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**DOCUMENTATION FOR THE
FRAMES-HWIR TECHNOLOGY SOFTWARE
SYSTEM, VOLUME 7:
EXIT LEVEL PROCESSOR-I**

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Summary

The U.S. Environmental Protection Agency (EPA) is developing a comprehensive environmental exposure and risk analysis software system for agency-wide application. The software system will be applied to the technical assessment of exposures and risks relevant to the Hazardous Waste Identification Rule (HWIR). The software system adapted to automate this assessment is the Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES), developed by the Pacific Northwest National Laboratory. The process used to develop the FRAMES-HWIR Technology Software System includes steps for requirements analysis, design, specification, and development with testing and quality assurance comprising a critical portion of each step. This report documents that process for one of the key components of the system: the Exit Level Processor (ELP-I).

The ELP has three subcomponents. Their primary purposes are to process and reformat risk-based information generated by the Multimedia Multipathway Simulation Processor (MMSP), provide a means for querying and summarizing this information graphically, and ultimately compute chemical-specific exit levels.

The ELP-I subcomponent meets the following requirements:

- 1) Read human- and ecological-risk/hazard data contained in the Human-Risk and Ecological-Risk Global Results Files (GRFs) (HR.GRF and ER.GRF, respectively).
- 2) Consolidate the human-risk/hazard results for the five cohorts output from the MMSP (infants, 1-6 years old, 7-12 years old, 13-17 years old, and 18 years or older) into four cohorts (infants, 1-12 years old, 13 years or older, and summation of all cohorts).
- 3) Store information related to the human- and ecological-risk/hazard data read from the GRFs in a set of Risk Summary Output File (RSOF) database files in Microsoft® Access™ format in accordance with the specifications for an RSOF.
- 4) Be designed in such a way that any number of sites, waste management unit types, realizations, chemicals, waste concentrations (C_w s), receptor types, exposure pathways (or summation of pathways), critical-year method, distance regions, ecological areas, and habitat types can be accommodated without changing the program code (but, be specifically designed to handle five human cohorts as input and four human cohorts as output, as described in Requirement 2).
- 5) Be capable of identifying the last in a series of C_w data. C_w data describe the range in waste-stream concentrations before disposal. When the last C_w is identified or when an error occurs, the results associated with the C_w range will be stored in the RSOFs.
- 6) Produce only those ELP-I tables that have non-zero entries per site-iteration combination by C_w and risk/hazard bin (to save computational space).
- 7) Generate warnings or errors when appropriate and report them to the System User Interface.

- 8) Be able to be tested as a stand-alone processor, independent of the other FRAMES-HWIR Technology Software System processors.
- 9) Operate within the Microsoft® Windows® 95 environment (32-bit).
- 10) Be able to read and store up to 1Gb of information on either permanent or removable media.

The ELP-I was tested to ensure that it met the above requirements. The processor was tested as a unit to ensure that it performed as expected, and the test cases evaluated the capability of the ELP-I to meet the requirements requested by the EPA. The ELP-I passed its tests. In addition, development of the ELP-I followed a quality assurance program designed to ensure that the processor met EPA expectations.

Acronyms and Abbreviations

ASCII	American Standard Code for Information Interchange
CPP	Chemical Properties Processor
ELP	Exit Level Processor
ELP-I	Exit Level Processor-I
ELP-II	Exit Level Processor-II
EPA	U.S. Environmental Protection Agency
FRAMES	Framework for Risk Analysis in Multimedia Environmental Systems
GRF	Global Results Files
HWIR	Hazardous Waste Identification Rule
HWIRIO.DLL	HWIR input/output dynamic link library
Mb	megabyte
MET	meteorological
MHZ	megahertz
MMSP	Multimedia Multipathway Simulation Processor
PC	personal computer
PNNL	Pacific Northwest National Laboratory
RAM	random access memory
SDP	Site Definition Processor
SSF	Site Simulation Files
SUI	System User Interface

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1.0 Introduction

The U.S. Environmental Protection Agency (EPA) is developing a comprehensive environmental exposure and risk analysis software system for agency-wide application. The software system will be applied to the technical assessment of exposures and risks relevant to the Hazardous Waste Identification Rule (HWIR). The HWIR is designed to determine quantitative criteria for allowing a specific class of industrial waste streams to no longer require disposal as a hazardous waste (that is, to *exit* Subtitle C) and to allow disposal in Industrial Subtitle D facilities. Hazardous-waste constituents with values less than these exit criteria levels would be reclassified as nonhazardous wastes under the Resource Conservation and Recovery Act.

The software system adapted to automate this assessment is the Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES), developed by the Pacific Northwest National Laboratory (PNNL). The FRAMES-HWIR Technology Software System consists of a series of components within a system framework (Figure 1.1). The process used to develop the FRAMES-HWIR Technology Software System includes steps for requirements analysis, design, specification, and development with testing and quality assurance comprising a critical portion of each step.

This report discusses a subcomponent of the Exit Level Processor (ELP), one of the major elements of the system. Overall, the ELP's three subcomponents process the human- and ecological-risk/hazard results generated by the Multimedia Multipathway Simulation Processor (MMSP) and compute chemical-specific exit levels, which are the final output of the FRAMES-HWIR Technology Software System. The ELP contains three primary subcomponents: ELP-I, Risk Visualization Processor (RVP), and ELP-II. The ELP-I reads the human-health and ecological-risk/hazard results from the global results files (GRF), which are generated by the MMSP, and stores risk/hazard information related to these results in a series of risk summary output files (RSOFs). The information in the RSOFs can be viewed graphically by the RVP. Based on a level of protectiveness and a set of risk factors chosen by an analyst, the ELP-II provides the chemical-specific waste-stream concentration, which exists within the range of waste concentrations (C_{ws}), that meets that level of protectiveness via the Protective Summary Output File (PSOF).

This report includes information on requirements of the ELP-I, as well as design elements necessary to meet those requirements. It also discusses testing plans, testing results, and the quality assurance program for the ELP-I. Information on the ELP-II and the RVP can be found in *Documentation for the FRAMES-HWIR Technology Software System, Volume 15: Exit Level Processor-II and Risk Visualization Processor*. Specifications for the ELP subcomponents are described in *Documentation for the FRAMES-HWIR Technology Software System, Volume 8: Specifications*. References cited in the text are listed in Section 6.0. Appendices A and B provide additional details on the testing program for the ELP-I. Other components developed by PNNL are described in companion documents as listed in the reference list; the system itself is documented in a summary report, *Overview of the FRAMES-HWIR Technology Software System*.

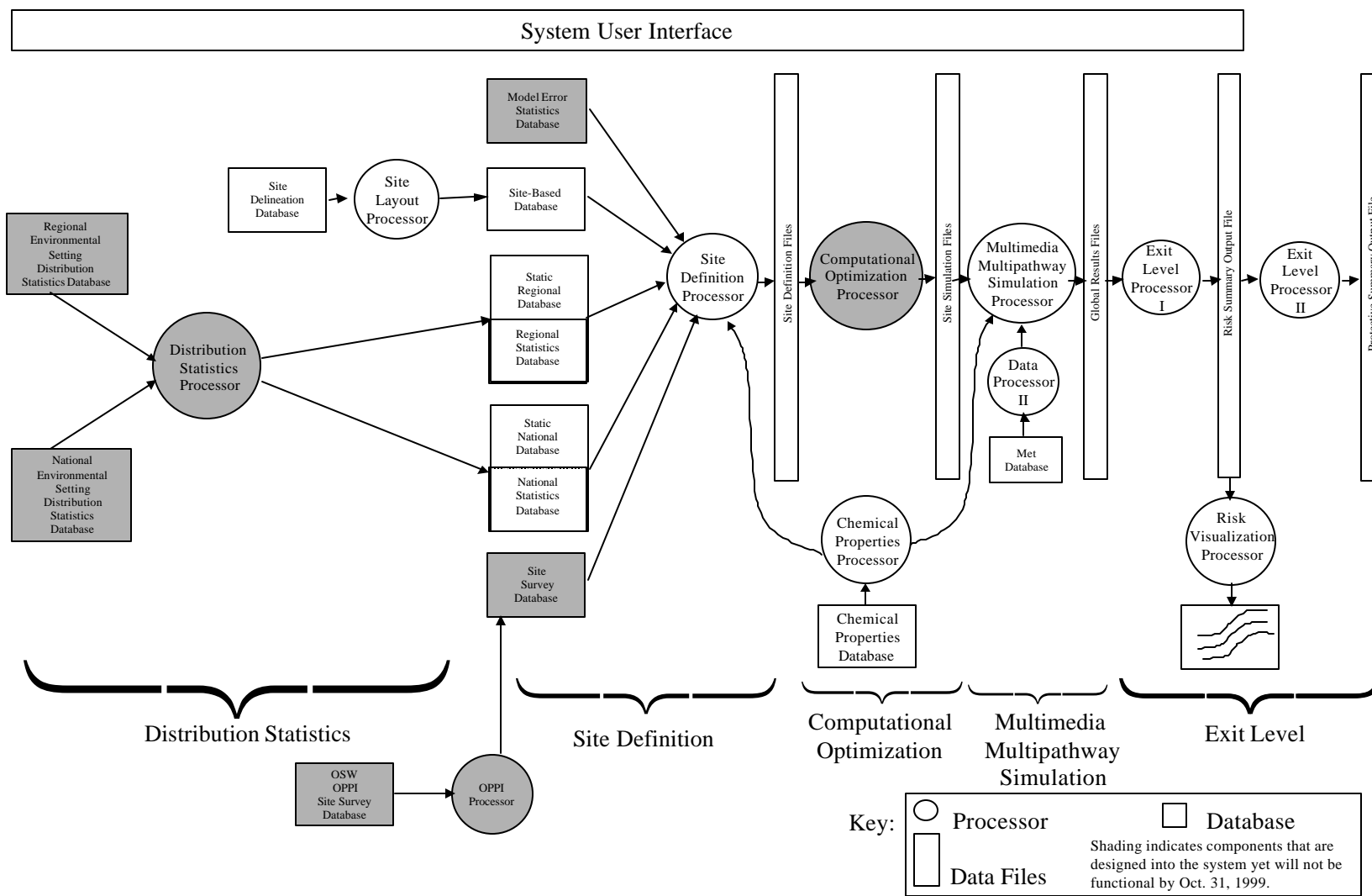


Figure 1.1 Overview of the FRAMES-HWIR Technology Software System

2.0 Requirements

Requirements are characteristics and behaviors that a piece of software must possess to function adequately for its intended purpose. The primary purposes of the ELP are to process and reformat risk-based information generated by the MMSP, provide a means for querying and summarizing this information graphically, and ultimately compute chemical-specific exit levels. The HWIR chemical-specific exit levels, in simplest terms, define a chemical-specific C_w that, if exceeded, defines that entire waste stream as hazardous and, thus, requires strict Subtitle C disposal. Waste-containing concentrations below the exit level may “exit” a strict Subtitle C disposal system and be disposed of in industrial Subtitle D facilities. Figure 1.1 illustrates where the three ELP subcomponents (ELP-I, RVP, and ELP-II) fit into the FRAMES-HWIR Technology Software System.

