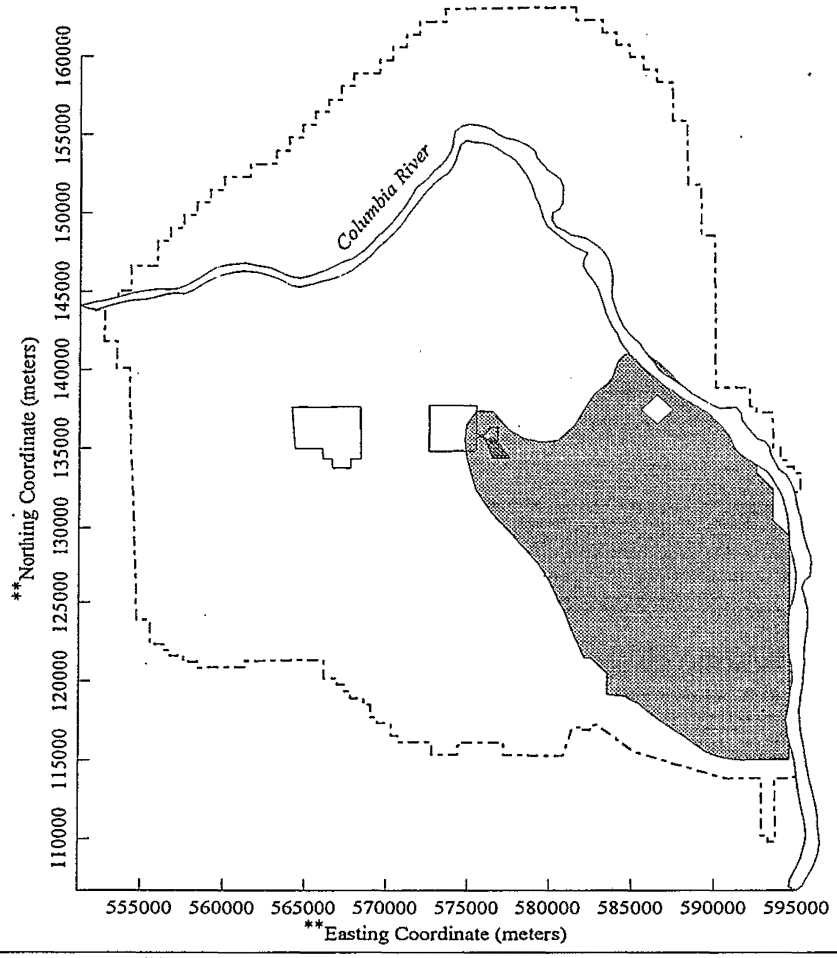


**Figure D.5.9.19 Ex Situ/In Situ Combination 2 Alternative, Native American Scenario, Post Remediation Risk from LAW Vaults at 10,000 Years from Present**

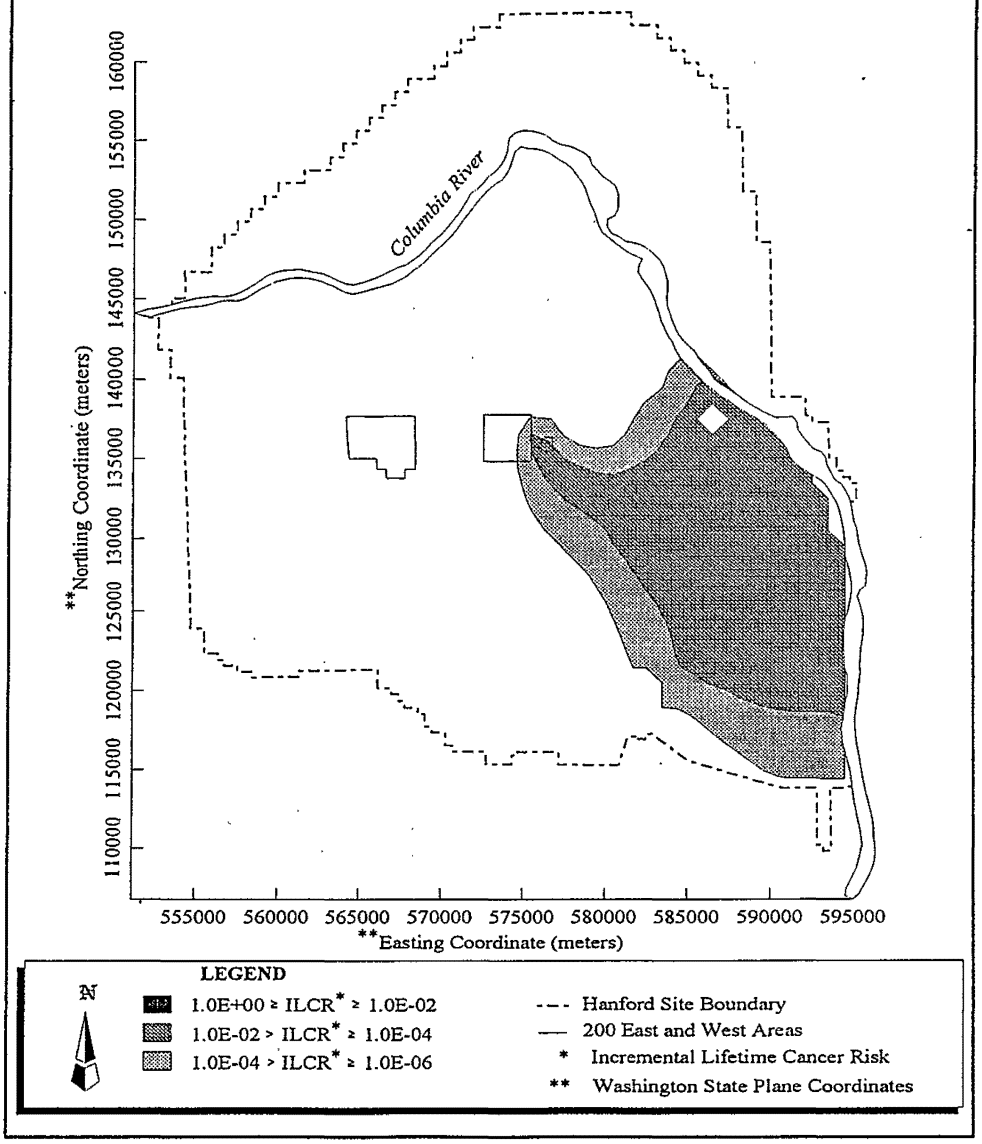


**Figure D.5.9.20 Ex Situ/In Situ Combination 2 Alternative, Residential Farmer Scenario, Post Remediation Risk from LAW Vaults at 5,000 Years from Present**

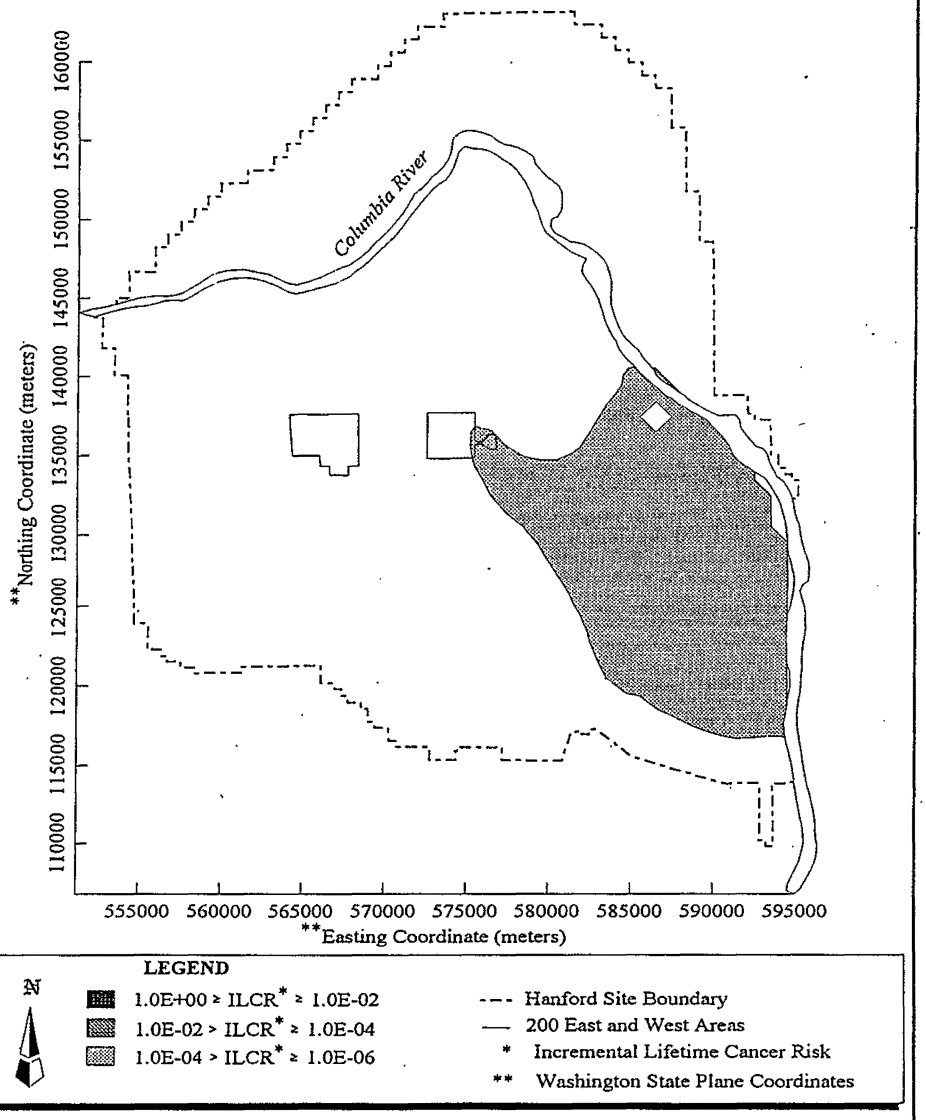


**Figure D.5.9.21 Ex Situ/In Situ Combination 2 Alternative, Residential Farmer Scenario, Post Remediation Risk from LAW Vaults at 10,000 Years from Present**

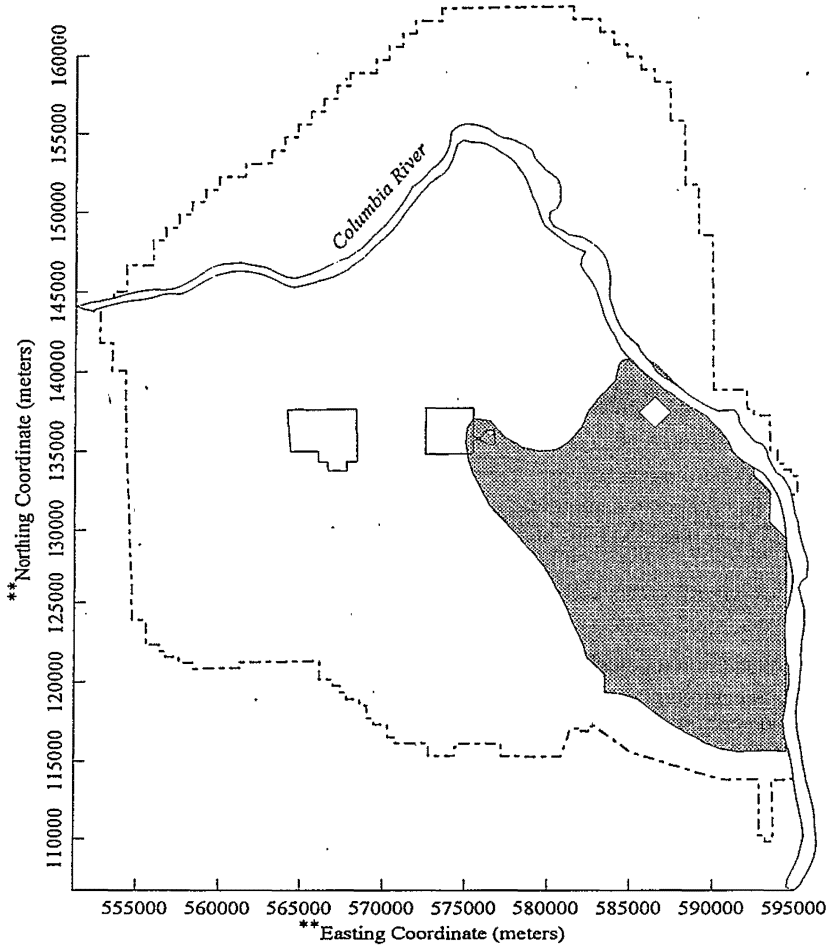


**Figure D.5.9.22 Ex Situ/In Situ Combination 2 Alternative, Industrial Worker Scenario, Post Remediation Risk from LAW Vaults at 5,000 Years from Present**

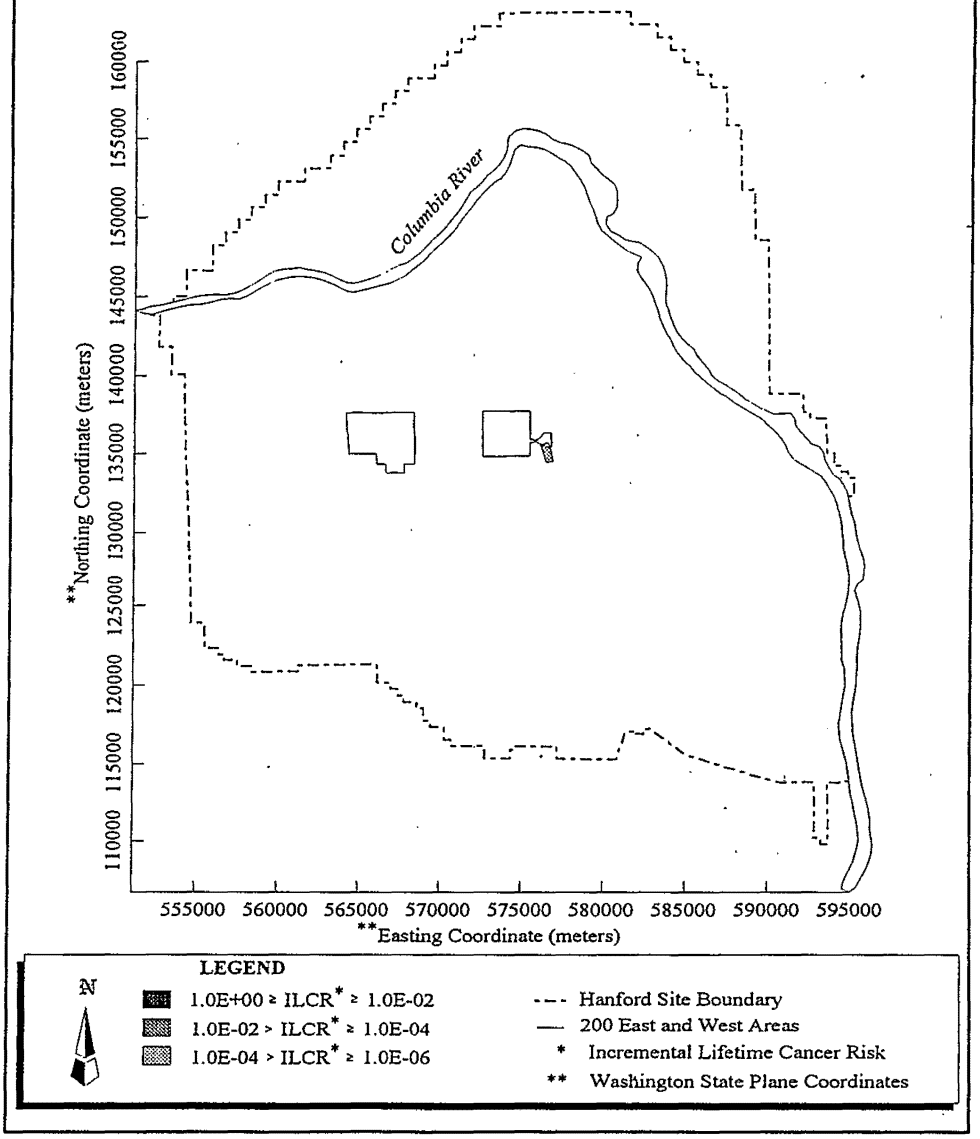


**Figure D.5.9.23 Ex Situ/In Situ Combination 2 Alternative, Industrial Worker Scenario, Post Remediation Risk from LAW Vaults at 10,000 Years from Present**

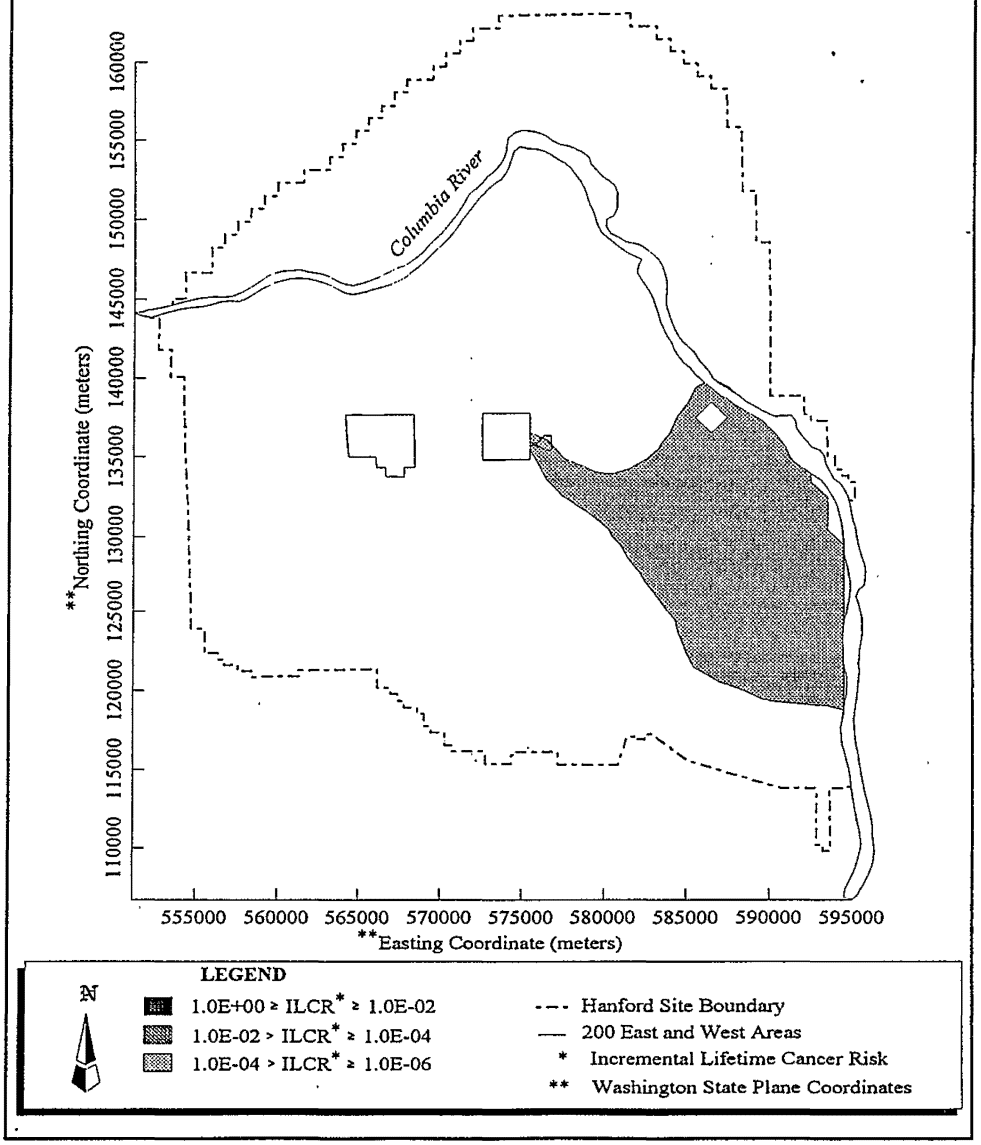


**Figure D.5.9.24 Ex Situ/In Situ Combination 2 Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 2,500 Years from Present**

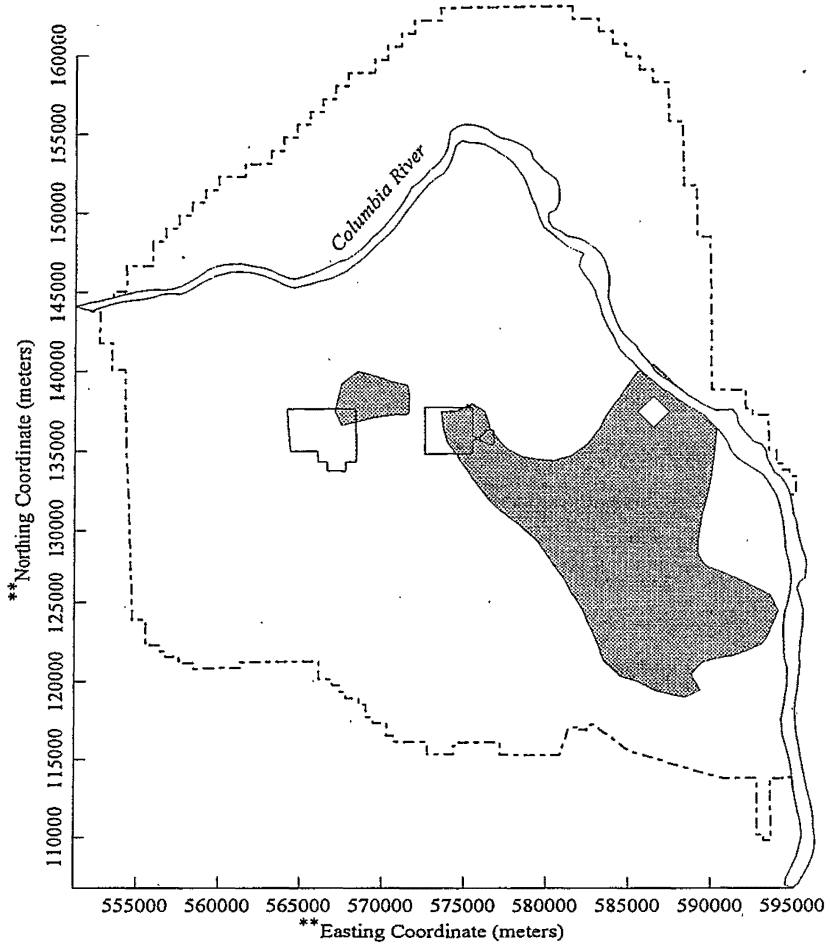


**Figure D.5.9.25 Ex Situ/In Situ Combination 2 Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

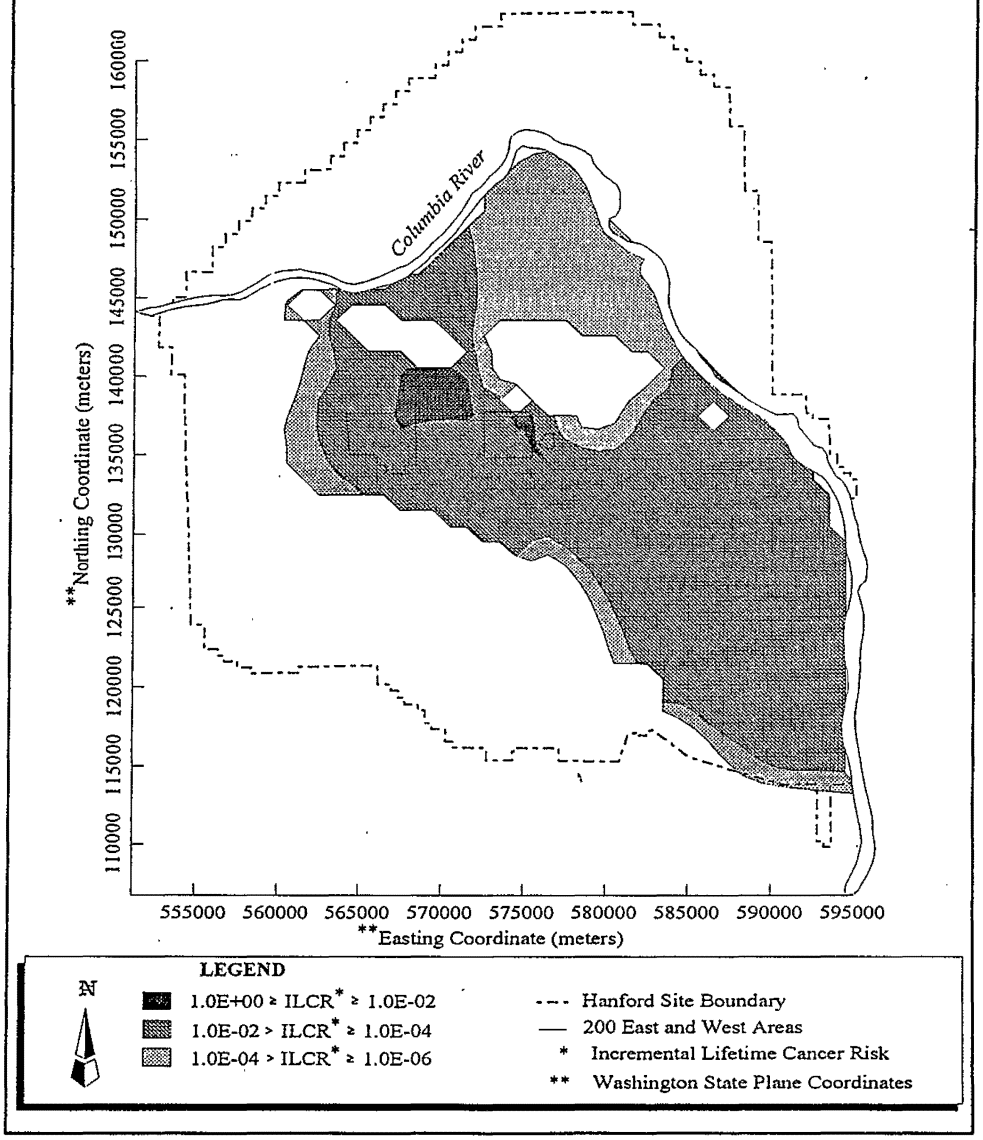


**Figure D.5.9.26 Ex Situ/In Situ Combination 2 Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 10,000 Years from Present**

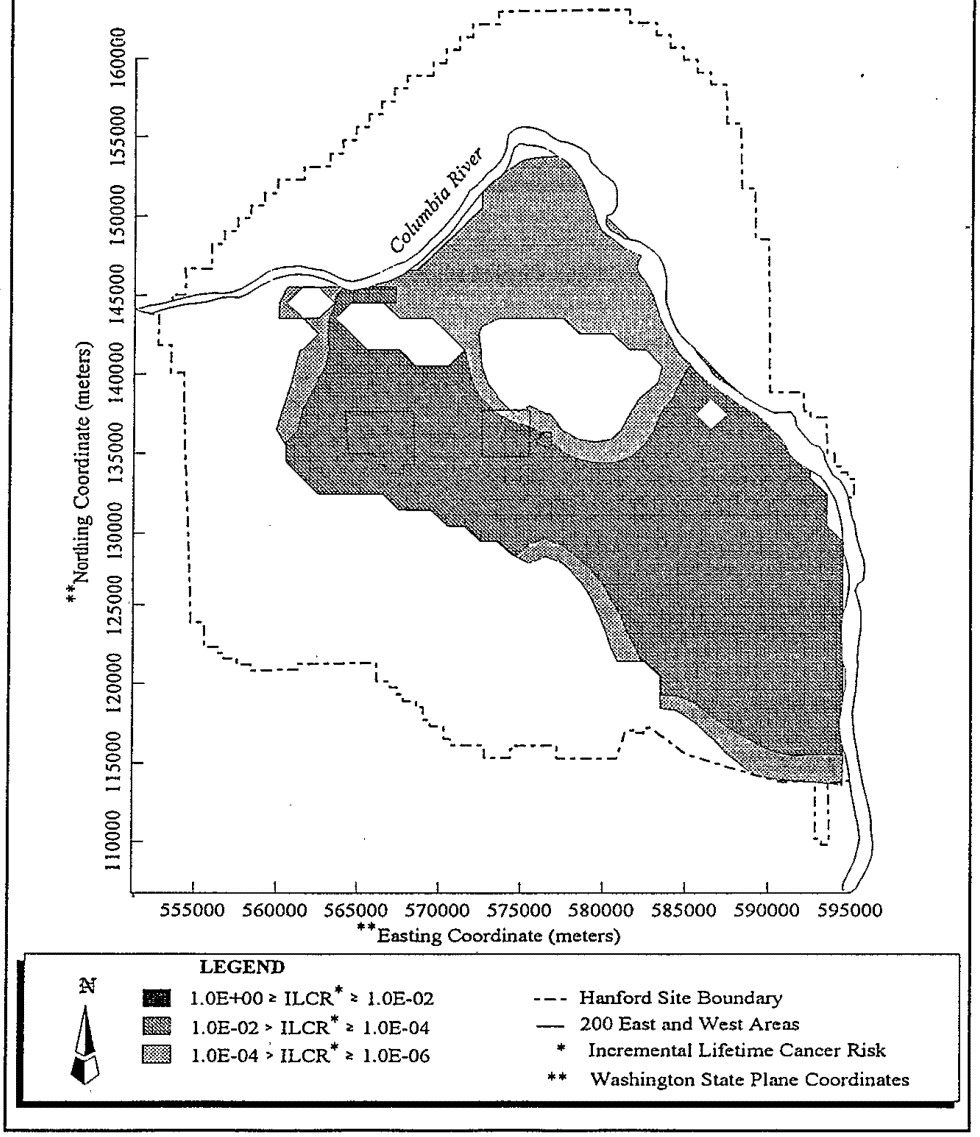


**Figure D.5.9.27 Ex Situ/In Situ Combination 2 Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 2,500 Years from Present**

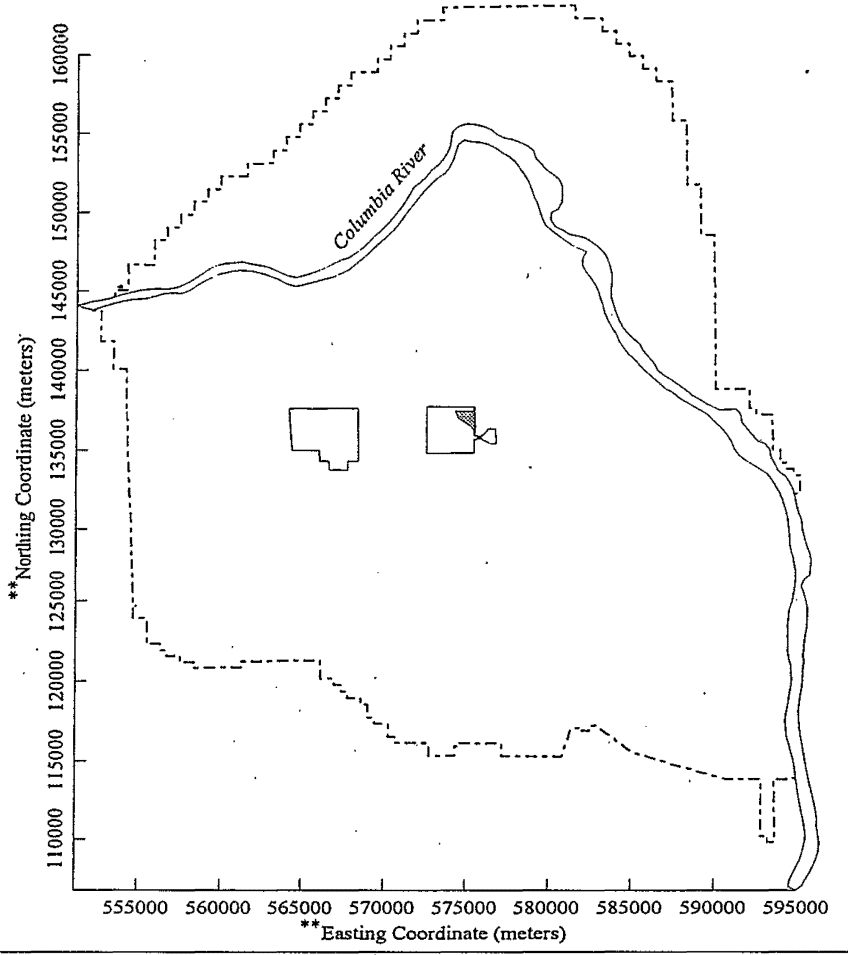


**Figure D.5.9.28 Ex Situ/In Situ Combination 2 Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

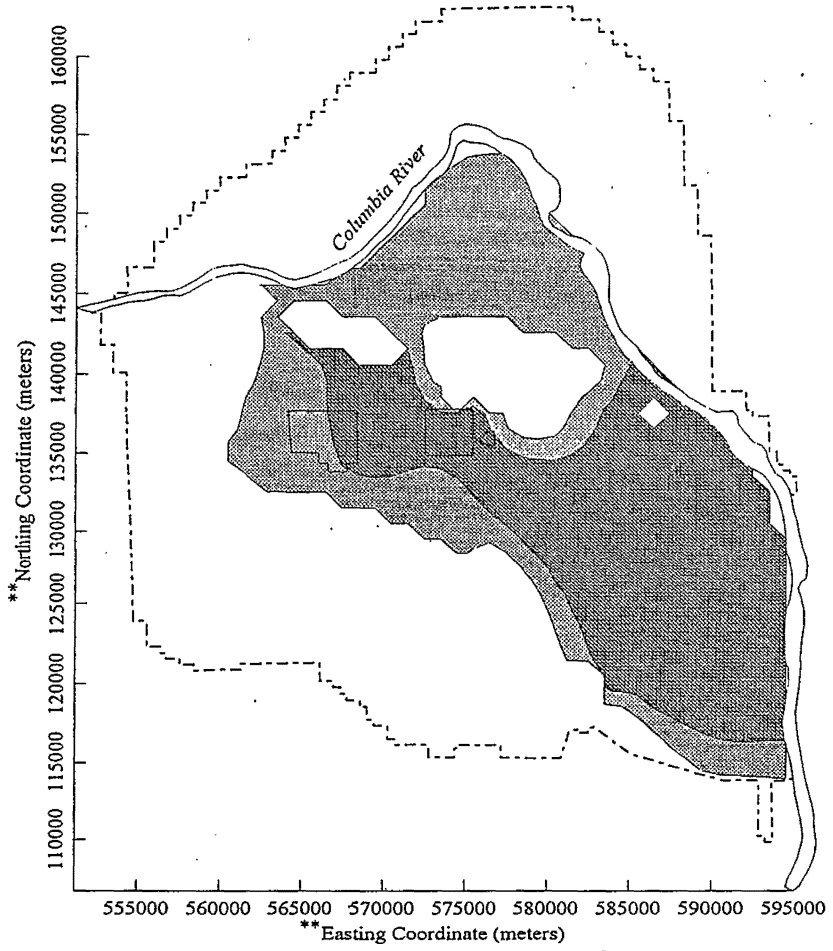


**Figure D.5.9.29 Ex Situ/In Situ Combination 2 Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 10,000 Years from Present**

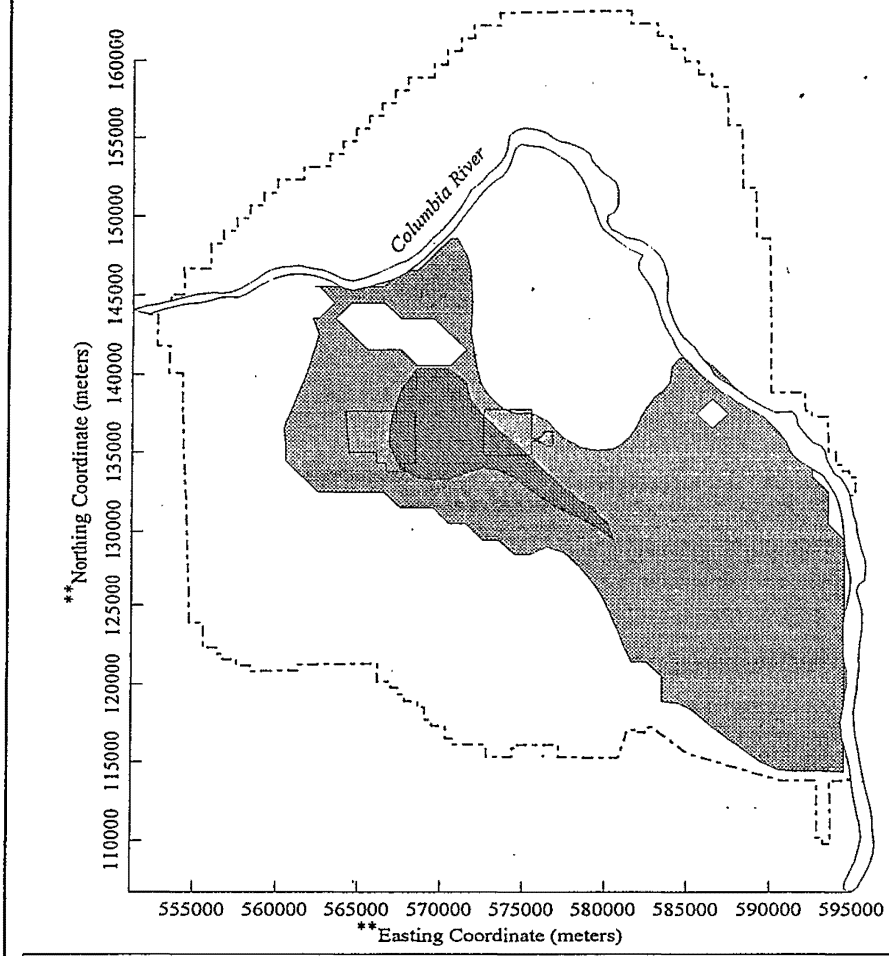


**Figure D.5.9.30 Ex Situ/In Situ Combination 2 Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

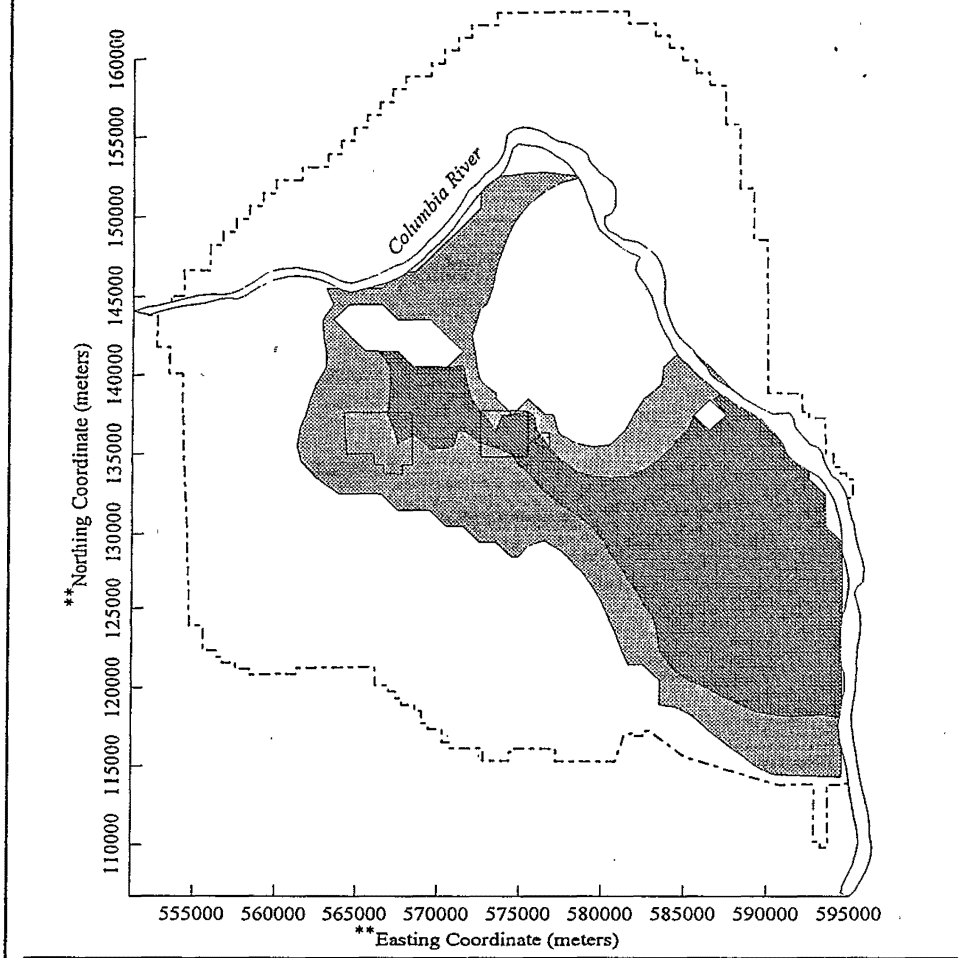


**Figure D.5.9.31 Ex Situ/In Situ Combination 2 Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 10,000 Years from Present**

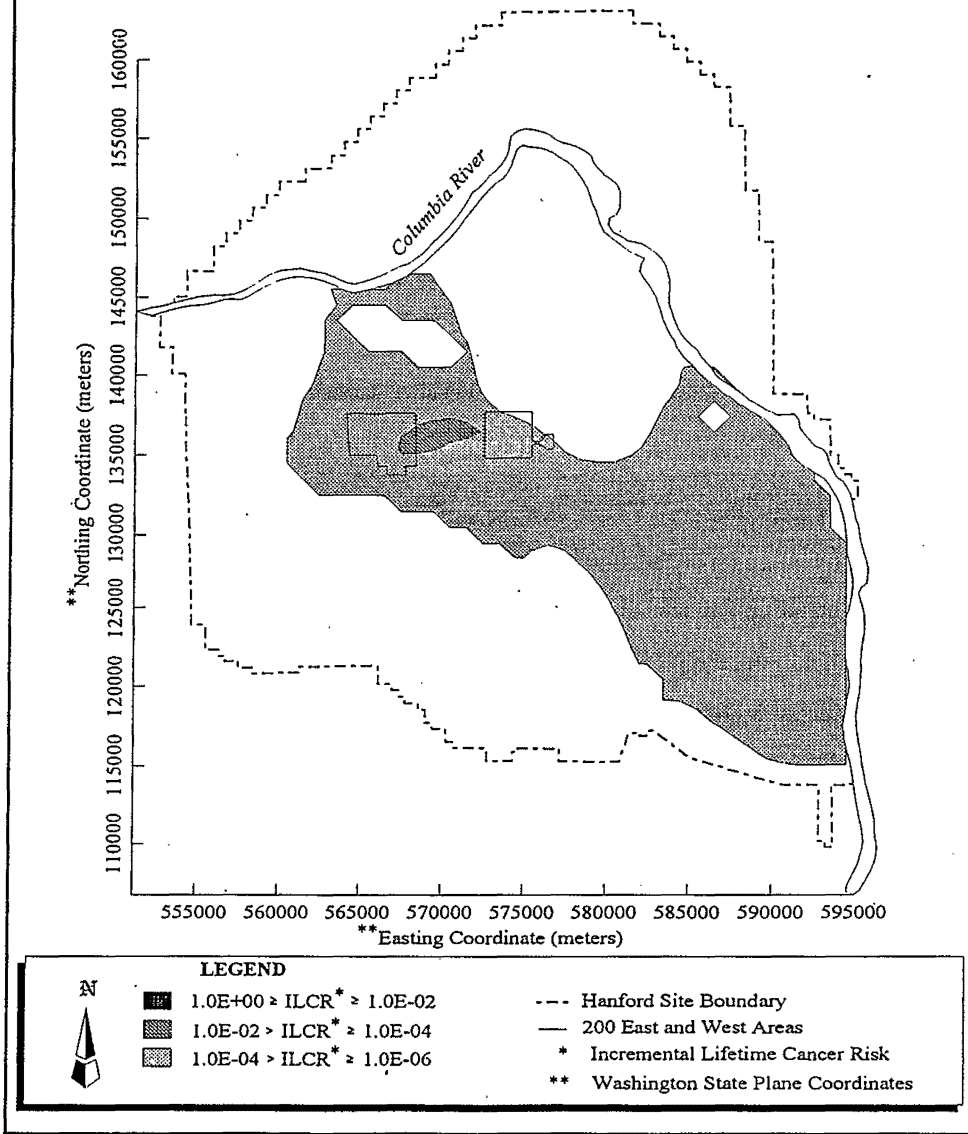


**Figure D.5.9.32 Ex Situ/In Situ Combination 2 Alternative, Recreational River User Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

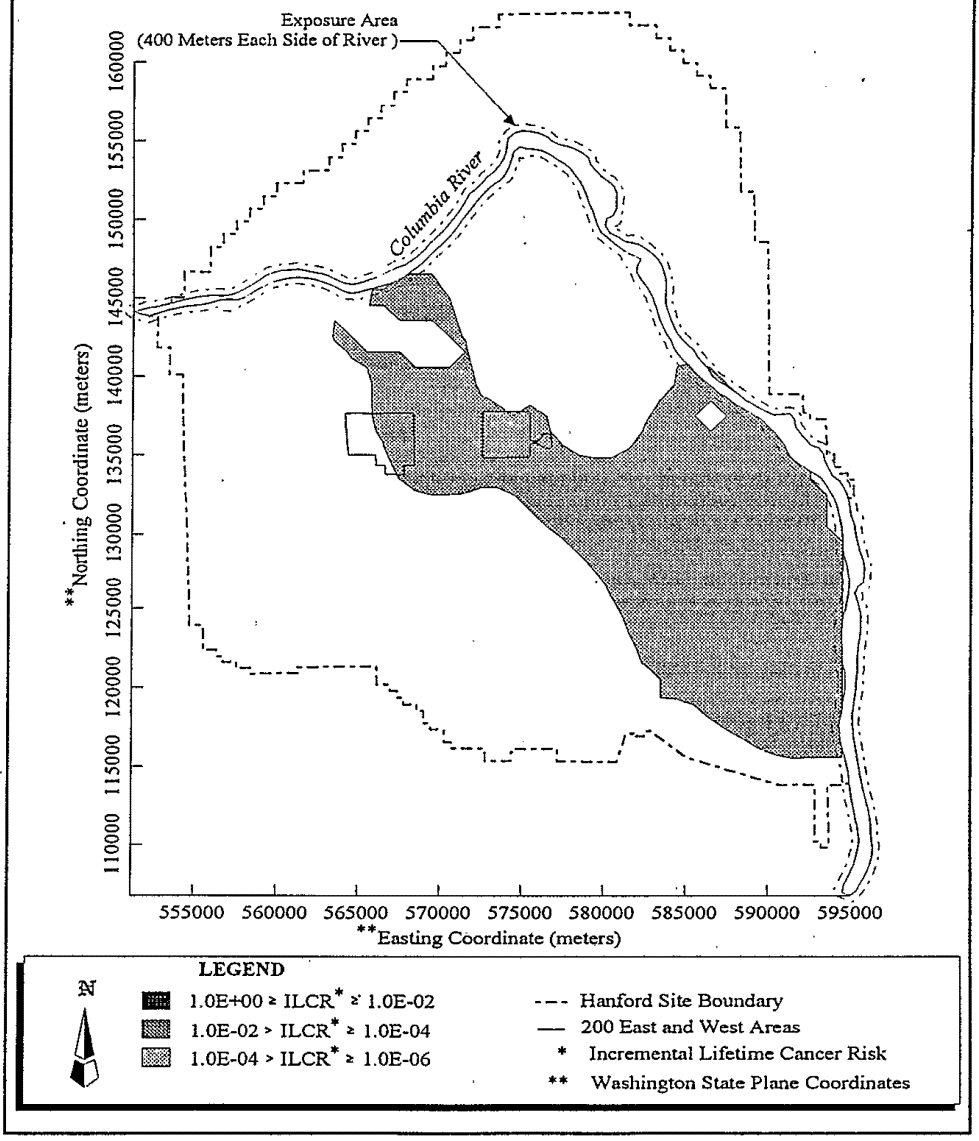


**Figure D.5.9.33 Ex Situ/In Situ Combination 2 Alternative, Recreational River User Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 10,000 Years from Present**

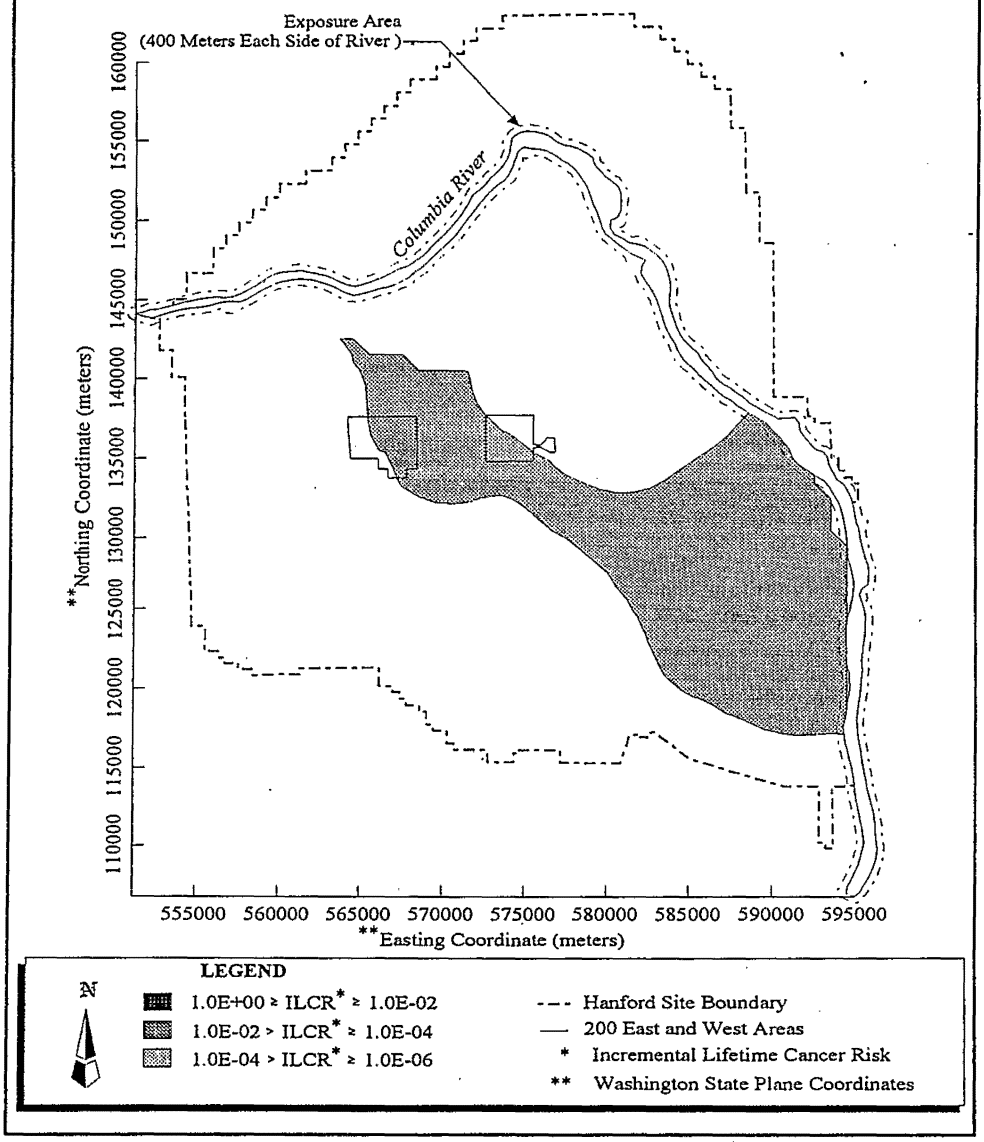


**Figure D.5.9.34 Ex Situ/In Situ Combination 2 Alternative, Native American Scenario, Post Remediation Hazard Index from Tank Residuals and LAW Vaults at 5,000 Years from Present**

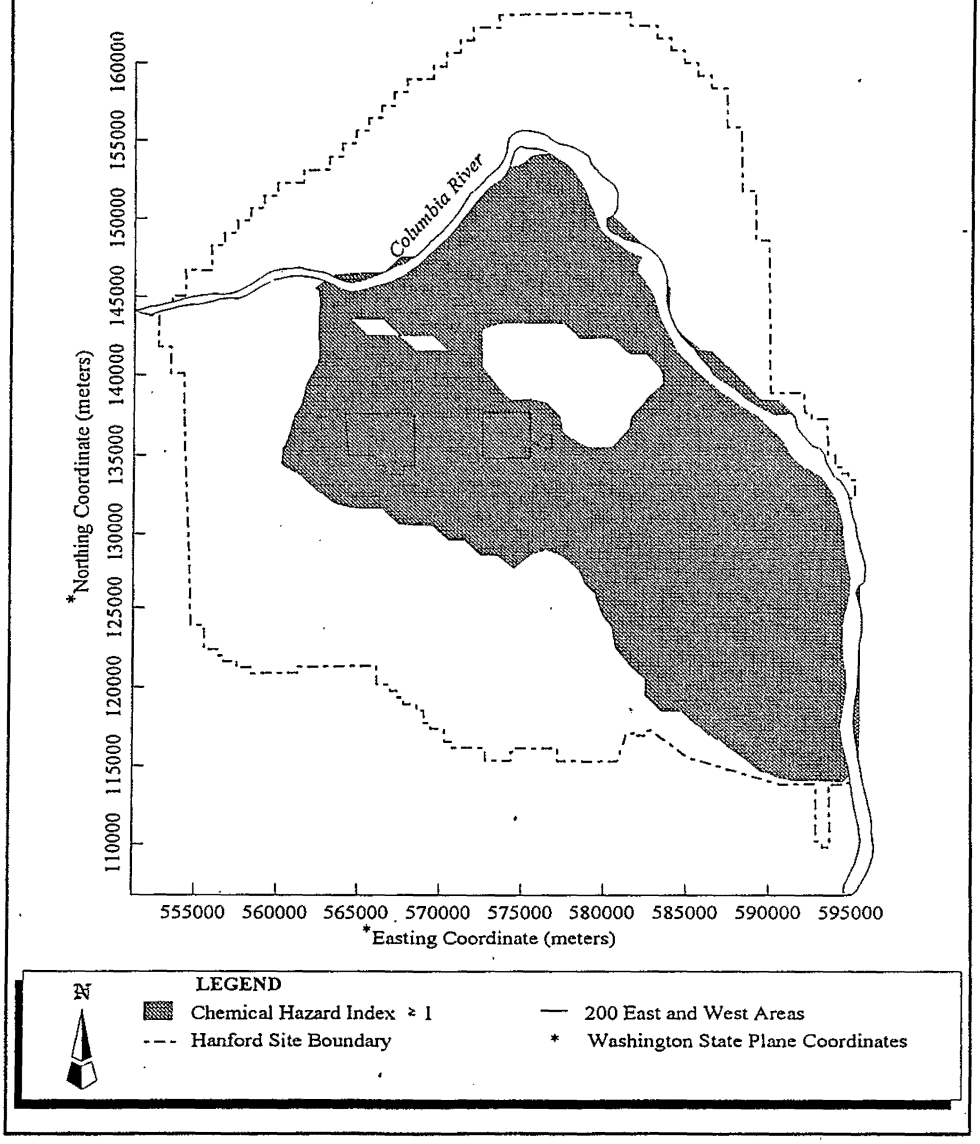


**Figure D.5.9.35 Ex Situ/In Situ Combination 2 Alternative, Native American Scenario, Post Remediation Hazard Index from Tank Residuals and LAW Vaults at 10,000 Years from Present**

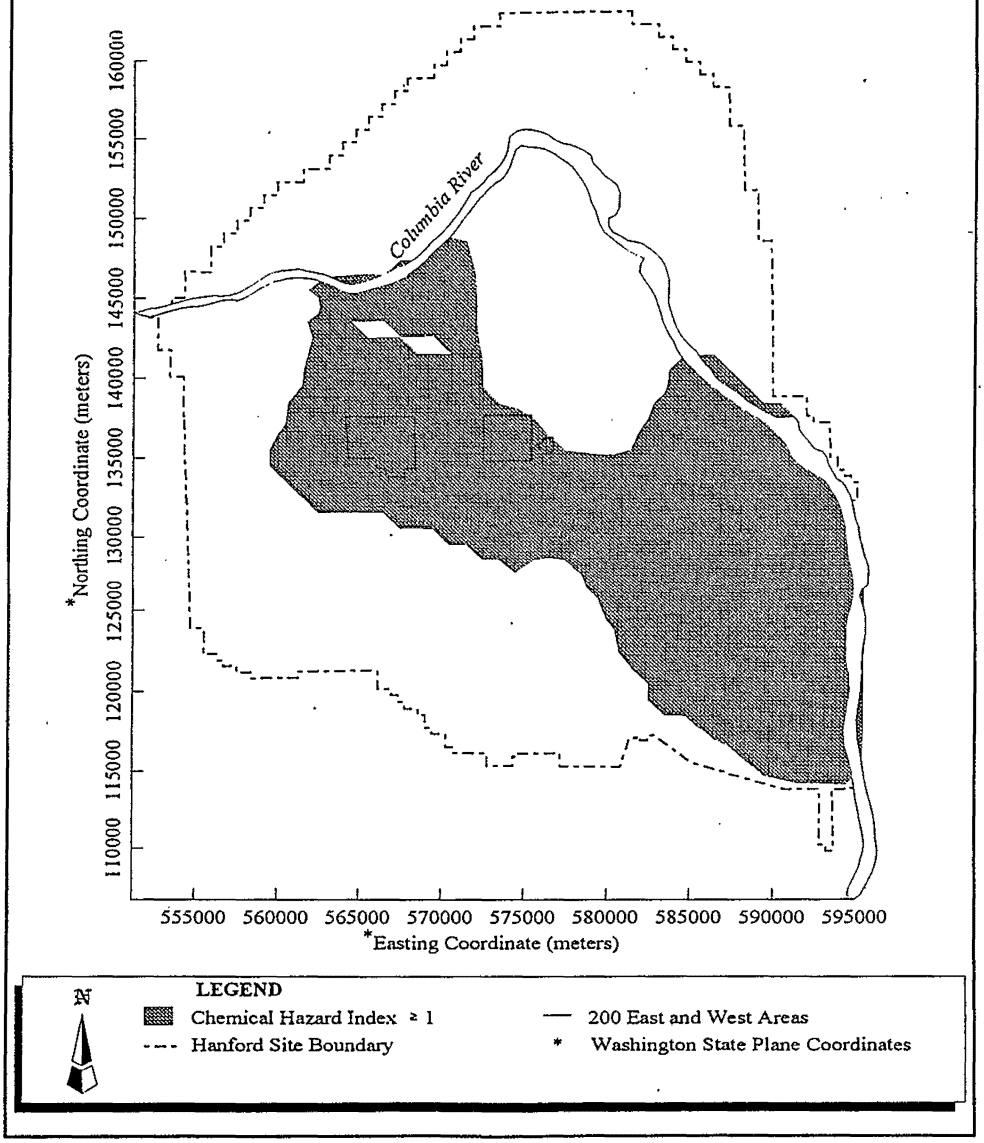


**Figure D.5.9.36 Ex Situ/In Situ Combination 2 Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from Tank Residuals and LAW Vaults at 5,000 Years from Present**

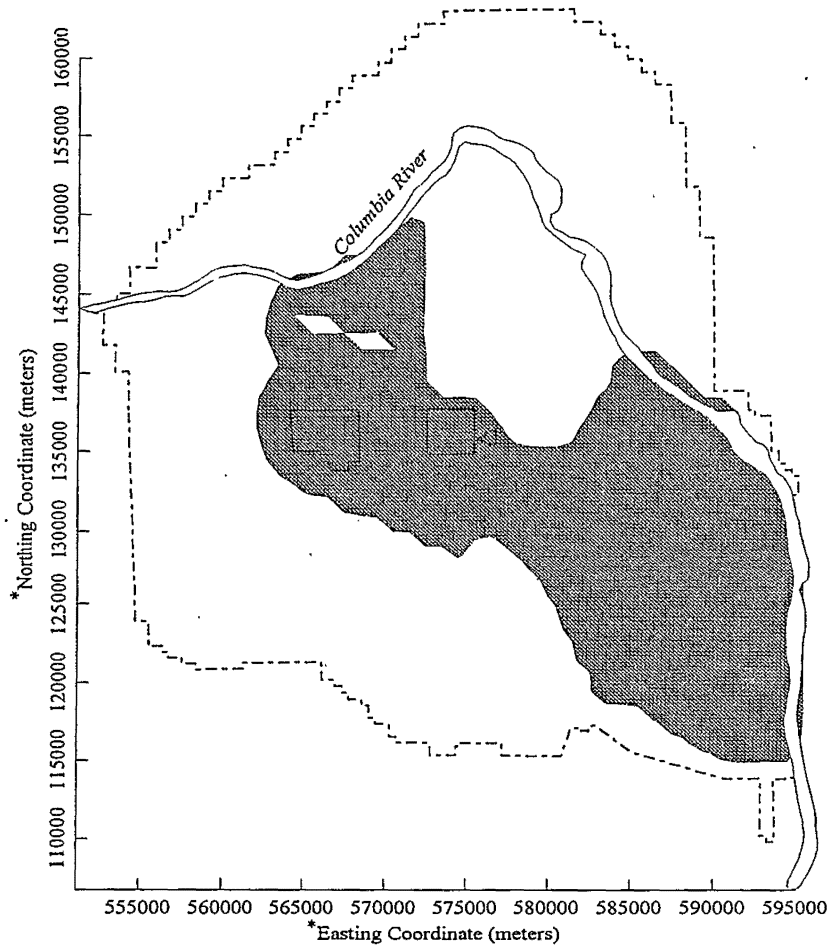


**Figure D.5.9.37 Ex Situ/In Situ Combination 2 Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from Tank Residuals & LAW Vaults at 10,000 Years from Present**

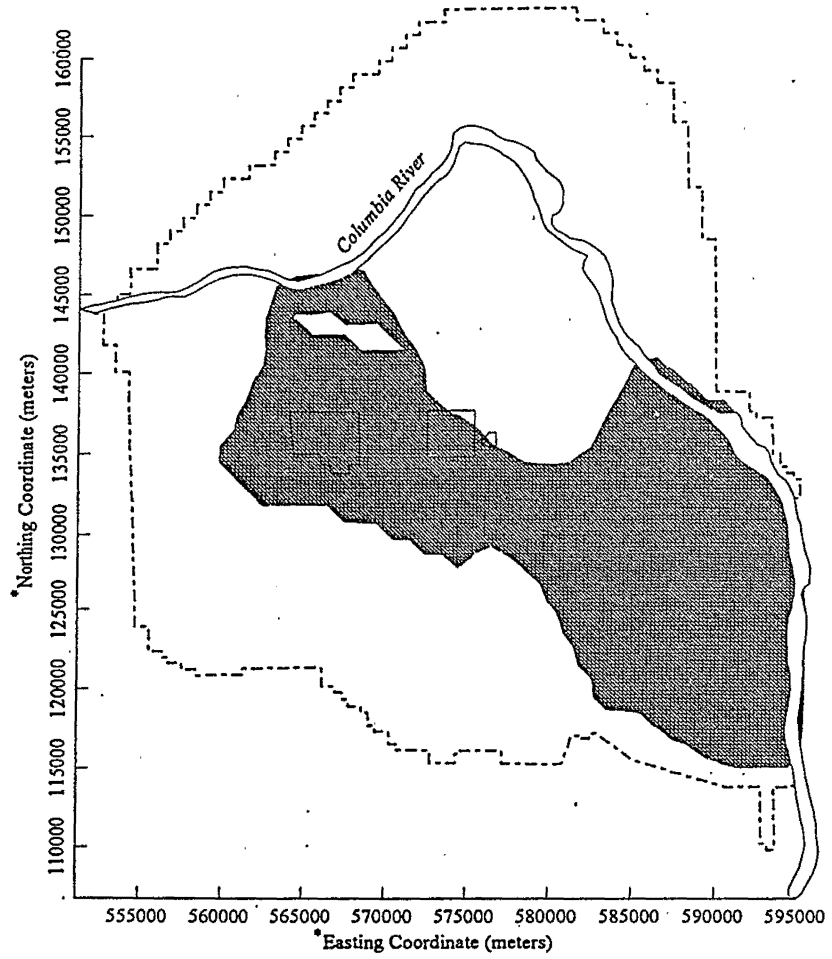


Figure D.5.10.1 Phased Implementation Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals at 2,500 Years from Present

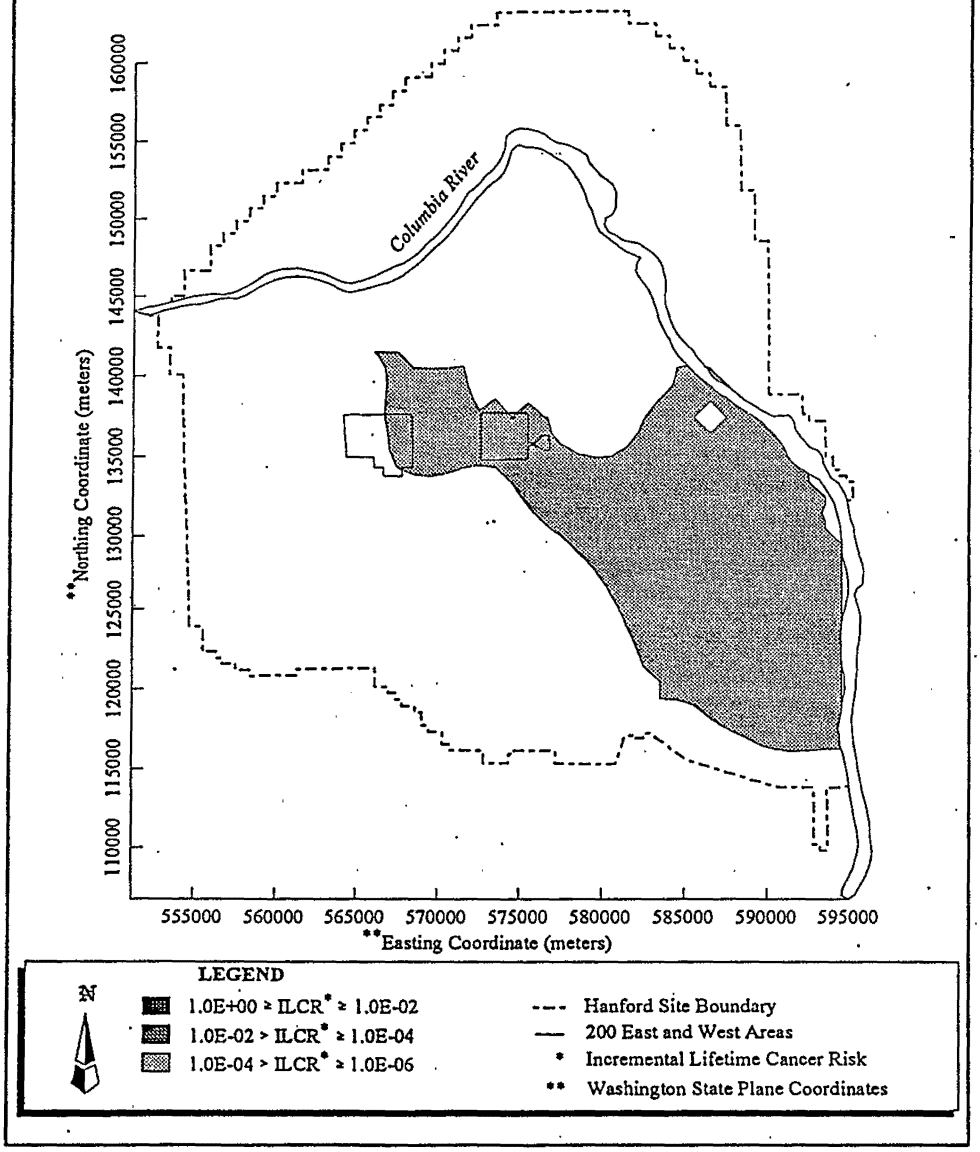


**Figure D.5.10.2 Phased Implementation Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

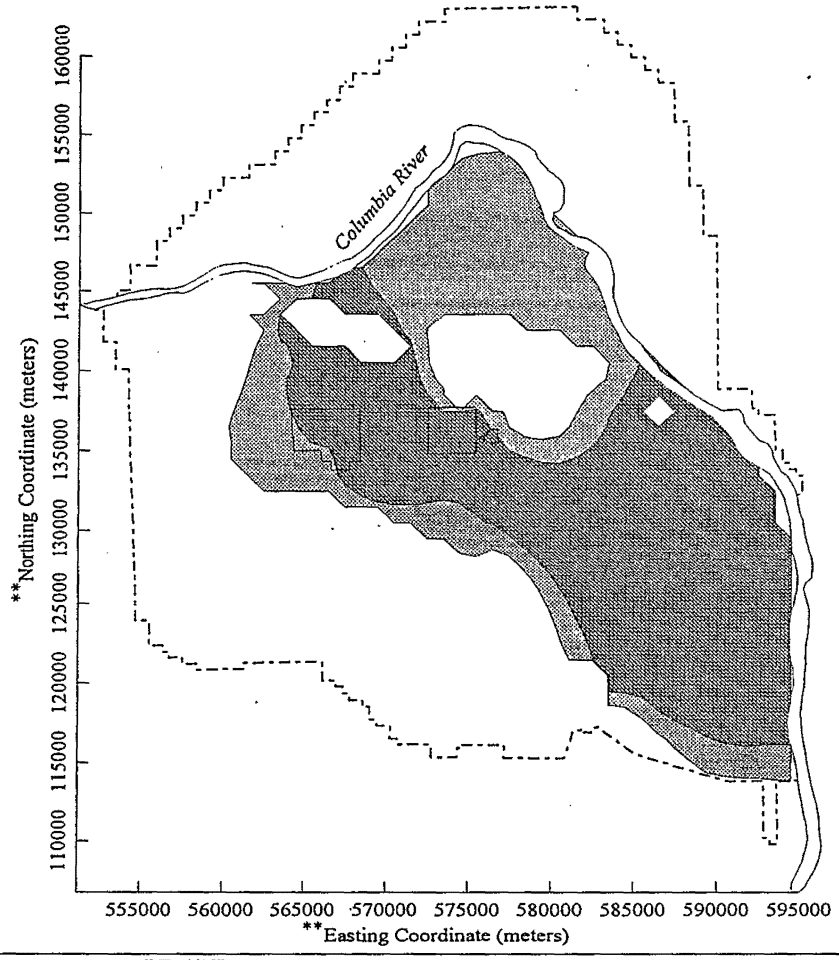


**Figure D.5.10.3 Phased Implementation Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals at 2,500 Years from Present**

