
**Pacific Northwest
National Laboratory**

Operated by Battelle for the
U.S. Department of Energy

**User Instructions for the Systems
Assessment Capability, Rev. 1,
Computer Codes**

Volume 2: Impact Modules

P. W. Eslinger
T. B. Miley

C. Arimescu
B. A. Kanyid

September 2004



Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RL01830

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Richland, Washington 99352

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1.0 Introduction and Background

In 1999, the U.S. Department of Energy (DOE) initiated the development of an assessment tool that will enable the users to model the movement of contaminants from all waste sites at Hanford through the vadose zone, groundwater and the Columbia River and estimate the impact of contaminants on human health, ecology and the local cultures and economy. This tool was named the System Assessment Capability (SAC). This tool is an integrated system of computer models and databases used to assess the impact of waste remaining on the Hanford Site. The SAC will help decision makers and the public evaluate the cumulative effects of contamination from Hanford.

The design of the SAC resulted from extensive interactions with Hanford projects, regulators, Tribal Nations, and stakeholders. The approach taken in the assessment follows that advanced by regulatory agencies such as the U.S. Environmental Protection Agency (EPA) in their guidance on uncertainty analyses (Firestone et al. 1997) and ecological risk assessments (EPA 1998), and DOE in its radioactive waste management manual (DOE 1999a) and implementation guide (DOE 1999b) which support DOE Order 435.1 on radioactive waste management. The SAC also was designed with the intent to use it to perform the next composite analysis, an assessment first performed to satisfy Defense Nuclear Facility Safety Board recommendation 94-2. The approach taken is also consistent with the methods, characteristics, and controls associated with acceptable analyses as described by the Columbia River Comprehensive Impact Assessment (CRCIA) team (DOE 1998).

1.1 Overview of the SAC Systems Code

The SAC Systems Code is a tool used to simulate the migration of contaminants (analytes) present on the Hanford Site and assess the potential impacts of the analytes, including dose to humans, socio-cultural, economic, and ecological impacts. The system of codes includes existing computer programs, new computer programs, electronic data libraries, and data formatting processors (or data translators). The relationships among code modules that make up the SAC systems code are illustrated in Figure 1.1.

Major modules appearing on the left side of the diagram perform inventory and transport calculations that provide estimates of the concentrations of analytes in various media. Modules shown on the right perform calculations related to impacts from the contaminated media. Impacts include potential effects on humans, the ecology of the area, the economy of the region, the proximity of contaminants to social and cultural resources.

The general approach to handling uncertainty in SAC, Rev. 1, is a Monte Carlo approach. Conceptually, a value is generated for every stochastic parameter in the code (the entire sequence of modules from inventory through transport and impacts) and then the simulation is executed, obtaining an output value, or result. This process is often called one *realization*. The entire process is then repeated, obtaining another result that is different from the first, but as equally likely to occur as the first result. After repeating this process a number of times, a set of equally likely consequences is obtained that represent the statistical distribution of all outcomes. Several specialized sampling techniques have been developed to reduce the number of realizations required in a Monte Carlo analysis to obtain a satisfactory description of the output distribution. One of the techniques, called Latin Hypercube Sampling (Iman and Conover 1982), has proven successful for mass transport applications in groundwater systems. The general Monte

Carlo approach still applies, and the specific values of the input parameters are chosen from the same statistical distributions; however, the sampling scheme spreads the values in such a way as to reduce sampling variability while also supporting a correlation structure between input variables.

1.2 Purpose of This Document

This document contains detailed user instructions for the following four impact codes developed for Rev. 1 of the SAC:

- CULTURE: Socio-cultural impact assessment
- ECEM: Ecological impact assessment
- HUMAN: Human impact assessment
- TCERM: Tri-Cities economic impact assessment.

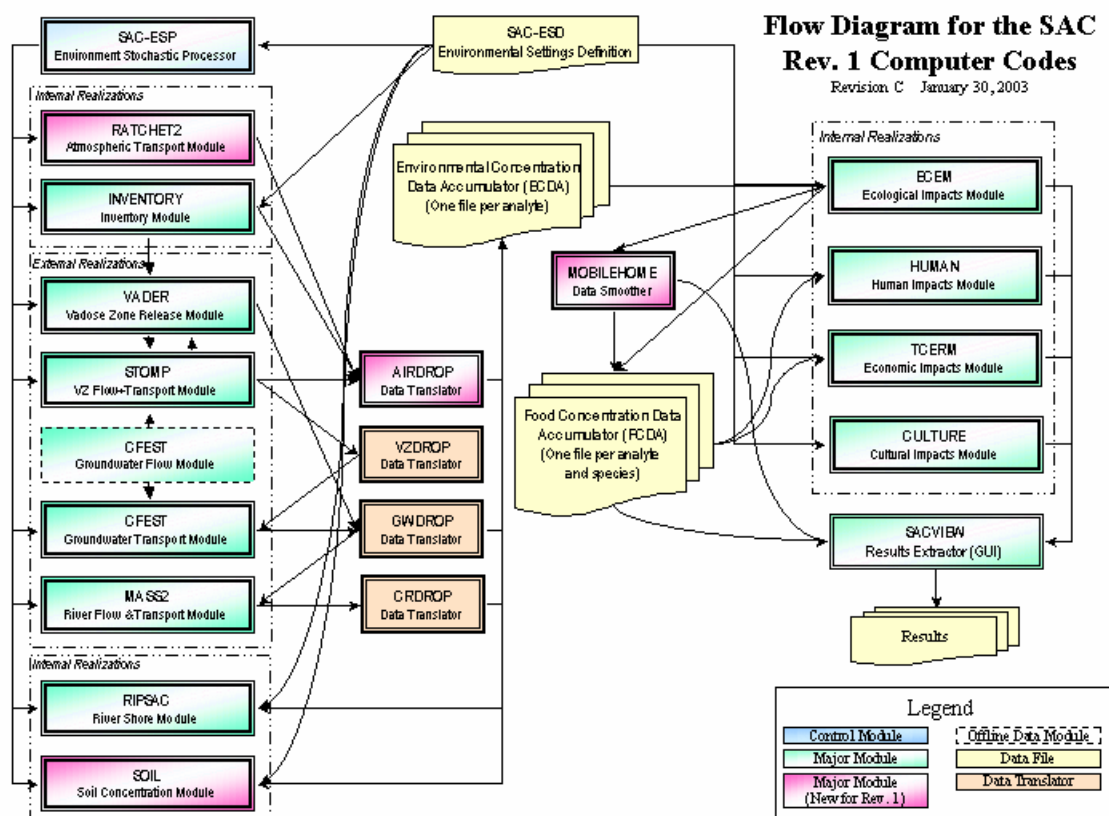


Figure 1.1 Module Information Flow for the SAC Rev. 1 Systems Code

The suite of computer codes for Rev. 1 of SAC performs many more functions than just impact assessments. It also performs inventory tracking, release of contaminants to the environment, and transport of contaminants through the unsaturated zone, saturated zone, and in the river. User instructions for the other codes are provided in Eslinger et al. (2004).

2.0 Environmental Settings Definition Files

As indicated in Figure 1.1, the inventory, release, and transport codes must all be executed to develop a data set of concentration data for use in the impact codes. Concentration data for every realization are saved only at specified times and locations. Control information for an analysis is provided in one of two general places. In general, if control information is needed by more than one code, it resides in the environmental settings definition (ESD) keyword file. The contents of the ESD keyword file are described in this section. For example, the codes ECDA, HEADER, GWDROP, CRDROP, RIPSAC, and HUMAN all need to know the locations for calculating human impacts; thus, the LOCATION keyword is provided in the ESD keyword file (see Section 2.3.5).

The structure of the concentration data files is also described in this section (see Section 2.4) even though the user generally will modify these files directly. The SACView code (see Section 1.0) is provided to allow the user to view the contents of these binary-format data files.

The river transport model can be run with or without background concentrations from upriver sources. A typical method to analyze a Hanford-related problem is to run the river code with two data sets. First, a transport run is made using background values, but no source term from the Hanford Site is introduced. Then, another transport run is made that is identical to the first run except a Hanford source term is introduced. If the impact codes are run using these two data sets, their results can be differenced to determine the contribution from Hanford sources. The groundwater model in SAC, Rev. 1 is not set up to model background concentrations; thus, differencing does not currently apply to impacts based on groundwater concentrations. A utility code called ImDiff (see Section 1.0) is provided to facilitate differencing the results from the impacts models.

2.1 General Keyword Syntax

Many of the programs for SAC Rev. 1 are controlled through the use of data files containing text entries called keywords. In the keyword descriptions, some data are optional for a particular problem definition and some are required. Data that are required are enclosed in square brackets. For example, if AB were required, it would be denoted by [AB]. If only one of the three items AB, BC, CD were required, it would be written as [AB|BC|CD]. The vertical bars indicate that the user must choose one of the items in the list. Optional items are enclosed in normal brackets; for example, if DE were an optional entry, it would be denoted by {DE}. The {} or [] brackets do not need to be entered when the keyword is constructed. The keyword name can contain one or more characters; however, only the first eight characters are used (for example, REALIZAT has the same effect as REALIZATION). In some instances, numerical values or quote strings are associated with a modifier. In this description, the association is indicated by using the = symbol. The = symbol is not required but may be used when the keyword is constructed. When a numerical value or quote string is associated with a modifier, it must be entered on the input line directly after the modifier. Quote strings must be enclosed in double quotation marks.

2.2 Stochastic Variable Generation

Many of the codes in SAC, Rev. 1, generate values for stochastic variables. All of the codes use the same suite of statistical routines to do this generation. The following are some major considerations for this process:

- Each distribution is generated using the Probability Integral Transformation method (Mood et al. 1974, p. 202).
- The uniform number generator uses a linear congruential method (Lewis et al. 1969).
- Stratified sampling is used when the number of values to be generated is greater than 1.
- Most distributions may be truncated between two limits that are specified as limits in the uniform domain on the interval 0 to 1.
- The user may specify a cumulative distribution function in the form of a table of values.
- Information about a stochastic variable is linked to a unique character ID. Access to all information about the variable is available through use of the variable ID.

The following statistical distributions are available:

- Constant value
- Uniform distribution between two limits
- Discrete uniform distribution on a set of contiguous integers
- Loguniform (base 10) distribution between two limits
- Loguniform (base e) distribution between two limits
- Triangular distribution defined using a lower limit, mode, and an upper limit
- Normal distribution with a mean and standard deviation
- Lognormal (base 10) distribution specified by the mean and standard deviation of the logarithms of the data
- Lognormal (base e) distribution specified by the mean and standard deviation of the logarithms of the data
- User specified cumulative distribution function input as a table of probabilities and exceedance values
- Beta distribution that can be shifted and scaled from the standard (0,1) interval
- Log-ratio from a normal distribution
- Hyperbolic arcsine from a normal distribution

In the following discussion, the description is presented such that the keyword name for entering stochastic variable information is STOCHASTIC. In reality, a variety of keyword names are used, including KDSOIL and DILUTE, for example. The keyword STOCHASTIC will be used in the following discussion in order to simplify the presentation. This keyword facilitates entering the statistical distribution for stochastic variables. The general syntax for the STOCHASTIC record is the following:

```
STOCHASTIC ["Quote1"] [Dist_Index Parameters] {TRUNCATE U1 U2} {"Quote2"}
```

The entry for Quote₁ must be a unique character string of up to 20 characters that will be used to identify this stochastic variable in subsequent uses. It is case sensitive and embedded spaces are significant. It is

sometimes useful to make the character string some combination of a variable name and other data such that it can be recreated easily when stochastic data is needed. The entry for Quote₂ is a description for the stochastic variable that can be up to 64 characters long that is used for output labeling purposes. The entry for Quote₂ is optional.

The entry for Index must be an integer in the range 1 to 13 that identifies the index of a statistical distribution. Table 2.1 defines the statistical distributions. The word 'Parameters' in the general syntax statement indicates the numerical values of parameters required to define the statistical distribution. The additional modifier TRUNCATE can be used for all distribution types except 1, 3, and 10. If TRUNCATE is entered, it must be followed by two values in the interval 0 to 1, inclusive of the endpoints. The lower value must be less than the upper value. These two values specify the tail probabilities at which to impose range truncation for the distribution. Truncation data must be entered after all of the other parameters that define the distribution.

Table 2.1 Statistical Distributions Available in All Codes

Index	Distribution	Truncate	Parameters Required
1	Constant	No	Single value.
2	Uniform	Yes	Lower limit, upper limit.
3	Discrete Uniform	No	Smallest integer, Largest integer.
4	Loguniform (base 10)	Yes	Lower limit, upper limit.
5	Loguniform (base e)	Yes	Lower limit, upper limit.
6	Triangular	Yes	Lower limit, mode, upper limit.
7	Normal	Yes	Mean, standard deviation.
8	Lognormal (base 10)	Yes	Mean, standard deviation of logarithms.
9	Lognormal (base e)	Yes	Mean, standard deviation of logarithms.
10	User Defined	Yes	Number of pairs, data for pairs of values (Prob(X _i),X _i).
11	Beta	Yes	Alpha, beta, lower limit, upper limit. The mean of the distribution would be alpha/(alpha+beta) if the limits were 0 and 1.
12	Log ratio	Yes	Mean, Standard deviation (of normal), lower limit, upper limit.
13	Hyperbolic arcsine	Yes	Mean, Standard deviation (of normal).

The following is an example stochastic keyword for a variable assigned a constant of 234.432:

```
STOCHASTIC "Unique1" 1 234.432 "Define a constant distribution"
```

The constant can take any value.

The following is an example stochastic keyword for a variable assigned a uniform distribution on -2 to 7:

```
STOCHASTIC "Unique2" 2 -2.0 7  
"Define a uniform distribution on -2 to 7"
```

The two limits can take any values as long as the second value is strictly greater than the first value.

The following is an example stochastic keyword for a variable assigned a discrete uniform distribution on the integers 6 to 70:

```
STOCHASTIC "Unique3" 3 6 70  
"Define a discrete uniform distribution on 6 to 70"
```

The two limits must be integers where the second integer is strictly greater than the first integer.

The following is an example stochastic keyword for a variable assigned a loguniform (base 10) distribution on the interval 1.0E-7 to 1.0E-3:

```
STOCHASTIC "Unique4" 4 1.0E-7 1.0E-3  
"Define a loguniform (base 10) distribution on 0.0000001 to 0.001"
```

The two limits must both be greater than zero and the second limit must be greater than the first limit.

The following is an example stochastic keyword for a variable assigned a loguniform (base e) distribution on the interval 1.0E+3 to 1.0E+5:

```
STOCHASTIC "Unique5" 5 1.0E3 1E+6  
"Define a loguniform (base e) distribution on 1000 to 1000000"
```

The two limits must both be greater than zero and the second limit must be greater than the first limit.

The following is an example stochastic keyword for a variable assigned a triangular distribution with a minimum of 2, a mode of 3, and a maximum of 7:

```
STOCHASTIC "Unique6" 6 2 3 7 "Define a triangular distribution on (2,3,6)"
```

The three values that define the triangular must all be different, and they must be entered in increasing order.

The following is an example stochastic keyword for a bioconcentration factor that is normally distributed with a mean of 125 and a standard deviation of 5 for a frog exposed to carbon-14:

```
STOCHASTIC "BCFC14Frog" 7 125.0 5.0 "Example normally distributed frog"
```

The mean value can be any number, but the standard deviation must be greater than zero.

The following keyword would define a different stochastic variable than the one just entered because the identification string (Quote1) is case sensitive:

```
STOCHASTIC "BCFC14FROG" 7 125.0 5.0 "Example normally distributed frog"
```

The following keyword entry would define a lognormal (base 10) distribution where the mean and standard deviation (of the logarithms) are -2.0 and 0.5:

```
STOCHASTIC "Unique8" 8 -2 0.5  
"Example for a lognormal (base 10) variable"
```

The mean value can be any number, but the standard deviation must be greater than zero.

The following keyword entry would define a lognormal (base e) distribution where the mean and standard deviation (of the logarithms) are -2.0 and 0.5. In addition, the lognormal distribution will be truncated between the lower 0.025 and upper 0.99 probabilities.

```
STOCHASTIC "Unique9" 9 -2 .5 TRUNCATE 0.025 0.99  
"Example for a truncated lognormal variable"
```

The mean value can be any number, but the standard deviation must be greater than zero.

The following keyword entry illustrates the use of the user-defined distribution (distribution type 10). This example entry uses seven pairs of values. The first pair of numbers uses a probability of 0 to define the lower limit of the distribution at 8.4E-7. The last pair of numbers uses a probability of 1 to define the upper limit of the distribution at 1.73E-6. The other values are associated with the probability levels of .025, .167, .5, .833, and .975. The probability data and distribution percentiles must be entered in strictly increasing order.

```
STOCHASTIC "Sr90Con" 10 7  
0 8.40E-7  
2.50E-02 9.20E-7  
1.67E-01 1.06E-6  
5.00E-01 1.21E-6  
8.33E-01 1.37E-6  
9.75E-01 1.58E-6  
1 1.73E-6
```

The first pair of numbers uses a probability of 0 to define the lower limit of the distribution. The last pair of numbers uses a probability of 1 to define the upper limit of the distribution. The intervening pairs define probability levels 0 and the associated data values. The probabilities and data values must be entered in strictly increasing order.

The following keyword entry would define a beta distribution with parameters 1.1 and 2.1 on the interval (0,1):

```
STOCHASTIC "Unique11-1" 11 1.1 2.1 0.0 1.0  
"Beta (1.1,2.1) on the interval 0,1"
```

Let the first parameter be denoted by α and the second parameter be denoted by β . The mean of the beta distribution would be $\alpha/(\alpha+\beta)$ if the limits were 0 and 1. Both α and β must be greater than zero. The lower limit must be less than the upper limit.

The following keyword entry would define a beta distribution with parameters 1.1 and 2.1 but on the interval -2 to 4:

```
STOCHASTIC "Unique11-2" 11 1.1 2.1 -2.0 4.0
"Beta (1.1,2.1) on the interval (-2,4) "
```

The following keyword entry would define a log ratio distribution from a normal(-1.459,1.523) distribution on the interval -5.756 to 4.33:

```
STOCHASTIC "Test1203" 12 -1.459 1.523 -5.756 4.330
"Log ratio from Normal(-1.4,1.5) on (-5.756,4.330) "
```

The entry for the normal standard deviation (a value of 1.523 in this example) must be greater than zero. The last two numerical values define the interval for the generated values, so the lower limit must be smaller than the upper limit.

The following keyword entry would define a hyperbolic arcsine distribution from a normal(0.189,0.146) distribution:

```
STOCHASTIC "Test1302" 13 0.189 0.146
"Hyperbolic Arcsine from Normal(0.189,0.146) "
```

The entry for the normal standard deviation (a value of 0.189 in this example) must be greater than zero.

2.3 ESD Keywords Used by the Impact Codes

The environmental settings are defined in the ESD keyword file. This file contains information used in more than one module of the suite of codes. A file containing example ESD keywords is provided in Table 2.2. This file is intended to give examples of keywords and does not form a consistent set of keywords that would result in a successful problem execution.

Table 2.2 Example ESD Keywords Used in the Impact Codes

```
!
REPORT "ESD_CA1_median.rpt"
TITLE  "2004 Composite Analysis 10,000-year (Median Inputs) Assessment"
USER   "Eslinger-DWE-WEN"
!
REALIZAT 1
!
!-----| Analytes |-----!
ANALYTE ID="C14"  NAME="Carbon-14"  TYPE="NR"  AIR="NOBLE"          COMPUTE
MOLWGT=1.400324E+01  HALFLIFE=5.715000E+03  SPECIFIC=4.470906E+00  DFIMM=5.122392E-05
DFSSED=7.200000E-23  GAMMA=0.000000E+00  MOLDIFF=1.050000E-05  GASDIFF=0.000000E+00
HENRY=0.000000E+00
ANALYTE ID="Sr90"  NAME="Strontium-90"  TYPE="NR"          COMPUTE
```

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```
MOLWGT=8.990774E+01 HALFLIFE=2.878000E+01 SPECIFIC=1.382778E+02 DFIMM=1.703575E-03
DFSED=3.720000E-21 GAMMA=0.000000E+00 MOLDDIFF=1.050000E-05 GASDIFF=0.000000E+00
HENRY=0.000000E+00
ANALYTE ID="H3" NAME="Tritium" TYPE="NR" BOMB COMPUTE
MOLWGT=3.016049E+00 HALFLIFE=1.232000E+01 SPECIFIC=9.629222E+03 DFIMM=0.000000E+00
DFSED=0.000000E+00 GAMMA=0.000000E+00 MOLDDIFF=1.050000E-05 GASDIFF=2.600000E-01
HENRY=0.000000E+00
!-----| ECDA Solution Times |-----!
TIMES
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
11900 11950 12000 12050
!- SACVIEW header file for ECDA concentration files
FILE HEADER NAME="/home/ANALYSIS4/CA1_median/ecda/Sacview_CA1_median.hdr" CREATE
!- ECDA record number index map file for concentration data
FILE I_ECDA NAME="/home/ANALYSIS4/CA1_median/ecda/ECDA_CA1_median.map" CREATE
!- ECDA Concentration data files for each analyte
FILE C_ECDA ANALYTE="H3" NAME="/home/ANALYSIS4/CA1_median/ecda/H3_CA1_median.dat"
FILE C_ECDA ANALYTE="C14" NAME="/home/ANALYSIS4/CA1_median/ecda/C14_CA1_median.dat"
FILE C_ECDA ANALYTE="Sr90" NAME="/home/ANALYSIS4/CA1_median/ecda/Sr90_CA1_median.dat"
!-----| Irrigation Control |-----!
IRRIGATE SPRING=121 FALL=256 RATE=75.0 NET=0.20 START=2004 THETAIRG=0.5 THETADRY=0.2
!-----| Impacts Locations |-----!
!- Upland locations - 2863, MEDIA - GWAT SOGW SODR AIRC AIRD
LOCATION ID="UH0001" NAME="UnsuitableForAgricul" EASTING=576022 NORTHING=154367
GWAT SOGW SOSW SODR AIRC AIRD, TYPE = "UPLAND", LOCUS = "HANFORD"
APSD = 4.00E-02 POROSITY= 3.50E-01 FOC = 1.0E+00
VEGCOV = 5.00E-01 NECF = 1.00E+00 RHOS = 1.50E+00 SRH = 1.8E-02
TEMP = 2.85E+02 MSWIND = 3.44E+00 MZWIND = 3.44E+00
IRG_SWAT ="QHP025" AREA = 1457376.1
!- Riparian locations(not islands) - 502, MEDIA - GWAT SEEP SORP AIRC AIRD
LOCATION ID="RHP250" NAME="RiparianBentonYakDeltaNorth" EASTING=597822 NORTHING=103016
GWAT SEEP SORP AIRC AIRD TYPE="RIPARIAN" LOCUS="HANFORD" MILE=335.20
APSD=4.00E-02 COXYGEN=1.10E-02 POROSITY=3.50E-01 FOC=1.0E+00 VEGCOV=5.00E-01
NECF=1.00E+00 RHOS=1.50E+00 SRH=1.8E-02 TEMP=2.85E+02 MSWIND=3.44E+00
MZWIND=3.44E+00 AREA=9360
!- Aquatic locations(not islands) - 502, MEDIA - SWAT PWAT SEDI
LOCATION ID="QFP001" NAME="AquaticGrantUpVernitaBridge" EASTING=557310 NORTHING=145159
SWAT SEDI PWAT TYPE="AQUATIC" LOCUS="FARSIDE" MILE=389.10
COXYGEN = 1.10E-02 AREA = 2.5E+03
!- Riparian locations(islands) - 190, MEDIA - GWAT SEEP SORP AIRC AIRD
LOCATION ID="R21I08" NAME="NELSON ISLAND" EASTING=595557.3 NORTHING=108833.7
GWAT SEEP SORP AIRC AIRD TYPE="RIPARIAN" LOCUS="HANFORD" MILE=339.67
APSD=4.00E-02 COXYGEN=1.10E-02 POROSITY=3.50E-01 FOC=1.0E+00 VEGCOV=5.00E-01
NECF=1.00E+00 RHOS=1.50E+00 SRH=1.8E-02 TEMP=2.85E+02 MSWIND=3.44E+00
MZWIND=3.44E+00 AREA=9360
!- Aquatic locations(islands) - 190, MEDIA - SWAT PWAT SEDI
LOCATION ID="Q02I01" NAME="ISLAND 02,BLM" EASTING=574295.6 NORTHING=155058.0
SWAT SEDI PWAT TYPE="AQUATIC" LOCUS="HANFORD" MILE=375.49
COXYGEN = 1.10E-02 AREA = 2.5E+03
!- Air locations - 43, MEDIA - GWAT SOGW SODR AIRC AIRD
LOCATION ID="AH0001" NAME="Air 100 D Area" EASTING=574436.00 NORTHING=151194.98
GWAT SOGW SOSW SODR AIRC AIRD TYPE="UPLAND" LOCUS="HANFORD", IRG_SWAT ="QHP136"
APSD = 4.00E-02 POROSITY= 3.50E-01 FOC = 1.0E+00 VEGCOV = 5.00E-01
NECF = 1.00E+00 RHOS = 1.50E+00 SRH = 1.8E-02 TEMP = 2.85E+02
MSWIND = 3.44E+00 MZWIND = 3.44E+00 AREA = 2500
!- Aquatic locations - 60, MEDIA - SWAT PWAT SEDI
LOCATION ID="QT3001" NAME="Transect300AREA-1 HRM 43.1" EASTING=595581 NORTHING=109846
```

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```
SWAT SEDI PWAT TYPE="AQUATIC" LOCUS="HANFORD" MILE=340.43
COXYGEN = 1.10E-02 AREA = 2.5E+03
!
LOCATION ID="QHRWI1" NAME="CityRichlandMunWaterIntake" EASTING=595499 NORTHING=109743
SWAT SEDI PWAT TYPE="AQUATIC" LOCUS="HANFORD" MILES=340.37
COXYGEN = 1.10E-02 AREA = 2500
! RADIUS Keywords:
RADIUS ID="Radius" 1.400E+00 2.000E+00 3.000E+00 5.000E+00 7.000E+00 1.000E+01
RADIUS ID="C14" 5.000E-02 5.000E-02 5.000E-02 5.000E-02 5.000E-02 5.000E-02
RADIUS ID="Sr90" 1.140E+00 1.140E+00 1.140E+00 1.140E+00 1.140E+00 1.140E+00
RADIUS ID="H3" 5.800E-03 5.800E-03 5.800E-03 5.800E-03 5.800E-03 5.800E-03
!-----| Biotic Species Information |-----!
! Model parameters for biotic plant and animal growth and respiration rates
GROWTH DELTA=0.002 BETA=0.25
RESPIRE GAMMA=0.2 PHI=0.032
! Type QP: Aquatic plants
SPECIES ID="QPERIP" TYPE="QP" NAME="periphyton" HABITAT="AQUATIC"
AWD=10 FLIPID=0.0418 FOC=0.35 RADIUS=1.4 WBMASS=0.000035
! Type QA: Aquatic animals
SPECIES ID="QCARPS" TYPE="QA" NAME="CARP " HABITAT="AQUATIC"
OCAR=8.0000E-01 AWD=5.0000E+00 FLIPID=7.4000E-02 FOC=4.5000E-01
WBMASS=1.0500E+03 RADIUS=7.0000E+00
! Type TA: Terrestrial animals - riparian locations
SPECIES ID="RGOOSE" TYPE="TA" NAME="Canada goose" HABITAT="RIPARIAN"
AE=8.1000E-01 DIFFHT=3.0000E-01 ETWATER=2.0000E+01 FMR=4.4969E+02
FWATER=5.0000E-01 FDW=0.4 GE=1.9000E+03 INHRATE=2.2396E+00
PCS=2.5000E-01 PCW=5.0000E-01 PSI=1.0000E+00 RADIUS=1.0000E+01
SADHER=1.4500E+00 THETA=1.0000E+00 SA=2.3988E+03 WATERING=1.4176E-01
WEIGHT=3.7000E+00
! Type TP: Terrestrial plants - upland locations
SPECIES ID="UGRASS" TYPE="TP" NAME="grasses" HABITAT="UPLAND" SURFACE=6.5000E-03
AE=4.7000E-01
DIFFHT=1.0000E-01 FPA=5.0000E-01 FPL=1.0000E-02 FPW=4.0000E-01 FW=7.8000E-01
GE=1.3000E+03
FWATER=0.0000E+00 RADIUS=3.0000E+00 RHOP=1.0000E+03 WEIGHT=1.0000E-01
ETWATER=0.0000E+00
!-----| End of ESD File |-----!
END
```

In the following keyword descriptions, some data are optional for a particular problem definition and some are required. Data that are required are enclosed in square brackets. For AB to be required, it would be denoted by [AB]. If only one of the three items AB, BC, CD were required, it would be written as [AB|BC|CD]. The vertical bars indicate to choose one of the items in the list. Optional items are enclosed in normal brackets. For DE to be an optional entry, it would be denoted by {DE}. The {} or [] symbols are indicators of whether the data are required; the symbols do not need to be entered when the keyword is constructed. The keyword name can contain any number of characters; however, only the first eight characters are read (for example, REALIZAT has the same effect as REALIZATION).