The simplest possible output from the ELP is a list of chemical-specific exit levels. However, because so many factors influence the determination of an actual exit level, the ELP will output additional information that describes these factors. Also, the database of risk information used to determine exit levels will be available for others to query and summarize in different ways to arrive at other possible exit levels.

Each of the ELP's three subcomponents functions to fulfill a specific requirement. The ELP-I reads the flat-ASCII global result files (GRFs), which contain the risk/hazard results generated by the MMSP, consolidate the risk/hazard data, reformat the information to ensure storage efficiency, and store this information in RSOFs, which are Microsoft® Access™ database files. The Output Requirements section discusses the specific data related to risk/hazard that are stored in the RSOFs. The RVP reads the RSOFs so users of the system can query and summarize these data in specific ways to visually inspect the ramifications of choosing risk factors (e.g., receptor types, distance), assuming different levels of protectiveness to arrive at possible exit levels. Once the risk factors and a level of protectiveness are chosen (by EPA), the ELP-II will produce chemical-specific exit levels per chemical per waste management unit (WMU) type that meet that level of protectiveness. Of the three ELP components (ELP-I, RVP, and ELP-II), this report addresses only the input, scientific, and output requirements of the ELP-I, which are described in the following subsections.

The general requirements of the ELP-I are to read human-health and ecological-risk/hazard data from the appropriate GRFs, consolidate the data, where appropriate, and store this information in a series of RSOFs. The ELP-I will be required to handle any number of WMU types, chemicals, sites, realizations, receptor types, and other risk/hazard data. In summary, the ELP-I will

- 1) Read human- and ecological-risk/hazard data contained in the Human-Risk and Ecological-Risk GRFs (HR.GRF and ER.GRF, respectively).
- 2) Consolidate the human-risk/hazard results for the five cohorts output from the MMSP (infants, 1-6 years old, 7-12 years old, 13-17 years old, and 18 years or older) into four cohorts (infants, 1-12 years old, 13 years or older, and summation of all cohorts).
- 3) Store information related to the human- and ecological-risk/hazard data read from the GRFs in a set of RSOF database files in Microsoft® Access™ format in accordance with the specifications

for an RSOF (see *Documentation for the FRAMES-HWIR Technology Software System, Volume 8: Specifications*, for a detailed description of the RSOF format).

- 4) Be designed in such a way that any number of sites, WMU types, realizations, chemicals, C_w s, receptor types, exposure pathways (or summation of pathways), critical-year method, distance regions, ecological areas, and habitat types can be accommodated without changing the program code (but, be specifically designed to handle five human cohorts as input and four human cohorts as output, as described in Requirement 2).
- 5) Be capable of identifying the last in a series of C_w data. C_w data describe the range in waste-stream concentrations before disposal. When the last C_w is identified or when an error occurs, the results associated with the C_w range will be stored in the RSOFs.
- 6) Produce only those ELP-I tables that have non-zero entries per site-iteration combination by C_w and risk/hazard bin (to save computational space).
- 7) Generate warnings or errors when appropriate and report them to the System User Interface (SUI).
- 8) Be able to be tested as a stand-alone processor, independent of the other FRAMES-HWIR Technology Software System processors.
- 9) Operate within the Microsoft® Windows® 95 environment (32-bit).
- 10) Be able to read and store up to 1Gb of information on either permanent or removable media.

2.1 Input Requirements

The ELP-I is required to read the human- and ecological-risk/hazard GRFs. Specifically, the ELP-I will read the Human-Risk Global Result File (HR.GRF) and the Ecological-Risk Global Result File (ER.GRF).

For the human-health assessment, HR.GRFs contain tallies of the number of receptors occurring in and below specific risk/hazard categories and constitute the input data for the ELP-I. Human-risk/hazard input information is tallied by chemical, WMU type, site, C_w , distance, exposure pathway, receptor type, cohort, and critical-year method by risk/hazard bin (summarized in Table 2.1):

- C **Chemical:** Each analysis begins with the chemical designation, and the risk/hazard information is stored by chemical. The chemicals stored in the GRFs are those specified by the user.
- C **Waste Management Unit Type:** There are five WMUs: Aerated Tank (AT), Land Application Unit (LAU), Landfill (LF), Surface Impoundment, and Waste Pile (WP). Each site may contain multiple WMU types, but each WMU type is assessed one at a time. The maximum possible number of combinations (sites and WMUs) is 419, as some sites may not contain a particular WMU type. The risk/hazard information is stored in the GRFs by WMU type.
- C **Site:** There are 200 specific sites associated with the HWIR assessment, and the risk/hazard information is stored by site.

Table 2.1. Summary of Parameter Requirements Associated with Human-Health Risk/Hazard for the ELP-I

Parameters ^(a)	Dimensions	
	Supplied by Human-Risk Module	Stored by ELP-I and Provided to RVP
Number of Distances	3	3
Number of Exposure Pathways plus Summation of Pathways	12	12
Number of Receptor Types plus Summation of Receptor Types	16	5
Number of Cohorts plus Summation of Cohorts	5	4
Number of Bins to Tally Individual Excess Cancers	7	7
Number of Bins to Tally Hazard Quotients (Non-Cancer)	4	4
Number of Critical Year Percentiles	1	1
Number of C _w s	5	5
Number of Chemicals	40	40
Number of WMU Types	5	5
Number of Sites/WMU-Type Combinations	419	— ^(b)
Number of Percentiles of Protected Population	—	10
<p>(a) See Sections 2.1 and 2.3 for additional details on these parameters.</p> <p>(b) The ELP-I stores the summation of results, accounting for the total number of Sites/WMU-Type combinations.</p>		

- C **C_w**: The user has the option of choosing up to five C_w levels. The risk/hazard information is stored in the GRFs by C_w level. C_ws are stored in units of mg/L for waste water (SI and AT), mg/kg dry weight for solids (WP and LF), and mg/kg wet weight for semi-solids (LAU). These levels are chemical specific.
- C **Distance**: “n” distance rings are designed into the ELP-I, but only three distances are stored for HWIR calculations: 0 to 0.5 km, 0 km to 1 km and 0 to 2 km from the edge of the waste site area.
- C **Exposure Pathway**: Exposure pathways include inhalation air, inhalation through showering, summation of all inhalation pathways, ingestion of groundwater, ingestion of soil, ingestion of meat, ingestion of milk, ingestion of fish, ingestion of breast milk, ingestion of vegetables, summation of all ingestion pathways, summation of all inhalation and ingestion pathways.
- C **Receptor Type**: The risk module analyzes 16 receptor types (8 each with and without drinking water): Beef farmer, dairy farmer, beef farmer fisher, dairy farmer fisher, gardener, gardener fisher, resident, and resident fisher. Of these 16 receptor types, the risk module rolls-up the

results and passes only five receptor types to the ELP-I: beef/dairy farmer, gardener, fisher, resident, and summation of receptor types.

- C **Cohort:** The risk module analyzes five cohorts: infants, 1-6 years old, 7-12 years old, 13-17 years old, and 18 years old and older (adult).
- C **Critical-Year Method:** The critical year is defined as the year in which a pre-specified percentage (i.e., 100% for this particular application of HWIR) of the population has the maximum total risk and/or HQ over all years (EPA 1999a). The maximum total risk for carcinogenic chemicals represents the maximum moving nine-year average risk, as defined by the mid-point of the risk-bin times population associated with the risk-bin, summed over the number of risk-bins. The same procedure is followed for HQ for noncarcinogenic chemicals, except an annual average hazard is employed. The critical year is associated with each C_w , site, iteration, and WMU type by receptor type, cohort, exposure pathway, and distance.
- C **Risk Bin:** Risk bins include $<1 \times 10^{-8}$, $(1 \times 10^{-8} - 5 \times 10^{-7})$, $(5 \times 10^{-7} - 1 \times 10^{-6})$, $(1 \times 10^{-6} - 5 \times 10^{-6})$, $(5 \times 10^{-6} - 1 \times 10^{-5})$, $(1 \times 10^{-5} - 1 \times 10^{-4})$, and $>1 \times 10^{-4}$. The Human-Risk module in the MMSP populates each risk bin with the cumulative number of people in that risk interval and below.
- C **Hazard Bin:** Hazard bins include <0.1 , $(0.1 - 1.0)$, $(1.0 - 10.0)$, and >10.0 . The Human-Risk module in the MMSP populates each hazard bin with the cumulative number of people in that hazard quotient interval and below.

Therefore, for each chemical, site, WMU type, C_w , distance, exposure pathway, receptor type, cohort, and critical-year method, the MMSP populates each human-health risk/hazard bin with the cumulative number of people in that risk/hazard interval and below.

For the ecological assessment, ER.GRFs contain tallies of the percentage of receptors occurring in and below specific ecological-hazard categories and constitute the input data for the ELP-I. Ecological-hazard input information is tallied by chemical, WMU type, site, C_w , distance (i.e., ring), habitat group, receptor group, habitat type, receptor type, trophic level, and critical-year method by ecological-hazard bin (summarized in Table 2.2):

- C **Chemical:** As previously defined in the Input Requirements section.
- C **Waste Management Unit Type:** As previously defined in the Input Requirements section.
- C C_w : As previously defined in the Input Requirements section.
- C **Distance:** Distance rings are designed into the ELP-I, and the following three distances are stored for HWIR calculations: 0 to 1 km, 1 km to 2 km, and 0 to 2 km from the edge of the waste site area.
- C **Habitat Group:** There are three habitat groups: Terrestrial, Aquatic, and Wetland.

- C **Receptor Group**: there are nine receptor groups: Reptile, Bird, Mammal, Amphibian, Soil Biota, Aquatic Biota, Sediment Biota, Terrestrial Plant, and Aquatic Plant.
- C **Habitat type**: There are 12 habitat types: Grassland, Shrub/Scrub, Forest, Cropland, Residential, Stream, Pond, Lake, PFGassland, PFShrubScrub, PFForest, and NoHabitat. PF refers to permanently flooded, a condition required to define a wetland with the potential to support aquatic life.
- C **Trophic Level**: There are five trophic levels: Trophic Level 1 (T1), Trophic Level 2 (T2), Trophic Level 3 (T3), Communities, and Producers.

Table 2.2. Summary of Parameter Requirements Associated with Ecological Hazard for the ELP-I

Parameters ^(a)	Dimensions	
	Supplied by Ecological-Risk Module	Stored by ELP-I and Provided to RVP
Number of Distances	3	— ^(b)
Number of Habitat Groups	3	—
Number of Receptor Groups	9	—
Number of Habitat Types	12	—
Number of Trophic Levels	5	—
Number of Ecological-Hazard Quotient Bins	5	5
By Distance and Habitat Group	— ^(c)	9
By Distance and Habitat Type	— ^(c)	36
By Distance and Receptor Group	— ^(c)	27
By Distance and Trophic Level	— ^(c)	15
By Receptor Group and Habitat Group	— ^(c)	27
By Trophic Level and Habitat Group	— ^(c)	15
Number of Critical Year Percentiles	1	1
Number of C _s s	5	5
Number of Chemicals	40	40
Number of WMU Types	5	5
Number of Sites/WMU-Type Combinations	419	— ^(d)
Number of Percentiles of Protected Population	—	10

(a) See Sections 2.1 and 2.3 for additional details on these parameters.
 (b) “—” refers to information that is not passed on or stored by this dimension.
 (c) The data are not passed to the ELP-I as a pair.
 (d) The ELP-I stores the summation of results, accounting for the total number of Sites/WMU-Type combinations.

