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Pre-Decisional Draft

Preliminary Design Studies for the DESCARTES and CIDER Codes

Hanford Environmental Dose
Reconstruction Project

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PREFACE

The primary objective of the Hanford Environmental Dose Reconstruction (HEDR) Project is to estimate the radiation dose that individuals could have received as a result of emissions since 1944 from the U.S. Department of Energy's (DOE) Hanford Site near Richland, Washington. An independent Technical Steering Panel (TSP) directs the project, which is conducted by Battelle Pacific Northwest Laboratories (BNW).

One of the major objectives of the HEDR Project is to develop several computer codes to model the airborne releases, transport and environmental accumulation of radionuclides resulting from Hanford operations from 1944 through 1972. In July 1992, the HEDR Project Manager determined that the computer codes being developed (DESCARTES, calculation of environmental accumulation from airborne releases, and CIDER, dose calculations from environmental accumulation) were not capable of calculating the doses required by the project.

A team of HEDR staff members developed a plan to assure that computer codes would be developed to meet HEDR Project goals. The plan consists of five tasks: 1) code requirements definition, 2) scoping studies, 3) design specifications, 4) benchmarking, and 5) data modeling. This report defines the preliminary design studies done for the DESCARTES and CIDER computer codes.

The work documented in this report was performed concurrently with the other tasks. Information developed in the course of the work for this document influenced the course of other scoping studies and vice versa. In the interest of prompt interaction between the HEDR staff, the TSP, and the public, this report is being issued in its current form. The reader should note that recommendations on several design issues have been made to the TSP, in part as a result of the preliminary design studies described here. The recommendations pertinent to this report are reducing the number of nuclides from three to one (iodine-131), using weekly data for the iodine-131 emitted in the 1940s and monthly thereafter, and dividing the geographic area in which a person may have received a dose of radiation into 1064 sections instead of the 2091 suggested by the draft requirements.

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1.0 INTRODUCTION

The Hanford Environmental Dose Reconstruction (HEDR) project is developing several computer codes to model the release and transport of radionuclides into the environment. This preliminary design addresses two of these codes: Dynamic Estimates of Concentrations and Radionuclides in Terrestrial Environments (DESCARTES) and Calculation of Individual Doses from Environmental Radionuclides (CIDER). The DESCARTES code will be used to estimate the concentration of radionuclides in environmental pathways, given the output of the air transport code RATCHET. The CIDER code will use information provided by DESCARTES to estimate the dose received by an individual.

In early October 1992, it was not apparent that the DESCARTES and CIDER codes could be designed to meet the requirements that Battelle set for these codes.[a] This document reports on preliminary design work performed by the code development team to determine if the requirements could be met. The document contains three major sections: i) a data flow diagram and discussion for DESCARTES, ii) a data flow diagram and discussion for CIDER, and iii) a series of brief statements regarding the design approach required to address each code requirement.

This document does not attempt to give specifics of the design, instead it addresses in general how the requirements would be met in the design.

(a) The requirements that Battelle (BNW) set for these two codes were released to the HEDR Technical Steering Panel (TSP) in a draft document on November 10th, 1992. The preliminary design includes revisions to these requirements as provided in the December 28, 1992 version of the Software Requirements Specification for The Hanford Environmental Dose Reconstruction Project Air Pathway Environmental Accumulation and Dose Codes (Shipler 1992, Attachment 2).

2.0 DATA FLOW AND LOGIC CONSIDERATIONS FOR DESCARTES

This section outlines the major features of the preliminary design of DESCARTES. Although the code design is not scheduled for completion until the end of January 1993, a preliminary design was identified to permit benchmarking activities.

Figure 1 depicts the conceptualization of data flow in the DESCARTES code under the preliminary design. In addition to the air deposition and concentration data, DESCARTES will import other data including the code run control input, the inactive nodes list, the plant-specific list of parameters, the reference animal diets, commercial distribution information (for milk and leafy vegetables), and other assorted parameters. All or only a few pathways can be simulated by DESCARTES. Air, soil, and food product concentrations are stored in environmental accumulation data files except for creamery milk concentrations, which are stored in a separate file.

Following the structure of Figure 1, the major features of DESCARTES are given below.

2.1 Code Run Control Input

The user will control code execution by supplying the following types of information and selecting computation options:

- the name and decay constant of the nuclide being modeled
- specifying the start and end dates of the period to simulate
- choosing the pathways and products to be computed
- making animal feeding regime choices (by supplying animal diet libraries)
- entering the deminimus dose level to be implemented