In some instances, numerical values or quote strings are associated with a modifier. In this description, the association is indicated by using the equal (=) symbol. The = symbol is not required but may be used when the keyword is constructed. When a numerical value or quote string is associated with a modifier, it must be physically entered on the input line directly after the modifier.

2.3.1 ANALYTE Keyword in the ESD Keyword File

The ANALYTE keyword is used to define the analytes used in the simulation. The syntax for this keyword is the following:

```
ANALYTE [ID="quote 1"] [NAME="quote 2"] [TYPE="quote 3"] {COMPUTE}  
      {MOLDIFF=N1} {HENRY=N2} {DFIMM=N3} {DFSED=N4} {GAMMA=N5}
```

A separate ANALYTE keyword must be entered for every analyte to be included in the simulation. The optional modifier COMPUTE can be entered. If COMPUTE is not present, the analyte will not be included in the run although information is included in the environmental settings file.

The modifiers associated with the ANALYTE keyword are given in Table 2.3.

Table 2.3 Modifiers Associated with the ANALYTE Keyword in the ESD File

Modifier	Description
ID	The quote string associated with the ID modifier is an analyte identification string up to six characters in length. The analyte identification string is case sensitive, and spaces or hyphens change the definition. All data in the analyte identification strings must satisfy the following conventions: <ul style="list-style-type: none">• Only the first entry in the analyte identification string is capitalized.• No embedded spaces or hyphens are used, even for radionuclides.• Individual elements are defined using the standard element abbreviation.
NAME	The quote string associated with the NAME modifier is an analyte name or description up to 72 characters in length.
TYPE	The quote string associated with the TYPE modifier string is a two-character analyte type indicator. The following are valid entries for this string: <ul style="list-style-type: none">• NR – if the analyte is a radioactive element or an inorganic compound containing a radionuclide• NS – if the analyte is a stable (nonradioactive) element or inorganic compound• OR – if the analyte is an organic compound containing a radionuclide• OS – if the analyte is an organic compound, containing a stable (nonradioactive) elemental analyte or compound
MOLDIFF	The numerical entry associated with the MOLDIFF modifier is the molecular diffusivity of the analyte. This value has units of cm ² /sec and is used only in the ecological modules. Entry of this modifier is optional. If it is not present, the value of MOLDIFF defaults to zero.
HENRY	The numerical entry associated with the HENRY modifier is the Henry's law coefficient for organic analytes. This value has units of Pa-m ³ /mole and is used only in the impacts modules. Entry of this modifier is optional. If it is not present, the value of HENRY defaults to zero.

Modifier	Description
DFIMM	The numerical entry associated with the DFIMM modifier is the immersion external dose factor for radioactive analytes. This value has units of mrad/yr per uCi/m ³ and is used only in the impacts modules. Entry of this modifier is optional. If it is not present, the value of DFIMM defaults to zero.
DFSED	The numerical entry associated with the DFSED modifier is the sediment external dose factor for radioactive analytes. This value has units of Sv-m ³ /sec-Bq and is used only in the impacts modules. Entry of this modifier is optional. If it is not present, the value of DFSED defaults to zero.
GAMMA	The numerical entry associated with the GAMMA modifier is the gamma decay energy for radioactive analytes. This value has units of MeV/nt and is used only in the impacts modules. Entry of this modifier is optional. If it is not present, the value of GAMMA defaults to zero.
COMPUTE	The optional modifier COMPUTE can be entered. If COMPUTE is not present, the analyte will not be included in the run although information is included in the environmental settings file.

The following ANALYTE keywords select the analytes carbon tetrachloride and strontium-90 for analysis:

```
ANALYTE ID="CCl4"    NAME="Carbon Tetrachloride" TYPE="NS"  COMPUTE
      HENRY  = 2.99E+03 MOLDIFF=5.0E-08

ANALYTE ID="Sr90"    NAME="Strontium 90"   TYPE="NR"  COMPUTE
      MOLDIFF=5.0E-11 HENRY=0 DFIMM=0 DFSED=3.72000E-21 GAMMA=0
```

2.3.2 END Keyword in the ESD Keyword File

The END keyword signifies the end of all keyword data. It should be the last keyword in the keyword file. Any data in the keyword file after the END keyword will be ignored. The following is the syntax for this keyword record:

```
END
```

There are no modifiers or quote strings associated with the END keyword.

2.3.3 FILE Keyword in the ESD Keyword File

The FILE keyword is used to enter the names of many of the files used in a simulation run. The following is the syntax for the FILE keyword record:

```
FILE [NAME="quote 1"] {ANALYTE="quote 2"} {HEADER} { I_ECDA }
      { C_ECDA }
```


The file names are entered in quote strings, which must be enclosed in double quotation marks. Path names up to 72 characters long are supported. At least one FILE keyword is required for every run of the code if concentrations are to be generated. Every file definition requires the entry of a separate FILE keyword. File type modifiers associated with the FILE keyword are given in Table 2.4.

Table 2.4 Modifiers Associated with the FILE Keyword in the ESD File

Modifier	Description
C_ECDA	This modifier indicates that the FILE keyword is defining a concentration file for impacts. Concentrations for each analyte are contained in separate files. The ANALYTE modifier is used to associate an analyte with this file (see the ANALYTE keyword in Section 2.3.1).
I_ECDA	This modifier indicates that the FILE keyword is defining a record index file for mapping into all binary files of concentrations supporting impacts.
HEADER	This modifier indicates that the FILE keyword is defining a header file for use by the SACView graphical user interface that allows extraction of human-readable concentration data.

The following are example entries that define the concentration files for carbon-14 and zinc for the full suite of cultural, ecological, economic, and human impact:

```
FILE C_ECDA ANALYTE="C14" NAME="\Test\ECDA\C14\Conc.dat"
FILE C_ECDA ANALYTE="Zn" NAME="\Test\ECDA\Zinc\Conc.dat"
```

The following are example entries that define the ECDA record number index files for all four impact types:

```
FILE I_ECDA NAME="\Test\ECDA\Conc.map"
```

2.3.4 IRRIGATE Keyword in the ESD Keyword File

The IRRIGATE keyword is used to define the first and last day of irrigation each year. These dates are used by the ECEM code to determine the length of the growing season for terrestrial plants. The following is the keyword's syntax:

```
IRRIGATE SPRING=value1 FALL=value2
```

The modifier SPRING and the value value1 identify the day of the year on which the irrigation begins. The modifier FALL and the value value2 identify the day of the year on which the irrigation ends. Spring and fall days should be entered as whole numbers with the fall end day no smaller than the spring start day. The following is an example IRRIGATE keyword that establishes a growing season that begins on the 121st day of the year and ends on the 256th day of the year:

```
IRRIGATE SPRING=121 FALL=256
```

2.3.5 LOCATION Keyword in the ESD Keyword File

The LOCATION keyword identifies the locations where concentrations will be generated for use in the impacts modules. The following is the keyword's syntax:

```
LOCATION [ID="quote1"] [EASTING=N1] [NORTHING=N2] [TYPE=[RIPARIAN | AQUATIC |
UPLAND]] [LOCUS=[HANFORD | FAR SIDE]] {AREA=N3} {POP=N4} {GWAT} {SWAT}
{PWAT} {SEEP} {SEDI} {SODR} {SOGW} {SOSW} {SORP} {AIRC} {AIRD} [TITLE=
"quote2"] {COMPUTE}
```

Table 2.5 contains the modifiers and associated data for the LOCATION keyword.

Table 2.5 Modifiers Associated with the LOCATION Keyword in the ESD File

Modifier	Description
COMPUTE	If the COMPUTE modifier is entered, this location will be included in the simulation. If COMPUTE is not entered, this location will be ignored.
ID	The location identification string is entered using the ID modifier. This string is limited to 15 characters and must be unique. It is used to associate other data with a specific location.
TITLE	A descriptive title for this location is entered using the TITLE modifier. This quote string is limited to 72 characters. It is used only for output labeling purposes.
EASTING	This entry is associated with the easting coordinate (meters, state plane coordinate system) for the location.
NORTHING	This entry is associated with the northing coordinate (meters, state plane coordinate system) for the location.
LOCUS	The locus is used to determine whether this location is on the Hanford side of the Columbia River or on the far side of the river.
TYPE	The location type is used to differentiate between riparian, aquatic, and upland locations.
GWAT	Presence of this optional modifier indicates that groundwater concentrations will be computed at this location.
SWAT	Presence of this optional modifier indicates that surface water concentrations will be computed at this location.
PWAT	Presence of this optional modifier indicates that river bottom pore water concentrations will be computed at this location.
SEEP	Presence of this optional modifier indicates that seep water concentrations (on the land surface) will be computed at this location.
SOGW	Presence of this optional modifier indicates that groundwater-irrigated soil concentrations will be computed at this location.

Modifier	Description
SOSW	Presence of this optional modifier indicates that surface water-irrigated soil concentrations will be computed at this location.
SODR	Presence of this optional modifier indicates that non-irrigated soil concentrations will be computed at this location.
SORP	Presence of this optional modifier indicates that riparian soil concentrations will be computed at this location.
SEDI	Presence of this optional modifier indicates that sediment concentrations (on the river bottom) will be computed at this location.
AIRC	Presence of this optional modifier indicates that air concentrations will be computed at this location.
AIRD	Presence of this optional modifier indicates that air deposition rates will be computed at this location.
APSD	Aggregate particle size distribution (mm) used in the erosion threshold wind speed calculations (used in the ecological model).
COXYGEN	Oxygen concentration in surface water (mg/L) (used in the ecological model).
FOC	Fraction soil organic carbon content (unitless) (used in the ecological model).
MSWIND	Mean annual wind speed (m/s) (used in the ecological model).
MZWIND	Mixing zone wind speed (m/s) (used in the ecological model).
NECF	Nonerodible elements correction factor (unitless) used in calculating the threshold air friction velocity (used in the ecological model).
POROSITY	Soil porosity at the location (unitless) (used in the ecological model).
RHOS	Soil density at the location (g/cm ³) (used in the ecological model).
SRH	Surface roughness height (m) used in calculating the threshold friction velocity. (used in the ecological model).
TEMP	Temperature (in Kelvins) used in calculating air concentrations of organic analytes (used in the ecological model).
VEGCOV	Fraction of vegetation cover at the location (unitless) (used in the ecological model).

Locations for cultural, ecological, economic, and human analyses may be different. The following example keywords define three locations for impacts:

```
LOCATION ID="UH0001" NAME="UnsuitableForAg" EASTING=576022 NORTHING=154367
  GWAT SOGW SOSW SODR AIRC AIRD TYPE = "UPLAND", LOCUS = "HANFORD"
  APSD      = 4.00E-02  POROSITY= 3.50E-01  FOC      = 1.0E+00
  VEGCOV    = 5.00E-01  NECF      = 1.00E+00  RHOS     = 1.50E+00
  SRH       = 1.8E-02   TEMP      = 2.85E+02  MSWIND   = 3.44E+00
  MZWIND    = 3.44E+00  AREA      = 1457376.1
```

```
LOCATION ID="RHP018" NAME="RpBentonUp100BC" EASTING=563263 NORTHING=145849
  GWAT SEEP SORP AIRC AIRD TYPE="RIPARIAN" LOCUS="HANFORD" MILE=385.10
  APSD      = 4.00E-02 COXYGEN = 1.10E-02 POROSITY= 3.50E-01
  FOC       = 1.0E+00  VEGCOV  = 5.00E-01 NECF      = 1.00E+00
  RHOS      = 1.50E+00 SRH      = 1.8E-02  TEMP      = 2.85E+02
  MSWIND    = 3.44E+00 MZWIND  = 3.44E+00 AREA      = 9360

LOCATION ID="QFP085" NAME="AqGrantUpR100H" EASTING=580594 NORTHING=151878
  SWAT SEDI PWAT      TYPE="AQUATIC" LOCUS="FARSIDE" MILE=371.00
  COXYGEN = 1.10E-02 AREA = 2.5E+03
```

2.3.6 RADIUS Keyword in the ESD Keyword File

The RADIUS keyword is used to build the radius library for radiological dose calculations. The following is the keyword's syntax:

```
RADIUS [ID="quote 1"] value1 value2 ... valuek
```

The first RADIUS keyword must always have ID="Radius" and the values are the radii for which the analyte data are given. The subsequent RADIUS keywords have an ID of an analyte name, and the values are the effective energies by radius for that analyte. The following is an example RADIUS keywords that provide effective energies for carbon-14, cesium-137 and chlorine-36:

```
RADIUS ID="Radius" 1.4E+0 2.0E+0 3.0E+0 5.0E+0 7.0E+0 1.0E+1 2.0E+1 3.0E+1
RADIUS ID="C14"      5.0E-2 5.0E-2 5.0E-2 5.0E-2 5.0E-2 5.0E-2 5.0E-2 5.0E-2
RADIUS ID="Cs137"    2.6E-1 2.7E-1 2.8E-1 3.2E-1 3.5E-1 3.9E-1 5.0E-1 5.8E-1
RADIUS ID="Cl36"     2.6E-1 2.6E-1 2.6E-1 2.6E-1 2.6E-1 2.6E-1 2.6E-1 2.6E-1
```

2.3.7 REALIZATION Keyword in the ESD Keyword File

The REALIZATION keyword identifies the number of realizations to be simulated. The following is the keyword's syntax:

```
REALIZATIONS N1
```

The number of realizations is given by the single numerical entry. The valid number of realizations is 1 or larger. Run times and disk storage requirements are directly proportional to the number of realizations. The following is an example REALIZAT keyword requesting 25 realizations:

```
REALIZAT 25
```

2.3.8 SPECIES Keyword in the ESD Keyword File

The SPECIES keyword is used to enter definitions for possible species to be simulated. The ECEM and MASS2 codes can select species from this master list. The following is the keyword's syntax:

```
SPECIES [ID="quote 1"] [TYPE="quote 2"] [NAME="quote 3"]
  [HABITAT=[UPLAND | RIPARIAN | AQUATIC]] {Modifier=N1} ... {Modifier=N36}
  {EMERGENT}
```

A separate SPECIES keyword must be entered for every species being defined. The modifiers associated with the SPECIES keyword are given in Table 2.6.

Table 2.6 Modifiers Associated with the SPECIES Keyword in the ESD File

Modifier	Description
ID	The quote string associated with the ID modifier is a unique species identification string up to six characters long. The analyte identification string is case sensitive, and spaces or hyphens change the definition.
TYPE	The quote string associated with the TYPE modifier string is a two-character analyte type indicator. The following are the valid entries for this string: TA – if the species is a terrestrial animal TP – if the species is a terrestrial plant QA – if the species is an aquatic animal QP – if the species is an aquatic plant
NAME	The quote string associated with the NAME modifier is a species name or description up to 72 characters in length.
HABITAT	The quote string associated with the HABITAT modifier identifies the species as living in either a riparian, upland, or aquatic environment.
AE	The numerical entry associated with the AE modifier is the assimilation efficiency of the species. This value is unitless. Entry of this modifier is optional. If it is not present, the value of AE defaults to zero.
AWD	The numerical entry associated with the AWD modifier is the wet-to-dry weight ratio of the species. This value has units of g wet/g dry. Entry of this modifier is optional. If it is not present, the value of AWD defaults to zero.
DIFFHT	The numerical entry associated with the DIFFHT modifier is the diffusion height of the species. This value has units of meters. Entry of this modifier is optional. If it is not present, the value of DIFFHT defaults to zero.
EMERGENT	There is no numerical entry associated with the EMERGENT modifier. Use of this modifier indicates that the species is an emergent plant. An emergent plant is one that has roots in water but grows in the air. This type of plant does not have rain splash of contaminated soil onto the leaves of the plant.
ETWATER	The numerical entry associated with the ETWATER modifier is the exposure time to water of the species. This value has units of hr/day. Entry of this modifier is optional. If it is not present, the value of ETWATER defaults to zero.
FLIPID	The numerical entry associated with the FLIPID modifier is the fraction lipid of the species. This value has units of g lipid/g wet. Entry of this modifier is optional. If it is not present, the value of FLIPID defaults to zero.
FMR	The numerical entry associated with the FMR modifier is the metabolic rate of predator species. This value has units of kcal/day. Entry of this modifier is optional. If it is not present, the value of FMR defaults to zero.

Modifier	Description
FOC	The numerical entry associated with the FOC modifier is the fraction organic carbon of the species. This value has units of g organic carbon/g dry weight. Entry of this modifier is optional. If it is not present, the value of FOC defaults to zero.
FPA	The numerical entry associated with the FPA modifier is the volume fraction of plant tissue that is air for the species. This value is unitless. Entry of this modifier is optional. If it is not present, the value of FPA defaults to zero.
FPL	The numerical entry associated with the FPL modifier is the volume fraction of plant tissue that is lipid for the species. This value is unitless. Entry of this modifier is optional. If it is not present, the value of FPL defaults to zero.
FPW	The numerical entry associated with the FPW modifier is the volume fraction of plant tissue that is water for the species. This value is unitless. Entry of this modifier is optional. If it is not present, the value of FPW defaults to zero.
FW	The numerical entry associated with the FW modifier is the water weight fraction of plant tissue for the species. This value is unitless. Entry of this modifier is optional. If it is not present, the value of FW defaults to zero.
FWATER	The numerical entry associated with the FWATER modifier is the fraction exposure to water for the species. This value is unitless. Entry of this modifier is optional. If it is not present, the value of FWATER defaults to zero.
FDW	The numerical entry associated with the FDW modifier is the conversion from dry weight to wet weight for the species. This value has units of kg dry/kg wet. Entry of this modifier is optional. If it is not present, the value of FDW defaults to zero.
GE	The numerical entry associated with the GE modifier is the gross energy for the species. This value has units of kcal/kg wet weight. Entry of this modifier is optional. If it is not present, the value of GE defaults to zero.
INHRATE	The numerical entry associated with the INHRATE modifier is the resting inhalation rate for the species. This value has units of m ³ /day. Entry of this modifier is optional. If it is not present, the value of INHRATE defaults to zero.
OCAR	The numerical entry associated with the OCAR modifier is the organic carbon assimilation rate for the species. This value has units of g organic carbon assimilated/g ingested. Entry of this modifier is optional. If it is not present, the value of OCAR defaults to zero.
PCS	The numerical entry associated with the PCS modifier is the fraction of surface area in contact with soil for the species. This value has units of 1/day. Entry of this modifier is optional. If it is not present, the value of PCS defaults to zero.
PCW	The numerical entry associated with the PCW modifier is the fraction of surface area available to water soil for the species. This value is unit less. Entry of this modifier is optional. If it is not present, the value of PCW defaults to zero.
PSI	The numerical entry associated with the PSI modifier is the seasonality factor for the species. This value is unitless. Entry of this modifier is optional. If it is not present, the value of PSI defaults to zero.

Modifier	Description
RADIUS	The numerical entry associated with the RADIUS modifier is the radius of the species. This value has units of cm. Entry of this modifier is optional. If it is not present, the value of RADIUS defaults to zero.
RHOP	The numerical entry associated with the RHOP modifier is the plant tissue density of the species. This value has units of kg/m ³ . Entry of this modifier is optional. If it is not present, the value of RHOP defaults to zero.
SA	The numerical entry associated with the SA modifier is the surface area of the species. This value has units of cm ² . Entry of this modifier is optional. If it is not present, the value of SA defaults to zero.
SADHER	The numerical entry associated with the SADHER modifier is the skin adherence factor for the species. This value has units of mg/cm ² . Entry of this modifier is optional. If it is not present, the value of SADHER defaults to zero.
SEDING	The numerical entry associated with the SEDING modifier is the fraction of diet that is sediment for the species. This value is unitless. Entry of this modifier is optional. If it is not present, the value of SEDING defaults to zero.
SOILING	The numerical entry associated with the SOILING modifier is the soil ingestion rate for the species. This value has units of kg soil ingested/kg dry weight. Entry of this modifier is optional. If it is not present, the value of SOILING defaults to zero.
THETA	The numerical entry associated with the THETA modifier is the area use factor for the species. This value is unitless. Entry of this modifier is optional. If it is not present, the value of THETA defaults to zero.
WATERING	The numerical entry associated with the WATERING modifier is the water ingestion rate for the species. This value has units of liters/day. Entry of this modifier is optional. If it is not present, the value of WATERING defaults to zero.
WBMAS	The numerical entry associated with the WBMAS modifier is the wet body mass for the species. This value has units of grams. Entry of this modifier is optional. If it is not present, the value of WBMAS defaults to zero.
WEIGHT	The numerical entry associated with the WEIGHT modifier is the wet body weight for the species. This value has units of kg (wet). Entry of this modifier is optional. If it is not present, the value of WEIGHT defaults to zero.

The following SPECIES keywords define the American Coot and Channel Catfish as species available for simulation:

```

SPECIES ID="RACOOT" TYPE="TA" NAME="American coot" HABITAT="RIPARIAN"
AE=8.1000E-01      DIFFHT=2.00E-01  ETWATER=2.00E+01  FMR=1.6309E+02
FWATER=5.0000E-01  FDW=0.4      GE=1.9000E+03    INHRATE=6.1593E-01
PCS=2.5000E-01     PCW=5.0000E-01  PSI=1.0000E+00    RADIUS=5.0000E+00
SADHER=1.4500E+00  THETA=1.0000E+00 SA=7.8406E+02    WATERING=4.6102E-02
WEIGHT=6.9200E-01

```

```
SPECIES ID="QCATFS" TYPE="QA" NAME="CHCATF" HABITAT="AQUATIC"  
OCAR=8.0000E-01 AWD=5.0000E+00 FLIPID=1.7800E-01 FOC=4.5000E-01  
WBMAS=6.8025E+03 RADIUS=1.0000E+01
```

2.3.9 TIMES Keyword in the ESD Keyword File

The TIMES keyword identifies the times at which concentration data will be generated to support the calculations by each of the impact codes. The following is the keyword's syntax:

```
TIMES [T1] {T2} ... {Tn}
```

The numerical entries T₁, T₂, ..., T_n are the times (whole number years) when outputs are desired. Multiple TIMES keywords can be entered.

The following is an example TIMES keyword that requests concentration data for the three years 2020, 2075, and 3014 for the impacts modules:

```
TIMES 2020 2075 3014
```

2.3.10 TITLE Keyword in the ESD Keyword File

The TITLE keyword is used to define a single-line problem title. The problem title will be written to output files. If the title is not supplied, then the program will error terminate. The following is the syntax for this keyword record:

```
TITLE ["quote"]
```

The title is entered in a quote string, which must be enclosed in double quotation marks. Titles up to 72 characters long are supported. The following example defines a title for a run of the code:

```
TITLE "Example title line for the environmental settings control file."
```

There are no modifiers associated with the TITLE keyword.