- C **Critical-Year Method:** The critical year is defined as the year in which a pre-specified percentage (i.e., 100% for this particular application of HWIR) of the population has the maximum total EHQ over all years (EPA 1999b). The maximum total EHQ represents the maximum annual average EHQ, as defined by the mid-point of the hazard-bin times population associated with the hazard-bin, summed over the number of hazard-bins. The critical year is associated with each C_w , site, iteration, and WMU type by habitat group, habitat type, receptor group, trophic level, and distance.
- C **Ecological-Hazard Quotient Bin:** Five ecological-hazard quotient bins include <0.1, (0.1 - 1.0), (1.0 - 10), (10 - 100), and >100. The ecological-risk module in the MMSPP populates each ecological-hazard quotient bin with the percentage of receptors associated with that hazard quotient interval and below.

Therefore, for each chemical, WMU type, site, C_w , distance (i.e., ring), habitat group, receptor group, habitat type, receptor type, trophic level, and critical-year method, the MMSPP populates each ecological-hazard quotient bin with the percentage of receptors associated with that hazard quotient interval and below.

2.2 Scientific Requirements

The mathematical equations, which define the parameters tabularized in the ELP-I, are documented in the *ORD/OSW Integrated Research and Development Plan for the Hazardous Waste Identification Rule (HWIR)*. The software will be designed, implemented, and tested under the FRAMES-HWIR Technology Software System effort.

2.3 Output Requirements

The ELP-I must provide output in such a way that users can manipulate the results to assist in decisions regarding exit chemical-specific criteria. The RSOFs constitute the output from the ELP-I and thus serve as input for the RVP and ELP-II. By requiring the RSOFs to be in Microsoft® Access™ format, the EPA can conduct additional “what-if” analyses of the results from the FRAMES-HWIR Technology Software System through Microsoft® Access™ software or compatible software that can read the Microsoft® Access™ format. Figure 2.1 illustrates the relationships between the ELP-I, RVP, and ELP-II as well as the type of information that is stored in the RSOF and the format.

The RSOF matrix presented in Figure 2.1 illustrates that the RSOF file contains a summation of “site and iteration” counts per percentile of population protected by C_w and risk/hazard bin by chemical, WMU type, distance, and critical-year method.

- C **For human-health risk/hazard,** the matrix is also a function of exposure pathway, receptor type, and cohort.
- C **For the ecological hazard,** the matrix is also a function of distance and habitat group, distance and habitat type, distance and receptor group, distance and trophic level, receptor group and habitat group, or trophic level and habitat group.

Risk Summary Output File

M = Number of Risk/Hazard Bins

N = Number of C_w s

C = Summation of counts per percentage of Population Protected

i = index on the percentage of Population Protected, varying from 1 to 10 (i.e., 0%, 5%, 25%, 50%, 75%, 85%, 90%, 95%, 98%, and 99%)

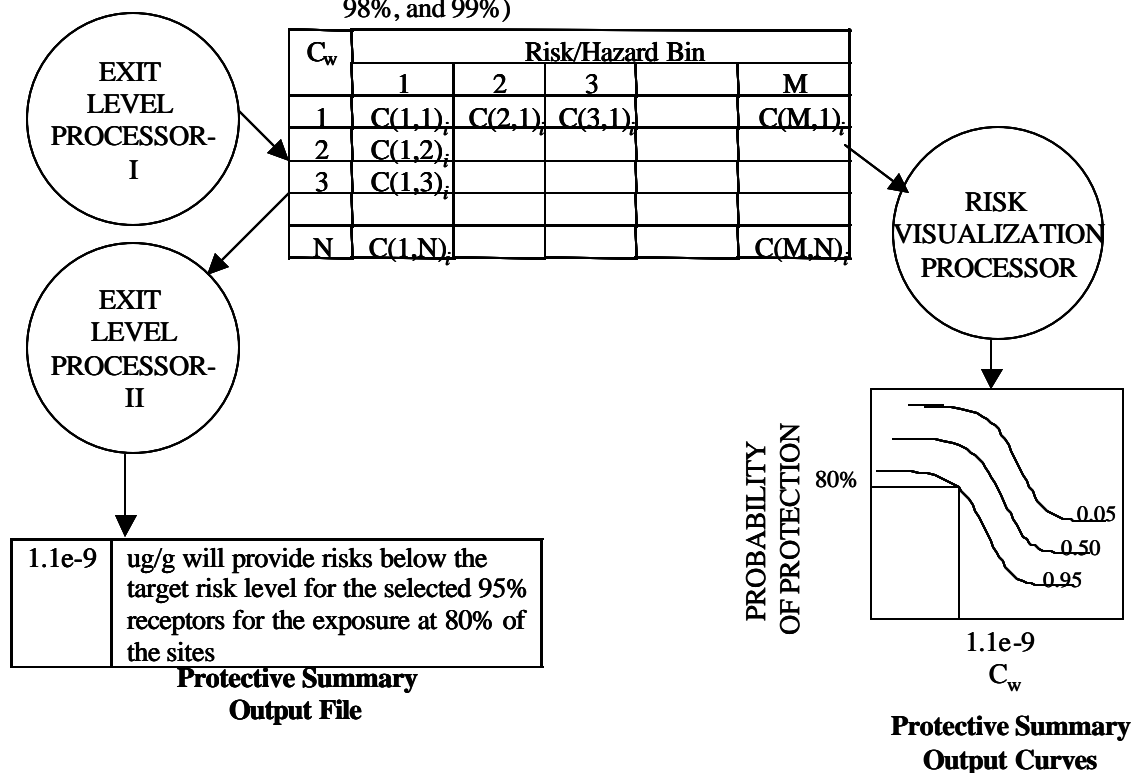


Figure 2.1. Example Results Indicating Potential Levels with Different Degrees of Conservativeness in RSOFs

Human-risk/hazard input information is tallied by chemical, WMU type, site, C_w , distance, exposure pathway, receptor type, cohort, critical-year method, risk/hazard bin, and percentiles of population protected (see Table 2.1):

- C **Chemical:** Although the actual number of chemicals assessed per production run varies, the ELP-1 was designed to at least address 40 chemicals, where 40 chemicals represent a subset of the total number of chemicals to be assessed as part of HWIR. The risk/hazard information is stored in the RSOF by chemical. For more information, refer to the Input Requirements section.

- C **Waste Management Unit Type:** The risk/hazard information is stored in the RSOF by WMU type. For more information, refer to Section 2.1.
- C **Site:** The risk/hazard information is stored in the RSOF by site. For more information, refer to the Section 2.1.
- C **C_w :** The risk/hazard information is stored in the RSOF by C_w . For more information, refer to Section 2.1.
- C **Distance:** The risk/hazard information is stored in the RSOF by distance. For more information, refer to Section 2.1.
- C **Exposure Pathway:** The risk/hazard information is stored in the RSOF by exposure pathway. For more information, refer to Section 2.1.
- C **Receptor Type:** The risk/hazard information is stored in the RSOF by receptor type. For more information, refer to Section 2.1.
- C **Cohort:** As noted earlier, the risk module analyzes five cohorts: Infants, 1-6 years old, 7-12 years old, 13-17 years old, and 18 years old and older (adult). Risk information on the five cohorts is passed to the ELP-I, where the ELP-I rolls-up the information into four cohorts: Infants, 1-12 years old, 13 years old and older (adult), and Summation of all Cohorts.
- C **Critical-Year Method:** The risk/hazard information is stored in the RSOF by critical-year method. For more information, refer to Section 2.1.
- C **Risk Bin:** Risk bins include $<1 \times 10^{-8}$, $(1 \times 10^{-8} - 5 \times 10^{-7})$, $(5 \times 10^{-7} - 1 \times 10^{-6})$, $(1 \times 10^{-6} - 5 \times 10^{-6})$, $(5 \times 10^{-6} - 1 \times 10^{-5})$, $(1 \times 10^{-5} - 1 \times 10^{-4})$, and $>1 \times 10^{-4}$. Each RSOF risk bin for human health stores, by chemical and WMU type, the number of “site and iteration” pairs that protects at least some percentile of the human population (0%, 5%, 25%, 50%, 75%, 85%, 90%, 95%, 98%, or 99%) for each “risk-bin/ C_w ” pair by distance, pathway, receptor, cohort, and critical-year method.
- C **Hazard Bin:** Hazard bins include <0.1 , $(0.1 - 1.0)$, $(1.0 - 10.0)$, and >10.0 . Each RSOF hazard bin for human health stores, by chemical and WMU type, the number of “site and iteration” pairs that protects at least some percentile of the human population for each “hazard-bin/ C_w ” pair by distance, pathway, receptor, cohort, and critical-year method.
- C **Percentiles of Population Protected:** Currently, 10 population protection percentiles have been identified: 99%, 98%, 95%, 90%, 85%, 75%, 50%, 25%, 5%, and 0%. These percentiles represent the percentile of the population that at least has been protected. For 90%, for example, at least 90% of the population has been protected at that C_w and risk/hazard level.

Therefore, for each chemical and WMU type, the ELP-I populates each cell with the number of “site and iteration” pairs that protects at least some percentile of the human population for each “hazard-bin/ C_w ” pair by distance, pathway, receptor, cohort, and critical-year method.

Ecological-hazard input information is tallied by chemical, WMU type, site, C_w , distance, critical-year method, hazard bin, and percentiles of population protected, by distance and habitat group, distance and habitat type, distance and receptor group, distance and trophic level, receptor group and habitat group, or trophic level and habitat group (see Table 2.2):

- C **Chemical:** Refer to Section 2.1.
- C **Waste Management Unit Type:** Refer to Section 2.1.
- C C_w : Refer to Section 2.1.
- C **Distance:** Refer to Section 2.1.
- C **Distance and Habitat Group:** 9 combinations (3 distances and 3 habitat groups).
- C **Distance and Habitat Type:** 36 combinations (3 distances and 12 habitat types).
- C **Distance and Receptor Group:** 27 combinations (3 distances and 9 receptor groups).
- C **Distance and Trophic Level:** 15 combinations (3 distances and 5 trophic levels).
- C **Receptor Group and Habitat Group:** 27 combinations (9 receptor groups and 3 habitat groups).
- C **Trophic Level and Habitat Group:** 15 combinations (5 trophic levels and 3 habitat groups).
- C **Critical-Year Method:** As previously defined in the Input Requirements section.
- C **Ecological-Hazard Quotient Bin:** Five ecological-hazard quotient bins include <0.1 , $(0.1 - 1.0)$, $(1.0 - 10)$, $(10 - 100)$, and >100 . Each RSOF ecological-hazard quotient bin stores, by chemical and WMU type, the number of “site and iteration” pairs that protects at least some percentile of the population for each critical-year method and “hazard-bin/ C_w ” pair by distance and habitat group, distance and habitat type, distance and receptor group, distance and trophic level, receptor group and habitat group, or trophic level and habitat group.
- C **Percentiles of Population Protected:** Refer to Section 2.3, human health outputs.

