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Risk Assessment for Air Emissions from the Integrated Waste Treatment Unit and INTEC Liquid Waste Management System

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Idaho Falls, Idaho 83415

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ABSTRACT

This risk assessment evaluates potential human health and ecological impacts due to air emissions from the INTEC Liquid Waste Management System (ILWMS) and the proposed Integrated Waste Treatment Unit (IWTU), both located at the Idaho Nuclear Technology and Engineering Center on the Idaho National Laboratory (INL) Site. Cumulative impacts from other contributing sources (e.g., Idaho CERCLA Disposal Facility [ICDF]) calculated in previous risk assessments are included. U.S. Environmental Protection Agency (EPA) guidance in *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* was used to evaluate continuous exposure to contaminant air and soil concentrations at on- and off-INL locations where maximum modeled impacts occurred. Both inhalation and ingestion pathways were evaluated with the latter including incidental soil and food product ingestion, including produce, beef, dairy, pork, and poultry/eggs. Four human exposure scenarios were evaluated in addition to an inhalation assessment for motorists on U.S. Highway 20/26 and an acute inhalation assessment at the point of maximum air concentration. Ecological risk was evaluated at the location of maximum contaminant soil concentration using ecologically based screening levels.

The maximum lifetime cancer risk from emissions from the Process Equipment Waste Evaporator, Liquid Effluent Treatment & Disposal facility, and the IWTU is estimated to be 4.8E-08, about 0.5% of the EPA risk target criterion (1E-05). The maximum non-cancer hazard index is estimated to be 0.0089, about 4% of the EPA hazard target criterion (0.25). Cumulative impacts from the Evaporator Tank System and the ICDF, which were calculated in previous risk assessments, increase these estimates to 9E-08 risk (1% of target) and <0.02 hazard index (7% of target). Maximum short-term inhalation impacts on Highway 20/26 are less than State of Idaho toxic air pollutant criteria, and the maximum 1-hour concentrations are less than EPA acute inhalation exposure criteria. The total screening level ecological hazard quotient from all sources is 0.64, compared to a conservative target criterion of 1.0. Uncertainties in these estimates are discussed in detail. These results demonstrate that the IWTU and ILWMS emissions, combined with other potentially contributing INL sources, do not pose a risk to human health or the environment.

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ACRONYMS

AAC	acceptable ambient concentration
ACFM	actual cubic feet per minute
AHQ	acute hazard quotient
AIEC	acute inhalation exposure criteria
BAF	(prey) bioaccumulation factor
BPIPPRM	Building Profile Input Program for PRIME
C1p	Maximum 1-hour particulate concentration (µg-second/g-m^3)
C1v	Maximum 1-hour vapor concentration (µg-second/g-m^3)
C24p	Maximum 24-hour particulate concentration (µg-second/g-m^3)
C24v	Maximum 24-hour vapor concentration (µg-second/g-m^3)
CAS	Chemical Abstract Service
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPC	constituent of potential concern (EPA)
Cp	annual average particulate concentration (µg-second/g-m^3)
CRR	Carbon Reduction Reformer
CSF	cancer slope factor
Cv	annual average vapor concentration (µg-second/g-m^3)
Ddp	annual average dry deposition of particulate (second/m^2-year)
Ddv	annual average dry deposition of vapor (second/m^2-year)
DEQ	Department of Environmental Quality (Idaho)
DMR	Denitration and Mineralization Reformer
DS	stack exit diameter
Dwp	annual average wet deposition of particulate (second/m^2-year)
Dwv	annual average wet deposition of vapor (second/m^2-year)
EBSL	ecologically-based screening level
ED	exposure duration
EDF	Engineering Design File

EL	emission level (IDAPA)
EPA	U.S. Environmental Protection Agency
ETS	Evaporator Tank System
GIS	Geographical Information System
GRD3	Grid 3 meteorological tower
HEPA	high-efficiency particulate air (filter)
HHRAP	Human Health Risk Assessment Protocol (for Hazardous Waste Combustion Facilities)
HI	hazard index
HQ	hazard quotient
HS	stack height
HVAC	heating, ventilating, and air conditioning
HWMA	Hazardous Waste Management Act
ICDF	Idaho CERCLA Disposal Facility
ICP	Idaho Cleanup Project
IDAPA	Idaho Administrative Procedures Act
ILWMS	INTEC Liquid Waste Management System
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
ISC3	Industrial Source Complex Model - 3
ISC3P	Industrial Source Complex Model - 3 with PRIME downwash
ISC-PRIME	Industrial Source Complex Model with PRIME downwash
ISCST3	Industrial Source Complex Short-Term Model -3
IWTU	Integrated Waste Treatment Unit
LET&D	Liquid Effluent Treatment & Disposal
MASSFRAX	particle mass fraction
NED	National Elevation Data (US Geological Survey)
NOAA	National Oceanic and Atmospheric Administration
NWCF	New Waste Calcining Facility
PARTDENS	particle density

PARTDIAM	particle diameter
PEWE	Process Equipment Waste Evaporator
PM	particulate matter
PUF	plant uptake factor
QA/QC	quality assurance/quality control
RAWP	Risk Assessment Work Plan
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RfD	reference dose
RH	remote handled
SBW	sodium-bearing waste
SLERAP	Screening Level Ecological Risk Assessment Protocol
SLQ	screening level quotient (for ecological receptors)
SUF	site use factor
SVOC	semi-volatile organic compound
TAP	toxic air pollutant
TRU	transuranic
TRV	toxicity reference value (ecological receptors)
TS	stack effluent temperature
TSLQ	total screening level quotient
UF	uncertainty factor
URF	unit risk factor
VOC	volatile organic compound
VS	stack exit velocity

Risk Assessment for Air Emissions for the Integrated Waste Treatment Unit and INTEC Liquid Waste Management System

1. PURPOSE AND SCOPE

This risk assessment evaluates the potential human health and ecological impacts from process operations of the Idaho Nuclear Technology Center (INTEC) Liquid Waste Management System (ILWMS) and the new Integrated Waste Treatment Unit (IWTU) facility that is proposed at INTEC on the Idaho National Laboratory (INL) Site. The IWTU utilizes a steam reforming process for treating INTEC sodium-bearing waste (SBW) and newly-generated liquid wastes. IWTU site preparation began in April 2007, and the start of operations is scheduled in December 2009.

The IWTU will be permitted under the Hazardous Waste Management Act (HWMA)/Resource Conservation and Recovery Act (RCRA) as a Class 3 (most significant) Permit Modification Request and Request for Temporary Authorization to the existing HWMA/RCRA Permit for the INTEC Liquid Waste Management System (Volume 14). This action is consistent with existing language in the Permit, which describes the current ILWMS treatment units as part of an overall treatment train for liquid wastes stored at INTEC. The IWTU is the final unit in the overall ILWMS treatment system and will be used to convert SBW and newly-generated liquid waste into a solid treatment product that is suitable for ultimate disposal. The methodology and assumptions used in this risk assessment were submitted in a Risk Assessment Work Plan (RAWP) to the Idaho Department of Environmental Quality (DEQ) as part of the Volume 14 Permit Modification Request, Appendix D-6, in December 2006.

There are currently three processes that operate within the ILWMS that have potential air pollutant emissions: (1) the Liquid Effluent Treatment & Disposal Facility (LET&D), (2) the Process Equipment Waste Evaporator (PEWE), and (3) the Evaporator Tank System (ETS). Cumulative impacts from these sources, and those from the Idaho CERCLA Disposal Facility (ICDF), a potentially contributing source adjacent to INTEC, were previously evaluated in the *Human and Ecological Risk Assessment of Air Emissions from the INTEC Liquid Waste Management System* (ICP 2004). Since then, new offgas measurements were obtained for LET&D and PEWE in 2005 and revised human health impacts were calculated in EDF-6252. This risk assessment therefore evaluates air emissions from the following sources:

1. IWTU – risks calculated from modeled (mass and energy balance) emission estimates (EDF-6495), which incorporate the findings from actual emissions measurements during pilot-scale testing

2. LET&D/PEWE – risks calculated from 2003 and 2005 offgas sampling emission estimates (ICP 2004; EDF-6252)

3. ETS – previously-calculated risk contribution taken from INEEL 2002 and the 2004 ILWMS risk assessment (ICP 2004)

4. ICDF – previously-calculated risk contribution taken from ICP 2004.

Both human health and ecological impacts are evaluated. Maximum human health impacts (cancer risk and non-cancer hazard index from both inhalation and ingestion) were evaluated at the off-INL Site locations with the highest modeled air concentrations and deposition rates. Impacts were assessed separately for each of the ILWMS sources, which are released from the INTEC main stack, and the

IWTU emissions, which will be released from a separate IWTU stack. The maximum impacts of emissions from these two separate stacks, which occur at slightly different locations, were then added to obtain a conservative estimate of maximum cumulative impacts from ILWMS and IWTU emissions. In addition, maximum inhalation impacts for an on-site worker and a public motorist on U.S. Highway 20/26 were evaluated. Impacts to ecological receptors were evaluated at the downwind locations of maximum modeled deposition rate, which occurred on-site. Only atmospheric emissions of non-radiological contaminants of potential concern (COPCs) were evaluated.

2. FACILITY AND SOURCE CHARACTERIZATION

2.1 Facility Location

The IWTU will be located in the east-central part of INTEC on the INL Site (Figures 1 and 2). The facility consists of three interconnected buildings (Figure 2): (1) product storage area, (2) mechanical equipment area, and (3) process area, which houses the SBW steam reforming processes and the heating, ventilating, and air conditioning (HVAC) equipment. The complete facility is approximately 380-ft long (north-south) by 198-ft wide (east-west). The ridge height of the process building is 69 ft. All offgas is routed to a single 120-ft high stack on the southwest corner of the building. Specific building and stack dimensions are addressed in Section 4, Air Dispersion and Deposition Modeling.

2.2 IWTU SBW Process Description

Approximately 900,000 gallons of mixed liquid waste, containing both hazardous and radioactive components, are stored in three 300,000-gallon tanks at the INTEC Tank Farm Facility. This waste is collectively known as sodium-bearing waste (SBW). The IWTU will use a steam reforming process to treat this waste. The specific steam reforming technology is a thermal, fluidized-bed process that uses superheated steam, carbon, and other additives to convert the SBW into a solid granular product that is packaged in canisters suitable for ultimate disposal.

The steam reforming process for the IWTU consists of two steam reformers that are integrated into a single process system (Drawings 632750, 632753, 632754 in Appendix III to the ILWMS Permit – Volume 14). The system converts the SBW into a dry, solid, mineral product suitable for ultimate disposal as remote-handled TRU waste. The steam reforming process includes a feed collection and transfer system through which waste from the Tank Farm is transferred into the first of two steam reformers, the Denitration and Mineralization Reformer (DMR). The DMR contains a hot (580–700°C) fluidized bed. The bed particles are fluidized by superheated steam. The superheated steam and a small amount of added oxygen react with carbon (a process additive) to produce process heat and a strong chemically reducing environment. The liquid waste is sprayed into the fluidized bed where it evaporates. As the waste evaporates in the DMR, the dissolved constituents form additional bed material that is eventually removed as solid treatment product. The DMR destroys organics, nitric acid, nitrates, and nitrites in the feed, and converts the bulk of the dissolved chemicals into a solid, mineral product. The DMR converts organics in the waste into carbon monoxide (CO), carbon dioxide (CO_2), hydrogen (H_2), and short-chained organic molecules such as methane (CH_4). The strong reducing environment inside the DMR transforms nitrates, nitrites, and nitric acid into elemental nitrogen. Nitrogen oxide (NO_X) formation is minimal. The DMR converts most of the dissolved constituents in the waste into a mineral form, comprised primarily of carbonates and oxides and transforms alkali metals such as sodium (Na) and potassium (K) into compounds that will not agglomerate at the operating temperature of the fluidized bed.

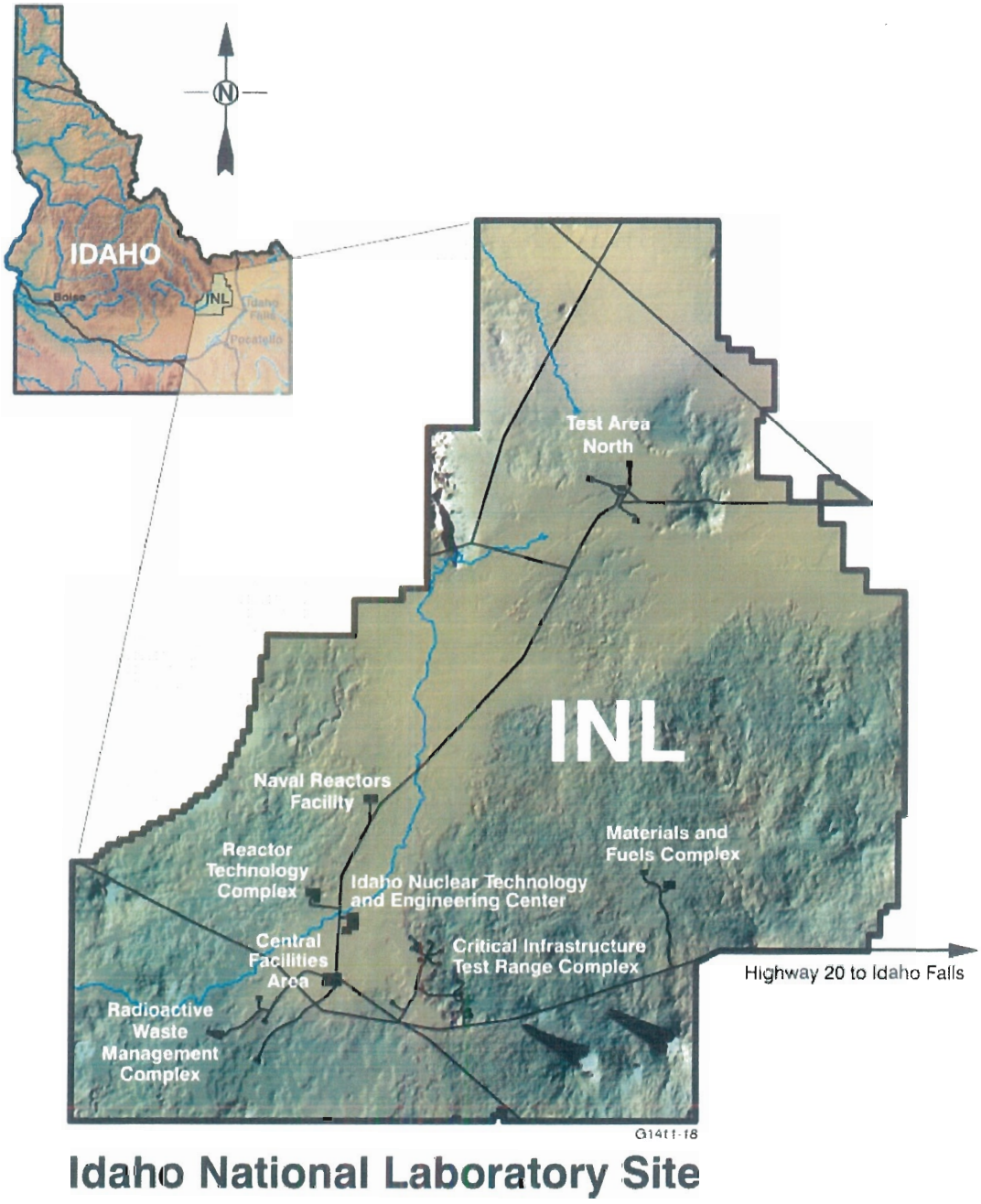

Figure 1. Location of the Idaho Nuclear Technology and Engineering Center on the INL Site.

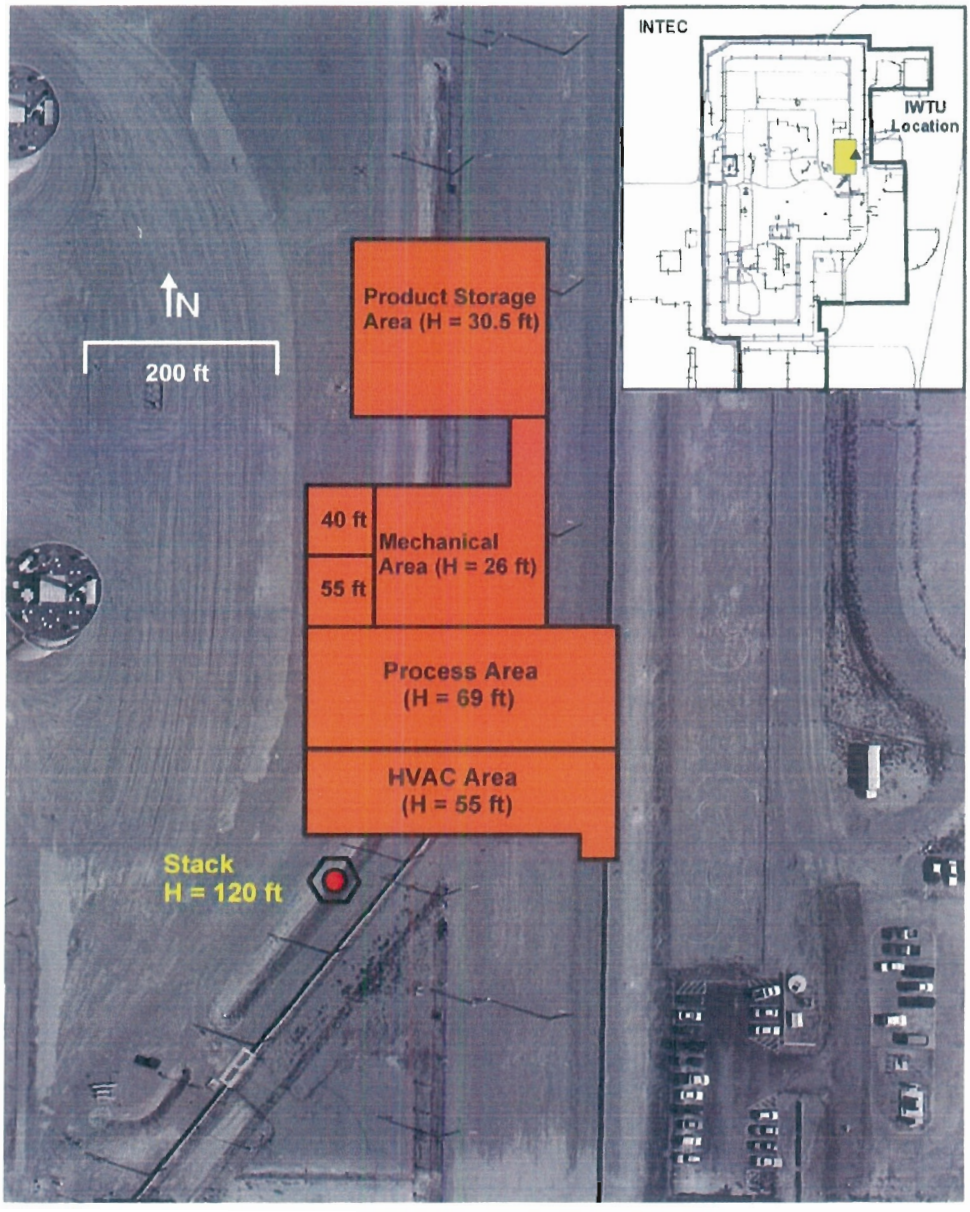

Figure 2. IWTU facility footprint and stack location in the east-central part of INTEC (building tier heights noted; stack location revised January 2007).

Process gas from the DMR goes through a sintered-metal (process) filter that removes fines. The fines are periodically removed from the filter and combined with the solid treatment product from the DMR for product packaging. The filtered process gas then flows to the Carbon Reduction Reformer (CRR) which operates at a higher temperature (775 to 1150°C) than the DMR and contains a semi-permanent fluidized bed of alumina particles. The bottom of the CRR operates in a reducing mode to convert residual NO_X from the DMR to nitrogen gas. Oxygen is added in the upper section of the bed to change from a reducing to oxidizing mode. The H_2, CO, and short-chained organics in the DMR process gas are oxidized to CO_2 and water in the CRR. Gases from the CRR (mainly oxygen, carbon dioxide, nitrogen, and water vapor) are cooled and sent through a high-efficiency sintered metal (offgas) filter and then routed to an offgas treatment system consisting of two high-efficiency particulate air (HEPA) filters (plus prefilter), a sulfur-impregnated, granular-activated-carbon mercury adsorber, and vented to the atmosphere through a dedicated stack. The treatment product from the DMR, CRR, and sintered metal filters is removed, cooled, and pneumatically transferred to a solid product packaging station. At the packaging station, the product is loaded into remote-handled disposal canisters.

2.3 IWTU Emissions

The major components in the IWTU offgas were estimated using mass and energy balance modeling to be non-hazardous nitrogen, water vapor, carbon dioxide, and oxygen. These components were verified through pilot-scale testing with SBW surrogate feed. Emission rates for potentially hazardous compounds (Table 1) were taken from EDF-6495. The criteria pollutant emission rates in Table 1 are conservative annual-average values for processing all tank waste, with an additional 40% added to account for other wastes that may be processed through the IWTU such as start-up testing surrogate and decontamination solution. For particulate matter (PM) and lead (Pb), the emissions take credit for the two process HEPA filters at a removal efficiency of 99.97%, which is the DOE standard for HEPA filters (*Specification for HEPA Filters Used by DOE Contractors*, DOE-STD-3020-2005).

Table 1 also lists potential toxic air pollutant (TAP) emissions from IWTU as defined by IDAPA 58.01.01, Sections 585 and 586, and as calculated in EDF-6495. These rates are the most conservative of seven different SBW tank processing mixture scenarios and represent upper-bound emission estimates. For comparison, the IDAPA screening emission level (EL), a conservative first-level screening criteria, is also listed in the table. Arsenic, beryllium, and hydrogen chloride exceed the IDAPA EL. This suggests that these pollutants may need to be examined more closely in the risk assessment, not necessarily that they are emitted at rates that are hazardous. No organic constituents are listed because the mass and energy balance calculations indicate that the IWTU process efficiently destroys essentially all organics in the SBW feed. Pilot plant demonstrations at the Hazen Research Facility (Golden, Colorado) support this conclusion. If future test results indicate that additional compounds may be emitted at rates which could significantly contribute to the total emissions risk, then IWTU emission rates will be revised as appropriate and re-evaluated for risk.

Table 1. IWTU air pollutant emission estimates from EDF-6495.

Criteria Pollutants	Emission Rate[a] (tons/year)	Emission Rate (lb/hr)	Emission Rate (g/s)
Carbon Monoxide (CO)	1.44	0.329	0.041
Nitrogen Oxides (NO_X)	31.77	7.25	0.914
Sulfur Dioxide (SO_2)	5.2	1.19	0.150
Particulate Matter (PM)	3.37E-09	7.69E-10	9.70E-11
Lead (Pb)	1.04E-13	2.37E-14	2.99E-15
Fluoride (F)	0.06	0.014	0.0018

Toxic Air Pollutants	IDAPA Emission Level (EL, in lb/hr)[b]	Annual-Average (lb/hr)[c]	Annual-Average (g/s)	Maximum Short-term (lb/hr)[d]	Maximum Short-term (g/s)
Aluminum (Al)	1.33E-01	5.18E-12	6.53E-13	1.52E-06	1.92E-07
Arsenic (As)	1.50E-06	3.16E-04	3.99E-05	9.42E-04	1.19E-04
Barium (Ba)	3.30E-02	1.16E-02	1.46E-03	1.95E-02	2.46E-03
Beryllium (Be)	2.80E-05	2.02E-04	2.55E-05	3.03E-04	3.82E-05
Bromine (Br_2)	4.70E-02	4.29E-05	5.41E-06	6.10E-05	7.69E-06
Cadmium (Cd)	3.70E-06	1.55E-10	1.95E-11	1.26E-08	1.59E-09
Calcium oxide (CaO)	1.33E-01	2.37E-12	2.99E-13	4.76E-07	6.00E-08
Chlorine (Cl_2)[e]	2.00E-01	1.57E-02	1.98E-03	6.14E-02	7.74E-03
Chromium (Cr)	3.30E-02	3.21E-14	4.05E-15	7.29E-09	9.19E-10
Fluorine (F_2)	1.67E-01	2.16E-02	2.72E-03	1.07E-01	1.35E-02
Hydrogen chloride (HCl)[e]	5.00E-02	1.62E-02	2.04E-03	6.32E-02	7.97E-03
Mercury (Hg)	3.00E-03	2.21E-04	2.79E-05	3.23E-04	4.07E-05
Molybdenum (Mo)	3.33E-01	3.25E-02	4.10E-03	4.81E-02	6.07E-03
Nickel (Ni)	2.70E-05	9.32E-15	1.18E-15	2.04E-09	2.57E-10
Rhodium (Rh)	1.00E-03	6.53E-04	8.24E-05	9.28E-04	1.17E-04
Selenium (Se)	1.30E-02	1.11E-04	1.40E-05	1.58E-04	1.99E-05
Silver (Ag)	1.00E-03	4.04E-04	5.09E-05	7.76E-04	9.79E-05
Tin (Sn)	1.33E-01	9.19E-03	1.16E-03	1.05E-02	1.32E-03
Zinc (Zn)	6.67E-01	7.15E-15	9.02E-16	2.01E-09	2.53E-10

a. From EDF-6495, Table 2 (abated emissions).
b. First-level TAP screening level from IDAPA 58.01.01 Sections 585 and 586 – does not imply an emission rate that is hazardous.
c. From EDF-6495 (Table 5, Scenario 1); assumes 1-year processing time, average composition of all SBW, and an additional 10,000 gallons of newly generated waste (NGLW) at the composition of Tank WM-187.
d. Highest emission rate for seven different SBW tank processing mixture scenarios, as calculated in EDF-6495.
e. Assumes all of the chlorine emissions are in this form.