2.4 Environmental Concentration Data Accumulator

The purpose of the Environmental Concentration Data Accumulator (ECDA) is to provide centralized storage for all concentration data of analytes at the locations and times needed to perform impact calculations.

2.4.1 Format of the Concentration Data (ECDA) Files

The general approach and file structure for the ECDA files has the following characteristics:

- Data storage for different analytes and are provided in separate files. This design feature allows addition of an additional analyte to a data set without recalculation of the other analytes.
- The files have a binary, fixed record length, direct-access format.
- A mapping scheme is used to store only “actual” data (no placeholders with wasted storage space).

Each data record in a concentration data file contains the following information: Year, Location ID, Media ID, and Concentration data (realizations 1 to the maximum). The following is the order in which media information always appear in the file:

- GWAT: Concentrations in groundwater (Ci/m^3 or kg/m^3)
- SEEP: Concentrations in seep water (Ci/m^3 or kg/m^3)
- SWAT: Concentrations in surface water (river) (Ci/m^3 or kg/m^3)
- PWAT: Concentrations in river bottom pore water (Ci/m^3 or kg/m^3)
- SEDI: Concentrations in river bottom sediment ($\text{Ci}/\text{kg}_{\text{sediment}}$ or $\text{kg}_{\text{analyte}}/\text{kg}_{\text{sediment}}$).
- SORP: Concentrations in riparian soil (land surface) ($\text{Ci}/\text{kg}_{\text{soil}}$ or $\text{kg}_{\text{analyte}}/\text{kg}_{\text{soil}}$)
- SODR: Concentrations in non-irrigated soil (land surface) ($\text{Ci}/\text{kg}_{\text{soil}}$ or $\text{kg}_{\text{analyte}}/\text{kg}_{\text{soil}}$)
- SOGW: Concentrations in groundwater-irrigated soil (land surface) ($\text{Ci}/\text{kg}_{\text{soil}}$ or $\text{kg}_{\text{analyte}}/\text{kg}_{\text{soil}}$)
- SOSW: Concentrations in surface water-irrigated soil (land surface) ($\text{Ci}/\text{kg}_{\text{soil}}$ or $\text{kg}_{\text{analyte}}/\text{kg}_{\text{soil}}$)
- AIRC: Concentrations in air (Ci/m^3 or kg/m^3)
- AIRD: Air deposition rate ($\text{Ci}/\text{m}^3/\text{yr}$ or $\text{kg}/\text{m}^2/\text{yr}$)

An overview of the structure of a concentration data file for impacts assuming 25 realizations were used is provided in Table 2.7. The structure for this file is identical for all analytes.

Table 2.7 Structure of a Concentration Data File

Analyte ID		
Eleven lines with units for the eleven media as character strings		
Time 1	Location 1	Media L1-1, 25 realizations
		...
		Media L1-L1MAX, 25 realizations

	Max Locations	Media LL-1, 25 realizations
		...
		Media LL-LLMAX, 25 realizations
Time 2	Location 1	Media L1-1, 25 realizations
		...
		Media L1-L1MAX, 25 realizations

	Max Locations	Media LL-1, 25 realizations
		...
		Media LL-LLMAX, 25 realizations
...
Max Time	Location 1	Media L1-1, 25 realizations
Human	Location 1	...
		Media L1-L1MAX, 25 realizations
		...
	Max Locations	Media LL-1, 25 realizations
		...
		Media LL-LLMAX, 25 realizations

2.4.2 Format of the Record Map File for Concentration Data

The record map file is an ASCII file that provides indexing information for the storage locations in the binary concentration data files. There is one record map file per impact type because the structure for the concentration data for a given impact type (human, ecological, cultural, or economic) is identical for all analytes. This file is generated by the ECDA code. The user should never modify this file.

The record map file has several header lines that are followed by indexing data. All character data are enclosed in double quotation marks, and records that contain more than one value have the data separated by commas. The following is the definition of the header lines:

- Problem title: The title from the ESD keyword file
- Code Name: The name of the code that generated the file
- Code Version: The version number of the code that generated the file
- Code Date: The modification date of the code that generated the file
- User Name: The user name from the ESD keyword file
- Run ID: The run ID from the code run that generated the file
- Block Size: Number of records in a time block
- Record Length: Record length for the binary data file
- Number of realizations: The number of realizations requested
- Number of times: The number of solution times requested
- List of times: A list of solution times for this impact type, with one time per line
- Number of locations: The number of locations requested
- List of locations: A list of locations IDs, with one ID per line
- Number of media: The number of media where contaminated data may be saved
- List of media: A list of the media IDs, with one value per line

The header data are followed by record map index data. There are as many lines of index data as there are locations. The index data for locations come in the same order as the location IDs provided earlier in the file. Each line of index data contains the location ID followed by as many indices as there are media types. The indices give an offset record number. If a particular medium is not saved at a location, the index value is set to negative 1. An example record map file for a very small problem is provided in Table 2.8.

Table 2.8 Example Record Index Map File

"ECOLOGICAL: Hanford Solid Waste EIS - 10,000 Years"
"ECDA"
"2.00.A.4"
"16 Oct 2003"
"Paul W. Eslinger"
"20020225135708"
18,"Records in a time block"
16,"Record Length"
1,"Number of realizations"
2,"Number of times"
8000
10000
6,"Number of locations"
"EL0001"
"EL0002"
"EL0003"
"EL0004"
"EL0005"
"EL0006"

```
11,"Number of media"  
"GWAT"  
"SEEP"  
"SWAT"  
"PWAT"  
"SEDI"  
"SORP"  
"SODR"  
"SOGW"  
"SOSW"  
"AIRC"  
"AIRD"  
"EL0001",8,9,10,-1,-1,-1,11,12,13,-1,-1  
"EL0002",-1,-1,-1,14,15,16,-1,-1,-1,-1,-1  
"EL0003",17,18,19,-1,-1,-1,-1,-1,-1,20,21  
"EL0004",-1,-1,-1,22,23,24,25,26,-1,-1,-1  
"EL0005",27,28,29,-1,-1,-1,-1,-1,-1,-1,-1  
"EL0006",-1,-1,-1,30,31,32,33,34,-1,-1,-1
```

3.0 Cultural Impacts Model (CULTURE)

3.1 Mathematical Formulation for the Cultural Model

The algorithms for the cultural model are provided in the following sections. The culture code provides three types of solutions:

- calculation of the areal extent where concentrations in surface water, river sediments, or in groundwater underlying soil are above user-specified thresholds
- calculation of the distance from each of a set of user-specified points to the closest location where the groundwater concentration is above a user-specified threshold
- calculation of the data for a map showing locations where the concentration of any one or more of several user-specified contaminants are above a set of user-specified thresholds

3.1.1 Area Calculations for the Cultural Model

The cultural code calculates the areal extent where concentrations in surface water, river sediments, or in groundwater underlying soil are above user-specified thresholds. The concentration data are defined at points in the coordinate system, but the concentration at the point is assumed to apply to an area surrounding the point. The area associated with each point is an input to the code. The area algorithm is the sum of the areas associated with points whose concentrations are above the user-specified thresholds.

3.1.2 Site Calculations for the Cultural Code

The cultural code calculates the distance from each of a set of user-specified points to the closest location where the groundwater concentration is above a user-specified threshold. The minimum distance to a point meeting the concentration threshold is provided by the code. If no concentration exceeds the specified thresholds, a huge distance is returned (typically on the order of 1.0E+39).

3.1.3 Map Calculations for the Cultural Code

The cultural code calculates data for a map showing locations where the concentration of any one or more of several user-specified contaminants are above a set of user-specified thresholds, allowing for a different threshold for each contaminant. The map data is a value from 0 to 1 at each of the locations in the concentration data grid for the cultural model. The actual value returned at a location is the fraction of realizations where one or more thresholds were exceeded at that location.

3.2 Code Environment

3.2.1 Location in the Processing Sequence

The CULTURE code requires access to a number of data files developed by the SAC inventory, release, and transport codes (Eslinger et al. 2004). In particular, every code on the left side of Figure 1.1 must have been executed to build a suite of concentration data files before the CULTURE code can be used to

calculate impacts. These concentration data files must have been developed under the control of the same ESD keyword file that the CULTURE code reads to determine processing options.

3.2.2 How the Code Is Invoked

CULTURE can run under either the Windows or the Linux operating system. Under the Windows operating system (Releases 98, NT, or 2000), CULTURE executes in a DOS box. A run of CULTURE is initiated by entering the following command line:

```
CULTURE "Keyfilename"
```

Under the Linux operating system, CULTURE is executed through the following Bourne Shell or C Shell command:

```
culture.exe "Keyfilename"
```

For this command, CULTURE or culture.exe is the name of the executable program and "Keyfilename" is the name of a cultural scenario keyword file. Both the name of the executable program and the keyword file may contain path information. If CULTURE is invoked without entering the name of the keyword file, the code will prompt the user for the file name. The keyword file, which should be prepared using an editor that can handle ASCII files without leaving embedded control codes, contains text control information describing the run. If CULTURE cannot open the keyword file, the code will terminate execution after writing an error message to the standard output device.

3.2.3 Memory Requirements

The CULTURE code uses dynamic memory allocation, so the memory requirements depend on the problem being analyzed. A reasonably large example run required approximately 10 MB of memory (on a Windows 2000 machine). It is expected that most, if not all, of the runs of the CULTURE code will require less than 20 MB of memory.

3.3 Data Files

The CULTURE code reads four or more input files and writes up to seven output files. The number of input files depends on the number of contaminants being analyzed. The number of output files depends on the options selected in the CULTURE code. These files are described in the following sections.

3.3.1 Input Files

The input files for the CULTURE code are keyword files and a suite of concentration-data-related files. One keyword file controls the case that the CULTURE code will execute, and it points to the ESD keyword file. The suite of concentration data files are all identified in the ESD keyword file – the user of the CULTURE code only needs to identify the ESD keyword file. The following are the input files:

- **ESD Keyword File.** The ESD keyword file contains the control information that the inventory and environmental transport codes use to generate concentration data files. Table 2.2 provides

examples of keywords in the ESD file that control the impact codes, including the CULTURE code. Definitions for these keywords are given in Section 2.1. Typically, the user of the CULTURE code will not modify the ESD keyword file.

- **CULTURE Keyword File.** The CULTURE keyword file controls the scenario to be analyzed by the CULTURE code. The options and data available are constrained by the case defined in the ESD Keyword file. Section 3.4 describes the contents of the CULTURE keyword file. An example keyword file for the CULTURE code is below provided in Table 3.1.
- **ECDA Concentration Files.** The ECDA files contain all the concentration data available for the impact codes. The concentrations for all analytes are based on the same time and location data. There is a “map” file for the ECEM code containing indexing information for each of the concentration data files. In addition, there is a separate concentration data file for every analyte used in the impacts scenario. For example, when running a scenario with seven analytes, there will be one map file and seven concentration data files. The structure of a concentration data file is described in Section 2.4.1.

3.3.1.1 ESD Keyword File

The CULTURE code also reads keywords from the environmental settings file. These keywords are read from a different file, and can have a different definition, from a keyword defined for internal use in the CULTURE code. The environmental settings keywords are defined in Section 2.1. The following ESD keywords are required by the CULTURE code:

- ANALYTE – definition of analytes in the environmental simulations
- END – end of the environmental settings keywords
- FILE – file names for the concentration file for each analyte
- LOCATION – locations at which concentrations were generated for the cultural impact
- REALIZAT – number of realizations that were simulated
- TIMES – times at which concentrations were generated for the cultural impact
- TITLE – environmental simulation title

3.3.1.2 CULTURE Keyword File

The keyword definition file contains control information for the desired impact simulation. Individual keywords are defined in Section 3.4. Table 3.1 contains an example keyword file for several analytes and three solution options.

Table 3.1 Example Keyword File for the CULTURE Code

```
!  
! Keyword file for the CULTURE program using drinking water standards for  
thresholds  
!  
REPORT "Culture_DW.rpt"  
! Input Environmental setting file  
FILE ESD "..\ESD_CA1_median.key"  
! Output header file for GUI data extraction  
FILE HEADER "Culture_DW.hdr"
```

```
! Output area detailed data
DETAILS AREA
FILE AREA_DAT "Culture_DW_area_det.csv"
! Output map data
FILE MAP "Culture_DW_map.csv"
!
EXECUTE
! User name
USER "Paul W. Eslinger"
!
REALIZATION 1
! Overall problem title
TITLE "SAC Rev. 1 Median value runs for culture - Groundwater (DW Standard)"
! Output times for calculations
TIMES ALL
!
THRESHOLD GWAT TERSE ANALYTE="C14"    VALUE=2000  UNITS="pCi/L"
THRESHOLD GWAT TERSE ANALYTE="H3"     VALUE=20000 UNITS="pCi/L"
THRESHOLD GWAT TERSE ANALYTE="Sr90"   VALUE=8      UNITS="pCi/L"
! Surface water concentration thresholds by analyte
THRESHOLD SWAT TERSE ANALYTE="C14"    VALUE=2000  UNITS="pCi/L"
THRESHOLD SWAT TERSE ANALYTE="H3"     VALUE=20000 UNITS="pCi/L"
THRESHOLD SWAT TERSE ANALYTE="Sr90"   VALUE=8      UNITS="pCi/L"
! Pore water concentration thresholds by analyte
THRESHOLD PWAT TERSE ANALYTE="C14"    VALUE=2000  UNITS="pCi/L"
THRESHOLD PWAT TERSE ANALYTE="H3"     VALUE=20000 UNITS="pCi/L"
THRESHOLD PWAT TERSE ANALYTE="Sr90"   VALUE=8      UNITS="pCi/L"
! Define area calculations
AREA ID="C14"    ANALYTE="C14"    GWAT TITLE "Area where GW threshold exeeded
for C14"
AREA ID="Sr90"  ANALYTE="Sr90"    GWAT TITLE "Area where GW threshold exeeded
for Sr90"
! Locations for the maps
LOCATION ALL
END
```

3.3.1.3 ECDA Concentration Files

The ECDA provides a central storage location for concentration data for all analytes at the environmental locations and times needed to perform social-cultural analyses. The ECDA files are described in Section 2.4.1.

3.3.2 Output Files

Up to seven output files can result from a run of the CULTURE code.

3.3.2.1 CULTURE Report File

Excerpted records for an example report file for the CULTURE code are provided in Table 3.2. The omitted records provided solution times and location IDs. This example file is about 30 KB in size and is the typical size for the report file if no debug options are selected. The size of this file grows rapidly when debug options are selected. A run using all debug options having a large number of locations, analytes, solution times, and realizations could easily generate a report file larger than the 2.1-GB file size limit under the Windows operating system.

Table 3.2 Excerpted Records from a Report File Written by the CULTURE Code

CCCCC	U	U L	TTTTTTT	U	U RRRRRR	EEEEEEE
C	C U	U L	T	U	U R	R E
C	U	U L	T	U	U R	R E
C	U	U L	T	U	U RRRRRR	EEEE
C	U	U L	T	U	U R R	E
C	C U	UU L	T	U	UU R	R E
CCCCC	UUUU	U LLLLLL	T	UUUU	U R	R EEEEEEE

Culture Version 2.00.A.3
 Last Modified on 16 Aug 2004

SAC Rev. 1 Socio-Cultural Impacts Model

Developed By Battelle Memorial Institute
 Pacific Northwest National Laboratories
 Richland, Washington

Current Run ID = 200408171221 User Name = Paul W. Eslinger
 System Date = 08-17-2004 System Time = 12:21:39

The software used to generate this output is experimental
 and has not been formally tested or peer reviewed.

Review Signatures

Input Prepared By: _____

Date: _____

Input Reviewed By: _____

Date: _____

===== Echo of the Problem Definition =====

Title: SAC Rev. 1 Median value runs for culture - Groundwater (DW Standard)
 User: Paul W. Eslinger
 1 Realizations in the ESD keyword file
 1 Realizations utilized in this run

File Name for this Report File
 File: Culture_DW.rpt
 File Name for CULTURE Input Keyword Data
 File: Culture_DW.key
 File Name for ESD Input Keyword Data
 File: ..\ESD_CA1_median.key
 File Name for the Output SACVIEW Header File
 File: Culture_DW.hdr

```

File Name for the Output AREA Details File
File: Culture_DW_area_det.csv
File Name for Concentration Index File
File: N:\CA1_median\ecda\ECDA_CA1_median.map
File Name for Media Concentrations: Analyte ID="C14"
File: N:\CA1_median\ecda\C14_CA1_median.dat
File Name for Media Concentrations: Analyte ID="Cs137"
File: N:\CA1_median\ecda\Cs137_CA1_median.dat
File Name for Media Concentrations: Analyte ID="Np237"
File: N:\CA1_median\ecda\Np237_CA1_median.dat
File Name for Media Concentrations: Analyte ID="Se79"
File: N:\CA1_median\ecda\Se79_CA1_median.dat
File Name for Media Concentrations: Analyte ID="Sr90"
File: N:\CA1_median\ecda\Sr90_CA1_median.dat
File Name for Media Concentrations: Analyte ID="Eu152"
File: N:\CA1_median\ecda\Eu152_CA1_median.dat

Analyte Information for 15 analytes.
  1 : C14      : Carbon-14
  2 : Sr90     : Strontium-90
  3 : H3       : ==> Not used

Number of times requested is 274

Number of locations requested is 4351

Internal (and threshold) data units by analyte and media
      GWAT  SEEP  SWAT  PWAT  SEDI   SORP   SODR   SOGW   SOSW   AIRC   AIRD
      ----  ----  ----  ----  ----   ----   ----   ----   ----   ----   ----
---
  1 : C14   : pCi/L pCi/L pCi/L pCi/L pCi/kg pCi/kg pCi/kg pCi/kg pCi/kg pCi/m^3
pCi/m^2/yr
  2 : Sr90  : pCi/L pCi/L pCi/L pCi/L pCi/kg pCi/kg pCi/kg pCi/kg pCi/kg pCi/m^3
pCi/m^2/yr

  Thresholds by analyte and media
      GWAT  SEEP  SWAT  PWAT  SEDI  SORP  SODR  SOGW  SOSW  AIRC  AIRD
      ----  ----  ----  ----  ----  ----  ----  ----  ----  ----  ----
1: C14 : UH0001: 2.0E+03 None 2.0E+03 2.0E+03 None None None None None None None
1: C14 : UH0002: 2.0E+03 None 2.0E+03 2.0E+03 None None None None None None None
1: C14 : UH0003: 2.0E+03 None 2.0E+03 2.0E+03 None None None None None None None
  Use the VERBOSE keyword to see more thresholds for C14
2: Sr90: UH0001: 8.0E+00 None 8.0E+00 8.0E+00 None None None None None None None
2: Sr90: UH0002: 8.0E+00 None 8.0E+00 8.0E+00 None None None None None None None
2: Sr90: UH0003: 8.0E+00 None 8.0E+00 8.0E+00 None None None None None None None
  Use the VERBOSE keyword to see more thresholds for Sr90

Area calculation definitions
Index  AreaID  Name
-----
  1 : C14      : Area where GW threshold exceeded for C14
  2 : Sr90     : Area where GW threshold exceeded for Sr90

===== End of the Problem Definition =====
Header information from the map file for cultural impacts
  ECDA_PTITILE = 2004 Composite Analysis 10,000-year (Median Inputs) Assessment
  ECDA_PRGNAM  = ECDA

```

```
ECDA_PRGVER = 2.00.A.4
ECDA_PRGDAT = 16 Oct 2003
ECDA_USRNAM = Eslinger-DWE-WEN
ECDA_CRUNID = 20040802132252
ECDA_BLOCK  = 23155
ECDA_RECLEN = 18
```

Concentration data units conversion factors

```
1: C14: NR: Groundwater concentrations      : 1.0E+09: From Ci/m^3 to pCi/L
1: C14: NR: Seep water (riparian zone) conc : 1.0E+09: From Ci/m^3 to pCi/L
1: C14: NR: Soil (riparian zone) concentrations : 1.0E+12: From Ci/kg to pCi/kg
1: C14: NR: Surface water (river) concentrations : 1.0E+09: From Ci/m^3 to pCi/L
1: C14: NR: Sediment (river bottom) concentrations : 1.0E+12: From Ci/kg to pCi/kg
1: C14: NR: Pore water (river bottom) concentrations: 1.0E+09: From Ci/m^3 to pCi/L
1: C14: NR: Non-irrigated upland soil concentrations: 1.0E+12: From Ci/kg to pCi/kg
1: C14: NR: Groundwater irrigated upland soil conc : 1.0E+12: From Ci/kg to pCi/kg
1: C14: NR: Surface water irrigated upland soil conc: 1.0E+12: From Ci/kg to pCi/kg
1: C14: NR: Air concentrations              : 1.0E+12: From Ci/m^3 to pCi/m^3
1: C14: NR: Air deposition rates            : 1.0E+12: From Ci/m^2/yr to
pCi/m^2/yr
```

```
2: Sr90: NR: Groundwater concentrations      : 1.0E+09: From Ci/m^3 to pCi/L
2: Sr90: NR: Seep water (riparian zone) conc : 1.0E+09: From Ci/m^3 to pCi/L
2: Sr90: NR: Soil (riparian zone) concentrations : 1.0E+12: From Ci/kg to pCi/kg
2: Sr90: NR: Surface water (river) concentrations : 1.0E+09: From Ci/m^3 to pCi/L
2: Sr90: NR: Sediment (river bottom) concentrations : 1.0E+12: From Ci/kg to pCi/kg
2: Sr90: NR: Pore water (river bottom) concentrations: 1.0E+09: From Ci/m^3 to pCi/L
2: Sr90: NR: Non-irrigated upland soil concentrations: 1.0E+12: From Ci/kg to pCi/kg
2: Sr90: NR: Groundwater irrigated upland soil concs : 1.0E+12: From Ci/kg to pCi/kg
2: Sr90: NR: Surface water irrigated upland soil conc: 1.0E+12: From Ci/kg to pCi/kg
2: Sr90: NR: Air concentrations              : 1.0E+12: From Ci/m^3 to pCi/m^3
2: Sr90: NR: Air deposition rates            : 1.0E+12: From Ci/m^2/yr to
pCi/m^2/yr
```

```
Run completed on:
Date: 08/17/2004
Time: 12:36:32
```

3.3.2.2 CULTURE Header File for SACView

The SACView header file is an output file containing information used by the interactive SACView program to allow easy extraction of subsets of the results computed by the CULTURE code. This file is required for every run of the CULTURE code. An example of this file is given in Table 3.3. The file contains the following sections of information:

- A header section of basic run information
- Number of realizations
- Solution times selected
- Site calculations processed
- Area calculations processed
- Map calculations processed
- Output file names

The user only specifies the name of this file; users should not modify the file after it is generated by the CULTURE code. See the instructions in Section 1.01.0 regarding the use of the SACView program. Because this file has at most a few hundred entries, the file size is always much smaller than 1 MB. File names for options not selected are set to null.

Table 3.3 Example Header File from CULTURE for the SACView Program

```

type: "Cultural"
title: "SAC Rev. 1 Median value runs for culture - Groundwater (DW Standard)"
user: "Paul W. Eslinger"
name: "Culture"
version: "2.00.A.3"
date: "16 Aug 2004"
id: "20040817122139"
envfile: "..\ESD_CA1_median.key"
realizations: 1
times: 1
    2000
sites: 0
summary: "NULL"
detail: "NULL"
areas: 6
"C14 ", "Area where GW threshold exeeded for C14"
analyte: 1
"C14 "
media: 1
"GWAT"
"Se79 ", "Area where GW threshold exeeded for Se79"
analyte: 1
"Se79 "
media: 1
"GWAT"
"Sr90 ", "Area where GW threshold exeeded for Sr90"
analyte: 1
"Sr90 "
media: 1
"GWAT"
"Cs137 ", "Area where GW threshold exeeded for Cs137"
analyte: 1
"Cs137 "
media: 1
"GWAT"
"Eu152 ", "Area where GW threshold exeeded for Eu152"
analyte: 1
"Eu152 "
media: 1
"GWAT"
"Np237 ", "Area where GW threshold exeeded for Np237"
analyte: 1
"Np237 "
media: 1

```

```
"GWAT"
summary: "NULL"
detail: "Culture_DW_area_det.csv"
maps:    0
summary: "Culture_DW_map.csv"
```

3.3.2.3 CULTURE Area Data File

The area data file is an optional output file that contains the detailed values for area calculations in the CULTURE code. The description of the AREA keyword (Section 3.4.1) explains how to define an area calculation. The description of the AREA_DAT modifier on the FILE keyword (Section 3.4.6) explains how to define the file name. The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file after the header line consists of three identifiers followed by a value for every generated realization. An example file for two areas, three realizations, and five times is provided in Table 3.4. The following are the three identifiers on each line:

- Time: Year for which the data are valid
- Area ID: The area identifier
- Solution type: A flag for solution type – the contaminated area

Table 3.4 Example Area Data File for the CULTURE Code

"Time",	"AREA ID",	"Variable",	"Values by realization"		
2000,"Area02",	"AREA_CONT",		7.884E+06,	8.438E+06,	6.759E+06
2000,"Area09",	"AREA_CONT",		3.663E+07,	2.169E+07,	1.693E+07
2050,"Area02",	"AREA_CONT",		1.181E+07,	1.350E+07,	1.069E+07
2050,"Area09",	"AREA_CONT",		3.960E+07,	2.305E+07,	1.999E+07
2100,"Area02",	"AREA_CONT",		1.519E+07,	1.723E+07,	1.350E+07
2100,"Area09",	"AREA_CONT",		4.469E+07,	2.655E+07,	2.094E+07
2500,"Area02",	"AREA_CONT",		5.719E+07,	7.021E+07,	4.329E+07
2500,"Area09",	"AREA_CONT",		5.532E+07,	1.967E+07,	2.229E+07
3050,"Area02",	"AREA_CONT",		1.297E+08,	1.486E+08,	1.152E+08
3050,"Area09",	"AREA_CONT",		5.319E+07,	1.756E+07,	2.043E+07

3.3.2.4 CULTURE Area Statistics File

This optional file contains summary statistics for area calculations for the CULTURE code. The description of the AREA keyword (Section 3.4.1) explains how to define an area calculation. The description of the AREA_STA modifier on the FILE keyword (Section 3.4.6) explains how to define the file name. The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file consists of two identifiers followed by summary statistics (nine percentiles, mean value, and standard deviation). A subset of the data written to this file for a run is provided in Table 3.5. The following are the two identifiers on each line:

- Time: Year for which the data are valid
- Area ID: The location identifier where the data are valid

The data for each record in this file are too long to present without line-wrapping in this document. Each record in the file occupies two lines in Table 3.5.