Table 2.3 elaborates on the information presented in the matrix of Figure 2.1 and explains the computational method upon which the ROSF database is based. The last row in Table 2.3 represents the actual counts that are stored in each RSOF table and is the third dimension associated with each cell in the matrix of Figure 2.1, of which the third dimension is not shown. The last row in Table 2.3 is the sum of the counts by column, contributed by the other rows. The “Sum of Counts by Column” in Table 2.3 is represented by $C(M,N)_i$ in Figure 2.1, where C is the sum of the counts by column, M is the number of risk/hazard bins (7 for human risk, 4 for human hazard, and 5 for ecological hazard), N is the number of C_w s (i.e., up to 5), and i is the index on the percentile of population protected in Figure 2.3, indexed from 1 to 10 (0%, 5%, 25%, 50%, 75%, 85%, 90%, 95%, 98%, and 99%). The counts by chemical and WMU

type represent the number of “site and iteration” pairs that protect at least some percentile of the population for each “risk/hazard-interval/ C_w ” pair by

- C distance, exposure pathway, receptor type, cohort, and critical-year method for human risk/hazard, or
- C distance and habitat group, distance and habitat type, distance and receptor group, distance and trophic level, receptor group and habitat group, or trophic level and habitat group.

For each site and iteration combination that meets the population protection criterion, the cell in Table 2.3 is assigned a value of unity, representing protection. When the cell does not meet the population protection criterion, the cell is assigned a value of zero, representing no protection. For example, if at least 75% of the population is protected at a given C_w and risk/hazard level, the appropriate cell under the 75% heading would receive a 1. If at least 75% of the population was not protected, the cell would receive a zero.

C_w data describe the range in waste-stream concentrations before disposal. When the last C_w is identified (e.g., $C_w=5$) or when an error occurs, the results associated with the C_w range ($C_w=1$ to 5) will be stored in the RSOFs.

Table 2.3 Procedure to Compute a Risk Summary Output File

C_{wi} and Risk/Hazard Bin,^(a)											
Index on Site (1 to N sites)	Index on Iteration (1 to M iterations)	Equal To or Greater Than Percentage of Population Protected									
		0%	5%	25%	50%	75%	85%	90%	95%	98%	99%
1	1	1 ^(b)	1	1	1	0	0	0	0	0	0
2	1	1	1	1	1	1	1	1	0	0	0
N	1	1	0	0	0	0	0	0	0	0	0
1	2	1	1	1	0	0	0	0	0	0	0
2	2	etc.									
N	2										
1	M										
2	M										
N	M										
Sum of Counts by Column ^(c)		Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9	Column 10

(a) “i” is the index on the C_w from one to five, and “j” is the index on the Risk/Hazard Bin. For human risk, there are seven excess cancer bins; for human hazard, four hazard quotient bins; for ecological hazard, five ecological-hazard quotient bins. A similar table is associated with each “ C_w &risk/hazard bin” pair.
 (b) For each site and iteration combination that meets the population protection criterion, the cell is assigned a value of unity, representing protection. When the cell does not meet the population-protection criterion, the cell is assigned a value of zero, representing no protection.
 (c) The ELP-1 only stores cumulative counts by column in the RSOFs (i.e., last row of Table 2.3).

3.0 Design Elements

The ELP is designed to meet the requirements identified in Section 2.0. Key to meeting those requirements is the ability to develop output files to determine exit levels. The following subsections describe the input, implementation, and output of the ELP-I.

3.1 Input

The input to the ELP-I is the HR.GRF and ER.GRF files produced by the human risk and ecological-risk modules, respectively. Specifications for the GRF are described in *Documentation of the FRAMES-HWIR Technology Software System, Volume 8: Specifications*. A description of the variables contained in these files can be found in the Human-Risk Module and Ecological-Risk Module documentation.

3.2 Implementation

A single execution of the MMSP results in a fate and transport analysis for a single site, WMU type, chemical, C_w , and realization. The MMSP produces human- and ecological-risk/hazard results by exposure pathway (as well as specific summations of pathways) for each human and ecological receptor in the scenario.

For human risk/hazard for each unique combination of chemical, site, WMU type, C_w , distance, exposure pathway (or summation of pathways), receptor type, cohort (or summation of cohorts), and critical-year method, the MMSP populates each human-health risk/hazard bin with the cumulative number of people in that risk/hazard interval and below. In effect, the MMSP tallies the number of such human receptors whose maximum risk/hazard occurs within predefined risk/hazard ranges (or bins) to produce a cumulative distribution of risk (i.e., a cumulative distribution function or CDF). A similar tally, based on percentage of receptors, is conducted for the ecological receptors by chemical, WMU type, site, C_w , distance (i.e., ring), habitat group, receptor group, habitat type, receptor type, trophic level, and critical-year method. These CDF bins will occur as a three-dimensional table (site versus statistical realization versus risk/hazard bin). For all sites and all realizations, each such three-dimensional table contains the 1) human risk/hazard results for a unique combination of chemical, site, WMU type, C_w , distance, exposure pathway (or summation of pathways), receptor type, cohort (or summation of cohorts), and critical-year method, or 2) ecological-hazard results for a unique combination of chemical, WMU type, site, C_w , distance, habitat group, receptor group, habitat type, receptor type, trophic level, and critical-year method. The ELP-I will simply read this binned risk/hazard information from the GRFs and store it in the RSOF format. In the process, the five cohort groups output by the MMSP will be collapsed into four cohort groups. Note that for this version of the MMSP, the critical-year method is always year 1.

3.3 Output

The intent of the RSOF is to make fast and efficient reading of data by the ELP-II and RVP. The RSOF collection of files is estimated to take up about 1 Gb of disk storage. Because the decision of which exit level C_w is acceptable is determined for each Chemical and Source Type, it seems reasonable to break up the 1 Gb by those two indices.

Each “Chemical (40) and WMU-Type (5)” pair will have its own database with the total number of databases being 200 (40×5 for 1Gb). Each of these 200 databases will have an identical structure within them. The structure will consist of 13 data description tables, 528 human-risk summary tables, and 129 ecological-risk summary tables. Additional information on the specifications for these tables can be found in *Documentation of the FRAMES-HWIR Technology Software System, Volume 8: Specifications*.

4.0 Testing Approach and Results

As noted, the primary purposes of the ELP are to process and reformat risk-based information generated by the MMSP, provide a means for querying and summarizing this information graphically, and to ultimately compute chemical-specific exit levels. This section describes the testing conducted for the ELP-I, summarizes the requirements on which testing was based, and describes test cases and results of their implementation. Additional information related to testing can be found in Appendices A and B.

4.1 Type of Testing

Software testing can be performed at both the unit and system levels. Unit testing evaluates individual components in isolation from other components (for example, the ELP-I in isolation from the RVP and ELP-II or the MMSP). System testing evaluates the performance of groups of components functioning together, data communication between the components comprising the system (also called integration testing), and the overall performance of the system (for example, testing the functioning of the ELP-I within the FRAMES-HWIR Technology Software System). This test plan currently addresses unit testing (i.e., of the ELP-I alone).

4.2 Summary of Requirements for the ELP-I

Requirements for the ELP-I are summarized in Section 2.0 of this document. These requirements were reworded into the list in Table 4.1 of fundamental requirements suitable for testing. Note that these requirements comprise only those related to the ELP-I. Requirements related to the RVP or ELP-II are discussed in *Documentation of the FRAMES-HWIR Technology Software System, Volume 15: Risk Visualization Processor and Exit Level-II Processor*.

Table 4.1 Fundamental Requirements for Testing the Exit Level Processor-I

Requirement Number	Requirement
1	Read the human health- and ecological-related GRFs produced by the MMSP (hr.grf and er.grf).
2	Consolidate the human risk/hazard results for 5 cohorts as output from the MMSP (infants, 1 to 6 years old, 7 to 12 years old, 13 to 17 years old, and 18 years or older) into 4 cohorts (infants, 1 to 12 years old, 13 years and older, and summation of all cohorts).
3	Store ecological and human risk/hazard-based information in Microsoft® Access™ database files (RSOFs).
4	Allow any number of waste concentrations, receptor types, exposure pathways, critical years (only one method implemented in modules at this time), distance regions, ecological areas, and habitat types without changing the program code.
5	Be capable of identifying the last in a series of waste-concentration data.
6	Only produce those tables that have data greater than zero across any row (to save computational space).
7	Generate errors when appropriate and create an error file.

To ensure the ELP-I meets the requirements listed in Table 4.1, test cases were developed to check performance. Table 4.2 shows the relationship between these requirements and the test cases, which are described in Section 4.3.

Table 4.2 Relationship Between Test Cases and Fundamental Requirements for the Exit Level Processor-I

		Test Case Name (ELPI_xx)			
		01	02	03	04
Requirement	1	x	x	x	
	2	x	x	x	
	3	x	x	x	
	4		x	x	
	5	x	x	x	
	6	x			
	7				x

4.3 Test Cases

All tests are conducted under Windows® 95, which represents the required operating system for implementing the HWIR Assessment Strategy. In addition, because the ELP-I requires the GRF to operate, all test cases test the ability of the ELP-I to read human health and ecological risk GRFs (Requirement 1). Also, all test cases test the processor’s ability to consolidate and store information in Access database files (Requirement 3), and its ability to identify the last waste-concentration level data (Requirement 5).

In the Access database produced by the ELP-I, there are up to 129 Ecological Risk tables and up to 528 Human Risk Information tables which contain the results of the simulation. Each table has a unique name which describes the information contained in that table. There are 6 basic groups of Ecological Risk tables (where the * is a placeholder for an integer):

- 1) ED*HG* - Ecological Ring and Habitat Group (Maximum 9 tables)
- 2) ED*HT* - Ecological Ring and Habitat Type (Max. 36 tables)
- 3) ED*RG* - Ecological Ring and Receptor Group (Max. 27 tables)
- 4) ED*TL* - Ecological Ring and Trophic Level (Max. 15 tables)
- 5) EHG*RG* - Habitat Group and Receptor Group (Max. 27 tables)
- 6) EHG*TL* - Habitat Group and Trophic Level (Max. 15 tables)

If all of the values in a table are 0, then it will not be created. For example, the LAU71-43-2.mdb database from test cases ELPI_02 and ELPI_03 does not contain any ED*TL* tables. Therefore, there are approximately 60 Ecological Risk tables in LAU71-43-2.mdb instead of 129.

The “E” at the start of each of the table names differentiates the ecological risk tables from the human risk information tables, which start with either an “H” or an “R.” The rest of the codes are

explained in Table 4.3. The description (DES) tables in the left column are from the database produced by the ELP-I. Each DES table shows what each letter and number stand for.

Table 4.3 Codes for the Ecological Hazard Tables

EDistDes	Prefix	Ring
	D0	Eco Ring #0
	D1	Eco Ring #1
	D2	Eco Ring #2
EHabGDes	Prefix	Habitat Group
	HG0	Terrestrial
	HG1	Aquatic
	HG2	Wetland
EHabTDes	Prefix	Habitat Type
	HT0	Crops
	HT1	Stream
	HT2	Residential
ERecGDes	Prefix	Receptor Group
	RG0	Reptile
	RG1	Bird
	RG2	Mammal
	RG3	Amphibian
	RG4	Soil Biota
	RG5	Aquatic Biota
	RG6	Sediment Biota
	RG7	Terrestrial Plant
	RG8	Aquatic Plant
ETrophicDes	Prefix	Trophic Level
	TL0	T3
	TL1	T2
	TL2	T1
	TL3	Communities
	TL4	Producers

There are 2 basic groups of Human Risk Information tables. They start with either an “H” or an “R” and then D*E*R*C*P0. The P stands for “critical percentage” and as can be seen in the CritDes

table, P0 stands for maximum. For all of the tables created by the ELP-I, the last two characters are always P0. Table 4.4 contains the names of the DES tables and the explanations of the codes for the Human Risk Information tables.