The following assumptions were made in EDF-6495 to calculate the emission rates shown in Table 1:

- The waste is fed to the DMR at the maximum rate of 3.5 gallons per minute (gpm) to maximize the emissions rate.

- The particulate carry-over from the DMR was increased from 30% (expected carry-over) to 50% (worst case carry-over seen during testing at the STAR center as reported in *Phase 2 THOR Steam Reforming Tests for Sodium Bearing Waste Treatment*, [INEEL 2004a]).

- The NO_X carry-over in the DMR was increased from 3% to 7% to reflect data from pilot plant testing data (RT-ESTD-PMR-001).

- The NO_X carry-over in the Carbon Reduction Reformer (CRR) was increased from 10% to 50% to reflect data from pilot plant testing data (RT-ESTD-PMR-001).

- To more accurately reflect carbon monoxide emissions from the IWTU as seen in the pilot plant test data (RT-ESTD-PMR-001) the carbon dioxide to carbon monoxide ratio in the offgas of the DMR was increased from 92% to 97%. Additionally, the CO carry-over of carbon monoxide from the CRR was increased from 0.1% to 3%.

- The mercury concentration was increased by 25% to increase it to the high end of the analytical uncertainty as reported in *Feed Composition for the Sodium Bearing Waste Treatment Process*, (INEEL 2004b).

- The mercury removal efficiency was reduced from 99.999% to 99.99% based on the minimum required removal efficiency per the mercury adsorber equipment data sheets *Equipment Data Sheets – Mercury Adsorber*" (COS-F-SRH-0141).

- The HEPA filters efficiency was increased to 99.97% to match the DOE standard for HEPA filters (*Specification for HEPA Filters Used by DOE Contractors*, DOE-STD-3020-2005). For annual-average emissions calculations, credit was taken for both HEPAs. For maximum short-term emission rates, credit was taken for only one HEPA. No credit was taken for solids removal through the HEPA prefilter.

For facilities without site-specific monitoring data, EPA 2005 recommends that organics and metal emissions be increased by factors of 2.8 and 1.45 respectively, to account for potential increases in emissions due to process upset conditions. Although process upsets are not currently anticipated at IWTU due to the stable, uniform operating characteristics of the fluid bed systems, the potential increase in emissions, and therefore downwind impacts, is quantified and discussed in the uncertainty section.

For assessing the indirect (i.e., ingestion) risk from buildup of contaminants in the environment, the IWTU emissions are assumed to last for 15 years. This is very conservative because all of the SBW is expected to be processed by the IWTU within 15 months. Aluminum, fluoride, and manganese were only evaluated for inhalation impacts because they are not in the *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (HHRAP) (EPA 2005) data base.

2.4 LET&D and PEWE Emissions

The COPCs emission estimates for the LET&D and PEWE were developed from offgas measurements in 2003 (INEEL 2003) and 2005 (ICP 2005a; ICP 2005b) and are contained in Appendix A. These emissions were previously evaluated for risk in the 2004 ILWMS risk assessment (ICP 2004), using the 2003 offgas measurements, and revised in EDF-6252 using the 2005 offgas measurements. These assessments evaluated all analytes that met one or both of the following conditions: (1) sampling results were greater than the quantification limit in at least one of the sampling runs or (2) fate, transport, and toxicity data are published by EPA (EPA 2005). Analytes were excluded from risk evaluation if all of the sampling data were less than the quantification limit and no compound-specific modeling and toxicity data were available in EPA 1998a. All SVOC and VOC analytes that were detected at greater than the quantification limit were evaluated for risk.

The risk assessment methodology in the previous ILWMS risk assessments (ICP 2004; EDF-6252) used COPC-specific "risk coefficients" developed for New Waste Calcining Facility (NWCF) emissions from the INTEC main stack (INEEL 1999a; INEEL 1996). These NWCF risk coefficients were developed using EPA risk assessment guidance and contaminant-specific parameter values available at that time. Since then, EPA has published a final version of the HHRAP and provided revised transport and toxicity data in an on-line companion data base: (http://www.epa.gov/epaoswer/hazwaste/combust/risk.htm). For this risk assessment, PEWE, LET&D, and IWTU COPC risks were recalculated using the new 2005 EPA HHRAP methodology and parameter values. For PEWE and LET&D, only those COPCs which contributed at least 0.01% of the total risk or hazard (i.e., individual COPC risk $\geq$ 1/10,000 of the total risk) as calculated in the previous ILWMS risk assessments were re-evaluated. This allows available resources to be focused on refined modeling of those COPCs that have been shown to be "of potential concern" (based on previous risk calculations) while eliminating those COPCs that are either artifacts of the sampling/analytical process, non-hazardous, or emitted in extremely low, insignificant quantities. The screened LET&D and PEWE COPCs and their emission rates are listed in Table 2.

2.5 ETS Emissions

ETS offgas emission estimates are documented in the *NWCF Evaporator Tank System 2001 Offgas Emissions Inventory* (INEEL 2002) and are only summarized here. More analytes were "detected" from the ETS (15/18 metals, 45/69 SVOCs, 18/65 VOCs) than the LET&D. However, many of these "detections" were only in the back portion of the sampling train (condensate fraction) and not in the front (XAD resin) portion, indicating that they are probably analytical artifacts rather than present in the offgas. Even using these "partial hit" values, emission rates from ETS were very low. The two highest volatile organics emitted during offgas sampling were dodecane and acetone, 50 parts per billion by volume (ppbv) and 30 ppbv, respectively. The two highest semi-volatile organics emitted were benzoic acid and benzaldehyde with maximum concentrations of 310 ppbv and 80 ppbv, respectively. The sum of all volatile and semi-volatile organics was less than 1 ppmv.

Human health risk assessments of these emissions were previously completed in INEEL 2002 and ICP 2004. These risk assessments used the previously described NWCF-calculated risk and hazard coefficients (e.g., risk per g/s released) and conservative emission rates from the ETS offgas measurements. In accordance with the Risk Assessment Work Plan (RAWP), the ETS risk contribution to ILWMS and IWTU was taken directly from INEEL 2002, rather than recalculated in this risk assessment.

Table 2. LET&D and PEWE COPCs that accounted for >99.99% of the risk/hazard calculated in previous ILWMS risk assessments.[a]

Analyte	CAS#	Emission Rate (g/s) Hourly	Annual
Anions			
Hydrogen chloride (HCl)	7647-01-0	1.97E+00	4.50E-01
Fluoride (F^-)[b]	16984-48-8	1.33E-03	3.04E-01
Metals			
Arsenic (As)	7440-38-2	1.82E-06	4.16E-07
Chromium (Cr)[c]	7440-47-3	5.32E-04	1.21E-04
Manganese (Mn)[b]	7439-96-5	8.01E-05	1.83E-05
Nickel (Ni)	7440-02-0	3.04E-03	6.94E-04
Mercury (Hg)	7439-97-6	6.84E-05	1.56E-05
SVOCs			
Benzo(a)pyrene (BaP)	50-32-8	2.44E-06	5.57E-07
bis(2-Ethylhexyl) phthalate	117-81-7	2.62E-05	5.98E-06
3,3'-Dichlorobenzidine	91-94-1	6.32E-06	1.44E-06
Fluoranthene	206-44-0	8.67E-07	1.98E-07
Hexachlorocyclopentadiene	77-47-4	7.41E-06	1.69E-06
N-Nitrosodi-n-propylamine	621-64-7	9.94E-07	2.27E-07
N-Nitrosodimethylamine[d]	62-75-9	2.38E-04	5.43E-05
Pyrene	129-00-0	7.50E-07	1.71E-07
VOCs			
1,4-Dichlorobenzene	106-46-7	2.53E-07	5.77E-08
1,2,3-Trichloropropane	96-18-4	5.47E-07	1.25E-07

a. ICP 2004 and EDF-6252.
b. No indirect pathway exposure parameters in HHRAP; evaluated for inhalation impacts only.
c. Evaluated as both Cr(III) and Cr(VI).
d. No indirect pathway exposure parameters in HHRAP; evaluated using N-nitrosodi-n-propylamine as a surrogate.

2.6 Other Potentially Contributing Sources

The previous ILWMS risk assessment (ICP 2004) evaluated potential contributions from other contributing INL Site facility emissions for cumulative impacts and found that only those from the ICDF were significant. Human health risks from these ICDF emissions were originally calculated in the "INEEL CERCLA Disposal Facility Short-Term Risk Assessment" (EDF-ER-327). In accordance with the RAWP, this ICDF risk contribution was taken directly from ICP 2004, rather than recalculated in this risk assessment.

3. RISK ASSESSMENT GUIDELINES

3.1 EPA Protocol

Previous NWCF and ILWMS risk assessments (INEEL 1999a; INEEL 1999b; INEEL 2002; ICP 2004) used COPC-specific "risk coefficients" (risk or hazard per g/s released) developed for emissions from the INTEC main stack. These risk coefficients were developed from modeled unit (1 g/s) release air concentrations/deposition rates and fate and transport equations given in the draft release of EPA's *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (EPA 1998a) and earlier EPA guidance. For the current IWTU/ILWMS risk assessment, both IWTU emission estimates and new offgas data from the LET&D and PEWE sources were re-assessed using new modeling and the methods and parameter values in EPA's *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities* (HHRAP), which was recently released in final form (EPA 2005). Since ETS and ICDF emissions have not been revised, human health impact contributions from those sources were taken directly from the 2004 ILWMS risk assessment (ICP 2004), in accordance with the RAWP.

3.2 Target Risk Criteria

To evaluate potential carcinogenic risks, EPA generally uses a risk range of 10^{-4} to 10^{-6} and a hazard index target criteria of 1.0. However, for purposes of RCRA permitting decisions involving thermal technologies, the INL Site has traditionally used risk target levels from U.S. EPA Region 6 (EPA 1998b; INEEL 1999a; INEEL 2002; ICP 2004).

For the purposes of RCRA permitting decisions, the maximum acceptable risk is reduced from 10^{-4} to 10^{-5} primarily to account for exposure to background levels of contamination. As a result, the total individual risk associated with exposures to potential carcinogens released from a single facility should not exceed 1.0×10^{-5}. A calculated risk that exceeds these targets, however, would not necessarily indicate that the proposed action is not safe or that it presents an unacceptable risk. It may indicate that the initial assumptions and parameter values used in the modeling were overly conservative and need to be further refined.

For non-carcinogenic contaminants, U.S. EPA Region 6 recommends a modified target hazard quotient (HQ) or hazard index (HI) of 0.25 to account for background contributions. An HQ or HI equal to or exceeding 0.25 indicates only that there is a potential for non-carcinogenic effects, based on a specific set of exposure, model, and toxicity assumptions.

Ecological impacts were assessed using a screening level quotient (SLQ) and total screening level quotient (TSLQ) approach. This method divides modeled COPC soil concentrations by conservatively-calculated ecologically-based screening levels (EBSLs) to obtain a COPC-specific SLQ. The SLQs are then summed to obtain a TSLQ, similar to the human health hazard quotient/index. The EBSL methodology was first developed in Van Horn et al. (1995) and has been used at the INL Site for all CERCLA and RCRA risk assessments to date (e.g., INEEL 1999a; DOE-ID 1999). CERCLA assessments at the INL often use a TSLQ criterion of 10 for eco-risk because of the conservatisms inherent in EBSL modeling methods and assumptions. For this risk assessment, a more conservative TSLQ criterion of 1.0 was used. As with the other risk criteria used in this assessment, calculated risks that exceed this criterion do not necessarily indicate a risk but identifies a contaminant that should be investigated further using more refined (realistic) parameter values.

4. AIR MODELING METHODOLOGY

Air modeling was performed to evaluate the atmospheric dispersion, transport, and ground deposition of contaminants from the IWTU and ILWMS sources to downwind locations at which members of the public could potentially reside (off-INL Site) and to both on- and off-INL Site locations where ecological receptors may exist. In addition, maximum 24-hour air concentrations were evaluated along U.S. Highway 20/26 to assess potential motorist exposure, and maximum 1-hour air concentrations were evaluated at on-site locations to assess acute exposure for workers (or visiting public) at any facility on the INL. In accordance with the HHRAP (EPA 2005), the separate modeling runs were done for a 1 g/second release of a generic particulate contaminant and a generic vapor contaminant. Model output for maximum air concentrations ($\mu g/m^3$ per g/second released) and maximum ground depositions (g/m^2-year per g/second released) were then multiplied by contaminant-specific release rates (g/second) and vapor and particulate partitioning factors to obtain contaminant-specific results.

For evaluation of PEWE/LET&D emissions, which are released out the 250-ft high INTEC main stack, the ISCST3 model (EPA 1995, Version 02035) was used. This model has been approved by the EPA and the State of Idaho and is specified for use in EPA's HHRAP (EPA 2005). For evaluation of IWTU emissions, the Building Profile Input Program for PRIME (BPIPPRM Version 04274) and ISC-PRIME model (Version 04269) were used to assess potential building downwash of the IWTU stack (http://www.epa.gov/scram001/). Building downwash is not a concern for the INTEC main stack because it is greater than 2.5 times the height of adjacent buildings. The following sections detail model input parameter values, many of which are specified in the guidance.

4.1 Control Options Input

The following control pathway modeling options were selected:

- Regulatory default job control and dispersion options (EPA 1995):
  - Final plume rise, stack-tip downwash
  - Buoyancy-induced dispersion
  - Calms processing routine
  - No use of missing data processing routine
  - Default wind profile exponents
  - Default vertical potential temperature gradients
  - Upper bound values for super-squat buildings
  - No exponential decay for RURAL mode.
- RURAL dispersion coefficients (sigmas).
- Calculate concentration and dry, wet, and total deposition and depletion for particulate runs.
- Calculate concentration, wet deposition and depletion for vapor runs.
- Annual and 1-hour averaging times for on-site receptor runs. (Section 4.4)
- Annual averaging time for offsite receptor runs. (Section 4.4)
- 24-hour averaging times for U.S. Highway 20/26 receptor runs. (Section 4.4)

- Terrain heights evaluated (taken from the INL Geographical Information System [GIS] database). These elevations were developed from the U.S. Geological Survey National Elevation Data (NED).
- Dry deposition parameters for vapor phase modeling run: (1) replace "DEFAULT" control option with "TOXICS", (2) add control option GASDEPVD<Uservd>, where Uservd is the dry vapor deposition velocity (meters/second) - 0.5 cm/s. Since the TOXICS option is not available in the ISC-PRIME model, dry vapor deposition of IWTU emissions was calculated manually (in risk spreadsheets) by multiplying the air concentration by deposition velocity, in accordance with the draft HHRAP procedure. The results were benchmarked against the ISCST3-calculated dry deposition and found to be identical for a deposition velocity of 0.5 cm/s.

4.2 Source Input – IWTU Stack

IWTU offgas will be routed to a new stack on the southwest corner of the IWTU Process Building. ISC-PRIME source pathway input parameters for this stack are:

- Base elevation = 1498.3 m (4916 ft)
- Stack coordinates based on January 2007 design
- Height (HS) = 36.6 m (120 ft)
- Exit diameter (DS) = 1.5 m
- Effluent temperature (TS) = 335.4K (144°F)
- Effluent exit velocity (VS) = 17.8 m/s.

COPC source input parameter values include the following (EPA 2005):

- Particulate diameter (PARTDIAM): 0.35, 0.7, 1.1, 2.0, 3.6, 5.5, 8.1, 12.5, and 15.0 μm
- Mass fraction (MASSFRAX): 0.22, 0.08, 0.08 0.11, 0.10, 0.07, 0.10, 0.11, and 0.13
- Particulate density (PARTDENS): 1 g/cm^3
- Particle scavenging coefficients (PARTSLIQ [liquid] and PARTSICE [frozen]) for particle sizes listed above (liquid and ice assumed to be the same): 0.7, 0.5, 0.6, 1.3, 2.6, 3.9, 5.2, 6.7, and 6.7 ($\times 10^{-4}$ s^{-1}/mm-h^{-1})
- Vapor scavenging coefficients (GAS-SCAV): 1.7×10^{-4} (both liquid and ice)
- Wake effects from the IWTU building (building downwash) were evaluated using the Building Profile Input Program for PRIME (BPIPPRM version 04274) (http://www.epa.gov/scram001/).

4.3 Source Input – INTEC Main Stack

Existing ILWMS offgas emissions occur through the 250-ft INTEC main stack. ISCST3 source pathway input parameters for this stack are:

- Elevation = 1498.3 m (4916 ft)
- Height (HS) = 76.2 m (250 ft)
- Exit diameter (DS) = 1.98 m (6.5 ft)

- Effluent temperature (TS) = 302.6K (85°F)
- Effluent exit velocity (VS) = 18.83 m/s (at 123,000 ACFM).

Particle diameter, mass fraction, density, and scavenging coefficients are the same as those used for the IWTU stack. Building downwash was not evaluated for the INTEC main stack because its height (76.2 m) is greater than 2.5 times adjacent building heights resulting in a plume that is not affected by building wake effects (EPA 2005).

4.4 Receptor Grids

The following three receptor grids were evaluated for each particulate and vapor model run (Figure 3):

- BIG: A large 33 × 33-km coarse grid with 1-km spacing was used to determine regional dispersion and deposition trends for contour plotting, siting of refined receptor grids (see INL Site grids below) maximum on-site inhalation exposure (for field workers and other INL Site workers), and for determining maximum on-Site deposition for ecological risk assessment.

- INL Site: Two refined (100-m spacing, 1200 receptors each) grids in areas of maximum impact along the INL south site boundary and in the Big Southern Butte area were used to determine maximum annual-average air concentrations and deposition rates for long-term public exposures. Different refined grids were required for the INTEC main stack ILWMS releases and the IWTU stack releases.

- HWY: Discrete receptors placed at 100-m intervals along major impact areas of U.S. Highway 20/26, which traverses the southern portion of the INL Site. The area of maximum impact along the highway was determined from appropriate time-averaged coarse (BIG) grid modeling runs. The highway receptors were only evaluated for short-term direct inhalation impacts from non-carcinogens because the only potential receptors are transient motorists. A 24-hour averaging time was selected for modeling to be consistent with the State of Idaho Acceptable Ambient Concentrations (AACs) for non-carcinogenic toxic air pollutants.

The above receptor grids were used to determine the impacts for hypothetical "maximally-exposed" individual in each class of receptors (see Exposure Assessment section). Impacts at all other locations and real communities (e.g. Atomic City, Mud Lake) will be less due to increased plume dispersion and plume depletion with distance. Although ISCST3 may be used to assess receptors at distances of up to 50 km, model predictions become much more uncertain at distances beyond 20 km because the meteorological conditions (e.g., wind direction, speed) will likely change over the time it takes to transport pollutants to the receptor. In addition, it is known based on past modeling studies (INEEL 1999a; ICP 2004) that most of the deposition occurs within 10 km of the source. Based on these considerations, only the above receptor grids will be evaluated to determine if the target risk criteria are met.

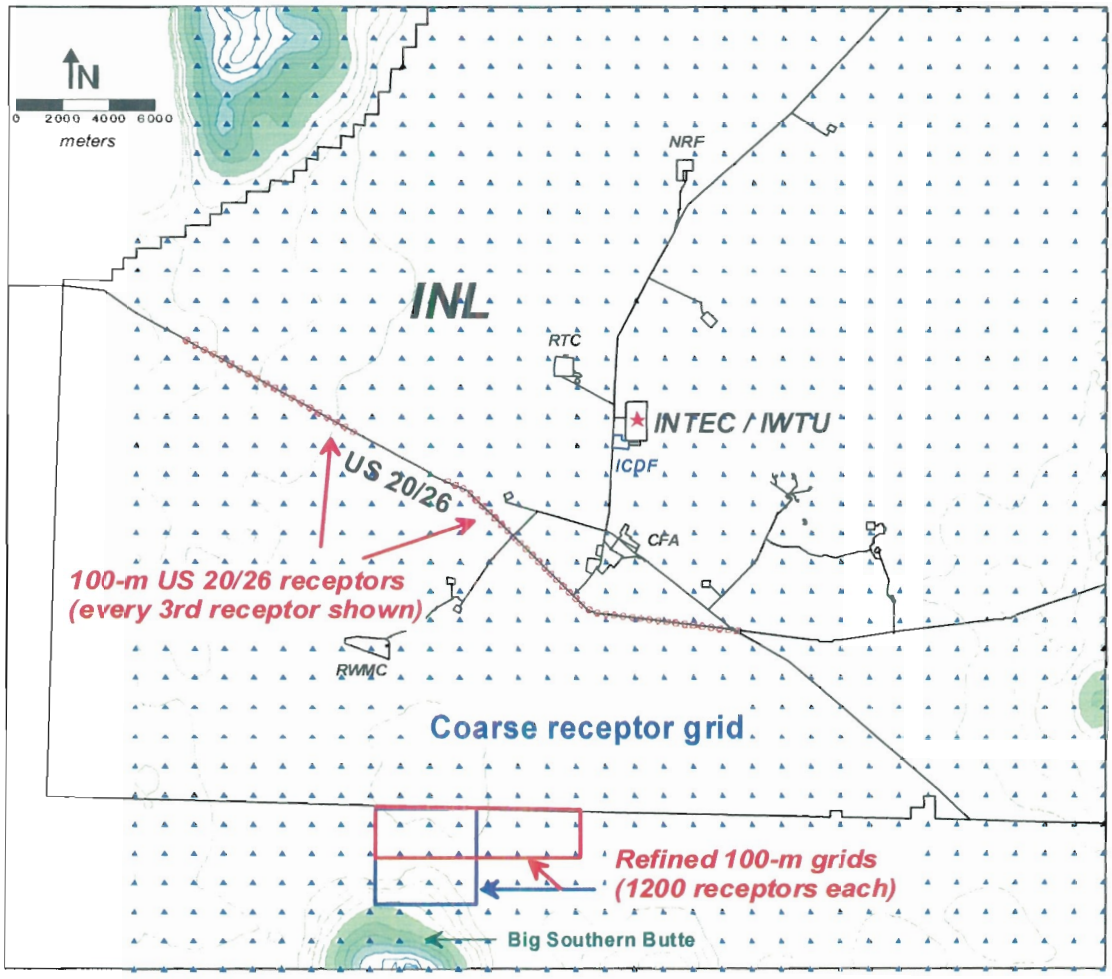

Figure 3. ISC3 receptor grids used in the modeling. Different refined grids (blue/red boxes) were required for the INTEC main stack ILWMS releases (blue box) and the IWTU stack releases (red box) because of the difference in stack parameters (250-ft vs. 120-ft heights).

4.5 Meteorological Information

Five years (1997 to 2001) of onsite meteorological data from the Grid 3 (GRD3) 200-ft (61-m) tower, located approximately 1.5 km north of the INTEC, were used for the modeling. The Grid 3 data were processed into sequential hourly ISC3 data input format by the National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory in Idaho Falls, Idaho.