Table 3.5 Example Area Statistics File for the CULTURE Code

"Time",	"AREA ID",	"Minimum",	"5th Percentile",	"10th Percentile",	"25th Percentile",	"Median",	"75th Percentile",	"90th Percentile",	"95th Percentile",	"Maximum",	"Mean",	"Standard Deviation"
2000,"Area01",	3.289E+01,	3.289E+01,	3.289E+01,	3.289E+01,	5.383E+01,	5.383E+01,	7.538E+01,	7.538E+01,	1.026E+02,	6.136E+01,	2.801E+01	
2000,"Area02",	1.282E+02,	1.282E+02,	1.282E+02,	1.282E+02,	3.953E+02,	3.953E+02,	4.848E+03,	4.848E+03,	1.203E+04,	3.526E+03,	5.155E+03	
2050,"Area01",	6.067E+03,	6.067E+03,	6.067E+03,	6.067E+03,	2.613E+04,	2.613E+04,	5.127E+04,	5.127E+04,	1.529E+05,	5.001E+04,	5.999E+04	
2050,"Area02",	1.162E+03,	1.162E+03,	1.162E+03,	1.162E+03,	1.114E+04,	1.114E+04,	8.869E+04,	8.869E+04,	1.168E+05,	4.461E+04,	5.410E+04	

3.3.2.5 Map Data File

The map data file is an optional output file that contains the detailed values for map calculations in the CULTURE code. The description of the MAP keyword (Section 3.4.8) explains how to define a map calculation. The description of the MAP modifier on the FILE keyword (Section 3.4.6) explains how to define the file name. The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file after the header line consists of two identifiers followed by a value for every location. A record is written for every location defined using the LOCATION keyword (see Section 3.4.7). Excerpted records from a map data file for three solution times are provided in Table 3.6. The following are the two identifiers on each line:

- Time: Year for which the data are valid
- Map ID: The map identifier

Table 3.6 Excerpted Records from a Map Data File in the CULTURE Code

"Time",	"MAP ID",	"Easting",	"Northing",	"Percent Exceedance"
1990,"Map11 "	5.745216E+05,	1.543666E+05,	0.920E+00	
1990,"Map11 "	5.765372E+05,	1.541413E+05,	0.010E+00	
...				
1990,"Map11 "	5.940311E+05,	1.027057E+05,	0.000E+00	
1990,"Map11 "	5.947682E+05,	1.026592E+05,	0.007E+00	
2000,"Map11 "	5.745216E+05,	1.543666E+05,	0.022E+00	
2000,"Map11 "	5.765372E+05,	1.541413E+05,	0.000E+00	
...				
2000,"Map11 "	5.940311E+05,	1.027057E+05,	0.310E+00	
2000,"Map11 "	5.947682E+05,	1.026592E+05,	0.000E+00	
2010,"Map11 "	5.745216E+05,	1.543666E+05,	0.222E+00	
2010,"Map11 "	5.765372E+05,	1.541413E+05,	0.000E+00	
...				
2010,"Map11 "	5.940311E+05,	1.027057E+05,	0.000E+00	
2010,"Map11 "	5.947682E+05,	1.026592E+05,	0.989E+00	

3.3.2.6 Site Distance Data File

The site distance data file is an optional output file that contains the detailed values for site distance calculations in the CULTURE code. The description of the SITE keyword (Section 3.4.10) explains how to define an area calculation. The description of the SITE_DAT modifier on the FILE keyword (Section 3.4.6) explains how to define the file name. The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file after the header line consists of three identifiers followed by a value for every generated realization. An example file for two sites, five realizations, and two times is provided in Table 3.7. The following are the three identifiers on each line:

- Time: Year for which the data are valid
- Site ID: The site identifier
- Solution type: A flag for solution type – the distance calculation

Table 3.7 Example Site Distance Data File for the CULTURE Code

"Time","SITE ID","Variable","Distance to the site"						
2000,"Site01","DIST",	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00
2000,"Site02","DIST",	1.562E-02,	1.562E-02,	1.562E-02,	7.500E+02,	1.562E-02,	
2050,"Site01","DIST",	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00
2050,"Site02","DIST",	1.704E+03,	3.092E+03,	2.250E+03,	4.387E+03,	7.500E+02,	

3.3.2.7 Site Distance Statistics File

This optional file contains summary statistics for site distance calculations for the CULTURE code. The description of the SITE keyword (Section 3.4.10) explains how to define an area calculation. The description of the SITE_STA modifier on the FILE keyword (Section 3.4.6) explains how to define the file name. The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file after the header line consists of two identifiers followed by summary statistics (nine percentiles, mean value, and standard deviation). A subset of the data written to this file for a run is provided in Table 3.8. The following are the two identifiers on each line:

- Time: Year for which the data are valid
- Site ID: The location identifier where the data are valid

The data for each record in this file are too long to present without line wrapping in this document. Each record in the file after the single header line occupies two lines in Table 3.8.

Table 3.8 Example Site Distance Statistics File for the CULTURE Code

"Time",	"SITE ID",	"Minimum",	"5th Percentile",	"10th Percentile",	"25th Percentile",	"Median",	"75th Percentile",	"90th Percentile",	"95th Percentile",	"Maximum",	"Mean",	"Standard Deviation"
2000,"Site01",	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00
2000,"Site02",	1.562E-02,	1.562E-02,	1.562E-02,	1.562E-02,	1.562E-02,	1.562E-02,	6.302E+02,	7.500E+02,	7.500E+02,	1.937E+02,	3.331E+02	
2050,"Site01",	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00,	0.000E+00
2050,"Site02",	7.500E+02,	7.500E+02,	7.500E+02,	1.704E+03,	4.387E+03,	4.387E+03,	4.500E+03,	4.500E+03,	4.500E+03,	3.414E+03,	1.340E+03	

3.4 Keyword Descriptions for the CULTURE Code

In the following keyword descriptions, some data are optional and some are required. Data required are enclosed in square brackets. For AB to be required, it would be denoted by [AB]. If only one of the three items AB, BC, CD were required, it would be written as [AB|BC|CD]. The vertical bars indicate to choose one of the items in the list. Optional items are enclosed in normal brackets. For DE to be an optional entry, it would be denoted by {DE}. The {} or [] symbols are indicators of whether the data are required; the symbols do not need to be entered when the keyword is constructed.

In some instances, numerical values or quote strings are associated with a modifier. In this description, the association is indicated by using the equal (=) symbol. The = symbol is not required but may be used when the keyword is constructed. When a numerical value or quote string is associated with a modifier, it must be physically entered on the input line directly after the modifier.

This section defines keywords needed to control the CULTURE code directly. The order in which keywords are entered does not matter for many keywords. However, two keywords have a required order of appearance, including the following requirements:

- The REPORT keyword must be the first keyword in the file
- The END keyword must be the last keyword in the file.

3.4.1 AREA Keyword for the CULTURE Code

The AREA keyword controls calculation of the area where concentrations exceed user-supplied thresholds (see the THRESHOLD keyword description in Section 3.4.11). Multiple AREA keywords can be entered. Each entry of the AREA card will cause the specific calculation to be performed for all times steps requested (see the TIMES keyword in Section 3.4.12). Each AREA keyword defines a different area calculation and must have a unique AREA ID. The following is the keyword's syntax:

```
AREA [ID="quote 1"] [ANALYTE="quote 2"] {"quote 3"} ... {"quote n"}]
    [GWAT | SWAT | PWAT | SEDI | SEEP | SORP | SODR | SOGW | SOSW | AIRC |
    AIRD ] [TITLE="quote k"]
```


The area calculation for more than one analyte or medium listed on a single AREA keyword returns the union of the area where each analyte and medium combination is above its respective threshold.

The AREA keyword uses quote strings to enter the following three items:

- A unique identification string up to six characters long (modifier ID)
- A title up to 72 characters long (modifier TITLE)
- A list of analytes (modifier ANALYTE) that will be included in the calculation.

These three modifiers can be entered in any order, together with their associated data, but the group of analyte names must be entered as a block.

The following AREA keyword calculates the area underlain by groundwater above the threshold concentration for cesium-137:

```
AREA ID= "Area #1" ANALYTE="Cs137" GWAT TITLE="Area #1 title"
```

The following AREA keyword calculates the area where the concentration of tritium exceeds the threshold for tritium in riparian soil:

```
AREA ID= "Area #2" ANALYTE= "H3" SORP TITLE="Area #2 title"
```

3.4.2 DEBUG Keyword for the CULTURE Code

The DEBUG keyword is used to activate writing of intermediate calculations to the report file. It should be used sparingly and with only one or two realizations; otherwise, the volume of output could fill the user's hard drive. The following is this keyword record's syntax:

```
DEBUG [modifier 1] {modifier 2}...{modifier k}
```

Multiple DEBUG cards can be entered with combinations of modifiers, or a single card can be entered containing all of the modifiers. The modifiers can be entered in any order. Table 3.9 describes the modifiers associated with the DEBUG keyword.

Table 3.9 Modifiers Associated with the DEBUG Keyword in the CULTURE Code

Modifier	Description
AREA	Intermediate outputs on calculations for area calculations.
CONC	Intermediate results for input concentration data.
SITE	Intermediate outputs on calculations for distance calculations on specific sites.
MAP	Intermediate outputs on calculations for generating map data.
LOGIC	Intermediate outputs tracking program execution flow logic.
THRESHOL	Threshold information by location.

The following entries provide examples of the use of the DEBUG keyword:

```
DEBUG SITE
DEBUG MAP
DEBUG MAP SITE AREA
```

There are no quote strings associated with the DEBUG keyword.

3.4.3 DETAILS Keyword for the CULTURE Code

The DETAILS keyword is used to activate reporting of calculations of AREA or SITE calculations by realization to output files. The following is this keyword record's syntax:

```
DETAILS {AREA} {SITE}
```

Multiple DETAILS keywords can be entered with combinations of modifiers, or a single card can be entered. The following is an example that turns on reporting for detailed data for both area and site calculations:

```
DETAILS SITE AREA
```

3.4.4 END Keyword for the CULTURE Code

The END keyword signifies the end of all keyword data. It should be the last keyword in the keyword file. All data in the keyword file after the END keyword will be ignored. The following is this keyword's syntax:

```
END
```

There are no modifiers or quote strings associated with the END keyword.

3.4.5 EXECUTE Keyword for the CULTURE Code

The EXECUTE keyword signifies that the user wishes to perform problem execution. If this keyword is not entered, then the inputs are checked for consistency, but the problem will not be executed. This is useful if the run being set up is expected to take a significant amount of computation time. The following is this keyword's syntax:

```
EXECUTE
```

There are no modifiers or quote strings associated with the EXECUTE keyword.

3.4.6 FILE Keyword for the CULTURE Code

The FILE keyword is used to enter the names of input and output files except for the report file. The names of the files providing concentration data are contained in the environmental scenario file rather than in the keyword file. The following is this keyword's syntax:

```
FILE [modifier1 "quote1"] {modifier2 "quote2"} ... {modifier5 "quote5"}
```

The file names are entered in quote strings, which must be enclosed in double quotation marks. Path names up to 200 characters long are supported. The file name associated with a modifier must be entered before the next modifier is entered. At least one FILE keyword is required for every run of the code. Table 3.10 describes the modifiers associated with the FILE keyword.

Table 3.10 Modifiers Associated with the FILE Keyword in the CULTURE Code

Modifier	Description
AREA_DAT	Output file containing the calculated data, by realization, for each of the area calculations. This file is required only if the AREA modifier is used on the DETAILS keyword.
AREA_STA	Output file containing summary statistics for each of the area calculations. This file is required if any AREA calculations are being performed.
ESD	Input environmental scenario file that contains the definition of the environmental runs from which impacts are to be calculated.
HEADER	Output file containing header type information associated with all of the other output files identified in this table.
MAP	Output file containing the calculated map data for each requested map.
SITE_DAT	Output file containing the calculated distance, for each realization, to concentrations that are above a threshold for every requested site. This file is required only if the SITE modifier is used on the DETAILS keyword.
SITE_STA	Output file containing summary statistics for the distance to concentrations that are above a threshold for every requested site. This file is required if any SITE calculations are being performed.

The following is an example entry:

```
FILE  HEADER "TestCase.hdr"  MAP "TestCase.map"
```

The following set of two entries has the same effect as the single entry above:

```
FILE  MAP "TestCase.map"
FILE  HEADER "TestCase.hdr"
```

3.4.7 LOCATION Keyword for the CULTURE Code

The LOCATION keyword identifies the locations that will be used in the impact calculations. At least one LOCATION keyword is required. Multiple LOCATION keywords are allowed. The locations must be a subset of the locations at which environmental data were computed and stored by the inventory, release, and transport modules. The list of desired locations builds sequentially with each LOCATION keyword. Upon program entry, no locations are active. The set of active locations applies to all area, site, or map calculations. The following is this keyword's syntax:

```
LOCATION [ALL | LIST "quote 1" ... "quote n"]
```

One of the modifiers ALL or LIST must be entered. If the modifier ALL is entered, then all locations are activated. If the modifier LIST is entered, then it must be followed by one or more location IDs entered as quote strings.

The following two examples illustrate the use of the LOCATION keyword. The first example activates all possible culture locations. The second example activates seven specific locations.

```
LOCATION ALL
LOCATION LIST TH0001 TH0002 TH0004 TH0008 TH0017 TH0018 TH0032
```

3.4.8 MAP Keyword for the CULTURE Code

The MAP keyword is used to define the output maps showing where concentrations exceed user-supplied thresholds (see the THRESHOLD keyword description) in a given set of analyte and medium combinations. The term "map" in this context means that a set of data will be generated that can be sent to a plotting or contouring program. The first data entry is the MAP ID, the second and third entries give the location (easting, northing), and the fourth entry gives a value at the location for the current map. All maps are written to a single MAP output file. The following is this keyword's syntax:

```
MAP [ID="quote 1"] [ANALYTE="quote 2"] {"quote 3"} ... {"quote n"}
    [GWAT | SWAT | PWAT | SEDI | SEEP | SORP | SODR | SOGW | SOSW | AIRC |
    AIRD ] [TITLE="quote k"]
```

The MAP keyword uses quote strings to enter the following three items:

- a unique identification string up to six characters long (modifier ID)
- a title up to 72 characters long (modifier TITLE)
- a list of analytes (modifier ANALYTE) that will be included in the calculation

These three modifiers can be entered in any order, together with their associated data, but the group of analyte names must be entered as a block.

Multiple MAP keywords can be entered. Each entry of the MAP keyword will cause the specific calculation to be performed for all times steps requested (see the TIMES keyword in Section 3.4.12). The map calculations will be done for all requested media concentrations at each location. The value reported in the map calculation at a location will be the average number of realizations where one or more analytes

exceed their respective thresholds in one or more requested media concentrations. This number could be interpreted loosely as the probability of contamination being above thresholds at the location for the requested media.

The following two examples illustrate the use of the MAP keyword:

```
MAP ID="Map #1" TITLE "Example map for radioactive analytes"  
ANALYTE="C14" "Tc99"
```

```
MAP ID="Map #2" ANALYTE "Zn" "Cu"  
TITLE "Example map for nonradioactive analytes"
```

3.4.9 REPORT Keyword for the CULTURE Code

The REPORT keyword is used to define the name of the output report (log) file. It must be the first keyword entered in the keyword file. The following is this keyword's syntax:

```
REPORT ["quote"]
```

The name of the report file is entered in a quote string. File names up to 72 characters long are supported, and path names can be included. The following is an example REPORT keyword record:

```
REPORT "/SAC/SystemCodes/Cultural/Test1.rpt"
```

3.4.10 SITE Keyword for the CULTURE Code

The SITE keyword is used to control calculations of the distance from a specified site to media concentrations above a specified threshold. The following is this keyword's syntax:

```
SITE ID="quote 1" NORTHING=N1 EASTING=N2  
[ANALYTE="quote 2"] {"quote 3"} ... {"quote n"}  
[GWAT | SWAT | PWAT | SEDI | SEEP | SORP | SODR | SOGW | SOSW | AIRC |  
AIRD ] [TITLE="quote k"]
```

Each site is defined by entering a SITE keyword. The quote string associated with the modifier ID contains an identification string for the site and is limited to 6 characters. The quote string associated with the TITLE modifier provides a brief site description and is limited to 72 characters. The values N1 and N2 are the northing and easting location coordinates for the site. The analytes to be considered in the distance calculations are listed following the ANALYTE modifier. The following are two examples for this keyword:

```
SITE ID="Example site 1" NORTHING=23.3445 EASTING=45.665  
ANALYTE = Cs137 H3 Tc99  
GWAT SWAT AIRC  
TITLE ="Located near the old willow"
```

```
SITE TITLE ="Under the old oak tree" EASTING=45.668 NORTHING=23.3456  
ANALYTE = H3 Tc99  
GWAT PWAT SWAT  
ID="Just north of F Slough"
```

The ID, ANALYTE, and TITLE modifiers can be entered in any order, together with their associated data, but the group of analyte names must be entered as a block. The media IDs can be entered anywhere on the keyword.

3.4.11 THRESHOLD Keyword for the CULTURE Code

The AREA, MAP, and SITE keywords all reference thresholds for their calculations. The values of the thresholds are entered using the THRESHOLD keyword. The thresholds apply by location, analyte and medium. The following is this keyword's syntax:

```
THRESHOLD [GWAT | SWAT | PWAT | SEDI | SORP | SEEP | SODR | SOGW | SOSW | AIRC
| AIRD ] [Analyte="quote"] [VALUE = N1] [UNITS = "quote"] [LOCATION "ID1"
"ID2"... "IDn" | TERSE]
```

The entry for the first quote string is the analyte identification string. The media modifiers for the THRESHOLD keyword are given in Table 3.11.

Table 3.11 Modifiers Associated with the THRESHOLD Keyword in the CULTURE Code

Modifier	Description	
ANALYTE	The quote string associated with the ANALYTE modifier identifies the analyte to which the threshold will be assigned.	
VALUE	The numerical value associated with the VALUE modifier is the threshold value for the area, map, or site calculations.	
UNITS	The quote string associated with the UNITS modifier identifies the units associated with the threshold value.	
LOCATION	The quote strings associated with the LOCATION modifier identify the locations where the threshold will be used.	
TERSE	If the modifier TERSE is supplied instead of a location list, the threshold will be used for all locations.	
MEDIUM	One of the following modifiers	
	GWAT	Groundwater concentration
	SEEP	Seep water concentration
	SORP	Riparian soil concentration
	SWAT	Surface water (river) concentration
	PWAT	Pore water (river bottom) concentration
	SEDI	Sediment concentration
	SODR	Non-irrigated upland soil concentration
	SOGW	Groundwater-irrigated upland soil concentration
	SOSW	Surface water-irrigated upland soil concentration
	AIRC	Air concentration
	AIRD	Air deposition.

The following is an example set of keywords defining some thresholds for several environmental media and several analytes:

```
THRESHOLD GWAT TERSE ANALYTE="C14"    VALUE=2000  UNITS="pCi/L"
THRESHOLD SEEP Analyte="Tc99"  VALUE=12.0   UNITS="pCi  LOCATION "TH0004"
THRESHOLD SWAT TERSE ANALYTE="H3"     VALUE=20000 UNITS="pCi/L"
THRESHOLD PWAT TERSE ANALYTE="Sr90"   VALUE=8     UNITS="pCi/L"
THRESHOLD AIRD TERSE Analyte="C14"   VALUE=0.15  UNITS="pCi/m^2/yr"
```

The set of example THRESHOLD keywords given above references four analytes. Depending on the desired set of area, site, or map calculations, the user may need to enter 11 THRESHOLD keyword records for every analyte (one for every possible environmental media identified in Table 3.11).

3.4.12 TIMES Keyword for the CULTURE Code

The TIMES keyword identifies the times at which the calculations are to be performed. The following is the keyword's syntax:

```
TIMES [ALL | LIST [T1] {T2} ... {Tn}]
```

One of the modifiers ALL or LIST must be entered. If the modifier ALL is entered, then all times are activated. If the modifier LIST is entered, then it must be followed by one or more times entered as quote strings.

The numerical entries T1, T2, ..., Tn are the times (whole number years) when outputs are desired. These times must be a subset of the times at which environmental data were computed and stored by the inventory, release, and transport modules. Only one TIMES card should be entered. The times entered will apply to all AREA, SITE, and MAP calculations.

The following is an example TIMES keyword that requests output for the three years 2020, 2075, and 3014:

```
TIMES 2020 2075 3014
```

3.4.13 TITLE Keyword for the CULTURE Code

The TITLE keyword is used to define a single-line problem title. The problem title will be written to output files. If the title is not supplied, then the program will error terminate. The following is this keyword's syntax:

```
TITLE ["quote"]
```

The title is entered in a quote string, which must be enclosed in double quotation marks. Titles up to 72 characters long are supported. The following example defines a title for a run of the code:

```
TITLE "Example title line for the cultural impacts code."
```

There are no modifiers associated with the TITLE keyword.

3.4.14 USER Keyword for the CULTURE Code

The USER keyword is used to identify the user of the program. The user name will be written to output files. If the user name is not supplied, then the program will error terminate. The following is this keyword's syntax:

```
USER ["quote"]
```

The user name is entered in a quote string, which must be enclosed in double quotation marks. User names up to 16 characters long are supported. The following example defines John Q. Public as the user running the code:

```
USER "John Q. Public"
```

There are no modifiers associated with the USER keyword.

3.4.15 VERBOSE Keyword for the CULTURE Code

The VERBOSE keyword is used to control the writing of detailed information about the run setup to the report file. If this optional keyword is entered in the keyword file, then detailed information about times, locations, and thresholds is written to the report file. The following is this keyword's syntax:

```
VERBOSE
```

There are no modifiers or quote strings associated with the VERBOSE keyword.

4.0 Ecological Impact Model (ECEM)

4.1 Mathematical Formulation for the Ecological Impact Model

The following sections give the intake and exposure equations for the ecological impact model. The equations are given for both terrestrial and aquatic species. The concentration equations given in this section are based on equilibrium concepts rather than dynamic formulations.

4.1.1 Terrestrial Species

Terrestrial species are subdivided into plant and animal species. The exposure equations for terrestrial species are given in this section.

4.1.1.1 Terrestrial Plants

The analyte concentrations in terrestrial plants can come from rain splash, root uptake or foliar absorption from vapor, and soil contact. The concentrations also depend on whether the analyte is organic or nonorganic.

4.1.1.1.1 Contaminant Deposition Caused by Rain Splash

The equilibrium concentration in above-ground plant parts from rain splash is calculated using the following equation:

$$C_{\text{par}} = EC_{\text{soil}} \times K_{\text{ps1}}$$

where

C_{par}	=	equilibrium concentration in above-ground plant parts from rain splash ($\mu\text{g/kg}$ or pCi/kg wet plant weight)
EC_{soil}	=	concentration in surface soil (top ~1 cm) ($\mu\text{g/kg}$ or pCi/kg dry)
K_{ps1}	=	plant-soil partition coefficient for rain splash on fresh-weight basis ($\text{kg soil/kg plant wet weight}$)

If the plant is an emergent plant (rooted in soil but grows in water), then C_{par} is set to zero.

4.1.1.1.2 Root Uptake to Above-Ground Plant Tissue

The equilibrium concentration in above-ground plant parts from root uptake is calculated using the following equations. For organic contaminants, the equation is:

$$C_{\text{pau}} = EC_{\text{soil}} \times K_{\text{ps2}}$$

For inorganic contaminants except tritium, the equation is:

$$C_{\text{pau}} = EC_{\text{soil}} \times B_v \times (1 - f_w)$$

where

- C_{pau} = equilibrium concentration in above-ground plant parts from root uptake ($\mu\text{g/kg}$ or pCi/kg wet)
- EC_{soil} = concentration in surface soil (top ~1 cm) ($\mu\text{g/kg}$ or pCi/kg dry)
- K_{ps2} = plant-soil partition coefficient for root-zone soil to above-ground plant parts for organic contaminants - fresh weight basis ($\text{kg soil/kg plant wet weight}$)
- B_v = bioconcentration factor for vegetative plant parts for inorganic contaminants – dry weight basis ($\text{kg-soil/kg-dry-plant}$)
- f_w = weight fraction of plant tissue that is water (wet to dry conversion)

For the inorganic contaminant tritium, the equation is:

$$C_{\text{pau}} = EC_{\text{water}} \times f_w \times 1$$

where

- C_{pau} = equilibrium tritium concentration in above-ground plant parts from root uptake ($\mu\text{g/kg}$ or pCi/kg wet)
- EC_{water} = tritium concentration in the water source ($\mu\text{g/L}$ or pCi/L)
- f_w = weight fraction of plant tissue that is water (wet to dry conversion)
- 1 = density of water (L/kg)

If the plant is an emergent plant (rooted in soil but grows in water), then the concentration of the analyte in sediment, EC_{sed} , is used in the equation for C_{pau} rather than EC_{soil} .