Table 4.4 Codes for the Human Risk Tables

DistDes	Prefix	Distance (meters)
	D0	500
	D1	1000
	D2	2000
ExpDes	Prefix	Exposure
	E0	Air Inhalation
	E1	Soil Ingestion
	E2	Water Ingestion
	E3	Crop Ingestion
	E4	Beef Ingestion
	E5	Milk Ingestion
	E6	Fish Ingestion
	E7	Shower Inhalation
	E8	Breast Milk
	E9	Summation of all Inhalation Pathways
	E10	Summation of all Ingestion Pathways
	E11	Summation of all Ingestion and Inhalation Pathways
	E12	Groundwater Total all Pathways
RecDes	Prefix	Receptor
	R0	Beef/Dairy Farmer
	R1	Gardener
	R2	Fisher
	R3	Resident
	R4	All Receptors
CohDes	Prefix	Cohort
	C0	Infants
	C1	1-12 years old
	C2	13 years and older
	C3	All cohorts

4.3.1 Test Case ELPI_01

4.3.1.1 Description and Rationale

This test case evaluates the processor's ability to produce an RSOF from a relatively simple scenario with a single waste concentration. Note that this test case was also used as Verification Test Case, Site 0223504.

4.3.1.2 Input Data

The input data for Test Case ELPI_01 consist of the hr.grf and er.grf found in subdirectory GRFTC01, their associated dictionaries in that same subdirectory, header file Hd01.ssf, and site layout file slwp0223504.ssf. The scenario assessed in these files assumes the following site characteristics:

- C a single waste-concentration level ($C_w=4$)
- C breast milk pathway to infants (with 100% of the population exposed across all bins, all distances, and all receptor types except fisher)
- C air inhalation and soil ingestion pathways to resident children and adults (with 100% of the population exposed across all bins and distances)
- C air inhalation, soil ingestion, and crop ingestion pathways to gardener children and adults (with 100% of the population exposed across all bins and distances)
- C air inhalation, soil ingestion, and fish ingestion pathways to fisher children and adults (with 100% of the population exposed across all bins and distances)
- C air inhalation, soil ingestion, and crop ingestion pathways to farmer children and adults (with 100% of the population exposed across all bins and distances)
- C terrestrial and aquatic plants in respective habitat groups (with 100% of the population exposed across all bins and distances).

4.3.1.3 Expected Results

The ELP-I should produce RSOF database WP1746-01-6.mdb. These are the waste pile results for 2,3,7,8-TCDD (2,3,7,8-tetrachlorodibenzo-para-dioxin). It should contain approximately 250 human risk information tables and approximately 40 ecological risk tables appropriately named and populated (at 100% across all bins and distances) for the fourth waste-concentration level only (i.e., $C_w=4$). No warning or error conditions should occur.

4.3.1.4 Procedure

Once input data have been set up as described in Appendix A, the tester runs the ELP-I, which populates the RSOF tables. The tester then checks a random selection of tables to ensure data are populated as expected. In this test case, the tester checked the following tables:

C HD0E8R0C0P0
C HD0E8R1C0P0
C HD2E8R0C0P0
C RD0E0R3C1P0
C RD1E0R3C2P0
C RD0E1R1C1P0
C RD2E0R1C2P0
C RD2E0R4C3P0
C RD1E4R4C2P0
C RD1E1R3C2P0
C RD2E3R1C1P0
C RD0E3R1C2P0
C RD0E9R0C1P0
C RD1E10R0C2P0
C RD2E9R1C1P0
C RD1E10R3C2P0
C RD0E9R0C1P0
C RD0E9R4C3P0
C RD1E11R0C1P0
C RD0E11R4C3P0
C ED0HG0
C ED0RG1
C EHG1RG0
C ED1HT0
C ED2HT2

4.3.1.5 Results

All of the fourth concentration level bins (i.e., $C_w=4$) for each of the selected database tables were completely populated. The ELP-I performed as expected. Therefore, it passed this test case.

4.3.2 Test Case ELPI_02

4.3.2.1 Description and Rationale

As mentioned, the ELP-I must be able to handle any number of waste concentrations, receptor types, exposure pathways, distance regions, ecological areas, and habitat types without changing the program code. This test case evaluates the processor's ability to produce and RSOF from a more complex scenari. Note that this test case was also used as Verification Test Case, Site 1632106.

4.3.2.2 Input Data

The input data for Test Case ELPI_02 consist of the hr.grf and er.grf found in subdirectory GRFTC02, their associated dictionaries in that same subdirectory, header file Hd02.ssf, and site layout file slla1632106.ssf. The scenario assessed in these files assumes the following site characteristics:

- C a single waste-concentration level ($C_w=5$)
- C air inhalation and soil ingestion pathways to resident children and adults
- C water ingestion and shower inhalation for resident adults
- C air inhalation, soil ingestion, water ingestion, and crop ingestion pathways to gardener children and adults
- C shower inhalation for gardener adults
- C air inhalation, soil ingestion, water ingestion, crop ingestion, and fish ingestion pathways to fisher children and adults
- C air inhalation, soil ingestion, water ingestion, and crop ingestion pathways to farmer children and adults
- C shower inhalation for farmer adults
- C summations of inhalation, ingestion, and all pathways for all receptor types
- C terrestrial and aquatic plants in respective habitat groups.

All values vary from 0 to 100% and anywhere in between for all bins across all distances. Note that fishers are only located in distance area 3 (D02).

4.3.2.3 Expected Results

The ELP-I should produce RSOF database LAU71-43-2.mdb. These are the Land Application Unit results for benzene. It should contain approximately 270 human risk information tables and 60 ecological risk tables appropriately named and populated. No warning or error conditions should occur.

4.3.2.4 Procedure

Once input data have been set up as described in Appendix A, the tester runs the ELP, which populates the RSOF tables. The tester then checks a random selection of database tables to ensure data are populated as expected. Appendix B gives the database tables and the corresponding percentages, similar to the 'Percent' row in Table 4.5. The database table will look similar to rows 6-15 of Table 4.5. In this test case, the tester checks the database tables listed in Appendix B to ensure data are compatible with those listed in Appendix B.

Table 4.5 shows an example of the roll-up of cohorts that the ELP-I performs. To calculate the percent of the population protected, two lines of values were taken from the hr.grf that is in the GRFTC02 directory. The hr.grf is the Global Result File (GRF) produced by the human risk module. It contains the population exposed to different hazard quotient and risk trigger levels. The values for different hazard quotients are used to calculate percentages for Ecological Risk tables, while risk trigger levels are used in Human Risk Information tables. This example shows the setup of the Human Risk Information table RD0E0R0C1P0 (row one in Table B.2). The two lines taken from the hr.grf were the resident cohort 2

populations from line 25 and the resident cohort 3 populations from line 115. Since it is impossible to have a fraction of a person, the values were rounded down to the nearest integer. For example, 34.989 would be rounded to 34. The integers are given in the 'Cohort 2' and 'Cohort 3' rows of Table 4.5. The two rows of information were added together to produce the total exposed population for cohort 2 and cohort 3 for each bin (i.e., each range of risk trigger levels). In Table 4.5, the range of risk trigger levels for each bin are listed underneath the bin name. In Bin 2, for example, the total exposed population between risk trigger levels 0 and $5e^{-7}$ is 128.

Bin 7 represents the cumulative population. Since Bin 7 includes all risk trigger levels greater than or equal to 0, its value represents the total population for cohort 2 and cohort 3 at the given site. That value is then used to compute the percent population protected for all other ranges of risk trigger levels. In Bin 2, for example, $128 \div 289 = 44.3\%$. These percentages are then compared against the ranges found in the left column below 'Percent'. If the calculated percentage is in that range, the count for that bin and percentage is incremented. For RD0E0R0C1P0, none of the population is at a risk trigger level between 0 and e^{-8} . Therefore, the cell below Bin 1 on the 'Percent' line is populated with 0 and the cell on the last line below Bin 1 is populated with a 1, since '\$0' is the only category that 0% is valid for. However, 44.3% of the population falls between risk trigger levels 0 and $5e^{-7}$, as you can see in the 'Percent' line underneath Bin 2. There are also three 1's populating the last three lines below Bin 2. This is because 44.3% fits into these three categories: '\$0', '\$5', and '\$25'.

Table 4.5 shows the values in the bins assuming that the previous counts were initialized to 0. If this test case is run again, the tables produced would be populated with 0's and 2's. The remainder of Ecological Risk and Human Risk Information tables that the tester checked are found in Tables B.1 and B.2 in Appendix B. The top part of Table 4.5 presents the number of receptors associated with each risk bin, as well as the totals and percent of total. The bottom part of Table 4.5 represents the counts (by site and iteration) that meet the percentage of population protected (e.g., \$99, \$98, . . . , \$5 and \$0). For more information, refer to Section 2.3 and Table 2.3.

4.3.2.5 Results

The data in the selected database tables matched the data listed in Appendix B. The ELP-I performed as expected. Therefore, it passed this test case.

4.3.3 Test Case ELPI_03

4.3.3.1 Description and Rationale

As mentioned, the ELP-I must be able to handle any number of waste concentrations, receptor types, exposure pathways, distance regions, ecological areas, and habitat types without changing the program code. This test case evaluates the processor's ability to produce and RSOF from a more complex scenario. Note that this test case was also used as Verification Test Case, Site 1632106.

4.3.3.2 Input Data

The input data for Test Case ELPI_03 consist of the hr.grf and er.grf found in subdirectory GRFTC03, their associated dictionaries in that same subdirectory, header file Hd03.ssf, and site layout file slla1632106.ssf. The scenario assessed in these files assumes the following site characteristics:

- C five waste-concentration levels
- C air inhalation and soil ingestion pathways to resident children and adults

Table 4.5 Example Roll-Up of Cohorts

	Bin 1 0 - 1.0E-8	Bin 2 0 - 5.0E-7	Bin 3 0 - 1.0E-6	Bin 4 0 - 5.0E-6	Bin 5 0 - 1.0E-5	Bin 6 0 - 0.0001	Bin 7 \$ 0
Cohort 2	0	71	148	158	158	158	158
Cohort 3	0	57	120	130	130	130	130
Totals	0	128	269	289	289	289	289
Percent	0	44.3%	93.1%	100 %	100 %	100 %	100 %
\$ 99	0	0	0	1	1	1	1
\$ 98	0	0	0	1	1	1	1
\$ 95	0	0	0	1	1	1	1
\$ 90	0	0	1	1	1	1	1
\$ 85	0	0	1	1	1	1	1
\$ 75	0	0	1	1	1	1	1
\$ 50	0	0	1	1	1	1	1
\$ 25	0	1	1	1	1	1	1
\$ 5	0	1	1	1	1	1	1
\$ 0	1	1	1	1	1	1	1

- C water ingestion and shower inhalation for resident adults
- C air inhalation, soil ingestion, water ingestion, and crop ingestion pathways to gardener children and adults
- C shower inhalation for gardener adults
- C air inhalation, soil ingestion, water ingestion, crop ingestion, and fish ingestion pathways to fisher children and adults
- C air inhalation, soil ingestion, water ingestion, and crop ingestion pathways to farmer children and adults
- C shower inhalation for farmer adults
- C summations of inhalation, ingestion, and all pathways for all receptor types
- C terrestrial and aquatic plants in respective habitat groups.