The NOAA determined stability classes using the lateral turbulence (σ_A) and wind speed method as outlined in the EPA report *Onsite Meteorological Program Guidance for Regulatory Modeling Applications* (EPA 1987). The small amount of missing data in the NOAA files was filled using hourly data (for the same month, day, and hour) from other INL Site towers (e.g., the Central Facilities Area) or, for single hour gaps, linear interpolation. Wind speeds less than the anemometer's starting threshold (0.26 m/second) were set to 0.0 for calms processing in ISC3. Wind speeds between the anemometer starting threshold and 1.0 m/second were set to 1.0 m/second to ensure that the model does not calculate

unrealistic concentration estimates (EPA 1995; EPA 1996). No long-term climatology of measured mixing heights exists for the INL Site, although NOAA has done numerous short-term measurements and estimated annual-average mixing heights of 800 m and short-term mixing heights of 100 m at the INL Site (memo from J. Saggendorf, NOAA, to Mike Abbott, February 11, 1991[a]). However, at the request of the DEQ, mixing heights were set to an extremely conservative value of 150 m for annual-average model runs and 50 m for hourly runs. These low mixing heights limit the vertical dispersion of the plume, producing very conservative model predictions, especially at the INL Site boundary distances from INTEC (~15 km).

Additional processing to determine ISC3-required deposition parameters was accomplished as follows:

1. Surface roughness height (z_0) was taken from the EPA 1998a for desert shrub land type, for spring, summer, fall, and winter (0.3, 0.3, 0.3, and 0.15 m, respectively).

2. The Monin-Obukhov length (L) was set, per EPA 1998a, at 2 m for "agricultural" (open) land use classification.

3. Friction velocity (u*) was calculated using an equation for atmospheric boundary layer similarity theory described by Ramsdell et al. 1994.

4. Daytime Bowen Ratios were set per EPA 1998a for "desert shrub land", average conditions, for the seasons of spring through winter, at 3.0, 4.0, 6.0, and 6.0, for the seasons: spring, summer, fall, and winter respectively.

4.6 Modeling Runs

Unit release (1 g/s) modeling runs were made for both the INTEC main stack and the IWTU stack to obtain the following modeling output (acronyms slightly modified from those in the HHRAP):

- Cv – Annual average vapor concentration (μg-second/g-m^3)
- Cp – Annual average particulate concentration (μg-second/g-m^3)
- Ddv – Annual average dry deposition of vapor (second/m^2-year) (ISCST3 runs only)
- Dwv – Annual average wet deposition of vapor (second/m^2-year)
- Ddp – Annual average dry deposition of particulate (second/m^2-year)
- Dwp – Annual average wet deposition of particulate (second/m^2-year).
- C1v – Maximum 1-hour vapor concentration (μg-second/g-m^3)
- C1p – Maximum 1-hour particulate concentration (μg-second/g-m^3)
- C24v – Maximum 24-hour vapor concentration (μg-second/g-m^3)
- C24p – Maximum 24-hour particulate concentration (μg-second/g-m^3).

Since there is no site-specific particle size information for the IWTU or ILWMS emissions, the additional "particle-bound" phase modeling run specified in the HHRAP was not made (i.e., there is no basis for apportioning pollutants on a different size basis).

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a. Saggendorf, J., NOAA, to Mike Abbott, INEL, February 11, 1991, "Average INEL Mixing Depths."

Separate modeling runs were made for the INTEC main stack and IWTU stack for each of the three receptor grids (BIG, INL, and HWY) depending upon the exposure scenarios evaluated (see next section). Annual-average concentration and deposition runs (Cp, Cv, Ddv, Dwv, Ddp, Dwp) were made on the BIG and INL receptor grids. Maximum 24-hour concentration runs (C24v, C24p) were made on the HWY receptor grid. Maximum 1-hour concentrations runs (C1p, C1v) were made on the BIG and HWY grids.

5. EXPOSURE ASSESSMENT

5.1 Exposure Scenarios

The risk assessment evaluated seven general exposure scenarios:

- Farmer (annual-average direct inhalation and indirect ingestion)
- Farmer child (direct and indirect)
- Resident (direct and indirect)
- Resident child (direct and indirect)
- Highway motorist (maximum 24-hour average direct inhalation only)
- Maximum INL Site worker outside of INTEC (maximum 1-hour average direct inhalation only)
- Maximum ecological receptor (annual average soil concentrations at maximum [on-site] deposition location).

The first four scenarios were evaluated at the point of maximum impact at or beyond the INL Site boundary (refined INL Site receptor grids, Figure 3). The highway motorist was evaluated at the point of maximum impact along U.S. Highway 20/26 which traverses the southern part of the INL Site (Figure 3). The maximum INL Site worker was evaluated at the point of maximum air concentration outside the INTEC fence line using the "BIG" receptor grid (Figure 3). By evaluating the worker at the point of maximum impact on this grid, the assessment conservatively bounds impacts to any real INL Site worker outside the INTEC fence line, including those from adjacent facilities (e.g., ICDF) or field workers working outside facilities on the INL Site.

The HHRAP (EPA 2005) suggests three other potential exposure scenarios: (1) adult fisher, (2) child fisher, and (3) nursing infant. The fisher scenarios were not evaluated because there are no significant fisheries in the assessment area. The nursing infant scenario was not evaluated because it is specific to exposures to dioxins (PCDDs, PCDFs) and dioxin-like PCBs, and neither the IWTU nor existing ILWMS sources emit these types of compounds in any significant quantity.

The HHRAP suggests an acute receptor scenario to assess potential acute health affects from relatively high, short-term concentrations that might occur downwind from the facility. This risk assessment evaluated acute risk from both ILWMS and IWTU for an INL Site worker (maximum 1-hour concentration on the BIG receptor grid). The acute hazard quotient (AHQ) calculated would also apply to an INL Site visitor.

Maximum 24-hour concentrations of non-carcinogenic pollutants along U.S. Highway 20/26 were also evaluated against AACs for non-carcinogenic TAPs, given in the Idaho DEQ "Rules for the Control of Air Pollution in Idaho" (IDAPA 58.01.01.585 - 586). Carcinogenic TAPs are not evaluated at highway receptors because of the lack of long-term chronic exposure there (required for carcinogenic impacts). Also, since the risk calculations for the off-INL Site receptors (farmer, resident) include assessment of inhalation risk in accordance with the HHRAP methods, no additional IDAPA TAP assessment was made for carcinogenic TAPs at or beyond the INL Site boundary.

Complete descriptions of the exposure pathways and intake rates for the other four scenarios (farmer, farmer child, resident, resident child) are contained in the HHRAP (EPA 2005). While these four scenarios are not intended to be representative of all real exposure scenarios around the INL Site, they provide a standardized and conservative evaluation of maximum potential risks and are consistent with EPA guidance (EPA 2005). The conservative methods and assumptions inherent in these scenarios and the maximum impact locations at which they are evaluated ensure protectiveness of other special subpopulations (herdsmen, hunters) and regionally specific and diverse land-uses. They also will conservatively bound both current and future land use during the maximum foreseeable time period of IWTU and ILWMS operations (15 years).

5.2 Exposure Pathways, Media Concentrations, and Intakes

Table 3 lists the exposure pathways that were evaluated for each exposure scenario. These pathways, and the methods and parameter values used to calculate them, follow HHRAP guidance (EPA 2005). Media concentrations in soil, homegrown produce, animal feeds (including forage, silage, and grain), beef, milk, chicken, eggs, and pork, as well as the scenario and pathway-specific intake rates were assessed.

Four classes of parameters were used in the risk assessment equations in accordance with the HHRAP (EPA 2005): (1) chemical/physical, (2) plant biotransfer factors, (3) animal biotransfer factors, and (4) health benchmarks. All parameter values were taken from the most recent version of EPA's on-line HHRAP Companion data base (http://www.epa.gov/epaoswer/hazwaste/combust/risk.htm). The HHRAP equations and parameter values used are contained in Appendix B of this risk assessment.

Table 3. Exposure scenarios and pathways evaluated in the risk assessment.

	Exposure Scenarios Evaluated					
Exposure Pathway	Farmer	Farmer Child	Resident	Resident Child	US 20/26 Motorist	INL Site Worker
Inhalation of vapor and particulates	•	•	•	•	•	•
Incidental ingestion of soil	•	•	•	•	—	—
Ingestion of drinking water from surface water sources	a	a	a	a	a	a
Ingestion of homegrown produce	•	•	•	•	—	—
Ingestion of homegrown beef	•	•	—	—	—	—
Ingestion of milk from homegrown cows	•	•	—	—	—	—
Ingestion of homegrown chickens	•	•	—	—	—	—

Table 3. (continued).

Exposure Pathway	Exposure Scenarios Evaluated					
	Farmer	Farmer Child	Resident	Resident Child	US 20/26 Motorist	INL Site Worker
Ingestion of eggs from homegrown chickens	•	•	—	—	—	—
Ingestion of homegrown pork	•	•	—	—	—	—
Ingestion of fish	b	b	b	b	b	b
Ingestion of breast milk	c	c	c	c	c	c

• = Pathway assessed for that exposure scenario.
— = Pathway not assessed for that exposure scenario (EPA 2005).

a. No surface drinking water supplies exist in the assessment area.
b. No significant fisheries exist in the assessment area.
c. Not evaluated because there are no significant dioxin or dioxin-like PCBs emitted.

6. RISK AND HAZARD CHARACTERIZATION

Risks for each COPC were calculated using EPA cancer slope factors (CSF) for ingestion and unit risk factors (URF) for inhalation. Hazard quotients (HQs) are calculated using EPA Reference Doses (RfD) for ingestion and Reference Concentrations (RfC) for inhalation. In addition, maximum non-cancer inhalation impacts on U.S. 20/26 were compared against the appropriate IDAPA AACs. Acute short-term (maximum 1-hour air concentration) inhalation hazard (AHQs) were assessed using acute inhalation exposure criteria (AIEC). The EPA toxicity criteria (CSFs, URFs, RfDs, RfCs, and AIECs) were taken from EPA's HHRAP Companion Data Base (http://www.epa.gov/epaoswer/hazwaste/combust/risk.htm, January 2007), which is maintained with up-to-date health benchmark values by EPA. The risk/hazard equations and parameter values used are contained in Appendix B of this risk assessment.

For each exposure pathway (Table 3), a total cancer risk was calculated by summing individual COPC risks. The cumulative cancer risk was then calculated by summing the total cancer risk from each pathway. Cumulative cancer risks were calculated for each source (IWTU, LET&D, and PEWE) and then summed. Cumulative risk from operation of other contributing sources (ETS and ICDF) were assessed by adding the maximum risk estimates from their respective risk assessments (INEEL 2002; EDF-ER-327) to the maximum exposure scenario risk estimates calculated in this risk assessment for IWTU, LET&D, and PEWE.

7. ECOLOGICAL RISK ASSESSMENT

A screening level ecological risk assessment of the IWTU and ILWMS emissions was performed using the EBSLs approach. EBSLs are back-calculated COPC-specific soil concentrations that provide a conservatively safe exposure level for ecological receptors under chronic exposure conditions. EBSLs were first developed and documented in VanHorn et al. 1995 to assess oral exposure of ecological receptors via food, water, and soil ingestion at the INL Site. Inhalation of dust and vapors and dermal contact with soils by birds and mammals are not assessed since they are considered insignificant contributors to risk (EPA 1999). In 1999, EBSLs were further developed and used in the *Work Plan for Waste Area Groups 6 and 10 Operable Unit 10-04 Comprehensive Remedial Investigation/Feasibility Study* (DOE-ID 1999). This Work Plan documents the exposure equations, receptors (functional groups), input parameters, and toxicity reference values (TRVs) used to calculate EBSLs for receptors at the INL Site. Since then, EPA published improved guidance on ecological risk assessment for organic and

inorganic COPCs in the document *Screening Level Ecological Risk Assessment Protocol (SLERAP) for Hazardous Waste Combustion Facilities* (EPA 1999). The EBSLs used in the previous ILWMS risk assessment (ICP 2004), and those used in this risk assessment, were updated using this SLERAP approach.

Conservative COPC-specific SLQs were calculated by dividing the maximum 1-year COPC soil concentration (CstD, see Appendix B) by the EBSL (see Section 9 Results for specific values). A TSLQ was then calculated by summing the COPC SLQs, similar to the HQs and HIs in the human health risk assessment. For initial screening, a conservative TSLQ value of 1.0 was used. EBSLs allow rapid screening of COPCs to identify those that are the most important for risk. Since EBSLs are calculated using very conservative exposure assumptions, a COPC with an SLQ exceeding 1 does not necessarily indicate a risk but that the EBSL should be re-assessed using more realistic parameter values.

For initial screening, the ecological risk assessment evaluated IWTU and ILWMS emissions at the INL Site location of maximum modeled deposition (BIG grid). In accordance with the RAWP, cumulative ecological impacts from other contributing sources (ETS and ICDF) were evaluated by adding their previously calculated ecological TSLQs (ICP 2004) to the TSLQs for the IWTU/ILWMS sources calculated in this risk assessment.

8. UNCERTAINTY EVALUATION

The risk assessment qualitatively addresses the uncertainty in the methods and parameter values used and their potential effects on the final calculated risk/hazard. This includes uncertainties in source emissions estimates, air dispersion and deposition modeling, exposure assessment, toxicity values and ecological risk assessment.

9. RESULTS

9.1 Air Modeling

Maximum modeled air concentrations and deposition rates for all of the modeling runs are tabulated in Table 4. Public human health impacts (both cancer risks and HQs) from ingestion and inhalation were calculated using the maximum modeled off-site (INL grid) impacts which includes particle (Ddp, Dwp) and vapor (Dydv, Dywv) annual deposition rates and particle (Cp) and vapor (Cv) annual-average air concentrations. For the IWTU runs using ISC3P, Dydv was calculated as the product of the maximum off-site vapor air concentration (Cv) and vapor dry deposition velocity (Vdv) since ISC3P does not have a vapor dry deposition algorithm. This methodology was recommended in the 1998 peer-reviewed draft HHRAP and was found to produce equivalent results to the ISCST3-calculated Dydv. Short-term public inhalation impacts (HQs) were calculated using maximum 24-hour (C24p, C24v) on U.S. Highway 20/26 (Hwy grid). On-site modeled impacts (BIG grid) were used to assess dispersion spatial variability for siting refined receptor grids (INL and Hwy), maximum short-term inhalation impacts for on-site workers (C1v-on), and ecological receptors (Ddp-on, Dwp-on, Dydv-on, Dywv-on).

Table 4. Unit release (1 g/s) air modeling results for the INTEC main (PEWE/LET&D) and IWTU stacks.

Grid	Model Output	Description	Units	UTM-E (m)	UTM-N (m)	Value
		INTEC main stack runs (ISCST3)				
BIG	Cp-on	On-site particle annual conc.	$\mu g\text{-}s/g\text{-}m^3$	344923	4824950	0.086
	Ddp-on	On-site particle annual dry dep.	$s/m^2\text{-}yr$	344923	4826950	0.068
	Dwp-on	On-site particle annual wet dep.	$s/m^2\text{-}yr$	344923	4826950	0.0076
	C1p-on	On-site particle 1-hr conc.	$\mu g\text{-}s/g\text{-}m^3$	334923	4828950	5.60
	Cv-on	On-site vapor annual conc.	$\mu g\text{-}s/g\text{-}m^3$	344923	4826950	0.092
	Dydv-on	On-site vapor annual dry dep.	$s/m^2\text{-}yr$	344923	4826950	0.014
	Dywv-on	On-site vapor annual wet dep.	$s/m^2\text{-}yr$	344923	4826950	0.0047
	C1v-on	On-site vapor 1-hr conc.	$\mu g\text{-}s/g\text{-}m^3$	343923	4828950	3.30
	C24v-on	On-site vapor 24-hr conc.	$\mu g\text{-}s/g\text{-}m^3$	Used for refined grid siting		
Hwy	C24p	US 20/26 particle 24-hr conc.	$\mu g\text{-}s/g\text{-}m^3$	341893	4819687	0.25
	C24v	US 20/26 vapor 24-hr conc.	$\mu g\text{-}s/g\text{-}m^3$	331300	4827066	0.29
INL	Cp	Off-site particle annual conc.	$\mu g\text{-}s/g\text{-}m^3$	337000	4810400	0.031
	Ddp	Off-site particle annual dry dep.	$s/m^2\text{-}yr$	337000	4810400	0.0049
	Dwp	Off-site particle annual wet dep.	$s/m^2\text{-}yr$	337000	4810400	0.00029
	Cv	Off-site vapor annual conc.	$\mu g\text{-}s/g\text{-}m^3$	337000	4810400	0.028
	Dydv	Off-site vapor annual dry dep.	$s/m^2\text{-}yr$	337000	4810400	0.0044
	Dywv	Off-site vapor annual wet dep.	$s/m^2\text{-}yr$	337000	4810400	0.00034
		IWTU runs (ICS3P with BPIPPRM)				
BIG	Cp-on	On-site particle annual conc.	$\mu g\text{-}s/g\text{-}m^3$	344923	4826950	0.32
	Ddp-on	On-site particle annual dry dep.	$s/m^2\text{-}yr$	344923	4826950	0.19
	Dwp-on	On-site particle annual wet dep.	$s/m^2\text{-}yr$	344923	4826950	0.0087
	C1p-on	On-site particle 1-hr conc.	$\mu g\text{-}s/g\text{-}m^3$	349923	4826950	13.0
	Cv-on	On-site vapor annual conc.	$\mu g\text{-}s/g\text{-}m^3$	344923	4826950	0.35
	Dydv-on	On-site vapor annual dry dep.	$s/m^2\text{-}yr$	Not available in ISC3-PRIME		
	Dywv-on	On-site vapor annual wet dep.	$s/m^2\text{-}yr$	344923	4826950	0.0056
	C1v-on	On-site vapor 1-hr conc.	$\mu g\text{-}s/g\text{-}m^3$	344923	4826950	14.4
	C24v-on	On-site vapor 24-hr conc.	$\mu g\text{-}s/g\text{-}m^3$	Used for refined grid siting		
Hwy	C24p	US 20/26 particle 24-hr conc.	$\mu g\text{-}s/g\text{-}m^3$	341538	4820039	0.89
	C24v	US 20/26 vapor 24-hr conc.	$\mu g\text{-}s/g\text{-}m^3$	340478	4821101	1.13
INL	Cp	Off-site particle annual conc.	$\mu g\text{-}s/g\text{-}m^3$	336800	4812500	0.052
	Ddp	Off-site particle annual dry dep.	$s/m^2\text{-}yr$	336500	4812500	0.0064
	Dwp	Off-site particle annual wet dep.	$s/m^2\text{-}yr$	338500	4812500	0.00040
	Cv	Off-site vapor annual conc.	$\mu g\text{-}s/g\text{-}m^3$	336500	4812500	0.062
	Dydv	Off-site vapor annual dry dep.	$s/m^2\text{-}yr$	Not available in ISC3-PRIME		
	Dywv	Off-site vapor annual wet dep.	$s/m^2\text{-}yr$	338500	4812500	0.00050

Plots of the dispersion trends for both ILWMS (INTEC main stack) and IWTU are shown in Figures 4–9. The plots were made using the PLOTFILE output from ISCST3/ISC3P and Surfer® 8 mapping software.[b,c] These figures show that the locations of the maximum off-site impact (Figures 4 and 5) are different for the INTEC main stack and the IWTU stack, with the INTEC main stack maximum occurring further out on the elevated northern slope of Big Southern Butte and the IWTU maximum occurring at the INL Site boundary. This is likely due to the fact that the 250-ft INTEC main stack is more than twice as high as the 120-ft IWTU stack, resulting in a higher INTEC main stack plume centerline which does not reach maximum at ground-level until it impacts the elevated slopes of Big Southern Butte. This difference in stack heights also influences the maximum ground-level relative (1 g/s) air concentrations off-site, with the IWTU maximum approximately twice as high as the INTEC main stack maximum. It also changes the relative dispersion patterns for the 1-hour and 24-hour model results. In both the annual-average and 24-hour modeling runs, maximum impacts were adequately resolved using refined 100-m receptor grids that extended well beyond the point of maximum impact determined in the coarse (INL) receptor grid. Maximum 1-hour concentrations on-site were deemed to be adequately assessed using the coarse (INL) receptor grid based on the very low AHQ calculated using these results.

b. Golden Software, Inc., Golden, CO (www.goldensoftware.com).

c. References herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government, any agency thereof, or any company affiliated with the Idaho Cleanup Project.

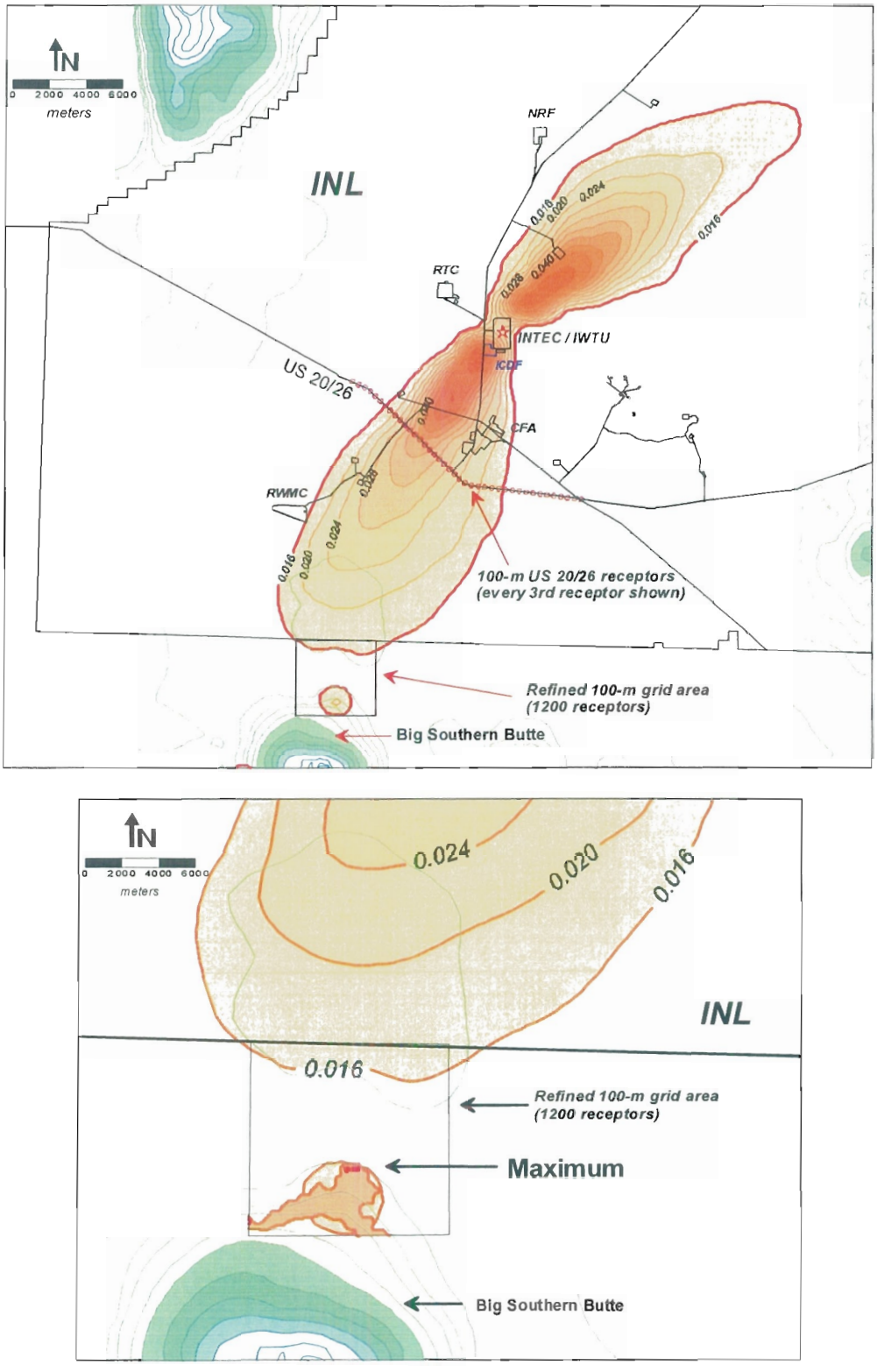

Figure 4. Annual-average vapor dispersion pattern ($\mu g/m^3$ per g/s, orange contour lines) for the INTEC main stack with maximum off-INL impact location noted.