The plant-soil partition coefficient for root-zone soil to above-ground plant parts for organic contaminants (fresh weight basis) is calculated using the following regression model (McKone 1993):

$$K_{\text{ps2}} = 7.7 \times K_{\text{ow}}^{-0.58}$$

where K_{ow} = the octanol-water partition coefficient (unitless)

4.1.1.1.3 Foliar Uptake from Soil by Vapor

The equilibrium concentration in above-ground plant parts from vapor uptake is calculated using the following equation (Hope 1995):

$$C_{\text{pav}} = (EC_{\text{vap}} + EC_{\text{airc}}) \times K_{\text{pa1}}$$

where:

- C_{pav} = equilibrium concentration in above-ground plant parts from vapor uptake ($\mu\text{g/kg}$ or pCi/kg wet)

- EC_{vap} = concentration of gas-phase contaminant ($\mu\text{g}/\text{m}^3$ or pCi/m^3)
 EC_{airc} = concentration of contaminant in air ($\mu\text{g}/\text{m}^3$ or pCi/m^3)
 K_{pal} = plant-air partition coefficient for air to above-ground plant parts for organic contaminants (m^3/kg wet weight)

The plant-air partition coefficient for transfer of analytes in the air to above-ground plant parts for organic contaminants is calculated using the following equation (Reiderer 1990):

$$K_{pal} = \left[f_{pa} + (f_{pw} + [f_{pl} \times K_{ow}]) \times \left[\frac{R \times T}{H} \right] \right] / \rho_p$$

where

- K_{pal} = plant-air partition coefficient for air to above-ground plant parts for organic contaminants (m^3/kg wet weight)
 f_{pa} = volume fraction of plant tissue in air (unitless)
 f_{pw} = volume fraction of plant tissue that is water (unitless)
 f_{pl} = volume fraction of plant tissue that is lipid (unitless)
 K_{ow} = octanol-water partition coefficient (unitless)
 R = universal gas constant ($\text{Pa}\cdot\text{m}^3/\text{mol}\cdot\text{K}$)
 T = temperature (K)
 H = contaminant-specific Henry's law constant ($\text{Pa}\cdot\text{m}^3/\text{mol}$)
 ρ_p = plant tissue density (kg/m^3)

The concentration of gas-phase contaminant is calculated using the following equation (EPA 1991):

$$EC_{vap} = \frac{EC_{soil} \times 10^4}{\left(\frac{LS \times V \times Dh}{A} \right) \times \left(\frac{[3.14 \times \zeta \times I]^{0.5}}{2 \times D_{ei} \times E \times K_{as} \times 10^{-3}} \right)}$$

where

- EC_{vap} = concentration of gas-phase contaminant ($\mu\text{g}/\text{m}^3$ or pCi/m^3)
 EC_{soil} = concentration in surface soil (top 15 cm) ($\mu\text{g}/\text{kg}$ or pCi/kg dry)
 LS = length of side of contaminated area (m)
 V = wind speed in mixing zone (m/s)
 Dh = diffusion height (m)
 A = area of contamination (m^2)
 ζ = effective diffusion rate (cm^2/s)
 I = exposure interval (s)
 D_{ei} = effective diffusivity (cm^2/s)
 E = soil porosity (unitless)
 K_{as} = soil/air partition coefficient ($\text{g soil}/\text{cm}^3$ air)
 10^4 = unit conversion factor (cm^2/m^2)
 10^{-3} = unit conversion factor (kg/g)

The effective diffusion rate is calculated from the expression:

$$\zeta = \frac{D_{ei} \times E}{E + \left(\rho_s \times \left[\frac{1-E}{K_{as}} \right] \right)}$$

where

- ζ = effective diffusion rate (cm²/s)
- D_{ei} = effective diffusivity (cm²/s)
- E = soil porosity (unitless)
- ρ_s = denotes the soil density (g/cm³)
- K_{as} = soil/air partition coefficient (g soil/cm³ air)

The soil/air partition coefficient is calculated (EPA 1991) from the expression:

$$K_{as} = \frac{41 \times H}{101,250 \times K_d}$$

where

- K_{as} = soil/air partition coefficient (g soil/cm³ air)
- H = contaminant-specific Henry's law constant (Pa-m³/mol)
- K_d = soil-water partition coefficient (cm³/g)
- 41 = unit conversion factor (mol/m³-atm)
- 101,250 = unit conversion factor (Pa/atm)

Furthermore, K_d is calculated (regression model in Nicholls [1991]) using the expression:

$$K_d = 0.62 \times K_{ow} \times f_{oc}$$

where

- K_d = soil-water partition coefficient (cm³/g)
- K_{ow} = octanol-water partition coefficient (unitless)
- f_{oc} = the soil organic carbon content (unitless)
- 0.62 = regression coefficient (cm³/g)

The effective diffusivity is calculated from the expression:

$$D_{ei} = D_i \times E^{0.33}$$

where:

- D_{ei} = effective diffusivity (cm²/s)
- D_i = molecular diffusivity (cm²/s)
- E = soil porosity (unitless)

4.1.1.1.4 Foliar Adsorption of Particulates from Soil

The equilibrium concentration in above-ground plant parts from foliar adsorption of particulates from soil is calculated from the expression:

$$C_{\text{pap}} = EC_{\text{par}} \times K_{\text{pa2}}$$

where

- C_{pap} = concentration in above-ground plant parts ($\mu\text{g/kg}$ or pCi/kg plant wet)
- EC_{par} = air concentration of particulate-bound contaminant ($\mu\text{g/m}^3$ or pCi/m^3)
- K_{pa2} = plant-air partition coefficient for air to above-ground plant parts for particulate-bound contaminants (m^3/kg wet weight)

The air concentration of particulate-bound contaminant is calculated (EPA 1991) as:

$$EC_{\text{par}} = \frac{EC_{\text{soil}}}{\text{PEF}}$$

where

- EC_{par} = air concentration of particulate-bound contaminant ($\mu\text{g/m}^3$ or pCi/m^3)
- EC_{soil} = concentration in surface soil (top ~1 cm) ($\mu\text{g/kg}$ or pCi/kg dry)
- PEF = the particulate emission factor (m^3/kg)

Furthermore, PEF is calculated from the following expression (EPA 1991):

$$\text{PEF} = \frac{LS \times V \times D_h \times 3600}{A} \times 1000 \left/ \left[Rf \times (1 - G) \times \left(\frac{U_m}{U_t} \right)^3 \times F(x) \right] \right.$$

where

- PEF = the particulate emission factor (m^3/kg)
- LS = length of side of contaminated area (m)
- V = wind speed in mixing zone (m/s)
- D_h = diffusion height (m)
- A = contaminated area (m^2)
- Rf = respirable fraction ($\text{g/m}^2\text{-hr}$)
- G = fraction of vegetative cover (unitless)
- U_m = mean annual wind speed (m/s)
- U_t = erosion threshold wind speed at 10 m (m/s)
- $F(x)$ = Cowherd function (Cowherd et al. 1985) (unitless)
- 3600 = unit conversion factor (s/hr)
- 1000 = unit conversion factor (g/kg)

The erosion threshold wind speed is calculated (Cowherd et al. 1985) from:

$$U_t = 2.5 \times \text{TFV} \times \ln\left(\frac{10}{\text{SRH}}\right)$$

where

- U_t = erosion threshold wind speed at 10 m (m/s)
- TFV = the threshold friction velocity (m/s)
- SRH = surface roughness height (m)
- 10 is a modeling factor with units of meters.

Furthermore, TFV is calculated from a regression model (Cowherd et al. 1985) using the following equation:

$$\text{TFV} = \text{NECF} \times \left(\frac{64 + 0.0055 \times \text{APSD} \times 1000}{100} \right)$$

where

- TFV = the threshold friction velocity (m/s)
- NECF = nonerodible elements correction factor (unitless)
- APSD = the aggregate particle size distribution (mm)
- 1000 = conversion factor (mm/m)

4.1.1.1.5 Foliar Adsorption of Particulates from Soil

The equilibrium concentration in above-ground plant parts from foliar adsorption of particulates from soil is calculated from the expression:

$$C_{\text{pad}} = \frac{\text{EC}_{\text{aird}} \times F_{\text{int}} \times \text{GS} \times \text{Surf}_i}{W_i}$$

where:

- C_{pad} = concentration in above-ground plant parts from air deposition ($\mu\text{g/kg}$ or pCi/kg plant wet)
- EC_{aird} = air deposition rate of contaminant ($\mu\text{g/m}^2/\text{yr}$ or $\text{pCi/m}^2/\text{yr}$)
- F_{int} = foliar interception for the plant species (unitless)
- GS = length of the growing season (yr)
- Surf_i = effective surface area for air deposition of plant species i (m^2)
- W_i = body weight of species i (kg wet weight)

4.1.1.1.6 Total Plant Burden

The total plant burden can be expressed either as an internal burden or the burden as eaten by herbivores. The internal plant burden (assuming that none of the adsorbed contaminant enters the plant) is calculated from the following expression:

$$C_{\text{pai}} = C_{\text{pav}} + C_{\text{pau}}$$

where

- C_{pai} = equilibrium tissue concentration of contaminants ($\mu\text{g/kg}$ or pCi/kg tissue)
- C_{pav} = equilibrium concentration in above-ground plant parts from vapor uptake ($\mu\text{g/kg}$ or pCi/kg wet)
- C_{pau} = equilibrium concentration in above-ground plant parts from root uptake ($\mu\text{g/kg}$ or pCi/kg wet)

The total plant burden as eaten by herbivores is calculated from the following expression:

$$C_{pat} = C_{par} + C_{pap} + C_{pai} + C_{pad}$$

where

- C_{pat} = equilibrium concentration of contaminants in and on plant tissue ($\mu\text{g/kg}$ or pCi/kg tissue)
- C_{par} = equilibrium concentration in above-ground plant parts from rain splash ($\mu\text{g/kg}$ or pCi/kg wet)
- C_{pap} = equilibrium concentration in above-ground plant parts from particulate adsorption ($\mu\text{g/kg}$ or pCi/kg wet)
- C_{pai} = equilibrium tissue concentration of contaminants ($\mu\text{g/kg}$ or pCi/kg tissue)
- C_{pad} = equilibrium concentration in above-ground plant parts from air deposition ($\mu\text{g/kg}$ or pCi/kg wet)

4.1.1.2 Terrestrial Animals

The body burden for terrestrial animals can come from any combination of dermal contact, ingestion, and inhalation. The equations for these exposure routes are provided in this section.

4.1.1.2.1 Dermal Contact with Soil

The equilibrium contaminant body burden in a terrestrial animal species from dermal contact with soil is calculated from the following equation (modified from Hope [1995]):

$$C_{dersi} = D_{dersi} / K_{ei}$$

where

- C_{dersi} = equilibrium contaminant body burden in species i from dermal contact with soil ($\mu\text{g/kg}$ or pCi/kg body weight)
- D_{dersi} = absorbed daily dose for species i from dermal contact with soil ($\mu\text{g/kg/day}$ or pCi/kg/day)
- K_{ei} = contaminant-specific depuration rate for species i ($1/\text{day}$)

The absorbed daily dose for species i from dermal contact with soil is calculated using the following equation (modified from EPA [1991]):

$$D_{dersi} = EC_{soil} \times SA_i \times P_{csi} \times S_{ai} \times CF \times \alpha_{dci} \times \theta_i \times \psi_i / W_i$$

where

D_{dersi}	=	absorbed daily dose for species i from dermal contact with soil ($\mu\text{g/kg/day}$ or pCi/kg/day)
EC_{soil}	=	concentration in surface soil (top ~1 cm) ($\mu\text{g/kg}$ or pCi/kg dry)
SA_i	=	surface area of species i (cm^2)
P_{csi}	=	fraction of surface area of species i in contact with soil per day (1/day)
S_{ai}	=	skin adherence factor for species i (mg/cm^2)
CF	=	unit conversion factor (10^{-6} kg/mg)
α_{dci}	=	contaminant-specific dermal absorption factor for species i (unitless)
θ_i	=	area use factor for species i (ratio of contaminant area to home range - unitless)
ψ_i	=	seasonality factor for species i (fraction of year spent at the contaminated site – unitless)
W_i	=	body weight of species i (kg wet weight)

4.1.1.2.2 Dermal Contact with Water

The equilibrium contaminant body burden in a species from dermal contact with water is calculated from the following equation (Hope 1995):

$$C_{derwi} = D_{derwi} / K_{ei}$$

where

C_{derwi}	=	equilibrium contaminant body burden for species i from dermal contact with water ($\mu\text{g/kg}$ or $\text{pCi/kg body weight}$)
D_{derwi}	=	absorbed daily dose for species i from dermal contact with water ($\mu\text{g/kg/day}$ or pCi/kg/day)
K_{ei}	=	contaminant-specific depuration rate for species i (1/day)

Furthermore, the value for D_{derwi} is calculated from the following equation (modified from EPA [1991] to include use and seasonality factors):

$$D_{derwi} = EC_{water} \times SA_i \times P_{cwi} \times ET_{wi} \times CF \times K_{pi} \times \theta_i \times \psi_i / W_i$$

where

D_{derwi}	=	absorbed daily dose for species i from dermal contact with water ($\mu\text{g/kg/day}$ or pCi/kg/day)
EC_{water}	=	concentration in water ($\mu\text{g/L}$ or pCi/L)
SA_i	=	surface area of species i (cm^2)
P_{cwi}	=	fraction of surface area of species i available for contact with water (unitless)
ET_{wi}	=	average exposure time to water per day for species i (hr/day)
CF	=	volumetric conversion factor for water ($1 \text{ L}/1,000 \text{ cm}^3$)
K_{pi}	=	contaminant-specific dermal absorption factor for species i from water (cm/hr)
θ_i	=	area use factor for species i (ratio of contaminant area to home range – unitless)
ψ_i	=	seasonality factor for species i (fraction of year spent at the contaminated site – unitless)
W_i	=	body weight of species i (kg wet weight)

4.1.1.2.3 Total Dermal Dose

The equilibrium body burden from dermal exposure is calculated from the equation:

$$C_{\text{deri}} = C_{\text{dersi}} + C_{\text{derwi}}$$

where

- C_{deri} = body burden from dermal exposure for species i ($\mu\text{g/kg}$ or pCi/kg body weight)
- C_{dersi} = body burden in species i from dermal contact with soil ($\mu\text{g/kg}$ or pCi/kg body weight)
- C_{derwi} = body burden for species i from dermal contact with water ($\mu\text{g/kg}$ or pCi/kg body weight)

The total daily dermal absorbed dose is calculated from the equation:

$$D_{\text{deri}} = D_{\text{dersi}} + D_{\text{derwi}}$$

where

- D_{deri} = total daily dermal absorbed dose for species i ($\mu\text{g/kg/day}$ or $\text{pCi/kg body weight/day}$)
- D_{dersi} = absorbed daily dose for species i from dermal contact with soil ($\mu\text{g/kg/day}$ or pCi/kg/day)
- D_{derwi} = absorbed daily dose for species i from dermal contact with water ($\mu\text{g/kg/day}$ or pCi/kg/day)

4.1.1.2.4 Inhalation of Air and Vapor

The equilibrium contaminant body burden for species i from inhalation of air and vapor is calculated from the following equation (Hope 1995):

$$C_{\text{ivi}} = D_{\text{ivi}} \times \left(\frac{\alpha_{\text{vapi}}}{K_{\text{ei}}} \right)$$

where

- C_{ivi} = body burden for species i from inhalation of vapor ($\mu\text{g/kg}$ or pCi/kg)
- D_{ivi} = applied daily dose to species i from vapor inhalation ($\mu\text{g/kg/day}$ or pCi/kg/day)
- α_{vapi} = inhalation absorption factor for species i (unitless)
- K_{ei} = contaminant-specific depuration rate for species i ($1/\text{day}$)

The applied daily dose to species i from vapor inhalation is calculated from the following equation (modified from Hope [1995] using EPA [1993] calculation for EC_{vap} as above):

$$D_{\text{ivi}} = \left[\frac{((EC_{\text{vap}} + EC_{\text{aire}}) \times IR_i)}{W_i} \right] \times \theta_i \times \psi_i$$

where

- D_{ivi} = applied daily dose to species i from vapor inhalation ($\mu\text{g/kg/day}$ or pCi/kg/day)
- EC_{vap} = concentration of gas-phase contaminant ($\mu\text{g/m}^3$ or pCi/m^3)

- EC_{airc} = concentration of contaminant in air ($\mu\text{g}/\text{m}^3$ or pCi/m^3)
 IR_i = resting inhalation rate of species i (m^3/day)
 W_i = body weight of species i (kg wet weight)
 θ_i = area use factor for species i (ratio of contaminant area to home range – unitless)
 ψ_i = seasonality factor for species i (fraction of year spent at the contaminated site – unitless)

4.1.1.2.5 Inhalation of Particulates

The equilibrium contaminant body burden for species i from inhalation of particulates is calculated from the following equation (Hope 1995):

$$C_{ipi} = D_{ipi} \times \left(\frac{\alpha_{pari}}{K_{ei}} \right)$$

where

- C_{ipi} = body burden for species i from inhalation of particulates ($\mu\text{g}/\text{kg}$ or pCi/kg)
 D_{ipi} = applied daily dose to species i from particulate inhalation ($\mu\text{g}/\text{kg}/\text{day}$ or $\text{pCi}/\text{kg}/\text{day}$)
 α_{pari} = inhalation particulate absorption factor (unitless)
 K_{ei} = contaminant-specific depuration rate for species i ($1/\text{day}$)

The applied daily dose to species i from particulate inhalation is calculated as (modified from Hope [1995] using EPA [1993] calculation for EC_{vap} as above):

$$D_{ipi} = \left[\frac{(EC_{par} \times IR_i)}{W_i} \right] \times \theta_i \times \psi_i$$

where

- D_{ipi} = applied daily dose to species i from particulate inhalation ($\mu\text{g}/\text{kg}/\text{day}$ or $\text{pCi}/\text{kg}/\text{day}$)
 EC_{par} = air concentration of particulate-bound contaminant ($\mu\text{g}/\text{m}^3$ or pCi/m^3)
 IR_i = resting inhalation rate of species i (m^3/day)
 W_i = body weight of species i (kg wet weight)
 θ_i = area use factor for species i (ratio of contaminant area to home range – unitless)
 ψ_i = seasonality factor for species i (fraction of year spent at the contaminated site – unitless)

4.1.1.2.6 Total Inhalation Dose

The total equilibrium burden from inhalation for species i is calculated as:

$$C_{inhi} = C_{ivi} + C_{ipi}$$

where

- C_{inhi} = body burden from inhalation for species i ($\mu\text{g}/\text{kg}$ or pCi/kg body weight)
 C_{ivi} = body burden for species i from inhalation of vapor ($\mu\text{g}/\text{kg}$ or pCi/kg)
 C_{ipi} = body burden for species i from inhalation of particulates ($\mu\text{g}/\text{kg}$ or pCi/kg)

The total inhalation applied dose for species i is calculated as:

$$D_{inhi} = D_{ivi} + D_{ipi}$$

where

- D_{inhi} = total inhalation applied dose for species i ($\mu\text{g/kg}$ or pCi/kg body weight/day)
- D_{ivi} = applied daily dose to species i from vapor inhalation ($\mu\text{g/kg/day}$ or pCi/kg/day)
- D_{ipi} = applied daily dose to species i from particulate inhalation ($\mu\text{g/kg/day}$ or pCi/kg/day)

4.1.1.2.7 Ingestion of Water

The equilibrium contaminant body burden for species i from ingestion of water is calculated from the following expression:

$$C_{ingwi} = D_{ingwi} \times \left(\frac{\alpha_{ingi}}{K_{ei}} \right)$$

where

- C_{ingwi} = body burden for species i from ingestion of water ($\mu\text{g/kg}$ or pCi/kg)
- D_{ingwi} = applied daily dose to species i from water ingestion ($\mu\text{g/kg/day}$ or pCi/kg/day)
- α_{ingi} = ingestion absorption factor for species i (unitless)
- K_{ei} = contaminant-specific depuration rate for species i (1/day)

The applied daily dose to species i from water ingestion is calculated from the equation (modified from EPA [1993] to incorporate site use fractions):

$$D_{ingwi} = \left[\frac{(EC_{\text{water}} \times WI_i)}{W_i} \right] \times \theta_i \times \psi_i$$

where

- D_{ingwi} = applied daily dose to species i from water ingestion ($\mu\text{g/kg/day}$ or pCi/kg/day)
- EC_{water} = concentration in water ($\mu\text{g/L}$ or pCi/L)
- WI_i = water ingestion rate of species i (L/day)
- W_i = body weight of species i (kg wet weight)
- θ_i = area use factor for species i (ratio of contaminant area to home range – unitless)
- ψ_i = seasonality factor for species i (fraction of year spent at the contaminated site – unitless)

4.1.1.2.8 Ingestion of Soil

The contaminant body burden to species i from ingestion of soil is calculated from the equation (modified from Hope [1995]):

$$C_{ingsi} = D_{ingsi} \times \left(\frac{\alpha_{ingsi}}{K_{ei}} \right)$$

where

- C_{ingsi} = contaminant body burden to species i from ingestion of soil ($\mu\text{g/kg}$ or pCi/kg body weight)
- D_{ingsi} = applied daily dose to species i from soil ingestion ($\mu\text{g/kg/day}$ or pCi/kg/day)
- K_{ei} = contaminant-specific depuration rate for species i (1/day)

The applied daily dose to species i from soil ingestion is calculated from the equation (modified from EPA [1993] to incorporate site use fractions):

$$D_{ingsi} = EC_{soil} \times SI_i \times NIR_{totali} \times F_{dwi} \times \theta_i \times \psi_i$$

where

- D_{ingsi} = applied daily dose to species i from soil ingestion ($\mu\text{g/kg/day}$ or pCi/kg/day)
- EC_{soil} = concentration in soil ($\mu\text{g/kg}$ or pCi/kg)
- SI_i = soil ingestion rate of species i (kg soil ingested/kg dry diet)
- NIR_{totali} = total normalized ingestion rate for species i (kg prey wet weight/kg predator body weight/day)
- F_{dwi} = conversion factor, dry diet to wet diet for species i (kg dry/kg wet)
- θ_i = area use factor for species i (ratio of contaminant area to home range – unitless)
- ψ_i = seasonality factor for species i (fraction of year spent at the contaminated site – unitless)

The total normalized ingestion rate for species i is calculated from the equation (EPA 1993):

$$NIR_{totali} = \frac{FMR_i}{W_i \times \sum_{j \neq i} (P_{ij} \times ME_j)}$$

where

- NIR_{totali} = total normalized ingestion rate for species i (kg prey wet weight/kg predator body weight/day)
- FMR_i = free-living metabolic rate of predator (kcal/day)
- W_i = body weight of species i (kg wet weight)
- P_{ij} = wet weight or volume fraction of i's diet consisting of prey j (unitless)
- ME_j = metabolizable energy from prey j (kcal/kg prey wet wt)

The metabolizable energy from prey j is calculated from (EPA 1993):

$$ME_j = GE_j \times AE_j$$

where

- ME_j = metabolizable energy from prey j (kcal/kg prey wet wt)
- GE_j = gross energy from prey j (kcal/kg wet weight)
- AE_j = assimilation efficiency of prey j (unitless)

4.1.1.2.9 Ingestion of Food

The equilibrium body burden for species *i* from ingestion of food is calculated (from Hope [1995]) as:

$$C_{\text{ingfi}} = D_{\text{ingfi}} \times \left(\frac{\alpha_{\text{ingi}}}{K_{\text{ei}}} \right)$$

where

- C_{ingfi} = equilibrium body burden for species *i* from ingestion of food (μg/kg or pCi/kg body wet weight)
- D_{ingfi} = applied daily dose to species *i* from food ingestion (μg/kg/day or pCi/kg/day)
- α_{ingi} = ingestion absorption factor for species *i* (unitless)
- K_{ei} = contaminant-specific depuration rate for species *i* (1/day)

The applied daily dose to species *i* from food ingestion is calculated from the equation (modified from Hope [1995] using EPA [1993]):

$$D_{\text{ingfi}} = \theta_i \times \psi_i \times \sum_j (C_j \times \text{NIR}_j)$$

where

- D_{ingfi} = applied daily dose to species *i* from food ingestion (μg/kg/day or pCi/kg/day)
- θ_i = area use factor for species *i* (ratio of contaminant area to home range – unitless)
- ψ_i = seasonality factor for species *i* (fraction of year spent at the contaminated site – unitless)
- C_j = average contaminant concentration in *j*th food item (μg/kg or pCi/kg wet weight)
- NIR_j = normalized ingestion rate of *j*th food type on a wet-weight basis (kg prey/kg body weight predator/day)

The normalized ingestion rate of *j*th food type on a wet-weight basis is calculated from (EPA 1993) as:

$$\text{NIR}_j = P_{ij} \times \text{NIR}_{\text{totali}}$$

where

- NIR_j = normalized ingestion rate of *j*th food type on a wet-weight basis (kg prey/kg body weight predator/day)
- P_{ij} = wet weight or volume fraction of *i*'s diet consisting of prey *j* (unitless)
- $\text{NIR}_{\text{totali}}$ = total normalized ingestion rate for species *i* (kg prey wet weight/kg predator body weight/day)

4.1.1.2.10 Total Ingestion Dose

The applied daily dose for species *i* from ingestion is calculated from the equation:

$$D_{\text{ingi}} = D_{\text{ingfi}} + D_{\text{ingsi}} + D_{\text{ingwi}}$$

where

- D_{ingi} = applied daily dose for species i from ingestion ($\mu\text{g/kg/day}$ or pCi/kg/day)
- D_{ingfi} = applied daily dose to species i from food ingestion ($\mu\text{g/kg/day}$ or pCi/kg/day)
- D_{ingsi} = applied daily dose to species i from soil ingestion ($\mu\text{g/kg/day}$ or pCi/kg/day)
- D_{ingwi} = applied daily dose to species i from water ingestion ($\mu\text{g/kg/day}$ or pCi/kg/day)

The equilibrium body burden for species i from ingestion is calculated from the equation:

$$C_i = C_{ingfi} + C_{ingsi} + C_{ingwi} + C_{inhi} + C_{deri}$$

where

- C_i = body burden for species i from ingestion ($\mu\text{g/kg}$ or pCi/kg)
- C_{ingfi} = body burden for species i from ingestion of food ($\mu\text{g/kg}$ or pCi/kg body weight)
- C_{ingsi} = body burden to species i from ingestion of soil ($\mu\text{g/kg}$ or pCi/kg body weight)
- C_{ingwi} = body burden for species i from ingestion of water ($\mu\text{g/kg}$ or pCi/kg)
- C_{inhi} = body burden from inhalation for species i ($\mu\text{g/kg}$ or pCi/kg body weight)
- C_{deri} = body burden from dermal exposure for species i ($\mu\text{g/kg}$ or pCi/kg body weight)

This is the concentration written to the food files for human consumption for terrestrial animals.