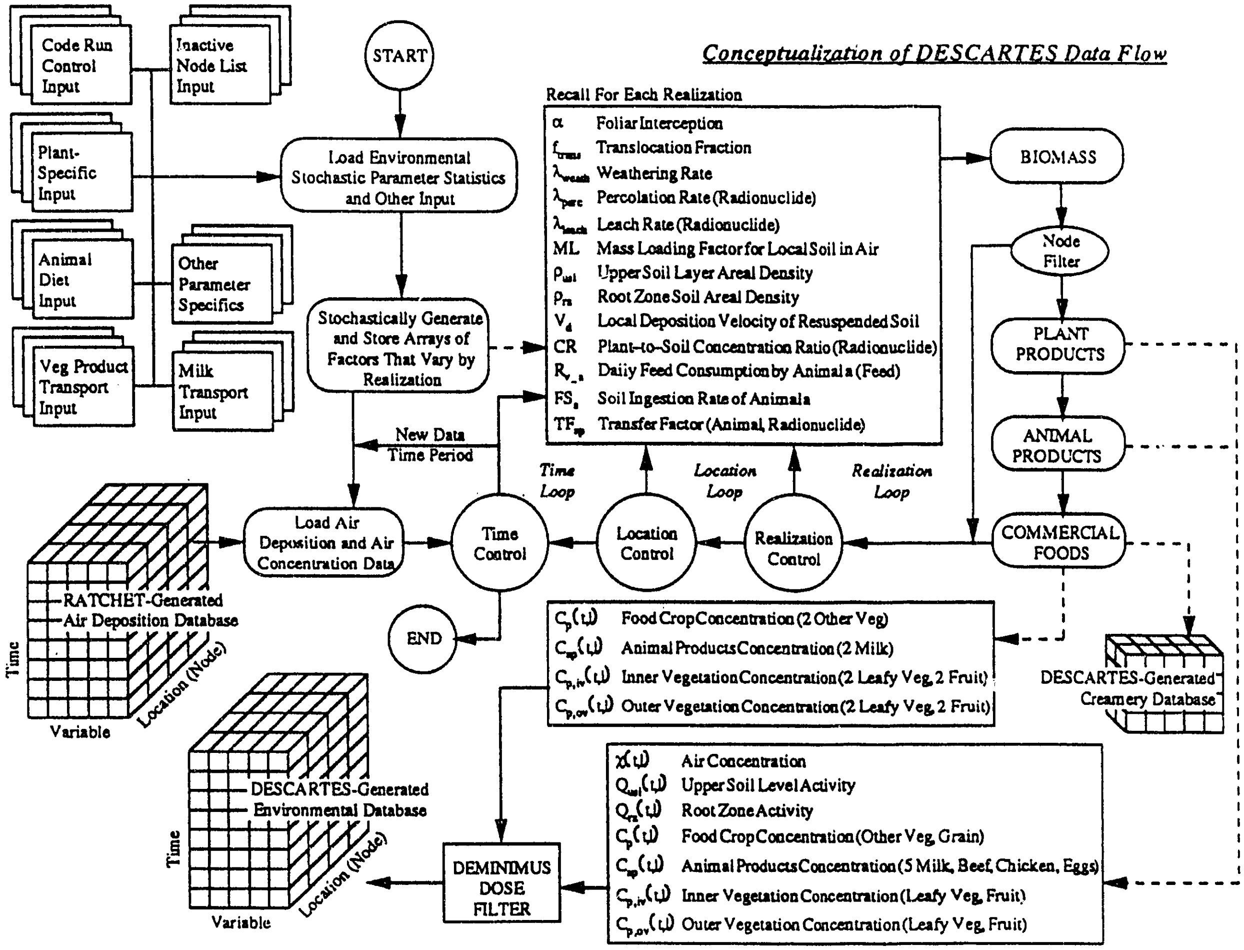

FIGURE 1. Conceptualization of DESCARTES Data Flow

2.2 Node Selection

The user can control several aspects in selecting the spatial extent of the code run including:

- choosing the nodes at which to perform calculations
- using a list of nodes where "significant" deposition has occurred (preprocessor-prepared input file) to reduce the data storage requirements by eliminating nodes with zero nuclide concentrations

2.3 Plant-Specific Input

Calculation of plant growth depends on the following types of information which will be contained in data files, but which the end user will not modify:

- plant-specific growth parameters
- tillage and harvest dates or seasons (which differ by location and are triggered by frost dates)

2.4 Animal Diet Input

The code will estimate the consumption of contaminated feed for cows, goats, and chickens. Some important considerations are

- different animals consume different proportions of plant products whose nuclide concentrations are computed by DESCARTES
- different growing seasons at the node locations (as well as availability of irrigation) affect animal diet regimes
- multiple cow diet regimes are represented at each node
- randomization of animal diets is accomplished through random selection of daily diets from the animal diet library

2.5 Commercial Milk Production and Distribution

The code will handle commercial milk production and distribution, modeling the radionuclide concentrations from animal feeding regimes through computation of nuclide concentrations in grocery milk at many locations. Some general considerations are:

- only nodes with irrigated pastures contribute to commercial milk production

- fractional contributions of commercial milk production nodes to creameries, and creameries to grocery milk are randomly sampled from a milk production library

- nuclide concentrations in milk at 26 identified creameries are saved to a separate data file for use by CIDER

- the nuclide concentration in grocery milk at any node is formed as a combination of the concentrations at several creameries

2.6 Commercial Leafy Vegetable Production and Distribution

The code will handle commercial growth and distribution of leafy vegetables. Some general considerations are