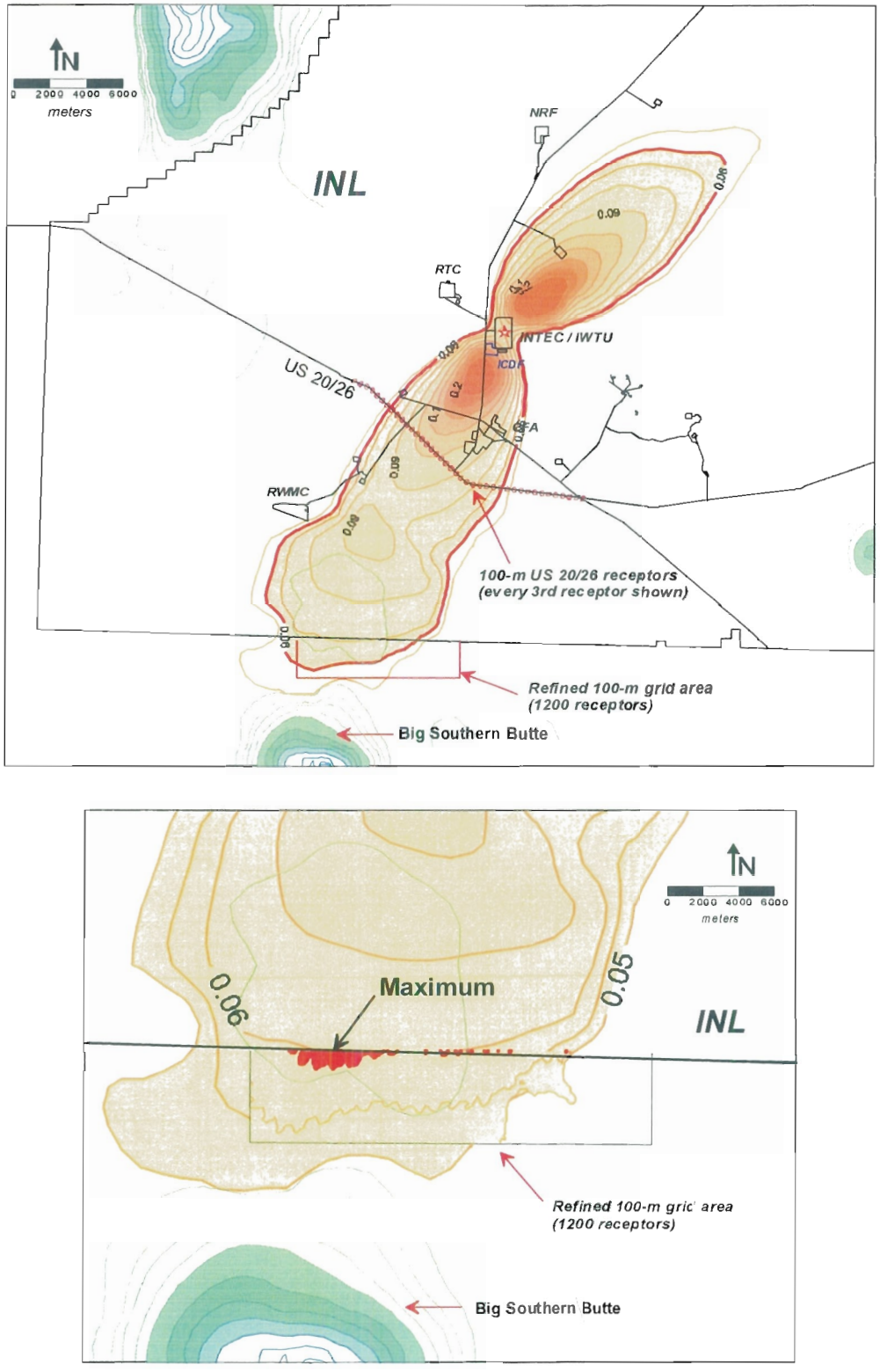

Figure 5. Annual-average vapor dispersion pattern ($\mu g/m^3$ per g/s, orange contour lines) for the IWTU stack with maximum off-INL impact location noted.

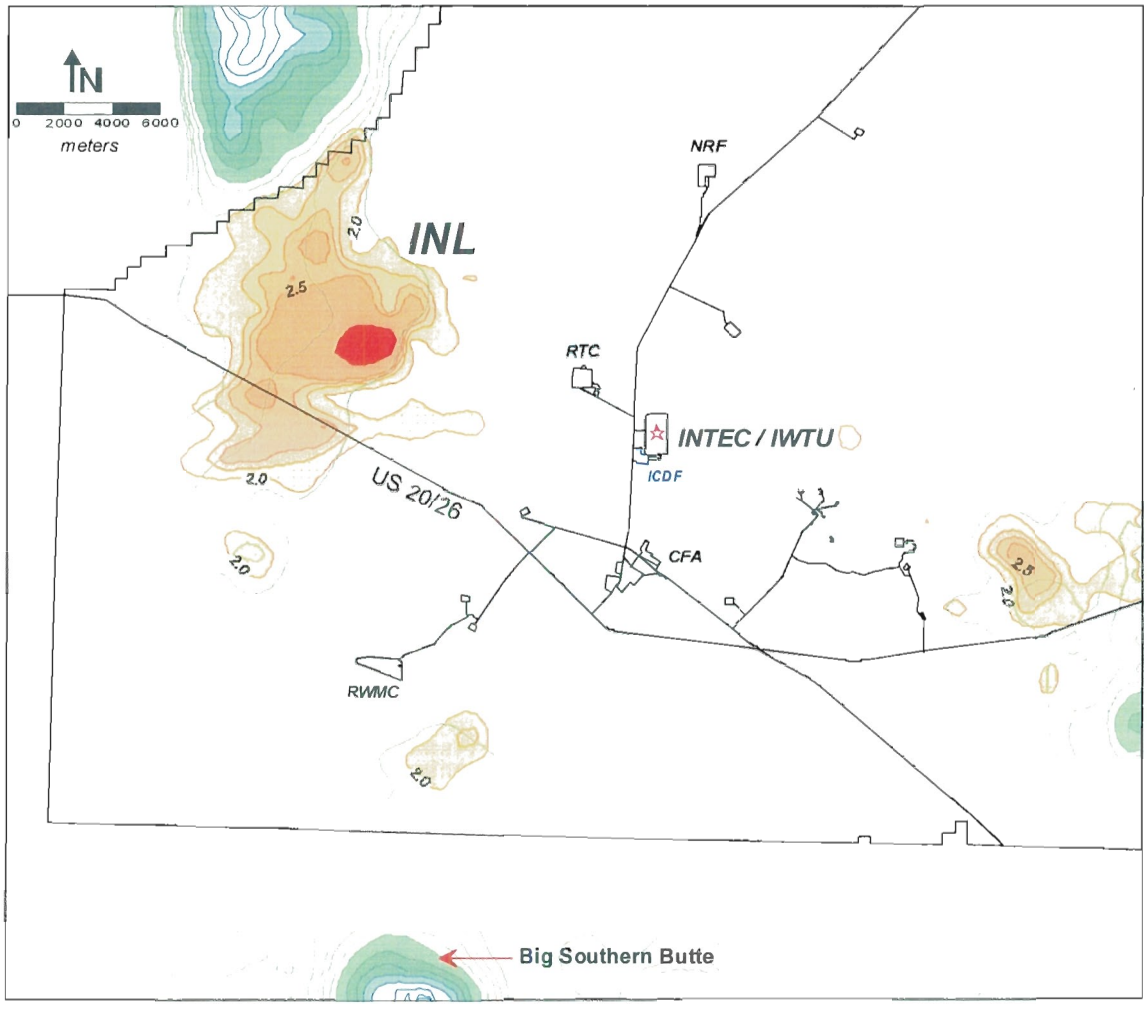

Figure 6. Maximum 1-hour vapor dispersion pattern for the INTEC main stack ($\mu g/m^3$ per g/s, orange contour lines). Used to evaluate maximum short-term acute inhalation impacts.

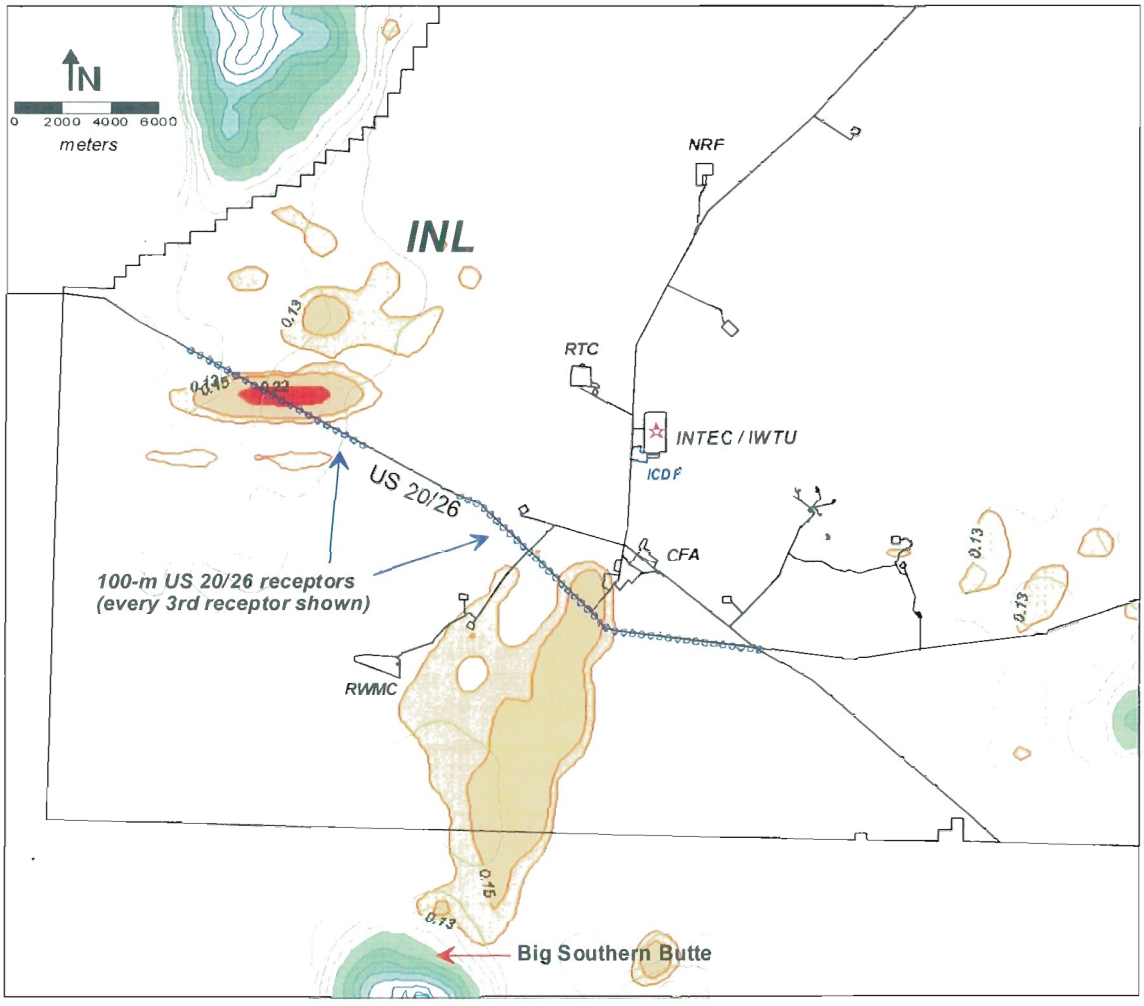

Figure 7. Maximum 24-hour vapor dispersion pattern for the INTEC main stack ($\mu g/m^3$ per g/s, orange contour lines). Used to site discrete 100-m interval receptors on U.S. Highway 20/26.

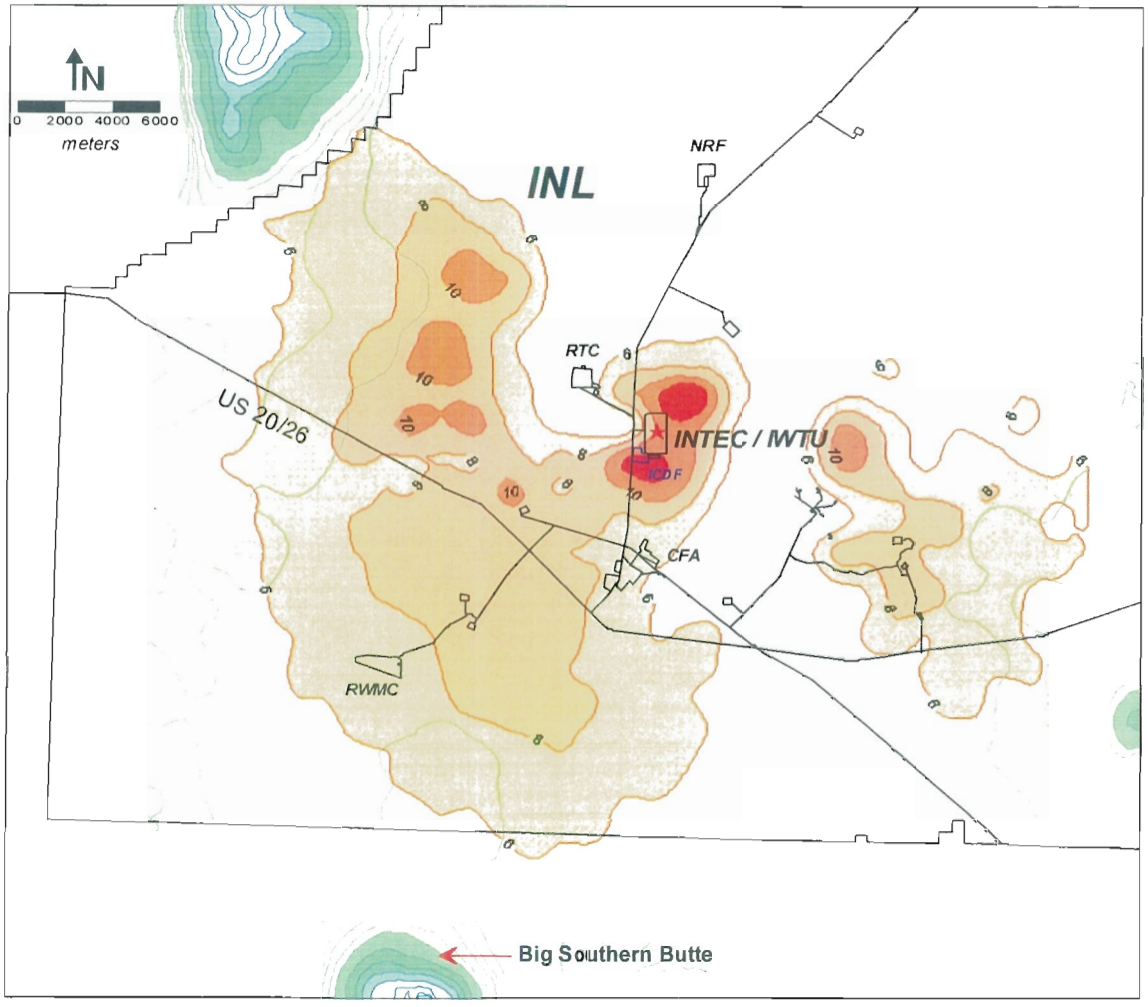

Figure 8. Maximum 1-hour vapor dispersion pattern from the IWTU stack ($\mu g/m^3$ per g/s, orange contour lines). Used to evaluate maximum short-term acute inhalation impacts.

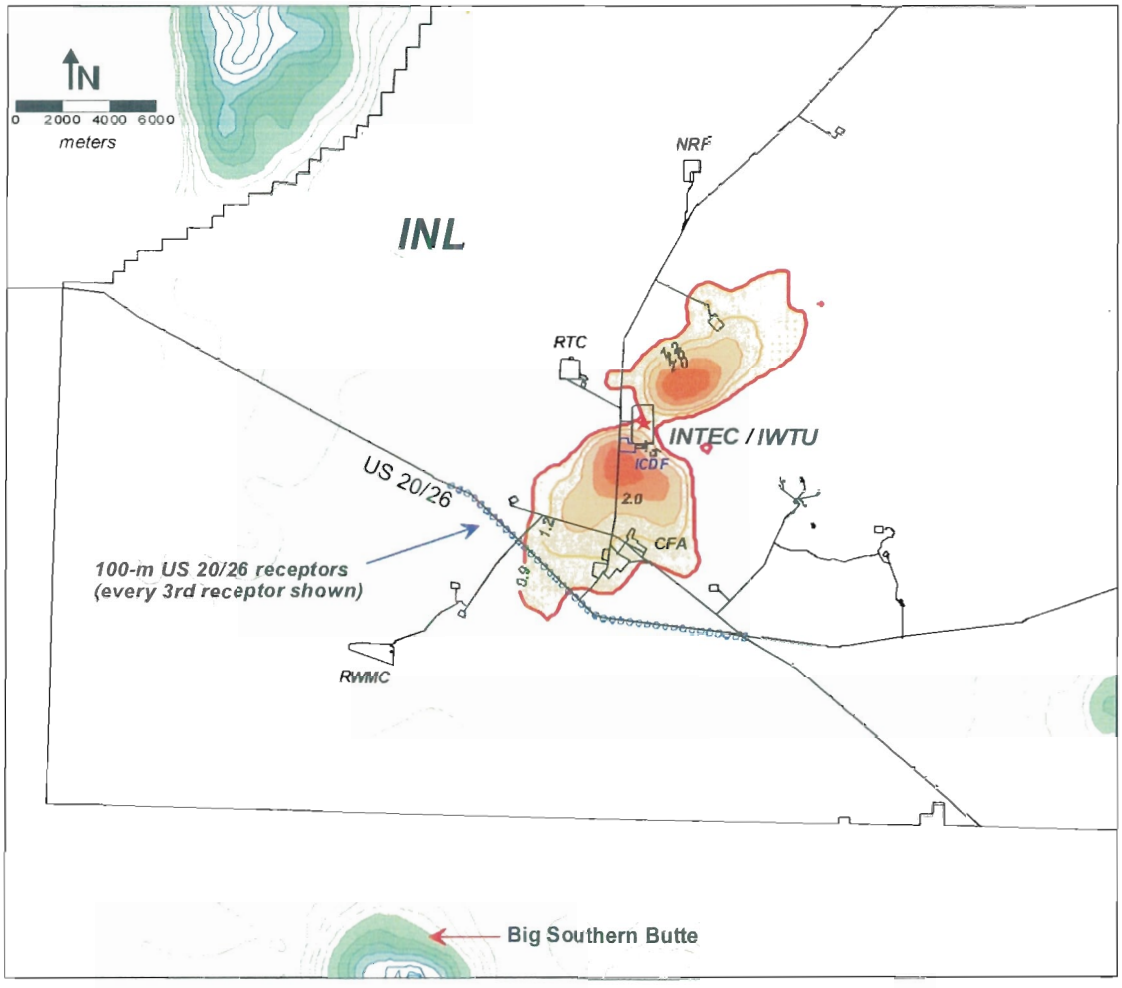

Figure 9. Maximum 24-hour vapor dispersion pattern from the IWTU stack ($\mu g/m^3$ per g/s, orange contour lines). Used to site discrete 100-m interval receptors on U.S. Highway 20/26.

9.2 Human Health Impacts

9.2.1 Off-INL Public Health Impacts – ILWMS and IWTU

This section gives the estimated human health impacts (cancer risks and hazard quotients) for the LET&D/PEWE and IWTU. These results were calculated using the HHRAP methods, equations, and parameter values listed in Section 5.2 and Appendix B. A summary of the combined estimated cancer risks and non-cancer hazards for both the LET&D/PEWE and IWTU is given in Table 5. Tables 6 through 11 provide detailed human health impact results for individual COPCs by source (IWTU, LET&D/PEWE), exposure pathway (ingestion, inhalation), and type of health impact (cancer risk, non-cancer hazard). The maximum cancer risk estimate for any of the scenarios is 4.8E-08 (farmer), which is about 0.5% of the EPA target criteria (1E-05). The maximum non-cancer hazard index estimate is 0.0089, less than 4% of the EPA target criteria (0.25). Because these scenarios were evaluated at the location of maximum off-site air concentrations and deposition rates (where no one resides), real impacts would be less for actual residents that live around the site (e.g., Atomic City). These results demonstrate that both

of these facilities can be simultaneously operated without unacceptable health impacts to the public at any off-site location.

Table 5. Summary of total estimated human health impacts from LET&D/PEWE and IWTU emissions.

Health Impact	Child	Farmer Child	Adult	Farmer
Ingestion Cancer Risk	2.2E-09	6.7E-09	8.7E-09	1.2E-08
Inhalation Cancer Risk	5.4E-09	5.4E-09	2.7E-08	3.6E-08
Total Cancer Risk	**7.6E-09**	**1.2E-08**	**3.6E-08**	**4.8E-08**
Ingestion Non-cancer Hazard	1.2E-04	1.3E-04	6.7E-05	2.7E-05
Inhalation Non-cancer Hazard	8.8E-03	8.8E-03	8.8E-03	8.8E-03
Total Non-cancer Hazard (HI)	**0.0089**	**0.0089**	**0.0088**	**0.0088**

Indirect (i.e., ingestion) cancer risks and hazard quotients for the four public exposure scenarios evaluated (child, farmer child, adult, farmer) are given in Tables 6 and 7 for the IWTU emissions and Tables 8 and 9 for the LET&D/PEWE emissions. For IWTU emissions, cancer risk (1.1E-09 maximum for the farmer scenario) is primarily due to arsenic, while hazard index (HI) (9.2E-05 maximum for the farmer child) is primarily due to mercury (mercuric chloride) and silver. For LET&D/PEWE emissions, cancer risk (1.1E-08 maximum for the farmer) is primarily due to N-nitrosodipropylene, while the HI (3.8E-05 maximum for the farmer child) is primarily due to hydrogen chloride, chromium (VI), and mercury (mercuric chloride). It should be noted that the actual valence state of the chromium emissions are unknown and that our assumption of the more hazardous chromium (VI) form is an upper-bound estimate for this metal. The sum of the maximum IWTU and ILWMS indirect impacts are 1.2E-08 cancer risk and 1.3E-04 HI.

Table 6. Ingestion cancer risk estimates for IWTU emissions.

	Ingestion Cancer Risk - IWTU Operations			
COPC	Child	Farmer Child	Adult	Farmer
Aluminum	NA	NA	NA	NA
Arsenic	1.17E-10	2.12E-10	9.33E-10	1.10E-09
Barium	NA	NA	NA	NA
Beryllium	NA	NA	NA	NA
Cadmium	4.85E-18	1.65E-17	5.98E-17	7.77E-17
Chlorine	NA	NA	NA	NA
Chromium	NA	NA	NA	NA
Hexavalent chromium	NA	NA	NA	NA
Hydrogen chloride	NA	NA	NA	NA
Lead	1.10E-22	1.50E-22	4.28E-22	3.13E-22
Mercuric chloride	NA	NA	NA	NA
Mercury - total	NA	NA	NA	NA
Methyl mercury	NA	NA	NA	NA
Nickel	NA	NA	NA	NA
Selenium	NA	NA	NA	NA
Silver	NA	NA	NA	NA
Zinc	NA	NA	NA	NA
Total Risk	**1.2E-10**	**2.1E-10**	**9.3E-10**	**1.1E-09**

Note: NA = not applicable (no toxicity or HHRAP transport parameter values for COPC)

Table 7. Non-cancer ingestion hazard quotients for IWTU emissions.

COPC	Ingestion Hazard Quotient – IWTU Operations			
	Child	Farmer Child	Adult	Farmer
Aluminum	NA	NA	NA	NA
Arsenic	3.05E-06	5.49E-06	4.84E-06	4.27E-06
Barium	2.45E-06	3.78E-06	1.77E-06	9.65E-07
Beryllium	1.20E-07	3.54E-07	3.13E-07	3.12E-07
Cadmium	1.49E-13	5.06E-13	3.67E-13	3.58E-13
Chlorine	5.55E-07	2.05E-06	7.48E-07	5.53E-07
Chromium	9.20E-19	9.81E-19	5.17E-19	1.96E-19
Hexavalent chromium	4.63E-16	4.94E-16	2.61E-16	9.86E-17
Hydrogen chloride	2.57E-08	2.57E-08	1.71E-09	1.06E-09
Lead	3.53E-16	4.80E-16	2.74E-16	1.50E-16
Mercuric chloride	2.71E-05	3.20E-05	2.15E-05	9.52E-06
Mercury - total	NA	NA	NA	NA
Methyl mercury	7.64E-07	1.37E-06	9.15E-07	9.32E-07
Nickel	1.17E-17	1.28E-17	8.17E-18	3.99E-18
Selenium	2.97E-06	3.02E-06	1.47E-06	3.00E-07
Silver	4.30E-05	4.38E-05	1.85E-05	2.37E-06
Zinc	3.63E-20	9.14E-20	6.21E-20	5.52E-20
Total Hazard Index (HI)	**8.0E-05**	**9.2E-05**	**5.0E-05**	**1.9E-05**

Note: NA = not applicable (no toxicity or HHRAP transport parameter values for COPC)

Table 8. Ingestion cancer risk estimates for LET&D/PEWE emissions.