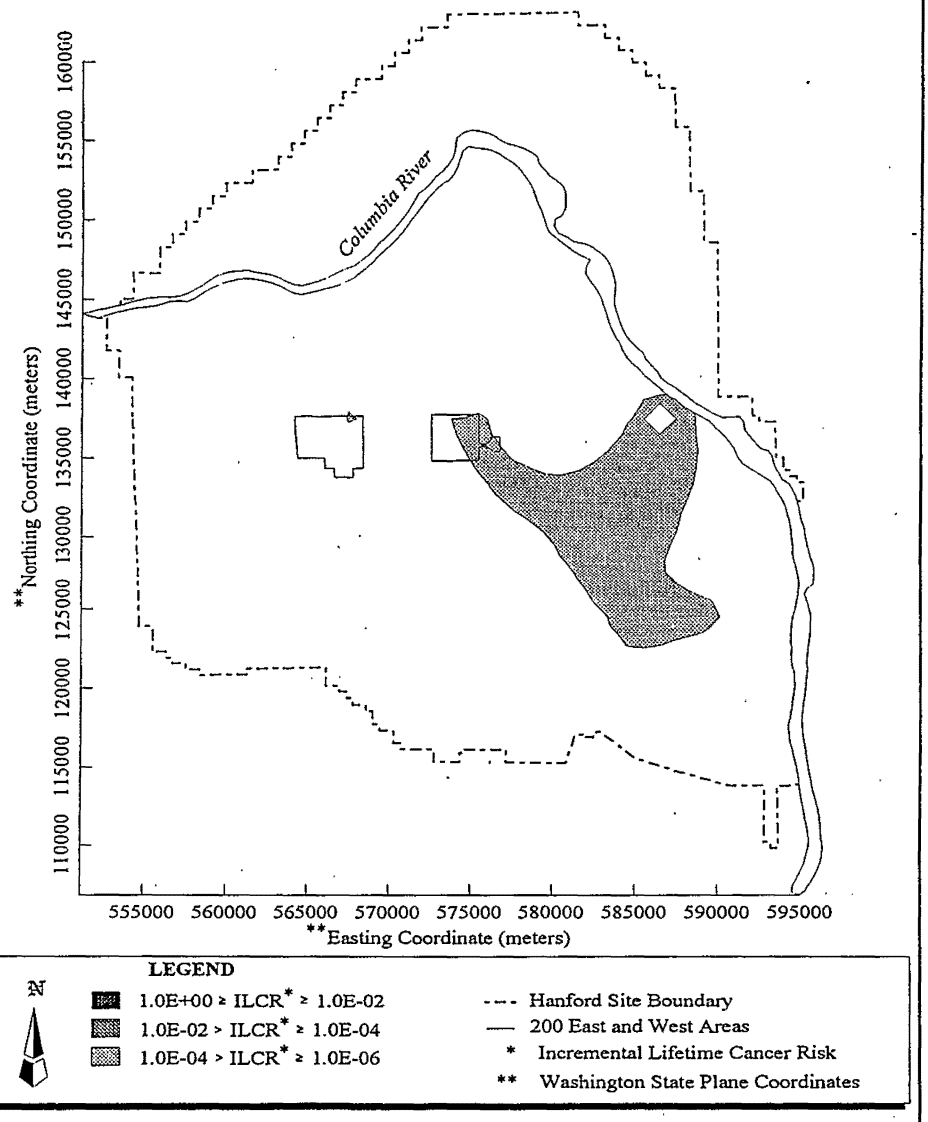


**Figure D.5.10.4 Phased Implementation Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

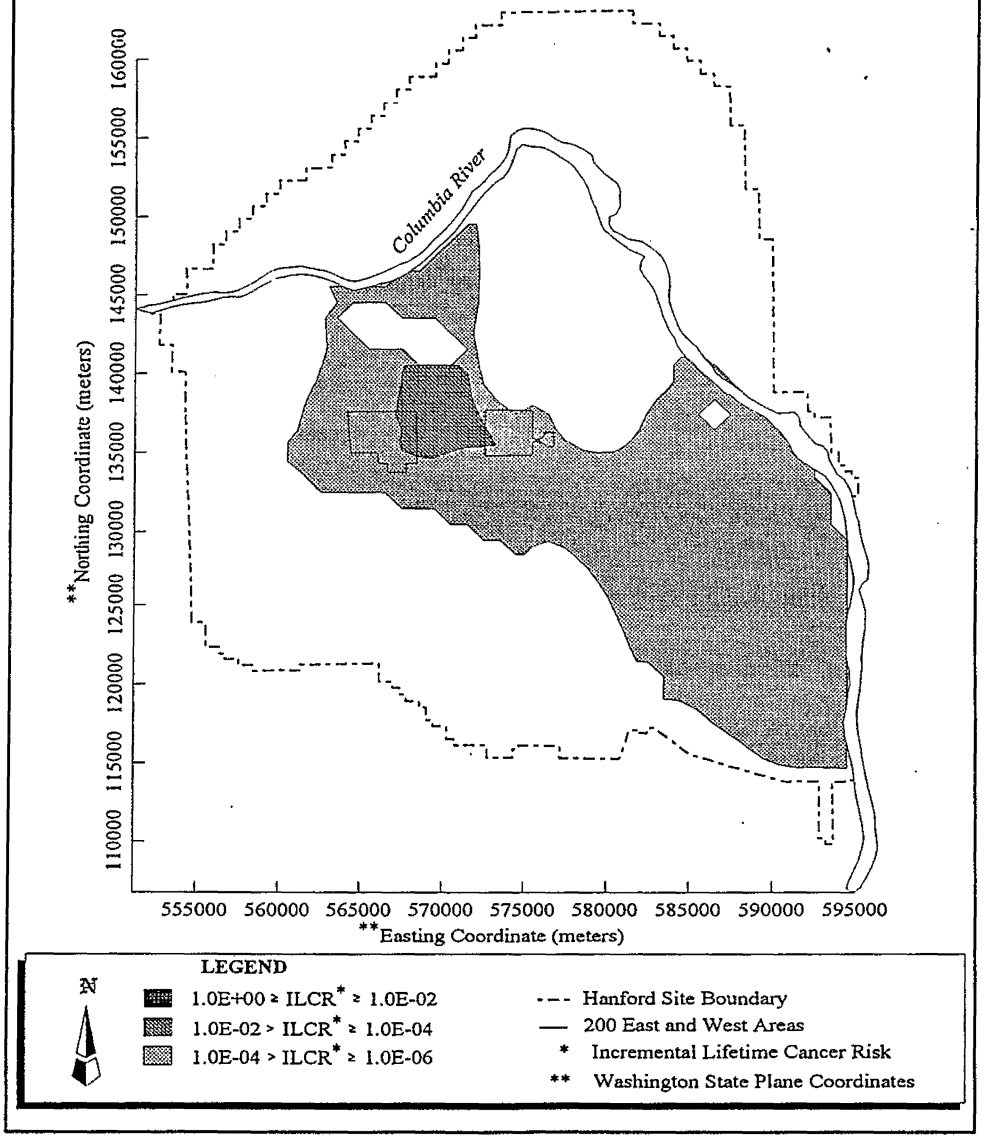


**Figure D.5.10.5 Phased Implementation Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals at 2,500 Years from Present**

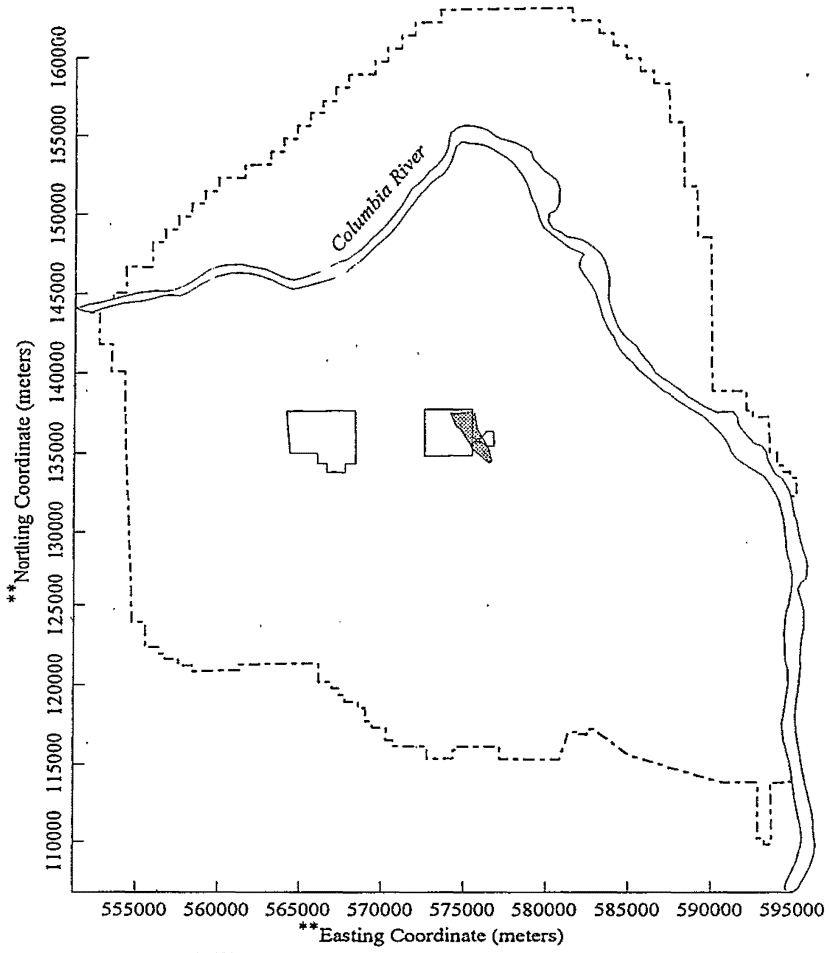


**Figure D.5.10.6 Phased Implementation Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

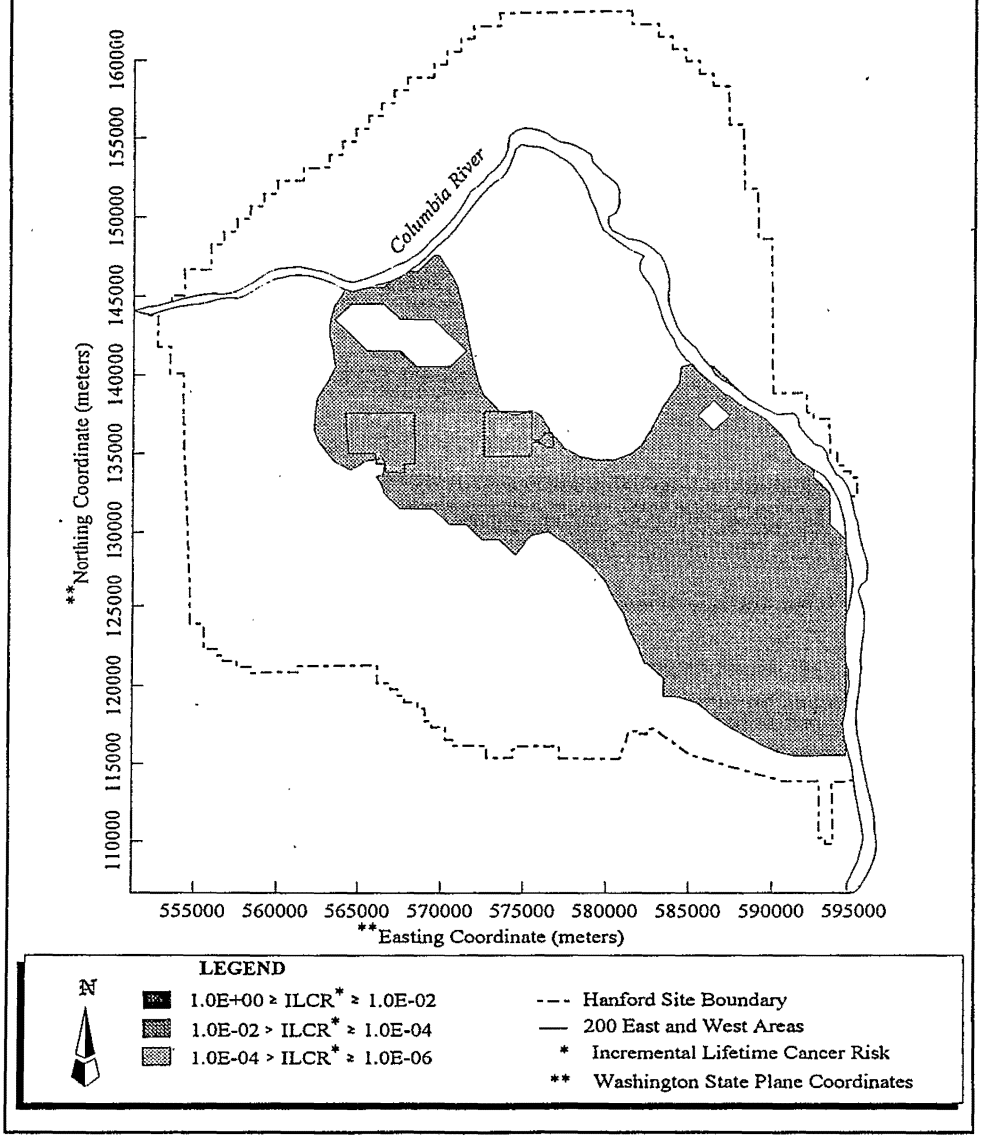


**Figure D.5.10.7 Phased Implementation Alternative, Recreational River User Scenario, Post Remediation Risk from Tank Residuals at 5,000 Years from Present**

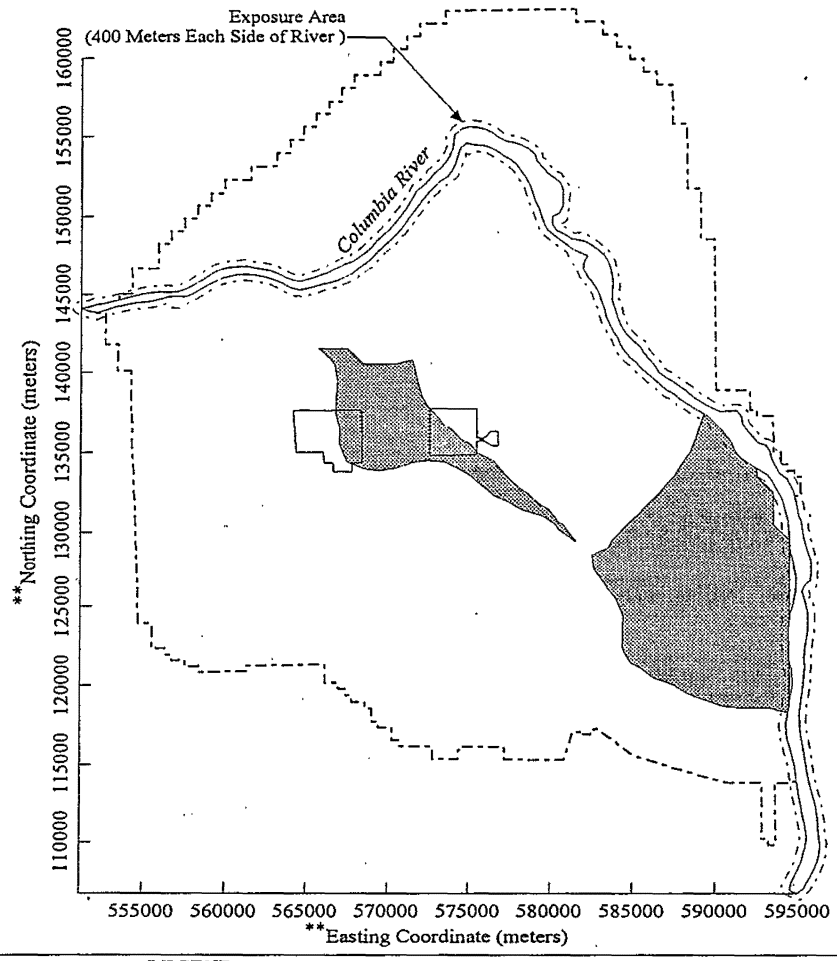


**Figure D.5.10.8 Phased Implementation Alternative, Native American Scenario, Post Remediation Hazard Index from Tank Residuals at 5,000 Years from Present**

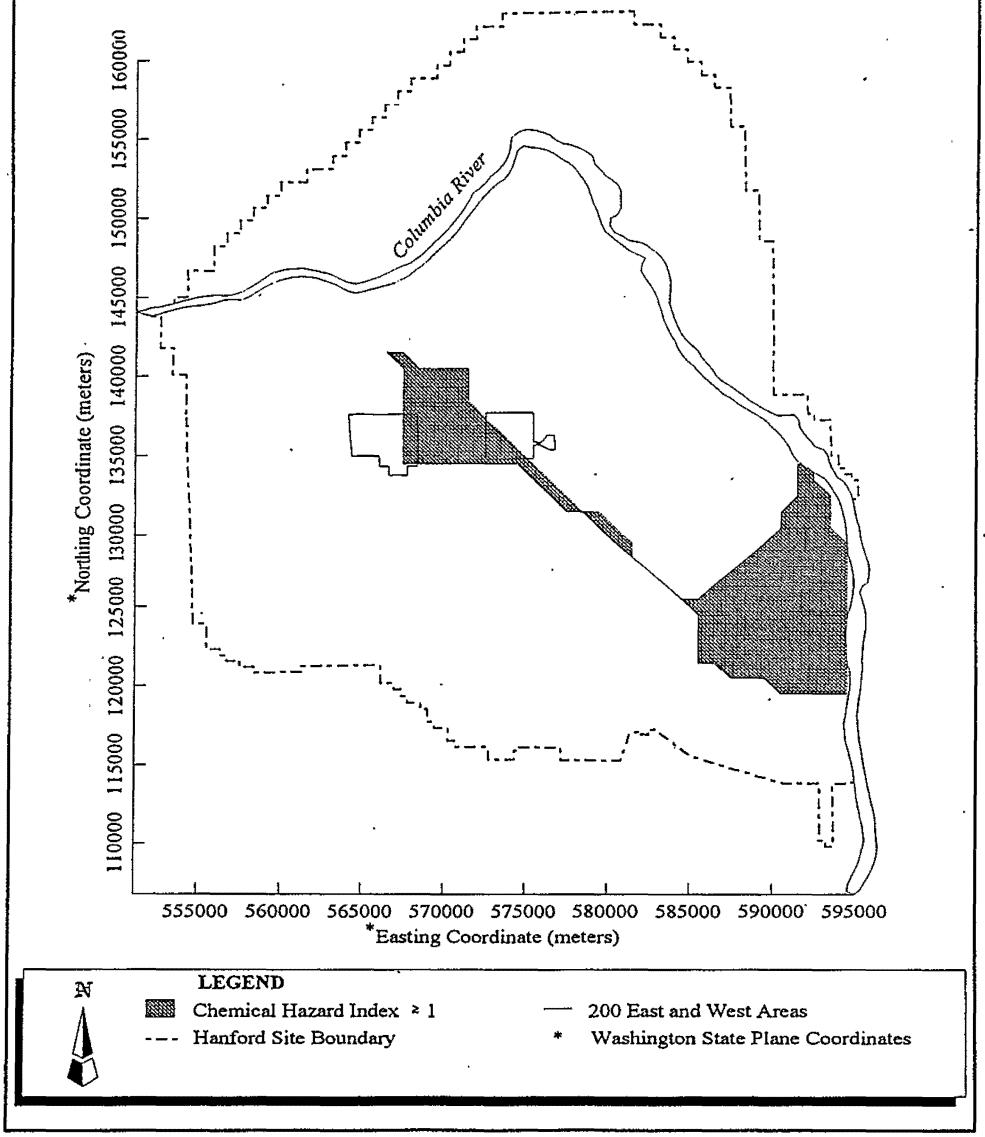


**Figure D.5.10.9 Phased Implementation Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from Tank Residuals at 5,000 Years from Present**

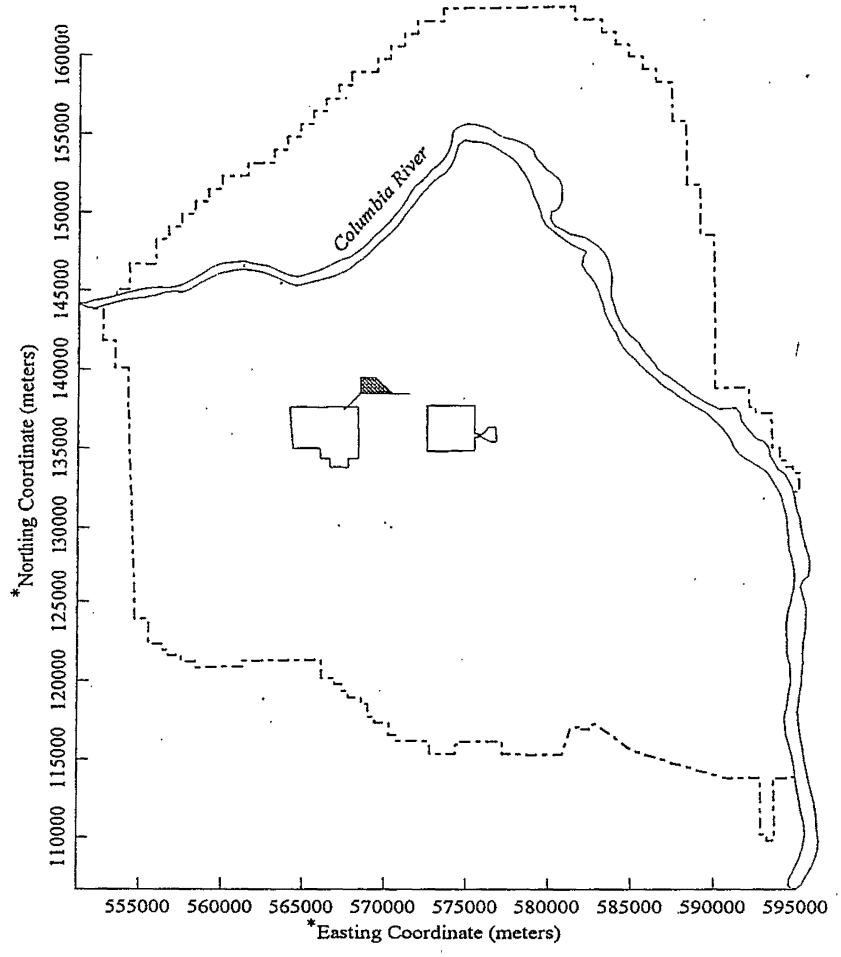


**Figure D.5.10.10 Phased Implementation Alternative, Native American Scenario, Post Remediation Risk from LAW Vaults at 5,000 Years from Present**

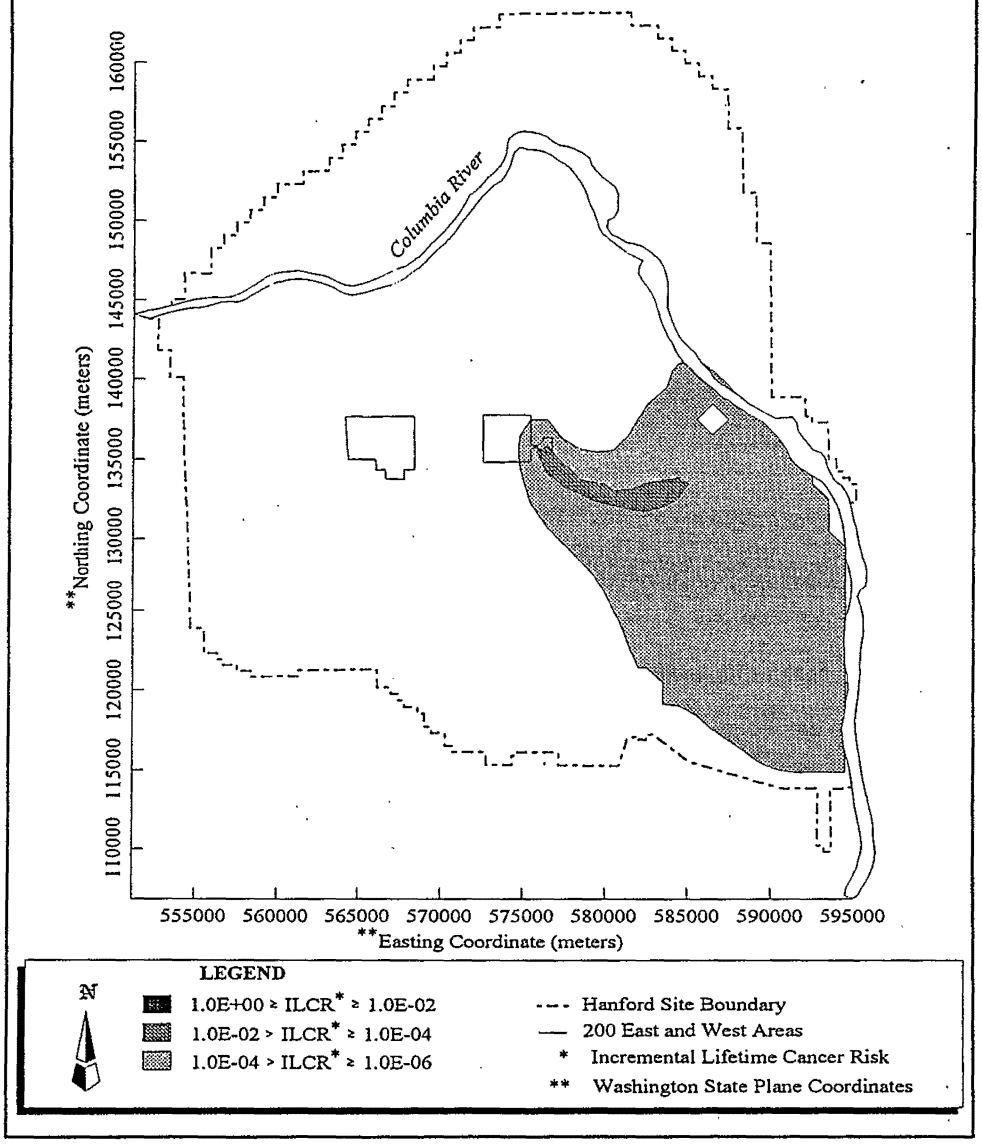


**Figure D.5.10.11 Phased Implementation Alternative, Native American Scenario, Post Remediation Risk from LAW Vaults at 10,000 Years from Present**

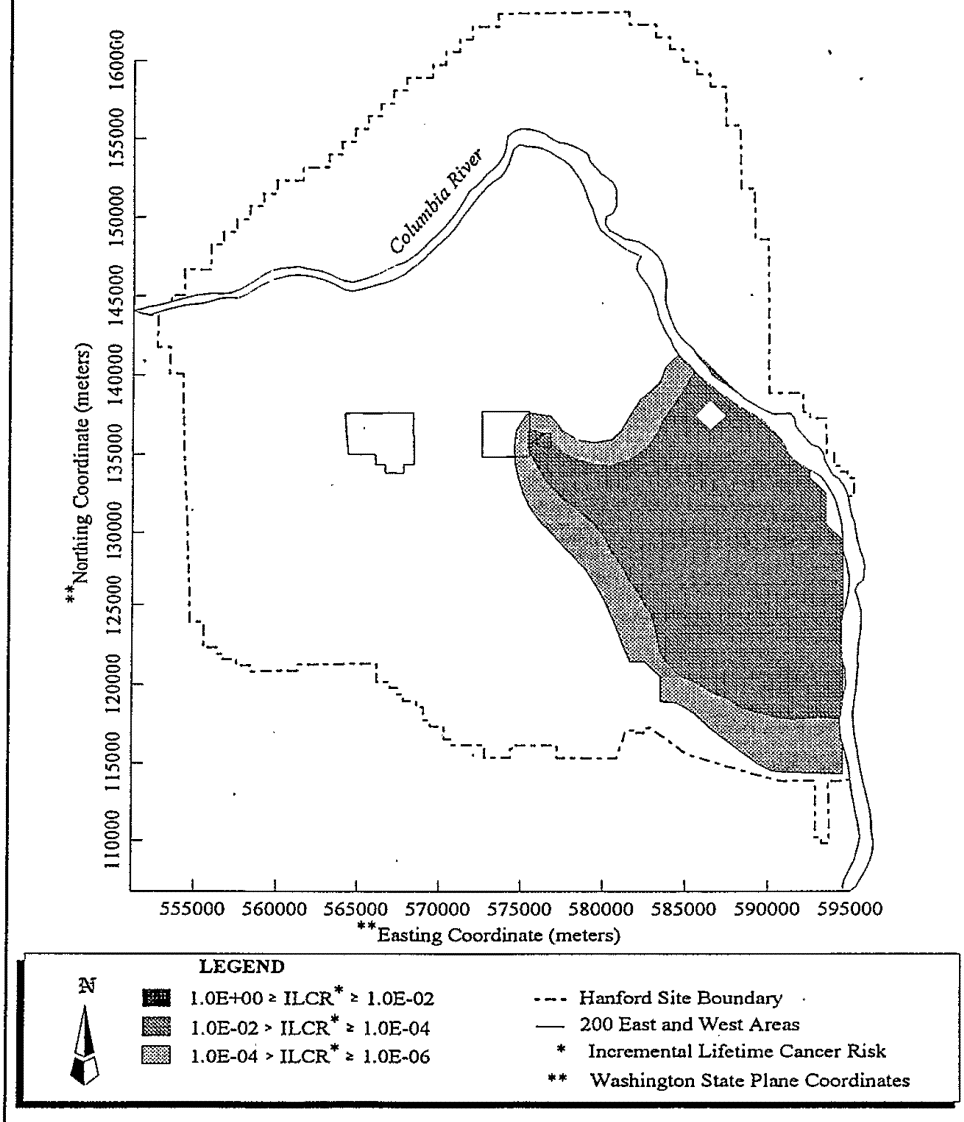


**Figure D.5.10.12 Phased Implementation Alternative, Residential Farmer Scenario, Post Remediation Risk from LAW Vaults at 5,000 Years from Present**

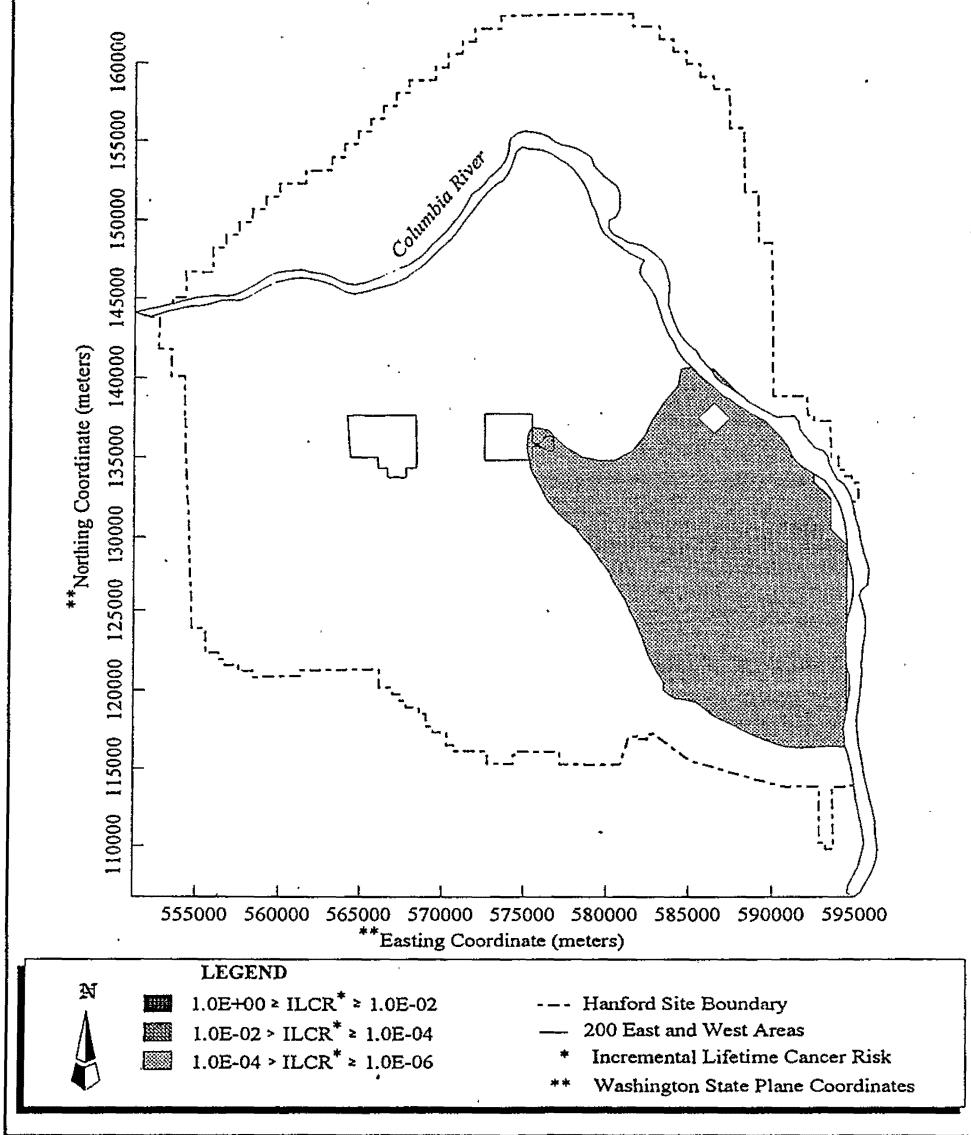


**Figure D.5.10.13 Phased Implementation Alternative, Residential Farmer Scenario, Post Remediation Risk from LAW Vaults at 10,000 Years from Present**

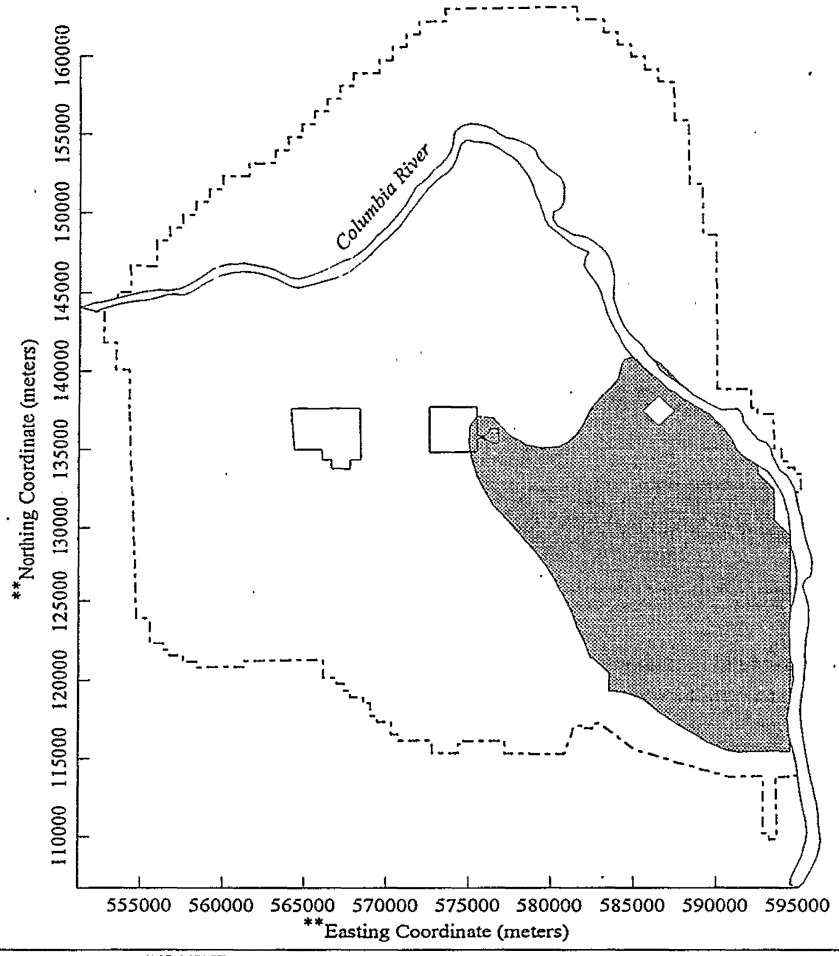


**Figure D.5.10.14 Phased Implementation Alternative, Industrial Worker Scenario, Post Remediation Risk from LAW Vaults at 5,000 Years from Present**

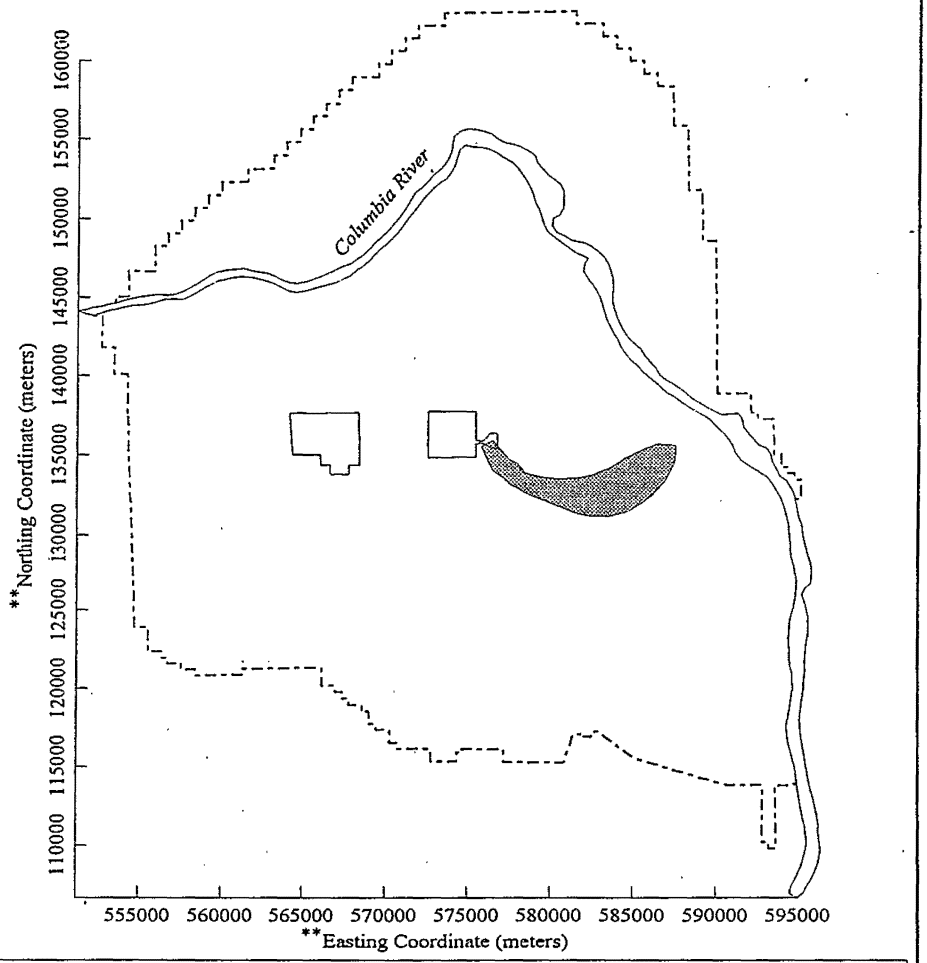


**Figure D.5.10.15 Phased Implementation Alternative, Industrial Worker Scenario, Post Remediation Risk from LAW Vaults at 10,000 Years from Present**

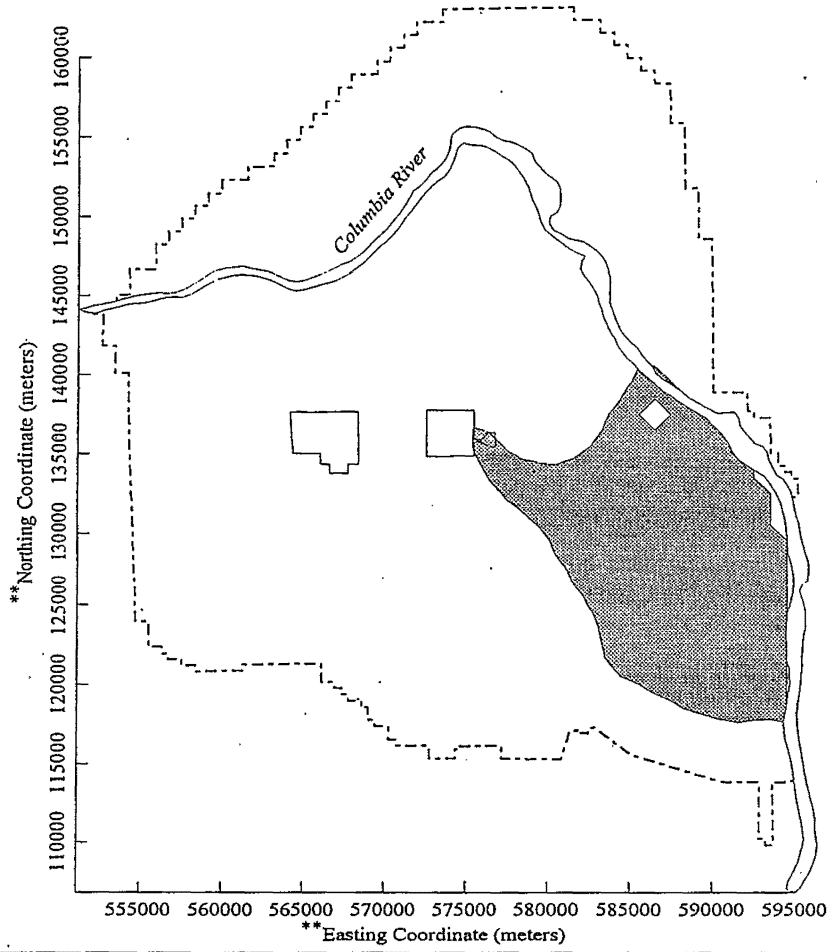


**Figure D.5.10.16 Phased Implementation Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 2,500 Years from Present**

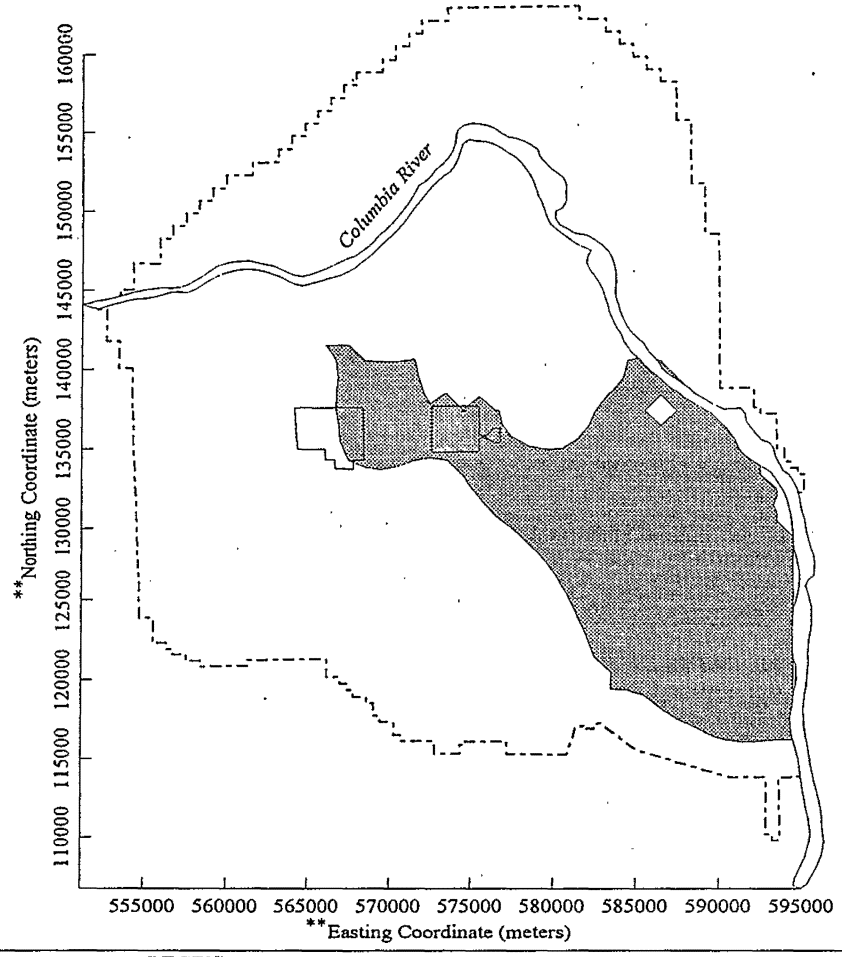


**Figure D.5.10.17 Phased Implementation Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

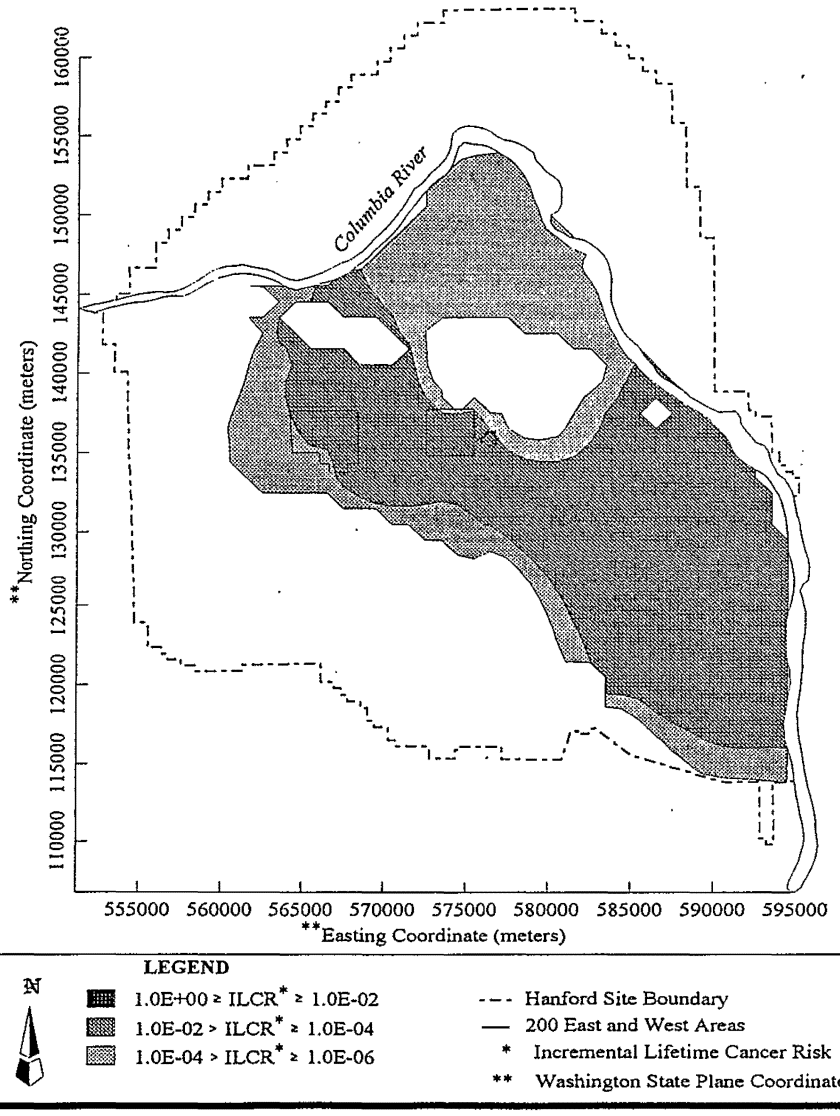


**Figure D.5.10.18 Phased Implementation Alternative, Native American Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 10,000 Years from Present**

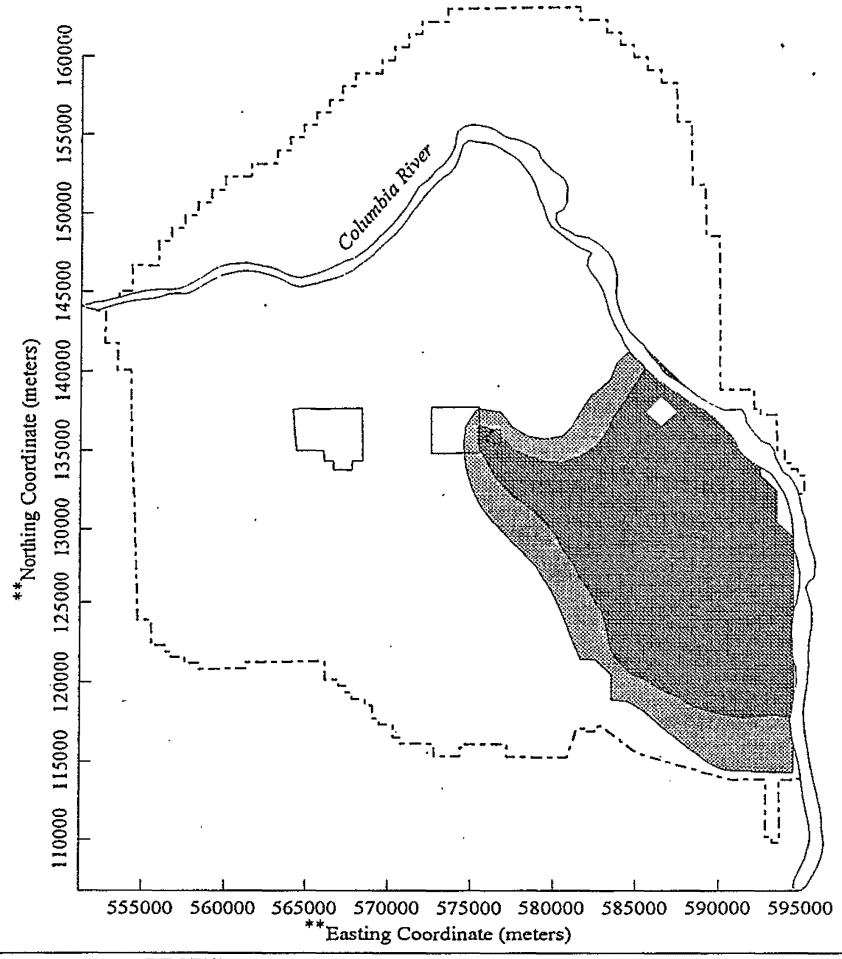


**Figure D.5.10.19 Phased Implementation Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 2,500 Years from Present**

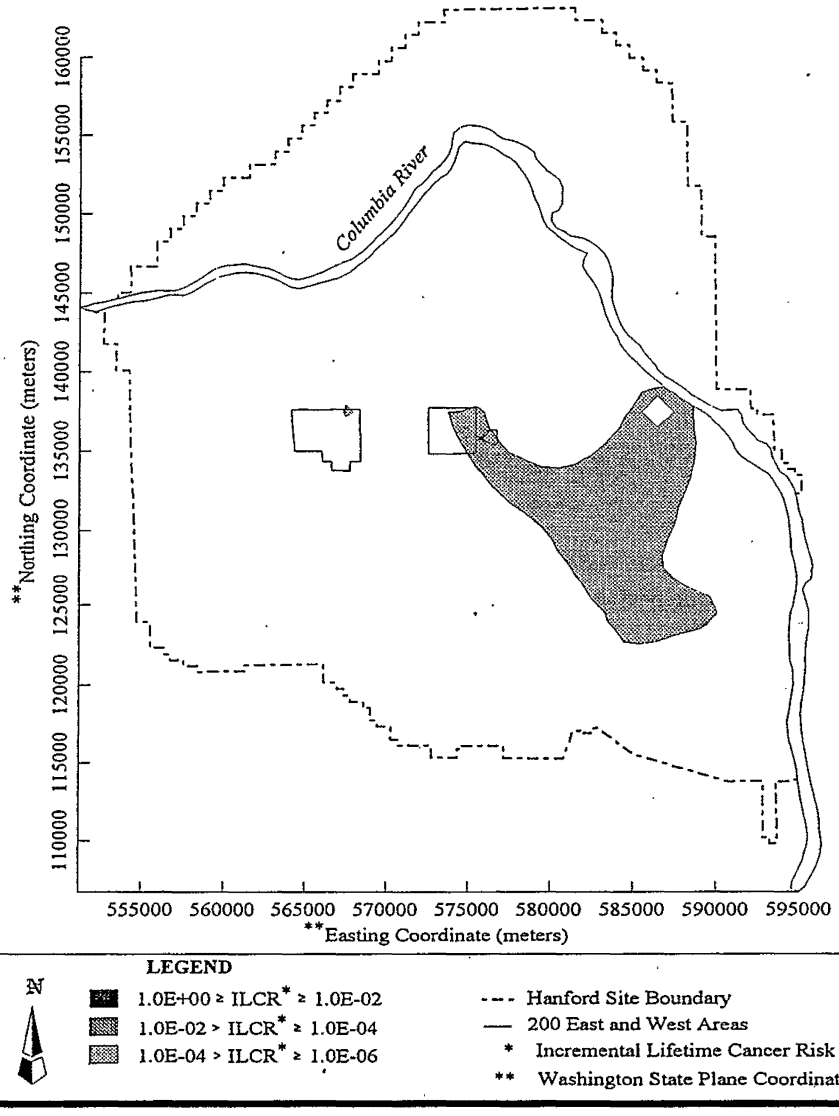


**Figure D.5.10.20 Phased Implementation Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

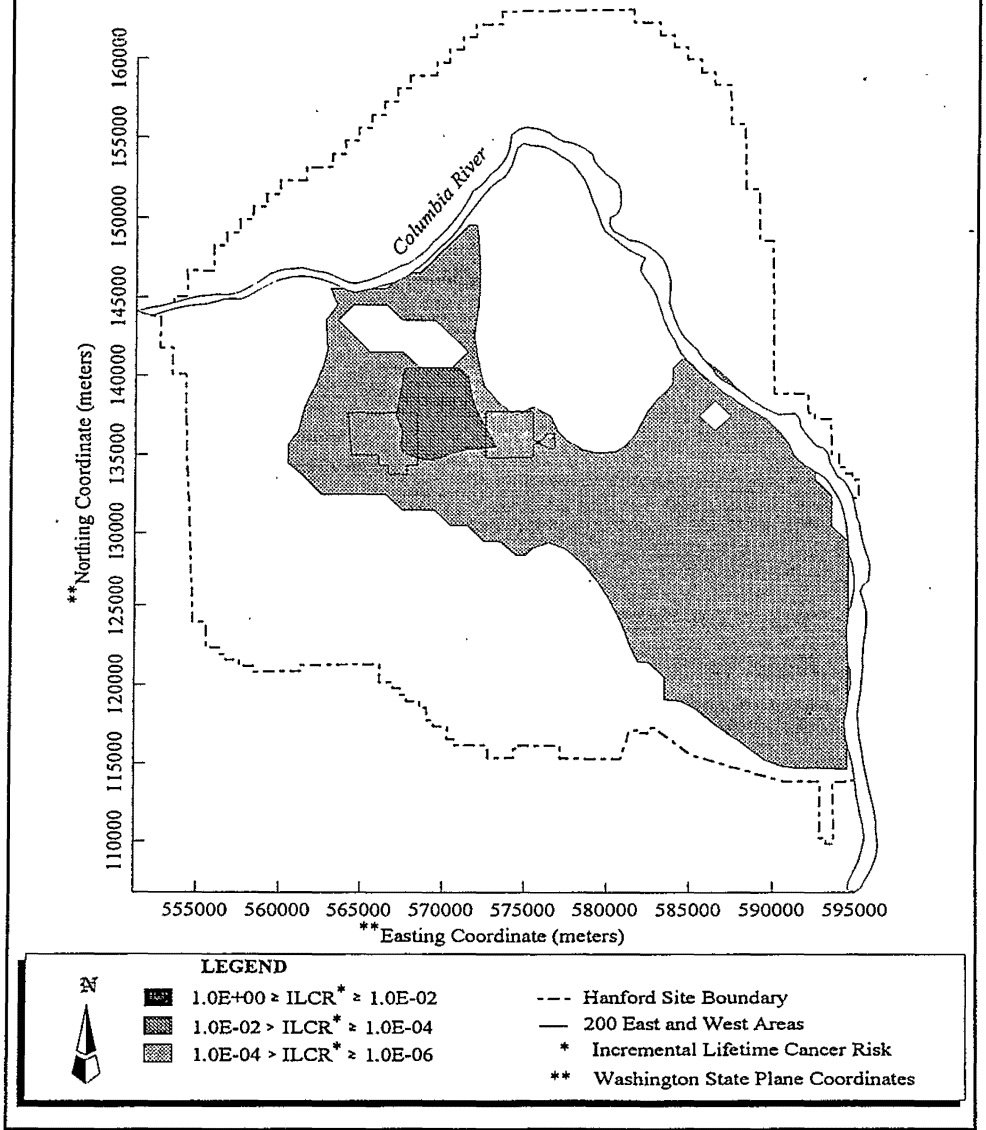


**Figure D.5.10.21 Phased Implementation Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 10,000 Years from Present**

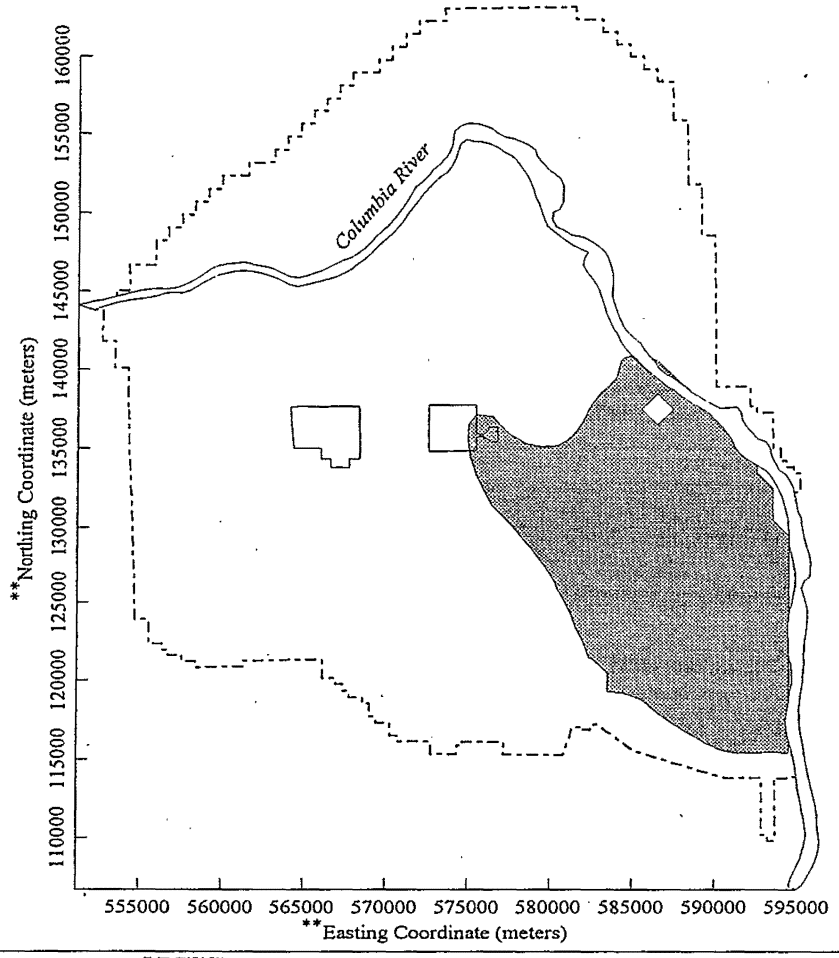


**Figure D.5.10.22 Phased Implementation Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 2,500 Years from Present**

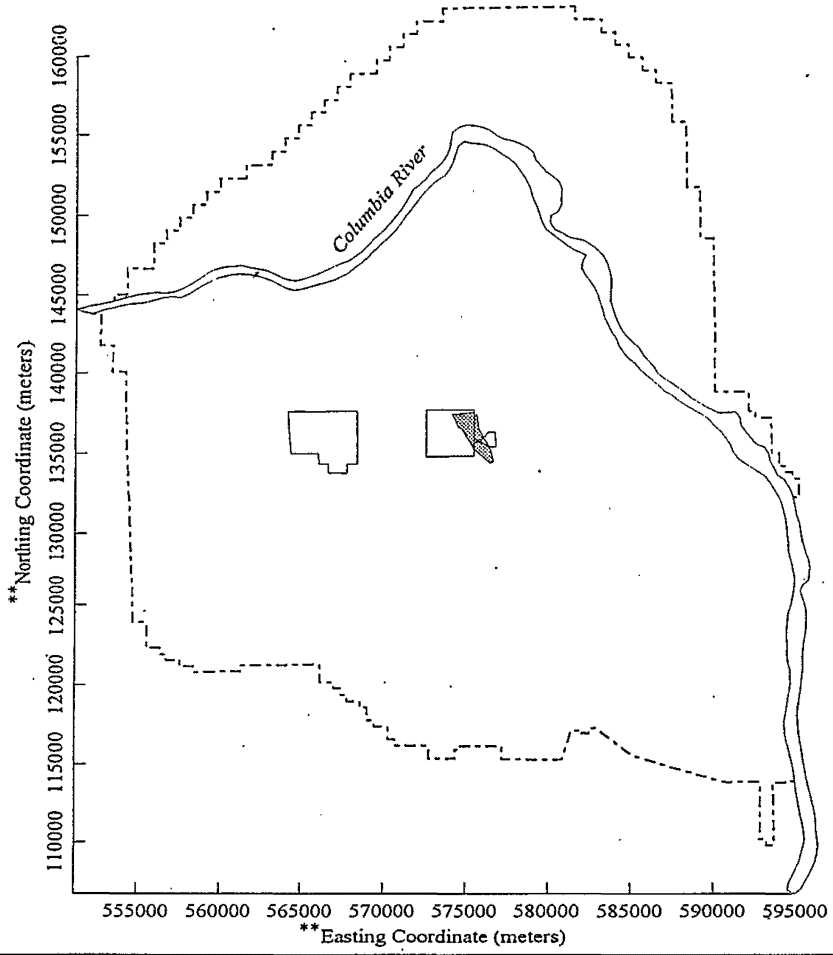


**Figure D.5.10.23 Phased Implementation Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

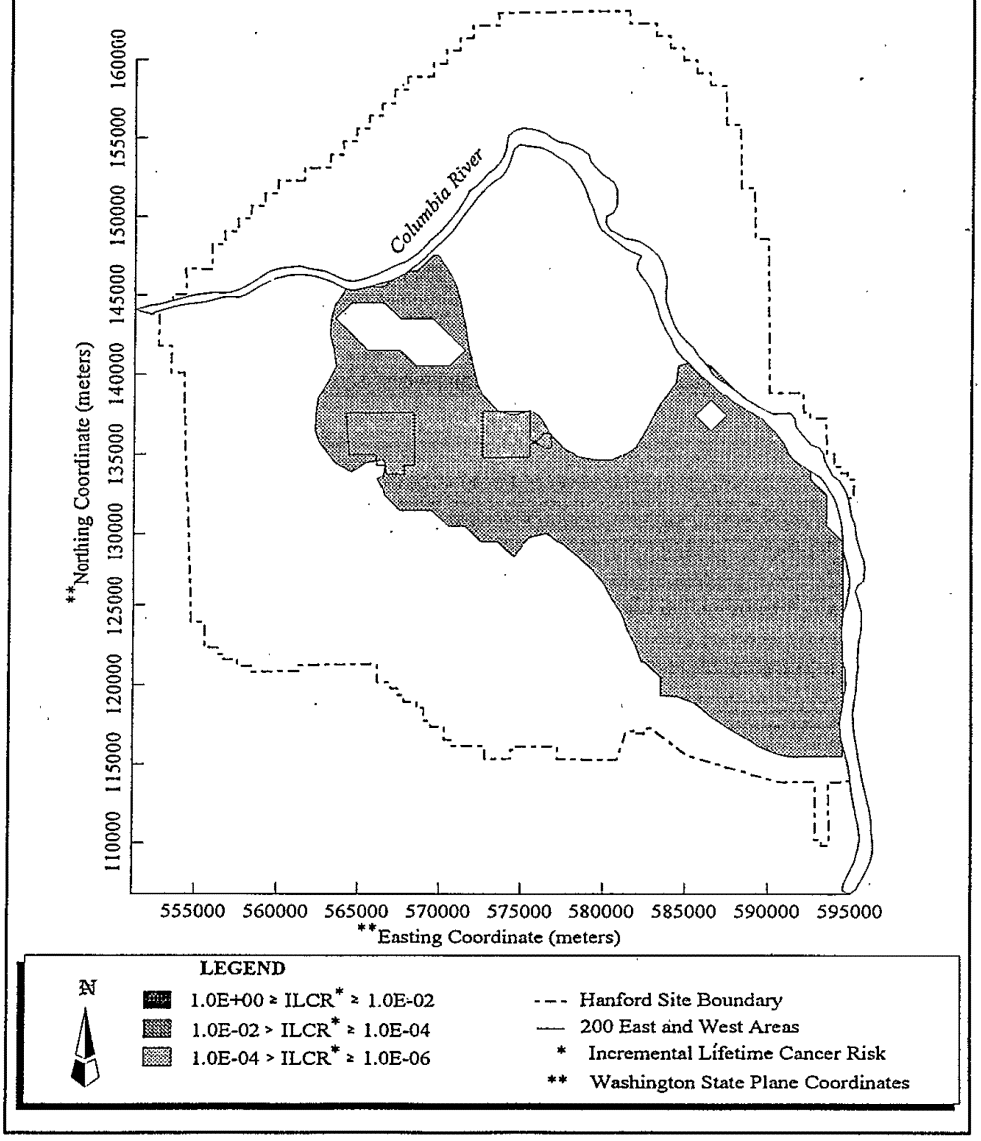


**Figure D.5.10.24 Phased Implementation Alternative, Industrial Worker Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 10,000 Years from Present**

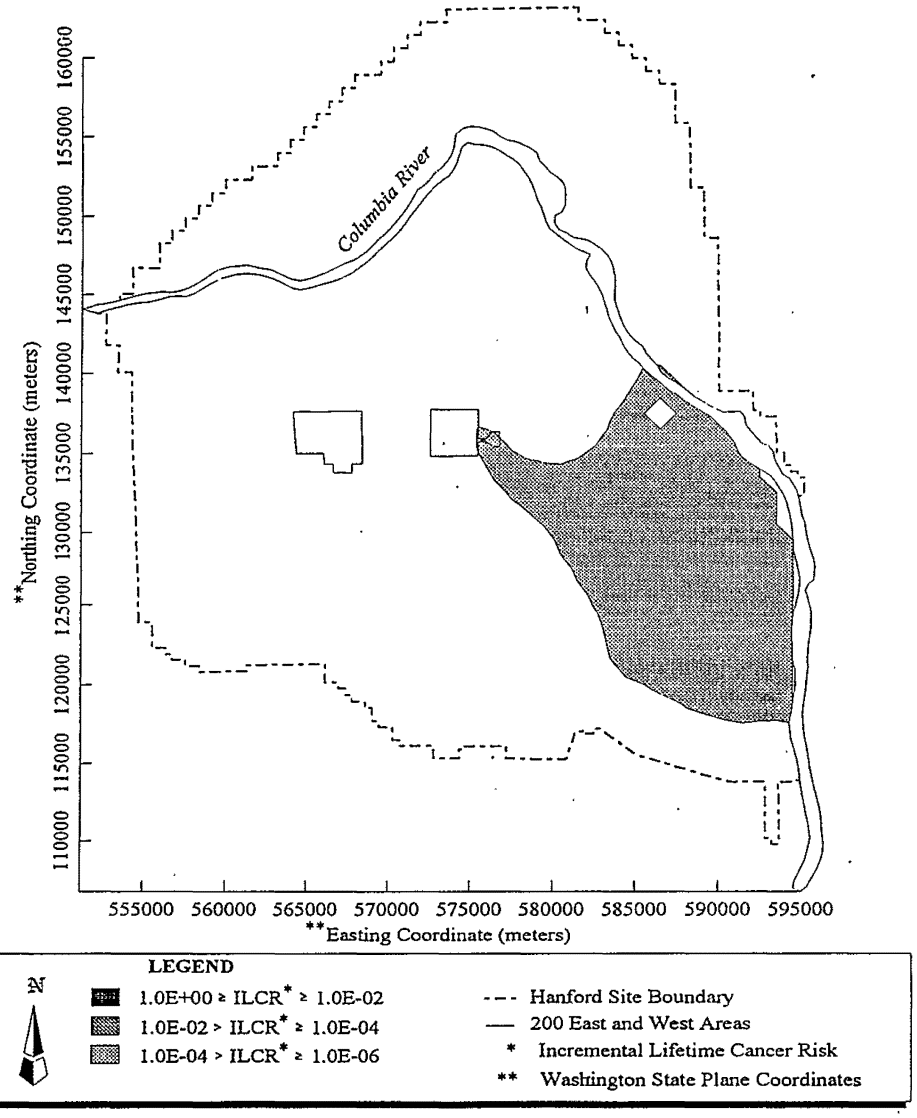


**Figure D.5.10.25 Phased Implementation Alternative, Recreational River User Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present**