All values vary from 0 to 100% and anywhere in between for all bins across all distances. Note that fishers are only located in distance area 3 (D02).

4.3.3.3 Expected Results

The ELP-I should produce RSOF database LAU71-43-2.mdb. These are the Land Application Unit results for benzene. It should contain approximately 270 human risk information tables and 60 ecological risk tables appropriately named and populated. The data in the 7 bins of the first concentration level ($C_n=1$) should be repeated consistently in each of the next four concentration levels. No warning or error conditions should occur.

4.3.3.4 Procedure

Once input data have been set up as described in Appendix A, the tester runs the ELP-I, which populates the RSOF tables. Appendix B gives the database tables and the corresponding percentages, similar to the 'Percent' row in Table 4.5. The database table will be similar to rows 6-15 of Table 4.5, except that the same data should be repeated for each concentration level. The tester then checks a random selection of database tables ensure that the data remains consistent for each repetition for each concentration level. In this test case, the tester checked the following database tables:

C ED0HG0
C ED2HG1
C ED0HT0
C ED1HT1
C ED1HT4
C ED0RG0
C ED1RG6
C EHG1RG8
C EHG0TL0
C EHG0TL4
C EHG1TL1
C ED0TL0
C ED1TL4
C RD0E0R0C1P0
C RD0E2R0C2P0
C RD2E2R0C2P0
C RD1E7R0C2P0
C RD0E3R1C1P0
C RD1E2R1C2P0
C RD2E7R1C2P0
C RD2E2R3C1P0
C RD1E10R0C1P0
C RD2E9R0C2P0
C RD0E10R1C2P0
C RD0E10R3C1P0

C RD1E9R3C2P0
C RD0E11R1C1P0
C RD1E11R3C1P0
C RD2E11R3C2P0

4.3.3.5 Results

For the randomly selected database tables, the data in the first concentration level ($C_w=1$) were consistent with the data in the remaining four concentration levels. The ELP-I performed as expected. Therefore, it passed this test case.

4.3.4 Test Case ELPI_04

4.3.4.1 Description and Rationale

The ELP-I must be able to identify processor-specific errors and report them to the System User Interface. Because of the nature of ELP, which is to aggregate data developed by other modules, the processor is actually capable of few error conditions. This test case evaluates the ELP's ability to identify and report the most likely of these errors, the lack of an appropriate human risk GRF.

4.3.4.2 Input Data

The input data for Test Case ELPI_04 consist of the same files as for ELPI_01, except the associated human risk GRF (which would be hr.grf) is missing.

4.3.4.3 Expected Results

The ELP will attempt to run and immediately return an error indicating that the hr.grf is missing.

4.3.4.4 Procedure

Once input data have been set up as described in Appendix A, the tester runs the ELP, which attempts to populate the RSOF tables. The tester checks that the error message correctly identifies the problem.

4.3.4.5 Results

The error file was created in subdirectory GRFTC01. The text of the error file read: "Failed to call CloseGroups writing', 'sl.grf', 'Data group hr.grf Can not find/open data group',". The ELP-I performed as expected. Therefore, it passed this test case.

5.0 Quality Assurance Program

The ELP-I was developed under a quality assurance program documented in Gelston et al. (1998). Quality is defined as the ability of the software to meet client needs. Meeting client needs starts with a shared understanding of how the software must perform and continues throughout the software life cycle of design, development, testing, and implementation through attention to details.

Figure 5.1 outlines the software development process used for the ELP-I, highlighting the quality check points. (The ELP-I activities flow down the left side of Figure 5.1 because it is software developed for the first time as opposed to a modification to existing software.) The process shown is designed for compatibility with similar processes used by other government agencies. For example, this quality process compares favorably with that in EPA Directive 2182, *System Design and Development Guidance* (EPA 1997). It also compares favorably with the Office of Civilian Radioactive Waste Management's *Quality Assurance Requirements and Description, Supplement I, Software* (OCRWM 1995). Activities roughly equivalent across these processes are shown in Table 5.1.

Development of the ELP-I included the implementation of a quality assurance checklist (see Figure 5.2). Because they studied the checklist, all of the team members understood the component requirements and design necessary to ensure quality. Completion of this checklist verified that all documentation was complete for transfer of the software to client use.

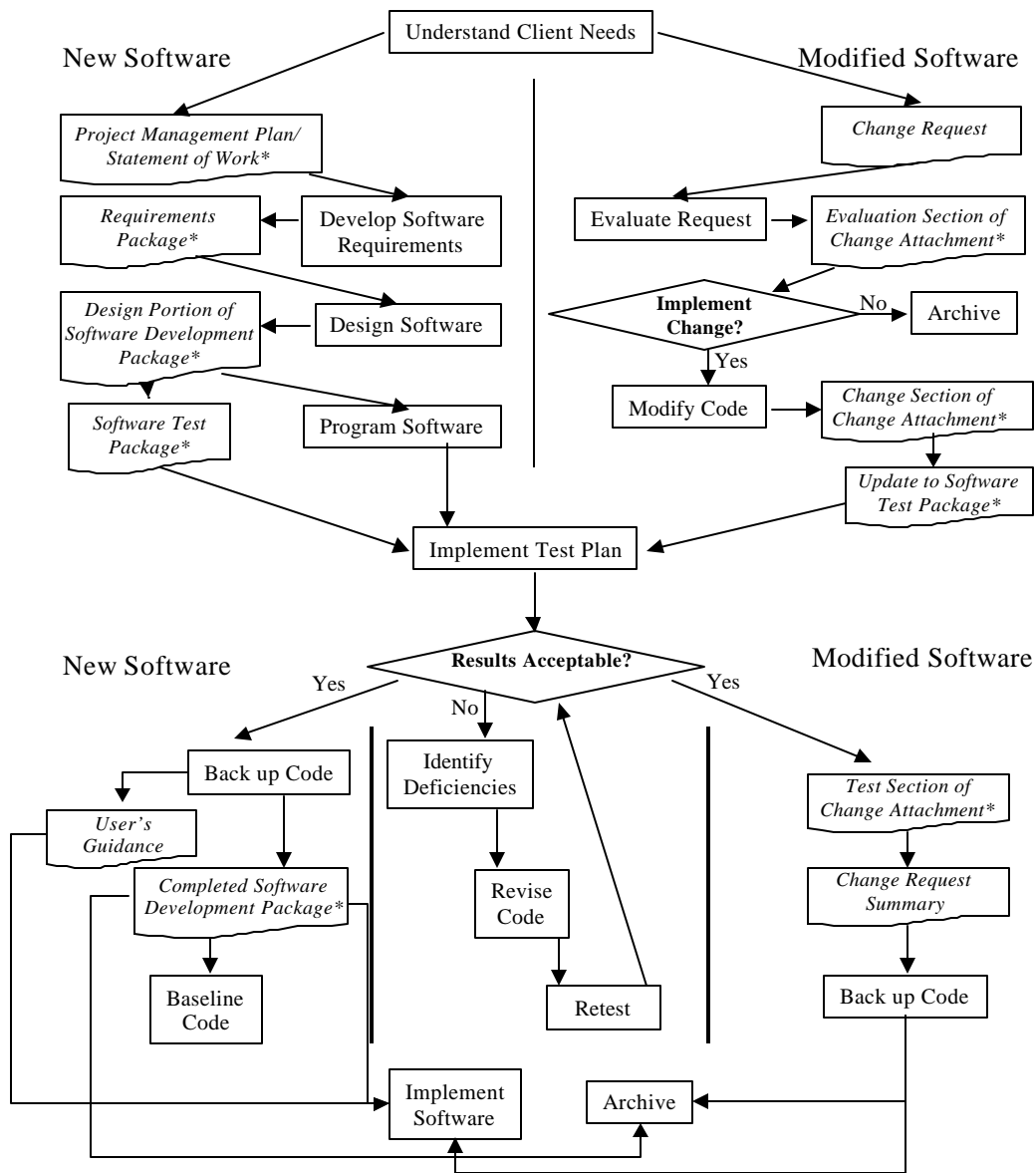


Figure 5.1. Ensuring Quality in the Environmental Software Development Process
 (* indicates quality review stage; box with wavy bottom line and italics font indicates a document rather than an activity)

Table 5.1 Relationship of PNNL Environmental Software Development Process to Quality Assurance Requirements (OCRWM 1995, EPA 1997)

OCRWM Quality Assurance Requirement^(a)	EPA Essential Element of Information^(b)	Environmental Software Process Equivalent (Section)
	4—System Implementation Plan	Project Management Plan or Statement of Work
I.2.5A Functional Requirements Information Documentation; I.2.5C Requirements and Design Documentation	5—System Detailed Requirements Document	Requirements Package
I.2.1 Software Life Cycles, Baselines (see their Appendix C), and Controls	6—Software Management Plan	Project Management Plan or Statement of Work and Gelston et al. (1998)
I.2.2 Software Verification ^(c) and Software Validation; I.2.4 Software Validation ^(d)	7—Software Test and Acceptance Plan	Software Test Package
I.2.3 Software Verification; I.2.5C Requirements and Design Information Documentation	8—Software Design Document	Design Portion of Software Development Package
I.2.6A Configuration Identification		Completed Software Development Package
I.2.6B Configuration Control; I.2.6C Configuration Status; I.2.7 Defect Reporting and Resolution ^(e)	9—Software Maintenance Document	Modification Documentation
	10—Software Operations Document	User's Guidance and Training
I.2.5B User Information Documentation	11—Software User's Reference Guide	User's Guidance and Training
	12—System Integration Test Reports	Software Test Package

- (a) Note that OCRWM requirement I.2.8, Control of the Use of Software, is the responsibility of the OCRWM-related client.
- (b) Elements 1 through 3 are generally completed by clients in the U.S. Environmental Protection Agency before contract initiation with the project team.
- (c) Verification includes informal code testing by software engineers (see their Appendix C) to ensure that code functions as required.
- (d) Validation includes testing by those other than the software engineers who developed the code to provide an independent confirmation that software functions as required.
- (e) Note that some changes requested by clients may not be made in the software unless funding has been allocated for such modifications.