COPC	Ingestion Cancer Risk – LET&D/PEWE			
	Child	Farmer Child	Adult	Farmer
Arsenic	9.30E-13	1.68E-12	7.39E-12	8.69E-12
Benzo(a)pyrene	3.66E-10	3.73E-10	1.01E-09	5.01E-10
Chromium	NA	NA	NA	NA
Hexavalent chromium	NA	NA	NA	NA
1,4-dichlorobenzene	1.71E-18	5.93E-18	3.12E-18	9.36E-18
3,3'-dichlorobenzidine	1.01E-10	1.38E-10	3.54E-10	2.80E-10
Bis(2-ethylhexyl phthalate)	1.15E-13	2.22E-13	7.22E-13	7.63E-13
Fluoranthene	NA	NA	NA	NA
Hexachlorocyclopentadiene	NA	NA	NA	NA
Hydrogen chloride	NA	NA	NA	NA
Mercuric chloride	NA	NA	NA	NA
Mercury - total	NA	NA	NA	NA
Methyl mercury	NA	NA	NA	NA
Nickel	NA	NA	NA	NA
N-nitrosodipropylamine	1.65E-09	6.01E-09	6.41E-09	1.00E-08
Pyrene	NA	NA	NA	NA
1,2,3-trichloropropane	2.28E-15	8.04E-15	5.86E-15	1.29E-14
Total Risk	**2.1E-09**	**6.5E-09**	**7.8E-09**	**1.1E-08**

Note: NA = not applicable (no toxicity or HHRAP transport parameter values for COPC)

Table 9. Non-cancer ingestion hazard quotients for LET&D/PEWE emissions.

	Ingestion Hazard Quotient – LET&D/PEWE			
COPC	Child	Farmer Child	Adult	Farmer
Arsenic	2.41E-08	4.34E-08	3.83E-08	3.38E-08
Benzo(a)pyrene	NA	NA	NA	NA
Chromium	2.09E-08	2.22E-08	1.17E-08	4.43E-09
Hexavalent chromium	1.05E-05	1.12E-05	5.91E-06	2.24E-06
1,4-dichlorobenzene	1.23E-13	4.27E-13	4.49E-14	1.01E-13
3,3'-dichlorobenzidine	NA	NA	NA	NA
Bis(2-ethylhexyl phthalate)	4.80E-09	9.25E-09	6.02E-09	4.77E-09
Fluoranthene	1.25E-09	1.35E-09	4.47E-10	1.41E-10
Hexachlorocyclopentadiene	7.25E-10	8.19E-10	2.22E-10	7.77E-11
Hydrogen chloride	1.15E-05	1.15E-05	7.62E-07	4.71E-07
Mercuric chloride	7.73E-06	9.07E-06	6.04E-06	2.64E-06
Mercury - total	6.13E-08	2.45E-07	1.75E-07	1.75E-07
Methyl mercury	2.55E-07	4.35E-07	2.85E-07	2.74E-07
Nickel	5.23E-06	5.72E-06	3.65E-06	1.78E-06
N-nitrosodipropylamine	NA	NA	NA	NA
Pyrene	3.98E-09	4.36E-09	2.08E-09	6.92E-10
1,2,3-trichloropropane	6.33E-13	2.23E-12	3.26E-13	5.36E-13
Total Hazard Index (HI)	**3.5E-05**	**3.8E-05**	**1.7E-05**	**7.6E-06**

Note: NA = not applicable (no toxicity or HHRAP transport parameter values for COPC)

Maximum inhalation impacts for the child scenarios, adult, and farmer exposure scenarios are given in Tables 10 and 11. For IWTU, cancer risk (6.7E-09 maximum for the farmer) is driven by arsenic and beryllium, and non-cancer hazards (0.0056 maximum for all scenarios) are driven by nitrogen oxides, chorine, barium, and arsenic. For LET&D/PEWE emissions, cancer risks (2.9E-08 maximum for the farmer) are driven by hexavalent chromium, and non-cancer hazards (0.003 maximum for all scenarios) are driven by hydrogen chloride. The sums of the maximum IWTU and LET&D/PEWE inhalation impacts are 3.6E-08 cancer risk (farmer) and 0.0088 HI non-cancer risk (for all) (see Table 5).

Table 10. Maximum inhalation health impact estimates for IWTU emissions.

	Inhalation Cancer Risk			Inhalation
COPC	Child	Adult	Farmer	HQ
Aluminum	NA	NA	NA	1.92E-09
Arsenic	7.35E-10	3.67E-09	4.90E-09	1.98E-04
Barium	NA	NA	NA	2.46E-04
Beryllium	2.63E-10	1.31E-09	1.75E-09	9.56E-05
Bromine	NA	NA	NA	2.67E-07
Cadmium	1.51E-16	7.53E-16	1.00E-15	3.98E-10
Calcium oxide	NA	NA	NA	3.54E-11
Carbon monoxide	NA	NA	NA	2.42E-07
Chlorine	NA	NA	NA	2.29E-03
Chromium	NA	NA	NA	1.84E-12
Fluorides	NA	NA	NA	8.18E-06

Table 10. (continued).

COPC	Inhalation Cancer Risk			Inhalation HQ
	Child	Adult	Farmer	
Fluorine	NA	NA	NA	7.97E-06
Hexavalent chromium	2.08E-19	1.04E-18	1.39E-18	5.75E-09
Hydrogen chloride	NA	NA	NA	2.35E-05
Lead	1.54E-22	7.69E-22	1.03E-21	9.97E-17
Mercuric chloride	NA	NA	NA	1.02E-06
Mercury - total	NA	NA	NA	1.60E-08
Methyl mercury	NA	NA	NA	NA
Molybdenum	NA	NA	NA	6.07E-07
Nickel	1.01E-21	5.06E-21	6.75E-21	6.43E-11
Nitrogen oxides	NA	NA	NA	2.70E-03
Particulate matter	NA	NA	NA	3.23E-14
Rhodium	NA	NA	NA	1.17E-07
Selenium	NA	NA	NA	9.94E-08
Silver	NA	NA	NA	9.80E-07
Sulfur dioxide	NA	NA	NA	2.43E-05
Tin	NA	NA	NA	6.59E-07
Zinc	NA	NA	NA	1.41E-11
Total	**1.0E-09**	**5.0E-09**	**6.7E-09**	**0.0056**

Note: NA = not applicable (no toxicity or HHRAP transport parameter values for COPC)

Table 11. Maximum inhalation health impact estimates for LET&D/PEWE emissions.

COPC	Inhalation Cancer Risk			Inhalation HQ
	Child	Adult	Farmer	
Arsenic	4.55E-12	2.28E-11	3.04E-11	4.12E-07
Benzo(a)pyrene	1.51E-12	7.56E-12	1.01E-11	NA
Chromium	NA	NA	NA	1.44E-07
Hexavalent chromium	3.70E-09	1.85E-08	2.47E-08	4.50E-04
1,4-dichlorobenzene	1.45E-15	7.24E-15	9.65E-15	1.92E-12
3,3'-dichlorobenzidine	1.18E-12	5.92E-12	7.90E-12	NA
Bis(2-ethylhexyl phthalate)	NA	NA	NA	NA
Fluoranthene	NA	NA	NA	3.77E-11
Hexachlorocyclopentadiene	NA	NA	NA	2.25E-07
Hydrogen chloride	NA	NA	NA	2.62E-03
Mercuric chloride	NA	NA	NA	1.84E-07
Mercury – total	NA	NA	NA	2.77E-09
Methyl mercury	NA	NA	NA	NA
Nickel	4.24E-10	2.12E-09	2.83E-09	1.03E-04
N-nitrosodipropylamine	2.49E-10	1.24E-09	1.66E-09	NA
Pyrene	NA	NA	NA	4.14E-11
1,2,3-trichloropropane	5.70E-13	2.85E-12	3.80E-12	NA
Total	**4.4E-09**	**2.2E-08**	**2.9E-08**	**0.003**

Note: NA = not applicable (no toxicity or HHRAP transport parameter values for COPC)

9.2.2 Contributions from Other Sources

Human health impacts from the other potentially contributing sources, ETS and ICDF, were previously calculated and documented in INEEL 2002, EDF-ER-327, and ICP 2004. The maximum cancer risks for ETS and ICDF were 1.3E-10 and 4.2E-08, respectively. The ETS contribution is insignificant, but the ICDF cancer risk estimate effectively doubles the maximum LET&D/PEWE/IWTU risk (4.8E-08, Table 5) to 9E-08, about 1% of the EPA target criteria target criteria (1E-05). The maximum HIs for ETS and ICDF were 6.5E-06 and <0.01, respectively. The ICDF HI estimate was calculated in EDF-ER-327 for an INL Site visitor, which conservatively bounds any off-site public receptor. The cumulative HI for all facilities (IWTU, LET&D, PEWE, ETS, and ICDF) is therefore less than 0.02, about 7% of the EPA target criteria (0.25).

9.2.3 Impacts to Public Motorists

Potential acute (non-cancer) inhalation impacts to passing motorists on U.S. Highway 20/26, which traverses the southern portion of the INL Site, were evaluated by dividing the modeled maximum 24-hour air concentrations on the highway by AACs for non-carcinogens published by the Idaho DEQ for toxic air pollutants (IDAPA 58.01.01.585). Tables 12 and 13 summarize the modeling results for this assessment. In all cases, maximum 24-hour air concentrations were well below the published AACs. The maximum impact was from IWTU fluorine emissions, which was less than 0.02% of the AAC. Inhalation cancer risk is not evaluated on Highway 20/26 because the transient nature of exposure to passing motorists does not meet the chronic exposure assumption needed to assess cancer risk.

Table 12. Comparison of maximum IWTU 24-hour air concentrations with Idaho Acceptable Ambient Concentrations for non-carcinogens on U.S. Highway 20/26.

COPC	24-hr Conc US 20/26 ($\mu g/m^3$)	AAC ($\mu g/m^3$)	Conc/AAC
Aluminum	1.71E-07	1.00E+02	1.71E-09
Arsenic	1.06E-04	NA	NA
Barium	2.19E-03	2.50E+01	8.75E-05
Beryllium	3.40E-05	NA	NA
Bromine	8.69E-06	3.50E+01	2.48E-07
Cadmium	1.41E-09	NA	NA
Calcium oxide	6.78E-08	1.00E+02	6.78E-10
Carbon monoxide	4.63E-02	NA	NA
Chlorine	8.75E-03	1.50E+02	5.83E-05
Chromium	8.17E-10	2.50E+01	3.27E-11
Fluorides	2.03E-03	1.25E+02	1.63E-05
Fluorine	1.53E-02	1.00E+02	1.53E-04
Hexavalent chromium	8.17E-10	NA	NA
Hydrogen chloride	9.01E-03	3.75E+02	2.40E-05
Lead	2.66E-15	NA	NA
Mercuric chloride	2.14E-05	2.50E+00	8.55E-06
Mercury – total	9.20E-07	2.50E+00	3.68E-07
Methyl mercury	NA	NA	NA
Molybdenum	5.38E-03	5.00E+02	1.08E-05
Nickel	2.29E-10	NA	NA
Nitrogen oxides	1.03E+00	NA	NA

Table 12. (continued).

COPC	24-hr Conc US 20/26 ($\mu g/m^3$)	AAC ($\mu g/m^3$)	Conc/AAC
Particulate matter	8.60E-11	NA	NA
Rhodium	1.04E-04	5.00E+01	2.08E-06
Selenium	1.77E-05	1.00E+01	1.77E-06
Silver	8.71E-05	5.00E+00	1.74E-05
Sulfur dioxide	1.70E-01	NA	NA
Tin	1.17E-03	1.00E+02	1.17E-05
Zinc	2.25E-10	5.00E+01	4.50E-12

Note: NA = no published AAC value. Methyl mercury is not of concern via the inhalation pathway (HHRAP).

Table 13. Comparison of maximum LET&D/PEWE 24-hour air concentrations with Idaho Acceptable Ambient Concentrations for non-carcinogens on U.S. Highway 20/26.

COPC	24-hr Conc US 20/26 ($\mu g/m^3$)	AAC ($\mu g/m^3$)	Conc/AAC
Arsenic	1.04E-07	NA	NA
Benzo(a)pyrene	1.46E-07	NA	NA
Chromium	3.03E-05	2.50E+01	1.21E-06
Hexavalent chromium	3.03E-05	NA	NA
1,4-dichlorobenzene	1.67E-08	2.25E+04	7.44E-13
3,3'-dichlorobenzidine	3.88E-07	NA	NA
Bis(2-ethylhexyl phthalate)	1.53E-06	NA	NA
Fluoranthene	5.74E-08	NA	NA
Hexachlorocyclopentadiene	4.90E-07	5.00E+00	9.80E-08
Hydrogen chloride	5.71E-01	3.75E+02	1.52E-03
Mercuric chloride	2.13E-06	2.50E+00	8.51E-07
Mercury – total	9.05E-09	2.50E+00	3.62E-09
Methyl mercury	NA	NA	NA
Nickel	1.74E-04	NA	NA
N-nitrosodipropylamine	1.58E-05	NA	NA
Pyrene	4.95E-08	NA	NA
1,2,3-trichloropropane	3.63E-08	3.00E+03	1.21E-11

Note: NA = no published AAC value. Methyl mercury is not of concern via the inhalation pathway (HHRAP).

9.2.4 Acute Inhalation Risk to a Worker

Maximum inhalation impacts to onsite workers were estimated by an acute hazard quotient (AHQ), which was calculated by dividing the maximum modeled 1-hr air concentration (C_{acute}) at any location on the INL Site by the COPC's acute inhalation exposure criteria (AIECs) taken from the EPA Companion Date Base. An AHQ of less than 1 is considered acceptable (EPA 2005). The results of this assessment (Tables 14 and 15) demonstrate that acute hazards to workers anywhere on the INL Site for both IWTU and ILWMS emissions are well within AIECs. Since AIECs are not worker-specific health criteria, this finding of no acute inhalation impact also applies to members of the public who may be visiting the site.

Table 14. IWTU acute (1-hour) inhalation impacts for a worker anywhere on the INL Site.

COPC	C_{acute} ($\mu g/m^3$)	AIEC (mg/m^3)	AHQ
Aluminum	NA	NA	NA
Arsenic	1.84E-07	1.90E-04	9.70E-07
Barium	7.88E-05	1.50E+00	5.25E-08
Beryllium	1.90E-08	5.00E-03	3.80E-09
Cadmium	3.29E-17	3.00E-02	1.10E-18
Chlorine	8.81E-04	2.10E-01	4.19E-06
Chromium	1.10E-17	1.50E+00	7.33E-21
Hexavalent chromium	1.10E-17	NA	NA
Hydrogen chloride	9.34E-04	2.10E+00	4.45E-07
Lead	1.16E-28	1.50E-01	7.76E-31
Mercuric chloride	NA	NA	NA
Mercury – total	2.44E-08	1.80E-03	1.35E-08
Methyl mercury	NA	NA	NA
Nickel	8.60E-19	6.00E-03	1.43E-19
Selenium	5.15E-09	1.47E+00	3.50E-12
Silver	1.25E-07	3.00E-01	4.16E-10
Zinc	8.33E-19	3.00E+01	2.78E-23
Total			**5.7E-06**

Note: NA = not applicable (no toxicity or HHRAP transport parameter values for COPC)

Table 15. LET&D/PEWE acute (1-hour) inhalation impacts for a worker anywhere on the INL Site.

COPC	C_{acute} ($\mu g/m^3$)	AIEC (mg/m^3)	AHQ
Arsenic	1.85E-11	1.90E-04	9.74E-11
Benzo(a)pyrene	2.94E-11	6.00E-01	4.89E-14
Chromium	1.58E-06	1.50E+00	1.05E-09
Hexavalent chromium	1.58E-06	NA	NA
1,4-dichlorobenzene	2.11E-13	6.00E+02	3.52E-19
3,3'-dichlorobenzidine	1.79E-10	6.00E+00	2.99E-14
Bis(2-ethylhexyl phthalate)	3.64E-09	1.00E+01	3.64E-13
Fluoranthene	2.49E-12	1.50E-02	1.66E-13
Hexachlorocyclopentadiene	1.81E-10	2.00E-01	9.06E-13
Hydrogen chloride	1.28E+01	2.10E+00	6.10E-03
Mercuric chloride	NA	NA	NA
Mercury – total	1.54E-08	1.80E-03	8.58E-09
Methyl mercury	NA	NA	NA
Nickel	5.16E-05	6.00E-03	8.59E-06
N-nitrosodipropylamine	1.88E-07	2.00E-01	9.42E-10
Pyrene	1.86E-12	1.50E+01	1.24E-16
1,2,3-trichloropropane	9.87E-13	6.00E+01	1.65E-17
Total			**6.11E-03**

Note: NA = not applicable (no toxicity or HHRAP transport parameter values for COPC)

9.2.5 Ecological Risk

Risk to ecological receptors was calculated using environmentally-based screening levels (EBSLs), which are COPC soil concentrations back-calculated from conservative ecological receptor exposure and toxicity criteria (Van Horn et al. 1995; ICP 2004). The maximum soil concentration calculated for anywhere on the INL Site was divided by the EBSL to obtain screening level quotients (SLQs). Individual COPC SLQs less than 1.0 and a TSLQ less than 10 are normally used as a target risk criteria in CERCLA risk assessments, although a more conservative TSLQ criterion of 1.0 was specified for this risk assessment in the RAWP. The TSLQ calculated for IWTU COPCs was 0.13, which was mostly due to the barium and silver (Table 16). The TSLQ calculated for the LET&D/PEWE COPC's was 0.0032 (Table 17). Combining these two TSLQs with the TSLQs previously calculated for ETS (0.25) and ICDF (0.26) (ICP 2004) gives a TSLQ for all contributing sources of 0.64, which is less than the conservative 1.0 TSLQ criterion specified in the RAWP. These results demonstrate that the IWTU and all contributing sources in the area will not adversely affect ecological receptors.

Table 16. Ecological screening level quotients for IWTU COPCs.

COPC	Max Soil (mg/kg)	EBSL	SLQ
Aluminum	1.79E-10	5.00E+00	3.59E-11
Arsenic	1.65E-09	1.00E+00	1.65E-09
Barium	1.27E-01	1.66E+00	7.65E-02
Beryllium	1.47E-06	1.00E-01	1.47E-05
Cadmium	5.17E-14	8.18E-02	6.31E-13
Chlorine	1.23E-04	NA	NA
Chromium	1.71E-13	3.31E+00	5.17E-14
Hexavalent chromium	1.72E-13	NA	NA
Hydrogen chloride	1.27E-04	NA	NA
Lead	1.18E-16	5.18E-02	2.28E-15
Mercuric chloride	1.53E-03	9.73E-01	1.58E-03
Mercury – total	0.00E+00	NA	NA
Methyl mercury	3.08E-05	9.73E-01	3.17E-05
Nickel	3.36E-18	2.50E+01	1.34E-19
Selenium	7.95E-09	5.00E-02	1.59E-07
Silver	9.49E-04	2.00E-02	4.75E-02
Zinc	2.45E-18	9.00E-01	2.72E-18
Total (TSLQ)			**1.3E-01**

Note: NA = not applicable (no toxicity or HHRAP transport parameter values for COPC)

Table 17. Ecological screening level quotients for LET&D/PEWE COPCs.

COPC	Max Soil (mg/kg)	EBSL	SLQ
Arsenic	4.53E-12	1.00E+00	4.53E-12
Benzo(a)pyrene	4.56E-06	2.07E-03	2.20E-03
Chromium	1.35E-03	3.31E+00	4.07E-04
Hexavalent chromium	1.36E-03	3.31E+00	4.10E-04
1,4-dichlorobenzene	2.37E-12	NA	NA
3,3'-dichlorobenzidine	1.80E-06	NA	NA
Bis(2-ethylhexyl phthalate)	2.46E-06	2.30E-01	1.07E-05
Fluoranthene	4.53E-07	4.06E+01	NA
Hexachlorocyclopentadiene	3.55E-08	1.00E-01	3.55E-07
Hydrogen chloride	3.90E-02	NA	NA
Mercuric chloride	2.02E-04	9.73E-01	2.08E-04
Mercury – total	NA	NA	NA
Methyl mercury	4.07E-06	9.73E-01	4.18E-06
Nickel	5.21E-07	2.50E+01	2.08E-08
N-nitrosodipropylamine	2.48E-06	NA	NA
Pyrene	1.46E-06	2.43E+01	5.99E-08
1,2,3-trichloropropane	3.41E-12	NA	NA
Total SLQ (TSLQ)			**3.2E-03**

Note: NA = not applicable (no toxicity or HHRAP transport parameter values for COPC)

9.3 Human Health Risk Assessment Uncertainty

Several sources of uncertainty affect the overall estimates of human health impacts (cancer risk and non-cancer hazard index) as calculated in this risk assessment. The sources are generally associated with characterization of COPC emission rates, air modeling, exposure assessment, toxicity values, and risk characterization.

9.3.1 Uncertainty Associated with COPC Emission Rate Characterization

Offgas sampling and analysis has numerous uncertainties associated with it including inherent variability in the analysis, representativeness of the samples, sampling errors, and heterogeneity of the sample matrix. Specific QA/QC procedures used in the ILWMS offgas sampling are contained in their respective emissions inventories (INEEL 2002; INEEL 2003; ICP 2005a; ICP 2005b). In general, the procedures used to select offgas emission rates evaluated in this risk assessment are conservative, meaning the actual emission rates from these facilities are likely to be less than those evaluated here. These conservative assumptions included the use of maximum values from all sampling runs and the use of detection limit values for "nondetect" analytes. In addition, the use of upper bound facility operating times (24/7) and operational lifetimes (15 years) likely overestimate annual average emission rates and the duration over which deposition occurs. These conservative emission rate assumptions produce calculated air concentrations, soil concentrations, and risk estimates that are likely biased high.

Another uncertainty associated with emission rate characterization involves facility process upset conditions that can temporarily increase COPC emission rates over those measured during offgas sampling (EPA 2005). For facilities without site-specific data to estimate the frequency and magnitude of process upsets, EPA 2005 recommends that organics and metal emissions be increased factors of 2.8 and 1.45 respectively, to account for these conditions. Process upsets are not currently anticipated at IWTU due to the stable, uniform operating characteristics of the fluid bed systems. This combined with the conservative assumptions used to estimate maximum emission rates from that facility (EDF-6495) make the need for a process upset correction factor unnecessary for IWTU emissions. For ILWMS, applying the above EPA process upset factors would increase the total ILWMS cancer risk from 4E-08 to 6E-08 and the HI from 0.0032 to 0.0035, which are both an insignificant increase compared to the EPA target criteria (1E-05 risk and 0.25 HI).

9.3.2 Uncertainty Associated with Air Modeling

In general, models are imperfect mathematical tools that attempt to simulate highly complex environmental phenomena. Therefore, significant uncertainty usually exists in modeling output for both air concentration and ground deposition rate. These uncertainties result from imperfect model structures and inaccuracies or natural variability in the model input parameter values. Although ISCST3 is the EPA-preferred refined air dispersion model for this type of risk assessment, it is subject to the same uncertainties.

A major source of model structural uncertainty results when the "straight-line" Gaussian plume model algorithm in ISCST3 is applied for large receptor distances. The Gaussian plume model assumes that atmospheric dispersion conditions (wind direction, wind speed, and turbulence) do not change between the release point and the receptor location over the time interval of the meteorological data (1-hr). Offsite distances from the INTEC are relatively large (e.g., >13 km), and dispersion conditions may change over the time required to transport the contaminants to receptors (>1-hr average). However, published validation studies have indicated that the Gaussian plume model is reasonably reliable for estimating the longer time-averaged (e.g., annual) concentrations and relatively flat terrain conditions evaluated in this risk assessment. Errors in the highest estimated concentrations of 10 - 40% are found to be typical.

A related major source of uncertainty exists in the prediction of model output at specific receptor locations. Because of shifting winds, contaminants may follow trajectories that are not straight, which may cause model predictions at specific downwind locations, especially over the large INL Site distances, to be highly uncertain. Adding to this spatial prediction problem is the uncertainty that exists in the meteorological data file wind vectors. Measurement or processing (time-averaging) errors of 5 to 10 degrees can result in concentration errors of 20 to 70%. Such uncertainties indicate that the precise time and location are in doubt, not necessarily that an estimated concentration does not occur.

For the offsite human health impacts evaluated in this risk assessment, potential underprediction due to this spatial prediction uncertainty is avoided by evaluating exposure scenarios at the point of maximum off-INL impacts (air concentration, deposition) regardless of whether there is an actual human receptor at that location. For example, INTEC main stack annual-average air concentrations at Atomic City, the nearest continually inhabited off-site location, were calculated to be less than half those at the point of maximum off-site impact (INEEL 1999a). Therefore, the air modeling results used in this risk assessment are likely to significantly over predict the actual impacts that might occur to any real public receptor.