- only nodes with irrigated crops will contribute to commercial leafy vegetable production

- the concentrations of radionuclides in commercial leafy vegetables at any node are computed as a combination of the concentration computed for multiple production nodes

- the fractional contributions of leafy vegetable production nodes to any consumption node are randomly sampled from a vegetable production library

2.7 Biomass Module

The code will compute the plant growth for each plant type. Some general considerations of this module are

- the biomass differs by plant type and location

- the biomass will be computed for a given year at a location only if that location is active within that year

- biomass will not be saved to the disk at the end of the run

2.8 Plant Products Module

The code will compute the nuclide concentrations in several plant products. Some general considerations for this module are

- the code will handle up to 15 plant products

- the nuclide concentration for each plant product is written to a separate (binary) file

- the set of animal pathways chosen will influence which plant products need to be simulated in the same run of the code

2.9 Animal Products Module

The code will compute the nuclide concentrations in several animal products. Some general considerations for this module are

- the code will handle up to 15 animal products
- the nuclide concentration in each animal product is written to a separate (binary) file
- all food pathways used for animal diets must have been previously or concurrently simulated in the plant products module

2.10 Commercial Foods Module

As previously discussed, the code handles the computation of nuclide concentrations in commercially available food products. Some important additional considerations are

- the only commercially-distributed foods modeled by the code are milk and leafy vegetables
- nuclide concentration in creamery milk is written to a file for direct use in CIDER
- grocery milk is distributed directly to nodes
- leafy vegetables are distributed directly to nodes
- no central processing facilities are modeled for leafy vegetables

2.11 DESCARTES-Generated Environmental Accumulation Data

The overall purpose of DESCARTES is to build a static data set of nuclide concentrations in the environment as a function of time, location, pathway and realization number for use by CIDER in computing individual doses. Some general considerations for the building of this data set are

- the concentrations are stored in a structured, indexed file to optimize data access by CIDER
- nuclide concentration data that are below a deminimus threshold are not stored

- the static data set contains local (backyard) plant and animal product concentrations, commercially-distributed milk and leafy vegetable concentrations, air concentrations, and soil compartment concentrations
- to maintain temporal and spatial relationships, the static data set can be accessed by realization number, location, and time
- partial replacement of data in the static data set is possible when simulating a limited number of pathways

3.0 DATA FLOW AND LOGIC CONSIDERATIONS FOR CIDER

This section outlines the major features of the preliminary design of CIDER. Figure 2 depicts the conceptualization of data flow in the CIDER code under the preliminary design. The major inputs of data into CIDER are control and individual-specific data, the reference diet library, the reference dose factor library, and the creamery and environmental accumulation files generated by DESCARTES. Some additional DESCARTES-generated data such as soil mass loading and harvest seasons are also input to CIDER. This information is used to generate individual radiation doses in either "reference individual map" or "specific individual" modes, depending on the control inputs. The dose is reported with respect to pathway and organ by CIDER.

Following the structure of Figure 2, the major features of CIDER are given below.

3.1 Code Control Input

The user will control code execution by supplying the following types of information and selecting computation options

- operation mode (map for a reference individual, or specific individual)
- name and decay constant of the radionuclide
- lifestyle of the selected individual (rural or urban)
- dates and locations of residence (specific individual mode) or mapping nodes (map mode)
- reference diet over-ride information (specific individual mode only)