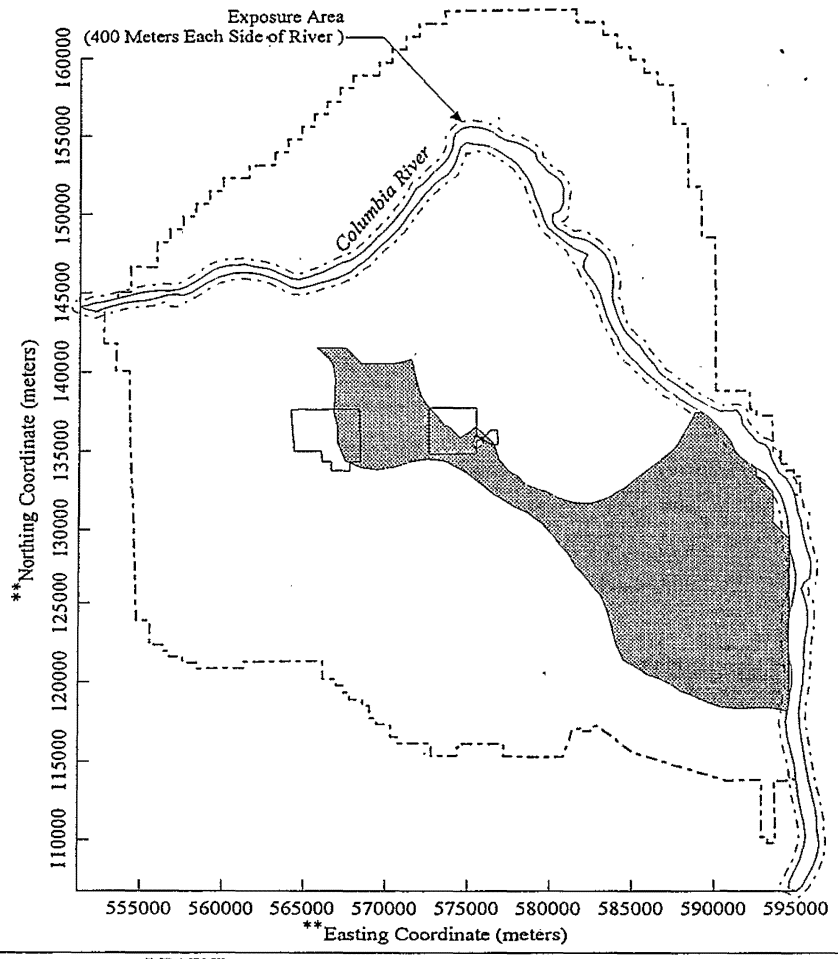


**Figure D.5.10.26 Phased Implementation Alternative, Native American Scenario, Post Remediation Hazard Index from Tank Residuals and LAW Vaults at 5,000 Years from Present**

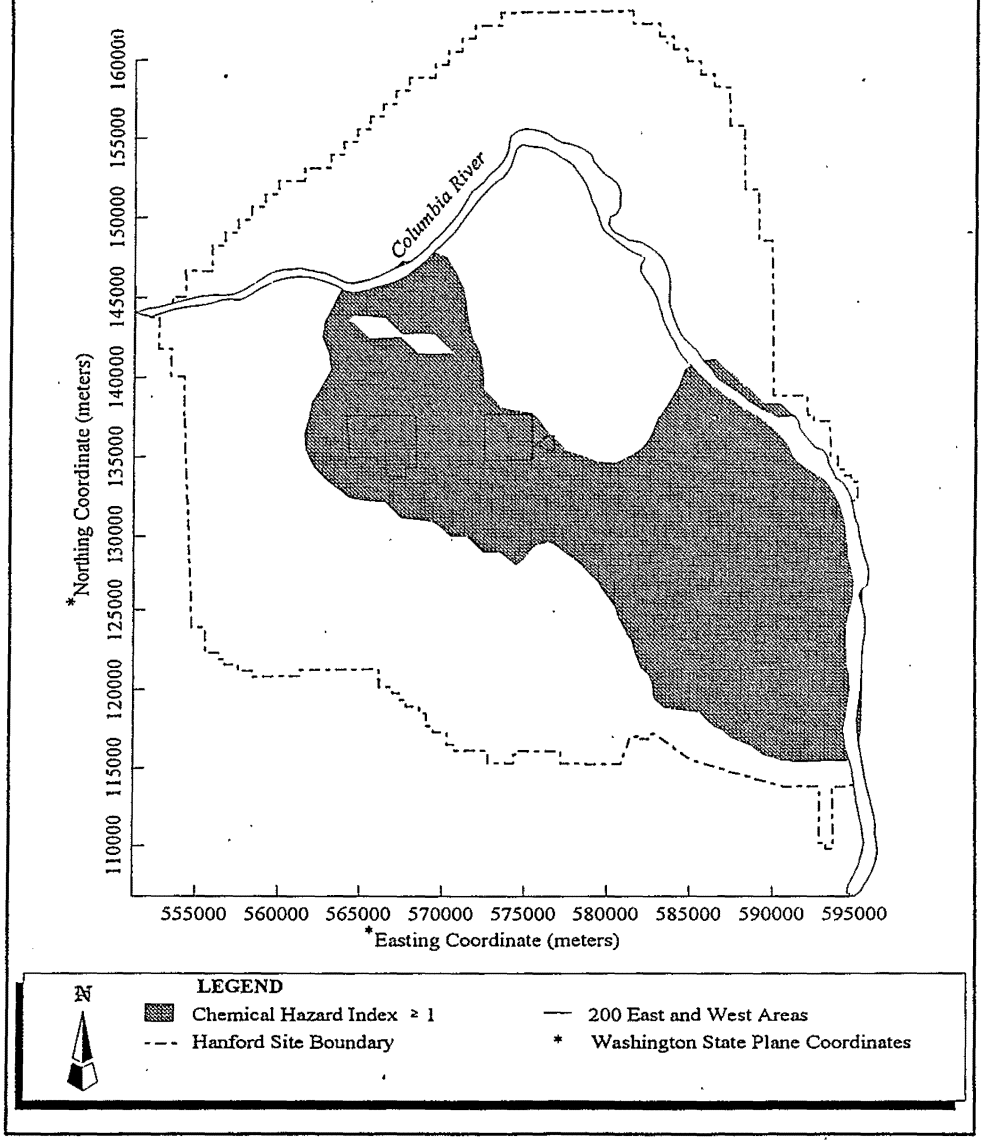


**Figure D.5.10.27 Phased Implementation Alternative, Residential Farmer Scenario, Post Remediation Hazard Index from Tank Residuals and LAW Vaults at 5,000 Years from Present**

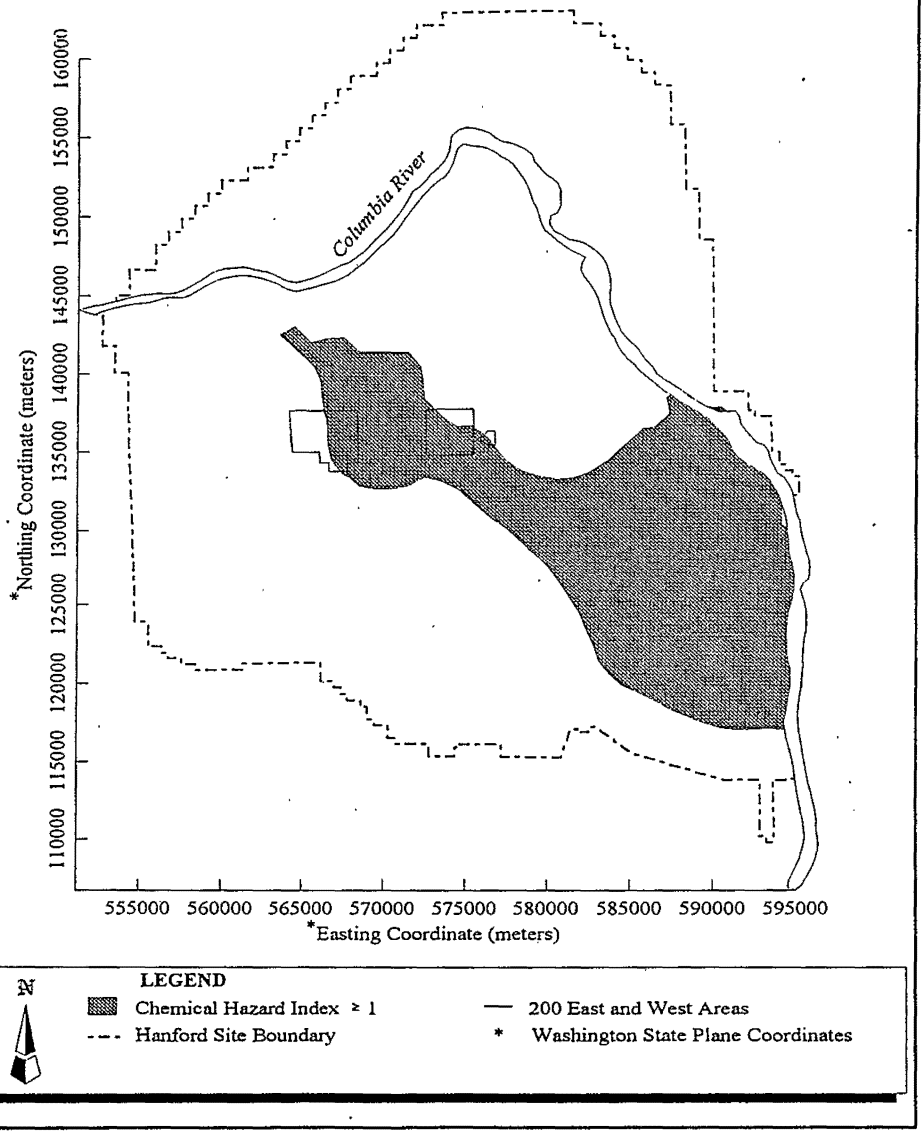


Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 595000 | 110000 | 0 | 1.00E-13 | 0 | 0 | 0 |
| 588000 | 111000 | 0 | 1.00E-13 | 0 | 0 | 0 |
| 589000 | 111000 | 0 | 2.00E-13 | 0 | 0 | 0 |
| 590000 | 111000 | 0 | 2.00E-13 | 0 | 0 | 0 |
| 591000 | 111000 | 0 | 3.00E-13 | 0 | 0 | 0 |
| 592000 | 111000 | 0 | 4.00E-13 | 0 | 0 | 0 |
| 593000 | 111000 | 0 | 6.00E-13 | 0 | 0 | 0 |
| 594000 | 111000 | 0 | 1.60E-12 | 0 | 0 | 0 |
| 595000 | 111000 | 0 | 6.40E-12 | 0 | 0 | 0 |
| 587000 | 112000 | 0 | 3.00E-13 | 0 | 0 | 0 |
| 588000 | 112000 | 0 | 6.80E-12 | 0 | 0 | 0 |
| 589000 | 112000 | 0 | 2.21E-11 | 0 | 0 | 0 |
| 590000 | 112000 | 0 | 4.08E-11 | 0 | 0 | 0 |
| 591000 | 112000 | 0 | 6.02E-11 | 0 | 0 | 0 |
| 592000 | 112000 | 0 | 1.03E-10 | 0 | 0 | 0 |
| 593000 | 112000 | 1.00E-13 | 2.17E-10 | 0 | 0 | 0 |
| 594000 | 112000 | 1.00E-13 | 5.02E-10 | 0 | 0 | 0 |
| 595000 | 112000 | 6.00E-13 | 8.79E-10 | 0 | 0 | 0 |
| 586000 | 113000 | 0 | 3.40E-12 | 0 | 0 | 0 |
| 587000 | 113000 | 1.00E-13 | 1.17E-10 | 0 | 0 | 0 |
| 588000 | 113000 | 3.95E-11 | 1.51E-09 | 0 | 0 | 0 |
| 589000 | 113000 | 1.15E-11 | 5.32E-09 | 0 | 0 | 0 |
| 590000 | 113000 | 4.72E-11 | 1.09E-08 | 0 | 0 | 0 |
| 591000 | 113000 | 2.52E-10 | 1.78E-08 | 0 | 0 | 0 |
| 592000 | 113000 | 4.54E-10 | 2.85E-08 | 0 | 0 | 0 |
| 593000 | 113000 | 9.39E-10 | 4.98E-08 | 1.00E-13 | 0 | 0 |
| 594000 | 113000 | 1.74E-09 | 7.76E-08 | 1.00E-13 | 0 | 0 |
| 595000 | 113000 | 2.48E-09 | 1.05E-07 | 1.00E-13 | 0 | 0 |
| 585000 | 114000 | 0 | 8.50E-12 | 0 | 0 | 0 |
| 586000 | 114000 | 3.70E-12 | 1.79E-10 | 0 | 0 | 0 |
| 587000 | 114000 | 2.00E-10 | 3.56E-09 | 0 | 0 | 0 |
| 588000 | 114000 | 7.40E-09 | 4.86E-08 | 1.00E-13 | 0 | 0 |
| 589000 | 114000 | 9.68E-08 | 3.80E-07 | 5.00E-13 | 0 | 0 |
| 590000 | 114000 | 3.27E-07 | 1.13E-06 | 1.40E-12 | 0 | 0 |
| 591000 | 114000 | 3.92E-07 | 1.57E-06 | 2.00E-12 | 0 | 0 |
| 592000 | 114000 | 3.02E-07 | 1.56E-06 | 1.90E-12 | 0 | 0 |
| 593000 | 114000 | 2.63E-07 | 1.67E-06 | 2.00E-12 | 0 | 0 |
| 594000 | 114000 | 2.43E-07 | 1.81E-06 | 2.20E-12 | 0 | 0 |
| 585000 | 115000 | 1.21E-11 | 3.65E-11 | 0 | 0 | 0 |
| 586000 | 115000 | 8.50E-10 | 2.22E-09 | 0 | 0 | 0 |

Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 587000 | 115000 | 3.21E-08 | 6.32E-08 | 1.00E-13 | 0 | 0 |
| 588000 | 115000 | 3.25E-07 | 5.87E-07 | 8.00E-13 | 0 | 0 |
| 589000 | 115000 | 2.54E-06 | 3.59E-06 | 4.70E-12 | 0 | 0 |
| 590000 | 115000 | 4.99E-06 | 7.32E-06 | 9.40E-12 | 1.00E-13 | 0 |
| 591000 | 115000 | 5.77E-06 | 9.65E-06 | 1.21E-11 | 1.00E-13 | 0 |
| 592000 | 115000 | 4.63E-06 | 9.49E-06 | 1.18E-11 | 1.00E-13 | 0 |
| 593000 | 115000 | 3.72E-06 | 9.21E-06 | 1.14E-11 | 1.00E-13 | 0 |
| 594000 | 115000 | 3.22E-06 | 9.49E-06 | 1.16E-11 | 1.00E-13 | 0 |
| 585000 | 116000 | 8.70E-10 | 1.00E-09 | 0 | 0 | 0 |
| 586000 | 116000 | 3.82E-08 | 4.25E-08 | 1.00E-13 | 0 | 0 |
| 587000 | 116000 | 1.00E-06 | 9.86E-07 | 1.40E-12 | 0 | 0 |
| 588000 | 116000 | 6.41E-06 | 5.96E-06 | 8.20E-12 | 1.00E-13 | 0 |
| 589000 | 116000 | 1.66E-05 | 1.56E-05 | 2.06E-11 | 2.00E-13 | 0 |
| 590000 | 116000 | 2.47E-05 | 2.53E-05 | 3.17E-11 | 2.00E-13 | 0 |
| 591000 | 116000 | 2.68E-05 | 3.06E-05 | 3.70E-11 | 3.00E-13 | 0 |
| 592000 | 116000 | 2.33E-05 | 3.05E-05 | 3.64E-11 | 3.00E-13 | 0 |
| 593000 | 116000 | 1.87E-05 | 2.86E-05 | 3.38E-11 | 3.00E-13 | 0 |
| 594000 | 116000 | 1.69E-05 | 2.97E-05 | 3.46E-11 | 3.00E-13 | 0 |
| 584000 | 117000 | 2.23E-09 | 2.13E-09 | 0 | 0 | 0 |
| 585000 | 117000 | 5.34E-08 | 4.44E-08 | 1.00E-13 | 0 | 0 |
| 586000 | 117000 | 2.49E-06 | 1.79E-06 | 2.70E-12 | 0 | 0 |
| 587000 | 117000 | 1.93E-05 | 1.31E-05 | 1.93E-11 | 1.00E-13 | 0 |
| 588000 | 117000 | 4.17E-05 | 2.94E-05 | 4.02E-11 | 3.00E-13 | 0 |
| 589000 | 117000 | 5.94E-05 | 4.62E-05 | 5.70E-11 | 4.00E-13 | 0 |
| 590000 | 117000 | 6.63E-05 | 5.92E-05 | 6.68E-11 | 5.00E-13 | 0 |
| 591000 | 117000 | 6.35E-05 | 6.54E-05 | 7.02E-11 | 5.00E-13 | 0 |
| 592000 | 117000 | 5.43E-05 | 6.30E-05 | 6.73E-11 | 5.00E-13 | 0 |
| 593000 | 117000 | 4.73E-05 | 6.28E-05 | 6.62E-11 | 5.00E-13 | 0 |
| 594000 | 117000 | 4.27E-05 | 6.83E-05 | 6.86E-11 | 5.00E-13 | 0 |
| 583000 | 118000 | 9.10E-08 | 8.44E-08 | 2.00E-13 | 0 | 0 |
| 584000 | 118000 | 1.83E-07 | 1.55E-07 | 3.00E-13 | 0 | 0 |
| 585000 | 118000 | 3.95E-06 | 2.60E-06 | 4.40E-12 | 0 | 0 |
| 586000 | 118000 | 4.83E-05 | 2.57E-05 | 4.16E-11 | 3.00E-13 | 0 |
| 587000 | 118000 | 8.75E-05 | 4.79E-05 | 6.77E-11 | 5.00E-13 | 0 |
| 588000 | 118000 | 0.000109 | 6.68E-05 | 8.00E-11 | 6.00E-13 | 0 |
| 589000 | 118000 | 0.000107 | 8.12E-05 | 8.32E-11 | 6.00E-13 | 0 |
| 590000 | 118000 | 9.09E-05 | 9.07E-05 | 8.38E-11 | 6.00E-13 | 0 |
| 591000 | 118000 | 7.52E-05 | 9.58E-05 | 8.41E-11 | 6.00E-13 | 0 |
| 592000 | 118000 | 6.38E-05 | 9.75E-05 | 8.41E-11 | 6.00E-13 | 0 |
| 593000 | 118000 | 4.97E-05 | 0.000103 | 8.39E-11 | 6.00E-13 | 0 |

**Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)**

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 594000 | 118000 | 2.61E-05 | 0.000136 | 8.29E-11 | 6.00E-13 | 0 |
| 583000 | 119000 | 3.41E-05 | 1.95E-05 | 4.31E-11 | 3.00E-13 | 0 |
| 584000 | 119000 | 4.95E-05 | 2.54E-05 | 5.23E-11 | 4.00E-13 | 0 |
| 585000 | 119000 | 9.05E-05 | 4.00E-05 | 7.30E-11 | 5.00E-13 | 0 |
| 586000 | 119000 | 0.000138 | 5.79E-05 | 8.69E-11 | 6.00E-13 | 0 |
| 587000 | 119000 | 0.000156 | 7.30E-05 | 8.82E-11 | 7.00E-13 | 0 |
| 588000 | 119000 | 0.00014 | 8.78E-05 | 8.39E-11 | 6.00E-13 | 0 |
| 589000 | 119000 | 9.23E-05 | 0.000103 | 8.14E-11 | 6.00E-13 | 0 |
| 590000 | 119000 | 3.87E-05 | 0.000124 | 8.12E-11 | 6.00E-13 | 0 |
| 591000 | 119000 | 1.83E-05 | 0.000142 | 8.13E-11 | 6.00E-13 | 8.41E-45 |
| 592000 | 119000 | 7.36E-06 | 0.000163 | 7.90E-11 | 6.00E-13 | 0 |
| 593000 | 119000 | 4.12E-06 | 0.000178 | 7.63E-11 | 6.00E-13 | 0 |
| 594000 | 119000 | 2.31E-06 | 0.000195 | 7.46E-11 | 6.00E-13 | 0 |
| 580000 | 120000 | 9.99E-10 | 1.65E-09 | 0 | 0 | 0 |
| 583000 | 120000 | 6.05E-05 | 2.59E-05 | 6.28E-11 | 5.00E-13 | 0 |
| 584000 | 120000 | 0.000151 | 5.08E-05 | 9.94E-11 | 7.00E-13 | 0 |
| 585000 | 120000 | 0.000196 | 6.36E-05 | 9.67E-11 | 7.00E-13 | 0 |
| 586000 | 120000 | 0.000207 | 7.46E-05 | 8.48E-11 | 6.00E-13 | 0 |
| 587000 | 120000 | 0.000176 | 8.74E-05 | 7.72E-11 | 6.00E-13 | 0 |
| 588000 | 120000 | 0.000108 | 0.000103 | 7.47E-11 | 6.00E-13 | 0 |
| 589000 | 120000 | 4.47E-05 | 0.00012 | 7.32E-11 | 5.00E-13 | 0 |
| 590000 | 120000 | 2.11E-05 | 0.000135 | 7.27E-11 | 5.00E-13 | 0 |
| 591000 | 120000 | 1.53E-05 | 0.000144 | 7.11E-11 | 5.00E-13 | 0 |
| 592000 | 120000 | 1.28E-05 | 0.000151 | 6.93E-11 | 5.00E-13 | 0 |
| 593000 | 120000 | 8.07E-06 | 0.000161 | 6.82E-11 | 5.00E-13 | 0 |
| 594000 | 120000 | 3.75E-06 | 0.000181 | 6.83E-11 | 5.00E-13 | 0 |
| 579000 | 121000 | 7.12E-11 | 4.79E-10 | 0 | 0 | 0 |
| 580000 | 121000 | 1.00E-08 | 2.48E-08 | 1.00E-13 | 0 | 0 |
| 581000 | 121000 | 6.35E-07 | 6.97E-07 | 2.40E-12 | 0 | 0 |
| 582000 | 121000 | 2.27E-05 | 1.24E-05 | 3.94E-11 | 3.00E-13 | 0 |
| 583000 | 121000 | 0.000144 | 4.71E-05 | 1.12E-10 | 8.00E-13 | 0 |
| 584000 | 121000 | 0.000226 | 5.86E-05 | 9.95E-11 | 7.00E-13 | 0 |
| 585000 | 121000 | 0.000245 | 6.58E-05 | 8.15E-11 | 6.00E-13 | 0 |
| 586000 | 121000 | 0.000234 | 7.46E-05 | 7.11E-11 | 5.00E-13 | 0 |
| 587000 | 121000 | 0.000189 | 8.76E-05 | 6.73E-11 | 5.00E-13 | 0 |
| 588000 | 121000 | 0.000134 | 9.99E-05 | 6.66E-11 | 5.00E-13 | 0 |
| 589000 | 121000 | 8.90E-05 | 0.00011 | 6.62E-11 | 5.00E-13 | 0 |
| 590000 | 121000 | 7.05E-05 | 0.000115 | 6.49E-11 | 5.00E-13 | 0 |
| 591000 | 121000 | 5.64E-05 | 0.000119 | 6.37E-11 | 5.00E-13 | 0 |
| 592000 | 121000 | 3.72E-05 | 0.000127 | 6.33E-11 | 5.00E-13 | 0 |

Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 593000 | 121000 | 2.65E-05 | 0.000133 | 6.25E-11 | 5.00E-13 | 0 |
| 594000 | 121000 | 1.61E-05 | 0.000142 | 6.27E-11 | 5.00E-13 | 0 |
| 578000 | 122000 | 1.80E-12 | 1.99E-11 | 0 | 0 | 0 |
| 579000 | 122000 | 3.89E-10 | 1.70E-09 | 0 | 0 | 0 |
| 580000 | 122000 | 5.73E-08 | 1.09E-07 | 4.00E-13 | 0 | 0 |
| 581000 | 122000 | 3.28E-06 | 3.06E-06 | 1.19E-11 | 1.00E-13 | 0 |
| 582000 | 122000 | 5.45E-05 | 2.60E-05 | 8.98E-11 | 7.00E-13 | 0 |
| 583000 | 122000 | 0.000199 | 5.06E-05 | 1.18E-10 | 9.00E-13 | 0 |
| 584000 | 122000 | 0.000248 | 5.21E-05 | 8.84E-11 | 7.00E-13 | 0 |
| 585000 | 122000 | 0.000264 | 5.61E-05 | 7.35E-11 | 5.00E-13 | 0 |
| 586000 | 122000 | 0.000266 | 6.12E-05 | 6.57E-11 | 5.00E-13 | 0 |
| 587000 | 122000 | 0.000251 | 6.99E-05 | 6.23E-11 | 5.00E-13 | 0 |
| 588000 | 122000 | 0.000217 | 8.13E-05 | 6.07E-11 | 5.00E-13 | 0 |
| 589000 | 122000 | 0.000192 | 8.75E-05 | 5.90E-11 | 4.00E-13 | 0 |
| 590000 | 122000 | 0.000167 | 9.34E-05 | 5.80E-11 | 4.00E-13 | 0 |
| 591000 | 122000 | 0.00013 | 0.000101 | 5.77E-11 | 4.00E-13 | 0 |
| 592000 | 122000 | 9.42E-05 | 0.000108 | 5.79E-11 | 4.00E-13 | 0 |
| 593000 | 122000 | 6.28E-05 | 0.000115 | 5.82E-11 | 4.00E-13 | 0 |
| 594000 | 122000 | 2.86E-05 | 0.000128 | 5.96E-11 | 4.00E-13 | 0 |
| 577000 | 123000 | 1.00E-13 | 1.30E-12 | 0 | 0 | 0 |
| 578000 | 123000 | 1.62E-11 | 1.05E-10 | 0 | 0 | 0 |
| 579000 | 123000 | 2.51E-09 | 7.09E-09 | 0 | 0 | 0 |
| 580000 | 123000 | 2.57E-07 | 3.74E-07 | 1.60E-12 | 0 | 0 |
| 581000 | 123000 | 1.30E-05 | 9.66E-06 | 4.06E-11 | 3.00E-13 | 0 |
| 582000 | 123000 | 9.79E-05 | 3.70E-05 | 1.35E-10 | 1.00E-12 | 0 |
| 583000 | 123000 | 0.000207 | 4.48E-05 | 1.13E-10 | 8.00E-13 | 0 |
| 584000 | 123000 | 0.000244 | 4.27E-05 | 8.14E-11 | 6.00E-13 | 0 |
| 585000 | 123000 | 0.000263 | 4.41E-05 | 6.78E-11 | 5.00E-13 | 0 |
| 586000 | 123000 | 0.000276 | 4.71E-05 | 6.11E-11 | 5.00E-13 | 0 |
| 587000 | 123000 | 0.000283 | 5.28E-05 | 5.70E-11 | 4.00E-13 | 0 |
| 588000 | 123000 | 0.000282 | 5.73E-05 | 5.41E-11 | 4.00E-13 | 0 |
| 589000 | 123000 | 0.000274 | 6.38E-05 | 5.27E-11 | 4.00E-13 | 0 |
| 590000 | 123000 | 0.000245 | 7.46E-05 | 5.26E-11 | 4.00E-13 | 0 |
| 591000 | 123000 | 0.000198 | 8.67E-05 | 5.31E-11 | 4.00E-13 | 0 |
| 592000 | 123000 | 0.00014 | 9.88E-05 | 5.40E-11 | 4.00E-13 | 0 |
| 593000 | 123000 | 7.98E-05 | 0.000111 | 5.55E-11 | 4.00E-13 | 0 |
| 594000 | 123000 | 4.14E-05 | 0.000121 | 5.67E-11 | 4.00E-13 | 0 |
| 576000 | 124000 | 0 | 1.00E-13 | 0 | 0 | 0 |
| 577000 | 124000 | 4.00E-13 | 7.00E-12 | 0 | 0 | 0 |
| 578000 | 124000 | 8.74E-11 | 5.01E-10 | 0 | 0 | 0 |

**Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)**

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 579000 | 124000 | 1.29E-08 | 3.42E-08 | 2.00E-13 | 0 | 0 |
| 580000 | 124000 | 1.44E-06 | 1.77E-06 | 8.60E-12 | 1.00E-13 | 0 |
| 581000 | 124000 | 4.02E-05 | 2.29E-05 | 1.06E-10 | 8.00E-13 | 0 |
| 582000 | 124000 | 0.000134 | 3.91E-05 | 1.51E-10 | 1.10E-12 | 0 |
| 583000 | 124000 | 0.000201 | 3.63E-05 | 1.01E-10 | 8.00E-13 | 0 |
| 584000 | 124000 | 0.000227 | 3.39E-05 | 7.32E-11 | 5.00E-13 | 0 |
| 585000 | 124000 | 0.000245 | 3.42E-05 | 6.07E-11 | 5.00E-13 | 0 |
| 586000 | 124000 | 0.000263 | 3.64E-05 | 5.43E-11 | 4.00E-13 | 0 |
| 587000 | 124000 | 0.000279 | 3.99E-05 | 4.98E-11 | 4.00E-13 | 0 |
| 588000 | 124000 | 0.000291 | 4.52E-05 | 4.80E-11 | 4.00E-13 | 0 |
| 589000 | 124000 | 0.000293 | 5.38E-05 | 4.74E-11 | 4.00E-13 | 0 |
| 590000 | 124000 | 0.000272 | 6.62E-05 | 4.82E-11 | 4.00E-13 | 0 |
| 591000 | 124000 | 0.000224 | 8.08E-05 | 4.94E-11 | 4.00E-13 | 0 |
| 592000 | 124000 | 0.000158 | 9.52E-05 | 5.08E-11 | 4.00E-13 | 0 |
| 593000 | 124000 | 9.70E-05 | 0.000107 | 5.19E-11 | 4.00E-13 | 0 |
| 594000 | 124000 | 5.33E-05 | 0.000118 | 5.29E-11 | 4.00E-13 | 0 |
| 576000 | 125000 | 0 | 1.10E-12 | 0 | 0 | 0 |
| 577000 | 125000 | 2.00E-12 | 5.66E-11 | 0 | 0 | 0 |
| 578000 | 125000 | 5.21E-10 | 3.66E-09 | 0 | 0 | 0 |
| 579000 | 125000 | 9.90E-08 | 2.45E-07 | 1.40E-12 | 0 | 0 |
| 580000 | 125000 | 1.04E-05 | 9.76E-06 | 5.52E-11 | 4.00E-13 | 0 |
| 581000 | 125000 | 9.10E-05 | 3.67E-05 | 1.81E-10 | 1.30E-12 | 0 |
| 582000 | 125000 | 0.000164 | 3.28E-05 | 1.25E-10 | 9.00E-13 | 0 |
| 583000 | 125000 | 0.000197 | 2.81E-05 | 7.55E-11 | 6.00E-13 | 0 |
| 584000 | 125000 | 0.000221 | 2.76E-05 | 5.54E-11 | 4.00E-13 | 0 |
| 585000 | 125000 | 0.000245 | 2.97E-05 | 4.63E-11 | 3.00E-13 | 0 |
| 586000 | 125000 | 0.000268 | 3.36E-05 | 4.17E-11 | 3.00E-13 | 0 |
| 587000 | 125000 | 0.000287 | 3.96E-05 | 4.03E-11 | 3.00E-13 | 0 |
| 588000 | 125000 | 0.000297 | 4.78E-05 | 4.07E-11 | 3.00E-13 | 0 |
| 589000 | 125000 | 0.000284 | 6.06E-05 | 4.18E-11 | 3.00E-13 | 0 |
| 590000 | 125000 | 0.000242 | 7.55E-05 | 4.35E-11 | 3.00E-13 | 0 |
| 591000 | 125000 | 0.000183 | 9.01E-05 | 4.57E-11 | 3.00E-13 | 0 |
| 592000 | 125000 | 0.000127 | 0.000102 | 4.72E-11 | 4.00E-13 | 0 |
| 593000 | 125000 | 7.43E-05 | 0.000114 | 4.86E-11 | 4.00E-13 | 0 |
| 594000 | 125000 | 3.45E-05 | 0.000132 | 4.99E-11 | 4.00E-13 | 0 |
| 576000 | 126000 | 0 | 1.77E-11 | 0 | 0 | 0 |
| 577000 | 126000 | 1.42E-11 | 7.19E-10 | 0 | 0 | 0 |
| 578000 | 126000 | 4.85E-09 | 4.31E-08 | 4.00E-13 | 0 | 0 |
| 579000 | 126000 | 1.12E-06 | 2.44E-06 | 1.82E-11 | 1.00E-13 | 0 |
| 580000 | 126000 | 4.37E-05 | 2.96E-05 | 1.90E-10 | 1.40E-12 | 0 |

Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 581000 | 126000 | 0.000139 | 3.62E-05 | 1.76E-10 | 1.30E-12 | 0 |
| 582000 | 126000 | 0.000172 | 2.48E-05 | 8.46E-11 | 6.00E-13 | 0 |
| 583000 | 126000 | 0.000198 | 2.29E-05 | 5.01E-11 | 4.00E-13 | 0 |
| 584000 | 126000 | 0.000236 | 2.57E-05 | 3.65E-11 | 3.00E-13 | 0 |
| 585000 | 126000 | 0.000279 | 3.27E-05 | 3.10E-11 | 2.00E-13 | 0 |
| 586000 | 126000 | 0.000303 | 4.51E-05 | 2.97E-11 | 2.00E-13 | 0 |
| 587000 | 126000 | 0.000286 | 6.09E-05 | 3.07E-11 | 2.00E-13 | 0 |
| 588000 | 126000 | 0.000241 | 7.53E-05 | 3.33E-11 | 2.00E-13 | 0 |
| 589000 | 126000 | 0.000186 | 8.88E-05 | 3.63E-11 | 3.00E-13 | 0 |
| 590000 | 126000 | 0.000137 | 0.000101 | 3.95E-11 | 3.00E-13 | 0 |
| 591000 | 126000 | 8.54E-05 | 0.000115 | 4.19E-11 | 3.00E-13 | 0 |
| 592000 | 126000 | 4.20E-05 | 0.000134 | 4.39E-11 | 3.00E-13 | 0 |
| 593000 | 126000 | 1.70E-05 | 0.000163 | 4.55E-11 | 3.00E-13 | 0 |
| 594000 | 126000 | 6.30E-06 | 0.000198 | 4.68E-11 | 3.00E-13 | 0 |
| 575000 | 127000 | 1.40E-12 | 8.08E-09 | 9.00E-13 | 0 | 0 |
| 576000 | 127000 | 2.00E-13 | 8.28E-10 | 1.00E-13 | 0 | 0 |
| 577000 | 127000 | 2.19E-10 | 1.42E-08 | 3.00E-13 | 0 | 0 |
| 578000 | 127000 | 1.06E-07 | 7.85E-07 | 1.01E-11 | 1.00E-13 | 0 |
| 579000 | 127000 | 1.22E-05 | 1.76E-05 | 1.67E-10 | 1.20E-12 | 0 |
| 580000 | 127000 | 9.79E-05 | 4.17E-05 | 2.77E-10 | 2.10E-12 | 0 |
| 581000 | 127000 | 0.00016 | 2.62E-05 | 1.11E-10 | 8.00E-13 | 0 |
| 582000 | 127000 | 0.000172 | 1.91E-05 | 5.23E-11 | 4.00E-13 | 0 |
| 583000 | 127000 | 0.000202 | 2.01E-05 | 3.24E-11 | 2.00E-13 | 0 |
| 584000 | 127000 | 0.000258 | 2.64E-05 | 2.54E-11 | 2.00E-13 | 0 |
| 585000 | 127000 | 0.00031 | 4.08E-05 | 2.33E-11 | 2.00E-13 | 0 |
| 586000 | 127000 | 0.000293 | 6.06E-05 | 2.29E-11 | 2.00E-13 | 0 |
| 587000 | 127000 | 0.000218 | 8.05E-05 | 2.42E-11 | 2.00E-13 | 0 |
| 588000 | 127000 | 0.000135 | 9.82E-05 | 2.66E-11 | 2.00E-13 | 0 |
| 589000 | 127000 | 6.99E-05 | 0.000117 | 2.99E-11 | 2.00E-13 | 0 |
| 590000 | 127000 | 3.69E-05 | 0.000138 | 3.36E-11 | 3.00E-13 | 0 |
| 591000 | 127000 | 1.70E-05 | 0.000166 | 3.68E-11 | 3.00E-13 | 0 |
| 592000 | 127000 | 5.19E-06 | 0.000209 | 3.92E-11 | 3.00E-13 | 0 |
| 593000 | 127000 | 1.04E-06 | 0.000255 | 4.10E-11 | 3.00E-13 | 0 |
| 594000 | 127000 | 1.63E-07 | 0.000269 | 4.21E-11 | 3.00E-13 | 0 |
| 574000 | 128000 | 5.30E-07 | 1.52E-05 | 9.91E-10 | 7.40E-12 | 0 |
| 575000 | 128000 | 2.38E-10 | 5.94E-07 | 5.60E-11 | 4.00E-13 | 0 |
| 576000 | 128000 | 2.51E-11 | 3.97E-08 | 8.50E-12 | 1.00E-13 | 0 |
| 577000 | 128000 | 1.18E-08 | 4.21E-07 | 1.75E-11 | 1.00E-13 | 0 |
| 578000 | 128000 | 4.62E-06 | 1.32E-05 | 2.42E-10 | 1.80E-12 | 0 |
| 579000 | 128000 | 6.56E-05 | 4.11E-05 | 3.98E-10 | 3.00E-12 | 0 |

Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 580000 | 128000 | 0.000141 | 3.06E-05 | 1.77E-10 | 1.30E-12 | 0 |
| 581000 | 128000 | 0.000164 | 1.81E-05 | 5.83E-11 | 4.00E-13 | 0 |
| 582000 | 128000 | 0.00017 | 1.58E-05 | 3.41E-11 | 3.00E-13 | 0 |
| 583000 | 128000 | 0.0002 | 1.82E-05 | 2.36E-11 | 2.00E-13 | 0 |
| 584000 | 128000 | 0.000272 | 2.70E-05 | 2.00E-11 | 1.00E-13 | 0 |
| 585000 | 128000 | 0.000322 | 4.17E-05 | 1.85E-11 | 1.00E-13 | 0 |
| 586000 | 128000 | 0.000295 | 6.10E-05 | 1.86E-11 | 1.00E-13 | 0 |
| 587000 | 128000 | 0.000206 | 8.17E-05 | 1.96E-11 | 1.00E-13 | 0 |
| 588000 | 128000 | 0.000104 | 0.000105 | 2.16E-11 | 2.00E-13 | 0 |
| 589000 | 128000 | 3.81E-05 | 0.000136 | 2.42E-11 | 2.00E-13 | 0 |
| 590000 | 128000 | 9.79E-06 | 0.000184 | 2.74E-11 | 2.00E-13 | 0 |
| 591000 | 128000 | 1.86E-06 | 0.000242 | 3.06E-11 | 2.00E-13 | 0 |
| 592000 | 128000 | 2.70E-07 | 0.000284 | 3.33E-11 | 2.00E-13 | 0 |
| 593000 | 128000 | 2.30E-08 | 0.000279 | 3.54E-11 | 3.00E-13 | 0 |
| 594000 | 128000 | 7.88E-10 | 0.000212 | 3.77E-11 | 3.00E-13 | 0 |
| 572000 | 129000 | 1.07E-05 | 6.66E-06 | 9.33E-10 | 7.00E-12 | 0 |
| 573000 | 129000 | 6.97E-06 | 9.15E-06 | 9.64E-10 | 7.20E-12 | 0 |
| 574000 | 129000 | 1.94E-06 | 1.49E-05 | 1.04E-09 | 7.80E-12 | 0 |
| 575000 | 129000 | 5.75E-08 | 1.11E-05 | 8.44E-10 | 6.30E-12 | 0 |
| 576000 | 129000 | 3.32E-08 | 2.17E-06 | 3.82E-10 | 2.90E-12 | 0 |
| 577000 | 129000 | 4.46E-06 | 1.39E-05 | 6.44E-10 | 4.80E-12 | 0 |
| 578000 | 129000 | 5.72E-05 | 3.46E-05 | 5.18E-10 | 3.90E-12 | 0 |
| 579000 | 129000 | 0.000112 | 3.19E-05 | 2.72E-10 | 2.00E-12 | 0 |
| 580000 | 129000 | 0.000158 | 1.75E-05 | 6.98E-11 | 5.00E-13 | 0 |
| 581000 | 129000 | 0.000163 | 1.48E-05 | 3.85E-11 | 3.00E-13 | 0 |
| 582000 | 129000 | 0.000167 | 1.39E-05 | 2.28E-11 | 2.00E-13 | 0 |
| 583000 | 129000 | 0.000201 | 1.71E-05 | 1.74E-11 | 1.00E-13 | 0 |
| 584000 | 129000 | 0.000276 | 2.53E-05 | 1.50E-11 | 1.00E-13 | 0 |
| 585000 | 129000 | 0.000328 | 3.77E-05 | 1.46E-11 | 1.00E-13 | 0 |
| 586000 | 129000 | 0.000315 | 5.51E-05 | 1.48E-11 | 1.00E-13 | 0 |
| 587000 | 129000 | 0.000233 | 7.49E-05 | 1.56E-11 | 1.00E-13 | 0 |
| 588000 | 129000 | 0.000118 | 0.0001 | 1.71E-11 | 1.00E-13 | 0 |
| 589000 | 129000 | 3.45E-05 | 0.000145 | 1.94E-11 | 1.00E-13 | 0 |
| 590000 | 129000 | 5.98E-06 | 0.000216 | 2.23E-11 | 2.00E-13 | 0 |
| 591000 | 129000 | 6.47E-07 | 0.000277 | 2.53E-11 | 2.00E-13 | 0 |
| 592000 | 129000 | 4.13E-08 | 0.000277 | 2.81E-11 | 2.00E-13 | 0 |
| 593000 | 129000 | 1.70E-09 | 0.000212 | 3.09E-11 | 2.00E-13 | 0 |
| 594000 | 129000 | 7.80E-11 | 0.000141 | 3.32E-11 | 2.00E-13 | 0 |
| 570000 | 130000 | 1.45E-05 | 5.04E-06 | 9.35E-10 | 7.00E-12 | 0 |
| 571000 | 130000 | 1.43E-05 | 5.28E-06 | 8.97E-10 | 6.70E-12 | 0 |

Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 572000 | 130000 | 1.24E-05 | 6.05E-06 | 8.96E-10 | 6.70E-12 | 0 |
| 573000 | 130000 | 8.73E-06 | 8.10E-06 | 9.13E-10 | 6.80E-12 | 0 |
| 574000 | 130000 | 2.91E-06 | 1.40E-05 | 9.92E-10 | 7.40E-12 | 0 |
| 575000 | 130000 | 4.17E-07 | 1.81E-05 | 1.11E-09 | 8.30E-12 | 0 |
| 576000 | 130000 | 1.12E-05 | 2.32E-05 | 9.08E-10 | 6.80E-12 | 0 |
| 577000 | 130000 | 6.11E-05 | 2.42E-05 | 4.79E-10 | 3.60E-12 | 0 |
| 578000 | 130000 | 0.000114 | 2.05E-05 | 2.19E-10 | 1.60E-12 | 0 |
| 579000 | 130000 | 0.000151 | 1.62E-05 | 8.46E-11 | 6.00E-13 | 0 |
| 580000 | 130000 | 0.000162 | 1.34E-05 | 3.52E-11 | 3.00E-13 | 0 |
| 581000 | 130000 | 0.000161 | 1.24E-05 | 1.95E-11 | 1.00E-13 | 0 |
| 582000 | 130000 | 0.000164 | 1.24E-05 | 1.30E-11 | 1.00E-13 | 0 |
| 583000 | 130000 | 0.000205 | 1.61E-05 | 1.07E-11 | 1.00E-13 | 0 |
| 584000 | 130000 | 0.000276 | 2.29E-05 | 1.00E-11 | 1.00E-13 | 0 |
| 585000 | 130000 | 0.000333 | 3.30E-05 | 1.02E-11 | 1.00E-13 | 0 |
| 586000 | 130000 | 0.00034 | 4.68E-05 | 1.07E-11 | 1.00E-13 | 0 |
| 587000 | 130000 | 0.000272 | 6.55E-05 | 1.16E-11 | 1.00E-13 | 0 |
| 588000 | 130000 | 0.000147 | 9.10E-05 | 1.31E-11 | 1.00E-13 | 0 |
| 589000 | 130000 | 4.15E-05 | 0.000141 | 1.52E-11 | 1.00E-13 | 0 |
| 590000 | 130000 | 4.46E-06 | 0.000234 | 1.82E-11 | 1.00E-13 | 0 |
| 591000 | 130000 | 1.75E-07 | 0.000272 | 2.16E-11 | 2.00E-13 | 0 |
| 592000 | 130000 | 3.30E-09 | 0.000198 | 2.51E-11 | 2.00E-13 | 0 |
| 593000 | 130000 | 9.70E-12 | 8.33E-05 | 2.92E-11 | 2.00E-13 | 0 |
| 567000 | 131000 | 7.44E-06 | 6.08E-06 | 1.77E-09 | 1.33E-11 | 0 |
| 568000 | 131000 | 1.51E-05 | 4.38E-06 | 1.02E-09 | 7.60E-12 | 0 |
| 569000 | 131000 | 2.31E-05 | 3.29E-06 | 6.47E-10 | 4.80E-12 | 0 |
| 570000 | 131000 | 2.68E-05 | 3.03E-06 | 5.24E-10 | 3.90E-12 | 0 |
| 571000 | 131000 | 2.61E-05 | 3.31E-06 | 5.10E-10 | 3.80E-12 | 0 |
| 572000 | 131000 | 2.18E-05 | 4.26E-06 | 5.72E-10 | 4.30E-12 | 0 |
| 573000 | 131000 | 1.41E-05 | 6.79E-06 | 6.73E-10 | 5.00E-12 | 0 |
| 574000 | 131000 | 7.32E-06 | 1.15E-05 | 7.51E-10 | 5.60E-12 | 0 |
| 575000 | 131000 | 1.75E-05 | 1.58E-05 | 5.85E-10 | 4.40E-12 | 0 |
| 576000 | 131000 | 9.58E-05 | 1.34E-05 | 2.26E-10 | 1.70E-12 | 0 |
| 577000 | 131000 | 0.000148 | 1.26E-05 | 8.93E-11 | 7.00E-13 | 0 |
| 578000 | 131000 | 0.000165 | 1.26E-05 | 4.08E-11 | 3.00E-13 | 0 |
| 579000 | 131000 | 0.000165 | 1.19E-05 | 2.02E-11 | 2.00E-13 | 0 |
| 580000 | 131000 | 0.000156 | 1.08E-05 | 1.04E-11 | 1.00E-13 | 0 |
| 581000 | 131000 | 0.000151 | 1.03E-05 | 6.70E-12 | 1.00E-13 | 0 |
| 582000 | 131000 | 0.000156 | 1.08E-05 | 5.80E-12 | 0 | 0 |
| 583000 | 131000 | 0.000188 | 1.34E-05 | 5.90E-12 | 0 | 0 |
| 584000 | 131000 | 0.00025 | 1.85E-05 | 6.30E-12 | 0 | 0 |

Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 585000 | 131000 | 0.000325 | 2.78E-05 | 6.90E-12 | 1.00E-13 | 0 |
| 586000 | 131000 | 0.000349 | 4.19E-05 | 7.70E-12 | 1.00E-13 | 0 |
| 587000 | 131000 | 0.000292 | 5.95E-05 | 8.70E-12 | 1.00E-13 | 0 |
| 588000 | 131000 | 0.000173 | 8.26E-05 | 1.00E-11 | 1.00E-13 | 0 |
| 589000 | 131000 | 5.33E-05 | 0.00013 | 1.18E-11 | 1.00E-13 | 0 |
| 590000 | 131000 | 6.02E-06 | 0.000225 | 1.43E-11 | 1.00E-13 | 0 |
| 591000 | 131000 | 1.99E-07 | 0.000265 | 1.76E-11 | 1.00E-13 | 0 |
| 592000 | 131000 | 1.52E-09 | 0.000163 | 2.16E-11 | 2.00E-13 | 0 |
| 593000 | 131000 | 3.00E-12 | 5.62E-05 | 2.61E-11 | 2.00E-13 | 0 |
| 562000 | 132000 | 3.00E-13 | 1.07E-09 | 4.91E-07 | 6.99E-09 | 6.00E-13 |
| 563000 | 132000 | 1.79E-11 | 4.62E-07 | 7.63E-08 | 7.07E-10 | 1.00E-13 |
| 564000 | 132000 | 5.00E-08 | 6.70E-06 | 1.52E-08 | 1.15E-10 | 0 |
| 565000 | 132000 | 3.90E-06 | 7.36E-06 | 1.24E-09 | 9.30E-12 | 0 |
| 566000 | 132000 | 1.25E-05 | 2.81E-06 | 4.52E-10 | 3.40E-12 | 0 |
| 567000 | 132000 | 2.81E-05 | 9.90E-07 | 1.31E-10 | 1.00E-12 | 0 |
| 568000 | 132000 | 4.84E-05 | 5.48E-07 | 6.26E-11 | 5.00E-13 | 0 |
| 569000 | 132000 | 6.29E-05 | 4.83E-07 | 4.85E-11 | 4.00E-13 | 0 |
| 570000 | 132000 | 6.28E-05 | 6.74E-07 | 6.46E-11 | 5.00E-13 | 0 |
| 571000 | 132000 | 5.52E-05 | 1.18E-06 | 1.17E-10 | 9.00E-13 | 0 |
| 572000 | 132000 | 3.97E-05 | 2.51E-06 | 2.37E-10 | 1.80E-12 | 0 |
| 573000 | 132000 | 2.56E-05 | 4.91E-06 | 3.77E-10 | 2.80E-12 | 0 |
| 574000 | 132000 | 3.38E-05 | 6.79E-06 | 3.14E-10 | 2.40E-12 | 0 |
| 575000 | 132000 | 0.000115 | 6.89E-06 | 1.24E-10 | 9.00E-13 | 0 |
| 576000 | 132000 | 0.000177 | 1.03E-05 | 3.51E-11 | 3.00E-13 | 0 |
| 577000 | 132000 | 0.000178 | 1.17E-05 | 1.19E-11 | 1.00E-13 | 0 |
| 578000 | 132000 | 0.00016 | 1.04E-05 | 5.50E-12 | 0 | 0 |
| 579000 | 132000 | 0.000141 | 8.71E-06 | 3.00E-12 | 0 | 0 |
| 580000 | 132000 | 0.000133 | 8.12E-06 | 2.30E-12 | 0 | 0 |
| 581000 | 132000 | 0.000132 | 8.10E-06 | 2.10E-12 | 0 | 0 |
| 582000 | 132000 | 0.000141 | 8.88E-06 | 2.30E-12 | 0 | 0 |
| 583000 | 132000 | 0.000176 | 1.16E-05 | 3.10E-12 | 0 | 0 |
| 584000 | 132000 | 0.000232 | 1.57E-05 | 4.10E-12 | 0 | 0 |
| 585000 | 132000 | 0.000302 | 2.23E-05 | 4.80E-12 | 0 | 0 |
| 586000 | 132000 | 0.000351 | 3.31E-05 | 5.40E-12 | 0 | 0 |
| 587000 | 132000 | 0.00033 | 4.84E-05 | 6.30E-12 | 0 | 0 |
| 588000 | 132000 | 0.000221 | 7.04E-05 | 7.40E-12 | 1.00E-13 | 0 |
| 589000 | 132000 | 8.21E-05 | 0.000111 | 8.90E-12 | 1.00E-13 | 0 |
| 590000 | 132000 | 1.13E-05 | 0.000203 | 1.12E-11 | 1.00E-13 | 0 |
| 591000 | 132000 | 4.49E-07 | 0.000267 | 1.41E-11 | 1.00E-13 | 0 |
| 592000 | 132000 | 4.92E-09 | 0.000185 | 1.75E-11 | 1.00E-13 | 0 |

**Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)**

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 593000 | 132000 | 2.56E-11 | 8.39E-05 | 2.09E-11 | 2.00E-13 | 0 |
| 561000 | 133000 | 0 | 1.79E-08 | 6.51E-07 | 1.31E-08 | 1.10E-12 |
| 562000 | 133000 | 2.88E-11 | 1.42E-06 | 6.30E-08 | 1.00E-09 | 1.00E-13 |
| 563000 | 133000 | 1.17E-07 | 8.98E-06 | 1.94E-09 | 2.23E-11 | 0 |
| 564000 | 133000 | 4.29E-06 | 7.53E-06 | 1.02E-10 | 8.00E-13 | 0 |
| 565000 | 133000 | 1.51E-05 | 1.18E-06 | 1.14E-11 | 1.00E-13 | 0 |
| 566000 | 133000 | 2.26E-05 | 8.98E-08 | 2.20E-12 | 0 | 0 |
| 567000 | 133000 | 6.92E-05 | 2.67E-08 | 1.00E-12 | 0 | 0 |
| 568000 | 133000 | 0.000154 | 2.62E-08 | 8.00E-13 | 0 | 0 |
| 569000 | 133000 | 0.000177 | 4.09E-08 | 1.00E-12 | 0 | 0 |
| 570000 | 133000 | 0.000162 | 1.01E-07 | 3.10E-12 | 0 | 0 |
| 571000 | 133000 | 0.000119 | 3.61E-07 | 1.94E-11 | 1.00E-13 | 0 |
| 572000 | 133000 | 7.91E-05 | 1.14E-06 | 7.42E-11 | 6.00E-13 | 0 |
| 573000 | 133000 | 8.78E-05 | 1.62E-06 | 7.60E-11 | 6.00E-13 | 0 |
| 574000 | 133000 | 0.000142 | 2.60E-06 | 4.68E-11 | 3.00E-13 | 0 |
| 575000 | 133000 | 0.000204 | 9.11E-06 | 1.56E-11 | 1.00E-13 | 0 |
| 576000 | 133000 | 0.000185 | 1.25E-05 | 3.80E-12 | 0 | 0 |
| 577000 | 133000 | 0.00015 | 9.23E-06 | 1.30E-12 | 0 | 0 |
| 578000 | 133000 | 0.000112 | 6.03E-06 | 6.00E-13 | 0 | 0 |
| 579000 | 133000 | 8.98E-05 | 4.61E-06 | 4.00E-13 | 0 | 0 |
| 580000 | 133000 | 8.11E-05 | 4.10E-06 | 3.00E-13 | 0 | 0 |
| 581000 | 133000 | 9.09E-05 | 4.78E-06 | 5.00E-13 | 0 | 0 |
| 582000 | 133000 | 0.000112 | 6.35E-06 | 9.00E-13 | 0 | 0 |
| 583000 | 133000 | 0.000153 | 9.16E-06 | 1.60E-12 | 0 | 0 |
| 584000 | 133000 | 0.000217 | 1.35E-05 | 2.60E-12 | 0 | 0 |
| 585000 | 133000 | 0.00029 | 1.95E-05 | 3.30E-12 | 0 | 0 |
| 586000 | 133000 | 0.000346 | 2.78E-05 | 4.00E-12 | 0 | 0 |
| 587000 | 133000 | 0.00035 | 4.01E-05 | 4.70E-12 | 0 | 0 |
| 588000 | 133000 | 0.000261 | 6.06E-05 | 5.70E-12 | 0 | 0 |
| 589000 | 133000 | 0.000105 | 9.92E-05 | 7.00E-12 | 1.00E-13 | 0 |
| 590000 | 133000 | 1.61E-05 | 0.000189 | 9.00E-12 | 1.00E-13 | 0 |
| 591000 | 133000 | 7.04E-07 | 0.000266 | 1.16E-11 | 1.00E-13 | 0 |
| 592000 | 133000 | 7.90E-09 | 0.000192 | 1.46E-11 | 1.00E-13 | 0 |
| 560000 | 134000 | 0 | 1.03E-07 | 3.84E-07 | 8.26E-09 | 7.00E-13 |
| 561000 | 134000 | 5.20E-12 | 1.17E-06 | 1.42E-07 | 2.92E-09 | 3.00E-13 |
| 562000 | 134000 | 2.29E-08 | 7.37E-06 | 6.91E-09 | 1.24E-10 | 0 |
| 563000 | 134000 | 1.69E-06 | 1.09E-05 | 1.70E-10 | 2.60E-12 | 0 |
| 564000 | 134000 | 1.25E-05 | 3.22E-06 | 2.50E-12 | 0 | 0 |
| 565000 | 134000 | 2.06E-05 | 1.90E-07 | 1.00E-13 | 0 | 0 |
| 566000 | 134000 | 1.78E-05 | 2.96E-09 | 0 | 0 | 0 |

Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 567000 | 134000 | 0.000275 | 1.59E-09 | 0 | 0 | 0 |
| 568000 | 134000 | 0.000337 | 8.84E-09 | 0 | 0 | 0 |
| 569000 | 134000 | 0.000332 | 3.23E-08 | 0 | 0 | 0 |
| 570000 | 134000 | 0.00029 | 5.65E-08 | 3.00E-13 | 0 | 0 |
| 571000 | 134000 | 0.000238 | 1.15E-07 | 2.20E-12 | 0 | 0 |
| 572000 | 134000 | 0.000211 | 2.42E-07 | 6.70E-12 | 1.00E-13 | 0 |
| 573000 | 134000 | 0.000225 | 9.53E-07 | 8.00E-12 | 1.00E-13 | 0 |
| 574000 | 134000 | 0.000264 | 9.91E-06 | 3.40E-12 | 0 | 0 |
| 575000 | 134000 | 0.000189 | 1.56E-05 | 8.00E-13 | 0 | 0 |
| 576000 | 134000 | 0.000147 | 8.46E-06 | 2.00E-13 | 0 | 0 |
| 577000 | 134000 | 8.01E-05 | 3.28E-06 | 1.00E-13 | 0 | 0 |
| 578000 | 134000 | 3.33E-05 | 1.29E-06 | 0 | 0 | 0 |
| 579000 | 134000 | 1.97E-05 | 7.73E-07 | 0 | 0 | 0 |
| 580000 | 134000 | 2.05E-05 | 8.25E-07 | 0 | 0 | 0 |
| 581000 | 134000 | 3.84E-05 | 1.70E-06 | 1.00E-13 | 0 | 0 |
| 582000 | 134000 | 7.01E-05 | 3.48E-06 | 3.00E-13 | 0 | 0 |
| 583000 | 134000 | 0.000115 | 6.25E-06 | 7.00E-13 | 0 | 0 |
| 584000 | 134000 | 0.00018 | 1.03E-05 | 1.40E-12 | 0 | 0 |
| 585000 | 134000 | 0.000259 | 1.58E-05 | 2.20E-12 | 0 | 0 |
| 586000 | 134000 | 0.000327 | 2.34E-05 | 2.90E-12 | 0 | 0 |
| 587000 | 134000 | 0.000353 | 3.47E-05 | 3.70E-12 | 0 | 0 |
| 588000 | 134000 | 0.000292 | 5.22E-05 | 4.50E-12 | 0 | 0 |
| 589000 | 134000 | 0.000136 | 8.61E-05 | 5.70E-12 | 0 | 0 |
| 590000 | 134000 | 2.04E-05 | 0.000178 | 7.40E-12 | 1.00E-13 | 0 |
| 591000 | 134000 | 7.34E-07 | 0.000264 | 9.80E-12 | 1.00E-13 | 0 |
| 592000 | 134000 | 1.92E-09 | 0.00016 | 1.33E-11 | 1.00E-13 | 0 |
| 560000 | 135000 | 0 | 5.84E-08 | 3.07E-07 | 6.79E-09 | 6.00E-13 |
| 561000 | 135000 | 3.20E-12 | 1.58E-06 | 4.82E-08 | 1.03E-09 | 1.00E-13 |
| 562000 | 135000 | 9.11E-09 | 8.37E-06 | 1.80E-09 | 3.47E-11 | 0 |
| 563000 | 135000 | 1.87E-06 | 1.39E-05 | 4.84E-11 | 8.00E-13 | 0 |
| 564000 | 135000 | 2.17E-05 | 3.25E-06 | 6.00E-13 | 0 | 0 |
| 565000 | 135000 | 4.41E-05 | 1.35E-07 | 0 | 0 | 0 |
| 566000 | 135000 | 6.49E-05 | 5.11E-09 | 0 | 0 | 0 |
| 567000 | 135000 | 0.000798 | 2.12E-08 | 0 | 0 | 0 |
| 568000 | 135000 | 0.000667 | 2.48E-07 | 0 | 0 | 0 |
| 569000 | 135000 | 0.000549 | 7.36E-07 | 0 | 0 | 0 |
| 570000 | 135000 | 0.000445 | 7.18E-07 | 0 | 0 | 0 |
| 571000 | 135000 | 0.000399 | 7.59E-07 | 1.00E-13 | 0 | 0 |
| 572000 | 135000 | 0.000397 | 1.58E-06 | 1.00E-13 | 0 | 0 |
| 573000 | 135000 | 0.000354 | 1.63E-05 | 1.00E-13 | 0 | 0 |

Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 574000 | 135000 | 0.000183 | 2.25E-05 | 1.00E-13 | 0 | 0 |
| 575000 | 135000 | 0.00015 | 9.80E-06 | 0 | 0 | 0 |
| 576000 | 135000 | 9.15E-05 | 2.11E-06 | 0 | 0 | 0 |
| 577000 | 135000 | 8.11E-06 | 2.06E-07 | 0 | 0 | 0 |
| 578000 | 135000 | 1.16E-06 | 3.61E-08 | 0 | 0 | 0 |
| 579000 | 135000 | 6.49E-07 | 2.09E-08 | 0 | 0 | 0 |
| 580000 | 135000 | 1.49E-06 | 4.58E-08 | 0 | 0 | 0 |
| 581000 | 135000 | 9.14E-06 | 3.34E-07 | 0 | 0 | 0 |
| 582000 | 135000 | 3.32E-05 | 1.43E-06 | 1.00E-13 | 0 | 0 |
| 583000 | 135000 | 8.34E-05 | 4.04E-06 | 3.00E-13 | 0 | 0 |
| 584000 | 135000 | 0.000141 | 7.44E-06 | 8.00E-13 | 0 | 0 |
| 585000 | 135000 | 0.000208 | 1.16E-05 | 1.40E-12 | 0 | 0 |
| 586000 | 135000 | 0.000278 | 1.74E-05 | 1.90E-12 | 0 | 0 |
| 587000 | 135000 | 0.000334 | 2.75E-05 | 2.70E-12 | 0 | 0 |
| 588000 | 135000 | 0.000301 | 4.56E-05 | 3.60E-12 | 0 | 0 |
| 589000 | 135000 | 0.000151 | 7.73E-05 | 4.70E-12 | 0 | 0 |
| 590000 | 135000 | 2.81E-05 | 0.000158 | 6.20E-12 | 0 | 0 |
| 591000 | 135000 | 1.28E-06 | 0.000261 | 8.10E-12 | 1.00E-13 | 0 |
| 558000 | 136000 | 0 | 3.00E-13 | 4.00E-12 | 1.00E-13 | 0 |
| 559000 | 136000 | 0 | 1.77E-11 | 1.91E-10 | 4.30E-12 | 0 |
| 560000 | 136000 | 0 | 4.79E-09 | 3.20E-08 | 7.24E-10 | 1.00E-13 |
| 561000 | 136000 | 1.40E-12 | 1.18E-06 | 4.88E-08 | 1.09E-09 | 1.00E-13 |
| 562000 | 136000 | 1.34E-08 | 1.02E-05 | 7.03E-10 | 1.45E-11 | 0 |
| 563000 | 136000 | 2.08E-06 | 1.74E-05 | 1.89E-11 | 3.00E-13 | 0 |
| 564000 | 136000 | 2.33E-05 | 4.85E-06 | 3.00E-13 | 0 | 0 |
| 565000 | 136000 | 5.11E-05 | 3.70E-07 | 0 | 0 | 0 |
| 566000 | 136000 | 8.23E-05 | 9.03E-08 | 0 | 0 | 0 |
| 567000 | 136000 | 0.000677 | 4.07E-07 | 0 | 0 | 0 |
| 568000 | 136000 | 0.0007 | 2.25E-06 | 0 | 0 | 0 |
| 569000 | 136000 | 0.000643 | 7.43E-06 | 0 | 0 | 0 |
| 570000 | 136000 | 0.00058 | 1.38E-05 | 0 | 0 | 0 |
| 571000 | 136000 | 0.000535 | 1.07E-05 | 0 | 0 | 0 |
| 572000 | 136000 | 0.000453 | 2.74E-05 | 0 | 0 | 0 |
| 573000 | 136000 | 0.000147 | 3.13E-05 | 0 | 0 | 0 |
| 574000 | 136000 | 0.000104 | 1.14E-05 | 0 | 0 | 0 |
| 575000 | 136000 | 0.000173 | 2.99E-06 | 0 | 0 | 0 |
| 576000 | 136000 | 1.65E-05 | 1.48E-07 | 0 | 0 | 0 |
| 577000 | 136000 | 2.04E-07 | 3.93E-09 | 0 | 0 | 0 |
| 578000 | 136000 | 1.73E-08 | 4.81E-10 | 0 | 0 | 0 |
| 579000 | 136000 | 2.90E-08 | 6.73E-10 | 0 | 0 | 0 |

Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 580000 | 136000 | 1.33E-07 | 4.44E-09 | 0 | 0 | 0 |
| 581000 | 136000 | 3.28E-06 | 1.04E-07 | 0 | 0 | 0 |
| 582000 | 136000 | 2.24E-05 | 8.27E-07 | 0 | 0 | 0 |
| 583000 | 136000 | 6.75E-05 | 2.87E-06 | 2.00E-13 | 0 | 0 |
| 584000 | 136000 | 0.000121 | 5.85E-06 | 5.00E-13 | 0 | 0 |
| 585000 | 136000 | 0.000167 | 8.61E-06 | 8.00E-13 | 0 | 0 |
| 586000 | 136000 | 0.000235 | 1.33E-05 | 1.30E-12 | 0 | 0 |
| 587000 | 136000 | 0.000306 | 2.24E-05 | 2.00E-12 | 0 | 0 |
| 588000 | 136000 | 0.000285 | 4.32E-05 | 2.90E-12 | 0 | 0 |
| 589000 | 136000 | 0.000143 | 7.36E-05 | 4.00E-12 | 0 | 0 |
| 590000 | 136000 | 3.72E-05 | 0.000137 | 5.10E-12 | 0 | 0 |
| 558000 | 137000 | 0 | 1.00E-13 | 3.00E-13 | 0 | 0 |
| 559000 | 137000 | 0 | 6.80E-12 | 3.89E-11 | 9.00E-13 | 0 |
| 560000 | 137000 | 0 | 2.41E-09 | 7.65E-09 | 1.74E-10 | 0 |
| 561000 | 137000 | 2.00E-13 | 3.95E-07 | 7.00E-08 | 1.59E-09 | 1.00E-13 |
| 562000 | 137000 | 9.39E-09 | 1.13E-05 | 7.42E-10 | 1.67E-11 | 0 |
| 563000 | 137000 | 1.55E-06 | 2.13E-05 | 1.18E-11 | 2.00E-13 | 0 |
| 564000 | 137000 | 2.04E-05 | 7.81E-06 | 2.00E-13 | 0 | 0 |
| 565000 | 137000 | 4.53E-05 | 1.63E-06 | 0 | 0 | 0 |
| 566000 | 137000 | 9.26E-05 | 1.08E-06 | 0 | 0 | 0 |
| 567000 | 137000 | 0.0025 | 3.20E-06 | 0 | 0 | 0 |
| 568000 | 137000 | 0.00128 | 1.30E-05 | 0 | 0 | 0 |
| 569000 | 137000 | 0.000869 | 3.32E-05 | 0 | 0 | 0 |
| 570000 | 137000 | 0.000682 | 5.38E-05 | 0 | 0 | 0 |
| 571000 | 137000 | 0.000574 | 7.97E-05 | 0 | 0 | 0 |
| 572000 | 137000 | 0.000175 | 6.02E-05 | 0 | 0 | 0 |
| 573000 | 137000 | 2.55E-05 | 6.24E-06 | 0 | 0 | 0 |
| 574000 | 137000 | 0.00025 | 1.69E-06 | 0 | 0 | 0 |
| 575000 | 137000 | 0.000137 | 6.14E-07 | 0 | 0 | 0 |
| 576000 | 137000 | 5.36E-06 | 2.57E-08 | 0 | 0 | 0 |
| 577000 | 137000 | 7.35E-08 | 5.04E-10 | 0 | 0 | 0 |
| 578000 | 137000 | 6.93E-09 | 1.03E-10 | 0 | 0 | 0 |
| 579000 | 137000 | 4.19E-09 | 6.80E-11 | 0 | 0 | 0 |
| 580000 | 137000 | 1.40E-08 | 1.08E-09 | 0 | 0 | 0 |
| 581000 | 137000 | 6.37E-07 | 3.34E-08 | 0 | 0 | 0 |
| 582000 | 137000 | 1.48E-05 | 5.46E-07 | 0 | 0 | 0 |
| 583000 | 137000 | 6.17E-05 | 2.42E-06 | 1.00E-13 | 0 | 0 |
| 584000 | 137000 | 0.000112 | 5.00E-06 | 3.00E-13 | 0 | 0 |
| 585000 | 137000 | 0.000164 | 8.13E-06 | 7.00E-13 | 0 | 0 |
| 587000 | 137000 | 0.000273 | 1.79E-05 | 1.40E-12 | 0 | 0 |

Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 588000 | 137000 | 0.000275 | 3.63E-05 | 2.20E-12 | 0 | 0 |
| 589000 | 137000 | 0.000127 | 7.09E-05 | 3.30E-12 | 0 | 0 |
| 590000 | 137000 | 4.11E-05 | 0.000115 | 4.10E-12 | 0 | 0 |
| 558000 | 138000 | 0 | 0 | 1.00E-13 | 0 | 0 |
| 559000 | 138000 | 0 | 5.40E-12 | 1.35E-11 | 3.00E-13 | 0 |
| 560000 | 138000 | 0 | 8.14E-10 | 9.75E-10 | 2.23E-11 | 0 |
| 561000 | 138000 | 2.00E-13 | 1.75E-07 | 3.22E-08 | 7.39E-10 | 1.00E-13 |
| 562000 | 138000 | 7.43E-10 | 8.53E-06 | 4.46E-09 | 1.05E-10 | 0 |
| 563000 | 138000 | 5.84E-07 | 2.40E-05 | 3.44E-11 | 8.00E-13 | 0 |
| 564000 | 138000 | 1.34E-05 | 1.36E-05 | 4.00E-13 | 0 | 0 |
| 565000 | 138000 | 3.04E-05 | 6.33E-06 | 0 | 0 | 0 |
| 566000 | 138000 | 7.61E-05 | 6.32E-06 | 0 | 0 | 0 |
| 567000 | 138000 | 0.00118 | 1.34E-05 | 0 | 0 | 0 |
| 568000 | 138000 | 0.00152 | 4.69E-05 | 0 | 0 | 0 |
| 569000 | 138000 | 0.00102 | 0.000102 | 0 | 0 | 0 |
| 570000 | 138000 | 0.000731 | 0.000138 | 0 | 0 | 0 |
| 571000 | 138000 | 0.00045 | 0.000179 | 0 | 0 | 0 |
| 572000 | 138000 | 1.68E-05 | 9.75E-06 | 0 | 0 | 0 |
| 573000 | 138000 | 3.00E-06 | 1.03E-07 | 0 | 0 | 0 |
| 575000 | 138000 | 1.21E-06 | 4.40E-09 | 0 | 0 | 0 |
| 578000 | 138000 | 2.05E-10 | 1.30E-12 | 0 | 0 | 0 |
| 579000 | 138000 | 1.18E-10 | 5.30E-12 | 0 | 0 | 0 |
| 580000 | 138000 | 5.63E-10 | 2.41E-10 | 0 | 0 | 0 |
| 581000 | 138000 | 5.75E-08 | 6.91E-09 | 0 | 0 | 0 |
| 582000 | 138000 | 2.30E-06 | 1.28E-07 | 0 | 0 | 0 |
| 583000 | 138000 | 3.11E-05 | 1.30E-06 | 0 | 0 | 0 |
| 584000 | 138000 | 8.26E-05 | 3.48E-06 | 2.00E-13 | 0 | 0 |
| 585000 | 138000 | 0.000151 | 7.22E-06 | 6.00E-13 | 0 | 0 |
| 586000 | 138000 | 0.000193 | 9.96E-06 | 7.00E-13 | 0 | 0 |
| 587000 | 138000 | 0.000274 | 1.89E-05 | 1.20E-12 | 0 | 0 |
| 588000 | 138000 | 0.000277 | 2.90E-05 | 1.70E-12 | 0 | 0 |
| 559000 | 139000 | 0 | 5.20E-12 | 7.70E-12 | 2.00E-13 | 0 |
| 560000 | 139000 | 0 | 5.15E-10 | 3.05E-10 | 7.00E-12 | 0 |
| 561000 | 139000 | 1.00E-13 | 5.01E-08 | 5.91E-09 | 1.36E-10 | 0 |
| 562000 | 139000 | 1.03E-10 | 2.64E-06 | 1.77E-08 | 4.11E-10 | 0 |
| 563000 | 139000 | 2.67E-07 | 2.32E-05 | 7.45E-10 | 1.79E-11 | 0 |
| 564000 | 139000 | 5.90E-06 | 2.26E-05 | 2.90E-12 | 1.00E-13 | 0 |
| 565000 | 139000 | 1.44E-05 | 1.73E-05 | 0 | 0 | 0 |
| 566000 | 139000 | 4.21E-05 | 2.04E-05 | 0 | 0 | 0 |
| 567000 | 139000 | 0.000507 | 4.07E-05 | 0 | 0 | 0 |

Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 568000 | 139000 | 0.000583 | 0.00012 | 0 | 0 | 0 |
| 569000 | 139000 | 0.000282 | 0.000211 | 0 | 0 | 0 |
| 570000 | 139000 | 0.000146 | 0.000259 | 0 | 0 | 0 |
| 571000 | 139000 | 0.000148 | 0.000218 | 0 | 0 | 0 |
| 572000 | 139000 | 8.67E-07 | 7.93E-07 | 0 | 0 | 0 |
| 573000 | 139000 | 3.60E-08 | 5.36E-09 | 0 | 0 | 0 |
| 574000 | 139000 | 1.54E-08 | 2.95E-10 | 0 | 0 | 0 |
| 577000 | 139000 | 1.90E-12 | 0 | 0 | 0 | 0 |
| 578000 | 139000 | 5.40E-12 | 0 | 0 | 0 | 0 |
| 579000 | 139000 | 7.80E-12 | 7.00E-13 | 0 | 0 | 0 |
| 580000 | 139000 | 8.60E-12 | 1.78E-11 | 0 | 0 | 0 |
| 581000 | 139000 | 4.14E-10 | 3.29E-10 | 0 | 0 | 0 |
| 582000 | 139000 | 2.55E-08 | 5.94E-09 | 0 | 0 | 0 |
| 583000 | 139000 | 1.16E-06 | 1.34E-07 | 0 | 0 | 0 |
| 584000 | 139000 | 5.76E-05 | 2.74E-06 | 1.00E-13 | 0 | 0 |
| 585000 | 139000 | 0.000131 | 6.08E-06 | 4.00E-13 | 0 | 0 |
| 586000 | 139000 | 0.000177 | 8.80E-06 | 5.00E-13 | 0 | 0 |
| 587000 | 139000 | 0.00021 | 1.19E-05 | 6.00E-13 | 0 | 0 |
| 558000 | 140000 | 0 | 6.00E-13 | 1.30E-12 | 0 | 0 |
| 559000 | 140000 | 0 | 6.10E-12 | 6.70E-12 | 2.00E-13 | 0 |
| 560000 | 140000 | 0 | 3.74E-10 | 1.53E-10 | 3.50E-12 | 0 |
| 561000 | 140000 | 2.00E-13 | 2.26E-08 | 2.26E-09 | 5.20E-11 | 0 |
| 562000 | 140000 | 5.28E-11 | 8.76E-07 | 1.17E-08 | 2.70E-10 | 0 |
| 563000 | 140000 | 2.18E-08 | 8.58E-06 | 9.53E-09 | 2.24E-10 | 0 |
| 564000 | 140000 | 2.72E-06 | 3.00E-05 | 3.28E-11 | 8.00E-13 | 0 |
| 565000 | 140000 | 5.26E-06 | 3.47E-05 | 1.00E-13 | 0 | 0 |
| 566000 | 140000 | 2.75E-05 | 5.02E-05 | 0 | 0 | 0 |
| 567000 | 140000 | 0.000174 | 9.23E-05 | 0 | 0 | 0 |
| 568000 | 140000 | 0.000158 | 0.00016 | 0 | 0 | 0 |
| 569000 | 140000 | 3.83E-05 | 0.00026 | 0 | 0 | 0 |
| 570000 | 140000 | 2.65E-06 | 0.000321 | 0 | 0 | 0 |
| 571000 | 140000 | 3.20E-05 | 8.71E-05 | 0 | 0 | 0 |
| 572000 | 140000 | 8.30E-08 | 2.16E-07 | 0 | 0 | 0 |
| 573000 | 140000 | 6.83E-10 | 1.46E-09 | 0 | 0 | 0 |
| 574000 | 140000 | 5.91E-11 | 1.54E-11 | 0 | 0 | 0 |
| 575000 | 140000 | 5.00E-13 | 2.00E-13 | 0 | 0 | 0 |
| 578000 | 140000 | 1.00E-13 | 0 | 0 | 0 | 0 |
| 579000 | 140000 | 0 | 1.00E-13 | 0 | 0 | 0 |
| 583000 | 140000 | 7.77E-08 | 5.68E-07 | 0 | 0 | 0 |
| 584000 | 140000 | 2.88E-05 | 3.48E-06 | 1.00E-13 | 0 | 0 |

Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 585000 | 140000 | 9.13E-05 | 5.97E-06 | 2.00E-13 | 0 | 0 |
| 586000 | 140000 | 0.00013 | 7.87E-06 | 3.00E-13 | 0 | 0 |
| 560000 | 141000 | 0 | 2.99E-10 | 7.45E-11 | 1.70E-12 | 0 |
| 561000 | 141000 | 1.70E-12 | 1.08E-08 | 8.83E-10 | 2.03E-11 | 0 |
| 562000 | 141000 | 5.36E-10 | 3.89E-07 | 6.25E-09 | 1.44E-10 | 0 |
| 563000 | 141000 | 1.24E-07 | 1.38E-05 | 8.16E-09 | 1.92E-10 | 0 |
| 564000 | 141000 | 1.46E-06 | 4.68E-05 | 1.05E-10 | 2.50E-12 | 0 |
| 565000 | 141000 | 5.45E-06 | 7.97E-05 | 7.00E-13 | 0 | 0 |
| 566000 | 141000 | 2.12E-05 | 0.000129 | 0 | 0 | 0 |
| 567000 | 141000 | 2.47E-05 | 0.000192 | 0 | 0 | 0 |
| 571000 | 141000 | 5.34E-06 | 1.72E-05 | 0 | 0 | 0 |
| 572000 | 141000 | 5.59E-08 | 1.63E-07 | 0 | 0 | 0 |
| 573000 | 141000 | 4.53E-10 | 1.35E-09 | 0 | 0 | 0 |
| 574000 | 141000 | 6.20E-12 | 1.73E-11 | 0 | 0 | 0 |
| 575000 | 141000 | 4.00E-13 | 3.00E-13 | 0 | 0 | 0 |
| 581000 | 141000 | 1.93E-08 | 4.20E-07 | 0 | 0 | 0 |
| 582000 | 141000 | 1.25E-08 | 4.49E-07 | 0 | 0 | 0 |
| 583000 | 141000 | 1.09E-08 | 4.89E-07 | 0 | 0 | 0 |
| 584000 | 141000 | 7.60E-08 | 5.72E-07 | 0 | 0 | 0 |
| 585000 | 141000 | 2.17E-06 | 7.15E-07 | 0 | 0 | 0 |
| 562000 | 142000 | 1.72E-09 | 4.07E-07 | 3.63E-09 | 8.39E-11 | 0 |
| 563000 | 142000 | 6.48E-07 | 4.59E-05 | 2.52E-09 | 5.94E-11 | 0 |
| 564000 | 142000 | 1.72E-06 | 9.38E-05 | 1.02E-10 | 2.40E-12 | 0 |
| 570000 | 142000 | 5.25E-06 | 2.14E-05 | 0 | 0 | 0 |
| 571000 | 142000 | 1.85E-06 | 6.35E-06 | 0 | 0 | 0 |
| 572000 | 142000 | 3.28E-08 | 1.03E-07 | 0 | 0 | 0 |
| 578000 | 142000 | 4.08E-08 | 3.57E-07 | 0 | 0 | 0 |
| 579000 | 142000 | 3.53E-08 | 3.74E-07 | 0 | 0 | 0 |
| 580000 | 142000 | 3.08E-08 | 3.92E-07 | 0 | 0 | 0 |
| 581000 | 142000 | 2.36E-08 | 4.24E-07 | 0 | 0 | 0 |
| 582000 | 142000 | 1.39E-08 | 4.71E-07 | 0 | 0 | 0 |
| 583000 | 142000 | 5.73E-09 | 5.38E-07 | 0 | 0 | 0 |
| 584000 | 142000 | 1.67E-09 | 5.65E-07 | 0 | 0 | 0 |
| 559000 | 143000 | 4.00E-13 | 2.27E-09 | 5.41E-11 | 1.30E-12 | 0 |
| 560000 | 143000 | 1.58E-10 | 7.95E-08 | 1.55E-09 | 3.60E-11 | 0 |
| 561000 | 143000 | 1.66E-10 | 7.15E-08 | 1.50E-09 | 3.46E-11 | 0 |
| 562000 | 143000 | 5.43E-09 | 8.79E-07 | 3.59E-09 | 8.32E-11 | 0 |
| 563000 | 143000 | 2.95E-07 | 2.60E-05 | 4.56E-09 | 1.07E-10 | 0 |
| 567000 | 143000 | 2.53E-06 | 2.31E-05 | 1.60E-12 | 0 | 0 |
| 568000 | 143000 | 3.43E-06 | 2.20E-05 | 0 | 0 | 0 |

Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 569000 | 143000 | 3.72E-06 | 1.96E-05 | 0 | 0 | 0 |
| 570000 | 143000 | 3.02E-06 | 1.36E-05 | 0 | 0 | 0 |
| 571000 | 143000 | 1.30E-06 | 4.90E-06 | 0 | 0 | 0 |
| 572000 | 143000 | 1.39E-07 | 4.80E-07 | 0 | 0 | 0 |
| 573000 | 143000 | 9.09E-08 | 3.34E-07 | 0 | 0 | 0 |
| 574000 | 143000 | 7.93E-08 | 3.20E-07 | 0 | 0 | 0 |
| 575000 | 143000 | 7.30E-08 | 3.33E-07 | 0 | 0 | 0 |
| 576000 | 143000 | 6.14E-08 | 3.55E-07 | 0 | 0 | 0 |
| 577000 | 143000 | 4.90E-08 | 3.84E-07 | 0 | 0 | 0 |
| 578000 | 143000 | 3.90E-08 | 4.14E-07 | 0 | 0 | 0 |
| 579000 | 143000 | 3.18E-08 | 4.39E-07 | 0 | 0 | 0 |
| 580000 | 143000 | 2.51E-08 | 4.73E-07 | 0 | 0 | 0 |
| 581000 | 143000 | 1.70E-08 | 5.20E-07 | 0 | 0 | 0 |
| 582000 | 143000 | 8.44E-09 | 5.88E-07 | 0 | 0 | 0 |
| 583000 | 143000 | 2.23E-09 | 6.27E-07 | 0 | 0 | 0 |
| 558000 | 144000 | 0 | 1.92E-11 | 4.00E-13 | 0 | 0 |
| 559000 | 144000 | 1.70E-12 | 1.88E-09 | 3.94E-11 | 9.00E-13 | 0 |
| 560000 | 144000 | 1.49E-10 | 7.80E-08 | 1.43E-09 | 3.31E-11 | 0 |
| 563000 | 144000 | 9.48E-08 | 1.01E-05 | 4.57E-09 | 1.07E-10 | 0 |
| 564000 | 144000 | 1.87E-07 | 2.07E-05 | 4.52E-09 | 1.06E-10 | 0 |
| 565000 | 144000 | 1.57E-07 | 2.45E-05 | 4.43E-09 | 1.04E-10 | 0 |
| 566000 | 144000 | 6.27E-07 | 2.64E-05 | 1.46E-09 | 3.45E-11 | 0 |
| 567000 | 144000 | 1.77E-06 | 2.30E-05 | 2.50E-12 | 1.00E-13 | 0 |
| 568000 | 144000 | 2.30E-06 | 1.98E-05 | 0 | 0 | 0 |
| 569000 | 144000 | 2.28E-06 | 1.57E-05 | 0 | 0 | 0 |
| 570000 | 144000 | 1.84E-06 | 1.04E-05 | 0 | 0 | 0 |
| 571000 | 144000 | 1.00E-06 | 4.33E-06 | 0 | 0 | 0 |
| 572000 | 144000 | 2.46E-07 | 9.47E-07 | 0 | 0 | 0 |
| 573000 | 144000 | 1.40E-07 | 5.64E-07 | 0 | 0 | 0 |
| 574000 | 144000 | 1.05E-07 | 4.64E-07 | 0 | 0 | 0 |
| 575000 | 144000 | 8.64E-08 | 4.45E-07 | 0 | 0 | 0 |
| 576000 | 144000 | 6.38E-08 | 4.62E-07 | 0 | 0 | 0 |
| 577000 | 144000 | 4.35E-08 | 4.96E-07 | 0 | 0 | 0 |
| 578000 | 144000 | 2.86E-08 | 5.37E-07 | 0 | 0 | 0 |
| 579000 | 144000 | 1.96E-08 | 5.70E-07 | 0 | 0 | 0 |
| 580000 | 144000 | 1.25E-08 | 6.18E-07 | 0 | 0 | 0 |
| 581000 | 144000 | 6.45E-09 | 6.81E-07 | 0 | 0 | 0 |
| 582000 | 144000 | 2.55E-09 | 7.32E-07 | 0 | 0 | 0 |
| 583000 | 144000 | 7.06E-10 | 7.28E-07 | 0 | 0 | 0 |
| 558000 | 145000 | 0 | 5.20E-12 | 1.00E-13 | 0 | 0 |

Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 559000 | 145000 | 3.00E-13 | 3.68E-10 | 7.50E-12 | 2.00E-13 | 0 |
| 560000 | 145000 | 1.84E-11 | 1.38E-08 | 2.68E-10 | 6.20E-12 | 0 |
| 561000 | 145000 | 9.09E-11 | 6.05E-08 | 1.05E-09 | 2.45E-11 | 0 |
| 562000 | 145000 | 5.99E-09 | 1.12E-06 | 2.33E-09 | 5.42E-11 | 0 |
| 563000 | 145000 | 3.52E-08 | 5.30E-06 | 3.99E-09 | 9.30E-11 | 0 |
| 564000 | 145000 | 1.00E-07 | 1.44E-05 | 4.50E-09 | 1.05E-10 | 0 |
| 565000 | 145000 | 1.05E-07 | 2.28E-05 | 4.50E-09 | 1.06E-10 | 0 |
| 566000 | 145000 | 2.22E-07 | 2.66E-05 | 2.73E-09 | 6.48E-11 | 0 |
| 567000 | 145000 | 1.16E-06 | 2.31E-05 | 4.80E-12 | 1.00E-13 | 0 |
| 568000 | 145000 | 1.45E-06 | 1.81E-05 | 0 | 0 | 0 |
| 569000 | 145000 | 1.32E-06 | 1.28E-05 | 0 | 0 | 0 |
| 570000 | 145000 | 1.12E-06 | 8.06E-06 | 0 | 0 | 0 |
| 571000 | 145000 | 7.69E-07 | 3.90E-06 | 0 | 0 | 0 |
| 572000 | 145000 | 2.48E-07 | 1.11E-06 | 0 | 0 | 0 |
| 573000 | 145000 | 1.54E-07 | 7.08E-07 | 0 | 0 | 0 |
| 574000 | 145000 | 1.18E-07 | 5.79E-07 | 0 | 0 | 0 |
| 575000 | 145000 | 9.11E-08 | 5.30E-07 | 0 | 0 | 0 |
| 576000 | 145000 | 5.91E-08 | 5.49E-07 | 0 | 0 | 0 |
| 577000 | 145000 | 3.38E-08 | 5.93E-07 | 0 | 0 | 0 |
| 578000 | 145000 | 1.86E-08 | 6.40E-07 | 0 | 0 | 0 |
| 579000 | 145000 | 1.02E-08 | 6.87E-07 | 0 | 0 | 0 |
| 580000 | 145000 | 5.46E-09 | 7.35E-07 | 0 | 0 | 0 |
| 581000 | 145000 | 2.33E-09 | 7.86E-07 | 0 | 0 | 0 |
| 582000 | 145000 | 8.30E-10 | 8.00E-07 | 0 | 0 | 0 |
| 583000 | 145000 | 4.00E-10 | 7.57E-07 | 0 | 0 | 0 |
| 567000 | 146000 | 8.66E-07 | 2.29E-05 | 5.30E-12 | 1.00E-13 | 0 |
| 568000 | 146000 | 9.44E-07 | 1.61E-05 | 0 | 0 | 0 |
| 569000 | 146000 | 8.10E-07 | 1.01E-05 | 0 | 0 | 0 |
| 570000 | 146000 | 6.87E-07 | 5.98E-06 | 0 | 0 | 0 |
| 571000 | 146000 | 5.64E-07 | 3.46E-06 | 0 | 0 | 0 |
| 572000 | 146000 | 2.35E-07 | 1.28E-06 | 0 | 0 | 0 |
| 573000 | 146000 | 1.42E-07 | 8.06E-07 | 0 | 0 | 0 |
| 574000 | 146000 | 1.14E-07 | 6.58E-07 | 0 | 0 | 0 |
| 575000 | 146000 | 9.08E-08 | 6.02E-07 | 0 | 0 | 0 |
| 576000 | 146000 | 5.31E-08 | 6.22E-07 | 0 | 0 | 0 |
| 577000 | 146000 | 2.53E-08 | 6.73E-07 | 0 | 0 | 0 |
| 578000 | 146000 | 1.15E-08 | 7.26E-07 | 0 | 0 | 0 |
| 579000 | 146000 | 5.62E-09 | 7.71E-07 | 0 | 0 | 0 |
| 580000 | 146000 | 2.81E-09 | 8.11E-07 | 0 | 0 | 0 |
| 581000 | 146000 | 1.29E-09 | 8.42E-07 | 0 | 0 | 0 |

**Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)**

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 582000 | 146000 | 5.66E-10 | 7.45E-07 | 0 | 0 | 0 |
| 569000 | 147000 | 5.55E-07 | 7.52E-06 | 0 | 0 | 0 |
| 570000 | 147000 | 4.49E-07 | 4.68E-06 | 0 | 0 | 0 |
| 571000 | 147000 | 3.79E-07 | 2.88E-06 | 0 | 0 | 0 |
| 572000 | 147000 | 2.05E-07 | 1.40E-06 | 0 | 0 | 0 |
| 573000 | 147000 | 1.24E-07 | 9.08E-07 | 0 | 0 | 0 |
| 574000 | 147000 | 9.92E-08 | 7.34E-07 | 0 | 0 | 0 |
| 575000 | 147000 | 8.35E-08 | 6.67E-07 | 0 | 0 | 0 |
| 576000 | 147000 | 5.01E-08 | 6.80E-07 | 0 | 0 | 0 |
| 577000 | 147000 | 2.37E-08 | 7.26E-07 | 0 | 0 | 0 |
| 578000 | 147000 | 1.17E-08 | 7.74E-07 | 0 | 0 | 0 |
| 579000 | 147000 | 5.87E-09 | 8.17E-07 | 0 | 0 | 0 |
| 580000 | 147000 | 2.79E-09 | 8.56E-07 | 0 | 0 | 0 |
| 581000 | 147000 | 1.17E-09 | 8.69E-07 | 0 | 0 | 0 |
| 582000 | 147000 | 3.26E-10 | 4.98E-07 | 0 | 0 | 0 |
| 570000 | 148000 | 2.78E-07 | 3.67E-06 | 0 | 0 | 0 |
| 571000 | 148000 | 2.59E-07 | 2.57E-06 | 0 | 0 | 0 |
| 572000 | 148000 | 1.68E-07 | 1.50E-06 | 0 | 0 | 0 |
| 573000 | 148000 | 1.08E-07 | 1.03E-06 | 0 | 0 | 0 |
| 574000 | 148000 | 8.41E-08 | 8.36E-07 | 0 | 0 | 0 |
| 575000 | 148000 | 7.14E-08 | 7.45E-07 | 0 | 0 | 0 |
| 576000 | 148000 | 4.61E-08 | 7.40E-07 | 0 | 0 | 0 |
| 577000 | 148000 | 2.49E-08 | 7.72E-07 | 0 | 0 | 0 |
| 578000 | 148000 | 1.35E-08 | 8.11E-07 | 0 | 0 | 0 |
| 579000 | 148000 | 7.16E-09 | 8.51E-07 | 0 | 0 | 0 |
| 580000 | 148000 | 3.46E-09 | 8.90E-07 | 0 | 0 | 0 |
| 581000 | 148000 | 1.42E-09 | 9.14E-07 | 0 | 0 | 0 |
| 571000 | 149000 | 1.79E-07 | 2.34E-06 | 0 | 0 | 0 |
| 572000 | 149000 | 1.30E-07 | 1.57E-06 | 0 | 0 | 0 |
| 573000 | 149000 | 9.21E-08 | 1.14E-06 | 0 | 0 | 0 |
| 574000 | 149000 | 7.38E-08 | 9.57E-07 | 0 | 0 | 0 |
| 575000 | 149000 | 6.25E-08 | 8.52E-07 | 0 | 0 | 0 |
| 576000 | 149000 | 4.36E-08 | 8.19E-07 | 0 | 0 | 0 |
| 577000 | 149000 | 2.75E-08 | 8.22E-07 | 0 | 0 | 0 |
| 578000 | 149000 | 1.60E-08 | 8.50E-07 | 0 | 0 | 0 |
| 579000 | 149000 | 8.33E-09 | 8.93E-07 | 0 | 0 | 0 |
| 580000 | 149000 | 5.03E-09 | 9.20E-07 | 0 | 0 | 0 |
| 572000 | 150000 | 9.63E-08 | 1.59E-06 | 0 | 0 | 0 |
| 573000 | 150000 | 7.64E-08 | 1.23E-06 | 0 | 0 | 0 |
| 574000 | 150000 | 6.45E-08 | 1.07E-06 | 0 | 0 | 0 |

Table D.5.1.1 Modeled Point Concentrations for Iodine-129 Released from Single- and Double-Shell Tanks, No Action Alternative (cont'd)

| Cell Location Coordinate | | Point Concentration ($g/m^3$) | | | | |
|---|---|---|---|---|---|---|
| Easting | Northing | 300 years from 1995 | 500 years from 1995 | 2,500 years from 1995 | 5,000 years from 1995 | 10,000 years from 1995 |
| 575000 | 150000 | 5.55E-08 | 9.74E-07 | 0 | 0 | 0 |
| 576000 | 150000 | 4.12E-08 | 9.26E-07 | 0 | 0 | 0 |
| 577000 | 150000 | 2.89E-08 | 9.04E-07 | 0 | 0 | 0 |
| 578000 | 150000 | 1.99E-08 | 9.03E-07 | 0 | 0 | 0 |
| 579000 | 150000 | 1.34E-08 | 9.24E-07 | 0 | 0 | 0 |
| 572000 | 151000 | 7.00E-08 | 1.50E-06 | 0 | 0 | 0 |
| 573000 | 151000 | 6.21E-08 | 1.31E-06 | 0 | 0 | 0 |
| 574000 | 151000 | 5.53E-08 | 1.18E-06 | 0 | 0 | 0 |
| 575000 | 151000 | 4.96E-08 | 1.10E-06 | 0 | 0 | 0 |
| 576000 | 151000 | 3.91E-08 | 1.05E-06 | 0 | 0 | 0 |
| 577000 | 151000 | 2.90E-08 | 1.03E-06 | 0 | 0 | 0 |
| 578000 | 151000 | 2.14E-08 | 1.02E-06 | 0 | 0 | 0 |
| 579000 | 151000 | 1.68E-08 | 1.03E-06 | 0 | 0 | 0 |
| 573000 | 152000 | 4.20E-08 | 1.20E-06 | 0 | 0 | 0 |
| 574000 | 152000 | 4.21E-08 | 1.27E-06 | 0 | 0 | 0 |
| 575000 | 152000 | 3.97E-08 | 1.22E-06 | 0 | 0 | 0 |
| 576000 | 152000 | 3.26E-08 | 1.19E-06 | 0 | 0 | 0 |
| 577000 | 152000 | 2.44E-08 | 1.18E-06 | 0 | 0 | 0 |
| 578000 | 152000 | 1.64E-08 | 1.21E-06 | 0 | 0 | 0 |
| 574000 | 153000 | 3.05E-09 | 1.49E-07 | 0 | 0 | 0 |
| 575000 | 153000 | 1.33E-08 | 6.97E-07 | 0 | 0 | 0 |
| 576000 | 153000 | 1.18E-08 | 9.17E-07 | 0 | 0 | 0 |
| 577000 | 153000 | 7.96E-09 | 9.37E-07 | 0 | 0 | 0 |
| 578000 | 153000 | 4.38E-09 | 7.75E-07 | 0 | 0 | 0 |
| 575000 | 154000 | 1.23E-11 | 2.12E-09 | 0 | 0 | 0 |
| 576000 | 154000 | 2.18E-11 | 9.65E-09 | 0 | 0 | 0 |
| 577000 | 154000 | 3.21E-11 | 2.17E-08 | 0 | 0 | 0 |

Table D.5.1.2 Risk for Recreational Shoreline User from Surface Water

| | Incremental Lifetime Cancer Risk Total from C-14, I-129, Tc-99, U-238 | | | | |
|---|---|---|---|---|---|
| Tank Waste Alternative | 300 Years from 1995 | 500 Years from 1995 | 2,500 Years from 1995 | 5,000 Years from 1995 | 10,000 Years from 1995 |
| No Action | 3.39E-05 | 8.29E-06 | 6.74E-07 | 7.39E-11 | 1.67E-15 |
| Long-Term Management | 6.43E-06 | 7.34E-06 | 4.26E-09 | 6.92E-11 | 2.22E-15 |
| In Situ Fill and Cap | 0 | 0 | 3.67E-13 | 6.69E-07 | 9.01E-08 |
| In Situ Vitrification | 0 | 0 | 0 | 1.56E-10 | 2.01E-10 |
| Ex Situ Intermediate Separations | 0 | 0 | 6.52E-10 | 1.82E-08 | 5.89E-14 |
| Ex Situ Intermediate Separations Vaults | 0 | 0 | 0 | 1.50E-10 | 4.06E-10 |
| Ex Situ No Separations | 0 | 0 | 6.52E-10 | 1.82E-08 | 5.59E-13 |
| Ex Situ Extensive Separations | 0 | 0 | 6.52E-10 | 1.82E-08 | 5.59E-13 |
| Ex Situ Extensive Separations Vaults | 0 | 0 | 0 | 1.04E-12 | 2.81E-12 |
| Ex Situ/In Situ Combination 1 | 0 | 0 | 4.28E-10 | 1.38E-07 | 4.79E-09 |
| Ex Situ/In Situ Combination 1 Vaults | 0 | 0 | 0 | 7.70E-11 | 2.07E-10 |
| Ex Situ/In Situ Combination 2 | 0 | 0 | 6.08E-10 | 2.00E-07 | 6.80E-09 |
| Ex Situ/In Situ Combination 2 Vaults | 0 | 0 | 0 | 2.75E-11 | 7.39E-10 |

**Table D.5.15.1 Bounding Case Post-Remediation Total Cancer Incidence and Cancer Fatalities for 10,000 Years from the Present for all Alternatives**

| Alternatives | Native American | | Residential Farmer | | Industrial Worker | | Recreational User | |
|---|---|---|---|---|---|---|---|---|
| | Cancer Incidence [1] | Cancer Fatality [2] | Cancer Incidence [1] | Cancer Fatality [2] | Cancer Incidence [1] | Cancer Fatality [2] | Cancer Incidence [1] | Cancer Fatality [2] |
| No Action | 2,597 | 2,164 | 759 | 632 | 441 | 367 | 52 | 43 |
| Long-Term Management | 2,720 | 2,266 | 681 | 567 | 441 | 367 | 50 | 41 |
| In Situ Fill and Cap | 1,261 | 1,051 | 400 | 333 | 459 | 383 | 29 | 24 |
| In Situ Vitrification | 3 | 2 | 1 | 1 | 2 | 1 | 0 | 0 |
| Ex Situ Intermediate Separations | 40 | 33 | 12 | 10 | 18 | 15 | 0 | 0 |
| Ex Situ No Separations | 40 | 33 | 12 | 10 | 18 | 15 | 0 | 0 |
| Ex Situ Extensive Separations | 40 | 33 | 12 | 10 | 18 | 15 | 0 | 0 |
| Ex Situ/In Situ Combination 1 | 200 | 166 | 72 | 60 | 183 | 153 | 1 | 0 |
| Ex Situ/In Situ Combination 2 | 225 | 204 | 77 | 64 | 183 | 153 | 4 | 3 |
| Phased Implementation | 40 | 33 | 12 | 10 | 18 | 15 | 0 | 0 |
| Population Density (number of Individuals/km$^2$) | 1.91 | | 4.97 | | N/A | | 18.75 | |
| Population per Generation (number of individuals) | 1,500 | | 3,900 | | 2,200 | | 1,950 | |
| Total population in 10,000 yr (number of individuals) | 214,286 | | 557,143 | | 733,333 | | 650,000 | |
| Area of Land Use (km$^2$) | 785 | | 785 | | Maximum Risk | | 104 | |

Notes:
[1] Dose-to-risk conversion factor for cancer incidence used is 6.0E-04 (ICRP 1991).
[2] Dose-to-risk conversion factor for cancer fatality used is 5.0E-04 (ICRP 1991).
N/A = Not applicable

**Table D.5.15.2 Estimated Arrival and Curies of Radionuclides that Reach the Columbia River Within a 10,0000-Year Period of Interest**

| Alternative | Time of First Arrival [1] | Time of Peak Concentration [1] | Time of Final Arrival [1] | C-14 Ci [2] | I-129 Ci [2] | Tc-99 Ci [2] | U-238 Ci [2] | Np-237 Ci [2] |
|---|---|---|---|---|---|---|---|---|
| No Action | 225 | 500 | 850 | 5007.8 | 38 | 31049.5 | 481 | 66.2 |
| Long-Term Management | 225 | 500 | 800 | 5007.8 | 38 | 31049.5 | 481 | 66.2 |
| In Situ Fill and Cap | 3000 | 5500 | >10000 | 2462.6 | 34.2 | 27503.3 | 433 | 59.5 |
| In Situ Vitrification | 3100 | 6500 | >>10000 | 0 | 0 | 0.03 | 0 | 0 |
| Ex Situ Intermediate Separations (Tanks) | 2250 | 4750 | 7000 | 86.7 | 1.0 | 534.7 | 30.4 | 1.1 |
| Ex Situ Intermediate Separations (Vaults) | 4000 | 6500 | >>>10000 | 0 | 0 | 0.24 | 0 | 0 |
| Ex Situ No Separations (Tanks) | 2250 | 4750 | 7000 | 86.7 | 1.0 | 534.7 | 30.4 | 1.1 |
| Ex Situ Extensive Separations (Tanks) | 2250 | 4750 | 7000 | 86.7 | 1.0 | 534.7 | 30.4 | 1.1 |
| Ex Situ Extensive Separations (Vaults) | 4000 | 6500 | >>>10000 | 0 | 0 | 0.02 | 0 | 0 |
| Ex Situ/ In Situ Combination 1 (Tanks) | 2250 | 5500 | >>10000 | 154.2 | 1.5 | 2577.5 | 58 | 8.0 |
| Ex Situ/ In Situ Combination 1 (Vaults) | 4000 | 6500 | >>>10000 | 0 | 0 | 0.02 | 0 | 0 |
| Ex Situ/ In Situ Combination 2 (Tanks) | 2250 | 5500 | >>10000 | 522.3 | 7.0 | 4433 | 214 | 20 |
| Ex Situ/ In Situ Combination 2 (Vaults) | 4000 | 6500 | >>>10000 | 0 | 0 | 0.02 | 0 | 0 |

Notes:
[1] Years from the present.
[2] Includes radioactive decay from the present until time of peak.

**Table D.5.15.3 Estimated Fatality, Population Dose (person-rem), and Maximum Incremental Dose (mrem) for the Columbia River User Over 10,000 Years for all Alternatives**

| Alternative | Total Fatality in 10,000 years | Cumulative Population Dose [1] (Person-rem) | Maximum Incremental Dose in mrem (Year Received) |
|---|---|---|---|
| No Action | 2.8 | 5580 | 0.84 (2,900) |
| Long-Term Management | 2.3 | 4520 | 0.77 (2,830) |
| In Situ Fill and Cap | 25.7 | 51400 | 0.15 (12,000) |
| In Situ Vitrification | 1.00E-06 | 0.002 | 0 |
| Ex Situ Intermediate Separations | 0.5 | 907 | 0.005 (9,060) |
| Ex Situ No Separations | 0.5 | 907 | 0.005 (9,060) |
| Ex Situ Extensive Separations | 0.5 | 907 | 0.005 (9,060) |
| Ex Situ/In Situ Combination 1 | 2.6 | 5150 | 0.014 (12,000) |
| Ex Situ/In Situ Combination 2 | 5.6 | 11200 | 0.03 (12,000) |
| Phased Implementation | 0.5 | 907 | 0.005 (9,060) |

Notes:
[1]The ICRP Publication 60 (ICRP 1991) dose to risk conversion factor of 5.0E-04 cancer fatality per rem is used.

Table D.5.16.1 Summary of Bounding Case Maximum Incremental Lifetime Cancer Risk and Hazard Indicies

| Alternative | 300 Years from 1995 Incremental Lifetime Cancer Risks | | | |
|---|---|---|---|---|
| | Native American | Residential Farmer | Industrial Worker | Recreational User |
| No Action | 1.00E+00 | 4.58E-01 | 1.34E-01 | 1.26E-02 |
| Long-Term Management | 1.00E+00 | 2.65E-01 | 1.18E-01 | 1.02E-02 |
| In Situ Fill and Cap | No Risk | No Risk | No Risk | No Risk |
| In Situ Vitrification | No Risk | No Risk | No Risk | No Risk |
| Ex Situ Intermediate Separations | No Risk | No Risk | No Risk | No Risk |
| Ex Situ No Separations | No Risk | No Risk | No Risk | No Risk |
| Ex Situ Extensive Separations | No Risk | No Risk | No Risk | No Risk |
| Ex Situ/In Situ Combination 1 | No Risk | No Risk | No Risk | No Risk |
| Ex Situ/In Situ Combination 2 | No Risk | No Risk | No Risk | No Risk |
| Phased Implementation | No Risk | No Risk | No Risk | No Risk |
| | Hazard Index | | | |
| No Action | 2.77E+05 | 5.04E+04 | 5.37E+01 | 7.33E+00 |
| Long-Term Management | 4.42E+04 | 7.99E+03 | 8.24E+00 | 1.12E+00 |
| In Situ Fill and Cap | No Hazard | No Hazard | No Hazard | No Hazard |
| In Situ Vitrification | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ Intermediate Separations | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ No Separations | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ Extensive Separations | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ/In Situ Combination 1 | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ/In Situ Combination 2 | No Hazard | No Hazard | No Hazard | No Hazard |
| Phased Implementation | No Hazard | No Hazard | No Hazard | No Hazard |
| | 500 Years from 1995 Incremental Lifetime Cancer Risks | | | |
| No Action | 1.00E+00 | 1.13E-01 | 2.82E-02 | 2.63E-03 |
| Long-Term Management | 1.00E+00 | 9.55E-02 | 2.75E-02 | 2.51E-03 |
| In Situ Fill and Cap | No Risk | No Risk | No Risk | No Risk |
| In Situ Vitrification | No Risk | No Risk | No Risk | No Risk |
| Ex Situ Intermediate Separations | No Risk | No Risk | No Risk | No Risk |
| Ex Situ No Separations | No Risk | No Risk | No Risk | No Risk |
| Ex Situ Extensive Separations | No Risk | No Risk | No Risk | No Risk |
| Ex Situ/In Situ Combination 1 | No Risk | No Risk | No Risk | No Risk |
| Ex Situ/In Situ Combination 2 | No Risk | No Risk | No Risk | No Risk |
| Phased Implementation | No Risk | No Risk | No Risk | No Risk |
| | Hazard Index | | | |
| No Action | 3.47E+04 | 6.25E+03 | 6.69E+00 | 9.10E-01 |
| Long-Term Management | 3.46E+04 | 6.24E+03 | 6.44E+00 | 8.78E-01 |
| In Situ Fill and Cap | No Hazard | No Hazard | No Hazard | No Hazard |
| In Situ Vitrification | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ Intermediate Separations | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ No Separations | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ Extensive Separations | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ/In Situ Combination 1 | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ/In Situ Combination 2 | No Hazard | No Hazard | No Hazard | No Hazard |
| Phased Implementation | No Hazard | No Hazard | No Hazard | No Hazard |

Table D.5.16.1 Summary of Bounding Case Maximum Incremental Lifetime Cancer Risk and Hazard Indicies (cont'd)

| Alternative | 2,500 Years from 1995 Incremental Lifetime Cancer Risks | | | |
|---|---|---|---|---|
| | Native American | Residential Farmer | Industrial Worker | Recreational User |
| No Action | 3.09E-02 | 1.17E-04 | 5.37E-05 | 4.47E-06 |
| Long-Term Management | 3.09E-02 | 1.17E-04 | 5.37E-05 | 4.47E-06 |
| In Situ Fill and Cap | 3.98E-07 | 3.47E-08 | 8.71E-09 | 7.94E-10 |
| In Situ Vitrification | No Risk | No Risk | No Risk | No Risk |
| Ex Situ Intermediate Separations | 1.17E-04 | 9.55E-06 | 3.02E-06 | 2.69E-07 |
| Ex Situ No Separations | 1.17E-04 | 9.55E-06 | 3.02E-06 | 2.69E-07 |
| Ex Situ Extensive Separations | 1.17E-04 | 9.55E-06 | 3.02E-06 | 2.69E-07 |
| Ex Situ/In Situ Combination 1 | 8.51E-05 | 6.92E-06 | 2.19E-06 | 2.00E-07 |
| Ex Situ/In Situ Combination 2 | 2.24E-05 | 1.86E-06 | 5.50E-07 | 4.90E-08 |
| Phased Implementation | 1.17E-04 | 9.55E-06 | 3.02E-06 | 2.69E-07 |
| | Hazard Index | | | |
| No Action | 5.16E+01 | 9.18E+00 | 8.91E-01 | 1.19E-01 |
| Long-Term Management | 5.17E+01 | 9.20E+00 | 8.91E-01 | 1.19E-01 |
| In Situ Fill and Cap | 2.00E-03 | 3.37E-04 | 4.79E-07 | 6.49E-08 |
| In Situ Vitrification | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ Intermediate Separations | 7.24E-01 | 1.23E-01 | 1.14E-04 | 1.57E-05 |
| Ex Situ No Separations | 7.24E-01 | 1.16E-01 | 1.14E-04 | 1.57E-05 |
| Ex Situ Extensive Separations | 7.24E-01 | 1.23E-01 | 1.14E-04 | 1.57E-05 |
| Ex Situ/In Situ Combination 1 | 4.69E-01 | 8.48E-02 | 1.84E-04 | 2.51E-05 |
| Ex Situ/In Situ Combination 2 | 1.20E-01 | 2.21E-02 | 1.92E-05 | 2.64E-06 |
| Phased Implementation | 7.24E-01 | 1.23E-01 | 1.14E-04 | 1.57E-05 |
| | 5,000 Years from 1995 Incremental Lifetime Cancer Risks | | | |
| No Action | 3.16E-03 | 8.13E-06 | 3.72E-06 | 3.09E-07 |
| Long-Term Management | 3.16E-03 | 8.13E-06 | 3.72E-06 | 3.09E-07 |
| In Situ Fill and Cap | 1.30E-01 | 1.10E-02 | 2.88E-03 | 2.63E-04 |
| In Situ Vitrification | 3.02E-04 | 2.34E-05 | 6.92E-06 | 6.31E-07 |
| Ex Situ Intermediate Separations | 4.27E-03 | 3.39E-04 | 1.02E-04 | 9.55E-06 |
| Ex Situ No Separations | 4.27E-03 | 3.39E-04 | 1.02E-04 | 9.55E-06 |
| Ex Situ Extensive Separations | 4.27E-03 | 3.39E-04 | 1.02E-04 | 9.55E-06 |
| Ex Situ/In Situ Combination 1 | 4.27E-02 | 3.31E-03 | 1.07E-03 | 9.55E-05 |
| Ex Situ/In Situ Combination 2 | 4.57E-02 | 3.63E-03 | 1.10E-03 | 1.02E-04 |
| Phased Implementation | 4.27E-03 | 3.39E-04 | 1.02E-04 | 9.55E-06 |
| | Hazard Index | | | |
| No Action | 2.17E+00 | 5.76E-01 | 1.16E-01 | 1.56E-02 |
| Long-Term Management | 2.69E+00 | 5.76E-01 | 1.16E-01 | 1.56E-02 |
| In Situ Fill and Cap | 3.01E+03 | 5.32E+02 | 4.21E-01 | 7.13E-02 |
| In Situ Vitrification | 1.00E-03 | 3.15E-04 | 6.68E-05 | 9.03E-06 |
| Ex Situ Intermediate Separations | 1.22E+02 | 2.11E+01 | 2.23E-02 | 3.00E-03 |
| Ex Situ No Separations | 1.22E+02 | 2.11E+01 | 2.21E-02 | 3.00E-03 |
| Ex Situ Extensive Separations | 1.22E+02 | 2.11E+01 | 2.23E-02 | 3.00E-03 |
| Ex Situ/In Situ Combination 1 | 3.31E+03 | 5.97E+02 | 6.26E-01 | 8.50E-02 |
| Ex Situ/In Situ Combination 2 | 3.37E+03 | 6.09E+02 | 6.54E-01 | 8.89E-02 |
| Phased Implementation | 1.22E+02 | 2.11E+01 | 2.23E-02 | 3.00E-03 |

Table D.5.16.1 Summary of Bounding Case Maximum Incremental Lifetime Cancer Risk and Hazard Indicies (cont'd)

| Alternative | 10,000 Years from 1995 Incremental Lifetime Cancer Risks | | | |
|---|---|---|---|---|
| | Native American | Residential Farmer | Industrial Worker | Recreational User |
| No Action | 1.82E-04 | 5.37E-07 | 2.45E-07 | 2.09E-08 |
| Long-Term Management | 1.82E-04 | 5.37E-07 | 2.45E-07 | 2.09E-08 |
| In Situ Fill and Cap | 1.78E-02 | 1.48E-03 | 3.98E-04 | 3.72E-05 |
| In Situ Vitrification | 3.89E-04 | 3.02E-05 | 9.12E-06 | 8.13E-07 |
| Ex Situ Intermediate Separations | 6.92E-04 | 6.76E-05 | 7.41E-06 | 7.76E-07 |
| Ex Situ No Separations | 1.91E-07 | 1.62E-08 | 3.72E-09 | 3.47E-10 |
| Ex Situ Extensive Separations | 1.91E-07 | 1.62E-08 | 3.72E-09 | 3.47E-10 |
| Ex Situ/In Situ Combination 1 | 2.24E-03 | 1.66E-04 | 5.50E-05 | 4.90E-06 |
| Ex Situ/In Situ Combination 2 | 6.92E-03 | 5.62E-04 | 1.55E-04 | 1.41E-05 |
| Phased Implementation | 6.92E-04 | 6.76E-05 | 7.41E-06 | 7.76E-07 |
| | Hazard Index | | | |
| No Action | 1.07E-01 | 2.79E-02 | 5.62E-03 | 7.51E-04 |
| Long-Term Management | 1.99E-01 | 2.79E-02 | 5.62E-03 | 7.51E-04 |
| In Situ Fill and Cap | 1.29E+02 | 1.86E+02 | 6.21E+00 | 5.73E-01 |
| In Situ Vitrification | 1.30E-03 | 4.06E-04 | 8.62E-05 | 1.16E-05 |
| Ex Situ Intermediate Separations | 7.68E-03 | 1.60E-03 | 3.65E-04 | 4.94E-05 |
| Ex Situ No Separations | 7.68E-03 | 8.99E-04 | 1.76E-06 | 2.10E-07 |
| Ex Situ Extensive Separations | 9.12E-01 | 1.35E-03 | 2.83E-04 | 3.72E-05 |
| Ex Situ/In Situ Combination 1 | 4.28E+02 | 6.98E+01 | 7.49E-02 | 9.76E-03 |
| Ex Situ/In Situ Combination 2 | 7.54E+02 | 1.21E+02 | 1.39E-01 | 1.80E-02 |
| Phased Implementation | 7.68E-03 | 1.60E-03 | 3.65E-04 | 4.94E-05 |

Table D.5.16.2 Summary of Nominal Case Maximum Incremental Lifetime Cancer Risk and Hazard Indicies

| Alternative | 300 Years from 1995 Incremental Lifetime Cancer Risks | | | |
|---|---|---|---|---|
| | Native American | Residential Farmer | Industrial Worker | Recreational User |
| No Action | 1.00E+00 | 1.92E-01 | 1.62E-02 | 2.45E-03 |
| Long-Term Management | 9.93E-01 | 3.63E-02 | 2.45E-03 | 3.80E-04 |
| In Situ Fill and Cap | No Risk | No Risk | No Risk | No Risk |
| In Situ Vitrification | No Risk | No Risk | No Risk | No Risk |
| Ex Situ Intermediate Separations | No Risk | No Risk | No Risk | No Risk |
| Ex Situ No Separations | No Risk | No Risk | No Risk | No Risk |
| Ex Situ Extensive Separations | No Risk | No Risk | No Risk | No Risk |
| Ex Situ/In Situ Combination 1 | No Risk | No Risk | No Risk | No Risk |
| Ex Situ/In Situ Combination 2 | No Risk | No Risk | No Risk | No Risk |
| Phased Implementation | No Risk | No Risk | No Risk | No Risk |
| | Hazard Index | | | |
| No Action | 2.77E+05 | 5.04E+04 | 5.37E+01 | 7.33E+00 |
| Long-Term Management | 4.42E+04 | 7.99E+03 | 8.24E+00 | 1.12E+00 |
| In Situ Fill and Cap | No Hazard | No Hazard | No Hazard | No Hazard |
| In Situ Vitrification | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ Intermediate Separations | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ No Separations | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ Extensive Separations | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ/In Situ Combination 1 | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ/In Situ Combination 2 | No Hazard | No Hazard | No Hazard | No Hazard |
| Phased Implementation | No Hazard | No Hazard | No Hazard | No Hazard |
| | 500 Years from 1995 Incremental Lifetime Cancer Risks | | | |
| No Action | 7.69E-01 | 5.50E-02 | 2.19E-03 | 3.63E-04 |
| Long-Term Management | 7.73E-01 | 4.57E-02 | 1.95E-03 | 3.09E-04 |
| In Situ Fill and Cap | No Risk | No Risk | No Risk | No Risk |
| In Situ Vitrification | No Risk | No Risk | No Risk | No Risk |
| Ex Situ Intermediate Separations | No Risk | No Risk | No Risk | No Risk |
| Ex Situ No Separations | No Risk | No Risk | No Risk | No Risk |
| Ex Situ Extensive Separations | No Risk | No Risk | No Risk | No Risk |
| Ex Situ/In Situ Combination 1 | No Risk | No Risk | No Risk | No Risk |
| Ex Situ/In Situ Combination 2 | No Risk | No Risk | No Risk | No Risk |
| Phased Implementation | No Risk | No Risk | No Risk | No Risk |
| | Hazard Index | | | |
| No Action | 3.47E+04 | 6.25E+03 | 6.69E+00 | 5.97E-01 |
| Long-Term Management | 3.46E+04 | 6.24E+03 | 6.44E+00 | 5.84E-01 |
| In Situ Fill and Cap | No Hazard | No Hazard | No Hazard | No Hazard |
| In Situ Vitrification | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ Intermediate Separations | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ No Separations | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ Extensive Separations | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ/In Situ Combination 1 | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ/In Situ Combination 2 | No Hazard | No Hazard | No Hazard | No Hazard |
| Phased Implementation | No Hazard | No Hazard | No Hazard | No Hazard |

**Table D.5.16.2 Summary of Nominal Case Maximum Incremental Lifetime Cancer Risk and Hazard Indicies (cont'd)**

| Alternative | 2,500 Years from 1995 Incremental Lifetime Cancer Risks | | | |
|---|---|---|---|---|
| | Native American | Residential Farmer | Industrial Worker | Recreational User |
| No Action | 1.00E+00 | 4.68E-02 | 2.04E-02 | 1.78E-03 |
| Long-Term Management | 1.00E+00 | 4.68E-02 | 2.04E-02 | 1.78E-03 |
| In Situ Fill and Cap | 3.39E-07 | 5.50E-08 | 3.55E-09 | 5.75E-10 |
| In Situ Vitrification | No Risk | No Risk | No Risk | No Risk |
| Ex Situ Intermediate Separations | 2.57E-05 | 1.91E-06 | 7.24E-08 | 1.15E-08 |
| Ex Situ No Separations | 2.57E-05 | 1.91E-06 | 7.24E-08 | 1.15E-08 |
| Ex Situ Extensive Separations | 2.57E-05 | 1.91E-06 | 7.24E-08 | 1.15E-08 |
| Ex Situ/In Situ Combination 1 | 3.24E-05 | 2.19E-06 | 9.33E-08 | 1.48E-08 |
| Ex Situ/In Situ Combination 2 | 7.76E-06 | 6.92E-07 | 2.57E-08 | 4.07E-09 |
| Phased Implementation | 2.57E-05 | 1.91E-06 | 7.24E-08 | 1.15E-08 |
| | Hazard Index | | | |
| No Action | 6.41E+01 | 9.18E+00 | 5.90E-01 | 1.12E-01 |
| Long-Term Management | 6.53E+01 | 9.20E+00 | 5.90E-01 | 1.12E-01 |
| In Situ Fill and Cap | 1.33E-03 | 2.41E-04 | 4.70E-07 | 6.15E-08 |
| In Situ Vitrification | No Hazard | No Hazard | No Hazard | No Hazard |
| Ex Situ Intermediate Separations | 5.99E-01 | 1.11E-01 | 9.05E-05 | 1.24E-05 |
| Ex Situ No Separations | 4.51E-01 | 1.05E-01 | 9.05E-05 | 1.24E-05 |
| Ex Situ Extensive Separations | 5.99E-01 | 1.11E-01 | 9.05E-05 | 1.24E-05 |
| Ex Situ/In Situ Combination 1 | 4.69E-01 | 8.48E-02 | 1.84E-04 | 2.51E-05 |
| Ex Situ/In Situ Combination 2 | 1.20E-01 | 2.21E-02 | 1.92E-05 | 2.64E-06 |
| Phased Implementation | 5.99E-01 | 1.11E-01 | 9.05E-05 | 1.24E-05 |
| | 5,000 Years from 1995 Incremental Lifetime Cancer Risks | | | |
| No Action | 1.75E-01 | 6.03E-03 | 2.63E-03 | 2.29E-04 |
| Long-Term Management | 1.77E-01 | 6.03E-03 | 2.69E-03 | 2.34E-04 |
| In Situ Fill and Cap | 1.25E-01 | 4.79E-03 | 3.09E-04 | 4.68E-05 |
| In Situ Vitrification | 3.02E-04 | 1.70E-05 | 7.94E-07 | 1.26e-07 |
| Ex Situ Intermediate Separations | 7.08E-04 | 2.04E-05 | 2.57E-06 | 2.63E-07 |
| Ex Situ No Separations | 7.08E-04 | 2.04E-05 | 1.70E-06 | 2.57E-07 |
| Ex Situ Extensive Separations | 7.08E-04 | 2.04E-05 | 2.04E-06 | 2.57E-07 |
| Ex Situ/In Situ Combination 1 | 2.19E-02 | 1.10E-03 | 6.17E-05 | 9.55E-06 |
| Ex Situ/In Situ Combination 2 | 4.57E-02 | 1.38E-03 | 1.15E-04 | 1.74E-05 |
| Phased Implementation | 7.08E-04 | 2.04E-05 | 2.57E-06 | 2.63E-07 |
| | Hazard Index | | | |
| No Action | 2.17E+00 | 4.38E-01 | 1.10E-01 | 1.55E-02 |
| Long-Term Management | 2.69E+00 | 4.38E-01 | 1.10E-01 | 1.55E-02 |
| In Situ Fill and Cap | 5.35E+03 | 9.66E+02 | 5.98E-01 | 1.17E-01 |
| In Situ Vitrification | 2.01E-03 | 6.30E-04 | 1.34E-04 | 1.81E-05 |
| Ex Situ Intermediate Separations | 3.41E+01 | 6.30E+00 | 5.15E-03 | 7.08E-04 |
| Ex Situ No Separations | 3.41E+01 | 6.30E+00 | 5.15E-03 | 7.08E-04 |
| Ex Situ Extensive Separations | 3.41E+01 | 6.30E+00 | 5.15E-03 | 7.08E-04 |
| Ex Situ/In Situ Combination 1 | 3.31E+03 | 5.97E+02 | 6.26E-01 | 8.50E-02 |
| Ex Situ/In Situ Combination 2 | 3.37E+03 | 6.09E+02 | 6.54E-01 | 8.89E-02 |
| Phased Implementation | 3.41E+01 | 6.30E+00 | 5.15E-03 | 7.08E-04 |

**Table D.5.16.2 Summary of Nominal Case Maximum Incremental Lifetime Cancer Risk and Hazard Indicies (cont'd)**

| Alternative | 10,000 Years from 1995 Incremental Lifetime Cancer Risks | | | |
|---|---|---|---|---|
| | Native American | Residential Farmer | Industrial Worker | Recreational User |
| No Action | 7.94E-03 | 2.69E-04 | 1.17E-04 | 1.02E-05 |
| Long-Term Management | 7.94E-03 | 2.69E-04 | 1.17E-04 | 1.02E-05 |
| In Situ Fill and Cap | 1.41E-02 | 5.89E-04 | 3.47E-05 | 5.25E-06 |
| In Situ Vitrification | 3.89E-04 | 2.19E-05 | 1.02E-06 | 1.62E-07 |
| Ex Situ Intermediate Separations | 6.17E-04 | 3.98E-05 | 6.17E-06 | 6.03E-07 |
| Ex Situ No Separations | 1.51E-04 | 5.37E-06 | 2.34E-06 | 2.04E-07 |
| Ex Situ Extensive Separations | 3.09E-04 | 1.10E-05 | 4.68E-06 | 4.07E-07 |
| Ex Situ/In Situ Combination 1 | 2.29E-03 | 5.13E-05 | 3.89E-06 | 5.25E-07 |
| Ex Situ/In Situ Combination 2 | 6.31E-03 | 2.45E-04 | 1.29E-05 | 2.00E-06 |
| Phased Implementation | 6.17E-04 | 3.98E-05 | 6.17E-06 | 6.03E-07 |
| | Hazard Index | | | |
| No Action | 1.01E-01 | 2.75E-02 | 5.62E-03 | 7.51E-04 |
| Long-Term Management | 1.80E-01 | 2.75E-02 | 5.62E-03 | 7.51E-04 |
| In Situ Fill and Cap | 1.23E+03 | 3.90E+02 | 9.98E-01 | 5.83E-01 |
| In Situ Vitrification | 2.59E-03 | 8.13E-04 | 1.73E-04 | 2.33E-05 |
| Ex Situ Intermediate Separations | 1.40E+00 | 2.17E-03 | 4.70E-04 | 6.25E-05 |
| Ex Situ No Separations | 5.98E-01 | 1.35E-03 | 2.83E-04 | 3.72E-05 |
| Ex Situ Extensive Separations | 1.82E+00 | 2.70E-03 | 5.66E-04 | 7.44E-05 |
| Ex Situ/In Situ Combination 1 | 4.28E+02 | 6.98E+01 | 7.49E-02 | 9.76E-03 |
| Ex Situ/In Situ Combination 2 | 7.54E+02 | 1.21E+02 | 1.39E-01 | 1.80E-02 |
| Phased Implementation | 1.40E+00 | 2.17E-03 | 4.70E-04 | 6.25E-05 |

Table D.5.16.3 Nominal Case Post-Remediation Total Cancer Incidence and Cancer Fatalities for 10,000 Years from the Present Time

| Alternatives | Native American | | Residential Farmer | | Industrial Worker | | Recreational user | |
|---|---|---|---|---|---|---|---|---|
| | Cancer Incidence [1] | Cancer Fatality [2] | Cancer Incidence [1] | Cancer Fatality [2] | Cancer Incidence[1] | Cancer Fatality [2] | Cancer Incidence [1] | Cancer Fatality [2] |
| No Action | 2,178 | 1,815 | 626 | 522 | 438 | 365 | 30 | 25 |
| Long-Term Management | 2,476 | 2,063 | 625 | 521 | 423 | 353 | 33 | 28 |
| In Situ Fill and Cap | 307 | 256 | 276 | 223 | 18 | 15 | 3 | 2 |
| In Situ Vitrification | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ex Situ intermediate Separations | 7 | 6 | 2 | 1 | 0 | 0 | 0 | 0 |
| Ex Situ No Separations | 7 | 6 | 2 | 1 | 0 | 0 | 0 | 0 |
| Ex Situ Extensive Separations | 7 | 6 | 2 | 1 | 0 | 0 | 0 | 0 |
| Ex Situ/In Situ Combination 1 | 82 | 68 | 55 | 46 | 10 | 8 | 0 | 0 |
| Ex Situ/In Situ Combination 2 | 98 | 82 | 58 | 48 | 18 | 15 | 0 | 0 |
| Phased Implementation | 7 | 6 | 2 | 1 | 0 | 0 | 0 | 0 |
| Population Density (number of individuals/km$^2$) | 1.91 | | 4.97 | | N/A | | 18.75 | |
| Population per Generation (number of individuals) | 1,500 | | 3,900 | | 2,200 | | 1,950 | |
| Total population in 10,000 yr (number of individuals) | 214,286 | | 557,143 | | 733,333 | | 650,000 | |
| Area of Land Use (km$^2$) | 785 | | 785 | | Maximum Risk | | 104 | |

Notes:
[1] Dose to risk conversion factor for cancer incidence used is 6.0E-04 (ICRP 1991).
[2] Dose to risk conversion factor for cancer fatality used is 5.0E-04 (ICRP 1991).
N/A = Not applicable

## D.6.0 ECOLOGICAL RISK ASSESSMENT METHODOLOGY AND RESULTS

### D.6.1 INTRODUCTION

This section summarizes the methodology and results of the ecological risk assessment (risks to plants and animals from potential exposure to radioactive and toxic contaminants) for the various TWRS alternatives. Potential ecological risks are evaluated under baseline conditions (i.e., the No Action alternative) with ecological impacts from other alternatives being compared to the baseline impacts. The No Action alternative is a conservative and bounding scenario since it assumes that all of the tank waste would remain in-place and would be available for direct contact and potential migration to groundwater and the Columbia River. Consequently, the No Action alternative represents the greatest potential impacts to ecological receptors (terrestrial and aquatic).

Under baseline conditions, radiological doses and chemical hazards were estimated for potential ecological receptors from 1) direct contact with tank waste; 2) exposure to tank waste contaminants in groundwater that reaches the Columbia River; and 3) exposure to routine contaminant releases to the air. For other alternatives (e.g., in situ and ex situ alternatives described previously), potential ecological risks were estimated from radionuclides and chemicals released to the air during remediation activities.

The ecological risk assessment methodology is conceptually identical to the methodology used to estimate potential human health risks. All chemicals of concern for human health were also considered chemicals of concern for potential ecological receptors. Consequently, the ecological risk assessment used the same source terms and contaminant transport data that were used in the human health risk assessment (Section D.2.0). The URF approach developed for human health risk was followed for terrestrial receptors except that ecological species-specific factors were substituted for the human land use-specific factors and are described in more detail in Section D.6.3.2. Potential radiation doses to aquatic organisms from tank waste contaminants calculated to reach the Columbia River by groundwater migration were evaluated using the CRITRII model (Baker-Soldat 1992).

The ecological risk assessment in this EIS follows the approaches recommended in EPA's Framework for Ecological Risk Assessment (EPA 1992) and the Hanford Site Baseline Risk Assessment Methodology (DOE 1993d). The basic components of this ecological risk assessment are 1) problem formulation; 2) characterization of potential exposures; 3) estimation of potential ecological impacts from radionuclides and toxic chemicals; and 4) summarization of the risk assessment results (EPA 1992).

### D.6.2 PROBLEM FORMULATION

This section describes the ecosystem potentially at risk, potential ecological effects of the contaminants of concern, endpoints selected for risk assessment, and the conceptual model.

#### D.6.2.1 Ecosystems Potentially at Risk

The Hanford Site supports a variety of arid terrestrial habitats, a major aquatic habitat in the Columbia River, and a number of threatened, endangered, or candidate species, as described in Volume Five,

Appendix I. The primary ecosystems potentially at risk from exposure to tank waste include the shrub-steppe habitat in and immediately adjacent to the Central Plateau; mobile organisms that may enter the area (for example, birds and deer); and aquatic wildlife in the Columbia River.

### D.6.2.2 Ecological Effects

To date, no specific ecological effects of exposure to tank waste have been documented. The waste is in tanks buried in the ground (i.e., 4.6 m [15 ft] below the ground surface), which limits potential contact with any leaking waste to deep-rooted plants and burrowing animals. The areas adjacent to the tanks are highly disturbed, kept clear of vegetation, and represent low quality habitat thereby further limiting organisms' access to the waste. No current ecological risk exists since there is no complete exposure pathway for the tank waste. Any potential ecological effects would occur in the future following the loss of institutional controls. Natural succession and potential failures of tanks could increase the likelihood of contact with the waste. The direct ecological effects of concern at this time would be radiation and toxic chemical exposures that could lead to individual mortality, reproductive and developmental effects, and a variety of potential indirect effects on other ecological variables. Examples of potential indirect effects include decreased biodiversity, habitat loss or alteration, and impacts on productivity and nutrient turnover. As described in the following sections, this screening level assessment focuses on radiation doses and chemical intakes in individual indicator organisms.

### D.6.2.3 Endpoint Selection

Human health risk assessment typically focuses on two well-defined endpoints associated with the health of individual humans, cancer incidence, and the noncancer effects of hazardous chemicals. However, ecological risk assessment is concerned with many species and attributes of ecosystems other than their species composition, such as nutrient turnover rates, energy flow, and food web complexity. Particular endpoints must therefore be chosen for each new ecological risk assessment.

#### D.6.2.3.1 Assessment Endpoints

Assessment endpoints are the specific ecological characteristics to be protected (EPA 1992, Suter 1993). For purposes of this EIS, the primary assessment endpoint for the effects of radionuclides and hazardous chemicals is prevention of the adverse effects of these substances on any ecological receptors. A second, more specific, endpoint is prevention of adverse effects on Federal or Washington State species of concern that may occur in the TWRS area. These species, described in Section 4.4 and Volume Five, Appendix I, include Piper's daisy (Erigeron piperianus), the sage sparrow (Amphispiza belli), Swainson's hawk (Buteo swainsoni), and the loggerhead shrike (Lanius ludovicianus).

#### D.6.2.3.2 Measurement Endpoints

Measurement endpoints are characteristics that are subject to measurement and correspond in some way to the assessment endpoints. The measurement endpoints chosen to correspond to the assessment endpoints are 1) estimated radiation doses to terrestrial organisms compared with the 0.1 rad/day expected to have no adverse effects (IAEA 1992) (this screening radiological value is intended to be protective of chronic reproductive and developmental effects for a wide range of terrestrial species and

is not specific for any one species); 2) the ratio of estimated hazardous chemical intake by terrestrial organisms to the intake expected to have no adverse effect (HI value greater than 1.0 indicates a potential for adverse effects); and 3) estimated radiation doses to aquatic organisms compared with the 1.0 rad/day expected to have no adverse effects (NCRP 1991).

### D.6.2.4 Conceptual Model

The primary objective of the conceptual model is to develop a series of working hypotheses about how contamination may impact the ecological components of the natural environment (EPA 1992). For purposes of this EIS, these hypotheses center on potential exposures of individual organisms to radiation and hazardous chemicals.

The conceptual model for terrestrial organisms is a flow diagram illustrating potential complete pathways for movement of tank waste or radiation to a selected suite of representative species (Figure D.6.2.1). The representative species included a generic plant, the great basin pocket mouse (Perognathus parvus), the coyote (Canis latrans), the mule deer (Odocoileus hemionus), the red-tailed hawk (Buteo jamaicensus), and the loggerhead shrike (Lanius ludovicianus). The exposure pathways considered were food, soil, and water ingestion; inhalation; and direct radiation. This model is designed to assess effects at several trophic levels such as the primary producer, herbivore, and mammalian and avian carnivores while being simple enough to efficiently assess potential effects at the waste sites within the scope of this EIS. The species chosen are all known to occur on the Hanford Site, and all of them could potentially be exposed to tank waste constituents at some future time.

As illustrated in Figure D.6.2.1, the pocket mouse serves as a vector for contaminant movement through the food chain from plants to mammalian and avian carnivores. Because the mouse has no requirement for drinking water and obtains all its water from food, it would be subject to impacts from radiological and nonradiological chemicals in soil and food and to direct radiation while in burrows. Its small home range would cause it to spend all its time within a contaminated area and obtain all its food there (Table D.6.2.1).

The mule deer has a wider home range than the mouse, requires water, and consumes small amounts of soil while grazing, allowing some direct exposure to contaminants unmodified by plant uptake (Table D.6.2.1; Arthur-Alldredge 1979). The fraction of contaminated plants consumed was set equal to the ratio of the grid cell area to the home range (100 hectare [ha]/1,240 ha = 0.008).

The coyote is a mammalian predator, requires water, and was assumed to consume only pocket mice as prey for purposes of this assessment. The fraction of contaminated prey consumed was set equal to the ratio of the grid area to the home range (100 ha/302 ha = 0.33).