9.3.3 Uncertainty Associated with Exposure Assessment

The equations and parameter values specified in the HHRAP used in this assessment are based on many exposure assessment assumptions that also contribute to uncertainties in the final calculated risk values. Most of these assumptions are likely to be conservative, including the assumption of a continuous 40-year exposure time (subsistence farmer scenario), the assumption that food products are produced at the point of maximum air concentration and ground deposition rate, and the assumption that 100% of the receptor's food products are grown at the point of maximum ground deposition rate. Since the error in the final calculated risk value is the sum of the errors in each of these parameter values, these conservative exposure assumptions likely produce overestimates of the actual risks to the public. EPA uncertainty estimates for individual parameters may be found in Appendixes B and C of the HHRAP document (EPA 2005).

9.3.4 Uncertainty Associated with COPC Toxicity

The health impacts calculated in this risk assessment use toxicity criteria from the EPA HHRAP Companion Database, which is continually updated to reflect current values. However, many uncertainties and unknowns are associated with the determination of these toxicity values. They include extrapolation from high to low doses and from animals to humans; species differences in uptake, metabolism, and organ distribution; species differences in target site susceptibility; and human population variability in diet, environment, activity patterns, and for cultural factors. However, safety factors are built into the determination of the final toxicity value to compensate for these sources of uncertainty, which likely result in a bias toward overestimating risk.

9.3.5 Uncertainty Associated with Risk Characterization

In the risk characterization, the assumption was made that the total risk of developing cancer from exposure to all COPCs is the sum of the risk attributed to each individual COPC. Likewise, the potential for the development of non-cancer adverse effects is the sum of the estimated exposure to each individual COPC. This approach, in accordance with EPA guidance, does not account for the possibility that constituents act synergistically or antagonistically. This uncertainty could over or underestimate total risk.

9.4 Ecological Risk Assessment Uncertainty

9.4.1 Uncertainty Associated with Exposure Assessment

EBSLs are modeled using a site use factor (SUF) and exposure duration (ED) parameter. The SUF represents the proportion of a species home range that overlaps the area of contamination. An SUF of 1.0 indicates that the home range is less than or equal to the area of contaminant exposure. For our EBSL calculations, the SUF was assumed to be 1.0 (100% use occurs in the area of contamination) for all groups and species (VanHorn et al. 1995; ICP 2004). Home range is poorly documented for many species and may be highly variable. Exposure duration is also included to account for seasonal use of the site, for example by migratory birds that are only present for 2–3 months of the year. The assumption of 100% exposure in the development of the EBLS is highly conservative and can significantly overestimate the risk at small sites. Finally, the ecological risk assessment is evaluated at the point of maximum ground deposition (and soil concentration) on the INL Site, which is a very conservative screening-level assumption. Exposures to real populations of ecological receptors would actually occur across the INL Site, at locations where the ground deposition rate is much less than at the maximum point.

9.4.2 Uncertainty Associated with Ingestion Rates

Few intake ingestion rate estimates used for terrestrial receptors are based on data in the scientific literature. Food ingestion rates used in the EBSL calculation are calculated using allometric equations available in the literature (Nagy 1987). The use of these values may moderately over or underestimate risk.

9.4.3 Uncertainty Associated with Uptake Factors

Two parameters used in the calculation of EBSLs, prey bioaccumulation factor (BAF) and plant uptake factor (PUF), were assumed to be the greater of either the calculated value or 1.0. This is a conservative assumption that will generally overestimate risk, since less than 40% of the COPCs have PUFs greater than 1.0 and less than 1% of the COPCs have BAFs greater than 1.0. In the absence of specific BAF or PUF, a value of 1.0 was assumed. This assumption could over or underestimate the true dose from the contaminant, and the magnitude of error cannot be quantified.

9.4.4 Uncertainty Associated with Toxicity Reference Values

The EBSLs used in this assessment were developed from toxicity reference values (TRVs) that were revised based on EPA 1999 guidelines. Many uncertainties and unknowns are associated with the determination of these toxicity values. They include extrapolation from high to low doses and from individual laboratory species to multiple species living in a natural environment; species differences in uptake, metabolism, and organ distribution; and species differences in target site susceptibility. Uncertainty factors (UFs) are applied to the TRVs to ensure they are protective and provide a conservative estimate of risk.

9.4.5 Uncertainty Associated with Functional Groups

INL-specific functional groups were designed as an assessment tool that would ensure representatives from all species potentially present at the INL Site (VanHorn et al. 1995). A hypothetical species is developed using input values to the exposure assessment that represents the greatest exposure of the combined functional group members. This provides a very conservative approach and will tend to overestimate risk for actual individual species of ecological receptors.

10. REFERENCES

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Appendix A

LET&D and PEWE COPC Offgas Emission Rates (from INEEL 2003, ICP 2005a, ICP 2005b)

Appendix A

LET&D and PEWE COPC Offgas Emission Rates (from INEEL 2003, ICP 2005a, ICP 2005b)

Table A-1. LET&D "anion" emission rates from offgas measurements (INEEL 2003).

Analyte	CAS No.	Detect ? LET&D	Transport Data?	Retain as COPC?	Emission Rate (g/s)
Hydrogen chloride	7647-01-0	Yes	Yes	Yes	1.97E+00
Nitrate (as HNO_3)	7697-37-2	Yes	Yes	Yes	2.63E-01
Nitrite	14797-65-0	Yes	No	No	–
Fluoride (as HF)	7664-39-3	No	Yes	Yes	1.33E-03

Table A-2. LET&D metal emission rates from offgas measurements (INEEL 2003).

Analyte	CAS No.	Detect ? LET&D	Transport Data?	Retain as COPC?	Emission Rate (g/s)	
					Hourly	Annual
Aluminum	7429-90-5	Yes	Yes	Yes	1.10E-04	2.51E-05
Antimony	7440-36-0	No	Yes	Yes	5.08E-06	1.16E-06
Arsenic	7440-38-2	No	Yes	Yes	1.82E-06	4.16E-07
Barium	7440-39-3	Yes	Yes	Yes	1.00E-05	2.29E-06
Beryllium	7440-41-7	No	No	No	–	–
Cadmium	7440-43-9	No	Yes	Yes	3.57E-07	8.16E-08
Calcium	7440-70-2	Yes	No	No[a]	–	–
Chromium	7440-47-3	Yes	Yes	Yes	5.32E-04	1.21E-04
Cobalt	7440-48-4	No	No	No	–	–
Copper	7440-50-8	Yes	Yes	Yes	1.97E-05	4.49E-06
Iron	7439-89-6	Yes	No	No[a]	–	–
Lead	7439-92-1	Yes	Yes	Yes	2.68E-06	6.11E-07
Manganese	7439-96-5	Yes	Yes	Yes	8.01E-05	1.83E-05
Mercury	7439-97-6	Yes	Yes	Yes	6.84E-05	1.56E-05
Nickel	7440-02-0	Yes	Yes	Yes	3.04E-03	6.94E-04
Phosphorus	PHQ000	Yes	No	No[a]	–	–
Potassium	7440-09-7	Yes	No	No[a]	–	–
Selenium	7782-49-2	No	Yes	Yes	2.05E-06	4.69E-07
Silver	7440-22-4	No	Yes	Yes	2.33E-06	5.32E-07
Sodium	7440-23-5	Yes	No	No[a]	–	–
Thallium	7440-28-0	No	Yes	Yes	4.81E-06	1.10E-06
Vanadium	7440-62-2	No	No	No	–	–
Zinc	7440-66-6	Yes	Yes	Yes	1.47E-04	3.35E-05

a. No toxicity data; not toxic at trace environmental levels.

Table A-3. LET&D SVOC emission rates from offgas measurements (ICP 2005a).

Analyte	CAS No.	Detect ? LET&D	Transport Data?	Retain as COPC?	Emission Rate (g/s)	
					Hourly	Annual
Acenaphthene	83-32-9	No	Yes	Yes	9.03E-07	2.06E-07
Acenaphthylene	208-96-8	No	No	No	–	–
Acetophenone	98-86-2	No	Yes	Yes	2.68E-06	6.12E-07
Aniline	62-53-3	No	Yes	Yes	9.94E-06	2.27E-06
Anthracene	120-12-7	No	Yes	Yes	8.13E-07	1.86E-07
Benzaldehyde	100-52-7	No	Yes	Yes	1.76E-06	4.01E-07
Benzidine	92-87-5	No	No	No	–	–
Benzoic acid	65-85-0	Yes	Yes	Yes	7.32E-05	1.67E-05
Benzo(a)pyrene (BaP)	50-32-8	No	Yes	Yes	2.43E-06	5.54E-07
Benzo(a)anthracene	56-55-3	No	Yes	Yes	included in BaP	
Benzo(b)fluoranthene	205-99-2	No	Yes	Yes	included in BaP	
Benzo(k)fluoranthene	207-08-9	No	Yes	Yes	included in BaP	
Chrysene	218-01-9	No	Yes	Yes	included in BaP	
Dibenz(a,h)anthracene	53-70-3	No	Yes	Yes	included in BaP	
Indeno(1,2,3-cd)pyrene	193-39-5	No	Yes	Yes	included in BaP	
Benzo(ghi)perylene	191-24-2	No	No	No	–	–
Benzonitrile	100-47-0	No	No	No	–	–
Benzyl alcohol	100-51-6	No	Yes	Yes	1.81E-05	4.12E-06
bis(2-Chloroethoxy)methane	111-91-1	No	No	No	–	–
bis(2-Chloroethyl) ether	111-44-4	No	Yes	Yes	8.49E-07	1.94E-07
bis(2-Ethylhexyl) phthalate	117-81-7	Yes	Yes	Yes	2.62E-05	5.98E-06
4-Bromophenyl phenyl ether	101-55-3	No	Yes	Yes	7.32E-07	1.67E-07
Butyl benzyl phthalate	85-68-7	No	Yes	Yes	1.35E-06	3.09E-07
Carbazole	86-74-8	No	No	No	–	–
4-Chloro-3-methylphenol	59-50-7	No	Yes	Yes	2.44E-06	5.57E-07
4-Chloroaniline	106-47-8	No	Yes	Yes	5.78E-06	1.32E-06
2-Chloronaphthalene	91-58-7	No	Yes	Yes	7.23E-07	1.65E-07
2-Chlorophenol	95-57-8	No	Yes	Yes	8.22E-07	1.88E-07
4-Chlorophenyl phenyl ether	7005-72-36	No	No	No	–	–
Di-n-butyl phthalate	84-74-2	No	Yes	Yes	4.61E-06	1.05E-06
Di-n-octyl phthalate	117-84-0	No	Yes	Yes	1.08E-06	2.47E-07
Dibenzofuran	132-64-9	No	No	No	–	–
1,2-Dichlorobenzene	95-50-1	No	Yes	Yes	Included in VOCs	
1,3-Dichlorobenzene	541-73-1	No	Yes	Yes	Included in VOCs	
1,4-Dichlorobenzene	106-46-7	No	Yes	Yes	Included in VOCs	
3,3'-Dichlorobenzidine	91-94-1	No	Yes	Yes	6.32E-06	1.44E-06

Table A-3. (continued).

Analyte	CAS No.	Detect ? LET&D	Transport Data?	Retain as COPC?	Emission Rate (g/s)	
					Hourly	Annual
2,4-Dichlorophenol	120-83-2	No	Yes	Yes	1.02E-06	2.32E-07
Diethyl phthalate	84-66-2	No	Yes	Yes	8.31E-07	1.90E-07
Dimethyl phthalate	105-67-9	No	Yes	Yes	6.96E-07	1.59E-07
2,4-Dimethylphenol	131-11-3	No	Yes	Yes	2.53E-06	5.77E-07
4,6-Dinitro-2-methylphenol	534-52-1	No	No	No	–	–
2,4-Dinitrophenol	51-28-5	No	Yes	Yes	1.08E-05	2.47E-06
2,4-Dinitrotoluene	121-14-2	No	Yes	Yes	1.35E-06	3.09E-07
2,6-Dinitrotoluene	606-20-2	No	Yes	Yes	9.25E-07	2.11E-07
1,2-Diphenylhydrazine	122-66-7	No	No	No	–	–
Fluoranthene	206-44-0	No	Yes	Yes	8.67E-07	1.98E-07
Fluorene	86-73-7	No	Yes	Yes	1.17E-06	2.68E-07
Hexachlorocyclopentadiene	77-47-4	No	Yes	Yes	7.41E-06	1.69E-06
Hexachlorobenzene	118-74-1	No	Yes	Yes	1.17E-06	2.68E-07
Hexachlorobutadiene	87-68-3	No	Yes	Yes	Included in VOCs	
Hexachloroethane	67-72-1	No	Yes	Yes	9.03E-07	2.06E-07
Isophorone	78-59-1	No	Yes	Yes	8.58E-07	1.96E-07
2-Methylnaphthalene	91-57-6	No	No	No	–	–
2-Methylphenol	95-48-7	No	Yes	Yes	2.26E-06	5.16E-07
3-Methylphenol & 4-Methylphenol	65794-96-9	No	No	No	–	–
N-Nitrosodi-n-propylamine	621-64-7	No	Yes	Yes	9.94E-07	2.27E-07
N-Nitrosodimethylamine	62-75-9	Yes	Yes	Yes	2.38E-04	5.43E-05
N-Nitrosodiphenylamine	86-30-6	No	Yes	Yes	8.94E-07	2.04E-07
Naphthalene	91-20-3	No	Yes	Yes	9.03E-07	2.06E-07
2-Nitroaniline	88-74-4	No	Yes	Yes	1.17E-06	2.68E-07
3-Nitroaniline	99-09-2	No	Yes	Yes	2.59E-06	5.91E-07
4-Nitroaniline	100-01-6	No	Yes	Yes	2.26E-06	5.16E-07
Nitrobenzene	98-95-1	No	Yes	Yes	1.48E-06	3.38E-07
2-Nitrophenol	88-75-5	No	No	No	–	–
4-Nitrophenol	100-02-7	No	Yes	Yes	4.34E-06	9.90E-07
2,2'-Oxybis(1-Chloropropane)	108-60-1	No	No	No	–	–
Pentachlorobenzene	608-93-5	No	Yes	Yes	9.94E-07	2.27E-07
Pentachloronitrobenzene	82-68-8	No	Yes	Yes	1.17E-06	2.68E-07
Pentachlorophenol	87-86-5	No	Yes	Yes	1.08E-05	2.47E-06
Phenanthrene	85-01-8	No	Yes	No	8.94E-07	2.04E-07
Phenol	108-95-2	No	Yes	Yes	1.20E-06	2.75E-07
Pyrene	129-00-0	No	Yes	Yes	7.50E-07	1.71E-07
Pyridine	110-86-1	No	No	No	–	–

Table A-3. (continued).

Analyte	CAS No.	Detect ? LET&D	Transport Data?	Retain as COPC?	Emission Rate (g/s) Hourly	Annual
1,2,4,5-Tetrachlorobenzene	95-94-3	No	No	No	–	–
1,2,4-Trichlorobenzene	120-82-1	No	Yes	Yes	Included in VOCs	
2,4,5-Trichlorophenol	95-95-4	No	Yes	Yes	1.35E-06	3.09E-07
2,4,6-Trichlorophenol	88-06-2	No	Yes	Yes	1.17E-06	2.68E-07

Table A-4. LET&D VOC emission rates from offgas measurements (ICP 2005a).

Analyte	CAS No.	Detect ? LET&D	Risk factor avail?	Transport Data?	Emission Rate (g/s) Hourly	Annual
Acetaldehyde	75-07-0	No	Yes	Yes	1.02E-05	2.33E-06
Acetone	67-64-1	Yes	Yes	Yes	7.13E-04	1.63E-04
Acrylonitrile	107-13-1	No	Yes	Yes	4.57E-06	1.04E-06
Benzene	71-43-2	No	Yes	Yes	3.70E-07	8.45E-08
Bromobenzene	108-86-1	No	Yes	Yes	2.12E-07	4.84E-08
Bromochloromethane	74-97-5	No	No	No	–	–
Bromodichloromethane	75-27-4	No	Yes	Yes	7.83E-07	1.79E-07
Bromoform	75-25-2	No	Yes	Yes	2.61E-07	5.96E-08
Bromomethane	74-83-9	No	Yes	Yes	8.09E-07	1.85E-07
2-Butanone (MEK)	78-93-3	No	Yes	Yes	3.40E-06	7.77E-07
n-Butylbenzene	104-51-8	No	No	No	–	–
sec-Butylbenzene	135-98-8	No	No	No	–	–
tert-Butylbenzene	98-06-6	No	No	No	–	–
Carbon disulfide	75-15-0	No	Yes	Yes	1.79E-07	4.10E-08
Carbon tetrachloride	56-23-5	No	Yes	Yes	2.49E-07	5.68E-08
Chlorobenzene	108-90-7	No	Yes	Yes	2.05E-07	4.67E-08
Chlorodibromomethane	124-48-1	No	Yes	Yes	3.59E-07	8.20E-08
Chloroethane	75-00-3	No	Yes	Yes	4.77E-07	1.09E-07
Chloroform	67-66-3	Yes	Yes	Yes	8.25E-06	1.88E-06
Chloromethane	74-87-3	Yes	Yes	Yes	6.72E-06	1.53E-06
2-Chlorotoluene	95-49-8	No	No	No	–	–
4-Chlorotoluene	106-43-4	No	No	No	–	–
1,2-Dibromo-3-chloropropane	96-12-8	No	Yes	Yes	7.51E-07	1.71E-07
1,2-Dibromoethane (EDB)	106-93-4	No	Yes	Yes	3.18E-07	7.26E-08
Dibromomethane	75-95-3	No	Yes	Yes	3.34E-07	7.64E-08
1,2-Dichlorobenzene	95-50-1	No	Yes	Yes	2.04E-07	4.66E-08
1,3-Dichlorobenzene	541-73-1	No	Yes	Yes	2.12E-07	4.84E-08
1,4-Dichlorobenzene	106-46-7	No	Yes	Yes	2.53E-07	5.77E-08
Dichlorodifluoromethane	75-71-8	No	Yes	Yes	2.45E-07	5.59E-08

Table A-4. (continued).

Analyte	CAS No.	Detect ? LET&D	Risk factor avail?	Transport Data?	Emission Rate (g/s) Hourly	Emission Rate (g/s) Annual
1,1-Dichloroethane	75-34-3	No	Yes	Yes	1.85E-07	4.23E-08
1,2-Dichloroethane	107-06-2	No	Yes	Yes	1.88E-07	4.28E-08
1,1-Dichloroethene	75-35-4	No	Yes	Yes	2.24E-07	5.11E-08
cis-1,2-Dichloroethene	156-59-2	No	Yes	Yes	2.12E-07	4.84E-08
trans-1,2-Dichloroethene	156-60-5	No	Yes	Yes	1.71E-07	3.91E-08
1,2-Dichloropropane	78-87-5	No	Yes	Yes	1.88E-07	4.28E-08
1,3-Dichloropropane	142-28-9	No	No	No	–	–
2,2-Dichloropropane	594-20-7	No	No	No	–	–
1,1-Dichloropropene	563-58-6	No	No	No	–	–
cis-1,3-Dichloropropene	542-75-6	No	Yes	Yes	1.66E-07	3.78E-08
trans-1,3-Dichloropropene	10061-02-6	No	No	No	–	–
Ethylbenzene	100-41-4	No	Yes	Yes	1.63E-07	3.73E-08
Hexachlorobutadiene	87-68-3	No	Yes	Yes	1.96E-07	4.47E-08
2-Hexanone	591-78-6	No	No	No	–	–
Isopropylbenzene	98-82-8	No	No	No	–	–
p-Isopropyltoluene	99-87-6	No	No	No	–	–
Methylene chloride	75-09-2	Yes	Yes	Yes	5.22E-05	1.19E-05
4-Methyl-2-pentanone (MIBK)	108-10-1	No	Yes	Yes	8.97E-07	2.05E-07
Naphthalene	91-20-3	No	Yes	Yes	2.94E-07	6.71E-08
n-Propylbenzene	103-65-1	No	No	No	–	–
Styrene	100-42-5	No	Yes	Yes	1.88E-07	4.28E-08
1,1,1,2-Tetrachloroethane	630-20-6	No	Yes	Yes	2.04E-07	4.66E-08
1,1,2,2-Tetrachloroethane	79-34-5	No	Yes	Yes	2.77E-07	6.33E-08
Tetrachloroethene	127-18-4	No	Yes	Yes	1.91E-07	4.35E-08
Toluene	108-88-3	No	Yes	Yes	1.96E-07	4.47E-08
1,2,3-Trichlorobenzene	87-61-6	No	No	No	–	–
1,2,4-Trichlorobenzene	120-82-1	No	Yes	Yes	2.69E-07	6.15E-08
1,1,1-Trichloroethane	71-55-6	No	Yes	Yes	1.96E-07	4.47E-08
1,1,2-Trichloroethane	79-00-5	No	Yes	Yes	3.59E-07	8.20E-08
Trichloroethene	79-01-6	No	Yes	Yes	2.69E-07	6.15E-08
Trichlorofluoromethane	75-69-4	No	Yes	Yes	2.77E-07	6.33E-08
1,2,3-Trichloropropane	96-18-4	No	Yes	Yes	5.47E-07	1.25E-07
1,2,4-Trimethylbenzene	95-63-6	No	No	No	–	–
1,3,5-Trimethylbenzene	108-67-8	No	No	No	–	–
Vinyl chloride	75-01-4	No	Yes	Yes	3.10E-07	7.08E-08
o-Xylene	95-47-6	No	Yes	Yes	2.37E-07	5.40E-08
m-Xylene & p-Xylene	108-38-3	No	Yes	Yes	3.34E-07	7.64E-08

Table A-5. PEWE "anion" emission rates from offgas measurements (ICP 2005b).

Analyte	CAS No.	Detect PEWE?	Transport Data?	Retain as COPC?	Emission Rate (g/s)
Hydrogen chloride	7647-01-0	Yes	Yes	Yes	2.21E-07
Chlorine	7782-50-5	Yes	Yes	Yes	2.35E-07
Nitrate (as HNO_3)	7697-37-2	Yes	Yes	Yes	3.96E-05
Fluoride (as HF)	7664-39-3	No	Yes	Yes	5.41E-07

Table A-6. PEWE metal emission rates from offgas measurements (ICP 2005b).

Analyte	CAS No.	Detect - PEWE?	Transport Data?	Retain as COPC?	Emission Rate (g/s)	
					Hourly	Annual
Aluminum	7429-90-5	Yes	Yes	Yes	3.35E-08	7.66E-09
Antimony	7440-36-0	No	Yes	Yes	3.10E-10	7.08E-11
Arsenic	7440-38-2	No	Yes	Yes	3.59E-10	8.20E-11
Barium	7440-39-3	Yes	Yes	Yes	4.37E-09	9.97E-10
Beryllium	7440-41-7	No	Yes	Yes	2.32E-10	5.30E-11
Cadmium	7440-43-9	No	Yes	Yes	1.28E-10	2.92E-11
Calcium	7440-70-2	Yes	No	No[a]	–	–
Chromium	7440-47-3	Yes	Yes	Yes	2.83E-09	6.47E-10
Cobalt	7440-48-4	No	No	No	–	–
Copper	7440-50-8	Yes	Yes	Yes	1.70E-09	3.89E-10
Iron	7439-89-6	Yes	No	No[a]	–	–
Lead	7439-92-1	Yes	Yes	Yes	2.30E-10	5.25E-11
Manganese	7439-96-5	Yes	Yes	Yes	4.06E-10	9.26E-11
Mercury	7439-97-6	Yes	Yes	Yes	9.06E-09	2.07E-09
Nickel	7440-02-0	Yes	Yes	Yes	2.00E-09	4.56E-10
Phosphorus	PHQ000	Yes	No	No[a]	–	–
Potassium	7440-09-7	Yes	No	No[a]	–	–
Selenium	7782-49-2	No	Yes	Yes	3.74E-10	8.55E-11
Silver	7440-22-4	No	Yes	Yes	3.27E-10	7.47E-11
Sodium	7440-23-5	Yes	No	No[a]	–	–
Thallium	7440-28-0	No	Yes	Yes	8.80E-10	2.01E-10
Vanadium	7440-62-2	No	No	No	–	–
Zinc	7440-66-6	Yes	Yes	Yes	7.63E-09	1.74E-09

a. No toxicity data; not toxic at trace environmental levels.