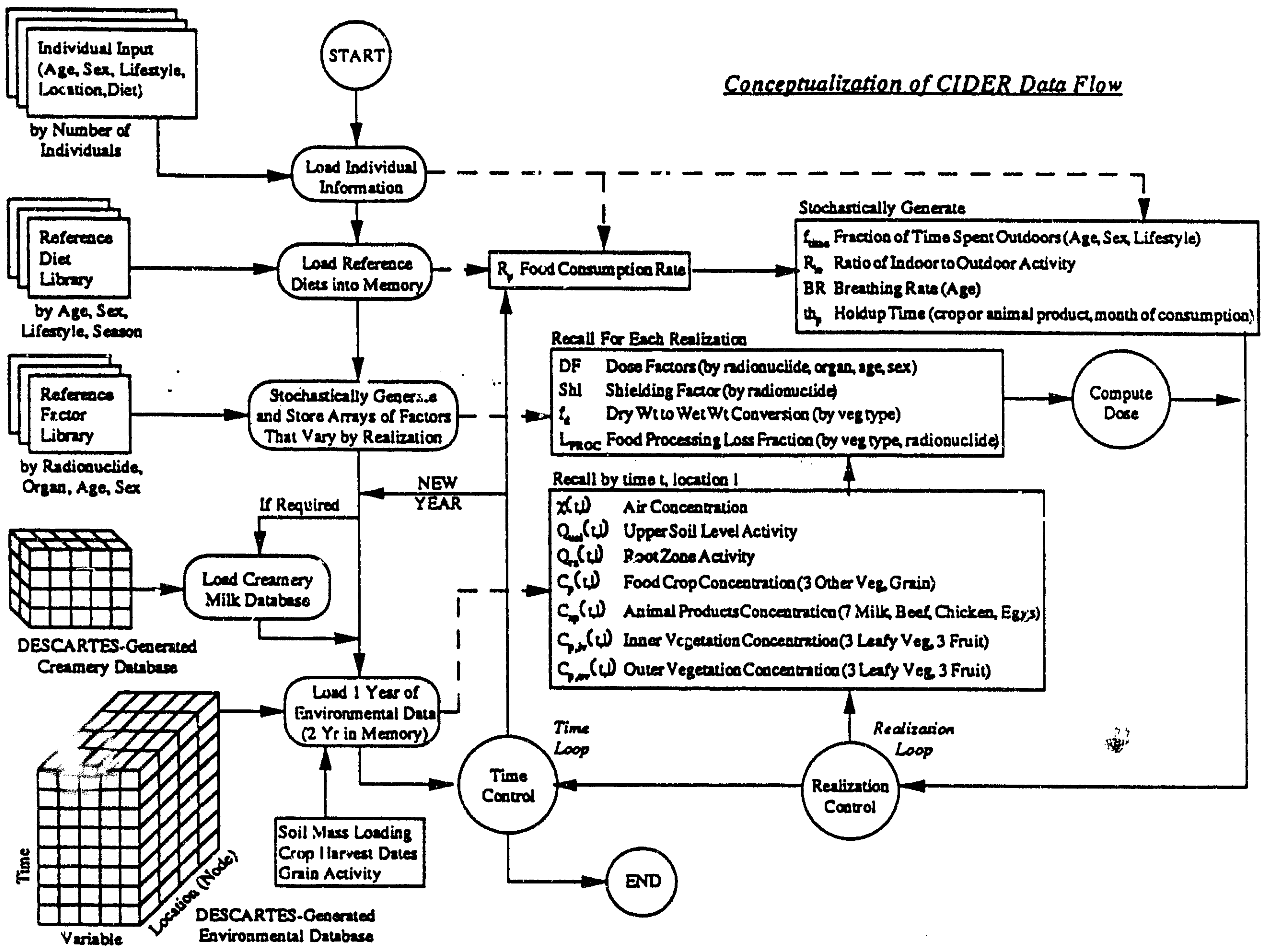

FIGURE 2. Conceptualization of CIDER Data Flow

3.2 Reference Diet Libraries

The code will estimate the consumption of contaminated food products for reference and specific individuals. Some important considerations are

- randomization of human diets is accomplished through random selection of daily diets from a reference diet library
- the reference diet library may be over-ridden in specific individual mode to include individual-specific diet information (e.g., an individual who consumed goat milk rather than cow milk)
- reference diet choices will be constrained by the age, sex, and lifestyle of the reference individual
- reference diets vary by season of the year

3.3 Reference Factor Libraries

Some parameters will vary by realization in the simulation. Values for these parameters will be input through reference libraries. Some general considerations for libraries are

- parameters in the libraries include dose factors, shielding factors, dry weight to wet weight conversion factors, and food processing loss fractions
- entry points in a library may include radionuclide name, organ, age and sex of the individual
- values for the parameters will be generated by randomly resampling representative values in the library

3.4 Creamery Milk Data

Concentrations of nuclides in creamery milk are generated by the DESCARTES code. General considerations for using creamery milk include

- concentrations in milk are being generated for 26 creameries
- diet input for a specific individual may include consumption of milk products from any creamery

3.5 DESCARTES-Generated Environmental Accumulation Data

DESCARTES builds a static data set of nuclide concentrations in the environment as a function of time, location, and realization number for use by CIDER in computing individual doses. Some general considerations for the use of this data set are:

- the concentrations are stored in a structured, indexed file to optimize data access by CIDER
- nuclide concentration data that are below a deminimus threshold are not stored
- the static data set contains local (backyard) plant and animal product concentrations, commercially-distributed milk and leafy vegetable concentrations, air concentrations, and soil compartment concentrations
- to maintain temporal and spatial relationships, the static data set can be accessed by realization number, location, and time

3.6 Dose Results

The CIDER code is being designed to provide dose estimates (up to 100 realizations) for an individual. Some general reporting and output considerations are

- doses for a specific individual are reported by pathway and by organ (including whole-body)
- when running in map mode, the dose report will be output in such a manner as to be easily transferred to the ArcInfo geographic information system for generation of maps
- the CIDER code will not prepare written reports of doses to individuals, reports will be generated using a post-processor

4.0 DESIGN APPROACH TO EACH CODE REQUIREMENT

This section provides a brief discussion of the implementation of the code requirements in the preliminary design. The presentation strategy identifies each code requirement and gives a preliminary indication of how the requirement will be met in the design. The code design has to be completed at the end of January 1993 under the current project schedule.

4.1 General Requirements

Requirement 1.1 The software shall calculate environmental accumulations and doses from atmospheric releases and transport of radionuclides from Hanford site operations as modeled by STRM and RATCHET.

Response: The DESCARTES and CIDER codes are being designed to use the air transport data output by RATCHET.

Requirement 1.2 The software shall be capable of reporting environmental accumulation estimates and dose estimates separately.