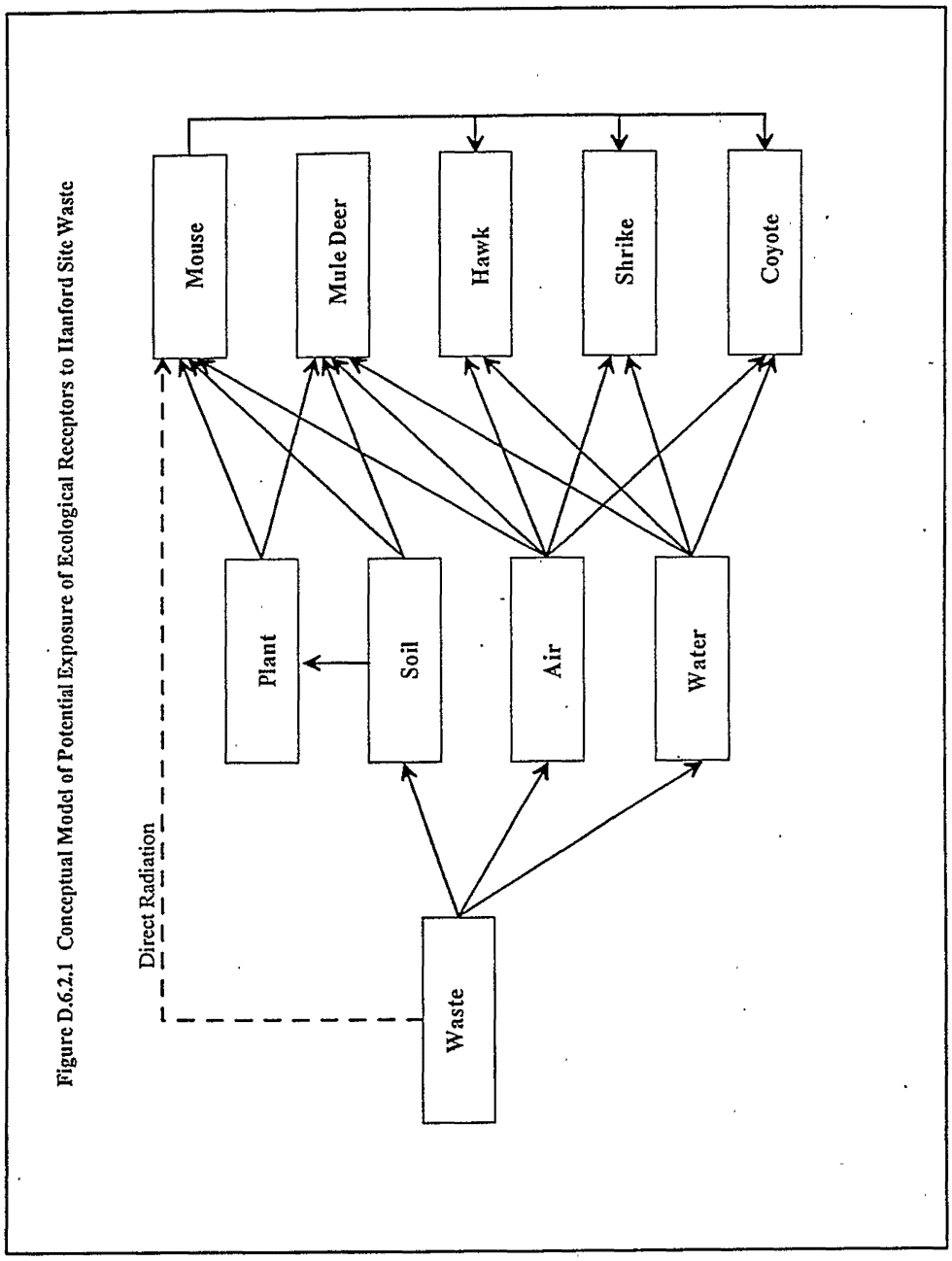



Figure D.6.2.1 Conceptual Model of Potential Exposure of Ecological Receptors to Hanford Site Waste

Table D.6.2.1 Organism Data Used to Estimate Radiation Doses and Hazard Quotients for Ecological Receptors

| | Variable | | | | | | |
|---|---|---|---|---|---|---|---|
| Organism | Size, kg [1] | Ingestion rate, food, kg/d | Ingestion rate, water, L/d | Ingestion rate, soil, kg/d | Inhalation rate, $m^3$/d | Home range, ha | Effective radius, cm |
| Great basin pocket mouse | 2.40E-02 | 3.27E-02 [1] | 0.00 [2] | 2.62E-04 [3] | 2.76E-02 [4] | 9.07E-02 [1] | 2 |
| Coyote | 9.80E+00 | 1.30E+00 | 7.72E-01 [5] | N/A | 3.39E+00 [4] | 3.02E+02 [1] | 30 |
| Mule deer | 5.70E+01 | 3.70E+00 [7] | 3.77E+00 [5] | 2.00E-02 [6] | 1.39E+01 [4] | 1.24E+03 [1] | 30 |
| Red-tailed hawk | 1.40E+00 | 1.65E-01 [8] | 7.74E-02 [9] | N/A | 5.59E-01 [10] | 2.18E+02 [11] | 5 |
| Loggerhead shrike | 4.00E-02 | 5.12E-03 [12] | 7.22E-03 [9] | N/A | 3.66E-02 [10] | 1.00E+01 [1] | 2 |

Notes:
[1] (Jacobs 1996).
[2] Assumed to obtain all water from metabolic sources.
[3] Wet weight ingestion (kg/d) · wet/dry weight conversion factor, 0.4 · 2 percent of dry vegetation intake (Beyer et al. 1991).
[4] Calculated using Equation 3-20 (EPA 1993).
[5] Calculated using Equation 3-17 (EPA 1993).
[6] Wet weight ingestion (kg/d) wet/dry weight conversion factor, 0.4 · mean of percent range (Arthur-Alldredge 1979).
[7] (Poston-Soldat 1992).
[8] 0.11 g/g-d, winter (EPA 1993) · 1,500 g wt./1,000 g/kg.
[9] Calculated using Equation 3-15 (EPA 1993).
[10] Calculated using Equation 3-19 (EPA 1993).
[11] (PNL 1994).
[12] Calculated using Equation 3-5 (EPA 1993).

The red-tailed hawk is an avian predator with a wide home range, requires water, and is assumed to consume only pocket mice as prey for purposes of this assessment. The fraction of contaminated prey consumed was set equal to the ratio of the grid cell area to the home range (100 ha/218 ha = 0.46). Potential effects on the red-tailed hawk also serve as measurement endpoints for effects on other raptors of concern such as the Swainson's hawk, for which relevant data are not available.

The loggerhead shrike is a passerine (songbird) bird species that is much smaller than the red-tailed hawk and has a smaller home range. The shrike feeds on insects, small mammals, and other birds (Fitzner-Rickard 1975). For purposes of this EIS, the shrike was assumed to consume only pocket mice as prey. Its small home range would cause it to spend all its time within a contaminated area and obtain all its food there (Table D.6.2.1).

The CRITRII model was used to estimate radiation doses to aquatic organisms (Baker-Soldat 1992). That model uses a simple food chain and bioaccumulation factors to estimate internal and external radiation doses to algae, fish, crustaceans, mollusks, and muskrats, raccoons, herons, and ducks feeding on aquatic organisms.

### D.6.3 ANALYSIS

The analysis phase of an ecological risk assessment consists of technically evaluating data for potential exposures to and effects of the contaminants (EPA 1992). This section describes how the exposures were estimated for each representative receptor of concern.

#### D.6.3.1 Source Terms and Direct Exposure

The source terms were the same as those used for the human health risk assessment. Constituent concentrations for direct exposure to tank waste were estimated from waste inventory data and volumes (WHC 1995g and Jacobs 1996), assuming an average density of 1.5 kg/L. Air concentrations for the No Action and remediation alternatives were estimated from average annual routine emissions and the minimum and maximum onsite Chi/Q values. Because ecological receptors would not have access to groundwater unless it reached the surface, water concentrations used were the minimum and maximum calculated (i.e., modeled) concentrations in groundwater reaching the Columbia River at 300, 500, 2,500, 5,000, and 10,000 years. Use of the maximum modeled concentrations provides conservative, upper-bound estimates of exposure point concentrations and potential exposures.

#### D.6.3.2 Characterization of Exposure

This section describes the general methods used to estimate the intake of hazardous chemicals, the associated HIs, and radiation doses resulting from radionuclide intake by terrestrial organisms. The section first describes the equations used as they are typically presented in the risk assessment literature and then describes how the equations were modified to calculate URFs to simplify computation. Strictly speaking, the "URFs" as applied to ecological receptors are unit dose or HI factors, in that the result is an estimated radiation dose or chemical HI, rather than a probability of some adverse effect. However, the term URF is maintained here for purposes of consistency with the methodology used for the human health risk assessment.

##### D.6.3.2.1 Estimation of Hazardous Chemical Intake

Uptake of contaminants from soil by a generic plant was estimated by multiplying the soil concentration by the soil-to-plant concentration factors used in the GENII model at the Hanford Site (Table D.6.3.1 and D.6.3.2).

The equation is:

(1) $C_{vi} = (C_{si})(B_{vi})(0.4)$

Where:

| | | |
|---|---|---|
| $C_{vi}$ | = | Contaminant concentration in plant, mg $kg^{-1}$ wet weight |
| $C_{si}$ | = | Contaminant concentration in soil, mg $kg^{-1}$ dry weight |
| $B_{vi}$ | = | Soil-to-plant concentration factor (unitless) (The factor for grain concentration was used for the pocket mouse, which is assumed to consume seeds. The vegetative portion values were used for the mule deer.) |
| 0.4 | = | Dry weight/wet weight conversion (DOE 1994) |

Table D.6.3.1 Transfer Factors Used to Estimate Radiation Doses to Ecological Receptors

| Radionuclide | Soil/Grain [1] ($B_r$) | Soil/Leaf [2] ($B_v$) |
|---|---|---|
| Ac-225 | 3.00E-04 | 1.00E-02 |
| Ac-227 | 3.00E-04 | 1.00E-02 |
| Ac-228 | 3.00E-04 | 1.00E-02 |
| Ag-110 | 6.00E-02 | 6.00E-01 |
| Am-241 | 2.00E-04 | 2.00E-03 |
| Am-242 | 2.00E-04 | 2.00E-03 |
| Am-242m | 2.00E-04 | 2.00E-03 |
| Am-243 | 2.00E-04 | 2.00E-03 |
| At-217 [3] | 1.50E-01 | 1.00E+00 |
| Au-195 | 4.00E-02 | 4.00E-01 |
| Ba-133 | 4.00E-03 | 4.00E-02 |
| Ba-135m | 4.00E-03 | 4.00E-02 |
| Ba-137m | 4.00E-03 | 4.00E-02 |
| Be-10 | 3.30E-03 | 8.00E-03 |
| Be-7 | 3.30E-03 | 8.00E-03 |
| Bi-210 | 6.00E-01 | 6.00E-01 |
| Bi-211 | 6.00E-01 | 6.00E-01 |
| Bi-212 | 6.00E-01 | 6.00E-01 |
| Bi-213 | 6.00E-01 | 6.00E-01 |
| Bi-214 | 6.00E-01 | 6.00E-01 |
| C-14 | 0.00E+00 | 0.00E+00 |
| Ca-45 | 2.00E+00 | 2.00E+00 |
| Cd-109 | 6.00E-01 | 2.00E+00 |
| Ce-144 | 4.00E-03 | 4.00E-02 |
| Cf-252 | 2.50E-03 | 2.50E-03 |
| Cl-36 | 1.00E+00 | 5.00E+01 |
| Cm-242 | 2.00E-04 | 2.00E-03 |
| Cm-243 | 2.00E-04 | 2.00E-03 |
| Cm-244 | 2.00E-04 | 2.00E-03 |
| Cm-245 | 2.00E-04 | 2.00E-03 |
| Co-57 | 4.00E-03 | 1.00E-01 |
| Co-58 | 4.00E-03 | 1.00E-01 |
| Cs-135 | 1.00E-02 | 2.00E-02 |
| Cs-137 | 1.00E-02 | 2.00E-02 |
| Es-254 | N/A | N/A |
| Eu-152 | 2.00E-03 | 1.00E-02 |
| Eu-154 | 2.00E-03 | 1.00E-02 |

Table D.6.3.1 Transfer Factors Used to Estimate Radiation Doses to Ecological Receptors (cont'd)

| Radionuclide | Soil/Grain [1] ($B_v$) | Soil/Leaf [2] ($B_v$) |
|---|---|---|
| Eu-155 | 2.00E-03 | 1.00E-02 |
| Fe-55 | 5.00E-03 | 2.00E-02 |
| Fe-59 | 5.00E-03 | 2.00E-02 |
| Fr-221 | 1.00E-02 | 2.00E-02 |
| Fr-223 | 1.00E-02 | 2.00E-02 |
| Ge-68 [3] | 8.00E-02 | 4.00E-01 |
| H-3 | 0.00E+00 | 0.00E+00 |
| Hf-181 | 2.00E-03 | 1.00E-02 |
| I-125 | 4.00E-01 | 4.00E-01 |
| I-129 | 4.00E-01 | 4.00E-01 |
| K-40 | 3.00E+00 | 3.00E+00 |
| Kr-85 | 0.00E+00 | 0.00E+00 |
| Mn-54 | 2.00E-01 | 7.00E-01 |
| Mo-93 | 1.00E-01 | 1.00E+00 |
| Na-22 | 1.00E+01 | 1.00E+01 |
| Nb-91 | 8.00E-03 | 4.00E-02 |
| Nb-93m | 8.00E-03 | 4.00E-02 |
| Nb-94 | 8.00E-03 | 4.00E-02 |
| Nb-95 | 8.00E-03 | 4.00E-02 |
| Ni-59 | 5.00E-02 | 1.00E-01 |
| Ni-63 | 5.00E-02 | 1.00E-01 |
| Np-237 | 1.00E-01 | 1.00E+00 |
| Np-238 | 1.00E-01 | 1.00E+00 |
| Np-239 | 1.00E-01 | 1.00E+00 |
| Pa-231 | 2.00E-02 | 5.00E-02 |
| Pa-233 | 2.00E-02 | 5.00E-02 |
| Pa-234 | 2.00E-02 | 5.00E-02 |
| Pa-234m | 2.00E-02 | 5.00E-02 |
| Pb-211 | 1.00E-02 | 1.00E-01 |
| Pb-212 | 1.00E-02 | 1.00E-01 |
| Pb-214 | 1.00E-02 | 1.00E-01 |
| Pd-107 | 5.00E-02 | 3.00E-01 |
| Pm-147 | 1.00E-03 | 1.00E-02 |
| Po-210 | 1.00E-03 | 1.00E-02 |
| Po-211 | 1.00E-03 | 1.00E-02 |
| Po-212 | 1.00E-03 | 1.00E-02 |
| Po-213 | 1.00E-03 | 1.00E-02 |

Table D.6.3.1 Transfer Factors Used to Estimate Radiation Doses to Ecological Receptors (cont'd)

| Radionuclide | Soil/Grain [1] ($B_r$) | Soil/Leaf [2] ($B_v$) |
|---|---|---|
| Po-214 | 1.00E-03 | 1.00E-02 |
| Po-215 | 1.00E-03 | 1.00E-02 |
| Po-216 | 1.00E-03 | 1.00E-02 |
| Po-218 | 1.00E-03 | 1.00E-02 |
| Pu-236 | 4.00E-05 | 4.00E-04 |
| Pu-238 | 4.00E-05 | 4.00E-04 |
| Pu-239 | 4.00E-05 | 4.00E-04 |
| Pu-240 | 4.00E-05 | 4.00E-04 |
| Pu-241 | 4.00E-05 | 4.00E-04 |
| Pu-242 | 4.00E-05 | 4.00E-04 |
| Ra-223 | 1.00E-02 | 1.00E-01 |
| Ra-224 | 1.00E-02 | 1.00E-01 |
| Ra-225 | 1.00E-02 | 1.00E-01 |
| Ra-226 | 1.00E-02 | 1.00E-01 |
| Ra-228 | 1.00E-02 | 1.00E-01 |
| Re-187 | 9.90E-04 | 9.90E-04 |
| Rh-106 | 5.00E+00 | 5.00E+01 |
| Rn-219 | 0.00E+00 | 0.00E+00 |
| Rn-220 | 0.00E+00 | 0.00E+00 |
| Rn-222 | 0.00E+00 | 0.00E+00 |
| Ru-103 | 2.00E-01 | 2.00E-01 |
| Ru-106 | 2.00E-01 | 2.00E-01 |
| S-35 | 2.00E+00 | 2.00E+00 |
| Sb-124 | 5.00E-02 | 5.00E-02 |
| Sb-126m | 5.00E-02 | 5.00E-02 |
| Sc-46 | 1.00E-02 | 1.00E-02 |
| Se-75 | 5.00E-02 | 5.00E-01 |
| Se-79 | 5.00E-02 | 5.00E-01 |
| Sm-147 | 2.00E-03 | 1.00E-02 |
| Sm-151 | 2.00E-03 | 1.00E-02 |
| Sn-113 | 1.00E-02 | 1.00E-01 |
| Sn-123M | 1.00E-02 | 1.00E-01 |
| Sn-126 | 1.00E-02 | 1.00E-01 |
| Sr-85 | 2.00E-01 | 2.00E+00 |
| Sr-90 | 2.00E-01 | 2.00E+00 |
| Ta-182 | 9.90E-04 | 9.90E-04 |
| Tc-99 | 4.00E+01 | 4.00E+01 |

Table D.6.3.1 Transfer Factors Used to Estimate Radiation Doses to Ecological Receptors (cont'd)

| Radionuclide | Soil/Grain [1] ($B_r$) | Soil/Leaf [2] ($B_v$) |
|---|---|---|
| Te-125M | 5.00E-01 | 5.00E+00 |
| Te-127 | 5.00E-01 | 5.00E+00 |
| Te-129M | 5.00E-01 | 5.00E+00 |
| Th-227 | 4.00E-04 | 4.00E-03 |
| Th-228 | 4.00E-04 | 4.00E-03 |
| Th-229 | 4.00E-04 | 4.00E-03 |
| Th-230 | 4.00E-04 | 4.00E-03 |
| Th-231 | 4.00E-04 | 4.00E-03 |
| Th-232 | 4.00E-04 | 4.00E-03 |
| Th-233 | 4.00E-04 | 4.00E-03 |
| Th-234 | 4.00E-04 | 4.00E-03 |
| Tl-204 | 9.90E-04 | 9.90E-04 |
| Tl-207 | 9.90E-04 | 9.90E-04 |
| Tl-208 | 9.90E-04 | 9.90E-04 |
| Tl-209 | 9.90E-04 | 9.90E-04 |
| Tm-170 [3] | 4.00E-03 | 1.00E-02 |
| U-232 | 2.00E-04 | 4.00E-03 |
| U-233 | 2.00E-04 | 4.00E-03 |
| U-234 | 2.00E-04 | 4.00E-03 |
| U-235 | 2.00E-04 | 4.00E-03 |
| U-238 | 2.00E-04 | 4.00E-03 |
| V-49 [3] | 3.00E-03 | 5.50E-03 |
| Y-88 | 1.00E-03 | 1.00E-02 |
| Y-90 | 1.00E-03 | 1.00E-02 |
| Zn-65 | 2.00E+00 | 2.00E+00 |
| Zr-93 | 4.00E-02 | 4.00E-02 |
| Zr-95 | 4.00E-02 | 4.00E-02 |

Notes:
[1] Source: PNL Food Transfer Factor Library, grain values, except where noted.
[2] Source: PNL Food Transfer Factor Library, leafy vegetable values, except where noted.
[3] Source: Baes et al. 1984; $B_r$, reproductive portion values; $B_v$, vegetative portion values.

Table D.6.3.2 Properties of Chemicals Used to Estimate Hazard Quotients

| Chemical | $T_b$ (Bio half-life,d) | $f_1$ (Ingest) | $f_1$ (Inhale) | Soil/Grain [1] ($B_r$) | Soil/Leaf [2] ($B_v$) |
|---|---|---|---|---|---|
| Ag+ | 5.00E+00 | 5.00E-02 | 5.00E-02 | 6.00E-02 | 6.00E-01 |
| Al total | N/A | N/A | N/A | 6.50E-04 [3] | 4.00E-03 [3] |
| Al(OH)-4 | N/A | N/A | N/A | 6.50E-04 [3] | 4.00E-03 [3] |
| Al+3 | N/A | N/A | N/A | 6.50E-04 [3] | 4.00E-03 [3] |
| As+5 | 2.80E+02 | 5.00E-01 | 5.00E-01 | 1.00E-02 | 1.00E-02 |
| B+3 | 9.00E-01 | N/A | N/A | 2.00E+00 [3] | 4.00E+00 [3] |
| Ba+2 | 6.50E+01 | 1.00E-01 | 1.00E-01 | 4.00E-03 | 4.00E-02 |
| Be+2 | 1.80E+02 | 5.00E-03 | 5.00E-03 | 3.30E-03 | 8.00E-03 |
| Bi+3 | 5.00E+00 | 5.00E-02 | 5.00E-02 | 6.00E-01 | 6.00E-01 |
| Ca+2 | 1.64E+04 | 3.00E-01 | 3.00E-01 | 2.00E+00 | 2.00E+00 |
| Cd+2 | 2.00E+02 | 5.00E-02 | 5.00E-02 | 6.00E-01 | 2.00E+00 |
| Ce+3 | 5.63E+02 | 3.00E-04 | 3.00E-04 | 4.00E-03 | 4.00E-02 |
| Cl- | 2.90E+01 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 5.00E+01 |
| CO3-2 | N/A | N/A | N/A | N/A | N/A |
| Cr+3 | 6.16E+02 | 1.00E-01 | 1.00E-01 | 4.00E-03 | 4.00E-02 |
| CrO4-2 as Cr | 6.16E+02 | 1.00E-01 | 1.00E-01 | 4.00E-03 | 4.00E-02 |
| Total Cr | 6.16E+02 | 1.00E-01 | 1.00E-01 | 4.00E-03 | 4.00E-02 |
| Cu+2 | 8.00E+01 | 5.00E-01 | 5.00E-01 | 5.00E-02 | 5.00E-01 |
| F- | 8.08E+02 | 1.00E+00 | 1.00E+00 | 2.00E-02 | 2.00E-02 |
| Fe(CN)6-4 | N/A | N/A | N/A | 5.00E-03 | 2.00E-02 |
| Fe+3 | 8.00E+02 | 1.00E-01 | 1.00E-01 | 5.00E-03 | 2.00E-02 |
| Hg+ | 1.00E+01 | 1.00E+00 | 1.00E+00 | 1.00E-01 | 1.00E+00 |
| K+ | N/A | 1.00E+00 | 1.00E+00 | 3.00E+00 | 3.00E+00 |
| La+ | 5.00E+02 | 1.00E-03 | 1.00E-03 | 3.00E-04 | 1.00E-02 |
| Li+ | N/A | N/A | N/A | 4.00E-03 | 2.50E-02 |
| Mg+2 | N/A | N/A | N/A | 9.90E-04 | 9.90E-04 |
| Mn+4 | 1.70E+01 | 1.00E-01 | 1.00E-01 | 2.00E-01 | 7.00E-01 |
| Mo+6 | 5.00E+00 | 8.00E-01 | 8.00E-01 | 1.00E-01 | 1.00E+00 |
| Na+ | 1.10E+01 | 1.00E+00 | 1.00E+00 | 1.00E+01 | 1.00E+01 |
| Ni+2 | 6.67E+02 | 5.00E-02 | 5.00E-02 | 5.00E-02 | 1.00E-01 |
| OH- | N/A | N/A | N/A | N/A | N/A |
| Pb+4 | 1.46E+03 | 2.00E-01 | 2.00E-01 | 1.00E-02 | 1.00E-01 |
| PO4-3 as P | 2.57E+02 | 8.00E-01 | 8.00E-01 | 4.00E+00 | 4.00E+00 |
| SiO3- as Si | 6.00E+01 | 1.00E-02 | 1.00E-02 | 3.50E-01 | 3.50E-01 |

Table D.6.3.2 Properties of Chemicals Used to Estimate Hazard Quotients (cont'd)

| Chemical | $T_b$ (Bio half-life,d) | $f_1$ (Ingest) | $f_1$ (Inhale) | Soil/Grain[a] ($B_r$) | Soil/Leaf[b] ($B_v$) |
|---|---|---|---|---|---|
| SO4-2 as S | 9.00E+01 | 8.00E-01 | 8.00E-01 | 2.00E+00 | 2.00E+00 |
| Sr+2 | 4.00E+03 | 3.00E-01 | 3.00E-01 | 2.00E-01 | 2.00E+00 |
| TOC (2) | N/A | N/A | N/A | N/A | N/A |
| TOC (4) | N/A | N/A | N/A | N/A | N/A |
| UO2+2 as U | 1.00E+02 | 5.00E-02 | 5.00E-02 | 2.00E-04 | 4.00E-03 |
| V+5 | N/A | 2.00E-02 | 1.00E-02 | 3.00E-03 [3] | 5.50E-03 [3] |
| W+4 | 1.00E+00 | 3.00E-01 | 3.00E-01 | 3.00E-01 | 3.00E+00 |
| Zn+2 | 9.33E+02 | 5.00E-01 | 5.00E-01 | 2.00E+00 | 2.00E+00 |
| Zr+4 | 4.50E+02 | 2.00E-03 | 2.00E-03 | 4.00E-02 | 4.00E-02 |

Notes:
[1] Source: PNL Food Transfer Factor Library, grain values, except where noted
[2] Source: PNL Food Transfer Factor Library, leafy vegetable values, except where noted
[3] Source: Baes et al. 1984; $B_r$, reproductive portion values; $B_v$, vegetative portion values

The intake rate of hazardous chemicals for a herbivore via consumption of plants is typically calculated as:

(2) $I_i = (C_{vi})(IR)(FI)/(BW)$

Where:

$I_i$ = Intake rate of the $i_{th}$ contaminant, mg $kg^{-1}$ $day^{-1}$
$C_{vi}$ = Contaminant concentration in plant, mg $kg^{-1}$
IR = Ingestion rate of food, kg $day^{-1}$ wet weight
FI = Fraction ingested from contaminated source, unitless
BW = Body weight, kg wet weight

Consumption rates by carnivores are calculated similarly, substituting the contaminant concentrations in the herbivore for the concentrations in plants. Contaminant concentrations in herbivore muscle are typically estimated using the equation:

(3) $C_{mi} = (C_{vi})(IR)(FI)(B_{mi})$

Where:

$C_{mi}$ = Contaminant concentration in muscle, mg $kg^{-1}$ wet weight
$C_{vi}$ = Contaminant concentration in plant, mg $kg^{-1}$ wet weight
IR = Ingestion rate of plants by herbivore, kg $day^{-1}$
FI = Fraction ingested from a contaminated source, unitless
$B_{mi}$ = Plant-to-muscle transfer factor, day $kg^{-1}$

However, as described in the following text, radionuclide body burdens were estimated from element-specific fractions retained, biological half-lives, and radiological half-lives. Therefore, for purposes of consistency, nonradiological body burdens were estimated in the same way, assuming an infinite radiological half-life. The resulting equation is:

(4) $C_{mi} = [(C_{vi})(IR)(FI)(FR)(B_i)]/BW$

Where:

| | | |
|---|---|---|
| $C_{mi}$ | = | Contaminant concentration in muscle, mg $kg^{-1}$ wet weight |
| $C_{vi}$ | = | Contaminant concentration in plant, mg $kg^{-1}$ wet weight |
| IR | = | Ingestion rate of plants by herbivore, kg $day^{-1}$ |
| FI | = | Fraction ingested from a contaminated source, unitless |
| FR | = | Fraction retained (Baker-Soldat 1992) |
| $B_i$ | = | Effective half-life (days), calculated as described in Baker and Soldat (Baker-Soldat 1992); assuming radiological half-life to be infinite reduces it to the biological half-life. |

This equation assumes that the body burden is at steady state following chronic intake by a secondary receptor.

Food ingestion rates and body weights used in estimating exposures for this EIS are listed in Table D.6.2.1. Intakes via inhalation and water ingestion were estimated following procedures recommended in EPA (EPA 1993) when species-specific values were not available (Table D.6.2.1).

D.6.3.2.2 Calculation of Hazard Indices

The HI, the ratio of estimated intake to that expected to have no adverse effect, is typically calculated as:

$HI = I/NOAEL$

Where I is calculated as described in equation (2), and the No Observed Adverse Effect Level (NOAEL) is obtained from the literature as described in the following text. Both are expressed as mg per kg body weight per day.

An HI greater than 1.0 for a given chemical indicates that the estimated intake exceeds the threshold level and adverse health effects may occur. An HI less than 1.0 is indicative of no adverse impacts. For sites with multiple chemicals, the HIs may be summed, making the assumption that the modes of action and target organs of the chemicals are similar. Thus, a site may be said to present a hazard if the sum of the HIs exceeds 1.0, even if the individual chemical HIs are less than 1.0. URFs were estimated to allow calculation of the HIs directly from media concentrations, without the necessity of separate calculations of uptake at each trophic level. This consists of simply combining all the variables except the medium concentration for each constituent of concern for each organism. URFs for food ingestion and water ingestion are summarized in Tables D.6.3.3 and D.6.3.4, respectively.

Table D.6.3.3 Food Ingestion Unit Risk Factors, Chemicals

| | Food Ingestion Unit Risk Factor (HQ/mg/kg soil) | | | | |
|---|---|---|---|---|---|
| Chemical | Mouse | Coyote | Deer | Hawk | Shrike |
| Ag+ | 4.09E-01 | 1.92E-02 | 2.10E-01 | 1.28E-03 | 3.02E-03 |
| Al total | N/A | N/A | N/A | N/A | N/A |
| Al(OH)-4 | N/A | N/A | N/A | N/A | N/A |
| Al+3 | 4.26E-04 | N/A | 1.34E-04 | N/A | N/A |
| As+5 | 1.00E-01 | 1.57E+00 | 5.15E-03 | 7.71E-03 | 5.58E-03 |
| B+3 | 6.56E-02 | N/A | 6.73E-03 | N/A | N/A |
| Ba+2 | 4.41E-04 | 5.28E-04 | 2.26E-04 | 1.17E-04 | 8.49E-05 |
| Be+2 | 2.79E-03 | 3.56E-04 | 3.47E-04 | 1.76E-03 | 4.18E-03 |
| Bi+3 | N/A | N/A | N/A | N/A | N/A |
| Ca+2 | N/A | N/A | N/A | N/A | N/A |
| Cd+2 | 3.97E+00 | 5.35E+00 | 6.78E-01 | 1.35E-01 | 9.74E-02 |
| Ce+3 | N/A | N/A | N/A | N/A | N/A |
| Cl- | N/A | N/A | N/A | N/A | N/A |
| CO3-2 | N/A | N/A | N/A | N/A | N/A |
| Cr+3 | 8.15E-07 | 3.18E-06 | 4.18E-07 | 3.66E-03 | 2.65E-03 |
| CrO4-2 | 6.80E-04 | 2.65E-03 | 3.49E-04 | 5.90E-03 | 4.27E-03 |
| Total Cr | N/A | N/A | N/A | N/A | N/A |
| Cu+2 | 1.68E-03 | 1.21E-02 | 8.60E-04 | 3.38E-03 | 2.45E-03 |
| F- | 2.51E-04 | 1.02E-02 | 1.28E-05 | 4.68E-02 | 3.39E-02 |
| Fe(CN)6-4 | 4.06E-04 | N/A | 8.32E-05 | N/A | N/A |
| Fe+3 | N/A | N/A | N/A | N/A | N/A |
| Hg+ | 8.71E+00 | 1.64E+01 | 4.47E+00 | 7.43E+00 | 5.38E+00 |
| K+ | N/A | N/A | N/A | N/A | N/A |
| La+ | N/A | N/A | N/A | N/A | N/A |
| Li+ | 2.38E-04 | N/A | 7.61E-05 | N/A | N/A |
| Mg+2 | N/A | N/A | N/A | N/A | N/A |
| Mn+4 | 1.27E-03 | 4.05E-04 | 2.27E-04 | 7.23E-03 | 1.71E-02 |
| Mo+6 | N/A | N/A | N/A | N/A | N/A |
| Na+ | N/A | N/A | N/A | N/A | N/A |
| Ni+2 | 6.97E-04 | 1.38E-03 | 7.15E-05 | 3.51E-04 | 2.54E-04 |
| NO2- | N/A | N/A | N/A | N/A | N/A |
| PO4-3 | N/A | N/A | N/A | N/A | N/A |
| SiO3- | N/A | N/A | N/A | N/A | N/A |

Table D.6.3.3 Food Ingestion Unit Risk Factors, Chemicals (cont'd)

| | Food Ingestion Unit Risk Factor (HQ/mg/kg soil) | | | | |
|---|---|---|---|---|---|
| Chemical | Mouse | Coyote | Deer | Hawk | Shrike |
| SO4-2 | N/A | N/A | N/A | N/A | N/A |
| Sr+2 | 4.24E-04 | 5.87E-03 | 2.17E-04 | N/A | N/A |
| TOC (2) | N/A | N/A | N/A | N/A | N/A |
| TOC (4) | N/A | N/A | N/A | N/A | N/A |
| UO2+2 | 8.24E-05 | 7.13E-05 | 8.45E-05 | 2.54E-06 | 1.84E-06 |
| V+5 | 7.97E-03 | N/A | 7.49E-04 | N/A | N/A |
| W+4 | 1.72E-03 | 9.73E-05 | 8.84E-04 | N/A | N/A |
| Zn+2 | 6.97E-03 | 1.45E-01 | 3.57E-04 | 3.51E+00 | 2.54E+00 |
| Zr+4 | 2.91E-02 | 2.12E-03 | 1.49E-03 | N/A | N/A |

Tables D.6.3.4 Water Ingestion Unit Risk Factors, Chemicals

| | Water Ingestion Unit Risk Factor (HQ/mg//L) | | | |
|---|---|---|---|---|
| Chemical | Coyote | Deer | Hawk | Shrike |
| Ag+ | 9.68E-01 | 3.55E-01 | 4.73E-02 | 3.32E-01 |
| Al total | N/A | N/A | N/A | N/A |
| Al(OH)-4 | N/A | N/A | N/A | N/A |
| Al+3 | 9.31E-02 | 3.42E-02 | 4.43E-04 | 9.49E-04 |
| As+5 | 1.43E+00 | 5.24E-01 | 5.16E-03 | 1.11E-02 |
| B+3 | 4.66E-03 | 1.71E-03 | 1.57E-01 | 3.37E-01 |
| Ba+2 | 1.57E-02 | 5.75E-03 | 2.57E-03 | 5.50E-03 |
| Be+2 | 1.20E-01 | 4.41E-02 | 4.38E-01 | 3.07E+00 |
| Bi+3 | N/A | N/A | N/A | N/A |
| Ca+2 | N/A | N/A | N/A | N/A |
| Cd+2 | 9.39E-01 | 3.45E-01 | 1.74E-02 | 3.73E-02 |
| Ce+3 | N/A | N/A | N/A | N/A |
| Cl- | N/A | N/A | N/A | N/A |
| CO3-2 | N/A | N/A | N/A | N/A |
| Cr+3 | 2.89E-05 | 1.06E-05 | 2.46E-02 | 5.27E-02 |
| CrO4-2 | 2.42E-02 | 8.87E-03 | 3.96E-02 | 8.49E-02 |
| Total Cr | N/A | N/A | N/A | N/A |
| Cu+2 | 4.77E-03 | 1.75E-03 | 9.83E-04 | 2.11E-03 |
| F- | 1.78E-03 | 6.54E-04 | 6.00E-03 | 1.29E-02 |
| Fe(CN)6-4 | 1.15E-02 | 4.24E-03 | N/A | N/A |
| Fe+3 | N/A | N/A | N/A | N/A |
| Hg+ | 1.24E+01 | 4.55E+00 | 4.14E+00 | 8.87E+00 |
| K+ | N/A | N/A | N/A | N/A |
| La+ | N/A | N/A | N/A | N/A |
| Li+ | 8.44E-03 | 3.10E-03 | N/A | N/A |
| Mg+2 | N/A | N/A | N/A | N/A |
| Mn+4 | 9.00E-04 | 3.31E-04 | 1.18E-02 | 8.30E-02 |
| Mo+6 | N/A | N/A | N/A | N/A |
| Na+ | N/A | N/A | N/A | N/A |
| Ni+2 | 1.98E-03 | 7.28E-04 | 3.71E-04 | 7.96E-04 |
| NO2- | 1.18E-03 | 4.34E-04 | N/A | N/A |
| PO4-3 | N/A | N/A | N/A | N/A |
| SiO3- | N/A | N/A | N/A | N/A |
| SO4-2 | N/A | N/A | N/A | N/A |
| Sr+2 | 3.01E-04 | 1.11E-04 | N/A | N/A |
| TOC (2) | N/A | N/A | N/A | N/A |
| TOC (4) | N/A | N/A | N/A | N/A |
| UO2+2 | 5.85E-02 | 2.15E-02 | 1.54E-03 | 3.29E-03 |
| V+5 | 3.77E-01 | 1.39E-01 | 2.21E-03 | 4.73E-03 |
| W+4 | 8.17E-04 | 3.00E-04 | N/A | N/A |
| Zn+2 | 4.95E-04 | 1.82E-04 | 8.83E-03 | 1.89E-02 |
| Zr+4 | 1.03E-01 | 3.80E-02 | N/A | N/A |

Table D.6.3.5 Ingestion No Observed Adverse Effect Levels Used to Estimate Hazard Quotients

| | | Test Species Data | | | | Wildlife Ingestion NOEL (mg/kg/d) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Chemical | Plant NOEL (soil, mg/kg)[a] | Mammal Test Species | NOEL[b] (mg/kg/d) | Bird Test Species | NOEL[b] (mg/kg/d) | Mouse | Coyote | Deer | Hawk | Shrike |
| Ag+ | 2.00E+00 | Human | 1.40E-02 | Unknown | 5.00E-01[c] | 2.00E-01 | 2.70E-02 | 1.50E-02 | 5.00E-01 | 5.00E-01 |
| Al total | 5.00E+01 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Al(OH)-4 | 5.00E+01 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Al+3 | 5.00E+01 | Mouse | 1.93E+00 | Ringed dove | 1.11E+02 | 2.08E+00 | 2.80E-01 | 1.56E-01 | 5.35E+01 | 1.75E+02 |
| As+5 | 1.00E+01 | Mouse | 1.26E-01 | Mallard | 5.14E+00 | 1.36E-01 | 1.83E-02 | 1.02E-02 | 4.59E+00 | 1.50E+01 |
| B+3 | 5.00E-01 | Rat | 1.70E+01 | Mallard | 5.10E-01 | 4.15E+01 | 5.60E+00 | 3.11E+00 | 1.51E-01 | 4.92E-01 |
| Ba+2 | 5.00E+02 | Rat | 5.06E+00 | Chick | 2.09E+01 | 1.24E+01 | 1.67E+00 | 9.27E-01 | 9.22E+00 | 3.02E+01 |
| Be+2 | 1.00E+01 | Rat | 6.60E-01 | Unknown | 5.40E-02[c] | 1.61E+00 | 2.17E-01 | 1.21E-01 | 5.40E-02 | 5.40E-02 |
| Bi+3 | ND | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Ca+2 | ND | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Cd+2 | 3.00E+00 | Mouse | 1.91E-01 | Mallard | 1.45E+00 | 2.06E-01 | 2.78E-02 | 1.54E-02 | 1.36E+00 | 4.45E+00 |
| Ce+3 | ND | N/A | Nontoxic[d] | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Cl- | ND | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| CO3-2 | ND | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Cr+3 | 1.00E+00 | Rat | 2.74E+03 | Black duck | 1.00E+00 | 6.69E+03 | 9.01E+02 | 5.01E+02 | 9.63E-01 | 3.15E+00 |
| CrO4-2 | 1.00E+00 | Rat | 3.28E+00 | Chick[d] | 8.24E-01 | 8.01E+00 | 1.08E+00 | 6.01E-01 | 5.98E-01 | 1.95E+00 |
| Total Cr | 1.00E+00 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Cu+2 | 1.00E+02 | Mink | 1.17E+01 | Chick | 3.32E+01 | 4.06E+01 | 5.47E+00 | 3.04E+00 | 2.41E+01 | 7.88E+01 |
| F- | 2.00E+02 | Mink | 3.14E+01 | Screech Owl | 7.80E+00 | 1.09E+02 | 1.47E+01 | 8.15E+00 | 3.94E+00 | 1.29E+01 |
| K+ | ND | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| La+ | ND | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Li+ | 2.00E+00 | Rat | 9.39E+00 | N/A | N/A | 2.29E+01 | 3.09E+00 | 1.72E+00 | N/A | N/A |
| Mg+2 | ND | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Mn+4 | 5.00E+02 | Rat | 8.80E+01 | Unknown[c] | 2.00E+00 | 2.15E+02 | 2.90E+01 | 1.61E+01 | 2.00E+00 | 2.00E+00 |
| Mo+6 | 2.00E+00 | Mule deer | 1.30E+00[d] | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Na+ | ND | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Ni+2 | 3.00E+01 | Rat | 4.00E+01 | Mallard duckling | 7.74E+01 | 9.77E+01 | 1.32E+01 | 7.32E+00 | 6.37E+01 | 2.09E+02 |
| NO2- | ND | Rat | 6.70E+01 | N/A | N/A | 1.64E+02 | 2.21E+01 | 1.23E+01 | N/A | N/A |
| NO3- | ND | Guinea pig | 5.07E+02 | N/A | N/A | 3.64E+03 | 4.90E+02 | 2.73E+02 | N/A | N/A |
| OH- | ND | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

Table D.6.3.5 Ingestion No Observed Adverse Effect Levels Used to Estimate Hazard Quotients (cont'd)

| | | Test Species Data | | | | Wildlife Ingestion NOEL (mg/kg/d) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Chemical | Plant NOEL (soil, mg/kg)[a] | Mammal Test Species | NOEL[b] (mg/kg/d) | Bird Test Species | NOEL[b] (mg/kg/d) | Mouse | Coyote | Deer | Hawk | Shrike |
| Pb+4 | 5.00E+01 | Rat | 8.00E+00 | Kestrel | 3.85E+00 | 1.95E+01 | 2.63E+00 | 1.46E+00 | 1.74E+00 | 5.70E+00 |
| PO4-3 | ND | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| SiO3- | ND | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| SO4-2 | ND | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Sr+2 | ND | Rat | 2.63E+02 | N/A | N/A | 6.43E+02 | 8.66E+01 | 4.82E+01 | N/A | N/A |
| TOC (2) | ND | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| TOC (4) | ND | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| UO2+2 | 5.00E+00 | Mouse | 3.07E+00 | Black duck | 1.60E+01 | 3.31E+00 | 4.46E-01 | 2.48E-01 | 1.54E+01 | 5.04E+01 |
| Zr+4 | ND | Mouse | 1.74E+00 | N/A | N/A | 1.87E+00 | 2.52E-01 | 1.40E-01 | N/A | N/A |

Notes:
[a] Source: (Will and Suter 1994)
[b] Source: (Opresko et al. 1994), except where noted.
[c] Source: (DOE 1994) No scaling attempted.
[d] Source: See Section D6.6, Derivation of Ecological No Observed Adverse Effect Levels.
ND: No published data.

NOAELs were obtained from a variety of sources, with Opresko et al. (Opresko et al. 1994) as the primary source (Table D.6.3.5). Wildlife NOAELs for test species other than those of interest here were scaled to the body weight of the organism using the equation:

(5) $NOAEL_y = (NOAEL_x)[(bw_x)/(bw_y)]^{1/3}$

Where:

$NOAEL_y$ = NOAEL for the organism of interest
$NOAEL_x$ = NOAEL for experimental animal available from the literature
$bw_y$ = Body weight of the organism of interest
$bw_x$ = Body weight of experimental animal with the known NOAEL (Table D.6.3.6)

Scaling factors estimated according to Equation (5) are summarized in Table D.6.3.6. NOAELs for plants (Table D.6.3.5) were obtained as benchmark soil concentrations from Will and Suter (Will-Suter 1994), and the vegetation HIs were calculated as the waste unit soil concentration divided by the NOAEL.

Table D.6.3.6 Scaling Factors for Extrapolating No Observed Adverse Effect Levels Between Species

| Test Organism, Chemical [2] | Test Organism wt, kg | NOEL Scaling Factor [1] | | | | |
|---|---|---|---|---|---|---|
| | | Mouse | Coyote | Deer | Hawk | Shrike |
| Rat | 3.50E-01 | 2.44E+00 | 3.29E-01 | 1.83E-01 | N/A | N/A |
| Mouse | 3.00E-02 | 1.08E+00 | 1.45E-01 | 8.07E-02 | N/A | N/A |
| Mink | 1.00E+00 | 3.47E+00 | 4.67E-01 | 2.60E-01 | N/A | N/A |
| Guinea pig | 8.86E+00 | 7.17E+00 | 9.67E-01 | 5.38E-01 | N/A | N/A |
| Mule deer, Mo | 5.70E+01 | 1.33E+01 | 1.80E+00 | 1.00E+00 | N/A | N/A |
| Human | 7.00E+01 | 1.43E+01 | 1.93E+00 | 1.07E+00 | N/A | N/A |
| Ringed dove, Al | 1.55E-01 | N/A | N/A | N/A | 4.80E-01 | 1.57E+00 |
| Mallard, As | 1.00E+00 | N/A | N/A | N/A | 8.94E-01 | 2.92E+00 |
| Chick, Ba | 1.21E-01 | N/A | N/A | N/A | 4.42E-01 | 1.45E+00 |
| Mallard, Cd | 1.15E+00 | N/A | N/A | N/A | 9.37E-01 | 3.07E+00 |
| Black duck, Cr | 1.25E+00 | N/A | N/A | N/A | 9.63E-01 | 3.15E+00 |
| Chicken, CrVI, Cu | 5.34E-01 | N/A | N/A | N/A | 7.25E-01 | 2.37E+00 |
| Screech owl, F | 1.81E-01 | N/A | N/A | N/A | 5.06E-01 | 1.65E+00 |
| Mallard, Hg | 1.00E+00 | N/A | N/A | N/A | 8.94E-01 | 2.92E+00 |
| Mallard, Ni | 7.82E-01 | N/A | N/A | N/A | 8.24E-01 | 2.69E+00 |
| Kestrel, Pb | 1.30E-01 | N/A | N/A | N/A | 4.53E-01 | 1.48E+00 |
| Black duck, U | 1.25E+00 | N/A | N/A | N/A | 9.63E-01 | 3.15E+00 |
| Mallard, V | 1.17E+00 | N/A | N/A | N/A | 9.42E-01 | 3.08E+00 |
| Mallard, Zn | 1.00E+00 | N/A | N/A | N/A | 8.94E-01 | 2.92E+00 |
| Mallard duckling, B | 3.60E-02 | N/A | N/A | N/A | 2.95E-01 | 9.65E-01 |

Notes:
[1] Calculated using Equation 4 (Opresko et al. 1994)
[2] See Table D.6.3.5 for data sources.
N/A= Not applicable

D.6.3.2.3 Estimation of Radiation Doses

Radiation doses to ecological receptors were calculated using URFs analogous to those for chemicals. The basic equation used to estimate radiation dose to the pocket mouse was as follows:

(6) Dose rate (rad $d^{-1}$) = $[(CS)(PS)(WW)(Q_v)(FI)(EF)(ED)(FR)(B_i)(E_i)(1\ y/365\ d)]/[(BW)(AT)]$

Where:

| | | |
|---|---|---|
| CS | = | Radionuclide concentration in soil, Ci/kg |
| PS | = | Soil-to-plant transfer factor |
| WW | = | Wet-to-dry weight conversion factor, 0.4 |
| $Q_v$ | = | Ingestion rate, kg/day |
| FI | = | Fraction ingested from contaminated source |
| EF | = | Exposure frequency, 365 day/year |
| ED | = | Exposure duration, 1 year |
| FR | = | Fraction retained (Baker-Soldat 1992) |

| | | |
|---|---|---|
| $B_i$ | = | Effective decay constant of the radionuclide (days), calculated as described in Baker and Soldat (Baker-Soldat 1992); takes both radioactive decay and biological turnover into account. |
| $E_i$ | = | Effective energy absorbed, ($5.12 \cdot 10^{6}$ kg rad $Ci^{-1}$ $d^{-1}$ $MeV^{-1}$ dis) (MeV $dis^{-1}$), using MeVs obtained from Baker and Soldat (Baker-Soldat 1992) |
| BW | = | Body weight, kg |
| AT | = | Averaging time, 1 year |

The doses to predators were calculated similarly, substituting the concentration in the mouse for that in the plant. Radionuclide properties and transfer factors used in the calculations are listed in Tables D.6.3.7 and D.6.3.1, respectively. URFs were estimated to allow calculation of doses directly from media concentrations, without the necessity of separate calculations of uptake at each trophic level. URFs for food ingestion are summarized in Table D.6.3.8. Radiation doses were calculated as the product of the URF and the medium concentration.

Doses resulting from ingestion of water, ingestion of soil, and inhalation were estimated in the same way, substituting the appropriate intake rates for the food ingestion rate and are summarized in Tables D.6.3.9, D.6.3.10 and D.6.3.11, respectively. As noted in Table D.6.2.1, inhalation and water ingestion rates were estimated using equations from the EPA (EPA 1993) when species-specific values were not available.

Doses to pocket mice and plants via direct radiation were calculated using the equation:

(7) Dose rate (rad $day^{-1}$) = [(24)(2.12)(E)(C)]/p (Jacobs 1996)

Where:

| | | |
|---|---|---|
| 24 | = | h/d |
| 2.12 | = | Constant to convert units to rad $h^{-1}$ |
| | = | (U)(V)(W)(X)(Y)(Z), dis-rad-g/$\mu$Ci-hr-MeV |

Where:

| | | |
|---|---|---|
| U | = | 1 Ci/$10^{6}$ $\mu$Ci |
| V | = | $3.7 \cdot 10^{10}$ disintegrations/Ci-sec |
| W | = | 3600 sec/hour |
| X | = | $10^{6}$ eV/MeV |
| Y | = | $1.6 \cdot 10^{-12}$ erg/eV |
| Z | = | 1 rad-g/100 ergs |
| E | = | Average gamma energy per disintegration, MeV/dis |
| C | = | Radionuclide concentration in soil, uCi/$cm^3$ |
| p | = | Soil density, g/$cm^3$ |

URFs for direct exposure are listed in Table D.6.3.12.

**Table D.6.3.7 Radionuclide Properties Used to Estimate Radiation Doses to Ecological Receptors**

| Radio-nuclide | $T_r$ (Rad half-life) | $T_r$ units | $T_b$ (Bio half-life,d) | $f_1$ (Ingest) | $f_1$ (Inhale) | Radionuclide Effective Energy ($MeVdis^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Plant (1.4 cm) | Mouse (2 cm) | Coyote (30 cm) | Deer (30 cm) | Hawk (5 cm) | Shrike (2 cm) |
| Ac-225 | 1.00E+01 | D | 2.40E+04 | 1.00E-03 | 1.00E-03 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ac-227 | 2.18E+01 | Y | 2.40E+04 | 1.00E-03 | 1.00E-03 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ac-228 | 6.13E+00 | H | 2.40E+04 | 1.00E-03 | 1.00E-03 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ag-110 | 2.50E+02 | D | 5.00E+00 | 5.00E-02 | 5.00E-02 | 1.88E-01 | 2.35E-01 | 1.68E+00 | 1.68E+00 | 4.56E-01 | 2.35E-01 |
| Am-241 | 4.32E+02 | Y | 2.00E+04 | 1.00E-03 | 1.00E-03 | 5.51E+00 | 5.51E+00 | 5.40E+00 | 5.40E+00 | 5.52E+00 | 5.51E+00 |
| Am-242 | 1.60E+01 | H | 2.00E+04 | 1.00E-03 | 1.00E-03 | N/A | N/A | N/A | N/A | N/A | N/A |
| Am-242m | 1.52E+02 | Y | 2.00E+04 | 1.00E-03 | 1.00E-03 | N/A | N/A | N/A | N/A | N/A | N/A |
| Am-243 | 7.38E+03 | Y | 2.00E+04 | 1.00E-03 | 1.00E-03 | N/A | N/A | N/A | N/A | N/A | N/A |
| At-217 | 3.23E-02 | S | 2.70E+01 | 1.00E+00 | 1.00E+00 | N/A | N/A | N/A | N/A | N/A | N/A |
| Au-195 | 1.83E+02 | D | 1.20E+02 | 1.00E-01 | 1.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ba-133 | 3.92E+03 | D | 6.50E+01 | 1.00E-01 | 1.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ba-135m | 2.87E+01 | H | 6.50E+01 | 1.00E-01 | 1.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ba-137m | 2.52E+00 | M | 6.50E+01 | 1.00E+00 | 1.00E+00 | N/A | N/A | N/A | N/A | N/A | N/A |
| Be-10 | 2.70E+06 | Y | 1.80E+02 | 5.00E-03 | 5.00E-03 | N/A | N/A | N/A | N/A | N/A | N/A |
| Be-7 | 5.30E+01 | D | 1.80E+02 | 5.00E-03 | 5.00E-03 | N/A | 4.90E-03 | 2.60E-02 | 2.60E-02 | N/A | 4.90E-03 |
| Bi-210 | 5.01E+00 | D | 5.00E+00 | 5.00E-02 | 5.00E-02 | N/A | N/A | N/A | N/A | N/A | N/A |
| Bi-211 | 2.13E+00 | M | 5.00E+00 | 5.00E-02 | 5.00E-02 | N/A | N/A | N/A | N/A | N/A | N/A |
| Bi-212 | 6.06E+01 | M | 5.00E+00 | 5.00E-02 | 5.00E-02 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ce-144 | 2.84E+02 | D | 5.63E+02 | 3.00E-04 | 3.00E-04 | 1.32E+00 | 1.32E+00 | 1.35E+00 | 1.35E+00 | 1.33E+00 | 1.32E+00 |
| Cf-252 | 2.64E+00 | Y | 6.50E+04 | 1.00E-03 | 1.00E-03 | 1.22E+01 | 1.22E+01 | 1.65E+01 | 1.65E+01 | 1.22E+01 | 1.22E+01 |
| C-l36 | 3.00E+05 | Y | 2.90E+01 | 1.00E+00 | 1.00E+00 | N/A | N/A | N/A | N/A | N/A | N/A |
| Cm-242 | 1.63E+02 | D | 2.40E+04 | 1.00E-03 | 1.00E-03 | 6.11E+00 | 6.11E+00 | 6.10E+00 | 6.10E+00 | 6.11E+00 | 6.11E+00 |
| Cm-243 | 3.20E+01 | Y | 2.40E+04 | 1.00E-03 | 1.00E-03 | N/A | N/A | N/A | N/A | N/A | N/A |
| Cm-244 | 1.81E+01 | Y | 2.40E+04 | 1.00E-03 | 1.00E-03 | 5.80E+00 | 5.80E+00 | 5.80E+00 | 5.80E+00 | 5.80E+00 | 5.80E+00 |
| Cm-245 | 8.50E+03 | Y | 2.40E+04 | 1.00E-03 | 1.00E-03 | N/A | N/A | N/A | N/A | N/A | N/A |
| Co-57 | 2.71E+02 | D | 9.50E+00 | 3.00E-01 | 3.00E-01 | 3.90E-02 | 4.09E-02 | 1.00E-01 | 1.00E-01 | 4.96E-02 | 4.09E-02 |
| Co-58 | 7.08E+01 | D | 9.50E+00 | 3.00E-01 | 3.00E-01 | 7.28E-02 | 9.05E-02 | 6.33E-01 | 6.33E-01 | 1.74E-01 | 9.05E-02 |
| Co-60 | 5.27E+00 | Y | 9.50E+00 | 3.00E-01 | 3.00E-01 | 1.95E-01 | 2.37E-01 | 1.56E+00 | 1.56E+00 | 4.37E-01 | 2.37E-01 |
| Cs-134 | 2.06E+00 | Y | 1.15E+02 | 1.00E+00 | 1.00E+00 | 2.30E-01 | 2.59E-01 | 1.14E+00 | 1.14E+00 | 3.96E-01 | 2.59E-01 |
| Cs-135 | 2.30E+06 | Y | 1.15E+02 | 1.00E+00 | 1.00E+00 | 5.80E-02 | 5.80E-02 | 5.80E-02 | 5.80E-02 | 5.80E-02 | 5.80E-02 |
| Cs-137 | 3.02E+01 | Y | 1.15E+02 | 1.00E+00 | 1.00E+00 | 2.57E-01 | 2.67E-01 | 5.82E-01 | 5.82E-01 | 3.16E-01 | 2.67E-01 |
| Es-254 | 2.76E+02 | D | N/A | 1.00E-03 | 1.00E-03 | N/A | N/A | N/A | N/A | N/A | N/A |

Table D.6.3.7 Radionuclide Properties Used to Estimate Radiation Doses to Ecological Receptors (cont'd)

| Radio-nuclide | $T_r$ (Rad half-life) | $T_r$ units | $T_b$ (Bio half-life,d) | $f_1$ (Ingest) | $f_1$ (Inhale) | Radionuclide Effective Energy (MeVdis$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Plant (1.4 cm) | Mouse (2 cm) | Coyote (30 cm) | Deer (30 cm) | Hawk (5 cm) | Shrike (2 cm) |
| Eu-152 | 1.33E+01 | Y | 6.35E+02 | 1.00E-03 | 1.00E-03 | 1.20E-01 | 1.20E-01 | 6.60E-01 | 6.60E-01 | 2.00E-01 | 1.20E-01 |
| Eu-154 | 8.80E+00 | Y | 6.35E+02 | 1.00E-03 | 1.00E-03 | 3.11E-01 | 3.11E-01 | 9.65E-01 | 9.65E-01 | 4.28E-01 | 3.11E-01 |
| Eu-155 | 4.96E+00 | Y | 6.35E+02 | 1.00E-03 | 1.00E-03 | 5.90E-02 | 6.10E-02 | 1.60E-01 | 1.60E-01 | 7.50E-02 | 6.10E-02 |
| Fe-55 | 2.70E+00 | Y | 8.00E+02 | 1.00E-01 | 1.00E-01 | 7.26E-03 | 7.26E-03 | 7.26E-03 | 7.26E-03 | 7.26E-03 | 7.26E-03 |
| Fe-59 | 4.45E+01 | D | 8.00E+02 | 1.00E-01 | 1.00E-01 | 1.71E-01 | 1.91E-01 | 8.24E-01 | 8.24E-01 | 2.86E-01 | 1.91E-01 |
| Fr-221 | 4.80E+00 | M | N/A | 1.00E+00 | 1.00E+00 | N/A | N/A | N/A | N/A | N/A | N/A |
| Hf-181 | 4.24E+01 | D | 5.63E+02 | 2.00E-03 | 2.00E-03 | N/A | N/A | N/A | N/A | N/A | N/A |
| I-125 | 6.00E+01 | D | 1.00E+02 | 1.00E+00 | 1.00E+00 | N/A | N/A | N/A | N/A | N/A | N/A |
| I-129 | 1.57E+07 | Y | 1.00E+02 | 1.00E+00 | 1.00E+00 | 6.02E-02 | 6.28E-02 | 8.72E-02 | 8.72E-02 | 6.94E-02 | 6.28E-02 |
| K-40 | 1.30E-09 | Y | 5.80E+01 | 1.00E+00 | 1.00E+00 | N/A | N/A | N/A | N/A | N/A | N/A |
| Kr-85 | 1.07E+01 | Y | 0.00E+00 | 0.00E+00 | 0.00E+00 | 2.24E-01 | 2.24E-01 | 2.25E-01 | 2.25E-01 | 2.24E-01 | 2.24E-01 |
| Mn-54 | 3.13E+02 | D | 1.70E+01 | 1.00E-01 | 1.00E-01 | 3.64E-02 | 5.14E-02 | 5.12E-01 | 5.12E-01 | 1.22E-01 | 5.14E-02 |
| Mo-93 | 1.28E+06 | D | 5.00E+00 | 8.00E-01 | 8.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Na-22 | 2.60E+00 | Y | 1.10E+01 | 1.00E+00 | 1.00E+00 | 2.86E-01 | 3.25E-01 | 1.51E+00 | 1.51E+00 | 5.07E-01 | 3.25E-01 |
| Nb-91 | N/A | | 7.60E+02 | 1.00E-02 | 1.00E-02 | N/A | N/A | N/A | N/A | N/A | N/A |
| Nb-93m | 1.46E+01 | Y | 7.60E+02 | 1.00E-02 | 1.00E-02 | N/A | N/A | N/A | N/A | N/A | N/A |
| Nb-94 | 7.41E+06 | D | 7.60E+02 | 1.00E-02 | 1.00E-02 | N/A | N/A | N/A | N/A | N/A | N/A |
| Nb-95 | 3.52E+01 | D | 7.60E+02 | 1.00E-02 | 1.00E-02 | 7.67E-02 | 9.06E-02 | 5.15E-01 | 5.15E-01 | 1.56E-01 | 9.06E-02 |
| Ni-59 | 7.50E+04 | Y | 6.67E+02 | 5.00E-02 | 5.00E-02 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ni-63 | 9.60E+01 | Y | 6.67E+02 | 5.00E-02 | 5.00E-02 | 1.76E-02 | 1.76E-02 | 1.76E-02 | 1.76E-02 | 1.76E-02 | 1.76E-02 |
| Np-237 | 2.14E+06 | Y | 3.90E+04 | 1.00E-03 | 1.00E-03 | 4.90E+00 | 4.90E+00 | 4.90E+00 | 4.90E+00 | 4.90E+00 | 4.90E+00 |
| Np-238 | 2.12E+00 | D | 3.90E+04 | 1.00E-03 | 1.00E-03 | 2.63E-01 | 2.70E-01 | 5.13E-01 | 5.13E-01 | 3.06E-01 | 2.70E-01 |
| Np-239 | 2.36E+00 | D | 3.90E+04 | 1.00E-03 | 1.00E-03 | 2.03E-01 | 2.05E-01 | 2.60E-01 | 2.60E-01 | 2.12E-01 | 2.05E-01 |
| Pa-231 | 3.28E+04 | Y | 4.10E+04 | 1.00E-03 | 1.00E-03 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pa-233 | 2.70E+01 | D | 4.10E+04 | 1.00E-03 | 1.00E-03 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pa-234 | 6.70E+00 | H | 4.10E+04 | 1.00E-03 | 1.00E-03 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pb-211 | 3.61E+01 | M | 1.46E+03 | 2.00E-01 | 2.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pb-212 | 1.06E+01 | H | 1.46E+03 | 2.00E-01 | 2.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pb-214 | 2.68E+01 | M | 1.46E+03 | 2.00E-01 | 2.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pd-107 | 6.50E+06 | Y | 5.00E+00 | 5.00E-03 | 5.00E-03 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pm-147 | 2.62E+00 | Y | 6.56E+02 | 3.00E-04 | 3.00E-04 | 6.20E-02 | 6.20E-02 | 6.20E-02 | 6.20E-02 | 6.20E-02 | 6.20E-02 |
| Po-210 | 1.38E+02 | D | 3.00E+01 | 1.00E-01 | 1.00E-01 | 5.51E+00 | 5.51E+00 | 5.51E+00 | 5.51E+00 | 5.51E+00 | 5.51E+00 |

Table D.6.3.7 Radionuclide Properties Used to Estimate Radiation Doses to Ecological Receptors (cont'd)

| Radio-nuclide | $T_r$ (Rad half-life) | $T_r$ units | $T_b$ (Bio half-life,d) | $f_1$ (Ingest) | $f_1$ (Inhale) | Radionuclide Effective Energy (MeVdis $^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Plant (1.4 cm) | Mouse (2 cm) | Coyote (30 cm) | Deer (30 cm) | Hawk (5 cm) | Shrike (2 cm) |
| Po-211 | 5.16E-01 | S | 3.00E+01 | 1.00E-01 | 1.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Po-212 | 2.98E-07 | S | 3.00E+01 | 1.00E-01 | 1.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Po-213 | 4.20E-06 | S | 3.00E+01 | 1.00E-01 | 1.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Po-214 | 1.64E-04 | S | 3.00E+01 | 1.00E-01 | 1.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Po-215 | 1.78E-03 | S | 3.00E+01 | 1.00E-01 | 1.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Po-216 | 1.46E-01 | S | 3.00E+01 | 1.00E-01 | 1.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Po-218 | 3.05E+00 | M | 3.00E+01 | 1.00E-01 | 1.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pu-236 | 2.85E+00 | Y | 6.50E+04 | 1.00E-03 | 1.00E-03 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pu-238 | 8.77E+01 | Y | 6.50E+04 | 1.00E-03 | 1.00E-03 | 5.51E+00 | 5.51E+00 | 5.50E+00 | 5.50E+00 | 5.51E+00 | 5.51E+00 |
| Pu-239 | 2.41E+04 | Y | 6.50E+04 | 1.00E-03 | 1.00E-03 | 5.15E+00 | 5.15E+00 | 5.15E+00 | 5.15E+00 | 5.15E+00 | 5.15E+00 |
| Pu-240 | 6.54E+03 | Y | 6.50E+04 | 1.00E-03 | 1.00E-03 | 5.16E+00 | 5.16E+00 | 5.16E+00 | 5.16E+00 | 5.16E+00 | 5.16E+00 |
| Pu-241 | 1.44E+01 | Y | 6.50E+04 | 1.00E-03 | 1.00E-03 | 5.35E-03 | 5.35E-03 | 6.36E-03 | 6.36E-03 | 5.35E-03 | 5.35E-03 |
| Pu-242 | 3.76E+05 | Y | 6.50E+04 | 1.00E-03 | 1.00E-03 | 4.90E+00 | 4.90E+00 | 4.80E+00 | 4.80E+00 | 4.90E+00 | 4.90E+00 |
| Ra-223 | 1.14E+01 | D | 8.10E+03 | 2.00E-01 | 2.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ra-228 | 5.75E+00 | Y | 8.10E+03 | 2.00E-01 | 2.00E-01 | 6.00E+00 | 6.00E+00 | 2.30E+01 | 2.30E+01 | 6.00E+00 | 6.00E+00 |
| Re-187 | 7.00E+10 | Y | 7.00E+00 | 5.00E-01 | 8.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Rh-106 | 2.99E+01 | S | 1.04E+01 | 5.00E-02 | 5.00E-02 | N/A | N/A | N/A | N/A | N/A | N/A |
| Rn-219 | 3.96E+00 | S | 0.00E+00 | 0.00E+00 | 1.00E+00 | N/A | N/A | N/A | N/A | N/A | N/A |
| Rn-220 | 5.56E+01 | S | 0.00E+00 | 0.00E+00 | 1.00E+00 | N/A | N/A | N/A | N/A | N/A | N/A |
| Rn-222 | 3.82E+00 | D | 0.00E+00 | 0.00E+00 | 1.00E+00 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ru-103 | 3.93E+01 | D | 7.30E+00 | 5.00E-02 | 5.00E-02 | 1.16E-01 | 1.25E-01 | 3.99E-01 | 3.99E-01 | 1.68E-01 | 1.25E-01 |
| Ru-106 | 3.68E+02 | D | 7.30E+00 | 5.00E-02 | 5.00E-02 | 1.44E+00 | 1.44E+00 | 1.56E+00 | 1.56E+00 | 1.46E+00 | 1.44E+00 |
| S-35 | 8.67E+01 | D | 9.00E+01 | 8.00E-01 | 8.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Sb-124 | 6.02E+01 | D | 3.80E+01 | 1.00E-01 | 1.00E-01 | 4.59E-01 | 4.91E-01 | 1.51E+00 | 1.51E+00 | 6.44E-01 | 4.91E-01 |
| Sb-125 | 2.77E+00 | Y | 3.80E+01 | 1.00E-01 | 1.00E-01 | 1.05E-01 | 1.13E-01 | 3.53E-01 | 3.53E-01 | 1.50E-01 | 1.13E-01 |
| Sb-126 | 1.24E+01 | D | 3.80E+01 | 1.00E-01 | 1.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Sb-126m | 1.90E+01 | M | 3.80E+01 | 1.00E-01 | 1.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Sc-46 | 8.38E+01 | D | 3.00E+01 | 1.00E-04 | 1.00E-04 | 1.97E-01 | 2.32E-01 | 1.32E+00 | 1.32E+00 | 3.99E-01 | 2.32E-01 |
| Se-75 | 1.20E+02 | D | 1.10E+01 | 8.00E-01 | 8.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Se-79 | 6.50E+04 | Y | 1.10E+01 | 8.00E-01 | 8.00E-01 | N/A | N/A | N/A | N/A | N/A | N/A |
| Sm-147 | 1.06E+11 | Y | 6.56E+02 | 3.00E-04 | 3.00E-04 | N/A | N/A | N/A | N/A | N/A | N/A |
| Sm-151 | 9.00E+01 | Y | 6.56E+02 | 3.00E-04 | 3.00E-04 | N/A | N/A | N/A | N/A | N/A | N/A |