Table A-7. PEWE SVOC emission rates from offgas measurements (ICP 2005b).

Analyte	CAS No.	Detect - PEWE?	Transport Data?	Retain as COPC?	Emission Rate (g/s)	
					Hourly	Annual
Acenaphthene	83-32-9	No	Yes	Yes	4.04E-09	9.23E-10
Acenaphthylene	208-96-8	No	No	No	–	–
Acetophenone	98-86-2	No	Yes	Yes	1.62E-08	3.69E-09
Aniline	62-53-3	No	Yes	Yes	5.01E-08	1.14E-08
Anthracene	120-12-7	No	Yes	Yes	3.80E-09	8.68E-10
Benzaldehyde	100-52-7	No	Yes	Yes	1.48E-08	3.37E-09
Benzidine	92-87-5	No	No	No	–	–
Benzoic acid	65-85-0	No	Yes	Yes	2.62E-07	5.97E-08
Benzo(a)pyrene (BaP)	50-32-8	No	Yes	Yes	1.20E-08	2.74E-09
Benzo(a)anthracene	56-55-3	No	Yes	Yes	included in BaP	
Benzo(b)fluoranthene	205-99-2	No	Yes	Yes	included in BaP	
Benzo(k)fluoranthene	207-08-9	No	Yes	Yes	included in BaP	
Chrysene	218-01-9	No	Yes	Yes	included in BaP	
Dibenz(a,h)anthracene	53-70-3	No	Yes	Yes	included in BaP	
Indeno(1,2,3-cd)pyrene	193-39-5	No	Yes	Yes	included in BaP	
Benzo(ghi)perylene	191-24-2	No	No	No	–	–
Benzonitrile	100-47-0	No	No	No	–	–
Benzyl alcohol	100-51-6	No	Yes	Yes	2.38E-07	5.43E-08
bis(2-Chloroethoxy)methane	111-91-1	No	No	No	–	–
bis(2-Chloroethyl) ether	111-44-4	No	Yes	Yes	4.52E-09	1.03E-09
bis(2-Ethylhexyl) phthalate	117-81-7	Yes	Yes	Yes	1.40E-07	3.20E-08
4-Bromophenyl phenyl ether	101-55-3	No	Yes	Yes	3.80E-09	8.68E-10
Butyl benzyl phthalate	85-68-7	No	Yes	Yes	5.23E-09	1.19E-09
Carbazole	86-74-8	No	No	No	–	–
4-Chloro-3-methylphenol	59-50-7	No	Yes	Yes	6.18E-09	1.41E-09
4-Chloroaniline	106-47-8	No	Yes	Yes	4.04E-08	9.23E-09
2-Chloronaphthalene	91-58-7	No	Yes	Yes	3.80E-09	8.68E-10
2-Chlorophenol	95-57-8	No	Yes	Yes	4.05E-09	9.25E-10
4-Chlorophenyl phenyl ether	7005-72-36	No	No	No	–	–
Di-n-butyl phthalate	84-74-2	No	Yes	Yes	4.75E-08	1.09E-08
Di-n-octyl phthalate	117-84-0	No	Yes	Yes	5.48E-09	1.25E-09
Dibenzofuran	132-64-9	No	No	No	–	–
1,2-Dichlorobenzene	95-50-1	No	Yes	Yes	Included in VOCs	

Table A-7. (continued).

Analyte	CAS No.	Detect - PEWE?	Transport Data?	Retain as COPC?	Emission Rate (g/s)	
					Hourly	Annual
1,3-Dichlorobenzene	541-73-1	No	Yes	Yes	Included in VOCs	
1,4-Dichlorobenzene	106-46-7	No	Yes	Yes	Included in VOCs	
3,3'-Dichlorobenzidine	91-94-1	No	Yes	Yes	4.99E-08	1.14E-08
2,4-Dichlorophenol	120-83-2	No	Yes	Yes	4.75E-09	1.09E-09
Diethyl phthalate	84-66-2	No	Yes	Yes	5.94E-09	1.36E-09
Dimethyl phthalate	105-67-9	No	Yes	Yes	3.80E-09	8.68E-10
2,4-Dimethylphenol	131-11-3	No	Yes	Yes	2.62E-08	5.97E-09
4,6-Dinitro-2-methylphenol	534-52-1	No	No	No	–	–
2,4-Dinitrophenol	51-28-5	No	Yes	Yes	1.24E-07	2.82E-08
2,4-Dinitrotoluene	121-14-2	No	Yes	Yes	4.77E-09	1.09E-09
2,6-Dinitrotoluene	606-20-2	No	Yes	Yes	4.52E-09	1.03E-09
1,2-Diphenylhydrazine	122-66-7	No	No	No	–	–
Fluoranthene	206-44-0	No	Yes	Yes	4.05E-09	9.25E-10
Fluorene	86-73-7	No	Yes	Yes	4.05E-09	9.25E-10
Hexachlorocyclopentadiene	77-47-4	No	Yes	Yes	7.13E-08	1.63E-08
Hexachlorobenzene	118-74-1	No	Yes	Yes	4.28E-09	9.77E-10
Hexachlorobutadiene	87-68-3	No	Yes	Yes	Included in VOCs	
Hexachloroethane	67-72-1	No	Yes	Yes	5.48E-09	1.25E-09
Isophorone	78-59-1	No	Yes	Yes	5.01E-09	1.14E-09
2-Methylnaphthalene	91-57-6	No	No	No	–	–
2-Methylphenol	95-48-7	No	Yes	Yes	2.07E-08	4.73E-09
3-Methylphenol & 4-Methylphenol	65794-96-9	No	No	No	–	–
N-Nitrosodi-n-propylamine	621-64-7	No	Yes	Yes	4.28E-09	9.77E-10
N-Nitrosodimethylamine	62-75-9	No	Yes	Yes	1.28E-08	2.93E-09
N-Nitrosodiphenylamine	86-30-6	No	Yes	Yes	3.80E-09	8.68E-10
Naphthalene	91-20-3	No	Yes	Yes	4.52E-09	1.03E-09
2-Nitroaniline	88-74-4	No	Yes	Yes	4.28E-09	9.77E-10
3-Nitroaniline	99-09-2	No	Yes	Yes	1.62E-08	3.70E-09
4-Nitroaniline	100-01-6	No	Yes	Yes	1.50E-08	3.43E-09
Nitrobenzene	98-95-1	No	Yes	Yes	4.52E-09	1.03E-09
2-Nitrophenol	88-75-5	No	No	No	–	–
4-Nitrophenol	100-02-7	No	Yes	Yes	2.38E-08	5.43E-09
2,2'-Oxybis(1-Chloropropane)	108-60-1	No	No	No	–	–
Pentachlorobenzene	608-93-5	No	Yes	Yes	4.04E-09	9.23E-10

Table A-7. (continued).

Analyte	CAS No.	Detect - PEWE?	Transport Data?	Retain as COPC?	Emission Rate (g/s)	
					Hourly	Annual
Pentachloronitrobenzene	82-68-8	No	Yes	Yes	4.28E-09	9.77E-10
Pentachlorophenol	87-86-5	No	Yes	Yes	1.33E-07	3.04E-08
Phenanthrene	85-01-8	No	No	No	–	–
Phenol	108-95-2	No	Yes	Yes	6.89E-09	1.57E-09
Pyrene	129-00-0	No	Yes	Yes	4.05E-09	9.25E-10
Pyridine	110-86-1	No	No	No	–	–
1,2,4,5-Tetrachlorobenzene	95-94-3	No	No	No	–	–
1,2,4-Trichlorobenzene	120-82-1	No	Yes	Yes	Included in VOCs	
2,4,5-Trichlorophenol	95-95-4	No	Yes	Yes	1.02E-08	2.33E-09
2,4,6-Trichlorophenol	88-06-2	No	Yes	Yes	1.18E-03	5.91E-04

Table A-8. PEWE VOC emission rates from offgas measurements (ICP 2005b).

Analyte	CAS No.	Detect - PEWE?	Transport Data?	Retain as COPC?	Emission Rate (g/s)	
					Hourly	Annual
Acetaldehyde	75-07-0	No	Yes	Yes	4.21E-08	9.60E-09
Acetone	67-64-1	Yes	Yes	Yes	8.66E-07	1.98E-07
Acrylonitrile	107-13-1	No	Yes	Yes	2.09E-08	4.76E-09
Benzene	71-43-2	No	Yes	Yes	8.60E-09	1.96E-09
Bromobenzene	108-86-1	No	Yes	Yes	1.13E-09	2.58E-10
Bromochloromethane	74-97-5	No	No	No	–	–
Bromodichloromethane	75-27-4	No	Yes	Yes	1.07E-09	2.45E-10
Bromoform	75-25-2	No	Yes	Yes	1.30E-09	2.98E-10
Bromomethane	74-83-9	No	Yes	Yes	1.83E-09	4.17E-10
2-Butanone (MEK)	78-93-3	No	Yes	Yes	8.52E-08	1.94E-08
n-Butylbenzene	104-51-8	No	No	No	–	–
sec-Butylbenzene	135-98-8	No	No	No	–	–
tert-Butylbenzene	98-06-6	No	No	No	–	–
Carbon disulfide	75-15-0	No	Yes	Yes	8.60E-10	1.96E-10
Carbon tetrachloride	56-23-5	No	Yes	Yes	8.69E-10	1.98E-10
Chlorobenzene	108-90-7	No	Yes	Yes	8.66E-10	1.98E-10
Chlorodibromomethane	124-48-1	No	No	Yes	8.69E-10	1.98E-10
Chloroethane	75-00-3	No	Yes	Yes	2.10E-09	4.80E-10
Chloroform	67-66-3	No	Yes	Yes	4.69E-09	1.07E-09

Table A-8. (continued).

Analyte	CAS No.	Detect - PEWE?	Transport Data?	Retain as COPC?	Emission Rate (g/s)	
					Hourly	Annual
Chloromethane	74-87-3	No	Yes	Yes	1.61E-09	3.67E-10
2-Chlorotoluene	95-49-8	No	No	No	—	—
4-Chlorotoluene	106-43-4	No	No	No	—	—
1,2-Dibromo-3-chloropropane	96-12-8	No	Yes	Yes	3.39E-09	7.74E-10
1,2-Dibromoethane (EDB)	106-93-4	No	Yes	Yes	9.56E-10	2.18E-10
Dibromomethane	74-95-3	No	Yes	Yes	1.39E-09	3.17E-10
1,2-Dichlorobenzene	95-50-1	No	Yes	Yes	1.13E-09	2.58E-10
1,3-Dichlorobenzene	541-73-1	No	Yes	Yes	1.30E-09	2.98E-10
1,4-Dichlorobenzene	106-46-7	No	Yes	Yes	1.48E-09	3.37E-10
Dichlorodifluoromethane	75-71-8	No	Yes	Yes	1.13E-09	2.58E-10
1,1-Dichloroethane	75-34-3	No	Yes	Yes	7.92E-10	1.81E-10
1,2-Dichloroethane	107-06-2	No	Yes	Yes	1.04E-09	2.38E-10
1,1-Dichloroethene	75-35-4	No	Yes	Yes	1.13E-09	2.58E-10
cis-1,2-Dichloroethene	156-59-2	No	Yes	Yes	1.04E-09	2.38E-10
trans-1,2-Dichloroethene	156-60-5	No	Yes	Yes	7.91E-10	1.81E-10
1,2-Dichloropropane	78-87-5	No	Yes	Yes	9.56E-10	2.18E-10
1,3-Dichloropropane	142-28-9	No	No	No	—	—
2,2-Dichloropropane	594-20-7	No	No	No	—	—
1,1-Dichloropropene	563-58-6	No	No	No	—	—
cis-1,3-Dichloropropene	542-75-6	No	Yes	Yes	8.08E-10	1.85E-10
trans-1,3-Dichloropropene	10061-02-6	No	No	No	—	—
Ethylbenzene	100-41-4	No	Yes	Yes	6.78E-10	1.55E-10
Hexachlorobutadiene	87-68-3	No	Yes	Yes	8.60E-10	1.96E-10
2-Hexanone	591-78-6	No	No	No	—	—
Isopropylbenzene	98-82-8	No	No	No	—	—
p-Isopropyltoluene	99-87-6	No	No	No	—	—
Methylene chloride	75-09-2	Yes	Yes	Yes	9.77E-08	2.23E-08
4-Methyl-2-pentanone (MIBK)	108-10-1	No	Yes	Yes	6.18E-09	1.41E-09
Naphthalene	91-20-3	No	Yes	Yes	1.39E-09	3.17E-10
n-Propylbenzene	103-65-1	No	No	No	—	—
Styrene	100-42-5	No	Yes	Yes	9.56E-10	2.18E-10
1,1,1,2-Tetrachloroethane	630-20-6	No	Yes	Yes	9.56E-10	2.18E-10
1,1,2,2-Tetrachloroethane	79-34-5	No	Yes	Yes	1.39E-09	3.17E-10
Tetrachloroethene	127-18-4	No	Yes	Yes	8.69E-10	1.98E-10

Table A-8. (continued).

Analyte	CAS No.	Detect - PEWE?	Transport Data?	Retain as COPC?	Emission Rate (g/s)	
					Hourly	Annual
Toluene	108-88-3	No	Yes	Yes	5.19E-09	1.19E-09
1,2,3-Trichlorobenzene	87-61-6	No	No	No	–	–
1,2,4-Trichlorobenzene	120-82-1	No	Yes	Yes	1.39E-09	3.17E-10
1,1,1-Trichloroethane	71-55-6	No	Yes	Yes	1.22E-09	2.80E-10
1,1,2-Trichloroethane	79-00-5	No	Yes	Yes	1.30E-09	2.98E-10
Trichloroethene	79-01-6	No	Yes	Yes	1.83E-09	4.17E-10
Trichlorofluoromethane	75-69-4	No	Yes	Yes	1.61E-09	3.68E-10
1,2,3-Trichloropropane	96-18-4	No	Yes	Yes	2.09E-09	4.76E-10
1,2,4-Trimethylbenzene	94-63-6	No	No	No	–	–
1,3,5-Trimethylbenzene	108-67-8	No	No	No	–	–
Vinyl chloride	75-01-4	No	Yes	Yes	8.17E-10	1.87E-10
o-Xylene	95-47-6	No	Yes	Yes	1.13E-09	2.57E-10
m-Xylene & p-Xylene	108-38-3	No	Yes	Yes	1.48E-09	3.37E-10

Appendix B

Equations and Parameter Values
EPA Human Health Risk Assessment Protocol

(HHRAP – EPA520-R-05-006)
Source: http://www.epa.gov/epaoswer/hazwaste/combust/risk.htm

Appendix B

Equations and Parameter Values
EPA Human Health Risk Assessment Protocol

(HHRAP – EPA520-R-05-006
Source: http:www.epa.gov/epaoswer/haswaste/combust/risk.htm

B-1. Media Concentration Equations – HHRAP Appendix B (See Section B-3 for parameter definitions and units.)

Cumulative soil concentration (Cs) for carcinogens:

For T_2<tD (child, farmer child scenarios):

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

For T_1<tD<T_2 (adult, farmer scenarios):

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

Cumulative soil concentration (Cs) for noncarcinogens:

$$Cs_{tD} = \frac{D_s \cdot (1 - \exp[-ks \cdot tD)])}{ks} .$$

Soil loss constant as recommended by EPA OSW:

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

Soil loss constant resulting from erosion (conservatively assumed to be 0 at INL):

$$kse = \frac{0.1 \cdot X_e \cdot SD \cdot ER}{BD \cdot Z_s} \cdot \frac{Kd_s \cdot BD}{\theta_{sw} + (Kd_s \cdot BD)} .$$

Soil loss constant due to runoff (conservatively assumed to be 0 at INL):

$$ksr = \frac{RO}{\theta_{sw} \cdot Z_s} \cdot \left(\frac{1}{1 + (Kd_S \cdot BD / \theta_{sw})}\right) .$$

Leach rate constant:

$$ksl = \frac{P + I - RO - Ev}{\theta_{sw} \cdot Z_s \cdot [1.0 + (BD \cdot Kd_s / \theta_{sw})]} \quad .$$

Volatilization loss rate constant:

$$ksv = \left(\frac{3.1536 \times 10^7 \cdot H}{Z_s \cdot Kd_s \cdot R \cdot T_a \cdot BD}\right) \cdot \left(\frac{D_a}{Z_s}\right) \cdot \left[1 - \left(\frac{BD}{\rho_{soil}}\right) - \theta_{sw}\right] \quad .$$

Deposition Term (HHRAP Draft equation – used for ISC-PRIME runs):

$$Ds = \left[\frac{100 \cdot Q}{Z_s \cdot BD}\right] \cdot [F_v \cdot (0.31536 \cdot Vdv \cdot Cyv + Dywv) + (Dydp + Dywp) \cdot (1 - F_v)] \quad .$$

Deposition Term (2005 HHRAP equation):

$$Ds = \left[\frac{100 \cdot Q}{Z_s \cdot BD}\right] \cdot [F_v \cdot (Dydv + Dywv) + (Dydp + Dywp) \cdot (1 - F_v)] \quad .$$

Mercury Deposition Term (2005 HHRAP equation):

$$Ds = \left[\frac{100 \cdot (0.48\ Q_{total})}{Z_s \cdot BD}\right] \cdot [F_v \cdot (Dydv + Dywv) + (Dydp + Dywp) \cdot (1 - F_v)] \quad .$$

Recommended values for Soil Mixing Depth (Z_s):

1cm – untilled

20cm – tilled.

Recommended values for Soil Dry Bulk Density (BD):

1.50 g/cm^3.

Recommended value for soil volumetric water content:

0.2 mL/cm^3.

Aboveground produce concentration due to direct deposition:

$$Pd = \frac{1000 \cdot Q \cdot (1 - F_v) \cdot [Dydp + (Fw \cdot Dywp)] \cdot Rp \cdot [1.0 - \exp(-kp \cdot Tp)]}{Yp \cdot kp} \quad .$$

Recommended value for interception fraction of the edible portion of plant (Rp):

0.39.

Calculating the measure of the amount of contaminant that is lost to physical processes over time:

$$kp = \left(\frac{\ln 2}{t_{1/2}}\right) \cdot 365 \quad .$$

Recommended value for plant surface loss coefficient (kp):

18.

Length of plant exposure to deposition per harvest of the edible portion of plant:

$$Tp = \frac{60 days}{365 days / yr} = 0.164 \ yr \quad .$$

Standing crop biomass (productivity):

$$Yp = \frac{Yh_i}{Ah_i} \quad .$$

Recommended values for standing crop biomass (productivity)(Yp):

Crops = 2.24 kg DW/m^2

Forage = 0.24 kg DW/m^2

Silage = 0.8 kg DW/m^2.

Aboveground produce concentration due to air-to-plant transfer:

$$Pv = Q \cdot F_v \cdot \frac{Cyv \cdot Bv_{ag} \cdot VG_{ag}}{\rho_a} \quad .$$

Correction factor for below ground produce:

$$VG_{rootveg} = \frac{M_{skin}}{M_{veg}} \quad .$$

Recommended values for Empirical Correction Factor for aboveground produce (VG_{ag}):

0.01 for COPCs with a log K_{ow} greater than 4

1.0 for COPCs with a log K_{ow} less than 4.

Produce concentration due to root uptake:

Exposed and protected aboveground produce:

$$Pr_{ag} = Cs \cdot Br \quad .$$

Belowground produce:

$$Pr_{bg} = \frac{Cs \cdot RCF \cdot VG_{rootveg}}{Kd_s \cdot 1\,kg/L} \quad .$$

Recommended values for empirical correction factor for belowground produce ($VG_{rootveg}$):

0.001 for COPCs with a log K_{ow} greater than 4

1.0 for COPCs with a log K_{ow} less than 4.

Recommended value for interception fraction of the edible portion of plant (Rp):

Forage = 0.5

Silage = 0.46.

Length of plant exposure to deposition per harvest of the edible portion of plant (Tp):

Considers the average of:

1. Average period between successive hay harvests
2. Average period between successive grazing.

$$Tp = \frac{0.5 \cdot (60\ days + 30\ days)}{365\ days/yr} = 0.12\ yr \quad .$$

Recommended value for plant exposure length to deposition per harvest of the edible portion of plant (Tp):

Forage = 0.12 yr

Silage = 0.16 yr.

Recommended values for empirical correction factor for forage and silage (VG_{ag}):

Forage = 1

Silage = 0.5.

COPC Concentration in beef:

$$A_{beef} = (\Sigma\ (F_i \cdot Qp_i \cdot P_i) + Qs \cdot Cs \cdot Bs) \cdot Ba_{beef} \cdot MF \quad .$$

Recommended value for fraction of plant type *i* grown on contaminated soil and eaten by the animal (cattle) (F_i) = 1.

Recommended values for quantity of plant type *i* eaten by the animal (cattle) each day (Qp_i):

Forage = 8.8 kg DW/day

Silage = 2.5 kg DW/day

Grain = 0.47 kg DW/day.

COPC concentration in plant type *i* eaten by the animal (cattle):

$$P_i = (Pd + Pv + Pr) \quad .$$

Recommended value for quantity of soil ingested by the animal (cattle) per day (Qs):

0.5 kg/day.

Recommended values for soil bioavailability factor (Bs):

1.0.

COPC concentration in milk:

$$A_{milk} = (\Sigma \ (F_i \cdot Qp_i \cdot P_i) + Qs \cdot Cs \cdot Bs) \cdot Ba_{milk} \cdot MF \quad .$$

Recommended values for quantity of plant type *i* eaten by the animal (dairy cattle) per day (Qp_i):

Forage = 13.2 kg DW/day

Silage = 4.1 kg DW/day

Grain = 3.0 kg DW/day.

Recommended values for quantity of soil eaten by the animal (dairy cattle) per day (Qs):

0.4 kg/day.

COPC concentration in pork:

$$A_{pork} = (\Sigma \ (F_i \cdot Qp_i \cdot P_i) + Qs \cdot Cs \cdot Bs) \cdot Ba_{pork} \cdot MF \quad .$$

Recommended values for quantity of plant type *i* eaten by the animal (swine) each day (Qp_i):

Grain = 3.3 kg DW/day

Silage = 1.4 kg DW/day.

Recommended value for quantity of soil eaten by the animal (swine) each day (Qs):

0.37 kg DW/day.

COPC concentration in chicken and eggs:

$$A_{chicken} \text{ or } A_{egg} = (\Sigma\ [F_i \cdot Qp_i \cdot Pi] + Qs \cdot Cs \cdot Bs) \cdot (Ba_{egg} \text{ or } Ba_{chicken}) \ .$$

Recommended value for quantity of plant type i eaten by the animal (chicken) each day (Qp_i):

Grain = 0.2 kg DW/day.

Recommended equation for calculating concentration of COPC in plant type i eaten by the animal (chicken):

$$Pi = \Sigma_i(Pr) \ .$$

Recommended value for quantity of soil eaten by the animal (chicken) each day (Qs):

0.022 kg DW/day.