Response: The requirements will be met using two major codes, DESCARTES and CIDER. DESCARTES will generate environmental accumulation estimates and CIDER will perform dose calculations for individuals. The two codes will implement separate reporting capabilities.

Requirement 1.3 The software shall be capable of operating on data for the time period from 1944 through 1972 inclusive.

Response: The codes will be able to handle data for the specified time periods. The design approach is to have all time-dependent data read from data files, rather than being hard-wired in the code.

4.2 Quality Assurance Requirements

Requirement 2.1 The software development and design shall be subject to the quality assurance (QA) requirements in the HEDR QA plan (QAP #OHE-003, dated 7/21/92) and the PNL Software Control Procedures (SCP's) in PNL-MA-70.

Response: The work is being conducted under the specified QA controls.

Requirement 2.2 The software shall log information such as names and versions of files used, data identification labels, and version of the software to provide complete traceability of the output.

Response: Each run of the code will produce a "report file" that will contain, among other things, the names of all data files used in the code. All output files will contain a header that contains the program name and version number, and a run identification number.

Requirement 2.3 The software shall produce the same output for separate runs using identical inputs.

Response: The only difficulty in meeting this requirement is to be able to repeat identically the generation of all stochastic information. All stochastic "seeds" for random number generation will be specified as an input by the user instead of being keyed on other things such as the system time.

Requirement 2.4 The software shall be documented with the following items as HEDR project records:

a. software development plan (SDP)
b. software design document (SDD)
c. interface requirements specification (IRS)
d. data dictionary (DD)
e. configuration management plan (CMP)
f. users guide (UG)
g. module development folders (MDF)
h. software requirements specification (SRS)
i. software test plan (STP)

Requirements for the contents of each document shall be identified in the SDP.

Response: The SDP and the SRS have already been completed and submitted to the TSP for their review. The SDP contains exhibits giving the required contents for each of the other documents.

Requirement 2.5 The software shall be subjected to the following HEDR internal reviews:

a. software design review
b. code walkthrough
c. final internal development review
d. independent testing review
e. operational readiness review

Requirements for each review shall be identified in the SDP.

Response: The SDP identifies each of these reviews as part of the software development cycle. Requirements for each review are contained either in the SDP or one of the PNL Software Control Procedures in PNL-MA-70 (SCP-312 through SCP-317).

4.3 Host System Requirements

Requirement 3.1 The software shall operate on the HEDR Sun 690 platform.

Response: The target development and implementation platform is the HEDR Sun 690.

Requirement 3.2 The following three operating environments shall be supported:

a. development and/or maintenance
b. test and/or verification
c. production

The operating environments do not have to function simultaneously. Production runs do not need to support more than a single nuclide at a time.

Response: The codes are being designed to process a single nuclide at a time. Available memory or disk space may limit concurrent activities for any two, or all three, operating environments.

4.4 General User Interface Requirements

Requirement 4.1 The software shall provide a procedure to allow operation by a trained non-developer through the use of script or text control files.

Response: Both DESCARTES and CIDER are being designed to be driven by a text "scenario file". A fragment of a scenario file for CIDER is given in Figure 3. The scenario files allow "batching" of multiple cases.

4.5 Data Size Requirements

Requirement 5.1 The software shall support calculations for one radionuclide ^{131}I, with the capability to expand to a total of five radionuclides. Implementation of future expansion may require code modifications.

Response: All nuclide specific information will be contained in data files. Some examples are dose factors, radiological decay, plant uptake, natal and nursing transfer factors, animal transfer factors, soil leaching and percolation, food processing loss fraction, air deposition data.

FIGURE 3. Fragment of a CIDER Scenario File

```
ENV_NODE_LIB   /data1/EXP_NODE_I131.NDX;
ENV_CREAM_LIB  /data1/EXP_CREAM_I131.NDX;
ORGAN_FACTOR   /data1/ORGAN_FACT.DAT;
SOIL_FACTOR    /data1/SOIL_FACT.DAT;
RESULT_FILE    /case1/case.out;
REALIZATIONS   100;
ORGANS         Thyroid, Liver;
PATHWAYS       ALL;
DIET_SPEC      MD1 RD13 FALL Milk1 DISTRIBUTION_1 0.0, OTHER_VEG  0.21 0.0;
       ; diet "MD1" is the same as reference diet "RD13" fall          ; except
       ; milk1 is stochastic dist 1 and oveg is 0.21 kg/day
DISTRIBUTION   1  NORMAL 3.0 .134  2.54  3.34;
BEGIN CASE1;
       SEX           MALE;
       BIRTH         5/23/46;
       WEANED        4/1/47;
       START         8/23/45;
       FINISH        12/31/90;
       LOC 23        8/23/45       1/15/47;
       LOC 0         5/2/47        7/18/78;
       LOC 478       7/19/78       12/31/90;
       DIET RD1      11/1/46       7/1/47;
       DIET RD2      7/2/47        9/1/52;
       DIET MD1      12/2/78       12/31/90;
       MOTHER RD7    8/23/45       12/7/55;
       LIFESTYLE RL1 11/1/46       7/1/47;
END; CASE1
BEGIN CASE2;
       SEX           MALE;
       BIRTH         1/1/46;
       WEANED        1/31/46;
       START         1/1/46;
       FINISH        12/31/46;
       MAP           ALL;
       DIET RD1      1/1/46        7/1/46;
       DIET RD2      7/2/46        1/1/47;
       MOTHER RD7    8/23/45       12/7/55;
       LIFESTYLE RL1 1/1/46        7/1/47;
END; CASE2
```

Requirement 5.2 The software shall be designed to support future expansion with up to 15 plant media and up to 12 animal media. Implementation of future expansion may require code modifications.