4.1.2 Water-Respiring/Transpiring Species

The basic models used in the risk assessment model to estimate exposures of aquatic organisms to metal or organic contaminants in sediments, pore water, surface water, and the subsequent transfer through the food chain consist of mass-balance equilibrium models originally derived by Thomann (1989) and Thomann et al. (1992, 1995). The basic equilibrium models presented in those papers were further modified by the authors to provide a system of equations generally applicable when only sediment data are available. The essential assumption used in that modification is that the aquatic system is not depurating contaminants, such that the three abiotic compartments (sediment, pore water, and surface water) are in static equilibrium (Thomann et al. 1992). This assumption may only be valid for large lacustrine systems; clearly, it is invalid for streams. However, the basic models may be used directly with only minor modification to address these more dynamic systems.

4.1.2.1 Body Burden for Aquatic Animals

The body burden in a predator species i , V_i , is calculated from direct exposure to contaminated water, ingestion of contaminated prey, and ingestion of contaminated sediment, using the following equation:

$$V_i = \left[BCF_{i,c} \times (b_{\text{pore}} \times EC_{\text{pore}} + [1 - b_{\text{pore}}] \times EC_{\text{surf}}) \right] + \left[\frac{\sum_{j \neq i} (P_{ij} \times \alpha_{ij} \times I_{ij} \times V_j)}{K_i + G_i} \right] + \left[EC_{\text{sed}} \times SD_i \times \alpha_{i,\text{sed}} \times \left(\frac{\sum_{j \neq i} (P_{ij} \times I_{ij})}{K_i + G_i} \right) \right]$$

where

- V_i = body burden in predator species i (metals: $\mu\text{g/kg}$ or pCi/kg dry weight [Thomann et al. 1995]; organics: $\mu\text{g/g}$ lipid [Thomann et al. 1992])
- $\text{BCF}_{i,c}$ = bioconcentration factor for species i and contaminant c (inorganics: L/kg dry weight; organics: L/g lipid)
- b_{pore} = relative exposure to pore water (unitless)
- EC_{pore} = contaminant concentration in pore water ($\mu\text{g/L}$ or pCi/L)
- EC_{surf} = contaminant concentration in surface water ($\mu\text{g/L}$ or pCi/L)
- P_{ij} = preference for consumption of food item j (unitless)
- α_{ij} = chemical assimilation efficiency for contaminant consumed along with prey j (g contaminant assimilated/g contaminant ingested)
- I_{ij} = feeding rate of species i on prey item j (organic model: g prey lipid/g predator lipid/day, metal model: g prey dry weight/g predator dry weight/day)
- V_j = body burden in prey species j (metals: $\mu\text{g/kg}$ or pCi/kg dry weight [Thomann et al. 1995]; organics: $\mu\text{g/g}$ lipid [Thomann et al. 1992]) or in sediment (metals: $\mu\text{g/kg}$ dry sediment [Thomann et al. 1995]; organics: $\mu\text{g/g}$ organic carbon [Thomann et al. 1992])
- EC_{sed} = contaminant concentration in sediment ($\mu\text{g/kg}$ or pCi/kg)
- SD_i = feeding rate of species i on sediment as a fraction of total diet intake (kg sediment dry weight/kg prey dry weight/day)
- $\alpha_{i,\text{sed}}$ = chemical assimilation efficiency for contaminant consumed along with sediment (g contaminant assimilated/g contaminant ingested)
- K_i = loss rate of contaminant for species i, including depuration and metabolism (1/day)
- G_i = growth rate of species i (1/day)

The loss rate of contaminant for species i, including depuration and metabolism, for organic contaminants is calculated from the equation (Thomann 1989):

$$K_i = \left[k_{ui,c} / \left(\frac{K_{ow}}{1000} \right) \right] + K_{mi}$$

where

- K_i = loss rate of contaminant for species i, including depuration and metabolism (1/day)
- $k_{ui,c}$ = contaminant uptake from dissolved sources for species i for contaminant c (metals: L/g dry weight/d [Thomann et al. 1995]; organics: L/g lipid/d [Thomann et al. 1992])
- K_{ow} = octanol-water partition coefficient (unitless)
- K_{mi} = chemical loss rate in species i due to metabolism and fecal loss (1/day)
- 1000 = Unit conversion factor (g/L)

The contaminant uptake from dissolved sources for species i for organic contaminants is calculated from the equation (Thomann 1989):

$$k_{ui,c} = \frac{2.67 \times f_{oci} \times \rho_i \times E_c}{\text{awd}_i \times C_0 \times f_{Li}}$$

where

- $k_{ui,c}$ = contaminant uptake from dissolved sources for species i for contaminant c (L/g lipid/day)
- f_{oci} = fraction organic carbon in species i (g organic carbon/g dry weight)
- ρ_i = oxygen respiration rate for species i (g O₂/g lipid/day)
- E_c = chemical transfer efficiency (g/g per g O₂/g lipid)
- awd_i = wet-to-dry weight ratio for species i (g wet/g dry)
- C_0 = oxygen concentration in the river (g O₂/L)
- f_{Li} = fraction lipid in species i (g lipid/g wet)
- 2.67 = grams of oxygen per gram of carbon (g O₂/g organic carbon)

This equation is not used in the model for metal uptake; instead, the BCF relationship is used and BCFs are obtained from the literature.

The growth rate of species i is given by the regression equation (Thomann et al. 1992):

$$G_i = \delta \times w_i^{-\beta}$$

where δ and β are regression parameters and w_i is the body weight of species i (kg wet weight) (modifier WBMASS on the SPECIES keyword, Section 2.3.8).

The feeding rate of species i on biotic prey item j for organic contaminants is calculated from the following equation (Thomann et al. 1992):

$$I_{ij} = \left(\frac{G_i + \rho_i}{a_i} \right) \times \left(\frac{awd_j}{awd_i} \right) \times \left(\frac{f_{Lj}}{f_{Li}} \right) \times \left(\frac{f_{oci}}{f_{ocj}} \right)$$

where

- I_{ij} = feeding rate of species i on prey item j (organic model: g prey lipid/g predator lipid/day)
- G_i = growth rate of species i (1/day)
- ρ_i = oxygen respiration rate for species i (1/day)
- a_i = organic carbon assimilation rate for species i (g organic carbon assimilated/g organic carbon ingested)
- $awdj$ = wet-to-dry weight ratio for prey species j (g wet/g dry)
- awd_i = wet-to-dry weight ratio for predator species i (g wet/g dry)
- f_{Lj} = fraction lipid in prey species j (g lipid/g wet)
- f_{Li} = fraction lipid in predator species i (g lipid/g wet)
- f_{ocj} = fraction organic carbon in prey species j (g organic carbon/g dry weight)
- f_{oci} = fraction organic carbon in predator species i (g organic carbon/g dry weight)

The oxygen respiration rate for species i is calculated from the equation:

$$\rho_i = \phi \times w_i^{-\gamma}$$

where ϕ and γ are regression parameters (Thomann 1989) and w_i is the body weight of species i (kg wet weight) (modifier WBMASS on the SPECIES keyword, Section 2.3.8).

The bioconcentration factor for species i and organic contaminant c is calculated from the equation:

$$BCF_{i,c} = \frac{k_{ui,c}}{K_i + G_i}$$

where

- $BCF_{i,c}$ = bioconcentration factor for species i for organic contaminant c (L/g lipid)
- $k_{ui,c}$ = contaminant uptake from dissolved sources for species i (L/g lipid/day)
- K_i = loss rate of contaminant for species i , including depuration and metabolism (1/day)
- G_i = growth rate of species i (1/day)

The equation for I_{ij} for organic contaminants returns values with units of (g prey lipid/g predator lipid/day). The equivalent units for the metal uptake model of Thomann et al. (1995) are (g prey dry weight/ g predator dry weight/day). For the purposes of evaluating metal uptake in aquatic systems, the following conversion was applied to produce consumption rates in the correct units for the feeding rate of species i on biotic prey item j for metallic contaminants:

$$I_{metalij} = I_{ij} \times \left(\frac{awd_i}{awd_j} \right) \times \left(\frac{f_{Li}}{f_{Lj}} \right) = \left(\frac{G_i + \rho_i}{a_i} \right) \times \left(\frac{f_{oci}}{f_{ocj}} \right)$$

where

- $I_{metalij}$ = feeding rate of species i on prey item j (inorganics model: g prey dry weight/ g predator dry weight/day)
- I_{ij} = feeding rate of species i on prey item j (organic model: g prey lipid/g predator lipid/day)
- awd_i = wet-to-dry weight ratio for predator species i (g wet/g dry)
- awd_j = wet-to-dry weight ratio for prey species j (g wet/g dry)
- f_{Li} = fraction lipid in predator species i (g lipid/g wet)
- f_{Lj} = fraction lipid in prey species j (g lipid/g wet)
- G_i = growth rate of species i (1/day)
- ρ_i = oxygen respiration rate for species i (1/day)
- a_i = organic carbon assimilation rate for species i (g organic carbon assimilated/g organic carbon ingested)
- f_{oci} = fraction organic carbon in predator species i (g organic carbon/g dry weight)
- f_{ocj} = fraction organic carbon in prey species j (g organic carbon/g dry weight)

4.1.2.2 Body Burden for Aquatic Plants

The body burden for aquatic plant species i , V_i , is calculated from the following equation:

$$V_i = BCF_{i,c} \times (b_{pore} \times EC_{pore} + [1 - b_{pore}] \times EC_{surface})$$

where

- V_i = body burden in aquatic plant species i (inorganics: $\mu\text{g/kg}$ or pCi/kg dry weight [Thomann et al. 1995]; organics: $\mu\text{g/g}$ lipid [Thomann et al. 1992])
- $\text{BCF}_{i,c}$ = bioconcentration factor for species i and contaminant c (inorganics: L/kg dry weight; organics: L/g lipid)
- b_{pore} = relative exposure to pore water (unitless)
- EC_{pore} = contaminant concentration in pore water ($\mu\text{g/L}$ or pCi/L)
- $\text{EC}_{\text{surface}}$ = contaminant concentration in surface water ($\mu\text{g/L}$ or pCi/L)

4.1.2.3 Body Burden as Consumed

The equilibrium body burden is calculated for all aquatic species for consumption by terrestrial species and by humans. These concentrations are written to the FOOD files for input into the HUMAN code.

The equilibrium body burden for species i from ingestion of inorganics is calculated from the equation:

$$C_i = V_i / \text{awd}_i$$

where

- C_i = body burden for species i from ingestion ($\mu\text{g/kg}$ or pCi/kg wet)
- V_i = body burden in predator species i ($\mu\text{g/kg}$ or pCi/kg dry weight)
- awd_i = wet-to-dry weight ratio for species i (g wet/g dry)

For the inorganic contaminant tritium in aquatic plants, the equation is:

$$C_i = V_i \times (1.0 - 1.0 / \text{awd}_i)$$

The equilibrium body burden for species i from ingestion of organics is calculated from the equation:

$$C_i = V_i \times 1000 \times f_{\text{Li}}$$

where

- C_i = equilibrium body burden for species i from ingestion ($\mu\text{g/kg}$ or pCi/kg wet)
- V_i = body burden in predator species i ($\mu\text{g/g}$ lipid)
- f_{Li} = fraction lipid in species i (g lipid/g wet)
- 1000 = unit conversion factor (g wet/kg wet)

4.1.2.4 Tissue Benchmark Concentration

The tissue benchmark calculation allows comparison of a body burden to a benchmark threshold. This value is calculated differently for organic and nonorganic nonradioactive analytes

The tissue benchmark value for both plant and animal aquatic species for organic, nonradioactive, contaminants is calculated from the following equation:

$$TB_i = V_i \times 1000 \times f_{Li} / BM_i$$

where

- TB_i = the calculated tissue benchmark value for species i (unitless)
- V_i = the body burden in predator species i ($\mu\text{g/g}$ lipid)
- f_{Li} = the fraction lipid in species i (g lipid/g wet)
- BM_i = the benchmark level for species i ($\mu\text{g/kg}$ lipid)
- 1000 = unit conversion factor (g/kg)

The tissue benchmark value for both plant and animal aquatic species for nonorganic, nonradioactive, contaminants is calculated from the following equation:

$$TB_i = \frac{V_i}{BM_i \times awd_i}$$

where

- TB_i = calculated tissue benchmark value for species i (unitless)
- V_i = body burden in predator species i ($\mu\text{g/kg wet}$ or pCi/kg wet)
- BM_i = benchmark level for species i ($\mu\text{g/kg dry}$)
- awd_i = wet-to-dry weight ratio for species i (g wet/g dry)

4.1.3 Radiological Dose Estimation

The exposure equations return estimates of ingestion exposure to radiological contaminants in units of $\text{pCi/kg body mass/day}$ (i.e., in units of radioactive decay rate density). However, radiological effects result from radioactive energy density absorbed by a body in a unit of time, which is usually expressed in units of rads/day . Consequently, decay rates must be converted to energy equivalents. Similarly, an organism can receive external energy from radioactive decay occurring in the abiotic media (air, water, or soil).

4.1.3.1 Internal Dose

The internal total-body dose rate to an organism is the sum of the individual dose rates from each radionuclide in the body. The equation is written as follows:

$$R_{i,int} = \sum_c (C_{i,c} \times E_{i,c})$$

where

- $R_{i,int}$ = radiological dose to organism i from internal radioactive decay (rad/day)
- $C_{i,c}$ = specific body burden of nuclide c in organism i (pCi/kg)
- $E_{i,c}$ = effective absorbed energy rate for nuclide c per unit activity in organism i (kg rad/ pCi/day)

Doses are summed across all radionuclides. As shown in Baker and Soldat (1992), the effective absorbed energy rate for nuclide c per unit activity in organism i can be calculated from the following equation:

$$E_{i,c} = 1 \text{ Ci}/10^{12} \text{ pCi} \times 3.7^{10} \text{ disintegrations/sec/Ci} \times 86,400 \text{ sec/day} \times 1.602^{-11} \text{ kg rad/MeV} \times \epsilon_{i,c}$$

$$E_{i,c} = 5.12^{-8} \times \epsilon_{i,c}$$

where

- $E_{i,c}$ = effective absorbed energy rate for nuclide c per unit activity in organism i (kg rad/pCi/d)
 $\epsilon_{i,c}$ = is the effective absorbed energy (MeV/disintegration)

4.1.3.2 External Dose

4.1.3.2.1 External Dose from Water Immersion for Aquatic Organisms

The external radiological dose to aquatic organism i from exposure to radioactive decay in water is calculated using the equation:

$$R_{i,imm} = \sum_c [(b_{pore} \times EC_{pore,c} + (1 - b_{pore}) \times EC_{surface,c}) \times DF_{imm,c} \times CF_{imm,q}]$$

where the sum extends over all radiological contaminants (with index c):

- $R_{i,imm}$ = external radiological dose to organism i from exposure to radioactive decay in water (rad/d)
 b_{pore} = relative exposure to pore water (unitless)
 $EC_{pore,c}$ = contaminant concentration in pore water for nuclide c (pCi/L)
 $b_{surface}$ = relative exposure to surface water ($b_{surface} = 1 - b_{pore}$) (unitless)
 $EC_{surface,c}$ = contaminant concentration in surface water for nuclide c (pCi/L)
 $DF_{imm,c}$ = water immersion dose factor for nuclide c (mrad/yr per pCi/m³)
 $CF_{imm,q}$ = 2.737851×10^{-9} (conversion factor: from (mrad m³)/(L yr) to rad/d)

4.1.3.2.2 External Dose from Water Immersion for Terrestrial Organisms

The external radiological dose to terrestrial organism i from exposure to radioactive decay in water is calculated using the equation:

$$R_{i,imm} = F_{water} \times ET_{water,i} \times CF_{imm,t} \times \sum_c [EC_{water,c} \times DF_{imm,c}]$$

where the sum extends over all radiological contaminants (with index c):

- $R_{i,imm}$ = external radiological dose to organism i from exposure to radioactive decay in water (rad/d)
 $EC_{water,c}$ = contaminant concentration in water for nuclide c (pCi/L)
 $DF_{imm,c}$ = water immersion dose factor for nuclide c (mrad/yr per $\mu\text{Ci}/\text{m}^3$)
 F_{water} = fraction of the organism exposed to water (unitless)

- ET_{water,i} = exposure time of organism i to the water (hr/d)
 CF_{imm,t} = unit conversion factor: $1.140771 \times 10^{-10} = (0.001 \text{ rad/mrad} \times 1\text{E-6 } \mu\text{Ci/pCi} \times 1000 \text{ L/m}^3) / (24 \text{ hr/d} \times 365.25 \text{ d/yr})$

4.1.3.2.3 External Dose from Contact with Sediment for Aquatic Organisms

External dose received from contact with sediment is calculated for aquatic species as the combination of external dose received above the sediment and below the sediment. The equations (Eckerman and Ryman 1993) are:

$$\begin{aligned} \text{RAbove}_{i,\text{sed}} &= \sum_c \left[\text{EC}_{\text{sed},c} \times (1 - b_{\text{pore}}) \times \text{DF}_{\text{sed},c} \times \text{CF}_{\text{elev}} \times \text{CF}_{\text{above}} \right] \\ \text{RBelow}_{i,\text{sed}} &= \sum_c \left[\text{EC}_{\text{sed},c} \times b_{\text{pore}} \times \gamma_c \times \text{CF}_{\text{below}} \right] \\ \text{R}_{i,\text{sed}} &= \text{RAbove}_{i,\text{sed}} + \text{RBelow}_{i,\text{sed}} \end{aligned}$$

where the sum extends over all radiological contaminants (with index c):

- R_{i,sed} = external radiological dose to organism i from exposure to radioactive decay in sediment (rad/d)
 EC_{sed,c} = contaminant concentration in sediment for nuclide c (pCi/kg)
 b_{pore} = relative exposure to pore water (unitless)
 DF_{sed,c} = sediment dose factor for 15 cm depth for nuclide c (mrad/yr per $\mu\text{Ci/m}^3$)
 F_{sed,i} = fractional exposure of organism i to the sediment (unitless)
 CF_{elev} = 2 if b_{pore} < 0.5 or 1 if b_{pore} ≥ 0.5
 CF_{above} = conversion factor applicable above the sediment: 0.7 (dose rate reduction fraction accounting for ground roughness) × 5.12×10^8 (unit conversion factor: $1.6\text{E-3 kg/m}^3 \times 86,400 \text{ s/d} \times 1/27 \text{ Bq/pCi} \times 100 \text{ rem/Sv} \times 1 \text{ rad/rem}$)
 CF_{below} = conversion factor applicable below the sediment: 1.05 (conversion factor to account for immersion in soil vs water) × 5.12×10^8 (unit conversion factor: $1\text{E-12 Ci/pCi} \times 3.7\text{E10 disintegration/s/Ci} \times 86,400 \text{ s/d} \times 1.602\text{E-11 kg-rad/MeV}$)
 γ_c = gamma energy for nuclide c (MeV/disintegration)

4.1.3.2.4 External Dose from Contact with Soil for Terrestrial Organisms

The external dose received from contact with sediment is calculated for terrestrial species as the combination of external dose received above the sediment and below the sediment. The equations (Eckerman and Ryman 1993) are:

$$\begin{aligned} \text{RAbove}_{i,\text{soil}} &= \sum_c \left[\text{EC}_{\text{soil},c} \times F_{\text{above}} \times \text{DF}_{\text{sed},c} \times \text{CF}_{\text{elev},i} \times \text{CF}_{\text{above}} \right] \\ \text{RBelow}_{i,\text{soil}} &= \sum_c \left[\text{EC}_{\text{soil},c} \times (1 - F_{\text{above},i}) \times \gamma_c \times \text{CF}_{\text{below}} \right] \\ \text{R}_{i,\text{soil}} &= \text{RAbove}_{i,\text{soil}} + \text{RBelow}_{i,\text{soil}} \end{aligned}$$

where the sum extends over all radiological contaminants (with index c):

- $R_{i,soil}$ = external radiological dose to organism i from exposure to radioactive decay in soil (rad/day)
- $EC_{soil,c}$ = contaminant concentration in soil for nuclide c (pCi/kg)
- $F_{above,i}$ = fractional time for exposure of organism i above the sediment (unitless)
- $DF_{sed,c}$ = sediment dose factor for 15 cm depth for nuclide c (mrad/yr per $\mu\text{Ci}/\text{m}^3$)
- $CF_{elev,i}$ = 2 if $Diffht_i < 1$ or 1 if $Diffht_i \geq 1$
- CF_{above} = conversion factor applicable above the sediment: 0.7 (dose rate reduction fraction accounting for ground roughness) $\times 5.12 \times 10^8$ (unit conversion factor: $1.6\text{E-}3 \text{ kg}/\text{m}^3 \times 86,400 \text{ s/d} \times 1/27 \text{ Bq/pCi} \times 100 \text{ rem/Sv} \times 1 \text{ rad/rem}$)
- CF_{below} = conversion factor applicable below the sediment: 1.05 (conversion factor to account for immersion in soil vs water) $\times 5.12 \times 1.0^{-8}$ (unit conversion factor: $1\text{E-}12 \text{ Ci/pCi} \times 3.7\text{E}10 \text{ disintegration/s/Ci} \times 86,400 \text{ s/d} \times 1.602\text{E-}11 \text{ kg-rad/MeV}$)
- γ_c = gamma energy for nuclide c (MeV/disintegration)

4.1.3.3 Total Dose

Finally, total radiological dose is obtained by summing the above quantities:

$$R_{i,total} = \sum_c (R_{i,imm} + R_{i,sed} + R_{i,int})$$

where the doses are summed across all radionuclides:

- $R_{i,imm}$ = external radiological dose to organism i from exposure to radioactive decay in water (rad/day)
- $R_{i,sed}$ = external radiological dose to organism i from exposure to radioactive decay in sediment (rad/day)
- $R_{i,int}$ = radiological dose to organism i from internal radioactive decay (rad/day)

4.2 Code Execution Environment

4.2.1 Location in the Processing Sequence

The Ecological Contaminant Exposure Model (ECEM) code requires access to a number of data files developed by the SAC inventory, release, and transport codes (Eslinger et al. 2002). In particular, every code on the left side of Figure 1.1 must have been executed to build a suite of concentration data files before the ECEM code can be used to calculate impacts. These concentration data files must have been developed under the control of the same ESD keyword file that the ECEM code reads to determine processing options.

4.2.2 How the Code Is Invoked

ECEM can run under either the Windows or the Linux operating system. Under the Windows operating system (Releases 98, NT, or 2000), ECCEM executes in a DOS box. A run of ECCEM is initiated by entering the following command line:

```
ECCEM "Keyfilename"
```

Under the Linux operating system, ECCEM is executed through any of the following Bourne Shell or C Shell commands:

```
ecem.exe "Keyfilename"
```

For these commands, ECCEM or ecem.exe is the name of the executable program and "Keyfilename" is the name of an ecological scenario keyword file. Both the name of the executable program and the keyword file may contain path information. If ECCEM is invoked without entering the name of the keyword file, the code will prompt the user for the file name. The keyword file, which should be prepared using an editor that can handle ASCII files without leaving embedded control codes, contains text control information describing the run. If ECCEM cannot open the keyword file, then the code will terminate execution after writing an error message to the standard output device.

4.2.3 Memory Requirements

The ECCEM code uses dynamic memory allocation, so the memory requirements depend on the problem being analyzed. A reasonably large example run where the ECCEM code required 2.54 MB of memory (on a Windows 2000 machine) used 10 analytes, 60 time steps, 11 realizations, and 168 locations. It is expected that most, if not all, of the runs of the ECCEM code will require less than 4 MB of memory. This run took about 10 minutes to execute on a 933-megahertz system.

4.3 Data Files

The ECCEM code reads four or more input files and writes up to five output files. The number of input files depends on the number of contaminants being analyzed. The number of output files depends on the options selected in the ECCEM code. These files are described in the following sections.

4.3.1 Input Files

The input files for the ECCEM code are keyword files and a suite of concentration data related files. One keyword file controls the case the ECCEM code will execute, and it points to the ESD keyword file. The suite of concentration data files are all identified in the ESD keyword file – the user of the ECCEM only needs to identify the ESD keyword file. The following are the input files:

- **ESD Keyword File.** The ESD keyword file contains the control information that the inventory and environmental transport codes use to generate concentration data files. Examples of keywords in the ESD file that control the impact codes, including the ECCEM code, are provided in Table 2.2. Definitions for these keywords are given in Section 2.1. Typically, the user of the ECCEM code will not modify the ESD keyword file.

- **ECDA Concentration Files.** The ECDA files contain all the concentration data available for the impact codes. The concentrations for all analytes are based on the same time and location data. There is a “map” file for the ECEM code containing indexing information for each of the concentration data files. In addition, there is a separate concentration data file for every analyte used in the impacts scenario. For example, when running a scenario with seven analytes, there will be one map file and seven concentration data files. The structure of a concentration data file is described in Section 2.4.1.
- **ECEM Keyword File.** The ECEM Keyword file controls the scenario to be analyzed by the ECEM code. The options and data available are constrained by the case defined in the ESD Keyword file. Section 4.4 describes the contents of the ECEM keyword file.