**Table D.6.3.7 Radionuclide Properties Used to Estimate Radiation Doses to Ecological Receptors (cont'd)**

| Radio-nuclide | $T_r$ (Rad half-life) | $T_r$ units | $T_b$ (Bio half-life, d) | $f_1$ (Ingest) | $f_1$ (Inhale) | Radionuclide Effective Energy (MeVdis $^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Plant (1.4 cm) | Mouse (2 cm) | Coyote (30 cm) | Deer (30 cm) | Hawk (5 cm) | Shrike (2 cm) |
| Sn-113 | 1.15E+02 | D | 3.50E+01 | 2.00E-02 | 2.00E-02 | N/A | N/A | N/A | N/A | N/A | N/A |
| Sn-123M | 4.01E+01 | M | 3.50E+01 | 2.00E-02 | 2.00E-02 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ta-182 | 1.15E+02 | D | 2.40E+02 | 1.00E-03 | 1.00E-03 | N/A | N/A | N/A | N/A | N/A | N/A |
| Tc-99 | 2.13E+05 | Y | 1.00E+00 | 8.00E-01 | 8.00E-01 | 8.40E-02 | 8.40E-02 | 8.40E-02 | 8.40E-02 | 8.40E-02 | 8.40E-02 |
| Te-125M | 5.80E+01 | D | 1.50E+01 | 2.00E-01 | 2.00E-01 | 1.11E-01 | 1.11E-01 | 1.14E-01 | 1.14E-01 | 1.12E-01 | 1.11E-01 |
| Te-127 | 9.35E+00 | H | 1.50E+01 | 2.00E-01 | 2.00E-01 | 2.23E-01 | 2.23E-01 | 2.24E-01 | 2.24E-01 | 2.23E-01 | 2.23E-01 |
| Te-129M | 3.36E+01 | D | 1.50E+01 | 2.00E-01 | 2.00E-01 | 5.99E-01 | 6.01E-01 | 6.67E-01 | 6.67E-01 | 6.12E-01 | 6.01E-01 |
| Th-227 | 1.87E+01 | D | 5.70E+04 | 2.00E-04 | 2.00E-04 | N/A | N/A | N/A | N/A | N/A | N/A |
| Th-228 | 1.91E+00 | Y | 5.70E+04 | 2.00E-04 | 2.00E-04 | 5.60E+00 | 5.60E+00 | 2.30E+01 | 2.30E+01 | 5.60E+00 | 5.60E+00 |
| Th-229 | 7.34E+03 | Y | 5.70E+04 | 2.00E-04 | 2.00E-04 | N/A | N/A | N/A | N/A | N/A | N/A |
| Th-230 | 7.70E+04 | Y | 5.70E+04 | 2.00E-04 | 2.00E-04 | 4.80E+00 | 4.80E+00 | 4.80E+00 | 4.80E+00 | 4.80E+00 | 4.80E+00 |
| Th-231 | 2.55E+01 | H | 5.70E+04 | 2.00E-04 | 2.00E-04 | N/A | N/A | N/A | N/A | N/A | N/A |
| Th-232 | 1.41E+10 | Y | 5.70E+04 | 2.00E-04 | 2.00E-04 | 4.10E+00 | 4.10E+00 | 6.20E+00 | 6.20E+00 | 4.10E+00 | 4.10E+00 |
| Th-233 | 2.23E+01 | M | 5.70E+04 | 2.00E-04 | 2.00E-04 | N/A | N/A | N/A | N/A | N/A | N/A |
| Th-234 | 2.41E+01 | D | 5.70E+04 | 2.00E-04 | 2.00E-04 | N/A | N/A | N/A | N/A | N/A | N/A |
| Tl-204 | 3.80E+00 | Y | 5.00E+00 | 1.00E+00 | 1.00E+00 | N/A | N/A | N/A | N/A | N/A | N/A |
| Tl-207 | 4.77E+00 | M | 5.00E+00 | 1.00E+00 | 1.00E+00 | N/A | N/A | N/A | N/A | N/A | N/A |
| Tl-208 | 3.05E+00 | M | 5.00E+00 | 1.00E+00 | 1.00E+00 | N/A | N/A | N/A | N/A | N/A | N/A |
| Tl-209 | 2.20E+00 | M | 5.00E+00 | 1.00E+00 | 1.00E+00 | N/A | N/A | N/A | N/A | N/A | N/A |
| Tm-170 | 1.29E+02 | D | 6.75E+02 | 3.00E-04 | 3.00E-04 | N/A | N/A | N/A | N/A | N/A | N/A |
| U-232 | 7.20E+01 | Y | 1.00E+02 | 5.00E-02 | 5.00E-02 | N/A | N/A | N/A | N/A | N/A | N/A |
| U-233 | 1.59E+05 | Y | 1.00E+02 | 5.00E-02 | 5.00E-02 | N/A | N/A | N/A | N/A | N/A | N/A |
| U-237 | 6.75E+00 | D | 1.00E+02 | 5.00E-02 | 5.00E-02 | 1.60E-01 | 1.60E-01 | 2.20E-01 | 2.20E-01 | 1.80E-01 | 1.60E-01 |
| U-238 | 4.47E+09 | Y | 1.00E+02 | 5.00E-02 | 5.00E-02 | 4.30E+00 | 4.30E+00 | 4.30E+00 | 4.30E+00 | 4.30E+00 | 4.30E+00 |
| V-49 | 3.30E+02 | D | 4.20E+01 | 2.00E-02 | 1.00E-02 | N/A | N/A | N/A | N/A | N/A | N/A |
| Y-88 | 1.07E+02 | D | 1.40E+04 | 1.00E-04 | 1.00E-04 | N/A | N/A | N/A | N/A | N/A | N/A |
| Y-90 | 6.40E+01 | H | 1.40E+04 | 1.00E-04 | 1.00E-04 | 9.39E-01 | 9.39E-01 | 9.39E-01 | 9.39E-01 | 9.39E-01 | 9.39E-01 |
| Zn-65 | 2.44E+02 | D | 9.33E+02 | 5.00E-01 | 5.00E-01 | 2.89E-02 | 3.86E-02 | 3.42E-01 | 3.42E-01 | 8.46E-02 | 3.86E-02 |
| Zr-93 | 1.53E+06 | Y | 4.50E+02 | 2.00E-03 | 2.00E-03 | N/A | N/A | N/A | N/A | N/A | N/A |
| Zr-95 | 6.40E+01 | D | 4.50E+02 | 2.00E-03 | 2.00E-03 | 2.27E-01 | 2.54E-01 | 1.07E+00 | 1.07E+00 | 3.80E-01 | 2.54E-01 |

Table D.6.3.8 Food Ingestion Unit Risk Factors, Radionuclides

| | Unit Dose Factor (Ingestion) (rad/day/Ci/kg soil) | | | | | |
|---|---|---|---|---|---|---|
| Radionuclide | Plant | Mouse | Coyote | Deer | Hawk | Shrike |
| Ac-225 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ac-227 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ac-228 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ag-110 | 5.78E+03 | 1.39E+02 | 2.06E+01 | 3.82E+01 | 6.88E+00 | 7.72E+00 |
| Am-241 | 5.64E+02 | 1.11E+01 | 1.76E+01 | 4.20E-01 | 2.21E+01 | 4.80E+01 |
| Am-242 | N/A | N/A | N/A | N/A | N/A | N/A |
| Am-242m | N/A | N/A | N/A | N/A | N/A | N/A |
| Am-243 | N/A | N/A | N/A | N/A | N/A | N/A |
| At-217 | N/A | N/A | N/A | N/A | N/A | N/A |
| Au-195 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ba-133 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ba-135m | N/A | N/A | N/A | N/A | N/A | N/A |
| Ba-137m | N/A | N/A | N/A | N/A | N/A | N/A |
| Be-10 | N/A | N/A | N/A | N/A | N/A | N/A |
| Be-7 | N/A | N/A | N/A | N/A | N/A | N/A |
| Bi-210 | N/A | N/A | N/A | N/A | N/A | N/A |
| Bi-211 | N/A | N/A | N/A | N/A | N/A | N/A |
| Bi-212 | N/A | N/A | N/A | N/A | N/A | N/A |
| Bi-213 | N/A | N/A | N/A | N/A | N/A | N/A |
| Bi-214 | N/A | N/A | N/A | N/A | N/A | N/A |
| C-14 | 0.00E+00 | 0.00E+00 | 2.55E+02 | 0.00E+00 | 3.14E+02 | 6.83E+02 |
| Ca-45 | N/A | N/A | N/A | N/A | N/A | N/A |
| Cd-109 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ce-144 | 2.70E+03 | 8.89E+00 | 1.45E-01 | 3.49E-01 | 1.75E-01 | 3.79E-01 |
| Cf-252 | 1.56E+03 | 2.73E+02 | 4.67E+01 | 1.42E+00 | 4.25E+01 | 9.25E+01 |
| Cl-36 | N/A | N/A | N/A | N/A | N/A | N/A |
| Cm-242 | 6.26E+02 | 6.30E+00 | 5.16E+00 | 2.42E-01 | 6.36E+00 | 1.38E+01 |
| Cm-243 | N/A | N/A | N/A | N/A | N/A | N/A |
| Cm-244 | 5.94E+02 | 1.15E+01 | 1.82E+01 | 4.43E-01 | 2.24E+01 | 4.88E+01 |
| Co-60 | 9.98E+02 | 1.08E+02 | 7.68E+02 | 6.84E+01 | 2.65E+02 | 3.13E+02 |
| Cs-134 | 2.36E+02 | 9.58E+03 | 7.36E+05 | 3.24E+02 | 3.15E+05 | 4.48E+05 |
| Cs-135 | 5.94E+01 | 2.39E+03 | 4.64E+04 | 1.83E+01 | 5.71E+04 | 1.24E+05 |
| Cs-137 | 2.63E+02 | 1.09E+04 | 4.59E+05 | 1.83E+02 | 3.07E+05 | 5.64E+05 |
| Es-254 | N/A | N/A | N/A | N/A | N/A | N/A |
| Eu-152 | 6.14E+01 | 1.97E+00 | 1.54E+00 | 2.08E-01 | 5.73E-01 | 7.48E-01 |
| Eu-154 | 1.59E+02 | 5.04E+00 | 2.19E+00 | 3.00E-01 | 1.20E+00 | 1.89E+00 |
| Eu-155 | 3.02E+01 | 9.61E-01 | 3.44E-01 | 4.84E-02 | 1.98E-01 | 3.51E-01 |

Table D.6.3.8 Food Ingestion Unit Risk Factors, Radionuclides (cont'd)

| | Unit Dose Factor (Ingestion) (rad/day/Ci/kg soil) | | | | | |
|---|---|---|---|---|---|---|
| Radionuclide | Plant | Mouse | Coyote | Deer | Hawk | Shrike |
| Fe-55 | 7.43E+00 | 2.81E+01 | 1.72E+02 | 4.33E-01 | 2.11E+02 | 4.60E+02 |
| Fe-59 | 1.75E+02 | 1.62E+02 | 9.30E+02 | 1.07E+01 | 3.97E+02 | 5.78E+02 |
| Fr-221 | N/A | N/A | N/A | N/A | N/A | N/A |
| Fr-223 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ge-68 | N/A | N/A | N/A | N/A | N/A | N/A |
| H-3 | 0.00E+00 | 0.00E+00 | 5.08E+01 | 0.00E+00 | 3.63E+01 | 7.89E+01 |
| Hf-181 | N/A | N/A | N/A | N/A | N/A | N/A |
| I-125 | N/A | N/A | N/A | N/A | N/A | N/A |
| I-129 | 1.23E+03 | 9.31E+04 | 7.91E+05 | 4.97E+02 | 7.75E+05 | 1.53E+06 |
| K-40 | N/A | N/A | N/A | N/A | N/A | N/A |
| Kr-85 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mn-54 | 1.30E+03 | 6.67E+02 | 7.47E+02 | 8.94E+01 | 2.19E+02 | 2.01E+02 |
| Mo-93 | N/A | N/A | N/A | N/A | N/A | N/A |
| Na-22 | 1.46E+05 | 1.42E+06 | 4.56E+06 | 2.54E+04 | 1.89E+06 | 2.63E+06 |
| Nb-91 | N/A | N/A | N/A | N/A | N/A | N/A |
| Nb-93m | N/A | N/A | N/A | N/A | N/A | N/A |
| Nb-94 | N/A | N/A | N/A | N/A | N/A | N/A |
| Nb-95 | 1.57E+02 | 9.80E+00 | 4.15E+00 | 1.07E+00 | 1.55E+00 | 1.95E+00 |
| Ni-59 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ni-63 | 9.01E+01 | 3.72E+02 | 3.46E+02 | 2.86E+00 | 4.26E+02 | 9.27E+02 |
| Np-237 | 2.51E+05 | 4.97E+03 | 9.54E+01 | 1.91E+02 | 1.17E+02 | 2.56E+02 |
| Pa-233 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pa-234 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pa-234m | N/A | N/A | N/A | N/A | N/A | N/A |
| Pb-209 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pb-210 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pb-211 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pb-212 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pb-214 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pd-107 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pm-147 | 3.17E+01 | 1.39E-01 | 1.03E-02 | 5.35E-03 | 1.27E-02 | 2.77E-02 |
| Po-210 | 2.82E+03 | 5.47E+02 | 1.79E+03 | 2.10E+01 | 2.21E+03 | 4.81E+03 |
| Po-211 | N/A | N/A | N/A | N/A | N/A | N/A |
| Po-212 | N/A | N/A | N/A | N/A | N/A | N/A |
| Po-213 | N/A | N/A | N/A | N/A | N/A | N/A |
| Po-214 | N/A | N/A | N/A | N/A | N/A | N/A |
| Po-215 | N/A | N/A | N/A | N/A | N/A | N/A |

Table D.6.3.8 Food Ingestion Unit Risk Factors, Radionuclides (cont'd)

| | Unit Dose Factor (Ingestion) (rad/day/Ci/kg soil) | | | | | |
|---|---|---|---|---|---|---|
| Radionuclide | Plant | Mouse | Coyote | Deer | Hawk | Shrike |
| Po-216 | N/A | N/A | N/A | N/A | N/A | N/A |
| Po-218 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pu-236 | N/A | N/A | N/A | N/A | N/A | N/A |
| Pu-238 | 1.13E+02 | 2.23E+00 | 1.78E+01 | 8.56E-02 | 2.19E+01 | 4.77E+01 |
| Pu-239 | 1.05E+02 | 2.09E+00 | 1.68E+01 | 8.05E-02 | 2.07E+01 | 4.50E+01 |
| Pu-240 | 1.06E+02 | 2.10E+00 | 1.68E+01 | 8.06E-02 | 2.07E+01 | 4.50E+01 |
| Pu-241 | 1.10E-01 | 2.12E-03 | 1.98E-02 | 9.70E-05 | 2.05E-02 | 4.45E-02 |
| Pu-242 | 1.00E+02 | 1.99E+00 | 1.56E+01 | 7.50E-02 | 1.97E+01 | 4.28E+01 |
| Ra-223 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ra-224 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ra-225 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ra-226 | 5.63E+04 | 2.21E+05 | 2.09E+06 | 8.47E+03 | 2.57E+06 | 5.59E+06 |
| Ra-228 | 3.07E+04 | 1.13E+05 | 3.88E+06 | 1.67E+04 | 1.25E+06 | 2.71E+06 |
| Rn-220 | N/A | N/A | N/A | N/A | N/A | N/A |
| Rn-222 | N/A | N/A | N/A | N/A | N/A | N/A |
| Ru-103 | 1.19E+03 | 3.10E+02 | 2.12E+01 | 3.80E+00 | 1.10E+01 | 1.78E+01 |
| Ru-106 | 1.47E+04 | 4.15E+03 | 1.12E+02 | 1.73E+01 | 1.29E+02 | 2.77E+02 |
| S-35 | N/A | N/A | N/A | N/A | N/A | N/A |
| Sb-124 | 1.18E+03 | 2.30E+03 | 1.46E+03 | 2.72E+01 | 7.68E+02 | 1.27E+03 |
| Sb-125 | 2.69E+02 | 8.32E+02 | 8.44E+02 | 9.99E+00 | 4.41E+02 | 7.23E+02 |
| Sb-126 | N/A | N/A | N/A | N/A | N/A | N/A |
| Sb-126m | N/A | N/A | N/A | N/A | N/A | N/A |
| Sc-46 | 1.01E+02 | 2.06E-01 | 4.93E-04 | 4.51E-03 | 1.83E-04 | 2.32E-04 |
| Se-75 | N/A | N/A | N/A | N/A | N/A | N/A |
| Se-79 | N/A | N/A | N/A | N/A | N/A | N/A |
| Sm-147 | N/A | N/A | N/A | N/A | N/A | N/A |
| Sm-151 | N/A | N/A | N/A | N/A | N/A | N/A |
| Sn-113 | N/A | N/A | N/A | N/A | N/A | N/A |
| Sn-123M | N/A | N/A | N/A | N/A | N/A | N/A |
| Sn-126 | N/A | N/A | N/A | N/A | N/A | N/A |
| Sr-85 | N/A | N/A | N/A | N/A | N/A | N/A |
| Sr-90 | 1.17E+05 | 6.67E+05 | 3.38E+06 | 2.56E+04 | 4.16E+06 | 9.05E+06 |
| Ta-182 | N/A | N/A | N/A | N/A | N/A | N/A |
| Tc-99 | 1.72E+05 | 1.08E+05 | 5.49E+03 | 4.16E+02 | 6.76E+03 | 1.47E+04 |
| Te-125M | 2.84E+04 | 5.33E+03 | 8.59E+02 | 2.10E+02 | 1.04E+03 | 2.24E+03 |
| Te-127 | 5.71E+04 | 3.41E+02 | 1.71E+00 | 1.32E+01 | 2.10E+00 | 4.57E+00 |
| Te-129M | 1.53E+05 | 2.51E+04 | 3.81E+03 | 1.07E+03 | 4.30E+03 | 9.19E+03 |

Table D.6.3.8 Food Ingestion Unit Risk Factors, Radionuclides (cont'd)

| | Unit Dose Factor (Ingestion) (rad/day/Ci/kg soil) | | | | | |
|---|---|---|---|---|---|---|
| Radionuclide | Plant | Mouse | Coyote | Deer | Hawk | Shrike |
| Th-227 | N/A | N/A | N/A | N/A | N/A | N/A |
| Th-228 | 1.15E+03 | 3.82E+00 | 2.15E+00 | 6.03E-01 | 6.44E-01 | 1.40E+00 |
| Th-229 | N/A | N/A | N/A | N/A | N/A | N/A |
| Th-230 | 9.83E+02 | 3.90E+00 | 6.37E-01 | 1.50E-01 | 7.84E-01 | 1.71E+00 |
| Th-231 | N/A | N/A | N/A | N/A | N/A | N/A |
| Tl-204 | N/A | N/A | N/A | N/A | N/A | N/A |
| Tl-207 | N/A | N/A | N/A | N/A | N/A | N/A |
| Tl-208 | N/A | N/A | N/A | N/A | N/A | N/A |
| Tl-209 | N/A | N/A | N/A | N/A | N/A | N/A |
| Tm-170 | N/A | N/A | N/A | N/A | N/A | N/A |
| U-232 | N/A | N/A | N/A | N/A | N/A | N/A |
| U-233 | N/A | N/A | N/A | N/A | N/A | N/A |
| U-234 | 1.00E+03 | 1.82E+02 | 5.35E+03 | 1.40E+01 | 6.58E+03 | 1.43E+04 |
| U-235 | 9.42E+02 | 1.70E+02 | 5.02E+03 | 1.31E+01 | 6.18E+03 | 1.34E+04 |
| U-236 | 9.63E+02 | 1.74E+02 | 5.13E+03 | 1.34E+01 | 6.31E+03 | 1.37E+04 |
| U-237 | 3.28E+01 | 4.07E-01 | 1.13E+00 | 4.30E-02 | 1.14E+00 | 2.21E+00 |
| U-238 | 8.81E+02 | 1.59E+02 | 4.69E+03 | 1.22E+01 | 5.78E+03 | 1.26E+04 |
| V-49 | N/A | N/A | N/A | N/A | N/A | N/A |
| Y-88 | N/A | N/A | N/A | N/A | N/A | N/A |
| Y-90 | 4.81E+02 | 1.01E-02 | 3.58E-06 | 3.87E-04 | 4.40E-06 | 9.58E-06 |
| Zn-65 | 2.96E+03 | 2.19E+05 | 8.77E+06 | 7.46E+03 | 2.67E+06 | 2.65E+06 |
| Zr-93 | N/A | N/A | N/A | N/A | N/A | N/A |
| Zr-95 | 4.65E+02 | 4.53E+01 | 2.01E+00 | 7.34E-01 | 8.79E-01 | 1.28E+00 |

Table D.6.3.9 Water Ingestion Unit Risk Factors, Radionuclides

| | Unit Dose Factor (Water ingestion) (rad/d/Ci/L) | | | |
|---|---|---|---|---|
| Radionuclide | Coyote | Deer | Hawk | Shrike |
| Ac-225 | N/A | N/A | N/A | N/A |
| Ac-227 | N/A | N/A | N/A | N/A |
| Ac-228 | N/A | N/A | N/A | N/A |
| Ag-110 | 7.94E+02 | 1.62E+02 | 1.95E+02 | 7.06E+02 |
| Am-241 | 2.61E+03 | 5.34E+02 | 2.42E+03 | 1.70E+04 |
| Am-242 | N/A | N/A | N/A | N/A |
| Am-242m | N/A | N/A | N/A | N/A |
| Am-243 | N/A | N/A | N/A | N/A |
| At-217 | N/A | N/A | N/A | N/A |
| Au-195 | N/A | N/A | N/A | N/A |
| Ba-133 | N/A | N/A | N/A | N/A |
| Ba-135m | N/A | N/A | N/A | N/A |
| Ba-137m | N/A | N/A | N/A | N/A |
| Be-10 | N/A | N/A | N/A | N/A |
| Be-7 | N/A | N/A | N/A | N/A |
| Bi-210 | N/A | N/A | N/A | N/A |
| Bi-211 | N/A | N/A | N/A | N/A |
| Bi-212 | N/A | N/A | N/A | N/A |
| Bi-213 | N/A | N/A | N/A | N/A |
| Bi-214 | N/A | N/A | N/A | N/A |
| C-14 | 9.64E+02 | 1.97E+02 | 8.74E+02 | 6.13E+03 |
| Ca-45 | N/A | N/A | N/A | N/A |
| Cd-109 | N/A | N/A | N/A | N/A |
| Ce-144 | 1.09E+02 | 2.22E+01 | 9.73E+01 | 6.77E+02 |
| Cf-252 | 7.06E+03 | 1.44E+03 | 4.74E+03 | 3.32E+04 |
| Cl-36 | N/A | N/A | N/A | N/A |
| Cm-242 | 1.51E+03 | 3.07E+02 | 1.37E+03 | 9.60E+03 |
| Cm-243 | N/A | N/A | N/A | N/A |
| Cm-244 | 2.76E+03 | 5.64E+02 | 2.50E+03 | 1.76E+04 |
| Co-60 | 8.53E+03 | 1.74E+03 | 2.17E+03 | 8.24E+03 |
| Cs-134 | 2.02E+05 | 4.12E+04 | 6.36E+04 | 2.92E+05 |
| Cs-135 | 1.14E+04 | 2.33E+03 | 1.04E+04 | 7.27E+04 |
| Cs-137 | 1.14E+05 | 2.32E+04 | 5.61E+04 | 3.32E+05 |
| Es-254 | N/A | N/A | N/A | N/A |
| Eu-152 | 2.59E+02 | 5.29E+01 | 7.12E+01 | 3.00E+02 |

Table D.6.3.9 Water Ingestion Unit Risk Factors, Radionuclides (cont'd)

| | Unit Dose Factor (Water ingestion) (rad/d/Ci/L) | | | |
|---|---|---|---|---|
| Radionuclide | Coyote | Deer | Hawk | Shrike |
| Eu-154 | 3.74E+02 | 7.64E+01 | 1.51E+02 | 7.67E+02 |
| Eu-155 | 6.03E+01 | 1.23E+01 | 2.57E+01 | 1.46E+02 |
| Fe-55 | 2.69E+02 | 5.50E+01 | 2.45E+02 | 1.71E+03 |
| Fe-59 | 6.68E+03 | 1.36E+03 | 2.10E+03 | 9.86E+03 |
| Fr-221 | N/A | N/A | N/A | N/A |
| Fr-223 | N/A | N/A | N/A | N/A |
| Ge-68 | N/A | N/A | N/A | N/A |
| H-3 | 1.92E+02 | 3.93E+01 | 1.01E+02 | 7.10E+02 |
| Hf-181 | N/A | N/A | N/A | N/A |
| I-125 | N/A | N/A | N/A | N/A |
| I-129 | 1.55E+04 | 3.16E+03 | 1.12E+04 | 7.09E+04 |
| K-40 | N/A | N/A | N/A | N/A |
| Kr-85 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mn-54 | 1.59E+03 | 3.25E+02 | 3.44E+02 | 1.02E+03 |
| Mo-93 | N/A | N/A | N/A | N/A |
| Na-22 | 3.16E+04 | 6.46E+03 | 9.64E+03 | 4.33E+04 |
| Nb-91 | N/A | N/A | N/A | N/A |
| Nb-93m | N/A | N/A | N/A | N/A |
| Nb-94 | N/A | N/A | N/A | N/A |
| Nb-95 | 3.33E+02 | 6.81E+01 | 9.16E+01 | 3.73E+02 |
| Ni-59 | N/A | N/A | N/A | N/A |
| Ni-63 | 3.56E+02 | 7.27E+01 | 3.23E+02 | 2.26E+03 |
| Pa-231 | N/A | N/A | N/A | N/A |
| Pa-233 | N/A | N/A | N/A | N/A |
| Pa-234 | N/A | N/A | N/A | N/A |
| Pa-234m | N/A | N/A | N/A | N/A |
| Pb-209 | N/A | N/A | N/A | N/A |
| Pb-210 | N/A | N/A | N/A | N/A |
| Pb-211 | N/A | N/A | N/A | N/A |
| Pb-212 | N/A | N/A | N/A | N/A |
| Pb-214 | N/A | N/A | N/A | N/A |
| Pd-107 | N/A | N/A | N/A | N/A |
| Pm-147 | 6.67E+00 | 1.36E+00 | 6.05E+00 | 4.24E+01 |
| Po-210 | 2.62E+04 | 5.35E+03 | 2.38E+04 | 1.67E+05 |
| Po-211 | N/A | N/A | N/A | N/A |

Table D.6.3.9 Water Ingestion Unit Risk Factors, Radionuclides (cont'd)

| | Unit Dose Factor (Water ingestion) (rad/d/Ci/L) | | | |
|---|---|---|---|---|
| Radionuclide | Coyote | Deer | Hawk | Shrike |
| Po-212 | N/A | N/A | N/A | N/A |
| Po-213 | N/A | N/A | N/A | N/A |
| Po-214 | N/A | N/A | N/A | N/A |
| Po-215 | N/A | N/A | N/A | N/A |
| Po-216 | N/A | N/A | N/A | N/A |
| Po-218 | N/A | N/A | N/A | N/A |
| Pu-236 | N/A | N/A | N/A | N/A |
| Pu-238 | 2.67E+03 | 5.44E+02 | 2.42E+03 | 1.70E+04 |
| Pu-239 | 2.51E+03 | 5.12E+02 | 2.27E+03 | 1.59E+04 |
| Pu-240 | 2.51E+03 | 5.13E+02 | 2.28E+03 | 1.60E+04 |
| Pu-241 | 3.02E+00 | 6.17E-01 | 2.31E+00 | 1.62E+01 |
| Pu-242 | 2.34E+03 | 4.77E+02 | 2.16E+03 | 1.52E+04 |
| Ra-223 | N/A | N/A | N/A | N/A |
| Ra-224 | N/A | N/A | N/A | N/A |
| Ra-225 | N/A | N/A | N/A | N/A |
| Rh-106 | N/A | N/A | N/A | N/A |
| Rn-219 | N/A | N/A | N/A | N/A |
| Rn-220 | N/A | N/A | N/A | N/A |
| Rn-222 | N/A | N/A | N/A | N/A |
| Ru-103 | 2.37E+02 | 4.83E+01 | 9.04E+01 | 4.72E+02 |
| Ru-106 | 1.08E+03 | 2.20E+02 | 9.14E+02 | 6.32E+03 |
| S-35 | N/A | N/A | N/A | N/A |
| Sb-124 | 6.78E+03 | 1.38E+03 | 2.62E+03 | 1.40E+04 |
| Sb-125 | 2.49E+03 | 5.08E+02 | 9.60E+02 | 5.07E+03 |
| Sb-126 | N/A | N/A | N/A | N/A |
| Sb-126m | N/A | N/A | N/A | N/A |
| Sc-46 | 5.62E+00 | 1.15E+00 | 1.54E+00 | 6.29E+00 |
| Se-75 | N/A | N/A | N/A | N/A |
| Se-79 | N/A | N/A | N/A | N/A |
| Sm-147 | N/A | N/A | N/A | N/A |
| Sm-151 | N/A | N/A | N/A | N/A |
| Sn-113 | N/A | N/A | N/A | N/A |
| Sn-123M | N/A | N/A | N/A | N/A |
| Sn-126 | N/A | N/A | N/A | N/A |
| Sr-85 | N/A | N/A | N/A | N/A |

Table D.6.3.9 Water Ingestion Unit Risk Factors, Radionuclides (cont'd)

| | Unit Dose Factor (Water ingestion) (rad/d/Ci/L) | | | |
|---|---|---|---|---|
| Radionuclide | Coyote | Deer | Hawk | Shrike |
| Sr-90 | 1.60E+05 | 3.26E+04 | 1.45E+05 | 1.02E+06 |
| Ta-182 | N/A | N/A | N/A | N/A |
| Tc-99 | 1.30E+02 | 2.65E+01 | 1.18E+02 | 8.24E+02 |
| Te-125M | 5.24E+02 | 1.07E+02 | 4.67E+02 | 3.24E+03 |
| Te-127 | 3.28E+01 | 6.70E+00 | 2.96E+01 | 2.08E+02 |
| Te-129M | 2.67E+03 | 5.45E+02 | 2.22E+03 | 1.53E+04 |
| Th-227 | N/A | N/A | N/A | N/A |
| Th-228 | 1.88E+03 | 3.83E+02 | 4.15E+02 | 2.91E+03 |
| Th-232 | 6.03E+02 | 1.23E+02 | 3.62E+02 | 2.54E+03 |
| Th-233 | N/A | N/A | N/A | N/A |
| Th-234 | N/A | N/A | N/A | N/A |
| Tl-204 | N/A | N/A | N/A | N/A |
| Tl-207 | N/A | N/A | N/A | N/A |
| Tl-208 | N/A | N/A | N/A | N/A |
| Tl-209 | N/A | N/A | N/A | N/A |
| Tm-170 | N/A | N/A | N/A | N/A |
| U-232 | N/A | N/A | N/A | N/A |
| U-233 | N/A | N/A | N/A | N/A |
| U-234 | 4.35E+04 | 8.88E+03 | 3.94E+04 | 2.77E+05 |
| U-235 | 4.08E+04 | 8.33E+03 | 3.70E+04 | 2.60E+05 |
| U-236 | 4.17E+04 | 8.51E+03 | 3.78E+04 | 2.65E+05 |
| U-237 | 1.34E+02 | 2.74E+01 | 9.95E+01 | 6.20E+02 |
| U-238 | 3.81E+04 | 7.79E+03 | 3.46E+04 | 2.43E+05 |
| V-49 | N/A | N/A | N/A | N/A |
| Y-88 | N/A | N/A | N/A | N/A |
| Y-90 | 4.83E-01 | 9.85E-02 | 4.38E-01 | 3.07E+00 |
| Zn-65 | 4.65E+04 | 9.50E+03 | 1.04E+04 | 3.34E+04 |
| Zr-93 | N/A | N/A | N/A | N/A |
| Zr-95 | 2.29E+02 | 4.67E+01 | 7.36E+01 | 3.45E+02 |

Table D.6.3.10 Soil Ingestion Unit Risk Factors, Radionuclides

| | Unit Dose Factor (rad/d/Ci/kg soil) | |
|---|---|---|
| Radionuclide | Mouse | Deer |
| Ac-225 | N/A | N/A |
| Ac-227 | N/A | N/A |
| Ac-228 | N/A | N/A |
| Ag-110 | 4.64E+01 | 8.60E-01 |
| Am-241 | 1.11E+03 | 2.83E+00 |
| Am-242 | N/A | N/A |
| Am-242m | N/A | N/A |
| Am-243 | N/A | N/A |
| At-217 | N/A | N/A |
| Au-195 | N/A | N/A |
| Ba-133 | N/A | N/A |
| Ba-135m | N/A | N/A |
| Ba-137m | N/A | N/A |
| Be-10 | N/A | N/A |
| Be-7 | N/A | N/A |
| Bi-210 | N/A | N/A |
| Bi-211 | N/A | N/A |
| Bi-212 | N/A | N/A |
| Bi-213 | N/A | N/A |
| Bi-214 | N/A | N/A |
| C-14 | 4.03E+02 | 1.04E+00 |
| Ca-45 | N/A | N/A |
| Cd-109 | N/A | N/A |
| Ce-144 | 4.44E+01 | 1.18E-01 |
| Cf-252 | 2.18E+03 | 7.65E+00 |
| Cl-36 | N/A | N/A |
| Cm-242 | 6.30E+02 | 1.63E+00 |
| Cm-243 | N/A | N/A |
| Co-58 | 1.83E+02 | 3.32E+00 |
| Co-60 | 5.41E+02 | 9.24E+00 |
| Cs-134 | 1.92E+04 | 2.19E+02 |
| Cs-135 | 4.78E+03 | 1.24E+01 |
| Cs-137 | 2.18E+04 | 1.23E+02 |
| Es-254 | N/A | N/A |
| Eu-152 | 1.97E+01 | 2.81E-01 |
| Eu-154 | 5.04E+01 | 4.05E-01 |
| Eu-155 | 9.61E+00 | 6.54E-02 |

Table D.6.3.10 Soil Ingestion Unit Risk Factors, Radionuclides (cont'd)

| | Unit Dose Factor (rad/d/Ci/kg soil) | |
|---|---|---|
| Radionuclide | Mouse | Deer |
| Fe-55 | 1.13E+02 | 2.92E-01 |
| Fe-59 | 6.47E+02 | 7.24E+00 |
| Fr-221 | N/A | N/A |
| Fr-223 | N/A | N/A |
| Ge-68 | N/A | N/A |
| H-3 | 4.66E+01 | 2.08E-01 |
| Hf-181 | N/A | N/A |
| I-125 | N/A | N/A |
| I-129 | 4.65E+03 | 1.68E+01 |
| K-40 | N/A | N/A |
| Kr-85 | 0.00E+00 | 0.00E+00 |
| Mn-54 | 6.67E+01 | 1.72E+00 |
| Mo-93 | N/A | N/A |
| Na-22 | 2.85E+03 | 3.43E+01 |
| Nb-91 | N/A | N/A |
| Nb-93m | N/A | N/A |
| Nb-94 | N/A | N/A |
| Nb-95 | 2.45E+01 | 3.61E-01 |
| Ni-59 | N/A | N/A |
| Ni-63 | 1.49E+02 | 3.86E-01 |
| Np-237 | 9.95E+02 | 2.58E+00 |
| Np-238 | 4.60E-01 | 2.27E-03 |
| Np-239 | 3.89E-01 | 1.28E-03 |
| Pa-231 | N/A | N/A |
| Pa-233 | N/A | N/A |
| Pa-234 | N/A | N/A |
| Pa-234m | N/A | N/A |
| Pb-209 | N/A | N/A |
| Pb-210 | N/A | N/A |
| Pb-211 | N/A | N/A |
| Pb-212 | N/A | N/A |
| Pb-214 | N/A | N/A |
| Pd-107 | N/A | N/A |
| Pm-147 | 2.79E+00 | 7.23E-03 |
| Po-210 | 1.09E+04 | 2.84E+01 |
| Po-211 | N/A | N/A |
| Po-212 | N/A | N/A |

Table D.6.3.10 Soil Ingestion Unit Risk Factors, Radionuclides (cont'd)

| | Unit Dose Factor (rad/d/Ci/kg soil) | |
|---|---|---|
| Radionuclide | Mouse | Deer |
| Po-213 | N/A | N/A |
| Po-214 | N/A | N/A |
| Po-215 | N/A | N/A |
| Po-216 | N/A | N/A |
| Po-218 | N/A | N/A |
| Pu-236 | N/A | N/A |
| Pu-238 | 1.12E+03 | 2.89E+00 |
| Pu-239 | 1.05E+03 | 2.72E+00 |
| Pu-240 | 1.05E+03 | 2.72E+00 |
| Pu-241 | 1.06E+00 | 3.27E-03 |
| Pu-242 | 9.96E+02 | 2.53E+00 |
| Ra-223 | N/A | N/A |
| Ra-224 | N/A | N/A |
| Ra-225 | N/A | N/A |
| Ra-226 | 4.41E+05 | 1.14E+03 |
| Ra-228 | 2.27E+05 | 2.25E+03 |
| Re-187 | N/A | N/A |
| Rh-106 | N/A | N/A |
| Rn-219 | N/A | N/A |
| Rn-220 | N/A | N/A |
| Rn-222 | N/A | N/A |
| Ru-103 | 3.10E+01 | 2.56E-01 |
| Ru-106 | 4.15E+02 | 1.17E+00 |
| S-35 | N/A | N/A |
| Sb-124 | 9.21E+02 | 7.34E+00 |
| Sb-125 | 3.33E+02 | 2.70E+00 |
| Sb-126 | N/A | N/A |
| Sb-126m | N/A | N/A |
| Sc-46 | 4.13E-01 | 6.09E-03 |
| Se-75 | N/A | N/A |
| Se-79 | N/A | N/A |
| Sm-147 | N/A | N/A |
| Sm-151 | N/A | N/A |
| Sn-113 | N/A | N/A |
| Sn-123M | N/A | N/A |
| Sn-126 | N/A | N/A |
| Sr-85 | N/A | N/A |

Table D.6.3.10 Soil Ingestion Unit Risk Factors, Radionuclides (cont'd)

| | Unit Dose Factor (rad/d/Ci/kg soil) | |
|---|---|---|
| Radionuclide | Mouse | Deer |
| Sr-90 | 6.67E+04 | 1.73E+02 |
| Ta-182 | N/A | N/A |
| Tc-99 | 5.41E+01 | 1.40E-01 |
| Te-125m | 2.13E+02 | 5.67E-01 |
| Te-127 | 1.36E+01 | 3.55E-02 |
| Te-129m | 1.00E+03 | 2.89E+00 |
| Th-227 | N/A | N/A |
| Th-228 | 1.91E+02 | 2.03E+00 |
| Th-229 | N/A | N/A |
| Th-230 | 1.95E+02 | 5.06E-01 |
| Th-231 | N/A | N/A |
| Th-232 | 1.67E+02 | 6.54E-01 |
| Th-233 | N/A | N/A |
| Th-234 | N/A | N/A |
| Tl-204 | N/A | N/A |
| Tl-207 | N/A | N/A |
| Tl-208 | N/A | N/A |
| Tl-209 | N/A | N/A |
| Tm-170 | N/A | N/A |
| U-232 | N/A | N/A |
| U-233 | N/A | N/A |
| U-234 | 1.82E+04 | 4.71E+01 |
| U-235 | 1.70E+04 | 4.42E+01 |
| U-236 | 1.74E+04 | 4.52E+01 |
| U-237 | 4.07E+01 | 1.45E-01 |
| U-238 | 1.59E+04 | 4.13E+01 |
| V-49 | N/A | N/A |
| Y-88 | N/A | N/A |
| Y-90 | 2.02E-01 | 5.23E-04 |
| Zn-65 | 2.19E+03 | 5.04E+01 |
| Zr-93 | N/A | N/A |
| Zr-95 | 2.27E+01 | 2.48E-01 |

Table D.6.3.11 Inhalation Unit Risk Factors, Radionuclides

| | Unit Dose Factor (Inhalation) (rad/d/Ci/m$^3$) | | | | |
|---|---|---|---|---|---|
| Radionuclide | Mouse | Coyote | Deer | Hawk | Shrike |
| Ac-225 | N/A | N/A | N/A | N/A | N/A |
| Ac-227 | N/A | N/A | N/A | N/A | N/A |
| Ac-228 | N/A | N/A | N/A | N/A | N/A |
| Ag-110 | 4.90E+03 | 3.48E+03 | 5.96E+02 | 1.41E+03 | 3.58E+03 |
| Am-241 | 1.18E+05 | 1.15E+04 | 1.96E+03 | 1.75E+04 | 8.60E+04 |
| Am-242 | N/A | N/A | N/A | N/A | N/A |
| Am-242m | N/A | N/A | N/A | N/A | N/A |
| Am-243 | N/A | N/A | N/A | N/A | N/A |
| At-217 | N/A | N/A | N/A | N/A | N/A |
| Au-195 | N/A | N/A | N/A | N/A | N/A |
| Ba-133 | N/A | N/A | N/A | N/A | N/A |
| Ba-135m | N/A | N/A | N/A | N/A | N/A |
| Ba-137m | N/A | N/A | N/A | N/A | N/A |
| Be-10 | N/A | N/A | N/A | N/A | N/A |
| Be-7 | N/A | N/A | N/A | N/A | N/A |
| Bi-210 | N/A | N/A | N/A | N/A | N/A |
| Bi-211 | N/A | N/A | N/A | N/A | N/A |
| Bi-212 | N/A | N/A | N/A | N/A | N/A |
| Bi-213 | N/A | N/A | N/A | N/A | N/A |
| Bi-214 | N/A | N/A | N/A | N/A | N/A |
| C-14 | 4.25E+04 | 4.23E+03 | 7.24E+02 | 6.31E+03 | 3.11E+04 |
| Ca-45 | N/A | N/A | N/A | N/A | N/A |
| Cd-109 | N/A | N/A | N/A | N/A | N/A |
| Ce-144 | 4.69E+03 | 4.77E+02 | 8.18E+01 | 7.02E+02 | 3.43E+03 |
| Cf-252 | 2.30E+05 | 3.10E+04 | 5.31E+03 | 3.42E+04 | 1.68E+05 |
| Cl-36 | N/A | N/A | N/A | N/A | N/A |
| Cm-242 | 6.65E+04 | 6.61E+03 | 1.13E+03 | 9.88E+03 | 4.86E+04 |
| Cm-243 | N/A | N/A | N/A | N/A | N/A |
| Cm-244 | 1.22E+05 | 1.21E+04 | 2.07E+03 | 1.81E+04 | 8.90E+04 |
| Cm-245 | N/A | N/A | N/A | N/A | N/A |
| Co-57 | 9.57E+03 | 2.33E+03 | 3.99E+02 | 1.72E+03 | 7.00E+03 |
| Cs-135 | 5.04E+05 | 5.02E+04 | 8.59E+03 | 7.49E+04 | 3.68E+05 |
| Cs-137 | 2.30E+06 | 5.00E+05 | 8.55E+04 | 4.05E+05 | 1.68E+06 |
| Es-254 | N/A | N/A | N/A | N/A | N/A |
| Eu-152 | 2.08E+03 | 1.14E+03 | 1.95E+02 | 5.14E+02 | 1.52E+03 |
| Eu-154 | 5.32E+03 | 1.64E+03 | 2.81E+02 | 1.09E+03 | 3.89E+03 |
| Eu-155 | 1.01E+03 | 2.65E+02 | 4.53E+01 | 1.85E+02 | 7.41E+02 |

Table D.6.3.11 Inhalation Unit Risk Factors, Radionuclides (cont'd)

| | Unit Dose Factor (Inhalation) (rad/d/Ci/m$^3$) | | | | |
|---|---|---|---|---|---|
| Radionuclide | Mouse | Coyote | Deer | Hawk | Shrike |
| Fe-55 | 1.19E+04 | 1.18E+03 | 2.03E+02 | 1.76E+03 | 8.68E+03 |
| Fe-59 | 6.83E+04 | 2.93E+04 | 5.02E+03 | 1.52E+04 | 4.99E+04 |
| Fr-221 | N/A | N/A | N/A | N/A | N/A |
| Fr-223 | N/A | N/A | N/A | N/A | N/A |
| Ge-68 | N/A | N/A | N/A | N/A | N/A |
| H-3 | 4.92E+03 | 8.44E+02 | 1.45E+02 | 7.30E+02 | 3.59E+03 |
| Hf-181 | N/A | N/A | N/A | N/A | N/A |
| I-125 | N/A | N/A | N/A | N/A | N/A |
| I-129 | 4.91E+05 | 6.79E+04 | 1.16E+04 | 8.06E+04 | 3.59E+05 |
| K-40 | N/A | N/A | N/A | N/A | N/A |
| Kr-85 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mn-54 | 7.04E+03 | 6.98E+03 | 1.20E+03 | 2.48E+03 | 5.15E+03 |
| Mo-93 | N/A | N/A | N/A | N/A | N/A |
| Na-22 | 3.00E+05 | 1.39E+05 | 2.38E+04 | 6.96E+04 | 2.20E+05 |
| Nb-91 | N/A | N/A | N/A | N/A | N/A |
| Nb-93m | N/A | N/A | N/A | N/A | N/A |
| Nb-94 | N/A | N/A | N/A | N/A | N/A |
| Nb-95 | 2.59E+03 | 1.46E+03 | 2.50E+02 | 6.61E+02 | 1.89E+03 |
| Ni-59 | N/A | N/A | N/A | N/A | N/A |
| Ni-63 | 1.57E+04 | 1.56E+03 | 2.67E+02 | 2.33E+03 | 1.15E+04 |
| Np-237 | 1.05E+05 | 1.05E+04 | 1.79E+03 | 1.56E+04 | 7.68E+04 |
| Np-238 | 4.86E+01 | 9.18E+00 | 1.57E+00 | 8.18E+00 | 3.55E+01 |
| Np-239 | 4.10E+01 | 5.18E+00 | 8.87E-01 | 6.30E+00 | 3.00E+01 |
| Pa-231 | N/A | N/A | N/A | N/A | N/A |
| Pa-233 | N/A | N/A | N/A | N/A | N/A |
| Pb-210 | N/A | N/A | N/A | N/A | N/A |
| Pb-211 | N/A | N/A | N/A | N/A | N/A |
| Pb-212 | N/A | N/A | N/A | N/A | N/A |
| Pb-214 | N/A | N/A | N/A | N/A | N/A |
| Pd-107 | N/A | N/A | N/A | N/A | N/A |
| Pm-147 | 2.94E+02 | 2.93E+01 | 5.01E+00 | 4.37E+01 | 2.15E+02 |
| Po-210 | 1.15E+06 | 1.15E+05 | 1.97E+04 | 1.71E+05 | 8.44E+05 |
| Po-211 | N/A | N/A | N/A | N/A | N/A |
| Po-212 | N/A | N/A | N/A | N/A | N/A |
| Po-213 | N/A | N/A | N/A | N/A | N/A |
| Po-214 | N/A | N/A | N/A | N/A | N/A |
| Po-215 | N/A | N/A | N/A | N/A | N/A |

**Table D.6.3.11 Inhalation Unit Risk Factors, Radionuclides (cont'd)**

| | Unit Dose Factor (Inhalation) (rad/d/Ci/m$^3$) | | | | |
|---|---|---|---|---|---|
| **Radionuclide** | **Mouse** | **Coyote** | **Deer** | **Hawk** | **Shrike** |
| Po-216 | N/A | N/A | N/A | N/A | N/A |
| Po-218 | N/A | N/A | N/A | N/A | N/A |
| Pu-236 | N/A | N/A | N/A | N/A | N/A |
| Pu-238 | 1.18E+05 | 1.17E+04 | 2.00E+03 | 1.75E+04 | 8.61E+04 |
| Pu-239 | 1.11E+05 | 1.10E+04 | 1.88E+03 | 1.64E+04 | 8.08E+04 |
| Pu-240 | 1.11E+05 | 1.10E+04 | 1.89E+03 | 1.64E+04 | 8.09E+04 |
| Pu-241 | 1.12E+02 | 1.33E+01 | 2.27E+00 | 1.66E+01 | 8.19E+01 |
| Pu-242 | 1.05E+05 | 1.03E+04 | 1.76E+03 | 1.56E+04 | 7.69E+04 |
| Ra-223 | N/A | N/A | N/A | N/A | N/A |
| Ra-224 | N/A | N/A | N/A | N/A | N/A |
| Ra-225 | N/A | N/A | N/A | N/A | N/A |
| Ra-226 | 4.66E+07 | 4.63E+06 | 7.94E+05 | 6.91E+06 | 3.40E+07 |
| Ra-228 | 2.39E+07 | 9.13E+06 | 1.56E+06 | 3.56E+06 | 1.75E+07 |
| Re-187 | N/A | N/A | N/A | N/A | N/A |
| Rh-106 | N/A | N/A | N/A | N/A | N/A |
| Rn-219 | N/A | N/A | N/A | N/A | N/A |
| Rn-220 | N/A | N/A | N/A | N/A | N/A |
| Rn-222 | N/A | N/A | N/A | N/A | N/A |
| Ru-103 | 3.27E+03 | 1.04E+03 | 1.78E+02 | 6.53E+02 | 2.39E+03 |
| Sb-125 | 3.51E+04 | 1.09E+04 | 1.87E+03 | 6.93E+03 | 2.57E+04 |
| Sb-126 | N/A | N/A | N/A | N/A | N/A |
| Sb-126m | N/A | N/A | N/A | N/A | N/A |
| Sc-46 | 4.36E+01 | 2.47E+01 | 4.22E+00 | 1.11E+01 | 3.18E+01 |
| Se-75 | N/A | N/A | N/A | N/A | N/A |
| Se-79 | N/A | N/A | N/A | N/A | N/A |
| Sm-147 | N/A | N/A | N/A | N/A | N/A |
| Sm-151 | N/A | N/A | N/A | N/A | N/A |
| Sn-113 | N/A | N/A | N/A | N/A | N/A |
| Sn-123M | N/A | N/A | N/A | N/A | N/A |
| Sn-126 | N/A | N/A | N/A | N/A | N/A |
| Sr-85 | N/A | N/A | N/A | N/A | N/A |
| Sr-90 | 7.04E+06 | 7.01E+05 | 1.20E+05 | 1.05E+06 | 5.15E+06 |
| Ta-182 | N/A | N/A | N/A | N/A | N/A |
| Tc-99 | 5.71E+03 | 5.68E+02 | 9.73E+01 | 8.48E+02 | 4.17E+03 |
| Te-125M | 2.25E+04 | 2.30E+03 | 3.94E+02 | 3.37E+03 | 1.64E+04 |
| Te-127 | 1.44E+03 | 1.44E+02 | 2.46E+01 | 2.14E+02 | 1.05E+03 |
| Te-129M | 1.06E+05 | 1.17E+04 | 2.00E+03 | 1.60E+04 | 7.74E+04 |

Table D.6.3.11 Inhalation Unit Risk Factors, Radionuclides (cont'd)

| | Unit Dose Factor (Inhalation) (rad/d/Ci/m$^3$) | | | | |
|---|---|---|---|---|---|
| Radionuclide | Mouse | Coyote | Deer | Hawk | Shrike |
| Th-227 | N/A | N/A | N/A | N/A | N/A |
| Th-228 | 2.02E+04 | 8.24E+03 | 1.41E+03 | 2.99E+03 | 1.47E+04 |
| Th-229 | N/A | N/A | N/A | N/A | N/A |
| Th-230 | 2.06E+04 | 2.05E+03 | 3.51E+02 | 3.06E+03 | 1.51E+04 |
| Th-231 | N/A | N/A | N/A | N/A | N/A |
| Th-232 | 1.76E+04 | 2.65E+03 | 4.53E+02 | 2.61E+03 | 1.29E+04 |
| Th-233 | N/A | N/A | N/A | N/A | N/A |
| Th-234 | N/A | N/A | N/A | N/A | N/A |
| Tl-204 | N/A | N/A | N/A | N/A | N/A |
| Tl-207 | N/A | N/A | N/A | N/A | N/A |
| Tl-208 | N/A | N/A | N/A | N/A | N/A |
| Tl-209 | N/A | N/A | N/A | N/A | N/A |
| Tm-170 | N/A | N/A | N/A | N/A | N/A |
| U-235 | 1.80E+06 | 1.79E+05 | 3.07E+04 | 2.67E+05 | 1.31E+06 |
| U-236 | 1.84E+06 | 1.83E+05 | 3.13E+04 | 2.73E+05 | 1.34E+06 |
| U-237 | 4.30E+03 | 5.88E+02 | 1.01E+02 | 7.18E+02 | 3.14E+03 |
| U-238 | 1.68E+06 | 1.67E+05 | 2.87E+04 | 2.50E+05 | 1.23E+06 |
| V-49 | N/A | N/A | N/A | N/A | N/A |
| Y-88 | N/A | N/A | N/A | N/A | N/A |
| Y-90 | 2.13E+01 | 2.12E+00 | 3.63E-01 | 3.16E+00 | 1.56E+01 |
| Zn-65 | 2.31E+05 | 2.04E+05 | 3.49E+04 | 7.53E+04 | 1.69E+05 |
| Zr-93 | N/A | N/A | N/A | N/A | N/A |
| Zr-95 | 2.39E+03 | 1.00E+03 | 1.72E+02 | 5.31E+02 | 1.75E+03 |

Table D.6.3.12 Direct Radiation Unit Risk Factors, Radionuclides

| | Unit Dose Factor (rad/d/Ci/kg) | |
|---|---|---|
| Radionuclide | Mouse | Plant |
| Ac-225 | N/A | N/A |
| Ac-227 | N/A | N/A |
| Ac-228 | N/A | N/A |
| Ag-110 | 1.20E+04 | 9.57E+03 |
| Am-241 | 2.80E+05 | 2.80E+05 |
| Am-242 | N/A | N/A |
| Am-242m | N/A | N/A |
| Am-243 | N/A | N/A |
| At-217 | N/A | N/A |
| Au-195 | N/A | N/A |
| Ba-133 | N/A | N/A |
| Ba-135m | N/A | N/A |
| Ba-137m | N/A | N/A |
| Be-10 | N/A | N/A |
| Be-7 | N/A | N/A |
| Bi-210 | N/A | N/A |
| Bi-211 | N/A | N/A |
| Bi-212 | N/A | N/A |
| Bi-213 | N/A | N/A |
| Bi-214 | N/A | N/A |
| C-14 | 2.54E+03 | 2.54E+03 |
| Ca-45 | N/A | N/A |
| Cd-109 | N/A | N/A |
| Ce-144 | 6.72E+04 | 6.72E+04 |
| Cf-252 | 6.21E+05 | 6.21E+05 |
| Cl-36 | N/A | N/A |
| Cm-242 | 3.11E+05 | 3.11E+05 |
| Cm-243 | N/A | N/A |
| Cm-244 | 2.95E+05 | 2.95E+05 |
| Cm-245 | N/A | N/A |
| Co-57 | 2.08E+03 | 1.98E+03 |
| Cs-135 | 2.95E+03 | 2.95E+03 |
| Cs-137 | 1.36E+04 | 1.31E+04 |
| Es-254 | N/A | N/A |

Table D.6.3.12 Direct Radiation Unit Risk Factors, Radionuclides (cont'd)

| | Unit Dose Factor (rad/d/Ci/kg) | |
|---|---|---|
| Radionuclide | Mouse | Plant |
| Eu-152 | 6.11E+03 | 6.11E+03 |
| Eu-154 | 1.58E+04 | 1.58E+04 |
| Eu-155 | 3.10E+03 | 3.00E+03 |
| Fe-55 | 3.69E+02 | 3.69E+02 |
| Fe-59 | 9.72E+03 | 8.70E+03 |
| Fr-221 | N/A | N/A |
| Fr-223 | N/A | N/A |
| Ge-68 | N/A | N/A |
| H-3 | 2.95E+02 | 2.95E+02 |
| Hf-181 | N/A | N/A |
| I-125 | N/A | N/A |
| I-129 | 3.20E+03 | 3.06E+03 |
| K-40 | N/A | N/A |
| Kr-85 | 1.14E+04 | 1.14E+04 |
| Mn-54 | 2.62E+03 | 1.85E+03 |
| Mo-93 | N/A | N/A |
| Na-22 | 1.65E+04 | 1.46E+04 |
| Nb-91 | N/A | N/A |
| Nb-93m | N/A | N/A |
| Nb-94 | N/A | N/A |
| Nb-95 | 4.61E+03 | 3.90E+03 |
| Ni-59 | N/A | N/A |
| Ni-63 | 8.95E+02 | 8.95E+02 |
| Np-237 | 2.49E+05 | 2.49E+05 |
| Np-238 | 1.37E+04 | 1.34E+04 |
| Np-239 | 1.04E+04 | 1.03E+04 |
| Pa-231 | N/A | N/A |
| Pa-233 | N/A | N/A |
| Pb-210 | N/A | N/A |
| Pb-211 | N/A | N/A |
| Pb-212 | N/A | N/A |
| Pb-214 | N/A | N/A |
| Pd-107 | N/A | N/A |
| Pm-147 | 3.15E+03 | 3.15E+03 |

Table D.6.3.12 Direct Radiation Unit Risk Factors, Radionuclides (cont'd)

| | Unit Dose Factor (rad/d/Ci/kg) | |
|---|---|---|
| Radionuclide | Mouse | Plant |
| Po-210 | 2.80E+05 | 2.80E+05 |
| Po-211 | N/A | N/A |
| Po-212 | N/A | N/A |
| Po-213 | N/A | N/A |
| Po-214 | N/A | N/A |
| Po-215 | N/A | N/A |
| Po-216 | N/A | N/A |
| Po-218 | N/A | N/A |
| Pu-236 | N/A | N/A |
| Pu-238 | 2.80E+05 | 2.80E+05 |
| Pu-239 | 2.62E+05 | 2.62E+05 |
| Pu-240 | 2.63E+05 | 2.63E+05 |
| Pu-241 | 2.72E+02 | 2.72E+02 |
| Pu-242 | 2.49E+05 | 2.49E+05 |
| Ra-223 | N/A | N/A |
| Ra-224 | N/A | N/A |
| Ra-225 | N/A | N/A |
| Ra-226 | 5.60E+05 | 5.60E+05 |
| Ra-228 | 3.05E+05 | 3.05E+05 |
| Re-187 | N/A | N/A |
| Rh-106 | N/A | N/A |
| Rn-219 | N/A | N/A |
| Rn-220 | N/A | N/A |
| Rn-222 | N/A | N/A |
| Ru-103 | 6.36E+03 | 5.90E+03 |
| Sb-125 | 5.75E+03 | 5.34E+03 |
| Sb-126 | N/A | N/A |
| Sb-126m | N/A | N/A |
| Sc-46 | 1.18E+04 | 1.00E+04 |
| Se-75 | N/A | N/A |
| Se-79 | N/A | N/A |
| Sm-147 | N/A | N/A |
| Sm-151 | N/A | N/A |
| Sn-113 | N/A | N/A |

Table D.6.3.12 Direct Radiation Unit Risk Factors, Radionuclides (cont'd)

| | Unit Dose Factor (rad/d/Ci/kg) | |
|---|---|---|
| Radionuclide | Mouse | Plant |
| Sn-123M | N/A | N/A |
| Sn-126 | N/A | N/A |
| Sr-85 | N/A | N/A |
| Sr-90 | 5.80E+04 | 5.80E+04 |
| Ta-182 | N/A | N/A |
| Tc-99 | 4.27E+03 | 4.27E+03 |
| Te-125M | 5.65E+03 | 5.65E+03 |
| Te-127 | 1.13E+04 | 1.13E+04 |
| Te-129M | 3.06E+04 | 3.05E+04 |
| Th-227 | N/A | N/A |
| Th-228 | 2.85E+05 | 2.85E+05 |
| Th-229 | N/A | N/A |
| Th-230 | 2.44E+05 | 2.44E+05 |
| Th-231 | N/A | N/A |
| Th-232 | 2.09E+05 | 2.09E+05 |
| Th-233 | N/A | N/A |
| Th-234 | N/A | N/A |
| Tl-204 | N/A | N/A |
| Tl-207 | N/A | N/A |
| Tl-208 | N/A | N/A |
| Tl-209 | N/A | N/A |
| Tm-170 | N/A | N/A |
| U-235 | 2.34E+05 | 2.34E+05 |
| U-236 | 2.39E+05 | 2.39E+05 |
| U-237 | 8.14E+03 | 8.14E+03 |
| U-238 | 2.19E+05 | 2.19E+05 |
| V-49 | N/A | N/A |
| Y-88 | N/A | N/A |
| Y-90 | 4.78E+04 | 4.78E+04 |
| Zn-65 | 1.96E+03 | 1.47E+03 |
| Zr-93 | N/A | N/A |
| Zr-95 | 1.29E+04 | 1.15E+04 |

### D.6.4 RESULTS

Results are summarized in Tables D.6.4.1 through D.6.4.11. Overall, the results of this screening analysis fall into two extreme classes. Direct contact with waste, which would be unlikely even under the No Action alternative, is estimated to result in radiation doses that would likely be lethal in a short time (Table D.6.4.1). The chemical hazards associated with direct exposure to tank waste, while less dramatic, are still estimated to be up to several orders of magnitude higher than the 1.0 HI benchmark for concern (Table D.6.4.4). Any direct effects on individual organisms exposed to stored waste could lead to a variety of indirect effects on the ecosystem, including decreased biodiversity, habitat loss or alteration, and impacts on productivity and nutrient turnover. Exposure to routine air emissions under the No Action alternative is estimated to result in a radiation exposure far below background levels (Table D.6.4.2). Exposure to contaminated groundwater reaching the Columbia River is not estimated to result in radiation doses approaching the 0.1 rad/day benchmark for terrestrial organisms (IAEA 1992) (Table D.6.4.3). Likewise, maximum radiation doses to aquatic organisms in the Columbia River, 300 or 500 years in the future, are well below the 1.0 rad/day benchmark for aquatic organisms (NCRP 1991) (Table D.6.4.6). Because the direct impacts of air and groundwater exposure are expected to be small, any associated indirect impacts on the ecosystem would be correspondingly minor.

Table D.6.4.5 presents the maximum HIs associated with ingestion of groundwater calculated to reach the Columbia River under the No Action alternative. For concentrations of contaminants calculated to reach the Columbia River 300, 500, 2,500, 5,000, and 10,000 years in the future, the maximum HIs for the coyote, mule deer, red-tailed hawk and loggerhead shrike were all well below the HI criterion of 1.0. The ecological hazards were based on a conservative, bounding scenario involving consumption of groundwater contaminants at the point where groundwater daylights on the Columbia River bank (e.g., springs or seeps) and assumes no dilution of the groundwater contaminants by the river before the receptors have access to it. Based on the conservative nature of the exposure scenarios, the estimated hazards for the representative species indicate that no adverse effects would be expected for terrestrial receptors consuming groundwater in the future. Consequently, no indirect ecosystem impacts would be anticipated from future groundwater consumption.

The only radiation or chemical exposures evaluated for ecological receptors during remediation were radiation doses associated with routine releases during tank waste remediation. No estimated radiation doses resulting from routine releases during the in situ or in situ/ex situ combination alternatives exceeded the 0.1 rad/day benchmark suggested by IAEA (IAEA 1992) for ecological impacts (Tables D.6.4.8 and D.6.4.11). For the Ex Situ Intermediate Separations and Phased Implementation alternatives, the maximum estimated radiation doses resulting from routine releases exceeded this benchmark because of C-14, Cs-137, I-129, and Sr-90 releases (Table D.6.4.7). Exposures exceeding 0.1 rad/day also would be expected under the Ex Situ No Separations and Ex Situ Extensive Separations alternatives (Table D.6.4.9). However, exceeding the 0.1 rad/day benchmark assumes long-term exposure at the location of the maximum Chi/Q. It is unlikely that any ecological receptor would spend all of its lifetime at this location of highest exposure. The exposure at the location of the

Table D.6.4.1 Total Estimated Dose from Direct Contact with Waste, No Action Alternative, Summed by Cell (rad/d)

| | Plant | | | Mouse | | | |
|---|---|---|---|---|---|---|---|
| Cell | Internal | Direct | Total | Soil Ingestion | Food Ingestion | Direct | Total |
| 1WSS | 3.21E+03 | 3.14E+03 | 6.34E+03 | 2.18E+03 | 1.84E+04 | 3.14E+03 | 2.37E+04 |
| 2WSS | 2.19E+04 | 2.06E+04 | 4.25E+04 | 1.36E+04 | 1.25E+05 | 2.06E+04 | 1.59E+05 |
| 1ESS | 2.06E+04 | 1.98E+04 | 4.04E+04 | 1.34E+04 | 1.18E+05 | 1.98E+04 | 1.51E+05 |
| 2ESS | 4.75E+04 | 4.35E+04 | 9.10E+04 | 2.73E+04 | 2.70E+05 | 4.36E+04 | 3.41E+05 |
| 4ESS | 1.61E+05 | 1.46E+05 | 3.06E+05 | 9.16E+04 | 9.14E+05 | 1.46E+05 | 1.15E+06 |
| 3WDS | 6.03E+04 | 6.36E+04 | 1.24E+05 | 2.61E+02 | 1.36E+03 | 6.36E+04 | 6.52E+04 |
| 3EDS | 9.22E+04 | 9.82E+04 | 1.90E+05 | 4.67E+02 | 1.87E+03 | 9.82E+04 | 1.01E+05 |
| 5EDS | 2.08E+04 | 2.19E+04 | 4.26E+04 | 8.81E+01 | 4.40E+02 | 2.19E+04 | 2.24E+04 |

| | Coyote | Deer | | | Hawk | Shrike |
|---|---|---|---|---|---|---|
| Cell | Food Ingestion | Soil Ingestion | Food Ingestion | Total | Food Ingestion | Food Ingestion |
| 1WSS | 9.98E+04 | 6.73E+00 | 7.03E+02 | 7.10E+02 | 1.19E+05 | 2.56E+05 |
| 2WSS | 6.55E+05 | 3.87E+01 | 4.80E+03 | 4.84E+03 | 7.93E+05 | 1.72E+06 |
| 1ESS | 6.30E+05 | 4.01E+01 | 4.51E+03 | 4.55E+03 | 7.55E+05 | 1.63E+06 |
| 2ESS | 1.37E+06 | 7.14E+01 | 1.04E+04 | 1.05E+04 | 1.69E+06 | 3.67E+06 |
| 4ESS | 4.64E+06 | 2.38E+02 | 3.51E+04 | 3.54E+04 | 5.70E+06 | 1.24E+07 |
| 3WDS | 3.10E+02 | 7.58E-01 | 4.77E+01 | 4.84E+01 | 3.19E+02 | 6.69E+02 |
| 3EDS | 2.78E+02 | 1.33E+00 | 7.10E+01 | 7.23E+01 | 2.73E+02 | 5.67E+02 |
| 5EDS | 5.10E+01 | 2.53E-01 | 1.61E+01 | 1.63E+01 | 5.38E+01 | 1.14E+02 |

**Table D.6.4.2 Estimated Radiation Doses to Ecological Receptors from Inhalation of Routine Releases, No Action Alternative**

| Retanking Operations Phase | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Source: Evaporator 1 | | | | Radiation Dose (rad/d) | | | | |
| Radio-nuclide | Ci/y released | Phase (y) | Ci/m$^3$ | Mouse | Coyote | Deer | Hawk | Shrike |
| Cs-137 | 2.80E-03 | 2037 to 2042 | 2.57E-18 | 5.93E-12 | 1.29E-12 | 2.20E-13 | 1.04E-12 | 4.33E-12 |
| H-3 | 4.00E+01 | 2037 to 2042 | 3.68E-14 | 1.81E-10 | 3.10E-11 | 5.32E-12 | 2.69E-11 | 1.32E-10 |
| I-129 | 2.70E-03 | 2037 to 2042 | 2.48E-18 | 1.22E-12 | 1.69E-13 | 2.89E-14 | 2.00E-13 | 8.91E-13 |
| Sr-90 | 3.10E-03 | 2037 to 2042 | 2.85E-18 | 2.01E-11 | 2.00E-12 | 3.42E-13 | 2.98E-12 | 1.47E-11 |
| | | | Total | 2.08E-10 | 3.45E-11 | 5.91E-12 | 3.11E-11 | 1.52E-10 |
| Source: Evaporator 2 | | | | Radiation Dose (rad/d) | | | | |
| Cs-137 | 8.70E-04 | 2087 to 2092 | 8.00E-19 | 1.84E-12 | 4.00E-13 | 6.84E-14 | 3.24E-13 | 1.35E-12 |
| H-3 | 2.30E+00 | 2087 to 2092 | 2.12E-15 | 1.04E-11 | 1.78E-12 | 3.06E-13 | 1.54E-12 | 7.60E-12 |
| I-129 | 2.70E-03 | 2087 to 2092 | 2.48E-18 | 1.22E-12 | 1.69E-13 | 2.89E-14 | 2.00E-13 | 8.91E-13 |
| Sr-90 | 9.00E-04 | 2087 to 2092 | 8.28E-19 | 5.83E-12 | 5.80E-13 | 9.93E-14 | 8.66E-13 | 4.26E-12 |
| | | | Total | 1.93E-11 | 2.93E-12 | 5.02E-13 | 2.93E-12 | 1.41E-11 |
| Operations Phase | | | | Radiation Dose (rad/d) | | | | |
| Cs-137 | 1.06E-05 | 1995 to 2042 | 1.34E-16 | 3.10E-10 | 6.72E-11 | 1.15E-11 | 5.44E-11 | 2.26E-10 |
| I-129 | 1.68E-06 | 1995 to 2042 | 2.13E-17 | 1.05E-11 | 1.45E-12 | 2.48E-13 | 1.72E-12 | 7.65E-12 |
| Sr-90 | 9.20E-06 | 1995 to 2042 | 1.17E-16 | 8.22E-10 | 8.18E-11 | 1.40E-11 | 1.22E-10 | 6.01E-10 |
| | | | Total | 1.14E-09 | 1.50E-10 | 2.58E-11 | 1.78E-10 | 8.35E-10 |
| Monitoring and Maintenance Phase | | | | Radiation Dose (rad/d) | | | | |
| Cs-137 | 5.30E-05 | 2042 to 2095 | 4.87E-20 | 1.12E-13 | 2.43E-14 | 4.17E-15 | 1.97E-14 | 8.20E-14 |
| I-129 | 8.40E-06 | 2042 to 2095 | 7.72E-21 | 3.80E-15 | 5.24E-16 | 8.98E-17 | 6.23E-16 | 2.77E-15 |
| Sr-90 | 4.60E-05 | 2042 to 2095 | 4.23E-20 | 2.98E-13 | 2.96E-14 | 5.08E-15 | 4.42E-14 | 2.18E-13 |
| | | | Total | 4.14E-13 | 5.45E-14 | 9.34E-15 | 6.46E-14 | 3.03E-13 |

Table D.6.4.3 Estimated Maximum Radiation Doses (rad/d) from Ingestion of Groundwater Reaching the Columbia River, No Action Alternative

| | Coyote | Deer | Hawk | Shrike |
|---|---|---|---|---|
| Years | Max | Max | Max | Max |
| 300 | 2.45E-05 | 5.01E-06 | 2.22E-05 | 1.55E-04 |
| 500 | 7.24E-05 | 1.48E-05 | 6.56E-05 | 4.59E-04 |
| 2500 | 1.98E-10 | 4.04E-11 | 1.79E-10 | 1.26E-09 |
| 5000 | 4.60E-07 | 9.39E-08 | 2.27E-07 | 1.34E-06 |
| 10000 | 1.27E-08 | 2.58E-09 | 5.97E-09 | 3.48E-08 |

Table D.6.4.4 Total Hazard Index from Direct Contact with Waste, No Action Alternative, Summed by Cell

| | Hazard Index | | | | | |
|---|---|---|---|---|---|---|
| Cell | Plant | Mouse | Coyote | Deer | Hawk | Shrike |
| 1WSS | 1.93E+02 | 9.22E+00 | 2.79E+01 | 7.02E-01 | 1.26E+02 | 9.58E+01 |
| 2WSS | 1.84E+03 | 1.33E+01 | 5.81E+00 | 1.88E+00 | 2.56E+01 | 2.03E+01 |
| 1ESS | 8.99E+02 | 2.14E+01 | 1.13E+02 | 5.99E+00 | 3.33E+02 | 2.44E+02 |
| 2ESS | 1.92E+03 | 5.27E+02 | 3.84E+02 | 3.38E+01 | 1.59E+03 | 1.20E+03 |
| 4ESS | 1.55E+02 | 3.27E+00 | 1.15E+00 | 6.62E-01 | 1.37E+01 | 3.00E+01 |
| 3WDS | 7.17E+03 | 7.21E+01 | 1.35E+02 | 1.34E+01 | 3.70E+02 | 2.70E+02 |
| 3EDS | 6.22E+02 | 1.35E+02 | 7.83E+01 | 8.33E+00 | 3.97E+02 | 2.87E+02 |
| 5EDS | 2.29E+03 | 5.34E+02 | 7.35E+02 | 9.76E+01 | 1.29E+02 | 9.88E+01 |

Table D.6.4.5 Estimated Maximum Hazard Indices from Ingestion of Groundwater Reaching the Columbia River, No Action Alternative

| | Coyote | Deer | Hawk | Shrike |
|---|---|---|---|---|
| Years | Maximum Hazard Index (HI) | Maximum Hazard Index (HI) | Maximum Hazard Index (HI) | Maximum Hazard Index (HI) |
| 300 | 1.35E-01 | 4.97E-02 | 5.12E-02 | 1.13E-01 |
| 500 | 1.21E-01 | 4.44E-02 | 4.95E-02 | 1.09E-01 |
| 2500 | 1.62E-03 | 5.95E-04 | 5.64E-05 | 1.21E-04 |
| 5000 | 3.70E-03 | 1.36E-03 | 9.36E-05 | 2.01E-04 |
| 10000 | 1.57E-04 | 5.75E-05 | 3.50E-06 | 7.50E-06 |

**Table D.6.4.6 Maximum Radiation Doses to Aquatic Organisms Exposed to Groundwater Entering the Columbia River at 300 and 500 Years [1]**

| Organism Dose Rate (rad/d) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Source | Fish | Crawdad | Duck-p | Duck-f | Heron | Muskrat | Raccoon-c | Raccoon-f |
| 300 Year Maximum | | | | | | | | |
| Internal | 3.1E-07 | 3.6E-07 | 2.9E-07 | 8.7E-07 | 5.6E-07 | 2.9E-07 | 3.9E-07 | 3.8E-07 |
| Immersion or Surface | 3.6E-10 | 1.8E-10 | 2.0E-10 | 2.0E-10 | 5.4E-11 | 1.1E-10 | 0.00E+00 | 0.00E+00 |
| Sediment | 9.5E-12 | 1.9E-11 | 3.8E-12 | 3.8E-12 | 5.7E-12 | 5.7E-12 | 3.8E-12 | 3.8E-12 |
| Total | 3.1E-07 | 3.6E-07 | 2.9E-07 | 8.7E-07 | 5.6E-07 | 2.9E-07 | 3.9E-07 | 3.8E-07 |
| 500 Year Maximum | | | | | | | | |
| Internal | 4.2E-07 | 4.3E-07 | 4.8E-07 | 1.2E-06 | 7.7E-07 | 4.8E-07 | 5.3E-07 | 5.2E-07 |
| Immersion or Surface | 2.6E-13 | 1.3E-13 | 1.4E-13 | 1.4E-13 | 3.9E-14 | 7.9E-14 | 0.00E+00 | 0.00E+00 |
| Sediment | 7.5E-12 | 1.5E-11 | 3.0E-12 | 3.0E-12 | 4.5E-12 | 4.5E-12 | 3.0E-12 | 3.0E-12 |
| Total | 4.2E-07 | 4.3E-07 | 4.8E-07 | 1.2E-06 | 7.7E-07 | 4.8E-07 | 5.3E-07 | 5.2E-07 |

Note:
[1] Calculated using the CRITRII model (Baker-Soldat 1992).