Response: The preliminary design does not preclude adding plant or animal media. Some code modifications will probably be required.

Requirement 5.3 The software shall support using up to 100 realizations of air concentration and deposition data through the environmental accumulation and dose estimates. A single realization of the code consists of all values input or calculated for each active mode for each operational time step.

Response: The software shall contain arrays to handle up to 100 realizations of data. The user can choose to use from 1 to 100 realizations in any code run.

Requirement 5.4 The software shall be capable of operating on a spatial grid containing up to 1064 nodes.

Response: The software and disk space requirements are being sized for a maximum of 1064 nodes.

4.6 Mathematical Models

Requirement 6.1 The software calculations shall implement the functionality of equations DES-1 through DES-18 and CID-1 through CID-5 as documented in:

> "Parameters used in the Environmental Pathways (DESCARTES) and Radiological Dose (CIDER) Modules of the Hanford Environmental Dose Reconstruction Integrated Codes (HEDRIC) for Air Pathway". S.F. Snyder, W.T. Farris, B.A. Napier, T.A. Ikenberry, and R.O. Gilbert. PNWD-2023 HEDR, September 1992.

Response: In addition to the equations cited here, goat milk will be computed in DESCARTES and passed to CIDER, and CIDER will also compute doses to prenatal and nursing infants.

Requirement 6.2 The software shall support only simple exponential decay of radionuclides.

Response: Radiological decay is being implemented. For example, it is used when implementing the concentration decrease due to the holdup time between harvest and consumption for both human and animal diets.

Requirement 6.3 The software shall provide the capability to generate random numbers from the following statistical distributions:

a. uniform
b. piecewise uniform
c. loguniform
d. normal
e. lognormal
f. triangular.
g. discrete uniform

Generation of values from the normal and lognormal distributions will be truncated at the tail probabilities of 0.01 and 0.99.

Response: All of these distributions were coded and tested for another project. The low-level routines will be incorporated in the DESCARTES and

CIDER codes. The tail probabilities for truncation of the normal and lognormal distributions will be user selectable, but will default to 0.01 and 0.99.

Requirement 6.4 The software shall provide the capability to generate all random numbers using a stratified sampling technique.

Response: The capability to perform this technique has already been coded for another project (SUBROUTINE U01S). It will be incorporated into the DESCARTES and CIDER codes.

Requirement 6.5 The software shall be capable of selecting identical stochastic parameters for separate runs which differ only by the radionuclide being processed.

Response: All stochastic "seeds" for random number generation will be specified by the user instead of keying them on other things such the system time. Multiple nuclides will each have to run on the same time steps for this requirement to be met.

Requirement 6.6 The environmental accumulation software shall use the Euler method for solution of all differential equations.

Response: The Euler method is the only method being considered.

Requirement 6.7 The software shall support the stochastic parameter definitions and sampling frequencies defined in Section 6.0 and Table A-1 of PNWD-2023 HEDR (dated September 1992).

Response: All parameter definitions will be data file driven. The stochastic keyword DISTRIBUTION will allow definition of any distribution in requirement 6.3. This approach allows the parameter document to be updated and implemented using data changes rather than code modifications.

4.7 Environmental Accumulation Data Interface Requirements

Requirement 7.1 The environmental accumulation software shall receive air transport information from the RATCHET code as documented in:

> "Regional Atmospheric Transport Code for Hanford Emission Tracking (RATCHET)", J.V. Ramsdell, Jr. and K.W. Burk, PNL-8003 HEDR, dated February 1992.

Response: Air transport data is already available from RATCHET for the nuclide ^{131}I for the years 1944-1947. A preprocessor/translator program is required to format the data for use in DESCARTES.

Requirement 7.2 The software shall implement milk information as presented in:

> "Milk Cow Feed Intake and Milk Production Estimates for Phase I", D.M. Beck, R.F. Darwin, A.R. Erickson, and R.L. Eckert, PNL-7227 HEDR, April 1992.

and

> "Milk Production and Distribution in Low-Dose Counties for Hanford Thyroid Disease Study", PNL-8153, June 1992.

Response: The mixing and distribution of milk is being designed as a post-processor to the animal products (milk) equations for the specified feeding regimes. The commercial milk production and distribution applies to a region of limited spatial extent.