- A. General Requirements Analysis
 - Documented in
 - ___ Statement of Work (stored in project file; see Gene Whelan, Gariann Gelston, or current Integration Leader)
 - Contains information on (all of the following)
 - ___ problem description
 - ___ deliverables
 - ___ project team
 - ___ capabilities to be used
 - ___ restrictions
 - ___ difficulties envisioned
 - ___ compatibilities with existing software/hardware
 - ___ scope of the project
- B. Specific Requirements Analysis
 - Documented in
 - ___ requirements section of documentation (PNNL-11914, Volume 7, Section 2.0)
 - Contains information on (all of the following)
 - ___ purpose of the software
 - ___ structure of the software
 - ___ hardware and software requirements
 - ___ input and output requirements
 - ___ scientific basis
 - ___ assumptions
 - ___ limitations
 - ___ post-October 31 requirements
- C. Design Documentation
 - Documented in
 - ___ design portion of documentation (PNNL-11914, Volume 7, Section 3.0)
 - ___ team task plans/Project Management Plan (stored in project file; see Gene Whelan, Gariann Gelston, or current Integration Leader)
 - Contains information on (all of the following)
 - ___ code type and description
 - ___ development team members
 - ___ specifications
 - ___ logic diagrams
 - ___ "help" descriptions
 - ___ methods to ensure consistency in components
 - ___ mathematical formulations
 - ___ need for pre/post-processors
 - ___ post-October 31 design elements
- D. Development Documentation
 - Documented in
 - ___ Specifications Document (PNNL-11914, Volume 8)
 - ___ Quality Assurance Archive (see Gariann Gelston or current Integration Leader)
 - Contains information on (all of the following)
 - ___ baseline hard copy of the source code
 - ___ diskette copy
 - ___ name of computer language(s) used
- E. Testing Documentation
 - Documented in
 - ___ test plan that meets quality assurance requirements (PNNL-11914, Volume 7, Section 4.0)
 - Contains information on (all of the following)
 - ___ description of software
 - ___ testing scope
 - ___ relationship between test cases and requirements
 - ___ test activity description
 - ___ hardware and software needed to implement plan
 - ___ test case specifications
 - ___ expected results

Figure 5.2 Quality Assurance Implementation Checklist for ELP-I

F. User's Guidance

- Documented in
 - hardcopy printout of user's guidance for system (PNNL-11914, Volume 11)
- Contains information on (all of the following)
 - description of software
 - description of use of user interface
 - mathematical formulations
 - example problems
 - explanation of modules included

G. General Quality Assurance Documentation

- Documented in
 - Quality Assurance Program Document (PNNL-11880)
 - Quality Assurance Software-Specific Checklist (PNNL-11914, Volume 7, Section 5.0)
- Contains information on (all of the following)
 - purpose of quality assurance program
 - client-specified activities
 - activities required to ensure quality in software

H. Quality Assurance Archive

- Documented in
 - hard-copy files (see Gariann Gelston or current Integration Leader)
 - back up disk files in multiple storage locations (see Gariann Gelston or current Integration Leader)
- Contains information on (all of the following)
 - all quality assurance documentation
 - client correspondence regarding software
 - modifications made to baselined software
 - disk copy back ups
 - reproducibility of code (check code for comments)

Completed by _____ Date _____

Approved by _____ Date _____

System/Module Manager _____ Date _____

Figure 5.2. Quality Implementation Checklist (contd)

6.0 References

Documentation for the FRAMES-HWIR Technology Software System

Volume 1: Overview of the FRAMES-HWIR Technology Software System. 1999. PNNL-11914, Vol. 1, Pacific Northwest National Laboratory, Richland, Washington.

Volume 2: System User Interface Documentation. 1999. PNNL-11914, Vol. 2, Pacific Northwest National Laboratory, Richland, Washington.

Volume 3: Distribution Statistics Processor Documentation. 1999. TetraTech, Lafayette, California.

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Volume 13: Chemical Properties Processor Documentation. 1999. PNNL-11914, Vol. 13, Pacific Northwest National Laboratory, Richland, Washington.

Volume 14: Site Layout Processor Documentation. 1999. PNNL-11914, Vol. 14, Pacific Northwest National Laboratory, Richland, Washington.

Volume 15: Risk Visualization Tool Documentation. 1999. PNNL-11914, Vol. 15, Pacific Northwest National Laboratory, Richland, Washington.

Quality Assurance Program Document

Gelston, G. M., R. E. Lundgren, J. P. McDonald, and B. L. Hoopes. 1998. *An Approach to Ensuring Quality in Environmental Software*. PNNL-11880, Pacific Northwest National Laboratory, Richland, Washington.

Additional References

Office of Civilian Radioactive Waste Management (OCRWM). 1995. *Quality Assurance Requirements and Description, Supplement I, Software*. U.S. Department of Energy, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1997. *System Design and Development Guidance*. EPA Directive Number 2182, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1999a. *Human Risk Module: Background and Implementation for The Multimedia, Multipathway, and Multireceptor Risk Assessment (3MRA) for HWIR99*. U.S. Environmental Protection Agency, Office of Solid Waste, Washington, DC (Draft).

U.S. Environmental Protection Agency (EPA). 1999b. *Ecological Risk Module: Background and Implementation for the Multimedia, Multipathway and Multireceptor Risk Assessment (3MRA) for HWIR99*. U.S. Environmental Protection Agency, Office of Solid Waste, Washington, DC (Draft).

Appendix A

Additional Testing Information

Appendix A

Additional Testing Information

This appendix lists instructions for setting up test cases for the Exit Level Processor-I of the FRAMES-HWIR Technology Software System. Before taking any of these steps, start the Windows® Explorer and set up an ELP-I test bed directory. Put the ELP executable and any other files received for testing into this directory. Conduct the following steps within that directory.

A.1 Create a Human-Risk Global Result File

- 1) Create a GRF subdirectory for the specific test case (for example, for Test Case ELP_01, the name might be GRF-01).
- 2) Copy the file hr.grf from the ELP files provided into the GRF subdirectory you created.
- 3) Open the new file.
- 4) Check that all data match the test case you will be running. Note: the hr.grf is an extremely complex file. It is recommended that you use files previously generated by the human-risk module, with minimal changes, rather than hand-generating a new file.
- 5) Save the file and exit.
- 6) Create a separate GRF subdirectory and follow these steps for each C_w and test case.

A.2 Create an Ecological-Risk Global Result File

- 1) Copy the file er.grf from the ELP files provided into the GRF subdirectory you created for the hr.grf.
- 3) Open the new file.
- 4) Check that all data match the test case you will be running. Note: the er.grf is a complex file. It is recommended that you use files previously generated by the ecological-risk module, with minimal changes, rather than hand-generating a new file.
- 5) Save the file and exit.
- 6) Create a separate GRF subdirectory and follow these steps for each C_w and test case.

A.3 Create a Header File

- 1) Open the ssf subdirectory.
- 2) Copy the file hd.ssf and name the copy for the test case and C_w level you will be running (for example, for Test Case ELPI_01, first C_w level, the name might be hd01C_w1.ssf).
- 3) Open the new file.
- 4) Check that all paths identified and other information match the test case you will be running, especially the parameters CASID, C_w , ELPI, GRFDirectory, Last C_w , RSOFDirectory, Source, Srcs, and SSFDirectory.
- 5) Save the file and exit.
- 6) Create another header file for each C_w being run for that test case.

A.4 Create a Site Layout File

- 1) Open the ssf subdirectory.
- 2) Copy the file sl.ssf and name the copy for the test case and C_w level you will be running (for example, for Test Case ELPI_01, first C_w level, the name might be sl01C_w1.ssf).
- 3) Open the new file.
- 4) Check that all paths identified and other information match the test case you will be running, especially the parameters EcoRingHabIndex, EcoRingNumHab, HabGroup, HabIndex, HabType, HumRcpType, NumHabGroup, NumHabType, NumTrophicLevel, ReceptorName, ReceptorType, RecGroup, RecTrophicLevel, and SrcType.
- 5) Save the file and exit.

A.5 Create a Shortcut for Each Waste-Concentration Level

- 1) Right-click on the ELP executable (elp1.exe). Select Create Shortcut.
- 2) Right-click on the shortcut you just created. Select Rename.
- 3) Name the shortcut for the test case and C_w you are running (for example, for Test Case ELP1_01, first C_w , the name might be ELP1_01-C_w1).
- 4) Right-click on the new shortcut and select Properties. Click on the tab Shortcut.
- 5) In the Target line, type the pathway to the files you will be using in the test case (for example, for Test Case ELP1_05, second C_w level, the pathway might be D:\HWIR\ELPI\elp1.exe ssf grf hdtc5C_w2.ssf). Note that you must include the location of the GRF and SSF subdirectories, and that they must be in the same main directory as the ELP executable.

Appendix B

Expected Results for Test Cases ELPI_02 and ELPI_03

Appendix B

Expected Results for Test Cases ELPI_02 and ELPI_03

Tables B.1 and B.2 list the selection of database tables checked by the tester and their corresponding percentages. Table B.1 lists the Ecological Risk tables and Table B.2 lists the Human Risk Information tables. The tester checked all of the database tables listed in both tables for test case ELPI_02, and only the highlighted tables for test case ELPI_03. The database table should be formatted similar to rows 6-15 of Table 4.5. For test case ELPI_02, only the fifth waste-concentration level should be populated. For test case ELPI_03, the data should be repeated through each of the five waste-concentration levels.

In Table B.1, the range of hazard quotients for each bin is given underneath the bin name. The percentage of population that are within that hazard quotient range are given below each bin name. For example, in database table ED0HG0 (row 1 of Table B.1), 100% of hazard quotients are between 0 and 0.1. Therefore, the cell below Bin 1 is populated with 100. Since all of the hazard quotients for ED0HG0 are between 0 and 0.1, 100% of hazard quotients are also between 0 and 1. Therefore, the cell below Bin 2 is populated with 100. Bins 3, 4 and 5 are also all populated with 100 for the same reason.

Table B.1 Ecological Hazard Tabulation

Table Name	Hazard Bin 1 0 - 0.1	Hazard Bin 2 0 - 1	Hazard Bin 3 0 - 10	Hazard Bin 4 0 - 100	Hazard Bin 5 \$0
ED0HG0	100	100	100	100	100
ED0HG1	100	100	100	100	100
ED1HG0	100	100	100	100	100
ED2HG0	100	100	100	100	100
ED2HG1	100	100	100	100	100
ED0HT0	90	100	100	100	100
ED0HT2	100	100	100	100	100
ED0HT4	100	100	100	100	100
ED1HT0	90	100	100	100	100
ED1HT1	91	100	100	100	100
ED1HT2	100	100	100	100	100
ED1HT4	100	100	100	100	100
ED2HT0	90	100	100	100	100
ED2HT1	91	100	100	100	100
ED2HT2	100	100	100	100	100
ED2HT4	100	100	100	100	100
ED0RG0	100	100	100	100	100
ED0RG6	100	100	100	100	100
ED0RG8	100	100	100	100	100
ED1RG0	100	100	100	100	100
ED1RG6	100	100	100	100	100