**Table D.6.4.7 Estimated Radiation Doses from Inhalation of Routine Releases, Ex Situ Intermediate Separations and Phased Implementation Alternatives**

| Project life 24 Years | | | | Minimum Dose, rad/day | | | | |
|---|---|---|---|---|---|---|---|---|
| Radio-nuclide | Total Ci released | Ci/y released | Ci/m$^3$ | Mouse | Coyote | Deer | Hawk | Shrike |
| Am-241 | 7.38E-02 | 3.08E-03 | 3.70E-14 | 4.35E-09 | 4.24E-10 | 7.26E-11 | 6.47E-10 | 3.18E-09 |
| C-14 | 5.30E+03 | 2.21E+02 | 2.65E-09 | 1.13E-04 | 1.12E-05 | 1.92E-06 | 1.67E-05 | 8.24E-05 |
| Cs-137 | 3.57E+01 | 1.49E+00 | 1.79E-11 | 4.12E-05 | 8.93E-06 | 1.53E-06 | 7.24E-06 | 3.01E-05 |
| I-129 | 5.10E+01 | 2.13E+00 | 2.55E-11 | 1.25E-05 | 1.73E-06 | 2.97E-07 | 2.06E-06 | 9.17E-06 |
| Pu-239 | 8.05E-03 | 3.35E-04 | 4.03E-15 | 4.46E-10 | 4.43E-11 | 7.59E-12 | 6.62E-11 | 3.26E-10 |
| Ru-106 | 1.16E-05 | 4.83E-07 | 5.81E-18 | 2.54E-13 | 2.74E-14 | 4.70E-15 | 3.83E-14 | 1.86E-13 |
| Sm-151 | 3.44E-01 | 1.43E-02 | 1.72E-13 | N/A | N/A | N/A | N/A | N/A |
| Sr-90 | 3.53E+01 | 1.47E+00 | 1.77E-11 | 1.25E-04 | 1.24E-05 | 2.12E-06 | 1.85E-05 | 9.10E-05 |
| Tc-99 | 2.03E-02 | 8.46E-04 | 1.02E-14 | 5.81E-11 | 5.78E-12 | 9.89E-13 | 8.62E-12 | 4.24E-11 |
| Zr-93 | 1.99E-01 | 8.29E-03 | 9.96E-14 | N/A | N/A | N/A | N/A | N/A |
| | | | Total | 2.91E-04 | 3.43E-05 | 5.87E-06 | 4.45E-05 | 2.13E-04 |
| | | | | Maximum Dose, rad/day | | | | |
| Am-241 | 7.38E-02 | 3.08E-03 | 6.06E-09 | 7.12E-04 | 6.95E-05 | 1.19E-05 | 1.06E-04 | 5.21E-04 |
| C-14 | 5.30E+03 | 2.21E+02 | 4.35E-04 | 1.85E+01 | 1.84E+00 | 3.15E-01 | 2.74E+00 | 1.35E+01 |
| Cs-137 | 3.57E+01 | 1.49E+00 | 2.93E-06 | 6.75E+00 | 1.46E+00 | 2.51E-01 | 1.19E+00 | 4.93E+00 |
| I-129 | 5.10E+01 | 2.13E+00 | 4.18E-06 | 2.06E+00 | 2.84E-01 | 4.86E-02 | 3.37E-01 | 1.50E+00 |
| Pu-239 | 8.05E-03 | 3.35E-04 | 6.61E-10 | 7.30E-05 | 7.26E-06 | 1.24E-06 | 1.08E-05 | 5.34E-05 |
| Ru-106 | 1.16E-05 | 4.83E-07 | 9.52E-13 | 4.17E-08 | 4.49E-09 | 7.70E-10 | 6.28E-09 | 3.05E-08 |
| Sm-151 | 3.44E-01 | 1.43E-02 | 2.82E-08 | N/A | N/A | N/A | N/A | N/A |
| Sr-90 | 3.53E+01 | 1.47E+00 | 2.90E-06 | 2.04E+01 | 2.03E+00 | 3.48E-01 | 3.03E+00 | 1.49E+01 |
| Tc-99 | 2.03E-02 | 8.46E-04 | 1.67E-09 | 9.51E-06 | 9.47E-07 | 1.62E-07 | 1.41E-06 | 6.95E-06 |
| Zr-93 | 1.99E-01 | 8.29E-03 | 1.63E-08 | N/A | N/A | N/A | N/A | N/A |
| | | | Total | 4.77E+01 | 5.62E+00 | 9.62E-01 | 7.30E+00 | 3.48E+01 |

Notes:
Emissions data, minimum and maximum Chi/Q values are from Jacobs 1996.

**Table D.6.4.8 Estimated Radiation Doses from Inhalation of Routine Releases, In Situ Alternatives**

| Radio-nuclide | Total Ci released | Ci/y released | Ci/m$^3$ | Mouse | Coyote | Deer | Hawk | Shrike |
|---|---|---|---|---|---|---|---|---|
| In Situ Fill and Cap, Project Life 14 Years | | | | Minimum Dose, rad/day | | | | |
| Am-241 | 1.50E-05 | 1.07E-06 | 1.29E-17 | 1.52E-12 | 1.48E-13 | 2.53E-14 | 2.25E-13 | 1.11E-12 |
| C-14 | 7.50E-07 | 5.36E-08 | 6.44E-19 | 2.74E-14 | 2.72E-15 | 4.66E-16 | 4.06E-15 | 2.00E-14 |
| Cs-137 | 4.90E-03 | 3.50E-04 | 4.21E-15 | 9.69E-09 | 2.10E-09 | 3.60E-10 | 1.70E-09 | 7.08E-09 |
| I-129 | 2.20E-09 | 1.57E-10 | 1.89E-21 | 9.28E-16 | 1.28E-16 | 2.20E-17 | 1.52E-16 | 6.78E-16 |
| Pu-239 | 2.30E-06 | 1.64E-07 | 1.97E-18 | 2.18E-13 | 2.17E-14 | 3.72E-15 | 3.24E-14 | 1.59E-13 |
| Ru-106 | 5.30E-12 | 3.79E-13 | 4.55E-24 | 1.99E-19 | 2.15E-20 | 3.68E-21 | 3.00E-20 | 1.46E-19 |
| Sm-151 | 8.80E-05 | 6.29E-06 | 7.55E-17 | N/A | N/A | N/A | N/A | N/A |
| Sr-90 | 7.60E-03 | 5.43E-04 | 6.52E-15 | 4.60E-08 | 4.57E-09 | 7.83E-10 | 6.82E-09 | 3.36E-08 |
| Tc-99 | 4.50E-06 | 3.21E-07 | 3.86E-18 | 2.21E-14 | 2.20E-15 | 3.76E-16 | 3.28E-15 | 1.61E-14 |
| Zr-93 | 5.50E-07 | 3.93E-08 | 4.72E-19 | N/A | N/A | N/A | N/A | N/A |
| | | | Total | 5.56E-08 | 6.67E-09 | 1.14E-09 | 8.53E-09 | 4.07E-08 |
| | | | | Maximum Dose, rad/day | | | | |
| Am-241 | 1.50E-05 | 1.07E-06 | 2.11E-12 | 2.48E-07 | 2.42E-08 | 4.15E-09 | 3.69E-08 | 1.81E-07 |
| C-14 | 7.50E-07 | 5.36E-08 | 1.05E-13 | 4.48E-09 | 4.46E-10 | 7.64E-11 | 6.66E-10 | 3.28E-09 |
| Cs-137 | 4.90E-03 | 3.50E-04 | 6.89E-10 | 1.59E-03 | 3.44E-04 | 5.90E-05 | 2.79E-04 | 1.16E-03 |
| I-129 | 2.20E-09 | 1.57E-10 | 3.09E-16 | 1.52E-10 | 2.10E-11 | 3.60E-12 | 2.49E-11 | 1.11E-10 |
| Pu-239 | 2.30E-06 | 1.64E-07 | 3.24E-13 | 3.58E-08 | 3.56E-09 | 6.09E-10 | 5.31E-09 | 2.61E-08 |
| Ru-106 | 5.30E-12 | 3.79E-13 | 7.46E-19 | 3.27E-14 | 3.52E-15 | 6.03E-16 | 4.92E-15 | 2.39E-14 |
| Sm-151 | 8.80E-05 | 6.29E-06 | 1.24E-11 | N/A | N/A | N/A | N/A | N/A |
| Sr-90 | 7.60E-03 | 5.43E-04 | 1.07E-09 | 7.53E-03 | 7.49E-04 | 1.28E-04 | 1.12E-03 | 5.50E-03 |
| Tc-99 | 4.50E-06 | 3.21E-07 | 6.33E-13 | 3.62E-09 | 3.60E-10 | 6.16E-11 | 5.37E-10 | 2.64E-09 |
| Zr-93 | 5.50E-07 | 3.93E-08 | 7.74E-14 | N/A | N/A | N/A | N/A | N/A |
| | | | Total | 9.12E-03 | 1.09E-03 | 1.87E-04 | 1.40E-03 | 6.66E-03 |

Table D.6.4.8 Estimated Radiation Doses from Inhalation of Routine Releases, In Situ Alternatives (cont'd)

| Radio-nuclide | Total Ci released | Ci/y released | Ci/m$^3$ | Mouse | Coyote | Deer | Hawk | Shrike |
|---|---|---|---|---|---|---|---|---|
| In Situ Vitrification, Project Life 9 Years | | | | Minimum Dose, rad/day | | | | |
| Am-241 | 9.40E-06 | 1.04E-06 | 1.26E-17 | 1.48E-12 | 1.44E-13 | 2.47E-14 | 2.20E-13 | 1.08E-12 |
| C-14 | 4.80E-07 | 5.33E-08 | 6.41E-19 | 2.72E-14 | 2.71E-15 | 4.64E-16 | 4.04E-15 | 1.99E-14 |
| Cs-137 | 3.10E-03 | 3.44E-04 | 4.14E-15 | 9.53E-09 | 2.07E-09 | 3.54E-10 | 1.68E-09 | 6.97E-09 |
| I-129 | 1.40E-09 | 1.56E-10 | 1.87E-21 | 9.18E-16 | 1.27E-16 | 2.17E-17 | 1.51E-16 | 6.71E-16 |
| Pu-239 | 1.50E-06 | 1.67E-07 | 2.00E-18 | 2.21E-13 | 2.20E-14 | 3.77E-15 | 3.29E-14 | 1.62E-13 |
| Ru-106 | 3.40E-12 | 3.78E-13 | 4.54E-24 | 1.99E-19 | 2.14E-20 | 3.67E-21 | 2.99E-20 | 1.45E-19 |
| Sm-151 | 5.70E-05 | 6.33E-06 | 7.61E-17 | N/A | N/A | N/A | N/A | N/A |
| Sr-90 | 4.80E-03 | 5.33E-04 | 6.41E-15 | 4.51E-08 | 4.49E-09 | 7.69E-10 | 6.70E-09 | 3.30E-08 |
| Tc-99 | 2.90E-06 | 3.22E-07 | 3.87E-18 | 2.21E-14 | 2.20E-15 | 3.77E-16 | 3.28E-15 | 1.62E-14 |
| Zr-93 | 3.50E-07 | 3.89E-08 | 4.67E-19 | N/A | N/A | N/A | N/A | N/A |
| | | | Total | 5.47E-08 | 6.56E-09 | 1.12E-09 | 8.38E-09 | 4.00E-08 |
| | | | | Maximum Dose, rad/day | | | | |
| Am-241 | 9.40E-06 | 1.04E-06 | 2.06E-12 | 2.42E-07 | 2.36E-08 | 4.04E-09 | 3.60E-08 | 1.77E-07 |
| C-14 | 4.80E-07 | 5.33E-08 | 1.05E-13 | 4.46E-09 | 4.44E-10 | 7.61E-11 | 6.63E-10 | 3.26E-09 |
| Cs-137 | 3.10E-03 | 3.44E-04 | 6.78E-10 | 1.56E-03 | 3.39E-04 | 5.80E-05 | 2.75E-04 | 1.14E-03 |
| I-129 | 1.40E-09 | 1.56E-10 | 3.06E-16 | 1.50E-10 | 2.08E-11 | 3.56E-12 | 2.47E-11 | 1.10E-10 |
| Pu-239 | 1.50E-06 | 1.67E-07 | 3.28E-13 | 3.63E-08 | 3.61E-09 | 6.18E-10 | 5.39E-09 | 2.65E-08 |
| Ru-106 | 3.40E-12 | 3.78E-13 | 7.44E-19 | 3.26E-14 | 3.51E-15 | 6.02E-16 | 4.91E-15 | 2.38E-14 |
| Sm-151 | 5.70E-05 | 6.33E-06 | 1.25E-11 | N/A | N/A | N/A | N/A | N/A |
| Sr-90 | 4.80E-03 | 5.33E-04 | 1.05E-09 | 7.40E-03 | 7.36E-04 | 1.26E-04 | 1.10E-03 | 5.41E-03 |
| Tc-99 | 2.90E-06 | 3.22E-07 | 6.35E-13 | 3.62E-09 | 3.61E-10 | 6.18E-11 | 5.38E-10 | 2.65E-09 |
| Zr-93 | 3.50E-07 | 3.89E-08 | 7.66E-14 | N/A | N/A | N/A | N/A | N/A |
| | | | Total | 8.96E-03 | 1.07E-03 | 1.84E-04 | 1.37E-03 | 6.55E-03 |

Notes:
Emissions data from WHC 1995f.
Minimum and maximum Chi/Q values are from Jacobs 1996.

**Table D.6.4.9 Estimated Radiation Doses from Inhalation of Routine Releases, Ex Situ No Separations Alternative**

| Project Life 14 Years | | | | Minimum Dose, rad/day | | | | |
|---|---|---|---|---|---|---|---|---|
| Radio-nuclide | Total Ci released | Ci/y released | Minimum Ci/m$^3$ | Mouse | Coyote | Deer | Hawk | Shrike |
| Am-241 | 7.37E-02 | 5.26E-03 | 6.33E-14 | 7.44E-09 | 7.26E-10 | 1.24E-10 | 1.11E-09 | 5.44E-09 |
| C-14 | 5.30E+03 | 3.79E+02 | 4.55E-09 | 1.93E-04 | 1.92E-05 | 3.29E-06 | 2.87E-05 | 1.41E-04 |
| Cs-137 | 2.56E+01 | 1.83E+00 | 2.20E-11 | 5.06E-05 | 1.10E-05 | 1.88E-06 | 8.90E-06 | 3.70E-05 |
| I-129 | 5.10E+01 | 3.64E+00 | 4.38E-11 | 2.15E-05 | 2.97E-06 | 5.09E-07 | 3.53E-06 | 1.57E-05 |
| Pu-239 | 8.10E-03 | 5.79E-04 | 6.95E-15 | 7.69E-10 | 7.65E-11 | 1.31E-11 | 1.14E-10 | 5.62E-10 |
| Ru-106 | 1.16E-05 | 8.29E-07 | 9.96E-18 | 4.36E-13 | 4.70E-14 | 8.05E-15 | 6.57E-14 | 3.19E-13 |
| Sm-151 | 3.44E-01 | 2.46E-02 | 2.95E-13 | N/A | N/A | N/A | N/A | N/A |
| Sr-90 | 3.52E+01 | 2.51E+00 | 3.02E-11 | 2.13E-04 | 2.12E-05 | 3.63E-06 | 3.16E-05 | 1.56E-04 |
| Tc-99 | 2.04E-02 | 1.46E-03 | 1.75E-14 | 1.00E-10 | 9.95E-12 | 1.70E-12 | 1.49E-11 | 7.31E-11 |
| Zr-93 | 1.98E-01 | 1.41E-02 | 1.70E-13 | N/A | N/A | N/A | N/A | N/A |
| | | | Total | 4.78E-04 | 5.44E-05 | 9.31E-06 | 7.27E-05 | 3.50E-04 |
| | | | | Maximum Dose, rad/day | | | | |
| Am-241 | 7.37E-02 | 5.26E-03 | 1.04E-08 | 1.22E-03 | 1.19E-04 | 2.04E-05 | 1.81E-04 | 8.91E-04 |
| C-14 | 5.30E+03 | 3.79E+02 | 7.46E-04 | 3.17E+01 | 3.15E+00 | 5.40E-01 | 4.70E+00 | 2.32E+01 |
| Cs-137 | 2.56E+01 | 1.83E+00 | 3.60E-06 | 8.29E+00 | 1.80E+00 | 3.08E-01 | 1.46E+00 | 6.06E+00 |
| I-129 | 5.10E+01 | 3.64E+00 | 7.17E-06 | 3.52E+00 | 4.87E-01 | 8.34E-02 | 5.78E-01 | 2.58E+00 |
| Pu-239 | 8.10E-03 | 5.79E-04 | 1.14E-09 | 1.26E-04 | 1.25E-05 | 2.15E-06 | 1.87E-05 | 9.20E-05 |
| Ru-106 | 1.16E-05 | 8.29E-07 | 1.63E-12 | 7.15E-08 | 7.70E-09 | 1.32E-09 | 1.08E-08 | 5.22E-08 |
| Sm-151 | 3.44E-01 | 2.46E-02 | 4.84E-08 | N/A | N/A | N/A | N/A | N/A |
| Sr-90 | 3.52E+01 | 2.51E+00 | 4.95E-06 | 3.49E+01 | 3.47E+00 | 5.94E-01 | 5.18E+00 | 2.55E+01 |
| Tc-99 | 2.04E-02 | 1.46E-03 | 2.87E-09 | 1.64E-05 | 1.63E-06 | 2.79E-07 | 2.43E-06 | 1.20E-05 |
| Zr-93 | 1.98E-01 | 1.41E-02 | 2.79E-08 | N/A | N/A | N/A | N/A | N/A |
| | | | Total | 7.84E+01 | 8.91E+00 | 1.53E+00 | 1.19E+01 | 5.73E+01 |

Notes:
Emissions data and minimum and maximum Chi/Q values are from Jacobs 1996.

**Table D.6.4.10 Estimated Radiation Doses from Inhalation of Routine Releases, Ex Situ/In Situ Combination 1 Alternative**

| Project Life 20 Years | | | | Minimum Dose, rad/day | | | | |
|---|---|---|---|---|---|---|---|---|
| Radio-nuclide | Total Ci released | Ci/year released | $Ci/m^3$ | Mouse | Coyote | Deer | Hawk | Shrike |
| Am-241 | 6.16E-02 | 3.08E-03 | 3.70E-14 | 1.48E-12 | 1.44E-13 | 2.47E-14 | 2.20E-13 | 1.08E-12 |
| C-14 | 4.42E+03 | 2.21E+02 | 2.66E-09 | 2.72E-14 | 2.71E-15 | 4.64E-16 | 4.04E-15 | 1.99E-14 |
| Cs-137 | 2.98E+01 | 1.49E+00 | 1.79E-11 | 9.53E-09 | 2.07E-09 | 3.54E-10 | 1.68E-09 | 6.97E-09 |
| I-129 | 4.26E+01 | 2.13E+00 | 2.56E-11 | 9.18E-16 | 1.27E-16 | 2.17E-17 | 1.51E-16 | 6.71E-16 |
| Pu-239 | 1.59E-02 | 7.96E-04 | 9.57E-15 | 2.21E-13 | 2.20E-14 | 3.77E-15 | 3.29E-14 | 1.62E-13 |
| Ru-106 | 9.66E-06 | 4.83E-07 | 5.80E-18 | 1.99E-19 | 2.14E-20 | 3.67E-21 | 2.99E-20 | 1.45E-19 |
| Sm-151 | 2.86E-01 | 1.43E-02 | 1.72E-13 | N/A | N/A | N/A | N/A | N/A |
| Sr-90 | 2.94E+01 | 1.47E+00 | 1.77E-11 | 4.51E-08 | 4.49E-09 | 7.69E-10 | 6.70E-09 | 3.30E-08 |
| Tc-99 | 1.69E-02 | 8.46E-04 | 1.02E-14 | 2.21E-14 | 2.20E-15 | 3.77E-16 | 3.28E-15 | 1.62E-14 |
| Zr-93 | 1.66E-01 | 8.29E-03 | 9.96E-14 | N/A | N/A | N/A | N/A | N/A |
| | | | Total | 5.47E-08 | 6.56E-09 | 1.12E-09 | 8.38E-09 | 4.00E-08 |
| | | | | Maximum Dose, rad/day | | | | |
| Am-241 | 6.16E-02 | 3.08E-03 | 6.07E-09 | 2.42E-07 | 2.36E-08 | 4.04E-09 | 3.60E-08 | 1.77E-07 |
| C-14 | 4.42E+03 | 2.21E+02 | 4.35E-04 | 4.46E-09 | 4.44E-10 | 7.61E-11 | 6.63E-10 | 3.26E-09 |
| Cs-137 | 2.98E+01 | 1.49E+00 | 2.93E-06 | 1.56E-03 | 3.39E-04 | 5.80E-05 | 2.75E-04 | 1.14E-03 |
| I-129 | 4.26E+01 | 2.13E+00 | 4.19E-06 | 1.51E-10 | 2.08E-11 | 3.56E-12 | 2.47E-11 | 1.10E-10 |
| Pu-239 | 1.59E-02 | 7.96E-04 | 1.57E-09 | 3.63E-08 | 3.61E-09 | 6.18E-10 | 5.39E-09 | 2.65E-08 |
| Ru-106 | 9.66E-06 | 4.83E-07 | 9.51E-13 | 3.26E-14 | 3.51E-15 | 6.02E-16 | 4.91E-15 | 2.38E-14 |
| Sm-151 | 2.86E-01 | 1.43E-02 | 2.82E-08 | N/A | N/A | N/A | N/A | N/A |
| Sr-90 | 2.94E+01 | 1.47E+00 | 2.89E-06 | 7.40E-03 | 7.36E-04 | 1.26E-04 | 1.10E-03 | 5.41E-03 |
| Tc-99 | 1.69E-02 | 8.46E-04 | 1.67E-09 | 3.62E-09 | 3.61E-10 | 6.18E-11 | 5.38E-10 | 2.65E-09 |
| Zr-93 | 1.66E-01 | 8.29E-03 | 1.63E-08 | N/A | N/A | N/A | N/A | N/A |
| | | | Total | 8.96E-03 | 1.07E-03 | 1.84E-04 | 1.37E-03 | 6.55E-03 |

Notes:
Emissions data from Table D.4.8.1
Minimum and maximum Chi/Q values are from Jacobs 1996.

**Table D.6.4.11 Estimated Radiation Doses from Inhalation of Routine Releases, Ex Situ/In Situ Combination 2 Alternative**

| Project Life 18 Years | | | | Minimum Dose, rad/day | | | | |
|---|---|---|---|---|---|---|---|---|
| Radio-nuclide | Total Ci released | Ci/year released | $Ci/m^3$ | Mouse | Coyote | Deer | Hawk | Shrike |
| Am-241 | 6.16E-02 | 3.42E-03 | 4.11E-14 | 1.48E-12 | 1.44E-13 | 2.47E-14 | 2.20E-13 | 1.08E-12 |
| C-14 | 4.43E+03 | 2.46E+02 | 2.96E-09 | 2.72E-14 | 2.71E-15 | 4.64E-16 | 4.04E-15 | 1.99E-14 |
| Cs-137 | 2.99E+01 | 1.66E+00 | 2.00E-11 | 9.53E-09 | 2.07E-09 | 3.54E-10 | 1.68E-09 | 6.97E-09 |
| I-129 | 3.49E+01 | 1.94E+00 | 2.33E-11 | 9.18E-16 | 1.27E-16 | 2.17E-17 | 1.51E-16 | 6.71E-16 |
| Pu-239 | 1.63E-02 | 9.08E-04 | 1.09E-14 | 2.21E-13 | 2.20E-14 | 3.77E-15 | 3.29E-14 | 1.62E-13 |
| Ru-106 | 9.67E-06 | 5.37E-07 | 6.45E-18 | 1.99E-19 | 2.14E-20 | 3.67E-21 | 2.99E-20 | 1.45E-19 |
| Sm-151 | 2.86E-01 | 1.59E-02 | 1.91E-13 | N/A | N/A | N/A | N/A | N/A |
| Sr-90 | 2.93E+01 | 1.63E+00 | 1.96E-11 | 4.51E-08 | 4.49E-09 | 7.69E-10 | 6.70E-09 | 3.30E-08 |
| Tc-99 | 1.69E-02 | 9.40E-04 | 1.13E-14 | 2.21E-14 | 2.20E-15 | 3.77E-16 | 3.28E-15 | 1.62E-14 |
| Zr-93 | 1.67E-01 | 9.26E-03 | 1.11E-13 | N/A | N/A | N/A | N/A | N/A |
| | | | Total | 5.47E-08 | 6.56E-09 | 1.12E-09 | 8.38E-09 | 4.00E-08 |
| | | | | Maximum Dose, rad/day | | | | |
| Am-241 | 6.16E-02 | 3.42E-03 | 6.73E-09 | 2.42E-07 | 2.36E-08 | 4.04E-09 | 3.60E-08 | 1.77E-07 |
| C-14 | 4.43E+03 | 2.46E+02 | 4.84E-04 | 4.46E-09 | 4.44E-10 | 7.61E-11 | 6.63E-10 | 3.26E-09 |
| Cs-137 | 2.99E+01 | 1.66E+00 | 3.27E-06 | 1.56E-03 | 3.39E-04 | 5.80E-05 | 2.75E-04 | 1.14E-03 |
| I-129 | 3.49E+01 | 1.94E+00 | 3.82E-06 | 1.51E-10 | 2.08E-11 | 3.56E-12 | 2.47E-11 | 1.10E-10 |
| Pu-239 | 1.63E-02 | 9.08E-04 | 1.79E-09 | 3.63E-08 | 3.61E-09 | 6.18E-10 | 5.39E-09 | 2.65E-08 |
| Ru-106 | 9.67E-06 | 5.37E-07 | 1.06E-12 | 3.26E-14 | 3.51E-15 | 6.02E-16 | 4.91E-15 | 2.38E-14 |
| Sm-151 | 2.86E-01 | 1.59E-02 | 3.13E-08 | N/A | N/A | N/A | N/A | N/A |
| Sr-90 | 2.93E+01 | 1.63E+00 | 3.21E-06 | 7.40E-03 | 7.36E-04 | 1.26E-04 | 1.10E-03 | 5.41E-03 |
| Tc-99 | 1.69E-02 | 9.40E-04 | 1.85E-09 | 3.62E-09 | 3.61E-10 | 6.18E-11 | 5.38E-10 | 2.65E-09 |
| Zr-93 | 1.67E-01 | 9.26E-03 | 1.82E-08 | N/A | N/A | N/A | N/A | N/A |
| | | | Total | 8.96E-03 | 1.07E-03 | 1.84E-04 | 1.37E-03 | 6.55E-03 |

Notes:
Emissions data from Table D.4.9.1
Minimum and maximum Chi/Q values are from Jacobs 1996.

minimum Chi/Q would be approximately 100,000 times lower. It is therefore considered unlikely that ecological receptors would be exposed to harmful levels of airborne radiation resulting from routine releases under any alternative. Corresponding indirect impacts on the ecosystem would be similarly unlikely.

### D.6.5 UNCERTAINTY

The greatest uncertainty in calculating both the HIs and radiation doses was associated with the source data. Source terms are based on estimated inventories and, for radionuclides, subsequent decay. Additional or better source data could either increase or decrease the estimated hazards. Secondary contributors to uncertainty are the transfer factors used to estimate plant uptake and assimilation in the mouse. Additional data on these factors could either increase or decrease the estimated hazards. Additional likely secondary contributors to uncertainty are the NOAELs for chemical hazard and the water ingestion and inhalation rates. The CRITRII model (Baker-Soldat 1992) was used only for estimating maximum radiation doses to aquatic organisms exposed to groundwater entering the Columbia River at 300 to 500 years. These estimates were all lower than one millionth of a rad per day, the benchmark recommended by NCRP (NCRP 1991) as protective of aquatic organisms. It is unlikely that detailed uncertainty analysis would alter the conclusion that groundwater risks are very low. Additional discussion of the uncertainties in the ecological risk assessment is provided in Volume Five, Appendix K.

### D.6.6 DERIVATION OF ECOLOGICAL NO OBSERVED ADVERSE EFFECT LEVELS

This section describes the derivation of those NOAELs not taken directly from Opresko et al. (Opresko et al. 1994) or DOE (DOE 1994). Table D.6.3.5 lists all the NOAELs used in this document.

#### D.6.6.1 Boron in Birds

According to Smith and Anders (Smith-Anders 1989), 30 mg/kg of boron in the diet substantially reduced weight gain in ducklings. Control ducklings weighed 36.2 g, (N = 23, SD = 0.7). 30 mg/kg of boron on a fresh weight basis was 35 mg/kg on a dry weight basis. Consider this portion of the study a subchronic study because it was less than 10 weeks, although the adult feeding portion included reproduction. Consider the 30 mg/kg in diet to be a subchronic lowest observed effect level (LOEL). Feeding rates of adult mallards were 222, 184, and 209 g food/day in feeding trials. The mean equals 205 g/day. Male adults weigh approximately 1.3 kg and females approximately 1.1 kg (Table 4 in Smith-Anders 1989). The mean duck weight is thus 1.2 kg. If a 1.2-kg adult consumes 205 g/day, a 36-g duckling is assumed to consume (36/1200) · 205 = 6.15 g/day.

[(30 mg B/ kg food) · (6.15 g food/day) · (1 kg/1000 g)]/0.036 kg body weight)] = 5.125 mg/kg/day as a subchronic LOEL.

5.125 mg/kg/day · 0.1 = 0.5125 mg/kg/day as a chronic LOEL for a 36-g mallard duckling, following the extrapolation suggested by Opresko et al. (Opresko et al. 1994).

### D.6.6.2 Boron in Mammals

Table 9 in Eisler (Eisler 1990) states that rats fed 350 or 525 mg B/kg diet as borax or boric acid for 2 years had no observable effects on fertility, lactation, litter size, weight, or appearance. Using the rat weight of 0.35 kg from Opresko et al. (Opresko et al. 1994), estimate the food intake rate from EPA (EPA 1993) Equation 8 as 0.017 kg/day. Assume that 350 mg B/kg diet dry weight is a chronic NOAEL. Then, [(350 mg/kg food) · (0.017 kg/day)]/0.35 kg body weight = 17 mg/kg/day as a chronic NOAEL for a rat.

### D.6.6.3 Cerium

The Hazardous Substance Data Bank (HSDB), May 1995 NTOX entry, reproduced in the following text, states that cerium compounds are nontoxic when ingested.

1 - HSDB
NAME - DICERIUM TRIOXIDE
RN - 1345-13-7
NTOX - INSOL CERIUM COMPD, SUCH AS THE OXIDES, ARE NONTOXIC WHEN INGESTED ORALLY... /CERIUM OXIDES/ [VENUGOPAL. METAL TOX IN MAMMALS 2 1978 , p. 151] **PEER REVIEWED**

### D.6.6.4 Chromium in Birds

Rosomer et al. (Rosomer et al. 1961), as cited in Driver (Driver 1994) state that "chickens appear to be resistant to hexavalent chromium since exposure to 100 ppm in the diet did not cause any adverse effects." The title of the Rosomer article indicates a "growing chick." Assume that 100 ppm CrVI is a reasonable subchronic NOAEL for chicks (not adults). Using the body weight (BW) and food consumption rate (IR) from Opresko et al. (Opresko et al. 1994), Page A-24: BW = 0.534 kg, IR = 0.044 kg/d, 100 ppm = 100 mg/kg, then [(100 mg/kg food) · (0.044 kg food/day)]/0.534 kg BW = 8.24 mg/kg/day as a subchronic NOAEL.

It can be extrapolated from the subchronic value suggested by Opresko et al. (Opresko et al. 1994) to arrive at (8.24) · (0.1) = 0.824 mg/kg/day as a chronic avian NOAEL.

### D.6.6.5 Molybdenum

Table 4 of Eisler (1989) states that female mule deer had no effects after 33 days on a diet of up to 200 mg Mo/kg in their feed. Assume this value is an acceptable subchronic NOAEL. Then, in a like manner, one can extrapolate a chronic NOAEL as follows:

$$\frac{(200 \text{ mg/kg food}) \cdot (37 \text{ kg food/day})}{57 \text{ kg Bw}} \cdot (0.1) = 1.3 \text{ mg/kg/day}$$

### D.6.6.6 Nitrite

The reference for this HSDB entry from May 1995 is reproduced in the following text. The test species is a rat with a body weight of 0.35 kg (EPA 1988) and a water ingestion rate of 0.046 L/day (EPA 1988, Table 1-4). The study duration is three generations and resulted in a 100 mg/kg/day

NOAEL, considered chronic due to the length of the study. The nitrite portion of sodium nitrite = (100-33.32) = 66.68 percent 100 · 0.6668 = 67 mg/kg/day. The final NOAEL is thus 67 mg/kg/day.

1 - HSDB
NAME OF SUBSTANCE SODIUM NITRITE
CAS REGISTRY NUMBER 7632-00-0

NONHUMAN TOXICITY EXCERPTS
... RATS RECEIVED SODIUM NITRITE AT 100 MG/KG IN DRINKING WATER DAILY DURING THEIR ENTIRE LIFE SPAN OVER THREE GENERATION; NO EVIDENCE OF CHRONIC TOXICITY, CARCINOGENICITY, OR TERATOGENICITY ... FOUND. [NRC. DRINKING WATER & HEALTH 1977 , p. 420] **PEER REVIEWED**

### D.6.6.7 Silver

The reference for this IRIS entry from May 1995 is reproduced in the following text. The test species is a human with a body weight of 70 kg (EPA 1989). The study duration was more than 2 years. The effect endpoint was argyria (skin discoloration) and the exposure route was oral and injection in medication at various dosages. Consider the reported NOAEL of 0.014 mg/kg/day to be a chronic NOAEL. Then the final NOAEL is 0.014 mg/kg/day.

1 - IRIS
NAME OF SUBSTANCE Silver
CAS REGISTRY NUMBER 7440-22-4

REFERENCE DOSE FOR ORAL EXPOSURE
ORAL RFD SUMMARY

| Critical Effect | Experimental Doses* | UF | MF | RfD |
|---|---|---|---|---|
| Argyria | NOEL: None | 3 | 1 | 5E-3 mg/kg/day |
| 2- to 9-Year | LOAEL: 1 g (total dose); Human i.v. Study converted to an oral dose of 0.014 mg/kg/day (Gaul-Staud 1935). | | | |

*Conversion Factors: Based on conversion from the total i.v. dose to a total oral dose of 25 g (i.v. dose of 1 g divided by 0.04, assumed oral retention factor; see Furchner et al., 1968 in Additional Comments section) and dividing by 70 kg (154 lb) (adult body weight) and 25,500 days (a lifetime, or 70 years).

### D.6.6.8 Tungsten

The reference is an HSDB entry from May 1995, reproduced in the following text. The test species is a rat with a body weight of 0.35 kg (EPA 1988) and a food ingestion rate of 0.017 kg/day, calculated using Equation 3-8, for rodents (EPA 1993). The study duration was 70 days. Two percent in the diet is considered a subchronic NOAEL, with the effect endpoint being growth rate and the exposure route being ingestion. The calculations are as follows:

([0.02] [0.017 kg/day][$10^6$ mg/kg])/0.35 kg = 971 mg/kg/day for a subchronic NOAEL. Multiply by 0.1 to get a chronic NOAEL of 97 mg/kg/day (Opresko et al. 1994).

> NTOX - TUNGSTEN METAL POWDER FED 70 DAYS TO WEANLING RATS...@ LEVELS 2, 5, & 10 PERCENT OF DIET...RESULTED IN NO EFFECT ON GROWTH RATE OF MALE RATS BUT CAUSED 15 PERCENT REDN IN WT GAIN IN FEMALES FROM THAT OF CONTROLS. PARTICLE SIZE...NOT REPORTED. [PATTY. INDUS HYG & TOX 2ND ED VOL2 1963 , p. 1162] **PEER REVIEWED**

### D.7.0 INTRUDER RISK

This section describes the potential risk to human health from inadvertent intrusion into the post-remediation contamination sources for each of the TWRS alternatives. The intruder scenarios used for this analysis were taken from prior Hanford Site evaluations, which estimated the risk from intrusion into a Hanford Site solid waste burial ground (Aaberg-Kennedy 1990, as modified in Rittmann 1994). The prior evaluations used 10 intruder scenarios summarized as follows.

1. **Well Driller** - A 30-cm (1-ft) diameter well is drilled through the waste. Dose to the intruder is from the 40-hour drilling activities.
2. **Post-Drilling Resident** - A resident has a vegetable garden in the soil exhumed by the well-drilling operation. This garden supplies 25 percent of the resident's vegetable intake each year.
3. **Excavation** - 100 $m^3$ (3,500 $ft^3$) of waste is exhumed in the course of constructing a house with a basement. Dose to the intruder is from the 80 hours excavation activity.
4. **Post Excavation** - A resident has a vegetable garden in the soil exhumed by the excavation operation.
5. **Residential Garden, Shallow Waste** - The waste is not disturbed but 30 percent of garden plant roots reach into the waste.
6. **Residential Garden, Deep Waste** - The waste is not disturbed but 1 percent of garden plant roots reach into the waste.
7. **Residential Garden, Deep Waste, Biotic Transport** - 1 percent of garden plants' roots reach into the waste and animals burrowing into the waste have been bringing contamination to the surface.
8. **Farming** - A farm over the waste site has 1 percent of plant roots in the waste. The farmer's intake is 25 percent of the vegetables and 100 percent of the meat and milk that are produced from this farm.
9. **Irrigated Garden** - A well near the waste site is used to irrigate a vegetable garden.
10. **Drinking Water** - Well water is consumed by the resident directly.

Of these 10 scenarios, the well driller and post-drilling resident were selected to represent inadvertent intrusion for this analysis. These two scenarios were selected based on their applicability to the deep contamination sources (i.e., tank residuals, LAW vaults, and capsules) involved in this analysis.

The underground depth of both the tank residuals and LAW vaults would make them inaccessible to the shallow intrusion of the other scenarios.

The human health risk for the two intruder scenarios is calculated as the carcinogenic effect resulting from exposure to the radionuclides contained in the waste exhumed during well drilling. Risk is expressed in terms of cancer fatalities and cancer incidence. The carcinogenic effects from chemical carcinogens and the toxic effects from chemical noncarcinogens are not included in the analysis.

The source was calculated as the total activity in curies of each constituent exhumed and made available at the surface. The source is calculated from a representative tank, LAW vault, or capsule canister corresponding to each alternative. The source activity (Ci) is then multiplied by a unit dose factor (mrem/yr/Ci) for each receptor (well driller and post-drilling resident) to produce the dose (mrem/yr). Unit dose factors are calculated for a unit activity (Ci) for each constituent based on the exposure conditions defined for each receptor. The well driller dose is from 40 hours of external exposure to the exhumed contaminants. The post-drilling resident is assumed to spread the exhumed contaminants uniformly over an area of 2,500 $m^2$ (0.62 acre), and the contaminated surface soil becomes the basis for the dose received. This receptor supplies 25 percent of his vegetable intake each year from this contaminated land. The resultant risk for each receptor is the product of the total dose and the dose to risk conversion factor.

### D.7.1 SOURCE

The source refers to the total inventory exhumed and brought to surface. The source for the intruder scenario is alternative dependent. The methodology used for estimating the source for each alternative is different and specific to the alternative.

#### D.7.1.1 No Action Alternative (Tank Waste)

Table D.7.1.1 shows the source term for this alternative for each of the eight aggregated source areas described in Volume Two, Appendix A. The source term is the inventory of each radionuclide ($Ci_{exh}$) in the volume of waste exhumed ($v_{exh}$) from a representative tank with a waste volume of $V_{avg}$. The inventory of each radionuclide in a representative tank ($Ci_{avg}$) within each of the eight source areas is calculated by dividing the radionuclide inventory for SST farms (Tables A.2.1.1 and A.2.1.2) and DST farms (Tables A.2.1.4 and A.2.1.5) by the number of tanks within each of the source areas. The exhumed activity ($Ci_{exh}$) from the average tank in each source area is calculated as follows:

$$Ci_{exh} = Ci_{avg} \cdot (v_{exh}/V_{avg})$$

$$V_{avg} = \pi R^2_{avg} h_{avg}$$

$$v_{exh} = \pi r^2_{exh} h_{exh}$$

$$h_{exh} = h_{avg}$$

$$Ci_{exh} = Ci_{avg} \cdot [(\pi r^2_{exh} h_{exh})/(\pi R^2_{avg} h_{avg})]$$

Therefore: $$Ci_{exh} = Ci_{avg} \cdot [r_{exh}/R_{avg}]^2$$

Where:

$R_{avg}$ is the radius of the average tank or 11.4 m (37.5 ft)
$r_{exh}$ is the radius of the exhumed waste or 0.15 m (0.49 ft), and
$h_{avg}$ represents the thickness or height of the waste in a representative tank.
$h_{exh}$ represents the thickness or height of the waste exhumed.

Then: $$Ci_{exh} = Ci_{avg} \times 1.73E\text{-}04.$$

### D.7.1.2 Long-Term Management Alternative

The source term for the Long-Term Management alternative would be the same as for the No Action alternative. Table D.7.1.1 shows the amount of activity that is exhumed for the No Action alternative for the eight source areas.

### D.7.1.3 In Situ Fill and Cap Alternative

The source term for the In Situ Fill and Cap alternative would be the same as for the No Action alternative. Table D.7.1.1 shows the amount of activity that is exhumed for the No Action alternative for the eight source areas.

### D.7.1.4 In Situ Vitrification Alternative

Table D.7.1.2 shows the source term for the In Situ Vitrification alternative. The source term ($Ci_{avg}$) is estimated from the average concentration ($C_{avg}$) in $Ci/m^3$ of each radionuclide in the final waste form for this alternative as given in Table 7.1 of WHC (1995f). This concentration assumes that the entire tank farm is vitrified to an 18-m (59-ft) depth, including the areas between the tanks. The total activity of the exhumed waste ($Ci_{exh}$) is calculated by multiplying this average concentration by the volume of exhumed waste ($v_{exh}$) as follows.

$$Ci_{exh} = C_{avg} \cdot v_{exh}$$

$$v_{exh} = \pi r^2_{exh} h_{exh}$$

$$= \pi \times (0.15\ m)^2 \cdot 18\ m$$

$$= 1.27\ m^3$$

Therefore: $$Ci_{exh} = C_{avg} \cdot 1.27\ m^3$$

Where:

$r_{exh}$ is the radius of the exhumed waste or 0.15 m (0.49 ft), and
$h_{exh}$ is the thickness or height of the waste or 18 m (59 ft).

Table D.7.1.1 Exhumed Inventory by Source Area for the No Action Alternative, Total Curies

| | Source Area | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Radionuclide [1] | 1WSS | 2WSS | 1ESS | 2ESS | 4ESS | 3WDS | 3EDS | 5EDS |
| Ac-225 | 7.43E-12 | 1.15E-11 | 2.60E-11 | 2.42E-11 | 4.89E-11 | N/A | N/A | N/A |
| Ac-227 | 2.23E-08 | 1.71E-08 | 3.81E-08 | 1.67E-08 | 4.77E-09 | N/A | N/A | N/A |
| Am-241 | 7.32E-03 | 3.80E-02 | 3.22E-02 | 1.05E-01 | 7.96E-02 | 6.83E-01 | 9.19E-01 | 6.13E-03 |
| Am-242 | 1.15E-05 | 7.75E-05 | 8.10E-05 | 2.15E-04 | 1.49E-04 | N/A | N/A | N/A |
| Am-242m | 1.16E-05 | 7.79E-05 | 8.14E-05 | 2.16E-04 | 1.50E-04 | N/A | N/A | N/A |
| Am-243 | 4.37E-06 | 3.13E-05 | 4.12E-05 | 1.25E-04 | 5.38E-05 | N/A | N/A | N/A |
| At-217 | 7.43E-12 | 1.15E-11 | 2.60E-11 | 2.42E-11 | 4.89E-11 | N/A | N/A | N/A |
| Ba-137m | 3.64E+00 | 1.51E+01 | 1.52E+01 | 1.36E+00 | 2.35E+00 | 2.10E+02 | 3.42E+02 | 4.79E+01 |
| Bi-210 | 6.46E-14 | 4.65E-14 | 5.77E-14 | 7.56E-14 | 4.85E-14 | N/A | N/A | N/A |
| Bi-211 | 2.23E-08 | 1.71E-08 | 3.81E-08 | 1.67E-08 | 4.77E-09 | N/A | N/A | N/A |
| Bi-212 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Bi-213 | 7.43E-12 | 1.15E-11 | 2.60E-11 | 2.42E-11 | 4.89E-11 | N/A | N/A | N/A |
| Bi-214 | 2.62E-13 | 2.01E-13 | 2.24E-13 | 3.21E-13 | 2.72E-13 | N/A | N/A | N/A |
| C-14 | 1.22E-03 | 1.96E-03 | 7.88E-03 | 2.31E-03 | 3.13E-03 | 4.63E-05 | 3.64E-02 | 6.44E-05 |
| Cm-242 | 9.56E-06 | 6.43E-05 | 6.72E-05 | 1.78E-04 | 1.24E-04 | N/A | N/A | N/A |
| Cm-244 | 1.39E-05 | 9.57E-05 | 2.16E-04 | 5.75E-04 | 1.24E-04 | N/A | N/A | N/A |
| Cm-245 | 8.95E-10 | 6.98E-09 | 1.65E-08 | 4.41E-08 | 9.50E-09 | N/A | N/A | N/A |
| Cs-135 | 8.90E-05 | 2.72E-04 | 2.27E-04 | 1.73E-05 | 3.67E-05 | N/A | N/A | N/A |
| Cs-137 | 3.84E+00 | 1.60E+01 | 1.61E+01 | 1.44E+00 | 2.49E+00 | 2.10E+02 | 3.42E+02 | 4.79E+01 |
| Eu-154 | N/A | N/A | N/A | N/A | N/A | 2.51E-02 | 1.15E+00 | 6.55E-03 |
| Fr-221 | 7.43E-12 | 1.15E-11 | 2.60E-11 | 2.42E-11 | 4.89E-11 | N/A | N/A | N/A |
| Fr-223 | 3.08E-10 | 2.35E-10 | 5.25E-10 | 2.31E-10 | 6.58E-11 | N/A | N/A | N/A |
| I-129 | 7.32E-06 | 1.76E-05 | 3.94E-05 | 6.43E-06 | 2.95E-06 | N/A | N/A | N/A |
| Nb-93m | 3.68E-04 | 2.71E-03 | 1.60E-03 | 4.36E-03 | 2.59E-02 | N/A | N/A | N/A |
| Ni-59 | N/A | 6.84E-03 | 1.43E-02 | N/A | N/A | N/A | N/A | N/A |
| Ni-63 | 2.94E-02 | 1.95E-01 | 2.28E-01 | 6.32E-01 | 1.88E+00 | N/A | N/A | N/A |
| Np-237 | 3.56E-05 | 4.41E-05 | 2.13E-04 | 3.63E-06 | 7.72E-06 | 2.18E-05 | 7.05E-04 | 1.75E-06 |
| Np-238 | 5.51E-08 | 3.71E-07 | 3.88E-07 | 1.03E-06 | 7.14E-07 | N/A | N/A | N/A |
| Np-239 | 4.37E-06 | 3.13E-05 | 4.12E-05 | 1.25E-04 | 5.38E-05 | N/A | N/A | N/A |
| Pa-231 | 4.14E-08 | 2.93E-08 | 6.57E-08 | 3.64E-08 | 1.10E-08 | N/A | N/A | N/A |
| Pa-233 | 3.56E-05 | 4.41E-05 | 2.13E-04 | 3.63E-06 | 7.72E-06 | N/A | N/A | N/A |
| Pa-234 | 1.18E-06 | 4.15E-07 | 1.12E-06 | 1.11E-06 | 4.55E-07 | N/A | N/A | N/A |
| Pa-234m | 7.40E-04 | 2.59E-04 | 7.02E-04 | 6.95E-04 | 2.84E-04 | N/A | N/A | N/A |
| Pb-209 | 7.43E-12 | 1.15E-11 | 2.60E-11 | 2.42E-11 | 4.89E-11 | N/A | N/A | N/A |
| Pb-210 | 6.46E-14 | 4.65E-14 | 5.77E-14 | 7.56E-14 | 4.85E-14 | N/A | N/A | N/A |
| Pb-211 | 2.23E-08 | 1.71E-08 | 3.81E-08 | 1.67E-08 | 4.77E-09 | N/A | N/A | N/A |
| Pb-214 | 2.62E-13 | 2.01E-13 | 2.24E-13 | 3.21E-13 | 2.72E-13 | N/A | N/A | N/A |

Table D.7.1.1 Exhumed Inventory by Source Area for the No Action Alternative, Total Curies (cont'd)

| | Source Area | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Radionuclide [1] | 1WSS | 2WSS | 1ESS | 2ESS | 4ESS | 3WDS | 3EDS | 5EDS |
| Pd-107 | 3.89E-05 | 9.32E-05 | 2.13E-04 | 3.94E-05 | 1.68E-05 | N/A | N/A | N/A |
| Po-210 | 6.46E-14 | 4.65E-14 | 5.77E-14 | 7.56E-14 | 4.85E-14 | N/A | N/A | N/A |
| Po-211 | 6.09E-11 | 4.66E-11 | 1.04E-10 | 4.56E-11 | 1.30E-11 | N/A | N/A | N/A |
| Po-213 | 7.27E-12 | 1.13E-11 | 2.54E-11 | 2.36E-11 | 4.78E-11 | N/A | N/A | N/A |
| Po-214 | 2.62E-13 | 2.01E-13 | 2.24E-13 | 3.21E-13 | 2.72E-13 | N/A | N/A | N/A |
| Po-215 | 2.23E-08 | 1.71E-08 | 3.81E-08 | 1.67E-08 | 4.77E-09 | N/A | N/A | N/A |
| Po-218 | 2.62E-13 | 2.01E-13 | 2.24E-13 | 3.21E-13 | 2.72E-13 | N/A | N/A | N/A |
| Pu-238 | 9.03E-04 | 1.19E-03 | 7.96E-04 | 2.14E-03 | 3.85E-03 | 6.04E-02 | 2.67E-03 | 2.40E-03 |
| Pu-239 | 8.96E-03 | 1.44E-02 | 1.25E-02 | 5.21E-02 | 7.91E-02 | 1.23E-01 | 7.74E-02 | 1.57E-02 |
| Pu-240 | 1.76E-03 | 3.17E-03 | 2.99E-03 | 1.33E-02 | 2.02E-02 | 4.38E-02 | 1.99E-02 | 4.42E-03 |
| Pu-241 | 1.69E-02 | 2.55E-02 | 3.64E-02 | 1.42E-01 | 1.91E-01 | 1.06E+00 | 1.69E-01 | 1.27E-01 |
| Pu-242 | 5.71E-11 | 3.84E-10 | 4.01E-10 | 1.06E-09 | 7.39E-10 | N/A | N/A | N/A |
| Ra-223 | 2.23E-08 | 1.71E-08 | 3.81E-08 | 1.67E-08 | 4.77E-09 | N/A | N/A | N/A |
| Ra-225 | 7.43E-12 | 1.15E-11 | 2.60E-11 | 2.42E-11 | 4.89E-11 | N/A | N/A | N/A |
| Ra-226 | 2.62E-13 | 2.01E-13 | 2.24E-13 | 3.21E-13 | 2.72E-13 | N/A | N/A | N/A |
| Rh-106 | 2.63E-10 | 6.79E-08 | 3.55E-07 | 1.05E-06 | 6.83E-06 | N/A | N/A | N/A |
| Rn-219 | 2.23E-08 | 1.71E-08 | 3.81E-08 | 1.67E-08 | 4.77E-09 | N/A | N/A | N/A |
| Rn-222 | 2.62E-13 | 2.01E-13 | 2.24E-13 | 3.21E-13 | 2.72E-13 | N/A | N/A | N/A |
| Ru-106 | 2.63E-10 | 6.79E-08 | 3.55E-07 | 1.05E-06 | 6.83E-06 | N/A | N/A | N/A |
| Sb-126 | 3.42E-05 | 9.33E-05 | 2.89E-05 | 1.50E-04 | 6.19E-04 | N/A | N/A | N/A |
| Sb-126m | 2.44E-04 | 6.66E-04 | 2.06E-04 | 1.07E-03 | 4.42E-03 | N/A | N/A | N/A |
| Se-79 | 4.18E-04 | 1.01E-03 | 2.24E-03 | 3.48E-04 | 1.64E-04 | N/A | N/A | N/A |
| Sm-151 | 2.69E-01 | 7.37E-01 | 2.36E-01 | 1.09E+00 | 4.27E+00 | N/A | N/A | N/A |
| Sn-126 | 2.44E-04 | 6.66E-04 | 2.06E-04 | 1.07E-03 | 4.42E-03 | N/A | N/A | N/A |
| Sr-90 | 6.46E+00 | 5.73E+01 | 3.58E+01 | 5.27E+01 | 3.27E+02 | N/A | N/A | N/A |
| Tc-99 | 5.04E-03 | 1.21E-02 | 2.71E-02 | 4.23E-03 | 1.98E-03 | N/A | N/A | N/A |
| Th-227 | 2.20E-08 | 1.68E-08 | 3.76E-08 | 1.65E-08 | 4.70E-09 | N/A | N/A | N/A |
| Th-229 | 7.43E-12 | 1.15E-11 | 2.60E-11 | 2.42E-11 | 4.89E-11 | N/A | N/A | N/A |
| Th-230 | 3.87E-11 | 3.15E-11 | 3.23E-11 | 4.86E-11 | 5.36E-11 | N/A | N/A | N/A |
| Th-231 | 3.11E-05 | 1.17E-05 | 2.98E-05 | 3.02E-05 | 1.20E-05 | N/A | N/A | N/A |
| Th-232 | 7.95E-20 | 1.43E-19 | 1.35E-19 | 6.02E-19 | 9.08E-19 | N/A | N/A | N/A |
| Th-234 | 7.40E-04 | 2.59E-04 | 7.02E-04 | 6.95E-04 | 2.84E-04 | N/A | N/A | N/A |
| Tl-207 | 2.22E-08 | 1.70E-08 | 3.80E-08 | 1.67E-08 | 4.76E-09 | N/A | N/A | N/A |
| Tl-209 | 1.60E-13 | 2.49E-13 | 5.61E-13 | 5.22E-13 | 1.06E-12 | N/A | N/A | N/A |
| U-233 | 5.16E-09 | 7.02E-09 | 2.54E-08 | 8.69E-09 | 2.03E-08 | N/A | N/A | N/A |
| U-234 | 2.11E-07 | 1.84E-07 | 1.86E-07 | 3.27E-07 | 4.34E-07 | N/A | N/A | N/A |
| U-235 | 3.11E-05 | 1.17E-05 | 2.98E-05 | 3.02E-05 | 1.20E-05 | N/A | N/A | N/A |

Table D.7.1.1 Exhumed Inventory by Source Area for the No Action Alternative, Total Curies (cont'd)

| | Source Area | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Radionuclide [1] | 1WSS | 2WSS | 1ESS | 2ESS | 4ESS | 3WDS | 3EDS | 5EDS |
| U-236 | 9.31E-10 | 1.67E-09 | 1.58E-09 | 7.04E-09 | 1.06E-08 | N/A | N/A | N/A |
| U-237 | 4.13E-07 | 6.24E-07 | 8.92E-07 | 3.48E-06 | 4.68E-06 | N/A | N/A | N/A |
| U-238 | 7.40E-04 | 2.59E-04 | 7.02E-04 | 6.95E-04 | 2.84E-04 | N/A | N/A | N/A |
| Y-90 | 6.52E+00 | 5.80E+01 | 3.62E+01 | 5.33E+01 | 3.30E+02 | 3.50E+00 | 1.72E+02 | 8.56E-01 |
| Zr-93 | 1.95E-04 | 3.20E-03 | 1.04E-03 | 6.06E-03 | 3.94E-02 | N/A | N/A | N/A |
| Total Ci | 2.08E+01 | 1.47E+02 | 1.04E+02 | 1.11E+02 | 6.69E+02 | 4.30E+02 | 1.03E+03 | 9.77E+01 |

Notes:
[1] Decayed to 12/31/1995.
N/A = Not applicable

### D.7.1.5 Ex Situ Intermediate Separations Alternative

Table D.7.1.3 shows the source term for tank residuals for the Ex Situ Intermediate Separations alternative. Table D.7.1.4 shows the source term for the LAW vaults for the Ex Situ Intermediate Separations alternative.

The source term for the tank residuals (Table D.7.1.3) is calculated using the same methodology as for the No Action alternative. However, the source term is estimated from 1 percent of the tank inventory in each of the eight source areas described in Volume Two, Appendix A because only 1 percent of the inventory is assumed to remain as residuals in the tanks after remediation.

The source term for LAW vaults (Table D.7.1.4) is estimated from data in Table 9.1 of WHC (WHC 1995j) and Jacobs (Jacobs 1996). The average concentration of each radionuclide in the vitrified waste form is multiplied by the volume exhumed. The volume exhumed is estimated to be 1.06 $m^3$ (37.4 $ft^3$) for a well with a diameter of 30 cm (1 ft) and a depth of 15 m (49 ft).

### D.7.1.6 Ex Situ No Separations Alternative

Table D.7.1.3 shows the source term for tank residuals for the Ex Situ No Separations alternative. The source term for the tank residuals is the same as for the Ex Situ Intermediate Separations alternative. As stated previously, it is calculated using the same methodology as for the No Action alternative. However, the source term is estimated from 1 percent of the tank inventory in each of the eight source areas described in Volume Two, Appendix A.

### D.7.1.7 Ex Situ Extensive Separations Alternative

Table D.7.1.3 shows the source term for tank residuals for the Ex Situ Extensive Separations alternative. Table D.7.1.4 shows the source term for the LAW vaults for the Ex Situ Extensive Separations alternative.

Table D.7.1.2 Exhumed Inventory for the In Situ Vitrification Alternative, Total Curies

| Radionuclide | Inventory | Radionuclide | Inventory | Radionuclide | Inventory |
|---|---|---|---|---|---|
| Ac-225 | 6.63E-12 | Pa-234 | 2.57E-07 | Rn-220 | 1.25E-20 |
| Ac-227 | 7.42E-09 | Pa-234m | 1.60E-04 | Rn-222 | 9.03E-14 |
| Am-241 | 3.07E-01 | Pb-209 | 6.63E-12 | Ru-106 | 1.27E-08 |
| Am-242 | 2.29E-05 | Pb-210 | 2.40E-14 | Sb-126 | 2.94E-05 |
| Am-242m | 2.29E-05 | Pb-211 | 7.49E-09 | Sb-126m | 2.10E-04 |
| Am-243 | 1.11E-05 | Pb-212 | 1.25E-20 | Se-79 | 3.05E-04 |
| At-217 | 6.63E-12 | Pb-214 | 9.03E-14 | Sm-151 | 2.11E-01 |
| Ba-137m | 1.11E+01 | Pd-107 | 2.90E-05 | Sn-126 | 2.10E-04 |
| Bi-210 | 2.40E-14 | Po-210 | 2.40E-14 | Sr-90 | 1.79E+01 |
| Bi-211 | 7.42E-09 | Po-211 | 2.02E-11 | Tc-99 | 1.08E-02 |
| Bi-212 | 1.25E-20 | Po-212 | 7.98E-21 | Th-227 | 7.32E-09 |
| Bi-213 | 6.63E-12 | Po-213 | 6.49E-12 | Th-228 | 1.25E-20 |
| Bi-214 | 9.03E-14 | Po-214 | 9.03E-14 | Th-229 | 6.63E-12 |
| Cm-242 | 1.90E-05 | Po-215 | 7.42E-09 | Th-230 | 1.31E-11 |
| Cm-244 | 3.96E-05 | Po-216 | 1.25E-20 | Th-231 | 6.90E-06 |
| Cm-245 | 3.49E-09 | Po-218 | 9.03E-14 | Th-232 | 2.15E-19 |
| Cs-135 | 4.86E-05 | Pu-238 | 3.61E-04 | Th-234 | 1.60E-04 |
| Cs-137 | 1.17E+01 | Pu-239 | 8.83E-03 | Tl-207 | 7.39E-09 |
| Fr-221 | 6.63E-12 | Pu-240 | 2.24E-03 | Tl-208 | 4.48E-21 |
| Fr-223 | 1.02E-10 | Pu-241 | 2.51E-02 | Tl-209 | 1.44E-13 |
| Nb-93m | 1.07E-03 | Pu-242 | 1.45E-10 | U-233 | 4.03E-09 |
| Ni-59 | 1.68E-03 | Ra-223 | 7.42E-09 | U-234 | 7.09E-08 |
| Ni-63 | 9.00E-02 | Ra-224 | 1.25E-20 | U-235 | 6.90E-06 |
| Np-237 | 2.33E-05 | Ra-225 | 6.63E-12 | U-236 | 9.64E-10 |
| Np-238 | 1.09E-07 | Ra-226 | 9.03E-14 | U-237 | 2.91E-07 |
| Np-239 | 1.11E-05 | Ra-228 | 2.48E-20 | U-238 | 1.60E-03 |
| Pa-231 | 1.27E-08 | Rh-106 | 1.27E-08 | Y-90 | 1.79E+01 |
| Pa-233 | 2.33E-05 | Rn-219 | 7.42E-09 | Zr-93 | 1.32E-03 |
| | | | | Total Ci | 5.93E+01 |

The source term for the tank residuals (Table D.7.1.3) is calculated using the same methodology as for the No Action alternative. However, the source term is estimated from 1 percent of the tank inventory in each of the eight source areas described in Volume Two, Appendix A.

The source term for LAW vaults (Table D.7.1.4) is estimated from data in Table 9.1B of WHC (WHC 1995e) and Jacobs (Jacobs 1996). The average concentration of each radionuclide in the vitrified waste form is multiplied by the volume exhumed. The volume exhumed is estimated to be 1.06 $m^3$ (37.4 $ft^3$) for a well with a diameter of 30 cm (1 ft) and a depth of 15 m (49 ft).