Requirement 7.3 The software shall implement a fresh, leafy vegetable distribution network as presented in:

> "Commercial Production and Distribution of Fresh Fruits and Vegetables: A Scoping Study on the Importance of Produce Pathways to Dose", T.L. March, D.M. Anderson, W.T. Farris, T.A. Ikenberry, B.A. Napier, and G.L. Wilfert, PNL-2022, September 1992.

Response: A commercial distribution system for leafy vegetables is being designed as a redistribution of production among nodes. The concentration of a nuclide in commercial leafy vegetables at a node is a combination of the concentrations in backyard leafy vegetables at possibly several nodes. No commercial distribution system is being implemented for any other plant products.

Requirement 7.4 Physical locations shall be specified by node.

Response: Physical locations in DESCARTES and CIDER will be identified by node number. A map of node number against physical location, county, census tract, etc., will be generated and maintained external to the codes.

Requirement 7.5 The software shall use a creamery id to identify creamery milk information.

Response: The software design will implement 26 creameries, with the ability to be easily expanded to additional creameries. Each creamery will be labeled by a unique identifier.

4.8 Environmental Accumulation Control Requirements

Requirement 8.1 The environmental accumulation software shall allow user selection of the set of nodes where environmental accumulation calculations shall be performed.

Response: The user will be able to select a subset of the nodes for generation of environmental accumulations by DESCARTES. However, commercial production regions may require additional nodes for some pathways.

Requirement 8.2 The environmental accumulation software shall allow the user to process one or more plant and/or animal media independently.

Response: The DESCARTES code is being designed to allow running of each plant and animal pathway as independently of the other pathways as possible. However, there are dependencies among the pathways. For example, a change in the computation of concentrations of nuclides in pasture grass may require the recalculation of concentrations in both backyard milk and commercial milk.

Requirement 8.3 The software shall be able to utilize default values when no input values exist.

Response: Many data will be assigned default values, but not all data will have a default value. For example, CIDER will require the user to specify things such as living location, sex, nuclide, lifestyle, and start and stop time of the run. Both DESCARTES and CIDER will require the user to specify the name of the scenario file.

4.9 Environmental Accumulation General Requirements

Requirement 9.1 The environmental accumulation software shall be able to accept information from RATCHET in daily time steps.

Response: The DESCARTES code is being designed to operate on data from RATCHET that comes only on a daily time step.

Requirement 9.2 The environmental accumulation software shall provide an environmental accumulation database to the dose code at user selectable intervals: daily, weekly, or monthly.

Response: The design of this data set (database) has been identified, built, and tested as part of the benchmarking tests to determine compliance with requirement 14.2 The benchmarking tests are described in a separate document.

Requirement 9.3 A deminimus dose threshold shall be implemented with respect to environmental media to restrict data passed to the dose software to significant levels. The algorithm for this calculation is to be determined.

Response: The codes are being designed to take advantage of the data reduction allowed by this feature. The specific algorithm defining exclusion of data has not yet been defined.

4.10 Environmental Accumulation Reporting Requirements

Requirement 10.1 The environmental accumulation software shall be able to report, in human-readable form or electronic media, the radionuclide concentrations in the following media for selected nodes and time steps:

Plant Media
- a. inner leafy vegetables
- b. outer leafy vegetables
- c. other vegetables
- d. inner fruit
- e. outer fruit
- f. grain
- g. alfalfa hay
- h. pasture
- i. grass hay
- j. silage
- k. sagebrush

Animal Media
- a. goat milk
- b. grocery cow milk (rural)
- c. grocery cow milk (urban)
- d. creamery cow milk
- e. cow feeding regime 1 milk
- f. cow feeding regime 2 milk
- g. cow feeding regime 3 milk
- h. cow feeding regime 4 milk
- i. eggs
- j. beef
- k. poultry

Other Media
- a. air
- b. upper soil layer
- c. soil root zone

Response: The code is being designed to output information for all of these media. The information for each media will be directed to a separate binary output file. A report generator will be written to extract information for testing and reporting purposes. In addition to these media, leafy vegetables are being carried as backyard and commercial products, and cow milk is output separately for individual cows and for cow herds.

4.11 Dose Model Requirements

Requirement 11.1 The software shall be able to calculate doses for both reference and real individuals.

Response: The design allows for 24 (or more) reference individuals (6 ages, 2 sexes, 2 lifestyles). Reference individuals will not move in the domain. Real individuals will be modeled, and differ from reference individuals in that they can move, they can change their diet, their age, etc.

Requirement 11.2 The dose software shall operate internally on a daily time step, even when the environmental data is passed on a weekly or monthly time step.

Response: The design is implementing a daily internal time step in CIDER.

Requirement 11.3 The dose software shall be able to calculate pre-natal doses for infants. Prenatal doses are based on the diet and lifestyle of the mother. The transfer function of the mother's intake to the infant's dose is represented by dose factors in units of rad to infant per curie of maternal intake.

Response: The design allows implementation of this function. The final form of the algorithm is not yet known.

Requirement 11.4 The dose software shall be able to calculate doses for nursing infants. Doses for nursing infants are based on the diet, location and lifestyle of both the mother and the child. The infant's dose is a function of infant's intake plus a transfer parameter multiplied by the mother's intake. The infant and mother are required to live at the same node.