Air Concentration (Direct Inhalation Equation):

$$C_a = Q \cdot [F_v \cdot Cyv + (1.0 - F_v) \cdot Cyp]$$

$$Hg^0: \quad C_a = 0.002 \cdot Q[Fv \cdot Cyv + (1.0 - Fv) \cdot Cyp]$$

$$Hg^{2+}: \quad C_a = 0.48 \cdot Q[Fv \cdot Cyv + (1.0 - Fv) \cdot Cyp] \ .$$

B-2. Intake and Risk Characterization Equations – HHRAP Appendix C

COPC intake from soil:

$$I_{soil} = \frac{Cs \cdot CR \cdot F_{soil}}{BW} \ .$$

COPC intake from produce:

$$I_{ag} = \left[\left((Pd + Pv + Pr) \cdot CR_{ag}\right) + \left(Pr \cdot CR_{pp}\right) + \left(Pr_{bg} \cdot Cr_{bg}\right)\right] \cdot F_{ag} \ .$$

COPC intake from beef, milk, pork, poultry, and eggs:

$$I_i = A_i \cdot CR_i \cdot F_i \quad .$$

Total daily intake:

$$I_T = I_{soil} + I_{ag} + I_{beef} + I_{milk} + I_{pork} + I_{poultry} + I_{eggs} \quad .$$

Individual cancer risk: carcinogens:

$$CancerRisk_i = \frac{I_T \cdot ED \cdot EF \cdot CSF}{AT \cdot 365} \quad .$$

Hazard Quotient: noncarcinogens:

$$HQ = \frac{I_T \cdot ED \cdot EF}{RfD \cdot AT \cdot 365} \quad .$$

Total cancer risk: carcinogens:

$$\text{Total Cancer Risk} = \sum_i \cdot \text{Cancer Risk}_i \quad .$$

Total Hazard Index: noncarcinogens:

$$\text{Total Hazard Index} = \sum_j \cdot HI_j \quad .$$

Inhalation cancer risk for individual chemicals: carcinogens:

$$\text{Cancer Risk}_{inh(i)} = EC \cdot URF_{(i)}$$

$$EC = \frac{C_a \cdot EF \cdot ED}{AT \cdot 365 \text{ days/yr}} \quad .$$

Inhalation hazard quotient for COPCs: noncarcinogens:

$$HQ_{inh(i)} = \frac{EC \cdot 0.001}{RfC} \quad .$$

Total inhalation cancer risk: carcinogens:

$$\text{Total Cancer Risk}_{inh} = \sum_i \text{Cancer Risk}_{inh(i)} \quad .$$

Total hazard index for inhalation: noncarcinogens:

$$HI_{inh} = \sum_i HQ_i \quad .$$

Acute hazard quotient:

$$AHQ_{inh(i)} = \frac{C_{acute} \cdot 0.001}{AIEC} \quad .$$

B-3. HHRAP Equation Parameter Definitions and Units

A_{beef}	=	Concentration of COPC in beef (mg COPC/kg FW tissue)
$A_{chicken}$	=	Concentration of COPC in chicken (mg COPC/kg FW tissue)
A_{egg}	=	Concentration of COPC in egg (mg COPC/kg FW tissue)
A_{milk}	=	Concentration of COPC in milk (mg COPC/kg milk)
A_{pork}	=	Concentration of COPC in pork (mg COPC/kg FW tissue)
A_j	=	Concentration of COPC in animal tissue j
AHQ	=	Acute hazard quotient (unitless)
AIEC	=	Acute inhalation exposure criteria (mg/m^3)
AT	=	Averaging time (yr)
Ba_{beef}	=	COPC biotransfer factor for beef (day/kg FW tissue)
$Ba_{chicken}$	=	COPC biotransfer factor for chicken (day/kg FW tissue)
Ba_{egg}	=	COPC biotransfer factor for egg (day/kg FW tissue)
Ba_{milk}	=	COPC biotransfer factor for milk (day/kg FW tissue)
Ba_{pork}	=	COPC biotransfer factor for pork (day/kg FW tissue)
BD	=	Soil bulk density (g soil/cm^3 soil)
Br	=	Plant-soil bioconcentration factor for produce (unitless)
Bs	=	Soil bioavailability factor (unitless)
Bv_{ag}	=	COPC air-to-plant biotransfer factor ([mg COPC/g DW plant]/[mg COPC/g air])(unitless)
BW	=	Body Weight (kg)
CR_{ag}, CR_{pp}, CR_{bg}	=	Consumption rate of aboveground, protected aboveground, and belowground produce respectively (kg/kg-day DW)
CR_{soil}	=	Consumption rate of soil (kg/day)
Cs	=	Average soil concentration over exposure duration (mg COPC/kg soil)
CS_{TD}	=	Soil concentration at time tD (mg/kg)
CSF	=	Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$
Cyp	=	Unitized yearly average air concentration from particle phase ($mg\text{-}s/g\text{-}m^3$)
Cyv	=	Unitized yearly average air concentration from vapor phase ($mg\text{-}s/g\text{-}m^3$)

Ds	=	Deposition term (mg COPC/kg soil/yr)
Dydp	=	Unitized yearly dry deposition from particle phase (s/m^2-yr)
Dydv	=	Unitized yearly dry deposition from vapor phase (s/ m^2-yr)
Dywp	=	Unitized yearly average wet deposition from particle phase (s/m^2-yr)
Dywv	=	Unitized yearly wet deposition from vapor phase (s/ m^2-yr)
EC	=	Exposure concentration ($\mu g/m^3$)
ED	=	Exposure duration (yr)
EF	=	Exposure frequency (days/yr)
ER	=	Soil enrichment ration (unitless)
E_v	=	Average annual evapotranspiration (cm/yr)
F_{ag}	=	Fraction of produce that is contaminated (unitless)
F_i	=	Fraction of plant type i grown on contaminated soil and ingested by the animal (cattle)(unitless)
F_{soil}	=	Fraction of soil that is contaminated (unitless)
F_v	=	Fraction of COPC air concentration in vapor phase (unitless)
H	=	Henry's Law constant ($atm\text{-}m^3/mol$)
I	=	Average annual irrigation (cm/yr)
I_{ag}	=	Daily intake of COPC from produce (mg/kg-day DW)
I_{beef}, I_{milk}, I_{pork}, $I_{poultry}$, I_{eggs}	=	Daily intake of COPC from beef, milk, pork, poultry, and eggs (mg/kg-day FW)
I_i	=	Daily intake of COPC i from animal tissue j (mg/kg-day)
I_T	=	Total daily intake of COPC from all food sources (mg/kg-day)
I_{soil}	=	Daily intake of COPC from soil (mg/kg-day)
IR	=	Inhalation rate (m^3/hr)
Kds	=	Soil-water partition coefficient (mL water/g soil)
kp	=	Plant surface loss coefficient (yr^{-1})
ks	=	COPC soil loss constant due to all processes (yr^{-1})
kse	=	COPC loss constant due to soil erosion (yr^{-1})
ksg	=	COPC loss constant due to biotic and abiotic degradation (yr^{-1})
ksl	=	COPC loss constant due to leaching (yr^{-1})
ksr	=	COPC loss constant due to surface runoff (yr^{-1})
ksv	=	COPC loss constant due to volatilization (yr^{-1})

MF	=	Metabolism factor (unitless)
M_{skin}	=	Mass of thin (skin) layer of belowground vegetable (g)
M_{veg}	=	Mass of the entire vegetable (g)
P	=	Average annual precipitation (cm/yr)
P_i	=	Concentration of COPC in each plant type i eaten by the animal (cattle) (mg/kg DW)
Pd	=	Plant (aboveground produce) concentration due to direct (wet and dry) deposition (mg COPC/kg DW)
Pr_{ag}	=	Concentration in exposed or protected produce due to root uptake (mg/kg)
Pr_{bg}	=	Concentration in below-ground produce due to root uptake (mg/kg)
Pv	=	Concentration of COPC in the plant resulting from air-to-plant transfer (µg COPC/g DW)
Q	=	COPC emission rate (g/s)
Qp_i	=	Quantity of plant type i eaten by the animal (cattle) per day (kg DW plant/day)
Qs	=	Quantity of soil eaten by the animal (cattle) each day (kg/day)
R	=	Universal gas constant (atm-m^3/mol-K)
RCF	=	Root concentration factor (unitless)
RfC	=	Reference concentration (mg/kg-day)
RfD	=	Reference dose (mg/kg-day)
RO	=	Average annual surface runoff from previous areas (cm/yr)
Rp	=	Interception fraction of the edible portion of plant (unitless)
SD	=	Sediment delivery ratio (unitless) (g/m^2-yr)
tD	=	Time period over which deposition occurs (assumed 15 yr of operations)
Tp	=	Length of plant exposure to deposition per harvest of the edible portion of the ith plant group (yr)
T_a	=	Ambient air temperature (K) = 278.8 K (42 °F annual-average at INL)
$T_{1/2}$	=	Half-life (days)
T_1	=	Time period at the beginning of combustion (0 yr)
T_2	=	Length of exposure (6, 30, 40 yr for child, adult, farmer, respectively)
URF	=	Inhalation Unit Risk Factor $(\mu g/m^3)^{-1}$
Vdv	=	Dry deposition velocity (cm/s)
VG_{ag}	=	Empirical correction factor for aboveground produce (unitless)
$VG_{rootveg}$	=	Correction factor for belowground produce (g/g)

W	=	Average annual wind speed (m/s)
X_e	=	Unit soil loss (kg/m^2-yr)
Yh_i	=	Harvest yield of the ith crop (kg DW)
Yp	=	Yield or standing crop biomass of the edible portion of the plant (productivity)(kg DW/m^2)
Yp_i	=	Yield or standing crop biomass of edible portion of the ith plant group (kg DW/m^2)
Z_s	=	Soil mixing zone depth (cm)
ρ_a	=	Density of air (g/cm^3)
ρ_s	=	Density of surface soil (g/cm^3)
θsw	=	Soil volumetric water content (mL water/cm^3 soil)

B-4. HHRAP Equation Parameter Values (LET&D, PEWE, IWTU COPCs)

All values from U.S. EPA on-line Companion Data Base, January 2007
(ND = no value in EPA data base)

Table B-1. COPC physical/chemical parameter values used in the risk assessment.

COPC	CAS #	*Log Kow*	*Kds* (mL/g)	*ksg* (year)-1	*Fv* (unitless)
ALUMINUM	7429-90-5	ND	1.50E+03	0.00E+00	0.00E+00
ARSENIC	7440-38-2	6.80E-01	2.90E+01	0.00E+00	6.00E-03
BARIUM	7440-36-3	2.30E-01	4.10E+01	0.00E+00	9.00E-03
BENZO(A)PYRENE	50-32-8	6.00E+00	1.60E+05	4.80E-01	2.94E-01
BERYLLIUM	7440-41-7	-5.70E-01	7.90E+02	0.00E+00	9.00E-03
BIS(2-ETHYLHEXYL PHTHALATE)	117-81-7	5.10E+00	2.30E+06	1.10E+01	1.31E-01
CADMIUM	7440-43-9	-7.00E-02	7.50E+01	0.00E+00	9.00E-03
CHLORINE	7782-50-5	8.50E-01	ND	0.00E+00	1.00E+00
CHROMIUM	7440-47-3	2.30E-01	1.90E+01	0.00E+00	9.00E-03
DICHLOROBENZENE,1,4-	106-46-7	3.50E+00	1.20E+00	1.41E+00	1.00E+00
DICHLOROBENZIDINE,3,3'-	91-94-1	3.51E+00	7.21E+00	1.41E+00	4.82E-01
FLUORANTHENE	206-44-0	5.00E+00	1.10E+04	5.70E-01	9.92E-01
HEXACHLOROCYCLOPENTADIENE	77-47-4	5.04E+00	1.17E+02	9.03E+00	1.00E+00
HEXAVALENT CHROMIUM	18540-29-9	0.00E+00	1.90E+01	0.00E+00	0.00E+00
HYDROGEN CHLORIDE	7647-01-0	ND	ND	0.00E+00	1.00E+00
LEAD	7439-92-1	7.30E-01	9.00E+02	0.00E+00	7.00E-03
MERCURIC CHLORIDE	7487-94-7	-2.15E-01	5.80E+04	0.00E+00	8.50E-01
MERCURY - TOTAL	7439-97-6	6.20E-01	1.00E+03	0.00E+00	1.00E+00
METHYL MERCURY	22967-92-6	ND	7.00E+03	0.00E+00	0.00E+00
NICKEL	7440-02-0	-5.70E-01	6.50E+01	0.00E+00	9.00E-03
N-NITROSODIPROPYLAMINE	621-64-7	1.36E+00	2.20E-01	1.41E+00	1.00E+00
PYRENE	129-00-0	4.90E+00	9.50E+03	1.30E-01	9.94E-01
SELENIUM	7782-49-2	2.40E-01	5.00E+00	0.00E+00	0.00E+00
SILVER	7440-22-4	2.30E-01	8.30E+00	0.00E+00	9.00E-03
TRICHLOROPROPANE,1,2,3-	96-18-4	2.00E+00	1.40E-01	7.00E-01	1.00E+00
ZINC	7440-66-6	-4.70E-01	6.20E+01	0.00E+00	8.00E-03

Table B-1. (continued).

COPC	*MW* (g/mole)	*Vp* (atm)	*S* (mg/L)	*H* (atm m³ /mol)	*Da* (cm²/s)
ALUMINUM	2.70E+01	0.00E+00	0.00E+00	0.00E+00	2.11E-01
ARSENIC	7.80E+01	3.30E-12	3.47E+04	7.70E-01	7.72E-02
BARIUM	1.39E+02	5.58E-12	5.48E+04	0.00E+00	7.72E-02
BENZO(A)PYRENE	2.52E+02	7.24E-12	1.60E-03	1.10E-06	4.30E-02
BERYLLIUM	9.01E+00	5.58E-12	1.49E+05	1.50E-02	7.72E-02
BIS(2-ETHYLHEXYL PHTHALATE)	3.91E+02	8.95E-11	3.40E-01	1.00E-07	3.51E-02
CADMIUM	1.12E+02	5.45E-12	1.23E+05	3.10E-02	7.72E-02
CHLORINE	7.09E+01	7.70E+00	6.30E+03	1.17E-02	1.00E-03
CHROMIUM	5.20E+01	5.58E-12	8.67E+04	0.00E+00	1.27E-01
DICHLOROBENZENE,1,4-	1.47E+02	1.32E-03	7.90E+01	2.40E-03	6.90E-02
DICHLOROBENZIDINE,3,3'-	2.53E+02	4.88E-11	3.10E+00	4.00E-09	1.00E-03
FLUORANTHENE	2.02E+02	1.03E-08	2.10E-01	1.60E-05	1.00E-03
HEXACHLOROCYCLOPENTADIENE	2.73E+02	7.89E-05	1.80E+00	2.70E-02	1.00E-03
HEXAVALENT CHROMIUM	5.20E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HYDROGEN CHLORIDE	3.65E+01	4.66E+01	7.20E+05	2.36E-03	1.00E-03
LEAD	2.09E+02	3.97E-12	9.58E+03	2.50E-02	7.72E-02
MERCURIC CHLORIDE	2.72E+02	1.20E-04	6.90E+04	7.10E-10	4.53E-02
MERCURY - TOTAL	2.01E+02	2.63E-06	6.00E-02	7.10E-03	1.09E-02
METHYL MERCURY	2.16E+02	ND	0.00E+00	4.70E-07	5.28E-02
NICKEL	5.87E+01	5.58E-12	4.22E+05	2.50E-02	7.72E-02
N-NITROSODIPROPYLAMINE	1.30E+02	1.71E-04	9.89E+03	2.25E-06	1.00E-03
PYRENE	2.02E+02	6.05E-09	1.40E+00	1.10E-05	1.00E-03
SELENIUM	7.90E+01	1.87E-13	2.06E+03	9.70E-03	7.72E-02
SILVER	1.08E+02	5.58E-12	7.05E+04	0.00E+00	7.72E-02
TRICHLOROPROPANE,1,2,3-	1.47E+02	4.87E-03	1.80E+03	4.10E-04	7.10E-02
ZINC	6.54E+01	5.09E-12	3.44E+05	2.50E-02	7.72E-02

Table B-2. COPC plant bio-transfer factor parameter values used in the risk assessment.

COPC	*Fv* (unitless)	*RCF (mL/g)*	*Brroot* (unitless)	*Brag* (unitless)	*Brf/s* (unitless)	*Brgrain* (unitless)	*Bvag* (unitless)
ALUMINUM	0.00E+00	ND	ND	ND	ND	ND	ND
ARSENIC	6.00E-03	ND	8.00E-03	6.33E-03	3.60E-02	4.00E-03	ND
BARIUM	9.00E-03	ND	1.50E-02	3.22E-02	1.50E-01	1.50E-02	ND
BENZO(A)PYRENE	2.94E-01	9.68E+03	6.05E-02	1.32E-02	1.32E-02	1.32E-02	1.25E+05
BERYLLIUM	9.00E-03	ND	1.50E-03	2.58E-03	1.00E-02	1.50E-03	ND
BIS(2-ETHYLHEXYL PHTHALATE)	1.31E-01	1.96E+03	8.54E-04	4.37E-02	4.37E-02	4.37E-02	1.51E+05
CADMIUM	9.00E-03	ND	6.40E-02	1.25E-01	3.84E-01	6.20E-02	ND
CHLORINE	1.00E+00	7.36E+00	ND	8.38E+00	8.38E+00	8.38E+00	ND
CHROMIUM	9.00E-03	ND	4.50E-03	4.88E-03	7.50E-03	4.50E-03	ND
DICHLOROBENZENE,1,4-	1.00E+00	1.15E+02	9.59E+01	3.67E-01	3.67E-01	3.67E-01	1.24E-01
DICHLOROBENZIDINE,3,3'-	4.82E-01	1.17E+02	1.62E+01	3.62E-01	3.62E-01	3.62E-01	7.65E+04
FLUORANTHENE	9.92E-01	1.64E+03	1.50E-01	4.99E-02	4.99E-02	4.99E-02	7.38E+02
HEXACHLOROCYCLOPENTADIENE	1.00E+00	1.77E+03	1.50E+01	4.73E-02	4.73E-02	4.73E-02	4.83E-01
HEXAVALENT CHROMIUM	0.00E+00	ND	4.50E-03	4.88E-03	7.50E-03	4.50E-03	ND
HYDROGEN CHLORIDE	1.00E+00	ND	ND	ND	ND	ND	ND
LEAD	7.00E-03	ND	9.00E-03	1.36E-02	4.50E-02	9.00E-03	ND
MERCURIC CHLORIDE	8.50E-01	ND	3.60E-02	1.45E-02	0.00E+00	9.30E-03	1.80E+03
MERCURY - TOTAL	1.00E+00	ND	ND	ND	ND	ND	0.00E+00
METHYL MERCURY	0.00E+00	ND	9.90E-02	2.94E-02	0.00E+00	1.90E-02	0.00E+00
NICKEL	9.00E-03	ND	8.00E-03	9.31E-03	3.20E-02	6.00E-03	ND
N-NITROSODIPROPYLAMINE	1.00E+00	8.90E+00	4.09E+01	6.34E+00	6.34E+00	6.34E+00	6.98E-01
PYRENE	9.94E-01	1.38E+03	1.45E-01	5.70E-02	5.70E-02	5.70E-02	8.40E+02
SELENIUM	0.00E+00	ND	2.20E-02	1.95E-02	1.60E-02	2.00E-03	ND
SILVER	9.00E-03	ND	1.00E-01	1.38E-01	4.00E-01	1.00E-01	ND
TRICHLOROPROPANE,1,2,3-	1.00E+00	8.05E+00	5.75E+01	2.70E+00	2.70E+00	2.70E+00	1.84E-02
ZINC	8.00E-03	ND	9.00E-01	9.70E-02	2.50E-01	5.40E-02	ND

Table B-3. Animal bio-transfer factor parameter values used in the risk assessment.

COPC	CAS #	*Bamilk* (day/kg FW)	*Babeef* (day/kg FW)	*Bapork* (day/kg FW)	*Baeggs* (day/kg FW)	*Bapoult* (day/kg FW)
ALUMINUM	7429-90-5	ND	ND	ND	ND	ND
ARSENIC	7440-38-2	6.00E-05	2.00E-03	ND	ND	ND
BARIUM	7440-36-3	3.50E-04	1.50E-04	ND	ND	ND
BENZO(A)PYRENE	50-32-8	7.91E-03	3.76E-02	4.55E-02	1.58E-02	2.77E-02
BERYLLIUM	7440-41-7	9.00E-07	1.00E-03	ND	ND	ND
BIS(2-ETHYLHEXYL PHTHALATE)	117-81-7	8.40E-03	3.99E-02	4.83E-02	1.68E-02	2.94E-02
CADMIUM	7440-43-9	6.50E-06	1.20E-04	1.91E-04	2.50E-03	1.06E-01
CHLORINE	7782-50-5	7.59E-05	3.60E-04	4.36E-04	1.52E-04	2.66E-04
CHROMIUM	7440-47-3	1.50E-03	5.50E-03	ND	ND	ND
DICHLOROBENZENE,1,4-	106-46-7	3.75E-03	1.78E-02	2.16E-02	7.50E-03	1.31E-02
DICHLOROBENZIDINE,3,3'-	91-94-1	3.79E-03	1.80E-02	2.18E-02	7.57E-03	1.32E-02
FLUORANTHENE	206-44-0	8.26E-03	3.92E-02	4.75E-02	1.65E-02	2.89E-02
HEXACHLOROCYCLOPENTADIENE	77-47-4	8.32E-03	3.95E-02	4.78E-02	1.66E-02	2.91E-02
HEXAVALENT CHROMIUM	18540-29-9	1.50E-03	5.50E-03	ND	ND	ND
HYDROGEN CHLORIDE	7647-01-0	1.10E-05	5.23E-05	6.33E-05	2.20E-05	3.86E-05
LEAD	7439-92-1	2.50E-04	3.00E-04	ND	ND	ND
MERCURIC CHLORIDE	7487-94-7	2.26E-03	5.22E-03	3.39E-05	2.39E-02	2.39E-02
MERCURY - TOTAL	7439-97-6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
METHYL MERCURY	22967-92-6	3.38E-04	7.80E-04	5.07E-06	3.58E-03	3.58E-03
NICKEL	7440-02-0	1.00E-03	6.00E-03	ND	ND	ND
N-NITROSODIPROPYLAMINE	621-64-7	2.06E-04	9.79E-04	1.19E-03	4.12E-04	7.21E-04
PYRENE	129-00-0	8.09E-03	3.84E-02	4.65E-02	1.62E-02	2.83E-02
SELENIUM	7782-49-2	5.86E-03	2.27E-03	1.88E-01	1.13E+00	1.13E+00
SILVER	7440-22-4	2.00E-02	3.00E-03	ND	ND	ND
TRICHLOROPROPANE,1,2,3-	96-18-4	6.11E-04	2.90E-03	3.51E-03	1.22E-03	2.14E-03
ZINC	7440-66-6	3.25E-05	9.00E-05	1.28E-04	8.75E-03	8.75E-03

Table B-4. COPC health benchmarks used in the risk assessment.

COPC	CAS #	*RfD* (mg/kg/d)	CSF (mg/kg-day)$^{-1}$	*RfC* (mg/m^3)	*URF* (µg/m^3)$^{-1}$	AIEC (mg/m3)
ALUMINUM	7429-90-5	ND	ND	5.00E-03	ND	ND
ARSENIC	7440-38-2	3.00E-04	1.50E+00	3.00E-05	4.30E-03	1.90E-04
BARIUM	7440-36-3	7.00E-02	ND	5.00E-04	ND	1.50E+00
BENZO(A)PYRENE	50-32-8	ND	7.30E+00	ND	1.10E-03	6.00E-01
BERYLLIUM	7440-41-7	2.00E-03	ND	2.00E-05	2.40E-03	5.00E-03
BIS(2-ETHYLHEXYL PHTHALATE)	117-81-7	2.00E-02	1.40E-02	ND	ND	1.00E+01
CADMIUM	7440-43-9	1.00E-03	3.80E-01	2.00E-04	1.80E-03	3.00E-02
CHLORINE	7782-50-5	1.00E-01	ND	2.00E-04	ND	2.10E-01
CHROMIUM	7440-47-3	1.50E+00	ND	5.30E+00	ND	1.50E+00
DICHLOROBENZENE,1,4-	106-46-7	3.00E-02	5.40E-03	8.00E-01	1.10E-05	6.00E+02
DICHLOROBENZIDINE,3,3'-	91-94-1	ND	4.50E-01	ND	3.40E-04	6.00E+00
FLUORANTHENE	206-44-0	4.00E-02	ND	1.40E-01	ND	1.50E-02
HEXACHLOROCYCLOPENTADIENE	77-47-4	6.00E-03	ND	2.00E-04	ND	2.00E-01
HEXAVALENT CHROMIUM	18540-29-9	3.00E-03	ND	8.00E-06	1.20E-02	ND
HYDROGEN CHLORIDE	7647-01-0	5.71E-03	ND	2.00E-02	ND	2.10E+00
LEAD	7439-92-1	4.29E-04	8.50E-03	1.50E-03	1.20E-05	1.50E-01
MERCURIC CHLORIDE	7487-94-7	3.00E-04	ND	1.10E-03	ND	1.25E-01
MERCURY - TOTAL	7439-97-6	8.57E-05	ND	3.00E-04	ND	1.80E-03
METHYL MERCURY	22967-92-6	1.00E-04	ND	3.50E-04	ND	3.00E-02
NICKEL	7440-02-0	2.00E-02	ND	2.00E-04	2.40E-04	6.00E-03
N-NITROSODIPROPYLAMINE	621-64-7	ND	7.00E+00	ND	2.00E-03	2.00E-01
PYRENE	129-00-0	3.00E-02	ND	1.10E-01	ND	1.50E+01
SELENIUM	7782-49-2	5.00E-03	ND	2.00E-02	ND	1.47E+00
SILVER	7440-22-4	5.00E-03	ND	1.80E-02	ND	3.00E-01
TRICHLOROPROPANE,1,2,3-	96-18-4	6.00E-03	7.00E+00	ND	2.00E-03	6.00E+01
ZINC	7440-66-6	3.00E-01	ND	ND	ND	3.00E+01