4.3.1.1 ESD Keyword File

The ECEM code reads keywords from the environmental settings file. These keywords are read from a different file and can have a different definition from a keyword defined for internal use in the ECEM code. The environmental settings keywords are defined in Section 2.3. The following keywords are required:

- ANALYTE – definition of analytes in the environmental simulations
- END – end of the environmental settings keywords
- FILE – file names for the concentration file for each analyte
- IRRIGATE – definition of the first and last days of the growing season
- LOCATION – locations at which concentrations were generated for the ecological impacts
- RADIUS – effective energy by organism radius
- REALIZAT – number of realizations for which concentration data were generated for ecological impact calculations
- SPECIES – definition of species for the ecological impacts calculations
- TIMES – times at which concentrations were generated for the ecological impacts
- TITLE – environmental simulation title

4.3.1.2 ECDA Concentration Files

The ECDA provides a central storage location for concentration data for all analytes at the environmental locations and times needed to perform social-cultural analyses. The ECDA files are described in Section 2.4.1.

4.3.1.3 ECEM Keyword File

The ECEM keyword definition file contains control information for the desired impact simulation. Individual keywords are defined in Section 4.4. Table 4.1 contains excerpted keywords for a run of ECEM using 7 realizations, 15 locations, 10 analytes and 57 ecological species. The complete file is 4400 lines long.

Table 4.1 Excerpted Records from an ECEM Keyword File

```

REPORT "Ecem_CA1_median.Rpt"
TITLE  "2004 CA - Confirmatory ECEM keyword file"
USER   "Carmen Arimescu"
EXECUTE
STATISTICS BURDEN SUMRAD BMTISS DOSDER DOSINH DOSING DOSRAD
DETAILS BURDEN SUMRAD BMTISS DOSDER DOSINH DOSING DOSRAD
! File Definitions (use full path in the name)
FILE STATISTICS "ECEM_Confirm-median_sta.Csv"
FILE HEADER     "ECEM_CA1_median.hdr"
FILE VALUES    "ECEM_CA1_median_Val.Csv"
FILE DETAILS    "ECEM_CA1_median_Det.Csv"
FILE THRESHOLD  "ECEM_Confirm-median_Thresh.csv"
! Environmental keyword file
FILE ESD "/home/ANALYSIS4/CA1_median/ESD_CA1_median.key"
FOODS MAP= "Food_Map_CA1_median.Dat"
          PATH="/home/ANALYSIS4/CA1_median/foods/"
          SACVIEW="ECEM_FCDA_Confirm-median.Hdr"
TIMES
  1945  1950  1955  1960  1965  1970  1975  1980  1985  1990
! Analyte definitions
ANALYTE ID="H3"      ELEMENT="H"    OUTPUT
ANALYTE ID="C14"     ELEMENT="C"    OUTPUT
ANALYTE ID="Sr90"    ELEMENT="Sr"   OUTPUT
ANALYTE ID="U233"    ELEMENT="U"    OUTPUT
ANALYTE ID="U235"    ELEMENT="U"    OUTPUT
! Random Seed for Stochastics
SEED 4453190
! Number of Realizations
REALIZATION 1
! Debug flags
DEBUG FCDA
GROWTH DELTA 0.002 BETA 0.25
RESPIRE PHI 0.032 GAMMA 0.2
! Other variables for terrestrial plants
VARIABLE COWHDFX 0.0497 ! unitless - Default val (EPA,1991) RAGS, Part B.
VARIABLE LENGTH 45.0 ! m - Default val (EPA,1991) RAGS, Part B.
! Location Definitions
! Riparian and Aquatic Hanford side locations
LOCATION PRIMARY="RHP001" SECOND="QHP001" OUTPUT
! Upland locations
LOCATION PRIMARY="UH0001" OUTPUT
!-----| Species Definitions |-----!
SPECIES ID="QCARPS" OUTPUT ! carp
SPECIES ID="UMDLRK" !OUTPUT ! Western meadowlark
!-----!
! Consume Keywords
CONSUME ID="QCARPS" PREY
"QCPBSN" 0.15000
"QMAYFL" 0.25000
"QPERIP" 0.50000

```

```

"QMLFOL"  0.10000
SEDING    0.16000
CONSUME ID="UHVMSSE" PREY
"UEWORM"  0.05000
"UFUNGI"  0.02500
"UGRAIN"  0.20000
"UGRASS"  0.22500
"ULFVEG"  0.02500
"UMLBRY"  0.05000
"URTVEG"  0.02500
"UTHSLE"  0.02500
"USHRUB"  0.20000
"UARTPD"  0.15000
"UTRFRT"  0.02500
SOILING   0.02000
! Values used for KOW
STOCHASTIC "CCL KOW" 1 4.36000E+02
! Values used for BCFVEG
! Use the variable TUPTAKE instead of BCFVEG for tritium
STOCHASTIC "Cs BCFVEG" 1 4.10000E-02
! Values used for aquatic animal BPORE
STOCHASTIC "QCARPSBPORE" 1 0.05
STOCHASTIC "QCLAMSBPORE" 1 0.5
! Values used for aquatic plant BPORE
STOCHASTIC "QMLFOLBPORE" 1 0.5
STOCHASTIC "RBBBATFABOVE" 1 1
STOCHASTIC "RWESELFABOVE" 1 0.1
STOCHASTIC "UTOADAFABOVE" 1 0.8
STOCHASTIC "UHAWKSFABOVE" 1 1
STOCHASTIC "RWILOWFABOVE" 1 0.5
STOCHASTIC "RWILOWKPS1" 1 0.0034
STOCHASTIC "RWILOWKPA2" 1 3300
STOCHASTIC "UFUNGIFABOVE" 1 0.5
STOCHASTIC "USHRUBKPA2" 1 3300
! Values used for aquatic animal ALPHAIJ
STOCHASTIC "Sr90 QCARPSALPHAIJ" 1 0.19
! Values used for aquatic animal BCF
STOCHASTIC "I129 QMAYFLBCF" 1 100
! Values used for aquatic animal METBLOSS
STOCHASTIC "U QSAMADMETBLOSS" 1 0
! Values used for aquatic animal DEPRATE
STOCHASTIC "H3 QLMPJVDEPRATE" 1 0.15
! Values used for aquatic plants
STOCHASTIC "Cl36 QMLFOLBCF" 1 1.0000E+00
! Values used for terrestrial animal DEPRATE
STOCHASTIC "Cs137 RACOOTDEPRATE" 1 0.04
! Values used for terrestrial animal ALPHAING
STOCHASTIC "Pa231 RROBINALPHAING" 1 0.013
! Values used for terrestrial animal ALPHAPAR
STOCHASTIC "CrVI RKSTRLALPHAPAR" 1 0.32
! Values used for terrestrial animal ALPHAVAP

```

```
STOCHASTIC "Np237 UMDLRKALPHAVAP" 1 0.00048
! Values used for terrestrial animal ALPHADW
STOCHASTIC "U      RWTADALPHADW" 1 0
! Values used for terrestrial animal ALPHADS
STOCHASTIC "Se79  UCHKADALPHADS" 1 0
! Values used for terrestrial plant FOLIAR
STOCHASTIC "H3      RCTWODFOLIAR" 1 0.01373
! End of Inputs
END
```

4.3.2 Output Files

Up to five output files can be written by the ECEM code. The number of files depends on the options selected in the scenario being analyzed. The following are the output files:

- **Report File.** This required file contains a summary of the scenario being analyzed and contains any error messages. An example report file for the ECEM code is provided in Table 4.2.
- **Stochastic Values File.** This optional file contains the values for every stochastic variable generated in the ECEM code. The description of the VALUES modifier on the FILE keyword (see Section 4.4.7) explains how to activate writing this file. A subset of the data written to this file for a run using five realizations is provided in Table 4.3.
- **SACView Header File.** This required file contains information used by the interactive SACView program to allow easy extraction of subsets of the results computed by the ECEM code. An example of this file is given in Table 4.4.
- **Detailed Data.** This optional file contains the detailed values for the dose and risk values generated in the ECEM code. The description of the DETAILS modifier on the FILE keyword (see Section 4.4.7) explains how to activate writing this file. A subset of the data written to this file for a run using five realizations is provided in Table 4.5.
- **Summary Statistics Data.** This optional file contains the summary statistics for the dose and risk values generated in the ECEM code. The description of the STATISTI modifier on the FILE keyword (see Section 4.4.7) explains how to activate writing this file. A subset of the data written to this file for a run using five realizations is provided in Table 4.6.
- **FCDA Map File.** This optional file provides a map into the FCDA binary data files. This file is required if FCDA files are created by ECEM.
- **FCDA Data Files.** The FCDA files contain all the food concentration data created by the ECEM code. The concentrations for all food species are based on the same analyte, time, and location data. There is a separate food concentration data file for every species requested in the ecological impacts keyword file.
- **FCDA SACView Header File.** This required file contains information used by the interactive SACView program to allow easy extraction of the food concentrations computed by the ECEM code.

4.3.2.1 ECEM Report File

Excerpted records for an example report file for the ECEM code are provided in Table 4.2. This file contains information for a run of the ECEM code using 12 analytes, 1 realization, 3555 locations, and

1 solution times. The size of this file is about 298 KB in size. The size of this file grows rapidly when debug options are selected. A run using all debug options having a large number of locations, analytes, solution times, and realizations could easily generate a report file larger than the 2.1-GB file size limit under the Windows operating system.

Table 4.2 Excerpted Records from an ECEM Report File

EEEEEEE	CCCC	EEEEEEE	MM	MM
E	C	C	E	M M M M
E	C		E	M M M
EEEEEE	C		EEEEEE	M M M
E	C		E	M M
E	C	C	E	M M
EEEEEEE	CCCC	EEEEEEE	M	M
<p style="text-align: center;">ECEM Version 3.01.004 Last Modified on 3 MAY 2004</p> <p style="text-align: center;">----- Ecological Contaminant Exposure Model Stochastic Ecological Pathways Risk Analysis ----- Developed By Battelle Memorial Institute Pacific Northwest National Laboratories Richland, Washington ----- Copyright Notice Copyright © Battelle Memorial Institute, 2000. All Rights Reserved. -----</p> <p style="text-align: center;">Current Run ID = 20040608141858 User Name = Carmen Arimescu System Date = 06-08-2004 System Time = 14:18:58</p> <p style="text-align: center;">The software used to generate this output is experimental and has not been formally tested or peer reviewed.</p> <p style="text-align: center;">Review Signatures</p> <p>Input Prepared By: _____ Date: _____</p> <p>Input Reviewed By: _____ Date: _____</p> <p>===== Echo of the Problem Definition =====</p> <p>Title: 2004 CA - Confirmatory ECEM keyword file User: Carmen Arimescu 1 Realizations requested</p> <p>File Name for Input Keyword Data File: ECEM_Confirm-median.key</p> <p>File Name for the Report File File: Ecem_Confirm-median.Rpt</p> <p>File Name for Media Concentrations for analyte with ID="File Name for Generated Stochastic Values" File: ECEM_Confirm-median_Val.Csv</p> <p>File Name for Output Summary Statistics File: ECEM_Confirm-median_sta.Csv</p> <p>File Name for Media Concentrations for analyte with ID="C14"</p>				

File: /home/ANALYSIS3/Confirm-median/ecda/C14_Confirm-median.dat

File Name for Media Concentrations for analyte with ID="Sr90"

File: /home/ANALYSIS3/Confirm-median/ecda/Sr90_Confirm-median.dat

File Name for Media Concentrations for analyte with ID="H3"

File: /home/ANALYSIS3/Confirm-median/ecda/H3_Confirm-median.dat

Debug Flag Information

No : Concentration Data
No : Stochastic Calculations
No : Air Concentration Calculations

...

No : Equations in subroutine NS_TP
No : Equations in subroutine NS_QA
No : Equations in subroutine NS_TA

Summary Statistics Output Flag Information

No : BURDEN : Body burden
No : BMTISS : Aquatic species tissue benchmark

...

No : DOSING : Ingestion dose by analyte
No : DOSINH : Inhalation dose by nuclide

Detailed Data Output Flag Information

No : BURDEN : Body burden
No : BMTISS : Aquatic species tissue benchmark

...

No : DOSING : Ingestion dose by analyte
No : DOSINH : Inhalation dose by nuclide

Growing season information for food calculations

121 : Day of year (Julian calendar) the growing season starts
256 : Day of year (Julian calendar) the growing season ends
0.3726 : Fraction of year assigned to the growing season

Starting Problem Execution

Date: 06/08/2004
Time: 14:19:10.957

Time Slices Requested: (Index, Calendar Year)

58 : 2050

A total of 1 times have been requested.

Locations Requested: (Index, ID, Type, Name)

1 : UH0001 : UPLAND : "UnsuitableForAgricul"
2 : UH0002 : UPLAND : "UnsuitableForAgricul"
3 : UH0003 : UPLAND : "UnsuitableForAgricul"

...

4055 : R21I06 : RIPARIAN : "NELSON ISLAND"
4056 : R21I07 : RIPARIAN : "NELSON ISLAND"
4057 : R21I08 : RIPARIAN : "NELSON ISLAND"

A total of 3555 locations have been requested.

Analytes Requested:

Index	ID	Element	Type	Description
1	C14	C	NR	Carbon-14
2	Cs137	Cs	NR	Cesium-137
3	Cl36	Cl	NR	Chlorine-36
4	I129	I	NR	Iodine-129
5	Np237	Np	NR	Neptunium-237

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```

      8 Se79      Se      NR      Selenium-79
      9 Sr90      Sr      NR      Strontium-90
     10 Tc99      Tc      NR      Technetium-99
     11 H3        H       NR      Tritium
     13 U233      U       NR      Uranium-233
     14 U235      U       NR      Uranium-235
     15 U238      U       NR      Uranium-238
A total of 12 analytes have been requested.

Species information listed in order of computation
Order Out Type Habitat      ID      Long Name
-----
      1 No      QP      AQUATIC  "QPERIP" periphyton
      2 No      QP      AQUATIC  "QPHYPK" phytoplankton
...
     76 No      TA      UPLAND   "UCYOTE" coyote
     64 No      TA      UPLAND   "UBDGER" American badger
A total of 128 species have been requested.

Consumption information for species 1 : "QPERIP" : "periphyton"

Consumption information for species 2 : "QPHYPK" : "phytoplankton"

Consumption information for species 3 : "QMLFOL" : "water milfoil"

Consumption information for species 4 : "QCARPS" : "CARP"
0.50000 of species 1 : "QPERIP" : "periphyton"
0.10000 of species 3 : "QMLFOL" : "water milfoil"
0.15000 of species 7 : "QCPBSN" : "CPBLSN"
0.25000 of species 12 : "QMAYFL" : "MAYFLY"
0.16000 of "sediment"

Consumption information for species 5 : "QCATFS" : "CHCATF"
0.60000 of species 1 : "QPERIP" : "periphyton"
0.20000 of species 3 : "QMLFOL" : "water milfoil"
0.20000 of species 12 : "QMAYFL" : "MAYFLY"
0.19000 of "sediment"
...
Consumption information for species 126 : "UTHSLE" : "Russian thistle"

Consumption information for species 127 : "USHRUB" : "shrubs"

Consumption information for species 128 : "UTRFRT" : "tree fruit"

No Thresholds Requested that Match with Requested Species and Analytes

Concentration data units conversion factors

      1 : C14      : NR : Ground water : 1.00000E+09 : From Ci/m^3      to pCi/L
      1 : C14      : NR : Surface water : 1.00000E+09 : From Ci/m^3      to pCi/L
      1 : C14      : NR : Seep water : 1.00000E+09 : From Ci/m^3      to pCi/L
      1 : C14      : NR : Sediment : 1.00000E+12 : From Ci/kg       to pCi/kg
      1 : C14      : NR : Pore water : 1.00000E+09 : From Ci/m^3      to pCi/L
      1 : C14      : NR : Soil-Riparian : 1.00000E+12 : From Ci/kg       to pCi/kg
      1 : C14      : NR : Soil-Dry Land : 1.00000E+12 : From Ci/kg       to pCi/kg
      1 : C14      : NR : Soil-GW Irrig : 1.00000E+12 : From Ci/kg       to pCi/kg
      1 : C14      : NR : Soil-SW Irrig : 1.00000E+12 : From Ci/kg       to pCi/kg
      1 : C14      : NR : Air Concen. : 1.00000E+12 : From Ci/m^3      to pCi/m^3
      1 : C14      : NR : Air Deposit. : 1.00000E+12 : From Ci/m^2/yr   to pCi/m^2/yr

Header information from the map file
FCDA_PTITLE = "2004 CA - Confirmatory ECEM keyword file"
FCDA_PRGNAM = "ECEM"

```

```

FCDA_PRGVER   = "3.01.004"
FCDA_PRGDAT   = " 3 MAy 2004"
FCDA_USRNAM   = "Carmen Arimescu"
FCDA_CRUNID   = "20040608141858"
FCDA_BLOCK_AQ = 0
FCDA_BLOCK_RP = 692
FCDA_BLOCK_UP = 8589
FCDA_NHEAD    = 3
FCDA_RECLEN   = 14
FCDA_NREAL    = 1

Creating food files

Unit: 21 Analyte: "C14 " Species: "QCARPS" File: "/home/ANALYSIS3/Confirm-
median/foods/Food_C14_QCARPS.fod"
Unit: 22 Analyte: "C14 " Species: "QCATFS" File: "/home/ANALYSIS3/Confirm-
median/foods/Food_C14_QCATFS.fod"
Unit: 23 Analyte: "C14 " Species: "QCLAMS" File: "/home/ANALYSIS3/Confirm-
median/foods/Food_C14_QCLAMS.fod"
...
Unit: 631 Analyte: "U238 " Species: "URTVEG" File: "/home/ANALYSIS3/Confirm-
median/foods/Food_U238_URTVEG.fod"
Unit: 632 Analyte: "U238 " Species: "UTRFRT" File: "/home/ANALYSIS3/Confirm-
median/foods/Food_U238_UTRFRT.fod"

Ending Problem Execution

Date: 06/08/2004
Time: 14:20:27.599

Message originating in routine ECEM
Message: Normal Termination

```

4.3.2.2 ECEM Stochastic Values File

The stochastic values file is an optional output file that contains the values for every stochastic variable generated in the ECEM code. The description of the VALUES modifier on the FILE keyword (see Section 4.4.7) explains how to activate writing this file. The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file consists of the ID of the stochastic variable followed by a value for every generated realization. Table 4.3 provides a subset of the data written to this file for a run using four realizations. Because this file has at most a few thousand entries, the file size is always smaller than 1 MB. For this example case, there were 57 species and 10 analytes. The resulting output file contained 2195 stochastic variables.

Table 4.3 Excerpted Records from the ECEM Stochastic Values File

"H3	KOW", 1.00000E+00, 1.00000E+00, 1.00000E+00, 1.00000E+00
"H3	BCFVEG", 4.76008E+00, 5.14824E+00, 4.68511E+00, 4.90057E+00
"H3	AMCOOTALPHAING", 2.99159E-01, 3.20625E-01, 3.12601E-01, 3.32825E-01
"H3	AMCOOTALPHAPAR", 2.95370E-01, 3.02699E-01, 3.07821E-01, 3.18973E-01
"H3	AMCOOTALPHAVAP", 3.03127E-01, 2.97189E-01, 3.12049E-01, 3.33042E-01
"H3	AMCOOTALPHADW", 1.42924E-03, 1.53292E-03, 1.56314E-03, 1.49832E-03
"H3	AMCOOTALPHADS", 7.90622E-04, 8.16154E-04, 7.95349E-04, 7.57446E-04
"H3	AMCOOTDEPRATE", 1.37955E-01, 1.47876E-01, 1.49062E-01, 1.52669E-01
"H3	CARP BCF", 9.91170E-01, 9.75634E-01, 1.03975E+00, 9.55665E-01
"AMCOOTFABOVE",	1.00000E+00, 1.00000E+00, 1.00000E+00, 1.00000E+00
"AMKSTLFABOVE",	1.00000E+00, 1.00000E+00, 1.00000E+00, 1.00000E+00

```
"AMWPELFABOVE", 1.00000E+00, 1.00000E+00, 1.00000E+00, 1.00000E+00
"BEAVERFABOVE", 5.00000E-01, 5.00000E-01, 5.00000E-01, 5.00000E-01
"BLCTWDKPS1", 3.28382E-03, 3.15453E-03, 3.69783E-03, 3.46070E-03
"BLCTWDKPA2", 3.30129E+03, 3.26486E+03, 3.53984E+03, 3.13465E+03
"TARTPDFABOVE", 5.00000E-01, 5.00000E-01, 5.00000E-01, 5.00000E-01
"TULE KPS1", 3.35116E-03, 3.41507E-03, 3.26583E-03, 3.50039E-03
"TULE KPA2", 3.45243E+03, 3.23831E+03, 3.13824E+03, 3.35585E+03
"TULE FABOVE", 1.00000E+00, 1.00000E+00, 1.00000E+00, 1.00000E+00
"WEASELFABOVE", 1.00000E+00, 1.00000E+00, 1.00000E+00, 1.00000E+00
"WMLFOLBPORE", 4.92350E-01, 4.97657E-01, 5.28679E-01, 5.16139E-01
"WOTDADFABOVE", 1.00000E+00, 1.00000E+00, 1.00000E+00, 1.00000E+00
"WOTDTPBPORE", 4.93585E-01, 5.35813E-01, 4.94853E-01, 4.74527E-01
"WAQGS FABOVE", 8.00000E-01, 8.00000E-01, 8.00000E-01, 8.00000E-01
"WSTRGNBPORE", 9.33988E-02, 9.83106E-02, 1.03638E-01, 1.07242E-01
```

4.3.2.3 ECEM SACView Header File

The SACView header file is an output file containing information used by the interactive SACView program to allow easy extraction of subsets of the results computed by the ECEM code. This file is required for every run of the ECEM code. An example of this file is given in Table 4.4. The file contains the following sections of information:

- A header section of basic run information
- Number of realizations
- Solution times selected
- Locations used
- Analytes processed
- Species with output selected
- Solutions selected
- Output file names

The user only specifies the name of this file; users should not modify the file after it is generated by the ECEM code. See the instructions in Section 1.0 regarding the use of the SACView program. Because this file has at most a few hundred entries, the file size is always much smaller than 1 MB. File names for options not selected are set to null.

Table 4.4 Example Header File from ECEM for the SACView Program

```
type: "Ecological"
title: "2004 CA - Confirmatory ECEM keyword file"
user: "Carmen Arimescu"
name: "ECEM"
version: "3.01.004"
date: " 3 MAY 2004"
id: "20040608141858"
envfile: "/home/ANALYSIS3/Confirm-median/ESD_Confirm-median.key"
realizations: 1
times: 1
2050
locations: 3555
```