Response: The design allows implementation of this function. The final form of the algorithm is not yet known.

Requirement 11.5 The dose software shall allow only one type of fresh milk and one type of stored milk to be included in a diet at any single time step.

Response: The design allows implementation of this requirement. A limitation is being imposed that if both fresh and stored milk come from a creamery, they must both come from the same creamery.

Requirement 11.6 The dose software shall utilize environmental concentration values from the node where an individual lives. An individual can only live at one node for a given time step.

Response: This requirement allows definition of a relatively simple design for CIDER, and keeps the data transfer from disk to memory at a minimum, thereby helping meet the run-time requirements (see requirement 14.2).

Requirement 11.7 The dose software calculations shall account for holdup times (decay) from the previous year's harvest in both fresh and stored food media.

Response: The code is being designed to access the concentration at the time of harvest for each product and implement radioactive decay for the holdup time between harvest and consumption. The concentration data is identified and accessed by time, node number (location), and realization number to ensure that spatial and temporal processes are not distorted.

4.12 Dose Control Requirements

Requirement 12.1 The dose software shall allow the user to select a start date and end date.

Response: The code design forces the user to select a start date and an end date.

Requirement 12.2 The dose software shall support "map" data generation for reference individuals and a user specified set of nodes.

Response: The scenario file for CIDER supports multiple cases in the same run. The keyword MAP will be used to specify the locations to be included in the map.

Requirement 12.3 A user specified diet shall be implemented as an override of a reference diet by food category.

Response: The scenario file for CIDER supports modification of reference diets. The appropriate keywords are DIET and MOTHERSDIET.

Requirement 12.4 The dose software shall allow the user to supply a diet that may change with time.

Response: The scenario file for CIDER supports modification of diets with time for real individuals. The appropriate keyword is DIET.

Requirement 12.5 The dose software shall allow the living location of an individual to change with time.

Response: The scenario file for CIDER supports a change of location with time for a real individual. The appropriate keyword is NODE.

Requirement 12.6 The dose software shall allow real individuals to exit and reenter the study area.

Response: The scenario file for CIDER supports a change of location with time for a real individual. One of the locations is a phantom node outside the modeling domain. The appropriate keyword is NODE.

Requirement 12.7 Changes to an individual's diet, living location, and lifestyle may be allowed to occur at a frequency no more rapid than the internal time step at which the dose software is running.

Response: The design for the CIDER code implements a check for modified information only once for each time step.

Requirement 12.8 The dose software shall be capable of running in a multiple run mode. The multiple run mode will allow the sequential calculation of doses to multiple individuals at different locations with different diets and lifestyles.

Response: The scenario file for CIDER supports multiple cases in the same run. However, some restrictions apply such as the individual in each case is exposed to the same nuclide, all individuals use the same exposure files (from DESCARTES), and all individuals use the same number of realizations.

4.13 Dose Reporting Requirements

Requirement 13.1 The dose software shall be able to report doses on an annual basis.

Response: The CIDER code is being designed to output an annual dose on each year-end time boundary.

Requirement 13.2 The dose software shall be able to report cumulative doses over the entire time period selected.

Response: The CIDER code is being designed to report the cumulative dose to a single individual for the entire simulation time period.

Requirement 13.3 The dose software shall be able to report doses to the thyroid, red bone marrow, lower large intestine and effective dose for the following pathways based on operator selection:

a. external
b. inhalation
c. beef ingestion
d. leafy vegetable ingestion
e. other vegetable ingestion
f. fruit ingestion
g. grain ingestion
h. poultry ingestion
i. eggs ingestion
j. milk ingestion
k. total over all pathways.

The doses shall be output for the entire set of realizations.

Response: The CIDER code is being designed to report the doses by organ and pathway. Adding an organ to the list will be a minor code change (the code will run slower, and the appropriate input data is required, i.e., dose factor by organ). Adding a pathway with an exposure function different than the ones identified in the equations CID-1 through CID-5 will require a major change to the code.

4.14 Computation Time Requirements

Requirement 14.1 The environmental software shall be capable of producing a full environmental accumulation database for use by the dose code (1 radionuclide, all media, 1064 nodes, years 1944 through 1972) in 10 days wall clock time.

Response: Benchmarking studies to determine if DESCARTES will meet this requirement are reported in a separate document. At this time it is not certain that this requirement can be met.

Requirement 14.2 The dose software shall be able to calculate and output data for a "map" run of 1064 nodes on a dedicated machine for a single year and a single radionuclide with an elapsed wall-clock time of no more than 532 minutes (30 seconds average per node). The output of a production run includes the doses to a representative individual at each node for 3 organs, 10 pathways, and subpathways and 100 realizations.

Response: Benchmarking studies to determine if CIDER will meet this requirement are reported in a separate document. At this time, it appears that the CIDER code can meet this timing requirement. The timing studies assumed that calculations will be done for 3 organs, 10 pathways, 100 realizations, and 366 time steps per year.

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