**Table D.7.1.3 Exhumed Inventory by Source Area for Tank Residuals from the Ex Situ Intermediate Separations, Ex Situ No Separations, Ex Situ Extensive Separations, and Phased Implementation Alternatives, Total Curies**

| | Source Area | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Radionuclide [1] | 1WSS | 2WSS | 1ESS | 2ESS | 4ESS | 3WDS | 3EDS | 5EDS |
| Ac-225 | 7.43E-14 | 1.15E-13 | 2.60E-13 | 2.42E-13 | 4.89E-13 | N/A | N/A | N/A |
| Ac-227 | 2.23E-10 | 1.71E-10 | 3.81E-10 | 1.67E-10 | 4.77E-11 | N/A | N/A | N/A |
| Am-241 | 7.32E-05 | 3.80E-04 | 3.22E-04 | 1.05E-03 | 7.96E-04 | 6.83E-03 | 9.19E-03 | 6.13E-05 |
| Am-242 | 1.15E-07 | 7.75E-07 | 8.10E-07 | 2.15E-06 | 1.49E-06 | N/A | N/A | N/A |
| Am-242m | 1.16E-07 | 7.79E-07 | 8.14E-07 | 2.16E-06 | 1.50E-06 | N/A | N/A | N/A |
| Am-243 | 4.37E-08 | 3.13E-07 | 4.12E-07 | 1.25E-06 | 5.38E-07 | N/A | N/A | N/A |
| At-217 | 7.43E-14 | 1.15E-13 | 2.60E-13 | 2.42E-13 | 4.89E-13 | N/A | N/A | N/A |
| Ba-137m | 3.64E-02 | 1.51E-01 | 1.52E-01 | 1.36E-02 | 2.35E-02 | 2.10E+00 | 3.42E+00 | 4.79E-01 |
| Bi-210 | 6.46E-16 | 4.65E-16 | 5.77E-16 | 7.56E-16 | 4.85E-16 | N/A | N/A | N/A |
| Bi-211 | 2.23E-10 | 1.71E-10 | 3.81E-10 | 1.67E-10 | 4.77E-11 | N/A | N/A | N/A |
| Bi-213 | 7.43E-14 | 1.15E-13 | 2.60E-13 | 2.42E-13 | 4.89E-13 | N/A | N/A | N/A |
| Bi-214 | 2.62E-15 | 2.01E-15 | 2.24E-15 | 3.21E-15 | 2.72E-15 | N/A | N/A | N/A |
| C-14 | 1.22E-05 | 1.96E-05 | 7.88E-05 | 2.31E-05 | 3.13E-05 | 4.63E-07 | 3.64E-04 | 6.44E-07 |
| Cm-242 | 9.56E-08 | 6.43E-07 | 6.72E-07 | 1.78E-06 | 1.24E-06 | N/A | N/A | N/A |
| Cm-244 | 1.39E-07 | 9.57E-07 | 2.16E-06 | 5.75E-06 | 1.24E-06 | N/A | N/A | N/A |
| Cm-245 | 8.95E-12 | 6.98E-11 | 1.65E-10 | 4.41E-10 | 9.50E-11 | N/A | N/A | N/A |
| Cs-135 | 8.90E-07 | 2.72E-06 | 2.27E-06 | 1.73E-07 | 3.67E-07 | N/A | N/A | N/A |
| Cs-137 | 3.84E-02 | 1.60E-01 | 1.61E-01 | 1.44E-02 | 2.49E-02 | 2.10E+00 | 3.42E+00 | 4.79E-01 |
| Eu-154 | N/A | N/A | N/A | N/A | N/A | 2.51E-04 | 1.15E-02 | 6.55E-05 |
| Fr-221 | 7.43E-14 | 1.15E-13 | 2.60E-13 | 2.42E-13 | 4.89E-13 | N/A | N/A | N/A |
| Fr-223 | 3.08E-12 | 2.35E-12 | 5.25E-12 | 2.31E-12 | 6.58E-13 | N/A | N/A | N/A |
| I-129 | 7.32E-08 | 1.76E-07 | 3.94E-07 | 6.43E-08 | 2.95E-08 | N/A | N/A | N/A |
| Nb-93m | 3.68E-06 | 2.71E-05 | 1.60E-05 | 4.36E-05 | 2.59E-04 | N/A | N/A | N/A |
| Ni-59 | N/A | 6.84E-05 | 1.43E-04 | N/A | NA | N/A | N/A | N/A |
| Ni-63 | 2.94E-04 | 1.95E-03 | 2.28E-03 | 6.32E-03 | 1.88E-02 | N/A | N/A | N/A |
| Np-237 | 3.56E-07 | 4.41E-07 | 2.13E-06 | 3.63E-08 | 7.72E-08 | 2.18E-07 | 7.05E-06 | 1.75E-08 |
| Np-238 | 5.51E-10 | 3.71E-09 | 3.88E-09 | 1.03E-08 | 7.14E-09 | N/A | N/A | N/A |
| Np-239 | 4.37E-08 | 3.13E-07 | 4.12E-07 | 1.25E-06 | 5.38E-07 | N/A | N/A | N/A |
| Pa-231 | 4.14E-10 | 2.93E-10 | 6.57E-10 | 3.64E-10 | 1.10E-10 | N/A | N/A | N/A |
| Pa-233 | 3.56E-07 | 4.41E-07 | 2.13E-06 | 3.63E-08 | 7.72E-08 | N/A | N/A | N/A |
| Pa-234 | 1.18E-08 | 4.15E-09 | 1.12E-08 | 1.11E-08 | 4.55E-09 | N/A | N/A | N/A |
| Pa-234m | 7.40E-06 | 2.59E-06 | 7.02E-06 | 6.95E-06 | 2.84E-06 | N/A | N/A | N/A |
| Pb-209 | 7.43E-14 | 1.15E-13 | 2.60E-13 | 2.42E-13 | 4.89E-13 | N/A | N/A | N/A |
| Pb-210 | 6.46E-16 | 4.65E-16 | 5.77E-16 | 7.56E-16 | 4.85E-16 | N/A | N/A | N/A |
| Pb-211 | 2.23E-10 | 1.71E-10 | 3.81E-10 | 1.67E-10 | 4.77E-11 | N/A | N/A | N/A |
| Pb-214 | 2.62E-15 | 2.01E-15 | 2.24E-15 | 3.21E-15 | 2.72E-15 | N/A | N/A | N/A |
| Pd-107 | 3.89E-07 | 9.32E-07 | 2.13E-06 | 3.94E-07 | 1.68E-07 | N/A | N/A | N/A |

Table D.7.1.3 Exhumed Inventory by Source Area for Tank Residuals from the Ex Situ Intermediate Separations, Ex Situ No Separations, Ex Situ Extensive Separations, and Phased Implementation Alternatives, Total Curies (cont'd)

| | Source Area | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Radionuclide [1] | 1WSS | 2WSS | 1ESS | 2ESS | 4ESS | 3WDS | 3EDS | 5EDS |
| Po-210 | 6.46E-16 | 4.65E-16 | 5.77E-16 | 7.56E-16 | 4.85E-16 | N/A | N/A | N/A |
| Po-211 | 6.09E-13 | 4.66E-13 | 1.04E-12 | 4.56E-13 | 1.30E-13 | N/A | N/A | N/A |
| Po-213 | 7.27E-14 | 1.13E-13 | 2.54E-13 | 2.36E-13 | 4.78E-13 | N/A | N/A | N/A |
| Po-214 | 2.62E-15 | 2.01E-15 | 2.24E-15 | 3.21E-15 | 2.72E-15 | N/A | N/A | N/A |
| Po-215 | 2.23E-10 | 1.71E-10 | 3.81E-10 | 1.67E-10 | 4.77E-11 | N/A | N/A | N/A |
| Po-218 | 2.62E-15 | 2.01E-15 | 2.24E-15 | 3.21E-15 | 2.72E-15 | N/A | N/A | N/A |
| Pu-238 | 9.03E-06 | 1.19E-05 | 7.96E-06 | 2.14E-05 | 3.85E-05 | 6.04E-04 | 2.67E-05 | 2.40E-05 |
| Pu-239 | 8.96E-05 | 1.44E-04 | 1.25E-04 | 5.21E-04 | 7.91E-04 | 1.23E-03 | 7.74E-04 | 1.57E-04 |
| Pu-240 | 1.76E-05 | 3.17E-05 | 2.99E-05 | 1.33E-04 | 2.02E-04 | 4.38E-04 | 1.99E-04 | 4.42E-05 |
| Pu-241 | 1.69E-04 | 2.55E-04 | 3.64E-04 | 1.42E-03 | 1.91E-03 | 1.06E-02 | 1.69E-03 | 1.27E-03 |
| Pu-242 | 5.71E-13 | 3.84E-12 | 4.01E-12 | 1.06E-11 | 7.39E-12 | N/A | N/A | N/A |
| Ra-223 | 2.23E-10 | 1.71E-10 | 3.81E-10 | 1.67E-10 | 4.77E-11 | N/A | N/A | N/A |
| Ra-225 | 7.43E-14 | 1.15E-13 | 2.60E-13 | 2.42E-13 | 4.89E-13 | N/A | N/A | N/A |
| Ra-226 | 2.62E-15 | 2.01E-15 | 2.24E-15 | 3.21E-15 | 2.72E-15 | N/A | N/A | N/A |
| Rh-106 | 2.63E-12 | 6.79E-10 | 3.55E-09 | 1.05E-08 | 6.83E-08 | N/A | N/A | N/A |
| Rn-219 | 2.23E-10 | 1.71E-10 | 3.81E-10 | 1.67E-10 | 4.77E-11 | N/A | N/A | N/A |
| Rn-222 | 2.62E-15 | 2.01E-15 | 2.24E-15 | 3.21E-15 | 2.72E-15 | N/A | N/A | N/A |
| Ru-106 | 2.63E-12 | 6.79E-10 | 3.55E-09 | 1.05E-08 | 6.83E-08 | N/A | N/A | N/A |
| Sb-126 | 3.42E-07 | 9.33E-07 | 2.89E-07 | 1.50E-06 | 6.19E-06 | N/A | N/A | N/A |
| Sb-126m | 2.44E-06 | 6.66E-06 | 2.06E-06 | 1.07E-05 | 4.42E-05 | N/A | N/A | N/A |
| Se-79 | 4.18E-06 | 1.01E-05 | 2.24E-05 | 3.48E-06 | 1.64E-06 | N/A | N/A | N/A |
| Sm-151 | 2.69E-03 | 7.37E-03 | 2.36E-03 | 1.09E-02 | 4.27E-02 | N/A | N/A | N/A |
| Sn-126 | 2.44E-06 | 6.66E-06 | 2.06E-06 | 1.07E-05 | 4.42E-05 | N/A | N/A | N/A |
| Sr-90 | 6.46E-02 | 5.73E-01 | 3.58E-01 | 5.27E-01 | 3.27E+00 | 3.50E-02 | 1.72E+00 | 8.56E-03 |
| Tc-99 | 5.04E-05 | 1.21E-04 | 2.71E-04 | 4.23E-05 | 1.98E-05 | 2.10E-03 | 2.48E-03 | 1.97E-04 |
| Th-227 | 2.20E-10 | 1.68E-10 | 3.76E-10 | 1.65E-10 | 4.70E-11 | N/A | N/A | N/A |
| Th-229 | 7.43E-14 | 1.15E-13 | 2.60E-13 | 2.42E-13 | 4.89E-13 | N/A | N/A | N/A |
| Th-230 | 3.87E-13 | 3.15E-13 | 3.23E-13 | 4.86E-13 | 5.36E-13 | N/A | N/A | N/A |
| Th-231 | 3.11E-07 | 1.17E-07 | 2.98E-07 | 3.02E-07 | 1.20E-07 | N/A | N/A | N/A |
| Th-232 | 7.95E-22 | 1.43E-21 | 1.35E-21 | 6.02E-21 | 9.08E-21 | N/A | N/A | N/A |
| Th-234 | 7.40E-06 | 2.59E-06 | 7.02E-06 | 6.95E-06 | 2.84E-06 | N/A | N/A | N/A |
| Tl-207 | 2.22E-10 | 1.70E-10 | 3.80E-10 | 1.67E-10 | 4.76E-11 | N/A | N/A | N/A |
| Tl-209 | 1.60E-15 | 2.49E-15 | 5.61E-15 | 5.22E-15 | 1.06E-14 | N/A | N/A | N/A |
| U-233 | 5.16E-11 | 7.02E-11 | 2.54E-10 | 8.69E-11 | 2.03E-10 | N/A | N/A | N/A |
| U-234 | 2.11E-09 | 1.84E-09 | 1.86E-09 | 3.27E-09 | 4.34E-09 | N/A | N/A | N/A |
| U-235 | 3.11E-07 | 1.17E-07 | 2.98E-07 | 3.02E-07 | 1.20E-07 | N/A | N/A | N/A |
| U-236 | 9.31E-12 | 1.67E-11 | 1.58E-11 | 7.04E-11 | 1.06E-10 | N/A | N/A | N/A |

Table D.7.1.3 Exhumed Inventory by Source Area for Tank Residuals from the Ex Situ Intermediate Separations, Ex Situ No Separations, Ex Situ Extensive Separations, and Phased Implementation Alternatives, Total Curies (cont'd)

| | Source Area | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Radionuclide [1] | 1WSS | 2WSS | 1ESS | 2ESS | 4ESS | 3WDS | 3EDS | 5EDS |
| U-237 | 4.13E-09 | 6.24E-09 | 8.92E-09 | 3.48E-08 | 4.68E-08 | N/A | N/A | N/A |
| U-238 | 7.40E-06 | 2.59E-06 | 7.02E-06 | 6.95E-06 | 2.84E-06 | N/A | N/A | N/A |
| Y-90 | 6.52E-02 | 5.80E-01 | 3.62E-01 | 5.33E-01 | 3.30E+00 | 3.50E-02 | 1.72E+00 | 8.56E-03 |
| Zr-93 | 1.95E-06 | 3.20E-05 | 1.04E-05 | 6.06E-05 | 3.94E-04 | N/A | N/A | N/A |
| Total Ci | 2.08E-01 | 1.47E+00 | 1.04E+00 | 1.11E+00 | 6.69E+00 | 4.30E+00 | 1.03E+01 | 9.77E-01 |

Notes:
[1] Decayed to 12/31/95.
N/A = Not applicable

### D.7.1.8 Ex Situ/In Situ Combination 1 Alternative

Table D.7.1.5 shows the source term for tank residuals for the Ex Situ/In Situ Combination 1 alternative. Table D.7.1.4 shows the source term for the LAW vaults for the Ex Situ/In Situ Combination 1 alternative.

The source term for the tank residuals (Table D.7.1.5) is calculated using the same methodology as for the No Action alternative for the 70 tanks retrieved. However, the source areas include the tank inventory for the 107 tanks not retrieved, and the residuals remaining in the tank inventory for the tanks that were retrieved (1 percent of tank inventory).

The source term for LAW vaults (Table D.7.1.4) is estimated from Jacobs (Jacobs 1996). The average concentration of each radionuclide in the vitrified waste form is multiplied by the volume exhumed. The volume exhumed is estimated to be 1.06 $m^3$ (37.4 $ft^3$) for a well with a diameter of 30 cm (1 ft) and a depth of 15 m (49 ft).

### D.7.1.9 Ex Situ/In Situ Combination 2 Alternative

Table D.7.1.6 shows the source term for tank residuals for the Ex Situ/In Situ Combination 2 alternative. Table D.7.1.4 shows the source term for the LAW vaults for the Ex Situ/In Situ Combination 2 alternative.

The source term for the tank residuals (Table D.7.1.6) is calculated using the same methodology as for the No Action alternative for the 25 tanks retrieved. However, the source areas include the tank inventory for the 152 tanks not retrieved and the residuals remaining in the tank inventory for the tanks that were retrieved (1 percent of tank inventory).

The source term for LAW vaults (Table D.7.1.4) is estimated from Jacobs (Jacobs 1996). The average concentration of each radionuclide in the vitrified waste form is multiplied by the volume exhumed. The volume exhumed is estimated to be 1.06 $m^3$ (37.4 $ft^3$) for a well with a diameter of 30 cm (1 ft) and a depth of 15 m (49 ft).

Table D.7.1.4 Exhumed Inventory for LAW Vaults for the Ex Situ Intermediate Separations, Ex Situ Extensive Separations, Ex Situ/In Situ Combination 1, Ex Situ/In Situ Combinaton 2, and Phased Implementation Alternatives, Total Curies

| Radionuclide [1] | Intermediate Separations | Extensive Separations | Ex Situ/In Situ Combination 1 | Ex Situ/In Situ Combination 2 |
|---|---|---|---|---|
| Am-241 | 4.13E-02 | 7.78E-04 | 4.13E-02 | 4.13E-02 |
| Am-243 | 1.38E-05 | 2.49E-07 | 1.38E-05 | 1.38E-05 |
| Cm-244 | 4.98E-06 | 4.83E-06 | 4.98E-06 | 4.98E-06 |
| Cs-135 | 5.09E-06 | 9.71E-07 | 5.09E-06 | 5.09E-06 |
| Cs-137 | 1.27E+00 | 2.34E-01 | 1.27E+00 | 1.27E+00 |
| Ni-63 | 2.76E-02 | 1.94E+00 | 2.76E-02 | 2.76E-02 |
| Np-237 | 3.39E-05 | 1.98E-05 | 3.39E-05 | 3.39E-05 |
| Pu-238 | 3.29E-04 | 8.27E-05 | 3.29E-04 | 3.29E-04 |
| Pu-239 | 8.06E-03 | 2.01E-03 | 8.06E-03 | 8.06E-03 |
| Pu-240 | 2.01E-03 | 5.13E-04 | 2.01E-03 | 2.01E-03 |
| Pu-241 | 7.10E-03 | 5.73E-03 | 7.10E-03 | 7.10E-03 |
| Ra-226 | N/A | 7.63E-16 | N/A | N/A |
| Rh-106 | 9.01E-09 | 1.07E-10 | 9.01E-09 | 9.01E-09 |
| Sm-151 | 3.29E-02 | 1.78E-03 | 3.29E-02 | 3.29E-02 |
| Sn-126 | 7.63E-04 | 1.77E-06 | 7.63E-04 | 7.63E-04 |
| Sr-90 | 4.56E+00 | 3.94E-02 | 4.56E+00 | 4.56E+00 |
| Tc-99 | 1.27E-01 | 1.12E-03 | 1.27E-01 | 1.27E-01 |
| Th-230 | 2.44E-12 | 1.10E-13 | 2.44E-12 | 2.44E-12 |
| U-233 | 2.97E-09 | 5.50E-11 | 2.97E-09 | 2.97E-09 |
| U-234 | 5.19E-08 | 9.65E-10 | 5.19E-08 | 5.19E-08 |
| U-235 | 5.09E-06 | 9.37E-08 | 5.09E-06 | 5.09E-06 |
| U-238 | 1.17E-04 | 2.18E-06 | 1.17E-04 | 1.17E-04 |
| Zr-93 | 1.70E-05 | 2.84E-02 | 1.70E-05 | 1.70E-05 |
| Total Ci | 6.08E+00 | 2.25E+00 | 6.08E+00 | 6.08E+00 |

Notes:
[1] Decayed to 12/31/95.
N/A = Not applicable

Table D.7.1.5 Exhumed Inventory for Tank Residuals for the Ex Situ/In Situ Combination 1 Alternative, Total Curies

| | Source Area | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Radionuclide [1] | 1WSS | 2WSS | 1ESS | 2ESS | 4ESS | 3WDS | 3EDS | 5EDS |
| Ac-225 | 2.59E-12 | 6.35E-12 | 3.70E-12 | 6.60E-12 | 2.31E-12 | N/A | N/A | N/A |
| Ac-227 | 2.99E-09 | 1.84E-09 | 4.01E-09 | 1.55E-09 | 1.57E-09 | N/A | N/A | N/A |
| Am-241 | 8.37E-04 | 9.90E-03 | 1.51E-03 | 3.26E-03 | 1.02E-02 | 6.56E-01 | 1.49E-01 | 4.49E-03 |
| Am-242 | 1.09E-06 | 1.74E-05 | 3.32E-06 | 5.22E-06 | 1.99E-05 | N/A | N/A | N/A |
| Am-242m | 1.10E-06 | 1.75E-05 | 3.34E-06 | 5.24E-06 | 2.00E-05 | N/A | N/A | N/A |
| Am-243 | 5.57E-07 | 5.44E-06 | 1.85E-06 | 2.79E-06 | 1.12E-05 | N/A | N/A | N/A |
| At-217 | 2.60E-12 | 6.35E-12 | 3.71E-12 | 6.60E-12 | 2.31E-12 | N/A | N/A | N/A |
| Ba-137m | 6.02E-01 | 1.83E+00 | 1.51E+00 | 5.66E-01 | 9.38E-01 | 3.63E+01 | 6.52E+01 | 3.05E+01 |
| Bi-210 | 7.79E-15 | 1.66E-14 | 5.19E-15 | 1.34E-14 | 1.96E-14 | N/A | N/A | N/A |
| Bi-211 | 2.99E-09 | 1.84E-09 | 4.01E-09 | 1.55E-09 | 1.57E-09 | N/A | N/A | N/A |
| Bi-213 | 2.59E-12 | 6.36E-12 | 3.71E-12 | 6.60E-12 | 2.31E-12 | N/A | N/A | N/A |
| Bi-214 | 3.30E-14 | 7.26E-14 | 2.02E-14 | 4.00E-14 | 4.49E-14 | N/A | N/A | N/A |
| C-14 | 1.68E-04 | 1.84E-04 | 4.89E-04 | 1.06E-04 | 3.72E-04 | 4.63E-05 | 3.64E-04 | 4.61E-05 |
| Cm-242 | 9.05E-07 | 1.44E-05 | 2.75E-06 | 4.33E-06 | 1.65E-05 | N/A | N/A | N/A |
| Cm-244 | 2.85E-06 | 5.42E-06 | 1.42E-05 | 1.16E-05 | 5.68E-05 | N/A | N/A | N/A |
| Cm-245 | 1.95E-10 | 3.93E-10 | 1.09E-09 | 8.86E-10 | 4.36E-09 | N/A | N/A | N/A |
| Cs-135 | 1.98E-05 | 4.47E-05 | 2.60E-05 | 7.85E-06 | 1.16E-05 | N/A | N/A | N/A |
| Cs-137 | 6.37E-01 | 1.93E+00 | 1.60E+00 | 5.98E-01 | 9.91E-01 | 2.61E+01 | 4.89E+01 | 2.93E+01 |
| Eu-154 | N/A | N/A | N/A | N/A | N/A | 3.48E-02 | 4.22E-01 | 9.05E-03 |
| Fr-221 | 2.59E-12 | 6.35E-12 | 3.71E-12 | 6.59E-12 | 2.31E-12 | N/A | N/A | N/A |
| Fr-223 | 4.12E-11 | 2.53E-11 | 5.54E-11 | 2.14E-11 | 2.16E-11 | N/A | N/A | N/A |
| I-129 | 1.33E-06 | 1.61E-06 | 2.74E-06 | 3.93E-07 | 1.06E-06 | N/A | N/A | N/A |
| Nb-93m | 5.04E-05 | 1.11E-03 | 9.76E-05 | 3.15E-04 | 7.04E-03 | N/A | N/A | N/A |
| Ni-63 | 9.00E-03 | 1.07E-01 | 2.35E-02 | 4.88E-02 | 3.32E-01 | N/A | N/A | N/A |
| Np-237 | 6.06E-06 | 7.61E-06 | 1.71E-05 | 2.85E-06 | 1.82E-06 | 2.18E-05 | 7.24E-06 | 1.74E-06 |
| Np-238 | 7.03E-09 | 6.45E-08 | 1.74E-08 | 2.29E-08 | 1.49E-07 | N/A | N/A | N/A |
| Np-239 | 5.58E-07 | 5.45E-06 | 1.85E-06 | 2.79E-06 | 1.13E-05 | N/A | N/A | N/A |
| Pa-231 | 4.68E-09 | 3.24E-09 | 6.16E-09 | 2.98E-09 | 3.32E-09 | N/A | N/A | N/A |
| Pa-233 | 6.05E-06 | 7.61E-06 | 1.71E-05 | 2.86E-06 | 1.82E-06 | N/A | N/A | N/A |
| Pa-234 | 5.73E-08 | 9.11E-08 | 8.15E-08 | 1.46E-07 | 7.99E-08 | N/A | N/A | N/A |
| Pa-234m | 3.58E-05 | 5.69E-05 | 5.09E-05 | 9.13E-05 | 4.99E-05 | N/A | N/A | N/A |
| Pb-209 | 2.60E-12 | 6.35E-12 | 3.71E-12 | 6.60E-12 | 2.31E-12 | N/A | N/A | N/A |
| Pb-210 | 7.80E-15 | 1.66E-14 | 5.18E-15 | 1.34E-14 | 1.96E-14 | N/A | N/A | N/A |
| Pb-211 | 2.99E-09 | 1.84E-09 | 4.01E-09 | 1.55E-09 | 1.57E-09 | N/A | N/A | N/A |
| Pb-214 | 3.29E-14 | 7.27E-14 | 2.02E-14 | 4.00E-14 | 4.48E-14 | N/A | N/A | N/A |
| Pd-107 | 6.98E-06 | 8.18E-06 | 1.42E-05 | 2.19E-06 | 6.20E-06 | N/A | N/A | N/A |
| Po-210 | 7.77E-15 | 1.66E-14 | 5.18E-15 | 1.39E-14 | 2.04E-14 | N/A | N/A | N/A |

**Table D.7.1.5 Exhumed Inventory for Tank Residuals for the Ex Situ/In Situ Combination 1 Alternative, Total Curies (cont'd)**

| | Source Area | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Radionuclide [1] | 1WSS | 2WSS | 1ESS | 2ESS | 4ESS | 3WDS | 3EDS | 5EDS |
| Po-211 | 7.31E-12 | 1.66E-11 | 9.34E-12 | 8.38E-12 | 5.49E-12 | N/A | N/A | N/A |
| Po-213 | 2.54E-12 | 6.21E-12 | 3.62E-12 | 6.46E-12 | 2.27E-12 | N/A | N/A | N/A |
| Po-214 | 3.29E-14 | 7.27E-14 | 2.02E-14 | 4.00E-14 | 4.48E-14 | N/A | N/A | N/A |
| Po-215 | 2.99E-09 | 1.83E-09 | 4.01E-09 | 1.55E-09 | 1.57E-09 | N/A | N/A | N/A |
| Po-218 | 3.29E-14 | 7.27E-14 | 2.02E-14 | 4.00E-14 | 4.49E-14 | N/A | N/A | N/A |
| Pu-238 | 1.81E-04 | 5.06E-04 | 1.06E-04 | 2.56E-04 | 1.30E-03 | 6.22E-02 | 1.05E-04 | 2.47E-03 |
| Pu-239 | 2.63E-03 | 5.77E-03 | 1.98E-03 | 5.23E-03 | 1.64E-02 | 1.20E-01 | 4.21E-02 | 1.51E-02 |
| Pu-240 | 4.44E-04 | 1.27E-03 | 3.91E-04 | 1.27E-03 | 4.50E-03 | 4.31E-02 | 1.05E-02 | 4.26E-03 |
| Pu-241 | 2.19E-03 | 9.68E-03 | 3.80E-03 | 1.03E-02 | 5.88E-02 | 1.29E+00 | 2.56E-02 | 1.54E-01 |
| Pu-242 | 1.67E-11 | 1.54E-10 | 6.35E-11 | 1.07E-10 | 1.53E-10 | N/A | N/A | N/A |
| Ra-223 | 2.99E-09 | 1.84E-09 | 4.01E-09 | 1.55E-09 | 1.57E-09 | N/A | N/A | N/A |
| Ra-225 | 2.60E-12 | 6.35E-12 | 3.70E-12 | 6.61E-12 | 2.32E-12 | N/A | N/A | N/A |
| Ra-226 | 3.29E-14 | 7.26E-14 | 2.02E-14 | 4.00E-14 | 4.48E-14 | N/A | N/A | N/A |
| Rh-106 | 3.31E-11 | 2.45E-08 | 3.20E-08 | 1.31E-07 | 1.13E-06 | N/A | N/A | N/A |
| Rn-219 | 2.80E-09 | 6.15E-09 | 3.43E-09 | 2.08E-09 | 7.86E-10 | N/A | N/A | N/A |
| Rn-222 | 3.29E-14 | 7.26E-14 | 2.02E-14 | 4.00E-14 | 4.48E-14 | N/A | N/A | N/A |
| Ru-106 | 1.40E-11 | 3.70E-08 | 1.71E-08 | 2.15E-08 | 6.25E-06 | N/A | N/A | N/A |
| Sb-126 | 1.69E-06 | 4.54E-05 | 2.30E-06 | 8.29E-06 | 2.01E-04 | N/A | N/A | N/A |
| Sb-126m | 1.21E-05 | 3.24E-04 | 1.64E-05 | 5.92E-05 | 1.44E-03 | N/A | N/A | N/A |
| Se-79 | 7.61E-05 | 9.12E-05 | 1.56E-04 | 2.20E-05 | 5.89E-05 | N/A | N/A | N/A |
| Sm-151 | 1.81E-02 | 3.62E-01 | 2.19E-02 | 7.97E-02 | 1.36E+00 | N/A | N/A | N/A |
| Sn-126 | 1.21E-05 | 3.25E-04 | 1.64E-05 | 5.92E-05 | 1.44E-03 | N/A | N/A | N/A |
| Sr-90 | 9.44E-01 | 3.02E+01 | 3.57E+00 | 3.24E+00 | 1.36E+02 | 1.84E+00 | 3.78E+01 | 8.96E-01 |
| Tc-99 | 9.18E-04 | 1.11E-03 | 1.89E-03 | 2.67E-04 | 7.14E-04 | 2.11E-03 | 1.15E-02 | 1.22E-02 |
| Th-227 | 2.94E-09 | 1.81E-09 | 3.96E-09 | 1.53E-09 | 1.55E-09 | N/A | N/A | N/A |
| Th-229 | 2.59E-12 | 6.35E-12 | 3.69E-12 | 6.60E-12 | 2.33E-12 | N/A | N/A | N/A |
| Th-230 | 5.11E-12 | 1.22E-11 | 3.15E-12 | 7.49E-12 | 7.03E-12 | N/A | N/A | N/A |
| Th-231 | 1.53E-06 | 2.70E-06 | 2.18E-06 | 3.87E-06 | 2.26E-06 | N/A | N/A | N/A |
| Th-232 | 3.90E-21 | 3.29E-20 | 9.88E-21 | 7.69E-20 | 1.71E-19 | N/A | N/A | N/A |
| Th-234 | 3.58E-05 | 5.69E-05 | 5.09E-05 | 9.12E-05 | 4.99E-05 | N/A | N/A | N/A |
| Tl-207 | 2.98E-09 | 1.83E-09 | 4.00E-09 | 1.55E-09 | 1.57E-09 | N/A | N/A | N/A |
| Tl-209 | 2.15E-14 | 2.68E-14 | 5.91E-14 | 4.85E-14 | 3.48E-13 | N/A | N/A | N/A |
| U-233 | 1.69E-09 | 3.49E-09 | 2.88E-09 | 2.59E-09 | 1.90E-09 | N/A | N/A | N/A |
| U-234 | 2.91E-08 | 7.21E-08 | 1.93E-08 | 3.67E-08 | 1.10E-07 | N/A | N/A | N/A |
| U-235 | 1.53E-06 | 2.70E-06 | 2.19E-06 | 3.87E-06 | 2.26E-06 | N/A | N/A | N/A |
| U-236 | 4.57E-11 | 3.85E-10 | 1.16E-10 | 9.01E-10 | 2.00E-09 | N/A | N/A | N/A |
| U-237 | 2.03E-08 | 1.43E-07 | 6.54E-08 | 4.45E-07 | 8.81E-07 | N/A | N/A | N/A |

Table D.7.1.5 Exhumed Inventory for Tank Residuals for the Ex Situ/In Situ Combination 1 Alternative, Total Curies (cont'd)

| | Source Area | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Radionuclide [1] | 1WSS | 2WSS | 1ESS | 2ESS | 4ESS | 3WDS | 3EDS | 5EDS |
| U-238 | 3.58E-05 | 5.69E-05 | 5.09E-05 | 9.13E-05 | 4.99E-05 | N/A | N/A | N/A |
| Y-90 | 9.52E-01 | 3.05E+01 | 3.61E+00 | 3.28E+00 | 1.37E+02 | 1.84E+00 | 3.78E+01 | 8.96E-01 |
| Zr-93 | 4.99E-05 | 1.71E-03 | 9.02E-05 | 3.53E-04 | 1.45E-02 | N/A | N/A | N/A |
| Total Ci | 3.17E+00 | 6.50E+01 | 1.04E+01 | 7.83E+00 | 2.77E+02 | 6.83E+01 | 1.90E+02 | 6.18E+01 |

Notes:
[1]Decayed to 12/31/95.
N/A = Not applicable

### D.7.1.10 Phased Implementation Alternative

Table D.7.1.3 shows the source term for tank residuals for the Phased Implementation alternative. Table D.7.1.4 shows the source term for the LAW vaults for the Phased Implementation alternative.

The source term for the tank residuals (Table D.7.1.3) is calculated using the same methodology as for the No Action alternative. However, the source term is estimated from 1 percent of the tank inventory in each of the eight source areas described in Volume Two, Appendix A because only 1 percent of the inventory assumed to remain as residuals in the tanks after remediation.

The source term for LAW vaults (Table D.7.1.4) is estimated from data in Table 9.1 of WHC (WHC 1995j) and Jacobs (Jacobs 1996). The average concentration of each radionuclide in the vitrified waste form is multiplied by the volume exhumed. The volume exhumed is estimated to be 1.06 $m^3$ (37.4 $ft^3$) for a well with a diameter of 30 cm (1 ft) and a depth of 15 m (49 ft).

### D.7.1.11 No Action Alternative (Capsules)

There is no source term for the No Action (Capsules) alternative. This is because the alternative does not involve disposal of the waste. The waste would be stored elsewhere within 10 years or put to productive uses.

### D.7.1.12 Onsite Disposal Alternative

Table D.7.1.7 shows the source term for the Onsite Disposal alternative. The source term for this alternative is the amount of activity resulting from exhuming the entire inventory of one drywell. A drywell contains one canister with a 30-cm (1-ft) diameter and a height of 3 m (10 ft). The canister contains three Sr-90 capsules and four Cs-137 capsules. Because the activity of the capsules varies, two cases are analyzed: an average case (38,470 Ci/capsule for Sr-90 and 40,100 Ci/capsule for Cs-137) and a maximum case (93,270 Ci/capsule for Sr-90 and 54,380 Ci/capsule for Cs-137) (Jacobs 1996).

Table D.7.1.6 Exhumed Inventory for Tank Residuals for the Ex Situ/In Situ Combination 2 Alternative, Total Curies

| | Source Area | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Radionuclide [1] | 1WSS | 2WSS | 1ESS | 2ESS | 4ESS | 3WDS | 3EDS | 5EDS |
| Ac-225 | 4.10E-12 | 9.07E-12 | 7.29E-12 | 1.46E-11 | 4.87E-11 | N/A | N/A | N/A |
| Ac-227 | 9.50E-09 | 7.63E-09 | 1.44E-08 | 5.61E-09 | 4.77E-09 | N/A | N/A | N/A |
| Am-241 | 1.36E-03 | 2.45E-02 | 1.23E-02 | 2.50E-02 | 8.12E-02 | 6.54E-01 | 9.21E-03 | 4.43E-03 |
| Am-242 | 1.53E-06 | 4.03E-05 | 2.75E-05 | 3.44E-05 | 1.38E-04 | N/A | N/A | N/A |
| Am-242m | 1.54E-06 | 4.05E-05 | 2.76E-05 | 3.45E-05 | 1.39E-04 | N/A | N/A | N/A |
| Am-243 | 7.56E-07 | 1.54E-05 | 1.74E-05 | 1.82E-05 | 5.37E-05 | N/A | N/A | N/A |
| At-217 | 4.10E-12 | 9.07E-12 | 7.29E-12 | 1.46E-11 | 4.87E-11 | N/A | N/A | N/A |
| Ba-137m | 4.06E+00 | 2.39E+01 | 1.69E+01 | 1.75E+00 | 7.06E+00 | 5.54E+00 | 8.01E+00 | 2.46E+01 |
| Bi-210 | 4.14E-14 | 3.56E-14 | 3.16E-14 | 3.58E-14 | 4.29E-14 | N/A | N/A | N/A |
| Bi-211 | 9.50E-09 | 7.63E-09 | 1.44E-08 | 5.61E-09 | 4.77E-09 | N/A | N/A | N/A |
| Bi-212 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Bi-213 | 4.10E-12 | 9.07E-12 | 7.29E-12 | 1.46E-11 | 4.87E-11 | N/A | N/A | N/A |
| Bi-214 | 1.75E-13 | 1.64E-13 | 1.27E-13 | 1.83E-13 | 2.61E-13 | N/A | N/A | N/A |
| C-14 | 4.53E-04 | 1.01E-03 | 1.80E-03 | 9.96E-04 | 3.93E-03 | 4.63E-05 | 3.70E-04 | 2.48E-05 |
| Cm-242 | 1.27E-06 | 3.34E-05 | 2.28E-05 | 2.85E-05 | 1.15E-04 | N/A | N/A | N/A |
| Cm-244 | 5.40E-06 | 3.18E-05 | 1.07E-04 | 5.95E-06 | 1.24E-04 | N/A | N/A | N/A |
| Cm-245 | 3.27E-10 | 2.29E-09 | 8.73E-09 | 4.50E-10 | 9.49E-09 | N/A | N/A | N/A |
| Cs-135 | 4.19E-05 | 1.48E-04 | 8.72E-05 | 8.03E-06 | 3.67E-05 | N/A | N/A | N/A |
| Cs-137 | 1.47E+00 | 8.66E+00 | 6.13E+00 | 6.33E-01 | 2.56E+00 | 5.54E+00 | 8.01E+00 | 2.46E+01 |
| Eu-154 | N/A | N/A | N/A | N/A | N/A | 2.58E-02 | 1.31E-02 | 6.71E-03 |
| Fr-221 | 4.10E-12 | 9.07E-12 | 7.29E-12 | 1.46E-11 | 4.87E-11 | N/A | N/A | N/A |
| Fr-223 | 1.31E-10 | 1.05E-10 | 1.98E-10 | 7.75E-11 | 6.58E-11 | N/A | N/A | N/A |
| I-129 | 4.02E-06 | 8.18E-06 | 1.13E-05 | 3.91E-07 | 3.35E-06 | 4.53E-06 | 7.04E-06 | 1.69E-05 |
| Nb-93m | 2.05E-04 | 2.77E-03 | 8.18E-04 | 1.55E-03 | 2.61E-02 | N/A | N/A | N/A |
| Ni-59 | N/A | 6.84E-03 | 1.43E-02 | N/A | N/A | N/A | N/A | N/A |
| Ni-63 | 1.32E-02 | 2.02E-01 | 8.53E-02 | 1.66E-01 | 1.87E+00 | N/A | N/A | N/A |
| Np-237 | 1.65E-05 | 2.05E-05 | 5.16E-05 | 2.63E-06 | 7.72E-06 | 2.18E-05 | 7.05E-06 | 1.75E-06 |
| Np-238 | 7.32E-09 | 1.93E-07 | 1.32E-07 | 1.64E-07 | 6.62E-07 | N/A | N/A | N/A |
| Np-239 | 7.56E-07 | 1.54E-05 | 1.74E-05 | 1.82E-05 | 5.37E-05 | N/A | N/A | N/A |
| Pa-231 | 1.70E-08 | 1.36E-08 | 2.53E-08 | 1.46E-08 | 1.10E-08 | N/A | N/A | N/A |
| Pa-233 | 1.65E-05 | 2.05E-05 | 5.16E-05 | 2.63E-06 | 7.72E-06 | N/A | N/A | N/A |
| Pa-234 | 4.31E-07 | 2.47E-07 | 5.13E-07 | 7.71E-07 | 4.54E-07 | N/A | N/A | N/A |
| Pa-234m | 2.69E-04 | 1.54E-04 | 3.21E-04 | 4.82E-04 | 2.84E-04 | N/A | N/A | N/A |
| Pb-209 | 4.10E-12 | 9.07E-12 | 7.29E-12 | 1.46E-11 | 4.87E-11 | N/A | N/A | N/A |
| Pb-210 | 4.14E-14 | 3.56E-14 | 3.16E-14 | 3.58E-14 | 4.29E-14 | N/A | N/A | N/A |
| Pb-211 | 9.50E-09 | 7.63E-09 | 1.44E-08 | 5.61E-09 | 4.77E-09 | N/A | N/A | N/A |
| Pb-212 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Pb-214 | 1.75E-13 | 1.64E-13 | 1.27E-13 | 1.83E-13 | 2.61E-13 | N/A | N/A | N/A |
| Pd-107 | 1.86E-05 | 3.73E-05 | 5.20E-05 | 1.87E-06 | 1.68E-05 | N/A | N/A | N/A |
| Po-210 | 4.14E-14 | 3.56E-14 | 3.16E-14 | 3.58E-14 | 4.29E-14 | N/A | N/A | N/A |
| Po-211 | 2.59E-11 | 2.08E-11 | 3.92E-11 | 1.53E-11 | 1.30E-11 | N/A | N/A | N/A |

Table D.7.1.6 Exhumed Inventory for Tank Residuals for the Ex Situ/In Situ Combination 2 Alternative, Total Curies (cont'd)

| | Source Area | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Radionuclide [1] | 1WSS | 2WSS | 1ESS | 2ESS | 4ESS | 3WDS | 3EDS | 5EDS |
| Po-212 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Po-213 | 4.01E-12 | 8.88E-12 | 7.14E-12 | 1.43E-11 | 4.76E-11 | N/A | N/A | N/A |
| Po-214 | 1.75E-13 | 1.64E-13 | 1.27E-13 | 1.83E-13 | 2.61E-13 | N/A | N/A | N/A |
| Po-215 | 9.50E-09 | 7.63E-09 | 1.44E-08 | 5.61E-09 | 4.77E-09 | N/A | N/A | N/A |
| Po-216 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Po-218 | 1.75E-13 | 1.64E-13 | 1.27E-13 | 1.83E-13 | 2.61E-13 | N/A | N/A | N/A |
| Pu-238 | 8.02E-04 | 1.09E-03 | 6.13E-04 | 1.50E-03 | 3.85E-03 | 6.04E-02 | 2.67E-05 | 2.40E-03 |
| Pu-239 | 5.11E-03 | 1.43E-02 | 1.15E-02 | 3.64E-02 | 7.98E-02 | 1.19E-01 | 7.91E-04 | 1.51E-02 |
| Pu-240 | 8.54E-04 | 3.18E-03 | 2.78E-03 | 9.49E-03 | 2.04E-02 | 4.30E-02 | 2.03E-04 | 4.26E-03 |
| Pu-241 | 4.05E-03 | 2.55E-02 | 3.46E-02 | 1.08E-01 | 1.91E-01 | 1.28E+00 | 2.04E-03 | 1.53E-01 |
| Pu-242 | 7.58E-12 | 2.00E-10 | 1.36E-10 | 1.70E-10 | 6.85E-10 | N/A | N/A | N/A |
| Ra-223 | 9.50E-09 | 7.63E-09 | 1.44E-08 | 5.61E-09 | 4.77E-09 | N/A | N/A | N/A |
| Ra-224 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Ra-225 | 4.10E-12 | 9.07E-12 | 7.29E-12 | 1.46E-11 | 4.87E-11 | N/A | N/A | N/A |
| Ra-226 | 1.75E-13 | 1.64E-13 | 1.27E-13 | 1.83E-13 | 2.61E-13 | N/A | N/A | N/A |
| Ra-228 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Rh-106 | 1.75E-11 | 6.97E-08 | 3.57E-07 | 4.85E-07 | 6.91E-06 | N/A | N/A | N/A |
| Rn-219 | 9.50E-09 | 7.63E-09 | 1.44E-08 | 5.61E-09 | 4.77E-09 | N/A | N/A | N/A |
| Rn-220 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Rn-222 | 1.75E-13 | 1.64E-13 | 1.27E-13 | 1.83E-13 | 2.61E-13 | N/A | N/A | N/A |
| Ru-106 | 1.75E-11 | 6.97E-08 | 3.57E-07 | 4.85E-07 | 6.91E-06 | N/A | N/A | N/A |
| Sb-126 | 4.08E-06 | 9.17E-05 | 2.10E-05 | 5.27E-05 | 6.19E-04 | N/A | N/A | N/A |
| Sb-126m | 2.92E-05 | 6.55E-04 | 1.50E-04 | 3.76E-04 | 4.42E-03 | N/A | N/A | N/A |
| Se-79 | 2.01E-04 | 4.09E-04 | 5.68E-04 | 1.93E-05 | 1.64E-04 | N/A | N/A | N/A |
| Sm-151 | 5.31E-02 | 7.21E-01 | 1.67E-01 | 3.91E-01 | 4.22E+00 | N/A | N/A | N/A |
| Sn-126 | 2.92E-05 | 6.55E-04 | 1.50E-04 | 3.76E-04 | 4.42E-03 | N/A | N/A | N/A |
| Sr-90 | 3.09E+00 | 5.12E+01 | 1.55E+01 | 2.39E+01 | 3.23E+02 | 1.49E+00 | 1.80E+00 | 7.41E-01 |
| Tc-99 | 2.77E-03 | 5.65E-03 | 7.84E-03 | 2.67E-04 | 2.26E-03 | 2.10E-03 | 4.31E-03 | 7.84E-03 |
| Th-227 | 9.37E-09 | 7.52E-09 | 1.42E-08 | 5.54E-09 | 4.70E-09 | N/A | N/A | N/A |
| Th-228 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Th-229 | 4.10E-12 | 9.07E-12 | 7.29E-12 | 1.46E-11 | 4.87E-11 | N/A | N/A | N/A |
| Th-230 | 2.56E-11 | 2.58E-11 | 1.83E-11 | 3.13E-11 | 5.03E-11 | N/A | N/A | N/A |
| Th-231 | 1.14E-05 | 7.32E-06 | 1.39E-05 | 2.10E-05 | 1.20E-05 | N/A | N/A | N/A |
| Th-232 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Th-234 | 2.69E-04 | 1.54E-04 | 3.21E-04 | 4.82E-04 | 2.84E-04 | N/A | N/A | N/A |
| Tl-207 | 9.48E-09 | 7.61E-09 | 1.43E-08 | 5.60E-09 | 4.75E-09 | N/A | N/A | N/A |
| Tl-208 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Tl-209 | 8.85E-14 | 1.96E-13 | 1.58E-13 | 3.16E-13 | 1.05E-12 | N/A | N/A | N/A |
| U-233 | 2.80E-09 | 4.57E-09 | 6.73E-09 | 5.34E-09 | 2.03E-08 | N/A | N/A | N/A |
| U-234 | 1.44E-07 | 1.59E-07 | 1.15E-07 | 2.25E-07 | 4.35E-07 | N/A | N/A | N/A |
| U-235 | 1.14E-05 | 7.32E-06 | 1.39E-05 | 2.10E-05 | 1.20E-05 | N/A | N/A | N/A |
| U-236 | 4.45E-10 | 1.65E-09 | 1.45E-09 | 4.94E-09 | 1.06E-08 | N/A | N/A | N/A |
| U-237 | 9.93E-08 | 6.24E-07 | 8.48E-07 | 2.65E-06 | 4.67E-06 | N/A | N/A | N/A |

Table D.7.1.6 Exhumed Inventory for Tank Residuals for the Ex Situ/In Situ Combination 2 Alternative, Total Curies (cont'd)

| | Source Area | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Radionuclide [1] | 1WSS | 2WSS | 1ESS | 2ESS | 4ESS | 3WDS | 3EDS | 5EDS |
| U-238 | 2.69E-04 | 1.54E-04 | 3.21E-04 | 4.82E-04 | 2.84E-04 | N/A | N/A | N/A |
| Y-90 | 3.21E+00 | 5.32E+01 | 1.61E+01 | 2.48E+01 | 3.34E+02 | 1.49E+00 | 1.80E+00 | 7.41E-01 |
| Zr-93 | 1.73E-04 | 3.39E-03 | 8.47E-04 | 2.08E-03 | 3.86E-02 | N/A | N/A | N/A |
| Total Ci | 1.19E+01 | 1.38E+02 | 5.51E+01 | 5.19E+01 | 6.74E+02 | 1.62E+01 | 1.96E+01 | 5.08E+01 |

Notes:
[1] Decayed to 12/31/95.
N/A = Not applicable

Table D.7.1.7 Exhumed Inventory for the Onsite Disposal Alternative

| Case | Capsule Type | No. of Capsules | Capsule Inventory[1], Ci | Canister Inventory, Ci |
|---|---|---|---|---|
| Average | Sr-90 | 3 | 38,470 | 115,410 |
| | Cs-137 | 4 | 40,100 | 160,400 |
| Maximum | Sr-90 | 3 | 93,270 | 279,810 |
| | Cs-137 | 4 | 54,380 | 217,520 |

Notes:
[1]Decayed to 12/31/95.

### D.7.1.13 Overpack and Ship Alternative

There is no source term for the Overpack and Ship alternative because the capsules are shipped offsite to a geologic repository.

### D.7.1.14 Vitrify with Tank Waste Alternative

There is no source term for the Vitrify with Tank Waste alternative because the capsules are vitrified to HLW glass and shipped offsite to a geologic repository.

## D.7.2 TRANSPORT

Contaminant transport is not considered for this analysis. The waste is assumed to be exhumed and spread over the surface of certain land areas. The intruders receive radiation exposures because of their proximity to and use of these contaminated surface areas.

## D.7.3 EXPOSURE

To calculate exposures, the exhumed inventory in the source is multiplied by a unit dose factor to produce a dose to each receptor from each constituent. The exposure parameters and unit dose factors used for this analysis are consistent with those used by prior Hanford Site studies for estimating the dose from intrusion into a Hanford Site solid waste burial ground (Aaberg-Kennedy 1990, as modified in Rittmann 1994).

The dose to the well driller is from the inhalation and external pathways and is calculated in Rittmann (Rittman 1994). This intruder is assumed to inhale the exhumed waste for 1 hour. The well driller

spreads the waste on the soil surface and works in this area for 40 hours with direct contact with the waste.

The post-drilling resident is assumed to live on a 2,500-$m^2$ (0.62-acre) parcel of land over which the exhumed waste has been spread (Rittmann 1994), grow different vegetables on this land, and obtain 25 percent of his vegetables from this garden. He ingests small amounts of contaminated soil each day and his total ingestion is 445 mg/yr. He inhales radionuclides suspended in the air by gardening activity and by wind for 4,380 hr/yr and is exposed externally to the contaminated soil while working in the garden or residing in the house built on top of the waste for 3,260 hr/yr.

Table D.7.3.1 presents the unit dose factors for each radionuclide in the exhumed waste under the previously listed exposure conditions for the well driller and post-drilling resident scenarios. These dose factors are calculated using the GENII computer code. The calculation methodology and assumptions are described in greater detail in Rittmann (Rittman 1994). Constituents listed in the source inventory tables that do not appear in Table D.7.3.1 are progeny in equilibrium with their parent, and the unit dose factor for the parent includes the dose from the progeny. Thus, all constituents in the source inventory are addressed. The unit dose factors shown in Table D.7.3.1 are calculated for a time 100 years from the present, corresponding to the time of assumed loss of institutional control. Time periods greater than 100 years are not evaluated because radioactive decay would cause the doses and corresponding risk at the later periods to be less than at 100 years.

Table D.7.3.2 presents the estimated doses to each receptor from intrusion into the eight tank sources and the LAW vaults under each alternative at 100 years from the present. These doses represent the total dose from all constituents in each source area. Of the eight tank source areas, Area 3EDS produces the greatest doses to both receptors under all the alternatives except the Ex Situ/In Situ Combination 2 alternative and is therefore carried forward to the risk calculation along with the LAW vaults. For the Ex Situ/In Situ Combination 2 alternative, the greatest doses are produced by Area 5EDS; therefore, area 5EDS, along with the LAW vaults, is carried forward to the risk calculation for the Ex Situ/In Situ Combination 2 alternative.

The capsule alternative would involve the same drilling scenario, but it represents the dose from exhuming a canister from the drywell disposal facility. The dose from exhuming a canister is shown in Table D.7.3.3.

### D.7.4 RISK

Risk is expressed in terms of the increased probability of the exposed receptor contracting a cancer (incidence) or dying from a cancer (fatality). The risk is calculated for each intruder as the product of the total dose times the dose-to-risk conversion factor. The dose for the driller is based on the annual doses provided in Tables D.7.3.2 and D.7.3.3. The risk for the post-driller resident is based on the annual doses provided in Tables D.7.3.2 and D.7.3.3 multiplied by an expected lifetime of 70 years. The dose-to-risk conversion factors used for the well driller are 4.00E-04 for cancer fatality and

4.80E-04 for cancer incidence. The dose-to-risk conversion factors used for the post-driller resident are 5.00E-04 for cancer fatality and 6.00E-04 for cancer incidence (ICRP 1991).

Table D.7.4.1 presents the estimated cancer incidence for the well driller and post-drilling resident from intrusion into tank source Area 3EDS or 5EDS and the LAW vaults under each alternative at 100 years from the present.

Table D.7.4.2 presents the estimated cancer fatalities for the well driller and post-drilling resident from intrusion into tank source Area 3EDS or 5EDS and the LAW vaults under each alternative at 100 years from the present.

**Table D.7.3.1 Intruder Scenario Dose Factors at 100 Years from Present**

| | Dose Factor (mrem per Ci exhumed) | |
|---|---|---|
| Radionuclide | Driller | Post-Driller |
| Ac-227 | 8.87E+01 | 3.12E+02 |
| Ag-108m | 1.01E+03 | 3.27E+03 |
| Am-241 | 1.87E+02 | 6.45E+02 |
| Am-242m | 2.02E+02 | 6.94E+02 |
| Am-243 | 3.83E+02 | 1.29E+03 |
| Ba-133 | 5.05E-01 | 1.59E+00 |
| Be-10 | 3.81E-01 | 1.34E+00 |
| Bi-207 | 2.05E+02 | 6.61E+02 |
| C-14 | 4.92E-02 | 1.44E+01 |
| Cd-109 | 6.55E-24 | 5.31E-23 |
| Cd-113m | 2.39E-02 | 1.75E+00 |
| Cl-36 | 5.30E-01 | 1.98E+03 |
| Cm-243 | 2.24E+01 | 7.42E+01 |
| Cm-244 | 2.91E+00 | 9.80E+00 |
| Cm-245 | 3.11E+02 | 1.05E+03 |
| Cm-246 | 2.12E+02 | 7.25E+02 |
| Cm-247 | 5.45E+02 | 1.81E+03 |
| Cm-248 | 7.61E+02 | 2.60E+03 |
| Co-60 | 5.31E-03 | 1.62E-02 |
| Cs-134 | 4.24E-12 | 1.19E-11 |
| Cs-135 | 1.66E-01 | 8.13E+00 |
| Cs-137 | 6.13E+01 | 2.03E+02 |
| Eu-150 | 2.30E+02 | 7.41E+02 |
| Eu-152 | 7.42E+00 | 2.36E+01 |
| Eu-154 | 5.03E-01 | 1.58E+00 |
| Eu-155 | 3.13E-05 | 9.53E-05 |
| Fe-55 | 9.53E-14 | 2.99E-13 |
| Gd-152 | 5.45E+01 | 2.08E+02 |
| H-3 | 2.27E-05 | 4.28E-04 |

Table D.7.3.1 Intruder Scenario Dose Factors at 100 Years from Present (cont'd)

| | Dose Factor (mrem per Ci exhumed) | |
|---|---|---|
| Radionuclide | Driller | Post-Driller |
| Ho-166m | 1.74E+03 | 5.67E+03 |
| I-129 | 8.87E+00 | 1.51E+02 |
| In-115 | 3.92E+00 | 1.32E+01 |
| K-40 | 1.73E+02 | 6.67E+02 |
| Mn-54 | 6.22E-33 | 1.39E-32 |
| Mo-93 | 1.89E-01 | 1.57E+00 |
| Na-22 | 6.41E-09 | 1.83E-08 |
| Nb-93m | 3.36E-04 | 1.34E-03 |
| Nb-94 | 1.70E+03 | 5.54E+03 |
| Ni-59 | 4.72E-03 | 1.66E-01 |
| Ni-63 | 6.32E-03 | 2.24E-01 |
| Np-237 | 4.01E+02 | 1.67E+03 |
| Pa-231 | 2.61E+03 | 9.25E+03 |
| Pb-210 | 6.91E+00 | 3.57E+01 |
| Pd-107 | 5.88E-03 | 8.67E-02 |
| Pm-147 | 4.74E-10 | 1.89E-09 |
| Po-209 | 2.54E+01 | 1.36E+02 |
| Pu-236 | 3.10E+01 | 1.04E+02 |
| Pu-238 | 8.29E+01 | 2.82E+02 |
| Pu-239 | 2.04E+02 | 6.96E+02 |
| Pu-240 | 2E+02 | 6.91E+02 |
| Pu-241 | 6.42E+00 | 2.21E+01 |
| Pu-242 | 1.94E+02 | 6.60E+02 |
| Pu-244 | 5.53E+02 | 1.83E+03 |
| Ra-226 | 1.99E+03 | 6.86E+03 |
| Ra-228 | 2.13E-02 | 6.62E-02 |
| Rb-87 | 1.36E-01 | 4.04E+00 |
| Re-187 | 1.95E-04 | 3.63E-02 |
| Ru-106 | 3.19E-28 | 7.63E-28 |
| Sb-125 | 6.04E-09 | 1.73E-08 |
| Se-79 | 1.90E-01 | 2.64E+00 |
| Sm-147 | 1.91E+01 | 7.65E+01 |
| Sm-151 | 6.45E-03 | 2.83E-02 |
| Sn-121m | 1.34E-01 | 4.73E-01 |
| Sn-126 | 2.13E+03 | 6.93E+03 |
| Sr-90 | 6.93E-01 | 8.42E+01 |
| Tc-99 | 5.57E-02 | 3.94E+01 |
| Th-228 | 3.23E-13 | 8.88E-13 |
| Th-229 | 8.07E+02 | 2.83E+03 |
| Th-230 | 1.66E+02 | 5.90E+02 |

Table D.7.3.1 Intruder Scenario Dose Factors at 100 Years from Present (cont'd)

| | Dose Factor (mrem per Ci exhumed) | |
|---|---|---|
| Radionuclide | Driller | Post-Driller |
| Th-232 | 3.19E+03 | 1.07E+04 |
| Tl-204 | 9.53E-09 | 2.84E-08 |
| U-232 | 7.53E+02 | 2.53E+03 |
| U-233 | 4.16E+01 | 1.78E+02 |
| U-234 | 3.37E+01 | 1.49E+02 |
| U-235 | 1.84E+02 | 6.33E+02 |
| U-236 | 3.12E+01 | 1.39E+02 |
| U-238 | 5.49E+01 | 2.15E+02 |
| Zr-93 | 1.42E-01 | 5.27E-01 |

Table D.7.3.2 Dose to Receptor for the Eight Tank Source Areas and LAW Vaults for Each Alternative

| Source Area | Alternative | Dose (Rem) | |
|---|---|---|---|
| | | Driller | Post-Driller |
| 1WSS | No Action | 2.45E-01 | 1.34E+00 |
| | Long-Term Management | 2.45E-01 | 1.34E+00 |
| | In Situ Fill and Cap | 2.45E-01 | 1.34E+00 |
| | In Situ Vitrification | 7.89E-01 | 4.09E+00 |
| | Ex Situ Intermediate Separations | 2.45E-03 | 1.34E-02 |
| | Ex Situ No Separations | 2.45E-03 | 1.34E-02 |
| | Ex Situ Extensive Separations | 2.45E-03 | 1.34E-02 |
| | Ex Situ/In Situ Combination 1 | 4.06E-02 | 2.12E-01 |
| | Ex Situ/In Situ Combination 2 | 9.40E-02 | 5.64E-01 |
| | Phased Implementation | 2.45E-03 | 1.34E-02 |
| 2WSS | No Action | 1.03E+00 | 8.11E+00 |
| | Long-Term Management | 1.03E+00 | 8.11E+00 |
| | In Situ Fill and Cap | 1.03E+00 | 8.11E+00 |
| | In Situ Vitrification | 7.89E-01 | 4.09E+00 |
| | Ex Situ Intermediate Separations | 1.03E-02 | 8.11E-02 |
| | Ex Situ No Separations | 1.03E-02 | 8.11E-02 |
| | Ex Situ Extensive Separations | 1.03E-02 | 8.11E-02 |
| | Ex Situ/In Situ Combination 1 | 1.43E-01 | 2.94E+00 |
| | Ex Situ/In Situ Combination 2 | 5.77E-01 | 6.10E+00 |
| | Phased Implementation | 1.03E-02 | 8.11E-02 |
| 1ESS | No Action | 1.02E+00 | 6.32E+00 |
| | Long-Term Management | 1.02E+00 | 6.32E+00 |
| | In Situ Fill and Cap | 1.02E+00 | 6.32E+00 |
| | In Situ Vitrification | 7.89E-01 | 4.09E+00 |
| | Ex Situ Intermediate Separations | 1.02E-02 | 6.32E-02 |
| | Ex Situ No Separations | 1.02E-02 | 6.32E-02 |
| | Ex Situ Extensive Separations | 1.02E-02 | 6.32E-02 |

Table D.7.3.2 Dose to Receptor for the Eight Tank Source Areas and LAW Vaults for Each Alternative (cont'd)

| Source Area | Alternative | Dose (Rem) | |
|---|---|---|---|
| | | Driller | Post-Driller |
| | Ex Situ/In Situ Combination 1 | 1.01E-01 | 6.27E-01 |
| | Ex Situ/In Situ Combination 2 | 3.93E-01 | 2.57E+00 |
| | Phased Implementation | 1.02E-02 | 6.32E-02 |
| 2ESS | No Action | 1.61E-01 | 4.85E+00 |
| | Long-Term Management | 1.61E-01 | 4.85E+00 |
| | In Situ Fill and Cap | 1.61E-01 | 4.85E+00 |
| 2ESS | In Situ Vitrification | 7.89E-01 | 4.09E+00 |
| | Ex Situ Intermediate Separations | 1.61E-03 | 4.85E-02 |
| | Ex Situ No Separations | 1.61E-03 | 4.85E-02 |
| | Ex Situ Extensive Separations | 1.61E-03 | 4.85E-02 |
| | Ex Situ/In Situ Combination 1 | 4.11E-02 | 4.02E-01 |
| | Ex Situ/In Situ Combination 2 | 7.11E-02 | 2.20E+00 |
| | Phased Implementation | 1.61E-03 | 4.85E-02 |
| 4ESS | No Action | 4.25E-01 | 2.82E+01 |
| | Long-Term Management | 4.25E-01 | 2.82E+01 |
| | In Situ Fill and Cap | 4.25E-01 | 2.82E+01 |
| | In Situ Vitrification | 7.89E-01 | 4.09E+00 |
| | Ex Situ Intermediate Separations | 4.25E-03 | 2.82E-01 |
| | Ex Situ No Separations | 4.25E-03 | 2.82E-01 |
| | Ex Situ Extensive Separations | 4.25E-03 | 2.82E-01 |
| | Ex Situ/In Situ Combination 1 | 1.65E-01 | 1.17E+01 |
| | Ex Situ/In Situ Combination 2 | 4.28E-01 | 2.79E+01 |
| | Phased Implementation | 4.25E-03 | 2.82E-01 |
| 3WDS | No Action | 1.31E+01 | 4.36E+01 |
| | Long-Term Management | 1.31E+01 | 4.36E+01 |
| | In Situ Fill and Cap | 1.31E+01 | 4.36E+01 |
| | In Situ Vitrification | 7.89E-01 | 4.09E+00 |
| | Ex Situ Intermediate Separations | 1.31E-01 | 4.36E-01 |
| | Ex Situ No Separations | 1.31E-01 | 4.36E-01 |
| | Ex Situ Extensive Separations | 1.31E-01 | 4.36E-01 |
| | Ex Situ/In Situ Combination 1 | 1.77E+00 | 6.03E+00 |
| | Ex Situ/In Situ Combination 2 | 5.10E-01 | 1.83E+00 |
| | Phased Implementation | 1.31E-01 | 4.36E-01 |
| 3EDS | No Action | 2.13E+01 | 8.45E+01 |
| | Long-Term Management | 2.13E+01 | 8.45E+01 |
| | In Situ Fill and Cap | 2.13E+01 | 8.45E+01 |
| | In Situ Vitrification | 7.89E-01 | 4.09E+00 |
| | Ex Situ Intermediate Separations | 2.13E-01 | 8.45E-01 |
| | Ex Situ No Separations | 2.13E-01 | 8.45E-01 |
| 3EDS | Ex Situ Extensive Separations | 2.13E-01 | 8.45E-01 |

Table D.7.3.2 Dose to Receptor for the Eight Tank Source Areas and LAW Vaults for Each Alternative (cont'd)

| Source Area | Alternative | Dose (Rem) | |
|---|---|---|---|
| | | Driller | Post-Driller |
| | Ex Situ/In Situ Combination 1 | 3.07E+00 | 1.32E+01 |
| | Ex Situ/In Situ Combination 2 | 4.95E-01 | 1.78E+00 |
| | Phased Implementation | 2.13E-01 | 8.45E-01 |
| 5EDS | No Action | 2.95E+00 | 9.81E+00 |
| | Long-Term Management | 2.95E+00 | 9.81E+00 |
| | In Situ Fill and Cap | 2.95E+00 | 9.81E+00 |
| | In Situ Vitrification | 7.89E-01 | 4.09E+00 |
| | Ex Situ Intermediate Separations | 2.95E-02 | 9.81E-02 |
| | Ex Situ No Separations | 2.95E-02 | 9.81E-02 |
| | Ex Situ Extensive Separations | 2.95E-02 | 9.81E-02 |
| | Ex Situ/In Situ Combination 1 | 1.81E+00 | 6.05E+00 |
| | Ex Situ/In Situ Combination 2 | 1.51E+00 | 5.07E+00 |
| | Phased Implementation | 2.95E-02 | 9.81E-02 |
| Vaults | No Action | N/A | N/A |
| | Long-Term Management | N/A | N/A |
| | In Situ Fill and Cap | N/A | N/A |
| | In Situ Vitrification | N/A | N/A |
| | Ex Situ Intermediate Separations | 9.27E-02 | 6.86E-01 |
| | Ex Situ No Separations | N/A | N/A |
| | Ex Situ Extensive Separations | 1.51E-02 | 5.38E-02 |
| | Ex Situ/In Situ Combination 1 | 9.27E-02 | 6.86E-01 |
| | Ex Situ/In Situ Combination 2 | 9.27E-02 | 6.86E-01 |
| | Phased Implementation | 9.27E-02 | 6.86E-01 |

Notes:
N/A = Not applicable

Table D.7.3.3 Dose to Receptor for the Onsite Disposal, Capsules Alternative

| Case | Capsule Type | Canister Inventory, Ci | Dose (Rem) | |
|---|---|---|---|---|
| | | | Driller | Post-Driller |
| Average | Sr-90 | 1.15E+05 | 8.00E+01 | 9.72E+03 |
| | Cs-137 | 1.60E+05 | 9.83E+03 | 3.26E+04 |
| Maximum | Sr-90 | 2.80E+05 | 1.94E+02 | 2.36E+04 |
| | Cs-137 | 2.18E+05 | 1.33E+04 | 4.42E+04 |

**Table D.7.4.1 Cancer Incidence for TWRS Alternatives from Intrusion into Tanks and Vaults at 100 Years from 1995**

| | Tanks [1] | | Vaults | |
|---|---|---|---|---|
| Alternative | Driller | Post-Driller | Driller | Post-Driller |
| No Action Alternative | 1.02E-02 | 5.07E-02 | No Vaults | No Vaults |
| Long-Term Management | 1.02E-02 | 5.07E-02 | No Vaults | No Vaults |
| In Situ Fill and Cap | 1.02E-02 | 5.07E-02 | No Vaults | No Vaults |
| In Situ Vitrification | 3.79E-04 | 2.54E-03 | No Vaults | No Vaults |
| Ex Situ Intermediate Separations | 1.02E-04 | 5.07E-04 | 4.45E-05 | 4.12E-04 |
| Ex Situ No Separations | 1.02E-04 | 5.07E-04 | No Vaults | No Vaults |
| Ex Situ Extensive Separations | 1.02E-04 | 5.07E-04 | 7.26E-06 | 3.23E-05 |
| Ex Situ/In Situ Combination 1 | 1.47E-03 | 7.94E-03 | 4.45E-05 | 4.12E-04 |
| Ex Situ/In Situ Combination 2 | 7.26E-04 | 3.04E-03 | 4.45E-05 | 4.12E-04 |
| Phased Implementation | 1.02E-04 | 5.07E-04 | 4.45E-05 | 4.12E-04 |

Notes:
[1] Values shown are based on tank source area 3EDS except for the Ex Situ/In Situ Combination 2 alternative, which is based on area 5EDS.

**Table D.7.4.2 Latent Cancer Fatalities for TWRS Alternatives from Intrusion into Tanks and Vaults at 100 Years from 1995**

| | Tanks [1] | | Vaults | |
|---|---|---|---|---|
| Alternatives | Driller | Post-Driller | Driller | Post-Driller |
| No Action Alternative | 8.52E-03 | 4.23E-02 | No Vaults | No Vaults |
| Long-Term Management | 8.52E-03 | 4.23E-02 | No Vaults | No Vaults |
| In Situ Fill and Cap | 8.52E-03 | 4.23E-02 | No Vaults | No Vaults |
| In Situ Vitrification | 3.16E-04 | 2.04E-03 | No Vaults | No Vaults |
| Ex Situ Intermediate Separations | 8.52E-05 | 4.23E-04 | 3.71E-05 | 3.43E-04 |
| Ex Situ No Separations | 8.52E-05 | 4.23E-04 | No Vaults | No Vaults |
| Ex Situ Extensive Separations | 8.52E-05 | 4.23E-04 | 6.05E-06 | 2.69E-05 |
| Ex Situ/In Situ Combination 1 | 1.23E-03 | 6.62E-03 | 3.71E-05 | 3.43E-04 |
| Ex Situ/In Situ Combination 2 | 6.05E-04 | 2.53E-03 | 3.71E-05 | 3.43E-04 |
| Phased Implementation | 8.52E-05 | 4.23E-04 | 3.71E-05 | 3.43E-04 |

Notes:
[1] Values shown are based on tank source area 3EDS except for the Ex Situ/In Situ Combination 2 alternative, which is based on area 5EDS.

## D.7.5 UNCERTAINTY

The greatest uncertainty in calculating the intruder risk is associated with the source data. Source terms are based on the estimated inventory and an average tank within the eight aggregated tank farms of the 200 Areas. The uncertainties associated with the source term, as well as with the intrusion frequency and exposure parameters, are discussed in detail in Volume Five, Appendix K.

# APPENDIX D
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