Table Name	Hazard Bin 1 0 - 0.1	Hazard Bin 2 0 - 1	Hazard Bin 3 0 - 10	Hazard Bin 4 0 - 100	Hazard Bin 5 \$0
ED1RG8	100	100	100	100	100
ED2RG0	100	100	100	100	100
ED2RG6	100	100	100	100	100
ED2RG8	100	100	100	100	100
EHG0RG0	100	100	100	100	100
EHG0RG6	50	100	100	100	100
EHG0RG8	100	100	100	100	100
EHG1RG0	100	100	100	100	100
EHG1RG6	100	100	100	100	100
EHG1RG8	100	100	100	100	100
EHG0TL0	100	100	100	100	100
EHG0TL1	100	100	100	100	100
EHG0TL2	100	100	100	100	100
EHG0TL3	100	100	100	100	100
EHG0TL4	50	100	100	100	100
EHG1TL0	100	100	100	100	100
EHG1TL1	100	100	100	100	100
EHG1TL2	100	100	100	100	100
EHG1TL3	100	100	100	100	100
EHG1TL4	100	100	100	100	100
ED0TL0	100	100	100	100	100
ED0TL1	100	100	100	100	100
ED0TL2	100	100	100	100	100
ED0TL3	100	100	100	100	100
ED0TL4	75	100	100	100	100
ED1TL0	100	100	100	100	100
ED1TL1	100	100	100	100	100
ED1TL2	100	100	100	100	100
ED1TL3	100	100	100	100	100
ED1TL4	50	100	100	100	100
ED2TL0	100	100	100	100	100
ED2TL1	100	100	100	100	100
ED2TL2	100	100	100	100	100
ED2TL3	100	100	100	100	100
ED2TL4	60	100	100	100	100

Table B.3 Human Risk Tabulation

Table Name	Bin 1 0 - 1.0E-8	Bin 2 0 - 5.0E-7	Bin 3 0 - 1.0E-6	Bin 4 0 - 5.0E-6	Bin 5 0 - 1.0E-5	Bin 6 0 - 0.0001	Bin 7 \$ 0
RD0E0R0C1P0	0	44.3	93.1	100	100	100	100
RD1E0R0C1P0	0	50.6	94.4	100	100	100	100
RD2E0R0C1P0	0	40.9	74.8	89.6	91.1	92.9	100
RD0E1R0C1P0	100	100	100	100	100	100	100
RD1E1R0C1P0	100	100	100	100	100	100	100
RD2E1R0C1P0	100	100	100	100	100	100	100
RD0E2R0C1P0	25	25	25	100	100	100	100
RD1E2R0C1P0	55.3	55.3	55.3	63.2	73.7	100	100
RD2E2R0C1P0	69.6	72.2	72.2	78.3	84.3	100	100
RD0E0R0C2P0	0	97.3	99.5	100	100	100	100
RD1E0R0C2P0	0	77.7	99.8	100	100	100	100
RD2E0R0C2P0	0.5	68.5	86.6	93.6	94.0	99.1	100
RD0E1R0C2P0	100	100	100	100	100	100	100
RD1E1R0C2P0	100	100	100	100	100	100	100
RD2E1R0C2P0	100	100	100	100	100	100	100
RD0E2R0C2P0	48.3	48.3	48.3	100	100	100	100
RD1E2R0C2P0	58.9	58.9	58.9	67.4	95.4	100	100
RD2E2R0C2P0	69.8	71.9	71.9	81.8	97.5	100	100
RD0E7R0C2P0	44.8	48.3	48.3	96.6	100	100	100
RD1E7R0C2P0	57.1	58.9	58.9	66.9	67.4	100	100
RD2E7R0C2P0	64.9	71.5	71.5	79.9	81.4	100	100
RD0E0R1C1P0	0	44.1	92.7	100	100	100	100
RD1E0R1C1P0	0	50.6	94.2	100	100	100	100
RD2E0R1C1P0	0	40.9	74.9	89.6	91.2	92.8	100
RD0E1R1C1P0	100	100	100	100	100	100	100
RD1E1R1C1P0	100	100	100	100	100	100	100
RD2E1R1C1P0	100	100	100	100	100	100	100
RD0E2R1C1P0	0	0	0	100	100	100	100
RD1E2R1C1P0	56.5	56.5	56.5	65.2	73.9	100	100
RD2E2R1C1P0	70	72.9	72.9	78.6	85.7	100	100
RD0E3R1C1P0	0	21.5	37.3	99.4	100	100	100
RD1E3R1C1P0	0	18.3	44.0	99.6	100	100	100
RD2E3R1C1P0	0	12.8	38.5	82.2	88.2	92.1	100
RD0E0R1C2P0	0	97.3	99.6	100	100	100	100
RD1E0R1C2P0	0	77.7	99.8	100	100	100	100
RD2E0R1C2P0	0.5	68.5	86.6	93.6	94.0	99.1	100

Table Name	Bin 1 0 - 1.0E-8	Bin 2 0 - 5.0E-7	Bin 3 0 - 1.0E-6	Bin 4 0 - 5.0E-6	Bin 5 0 - 1.0E-5	Bin 6 0 - 0.0001	Bin 7 \$ 0
RD0E1R1C2P0	100	100	100	100	100	100	100
RD1E1R1C2P0	100	100	100	100	100	100	100
RD2E1R1C2P0	100	100	100	100	100	100	100
RD0E2R1C2P0	44.4	44.4	44.4	100	100	100	100
RD1E2R1C2P0	58.9	58.9	58.9	67.3	95.3	100	100
RD2E2R1C2P0	69.7	71.8	71.8	81.7	97.5	100	100
RD0E3R1C2P0	0	12.5	71.1	99.9	100	100	100
RD1E3R1C2P0	0	7.3	42.6	99.9	100	100	100
RD2E3R1C2P0	0	5.6	32.1	81.9	89.2	94.0	100
RD0E7R1C2P0	44.4	44.4	44.4	94.4	100	100	100
RD1E7R1C2P0	57.0	58.9	58.9	67.3	67.3	100	100
RD2E7R1C2P0	64.7	71.5	71.5	79.9	81.4	100	100
RD0E0R3C1P0	0	44.1	93.1	100	100	100	100
RD1E0R3C1P0	0	50.4	94.2	100	100	100	100
RD2E0R3C1P0	0	40.9	74.8	89.7	91.2	93.0	100
RD0E1R3C1P0	100	100	100	100	100	100	100
RD1E1R3C1P0	100	100	100	100	100	100	100
RD2E1R3C1P0	100	100	100	100	100	100	100
RD0E2R3C1P0	0	0	0	100	100	100	100
RD1E2R3C1P0	53.8	53.8	53.8	61.5	76.9	100	100
RD2E2R3C1P0	68.3	73.2	73.2	78.0	85.4	100	100
RD0E3R3C1P0	0	21.6	37.3	100	100	100	100
RD1E3R3C1P0	0	18.0	43.9	100	100	100	100
RD2E3R3C1P0	0	12.7	38.5	82.4	88.5	92.4	100
RD0E9R0C1P0	0	44.3	93.1	100	100	100	100
RD1E9R0C1P0	0	50.6	94.4	100	100	100	100
RD2E9R0C1P0	0	40.9	74.8	89.6	91.1	92.9	100
RD0E10R0C1P0	98.9	98.9	98.9	100	100	100	100
RD1E10R0C1P0	95.7	95.7	95.7	96.4	100	100	100
RD2E10R0C1P0	96.3	96.6	96.6	97.3	100	100	100
RD0E9R0C2P0	0	95.9	98.2	99.9	100	100	100
RD1E9R0C2P0	0	74.9	96.9	97.6	99.7	100	100
RD2E9R0C2P0	0.5	66.0	84.0	91.8	93.7	99.1	100
RD0E10R0C2P0	98.6	98.6	98.6	100	100	100	100
RD1E10R0C2P0	97.1	97.1	97.1	97.7	100	100	100
RD2E10R0C2P0	97.3	97.5	97.5	98.4	100	100	100
RD0E9R1C1P0	0	44.1	92.7	100	100	100	100

Table Name	Bin 1 0 - 1.0E-8	Bin 2 0 - 5.0E-7	Bin 3 0 - 1.0E-6	Bin 4 0 - 5.0E-6	Bin 5 0 - 1.0E-5	Bin 6 0 - 0.0001	Bin 7 \$ 0
RD1E9R1C1P0	0	50.6	94.2	100	100	100	100
RD2E9R1C1P0	0	40.9	74.9	89.6	91.2	92.8	100
RD0E10R1C1P0	0	21	36	99.6	100	100	100
RD1E10R1C1P0	0	17.8	40.7	96.3	100	100	100
RD2E10R1C1P0	0	11.8	35.7	79.3	86.3	92.1	100
RD0E9R1C2P0	0	96.0	98.2	100	100	100	100
RD1E9R1C2P0	0	74.9	96.9	97.7	99.7	100	100
RD2E9R1C2P0	0.5	65.9	84.0	91.8	93.7	99.1	100
RD0E10R1C2P0	0	12.5	69.7	99.9	100	100	100
RD1E10R1C2P0	0	7.3	41.7	97.6	99.7	100	100
RD2E10R1C2P0	0	5.7	31.0	80.1	89.2	94.0	100
RD0E9R3C1P0	0	44.1	93.1	100	100	100	100
RD1E9R3C1P0	0	50.4	94.2	100	100	100	100
RD2E9R3C1P0	0	40.9	74.8	89.7	91.2	93.0	100
RD0E10R3C1P0	0	20.6	36.3	100	100	100	100
RD1E10R3C1P0	0	18.0	40.3	96.4	100	100	100
RD2E10R3C1P0	0	11.8	35.8	79.4	86.4	92.4	100
RD0E9R3C2P0	0	95.9	98.2	100	100	100	100
RD1E9R3C2P0	0	74.8	96.8	97.6	99.7	100	100
RD2E9R3C2P0	0.5	66.0	84.0	91.8	93.8	99.2	100
RD0E10R3C2P0	0	12.5	69.6	100	100	100	100
RD1E10R3C2P0	0	7.3	41.6	97.6	99.7	100	100
RD2E10R3C2P0	0	5.7	31.0	80.1	89.2	94.0	100
RD0E11R0C1P0	0	43.3	92.0	100	100	100	100
RD1E11R0C1P0	0	47.1	90.1	96.4	100	100	100
RD2E11R0C1P0	0	37.8	71.4	86.8	89.2	92.9	100
RD0E11R0C2P0	0	95.9	98.2	99.9	100	100	100
RD1E11R0C2P0	0	74.9	96.9	97.6	97.7	100	100
RD2E11R0C2P0	0.5	65.9	84.0	91.5	92.2	99.1	100
RD0E11R1C1P0	0	11.3	22.0	99.4	100	100	100
RD1E11R1C1P0	0	8.7	20.3	95.9	97.1	100	100
RD2E11R1C1P0	0	4.7	17.6	76.4	83.0	91.7	100
RD0E11R1C2P0	0	11.2	62.9	99.7	100	100	100
RD1E11R1C2P0	0	6.7	34.2	97.6	97.7	100	100
RD2E11R1C2P0	0	4.4	25.8	79.0	85.9	94.0	100
RD0E11R3C1P0	0	10.8	22.5	100	100	100	100
RD1E11R3C1P0	0	8.6	20.1	95.7	97.1	100	100

Table Name	Bin 1 0 - 1.0E-8	Bin 2 0 - 5.0E-7	Bin 3 0 - 1.0E-6	Bin 4 0 - 5.0E-6	Bin 5 0 - 1.0E-5	Bin 6 0 - 0.0001	Bin 7 \$ 0
RD2E11R3C1P0	0	4.5	17.3	76.4	83.0	91.8	100
RD0E11R3C2P0	0	11.2	63.0	99.7	100	100	100
RD1E11R3C2P0	0	6.6	34.1	97.5	97.6	100	100
RD2E11R3C2P0	0	4.4	25.7	79.0	85.9	94.0	100