```
"UH0001", "UnsuitableForAgricul"
"UH0002", "UnsuitableForAgricul"
"UH0003", "UnsuitableForAgricul"
...
"R21I05", "NELSON ISLAND"
"R21I06", "NELSON ISLAND"
"R21I07", "NELSON ISLAND"
"R21I08", "NELSON ISLAND"
analytes: 12
"C14 ", "NR", "Carbon-14"
"Cs137 ", "NR", "Cesium-137"
"Cl36 ", "NR", "Chlorine-36"
"I129 ", "NR", "Iodine-129"
"Np237 ", "NR", "Neptunium-237"
"Se79 ", "NR", "Selenium-79"
"Sr90 ", "NR", "Strontium-90"
"Tc99 ", "NR", "Technetium-99"
"H3 ", "NR", "Tritium"
"U233 ", "NR", "Uranium-233"
"U235 ", "NR", "Uranium-235"
"U238 ", "NR", "Uranium-238"
species: 51
"QCARPS", "QA", "CARP"
"QCATFS", "QA", "CHCATF"
"QCLAMS", "QA", "CLAMS"
"QCPBSN", "QA", "CPBLSN"
"QCRYFS", "QA", "CRYFSH"
...
"UGRAPE", "TP", "grapes"
"ULFVEG", "TP", "leafy vegetables"
"UMLBRY", "TP", "mulberry"
"URTVEG", "TP", "root vegetables"
"UTRFRT", "TP", "tree fruit"
media: 0
solutions: 0
summary: "ECEM_Confirm-median_sta.Csv"
detail: "NULL"
```

4.3.2.4 ECEM Detailed Data

The detailed data file is an optional output file that contains the detailed values for body burdens and dose generated in the ECEM code. The description of the DETAILS modifier on the FILE keyword (see Section 4.4.7) explains how to activate writing this file. The solution types that can be written to the file are described in Section 4.4.4. The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file consists of six identifiers followed by a value for every generated realization. A subset of the data written to this file for a run

using two realizations is provided in Table 4.5. The header line occupies one line in the file even though it occupies two lines in the table. The following are the six identifiers on each line:

- Time: Year for which the data are valid
- Location ID: The location identifier where the data are valid
- Analyte ID: The identification of the analyte for which the data were computed
- Species ID: The identification for the species for which data were computed
- Solution type: A flag for solution type
- Units: The units associated with the computed data

Table 4.5 Excerpted Records from an ECEM Detailed Data File

"Time", "Location ID", "Analyte ID", "Specie", "Solution Type", "Units", "Values by realization"					
1990	"EL0050"	"H3	"", "RCANGS"	"BURDEN"	"pCi/kg", 8.01585E+04, 2.06622E+04
1990	"EL0050"	"H3	"", "RCANGS"	"DOSRAD"	"rad/day", 2.38039E-05, 6.13585E-06
1990	"EL0050"	"H3	"", "MAYFLY"	"BURDEN"	"pCi/kg", 1.76211E+04, 4.70257E+03
1990	"EL0050"	"H3	"", "MAYFLY"	"BMTISS"	"unitless", 1.80153E+04, 4.96552E+03
1990	"EL0050"	"H3	"", "MAYFLY"	"DOSRAD"	"rad/day", 5.23275E-06, 1.39648E-06
3000	"EL0666"	"CC14	"", "SALMJV"	"BURDEN"	"ug/kg", 2.65356E-02, 2.34807E-02
3000	"EL0666"	"CC14	"", "SALMJV"	"BMTISS"	"unitless", 2.65356E-02, 2.34807E-02
3000	"EL0666"	"CC14	"", "HRVMSE"	"BURDEN"	"ug/kg", 1.66776E-02, 1.18353E-02
3000	"EL0666"	"CC14	"", "HRVMSE"	"DOSDER"	"ug/kg/day", 0.00000E+00, 0.00000E+00
3000	"EL0666"	"CC14	"", "HRVMSE"	"DOSINH"	"ug/kg/day", 0.00000E+00, 0.00000E+00
3000	"EL0666"	"CC14	"", "HRVMSE"	"DOSING"	"ug/kg/day", 2.03146E-02, 1.79998E-02
3000	"EL0666"	"CrVI	"", "HRVMSE"	"BURDEN"	"ug/kg", 1.48222E+00, 8.03919E-01
3000	"EL0666"	"CrVI	"", "HRVMSE"	"DOSDER"	"ug/kg/day", 0.00000E+00, 0.00000E+00
3000	"EL0666"	"CrVI	"", "HRVMSE"	"DOSINH"	"ug/kg/day", 0.00000E+00, 0.00000E+00
3000	"EL0666"	"CrVI	"", "HRVMSE"	"DOSING"	"ug/kg/day", 3.80876E+00, 2.32534E+00

This file can have several rows of information for every combination of time, location, species, and analyte. Therefore, this file can become very large. As an example, a 2,800 KB file was generated for a case involving 14 locations, 10 analytes, 7 realizations, 12 times, and 4 output species. The file size directly scales with the number of analytes, locations, species, and times. The file size grows more slowly than a direct scaling by the number of realizations. The file size can be reduced by selecting fewer times, locations, output species, or solution types.

4.3.2.5 ECEM Summary Statistics

This optional file contains summary statistics for dose generated in the ECEM code. The description of the STATISTI modifier on the FILE keyword (see Section 4.4.7) explains how to activate writing this file. The solution types that can be written to the file are described in Section 4.4.4. The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file consists of six identifiers followed by summary statistics (nine percentiles, mean value, and standard deviation). A subset of the data written to this file for a run using five realizations is provided in Table 4.6. The following are the six identifiers on each line:

- Time: Year for which the data are valid
- Location ID: The location identifier where the data are valid

- Analyte ID: The identification of the analyte for which the data were computed
- Species ID: The identification for the species for which data were computed
- Solution type: A flag for solution type
- Units: The units associated with the computed data

The data for each record in this file are too long to present without line-wrapping in this document. Each record in the file occupies two lines in Table 4.6.

Table 4.6 Excerpted Records from the ECEM Summary Statistics File

"Time", "Location ID", "Specie ID", "Analyte ID", "Result Type", "Units", "Minimum", "5th Percentile", "10th Percentile", "25th Percentile", "Median", "75th Percentile", "90th Percentile", "95th Percentile", "Maximum", "Mean", "Standard Deviation"
1990,"EL0050","RCANGS","H3","BURDEN","pCi/kg", 2.54241E+01, 2.54241E+01, 2.54241E+01, 2.54241E+01, 2.73537E+04, 3.38985E+04, 4.51161E+04, 4.51161E+04, 8.01585E+04, 3.32611E+04, 2.48229E+04
1990,"EL0050","RCANGS","H3","DOSRAD","rad/day", 7.54994E-09, 7.54994E-09, 7.54994E-09, 7.54994E-09, 8.12296E-06, 1.00665E-05, 1.33977E-05, 1.33977E-05, 2.38039E-05, 9.87721E-06, 7.37140E-06
1990,"EL0050","MAYFLY","H3","BURDEN","pCi/kg", 1.22778E+01, 1.22778E+01, 1.22778E+01, 1.22778E+01, 6.70630E+03, 8.25514E+03, 1.05390E+04, 1.05390E+04, 1.76211E+04, 7.74609E+03, 5.44027E+03
1990,"EL0050","MAYFLY","H3","BMTISS","unitless", 1.23215E+01, 1.23215E+01, 1.23215E+01, 1.23215E+01, 6.88845E+03, 8.12850E+03, 1.02607E+04, 1.02607E+04, 1.80153E+04, 7.76516E+03, 5.52208E+03
1990,"EL0050","MAYFLY","H3","DOSRAD","rad/day", 3.64601E-09, 3.64601E-09, 3.64601E-09, 3.64601E-09, 1.99150E-06, 2.45145E-06, 3.12967E-06, 3.12967E-06, 5.23275E-06, 2.30028E-06, 1.61554E-06
1990,"EL0050","SALMJV","H3","BURDEN","pCi/kg", 6.28882E+00, 6.28882E+00, 6.28882E+00, 6.28882E+00, 1.38113E+03, 1.89246E+03, 2.46386E+03, 2.46386E+03, 4.66751E+03, 1.82576E+03, 1.46418E+03
1990,"EL0050","SALMJV","H3","BMTISS","unitless", 6.32028E+00, 6.32028E+00, 6.32028E+00, 6.32028E+00, 1.48005E+03, 1.87565E+03, 2.34242E+03, 2.34242E+03, 4.54303E+03, 1.81281E+03, 1.40662E+03
1990,"EL0050","SALMJV","H3","DOSRAD","rad/day", 1.86753E-09, 1.86753E-09, 1.86753E-09, 1.86753E-09, 4.10141E-07, 5.61986E-07, 7.31668E-07, 7.31668E-07, 1.38607E-06, 5.42179E-07, 4.34802E-07
1990,"EL0050","HRVMSE","H3","BURDEN","pCi/kg", 1.90977E+01, 1.90977E+01, 1.90977E+01, 1.90977E+01, 1.79798E+04, 2.42002E+04, 3.12386E+04, 3.12386E+04, 5.20661E+04, 2.18047E+04, 1.65240E+04
1990,"EL0050","HRVMSE","H3","DOSRAD","rad/day", 5.67125E-09, 5.67125E-09, 5.67125E-09, 5.67125E-09, 5.33928E-06, 7.18650E-06, 9.27663E-06, 9.27663E-06, 1.54616E-05, 6.47513E-06, 4.90697E-06
1990,"EL0050","HRVMSE","H3","DOSDER","rad/day", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
1990,"EL0050","HRVMSE","H3","DOSING","rad/day", 3.09753E+01, 3.09753E+01, 3.09753E+01, 3.09753E+01, 2.85303E+04, 3.52527E+04, 4.67677E+04, 4.67677E+04, 8.33295E+04, 3.45718E+04, 2.57908E+04
1990,"EL0050","HRVMSE","H3","DOSINH","rad/day", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
1990,"EL0050","RCANGS","CC14","BURDEN","ug/kg", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
1990,"EL0050","MAYFLY","CC14","BURDEN","ug/kg", 5.06943E-02, 5.06943E-02, 5.06943E-02, 5.06943E-02, 5.83496E-02, 6.45637E-02, 7.07093E-02, 7.07093E-02, 1.01457E-01, 6.48589E-02, 1.75829E-02
1990,"EL0050","MAYFLY","CC14","BMTISS","unitless", 5.06943E-02, 5.06943E-02, 5.06943E-02, 5.06943E-02, 5.83496E-02, 6.45637E-02, 7.07093E-02, 7.07093E-02, 1.01457E-01, 6.48589E-02, 1.75829E-02
1990,"EL0050","HRVMSE","CC14","DOSINH","ug/kg/day", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
1990,"EL0050","HRVMSE","-Rads-","SUMRAD","rad/day", 6.53884E-08, 6.53884E-08, 6.53884E-08, 6.53884E-08, 5.34093E-06, 7.32354E-06, 9.27913E-06, 9.27913E-06, 1.54730E-05, 6.51136E-06, 4.89722E-06
1990,"EL0050","MAYFLY","-Rads-","SUMRAD","rad/day", 4.00539E-05, 4.00539E-05, 4.00539E-05, 4.00539E-05, 9.29692E-05, 1.36747E-04, 2.07406E-04, 2.07406E-04, 3.78735E-04, 1.40443E-04, 1.19386E-04
1990,"EL0050","RCANGS","-Rads-","SUMRAD","rad/day", 7.54994E-09, 7.54994E-09, 7.54994E-09, 7.54994E-09, 8.12296E-06, 1.00665E-05, 1.33977E-05, 1.33977E-05, 2.38039E-05, 9.87721E-06, 7.37140E-06
1990,"EL0050","SALMJV","-Rads-","SUMRAD","rad/day", 2.13907E-06, 2.13907E-06, 2.13907E-06, 2.13907E-06, 3.69897E-06, 5.16700E-06, 7.70061E-06, 7.70061E-06, 1.60394E-05, 5.71137E-06, 4.94818E-06

This file can have several rows of information for every combination of time, location, specie, and analyte. Therefore, this file can become very large. As an example, a 3,890 KB file was generated for a case involving 14 locations, 10 analytes, 7 realizations, 12 times, and 4 output species. The file size directly scales with the number of analytes, locations, species, and times. The file size grows more slowly than a direct scaling by the number of realizations. The file size can be reduced by selecting fewer times, locations, output species, or solution types.

4.3.2.6 FCDA Map File

The file format for the map (index) file for foods (FCDA) is the following:

Header data

- Problem title: The title from the ESD keyword file
- Code Name: The name of the code that generated the file
- Code Version: The version number of the code that generated the file
- Code Date: The modification date of the code that generated the file
- User Name: The user name from the ESD keyword file
- Run ID: The run ID from the code run that generated the file
- Block Size: The number of records with data in a time block in the binary data file for aquatic species
- Block Size: The number of records with data in a time block in the binary data file for riparian species
- Block Size: The number of records with data in a time block in the binary data file for upland species
- Record Length: Record length for the binary data file
- Number of realizations: The number of realizations requested for this run
- Number of times: From the ESD keyword file
- List of ESD times, and flag whether computed, one pair per line
- Number of locations: From the ESD keyword file
- List of ESD location IDs, location names, and flag whether computed, one triple per line
- Number of species: From the ESD keyword file
- List of ESD species IDs, species names, and flag whether computer, one triple per line
- Number of upland soils: From the ECDA structure
- List of soil IDs, soil names, a pair per line (Soils are SODR, SOGW, SOSW)

The header data are followed by record index data. The index data are split into three types. One type is for aquatic locations, another type is for riparian locations, the other type is for upland locations. There are as many lines of index data as there are locations for the aquatic and riparian locations. There are three times as many lines of index data as for locations for the upland data. The index data for locations appear in the same order as the location IDs provided earlier in the file. Each line of index data contains the location ID followed by as many indices as there are food species types. The indices give an offset record number. If a particular media is not saved at a location, then the index value is set to negative 1. These lines contain data as follows:

- “Map: Aquatic Species”
- Map data for aquatic locations (map includes all locations). Each line has a Location ID, index for all aquatic species (-1 = not computed)

- “Map: Riparian Species”
- Map data for riparian locations (map includes all locations). Each line has a Location ID, index for all riparian species (-1 = not computed)
- “Map: Upland Species”
- Map data for upland locations (map includes 3 lines for all locations). Each line has Location ID, index for all upland species (-1 = not computed)

Soil indices are as follows:

- 1 = Dry land (no irrigation)
- 2 = Soil using groundwater for irrigation
- 3 = Soil using surface water for irrigation

An example record index file is provided in Table 4.7.

Table 4.7 Example FCDA Record Map File

```
"SAC Rev. 1 - Test incorporation of the FCDA Routines"
"ECEM"
"3.00.A.0"
" 4 Mar 2003"
"Paul W. Eslinger"
"20030305094258"
3,"Records in a time block - aquatic species"
4,"Records in a time block - riparian species"
16,"Records in a time block - upland species"
110,"Record length in the FCDA file"
25,"Number of realizations"
3,"Number of header lines in binary files"
198,"Number of times"
1945,T
1950,T
1955,T
...
11900,T
12000,T
12050,T
18,"Number of locations"
"TH0001",T,"TH0001 - Riparian - Pair with TH0002"
"TH0002",T,"TH0002 - River - Pair with TH0001"
"TH0017",T,"TH0017 - Riparian - Pair with TH0018"
"TH0018",F,"TH0018 - River - Pair with TH0017"
"TH0003",T,"TH0003 - Riparian - Pair with TH0004"
"TH0004",F,"TH0004 - River - Pair with TH0003"
"TH0015",T,"TH0015 - Riparian - Pair with TH0016"
"TH0016",F,"TH0016 - River - Pair with TH0015"
"TH0005",T,"TH0005 - River Only"
"TH0006",T,"TH0006 - River Only"
"TH0007",T,"TH0007 - Upland groundwater irrigated location"
"TH0008",T,"TH0008 - Upland groundwater irrigated location"
"TH0011",T,"TH0011 - Upland surface water irrigated location"
"TH0012",T,"TH0012 - Upland surface water irrigated location"
"TH0013",T,"TH0013 - Upland irrigated (both) location"
"TH0014",T,"TH0014 - Upland irrigated (both) location"
```

```

"TH0009",T,"TH0009 - Upland dry location"
"TH0010",T,"TH0010 - Upland dry location"
18,"Number of foods"
"AMCOOT",T,"American coot"
"AMCOUP",T,"American coot - upland"
"EGGS",T,"Chicken eggs - upland"
"BEAVER",T,"Beaver"
"CARP",T,"Carp"
"COYOTE",T,"Coyote"
"DAPMAG",T,"Daphnia magna"
"DENSDG",T,"Dense sedge"
"DENSUP",T,"Dense sedge - upland"
"FUNGI",T,"Fungi"
"MULBRY",T,"Mulberry"
"MULBUP",T,"Mulberry - upland"
"MULDER",T,"Mule deer"
"GRAIN",T,"Generic grain species"
"POTATO",T,"Potato"
"MILKCW",T,"Milk cow"
"PERPHY",T,"Periphyton"
"PHYPLK",T,"Phytoplankton"
"Map: Aquatic Species"
"TH0001",-1
"TH0002",4
"TH0017",-1
"TH0018",-1
"TH0003",-1
"TH0004",-1
"TH0015",-1
"TH0016",-1
"TH0005",5
"TH0006",6
"TH0007",-1
"TH0008",-1
"TH0011",-1
"TH0012",-1
"TH0013",-1
"TH0014",-1
"TH0009",-1
"TH0010",-1
"Map: Riparian Species"
"TH0001",4
"TH0002",-1
"TH0017",5
"TH0018",-1
"TH0003",6
"TH0004",-1
"TH0015",7
"TH0016",-1
"TH0005",-1
"TH0006",-1
"TH0007",-1
"TH0008",-1
"TH0011",-1
"TH0012",-1
"TH0013",-1

```

```
"TH0014",-1
"TH0009",-1
"TH0010",-1
"Map: Upland Species"
"TH0001",-1
"TH0001",-1
"TH0001",-1
"TH0002",-1
"TH0002",-1
"TH0002",-1
"TH0017",-1
"TH0017",-1
"TH0017",-1
"TH0018",-1
"TH0018",-1
"TH0018",-1
"TH0003",-1
"TH0003",-1
"TH0003",-1
"TH0004",-1
"TH0004",-1
"TH0004",-1
"TH0015",-1
"TH0015",-1
"TH0015",-1
"TH0016",-1
"TH0016",-1
"TH0016",-1
"TH0005",-1
"TH0005",-1
"TH0005",-1
"TH0006",-1
"TH0006",-1
"TH0006",-1
"TH0007",4
"TH0007",5
"TH0007",-1
"TH0008",6
"TH0008",7
"TH0008",-1
"TH0011",8
"TH0011",-1
"TH0011",9
"TH0012",10
"TH0012",-1
"TH0012",11
"TH0013",12
"TH0013",13
"TH0013",14
"TH0014",15
"TH0014",16
"TH0014",17
"TH0009",18
"TH0009",-1
"TH0009",-1
"TH0010",19
```

"TH0010", -1 "TH0010", -1

4.3.2.7 FCDA Data File

The binary food data file contains three header lines that are followed by concentration data. The header lines have the following definition:

- Record 1: Analyte ID – 6 Characters
- Record 2: Species ID – 6 Characters
- Record 3: Species Habitat – 8 Characters (AQUATIC, RIPARIAN or UPLAND)

Each of the succeeding data records has the following information (output in the following order):

- Time: Integer (kind=4)
- Location ID: 6 Characters
- Concentration values: As many concentration values as realizations, each of type Real (kind=4)

4.3.2.8 FCDA SacView Header File

The file format for the header file for foods for use by SACVIEW is an ASCII file with the following items entered sequentially. Lines in the file that contain a directive for SacView have a keyword followed by a colon. All SacView keywords are entered in lower case. All character strings are enclosed in double quote marks. An example file is provided in Table 4.8. The type of data for each line of the file are the following (the Sacview keywords are identified using bold characters):

- **type**: "FCDA" (This line never changes.)
- **title**: The problem title from the ECEM keyword file
- **user**: The user name from the ESD keyword file
- **name**: The name of the code that generated the header file
- **version**: The version number of the code that generated the file
- **date**: The modification date of the code that generated the file
- **id**: The run ID from the code run that generated the file
- **ecemfile**: The name of the ECEM keyword file controlling the food definitions
- **realizations**: The number of realizations in the data files
- **foods**: The number of foods output from ECEM
- List of food (species) ID's, food (species) type, food (species) names, one triple per line
- **times**: The number of times output from ECEM
- List of times, one value per line
- **locations**: The number of locations output from ECEM
- List of location ID's and location names one pair per line
- **analytes**: The number of analytes processed by ECEM
- List of analyte ID's, analyte types, and analyte names, one triple per line
- Number of upland soils: From the ECDA structure
- **recordmap**: The name of the record map file for FCDA files

Table 4.8 Example SacView Header File for Foods

```

type: "FCDA"
title: "SAC Rev. 1 - Testing of the FCDA Routines"
user: "Paul W. Eslinger"
name: "FCDA"
version: "1.00.A.0"
date: "30 Jan 2003"
id: "20030130170205"
ecemfile: "ECEM.key"
realizations: 25
foods: 12
"AMCOOT", "TA", "American coot"
"AMCOUP", "TA", "American coot - upland"
"CARP ", "QA", "Carp"
"COYOTE", "TA", "Coyote"
"DAPMAG", "QA", "Daphnia magna"
"DENSDG", "TP", "Dense sedge"
"DENSUP", "TP", "Dense sedge - upland"
"FUNGI ", "TP", "Fungi"
"MULBRY", "TP", "Mulberry"
"MULBUP", "TP", "Mulberry - upland"
"PERPHY", "QP", "Periphyton"
"PHYPLK", "QP", "Phytoplankton"
times: 8
2000
2005
2015
2023
2100
2400
2700
3050
locations: 10
"TH0001", "TH0001 - Riparian - Pair with TH0002"
"TH0002", "TH0002 - River - Pair with TH0001"
"TH0003", "TH0003 - Riparian - Pair with TH0004"
"TH0004", "TH0004 - River - Pair with TH0003"
"TH0005", "TH0005 - River Only"
"TH0006", "TH0006 - River Only"
"TH0007", "TH0007 - Upland irrigated location"
"TH0008", "TH0008 - Upland irrigated location"
"TH0009", "TH0009 - Upland dry location"
"TH0010", "TH0010 - Upland dry location"
analytes: 2
"CrVI", "NS", "Hexavalent Chromium"
"H3", "NR", "Tritium"
recordmap: "ECEM_Food.Map"

```

4.4 Keyword Descriptions for the ECEM Code

In the following keyword descriptions, some data are optional and some are required. Data required are enclosed in square brackets. For AB to be required, it would be denoted by [AB]. If only one of the three items AB, BC, CD were required, it would be written as [AB|BC|CD]. The vertical bars indicate to choose one of the items in the list. Optional items are enclosed in normal brackets. For DE to be an optional

entry, it would be denoted by {DE}. The {} or [] symbols are indicators of whether the data are required. These symbols are not entered when the keyword is constructed.

In some instances, numerical values or quote strings are associated with a modifier. In this description, the association is indicated by using the equal (=) symbol. The = symbol is not required but may be used when the keyword is constructed. When a numerical value or quote string is associated with a modifier, it must be physically entered on the input line directly after the modifier.

This section defines keywords needed to control the ECEM code directly. The order in which keywords are entered does not matter for many keywords. Several keywords have a required order of appearance, including the following requirements:

- The REPORT keyword must be the first keyword in the file.
- The END keyword must be the last keyword in the file.
- The SPECIES keywords (Section 4.4.15) must all be entered before the CONSUME keywords (Section 4.4.2) are entered.

4.4.1 ANALYTE Keyword for the ECEM Code

The ANALYTE keyword is used to define the analytes to be used in calculating ecological risk metrics. The following is this keyword's syntax:

```
ANALYTE [ID="quote 1"] [ELEMENT="quote 1"] {OUTPUT}
```

Analytes chosen must be a subset of the analytes used in the fate and transport activities controlled through the ESD keyword file. Multiple analyte keywords can be entered. A separate ANALYTE keyword is required for each desired analyte. The modifiers can be entered in any order. The modifiers associated with the ANALYTE keyword are described in Table 4.9.

Table 4.9 Modifiers Associated with the ANALYTE Keyword in the ECEM Code

Modifier	Description
ID	The entry associated with the ID modifier is an analyte identification string (up to six characters long). The analyte ID entered must be one of the set of analytes identified in the environmental scenario file.
ELEMENT	The entry associated with the ELEMENT modifier is the non-speciated chemical name of the analyte. The ELEMENT is used to enter the KOW and BCFVEG parameters which are equal for all analytes of the same element.
OUTPUT	The OUTPUT modifier is necessary for data to be output for this species.

The following is an example ANALYTE keyword defining zinc as an analyte that is an animal nutrient:

```
ANALYTE ID="Zn" OUTPUT
```

4.4.2 CONSUME Keyword for the ECEM Code

The CONSUME keyword is to define the diet of the species identified by the ID modifier. The following is this keyword's syntax:

```
CONSUME [ID= "Quote1"] [PREY] ["Quote2"=Value1] ... { "Quotek"=Valuek+1}
      {SOILING=valueK+2} {SEDING=valuek+3}
```

The diet is defined by entering a series of prey species ID's. Each prey species ID must be immediately followed by the normalized fraction of the diet coming from the prey species. If any prey species are entered, the sum of normalized diet fractions must sum to 1. The optional SEDING modifier can be used to identify incidental sediment ingestion for aquatic species while the optional modifier SOILING can be used to identify incidental soil ingestion for terrestrial species. The modifiers associated with the CONSUME keyword are described in Table 4.10.

Table 4.10 Modifiers Associated with the CONSUME Keyword in the ECEM Code

Modifier	Description
ID	The entry associated with the ID modifier is an analyte identification string (up to six characters long). The analyte ID entered must be one of the set of analytes identified in the environmental scenario file.
SEDING	Optional sediment ingestion rate for this aquatic species entered as a fraction of diet.
SOILING	Optional soil ingestion rate for this riparian or terrestrial species entered as a fraction of diet.
PREY	The list of prey species consumed and consumption rates as a fraction of diet for this predator species.

The following are example CONSUME keywords for carp and riparian beaver:

```
CONSUME ID="QCARPS" PREY
  "QCPBSN" 0.15000
  "QMAYFL" 0.25000
  "QPERIP" 0.50000
  "QMLFOL" 0.10000
  SEDING 0.16000
```

```
CONSUME ID="RBEAVR" PREY
  "RCTWOD" 0.50000
  "RMLBRY" 0.50000
  SOILING 0.09000
```

4.4.3 DEBUG Keyword for the ECEM Code

The DEBUG keyword is used to activate dumping of intermediate calculations to the report file. It should be used sparingly and with only one or two realizations; otherwise, the volume of output could fill the user's hard drive. The following is this keyword's syntax:

```
DEBUG [modifier 1] {modifier 2}...{modifier k}
```

Multiple DEBUG cards can be entered with combinations of modifiers, or a single card can be entered containing all of the modifiers. The modifiers can be entered in any order. Table 4.11 describes the modifiers associated with the DEBUG keyword.

Table 4.11 Modifiers Associated with the DEBUG Keyword in the ECEM Code

Modifier	Description
AIR	Intermediate outputs on calculations for air calculations.
ANALYTES	Intermediate results for analyte information.
CONCENTR	Intermediate outputs for concentration data.
CONSTANT	Intermediate outputs for constant data.
RADSUM	Intermediate results for radioactive doses.
GENERATE	Intermediate results for the stochastic variable generation.
LOOP	Messages on the control looping.
SPECIES	Intermediate results for species information.
VERBOSE	Additional messages to the screen showing simulation progress.
OR_QP	Intermediate results for organic radioactive analytes and aquatic plants.
OR_TP	Intermediate results for organic radioactive analytes and terrestrial plants.
OR_QA	Intermediate results for organic radioactive analytes and aquatic animals.
OR_TA	Intermediate results for organic radioactive analytes and terrestrial animals.
NR_QP	Intermediate results for inorganic radioactive analytes and aquatic plants.
NR_TP	Intermediate results for inorganic radioactive analytes and terrestrial plants.
NR_QA	Intermediate results for inorganic radioactive analytes and aquatic animals.
NR_TA	Intermediate results for inorganic radioactive analytes and terrestrial animals.
OS_QP	Intermediate results for organic stable analytes and aquatic plants.
OS_TP	Intermediate results for organic stable analytes and terrestrial plants.
OS_QA	Intermediate results for organic stable analytes and aquatic animals.
OS_TA	Intermediate results for organic stable analytes and terrestrial animals.
NS_QP	Intermediate results for inorganic stable analytes and aquatic plants.
NS_TP	Intermediate results for inorganic stable analytes and terrestrial plants.
NS_QA	Intermediate results for inorganic stable analytes and aquatic animals.
NS_TA	Intermediate results for inorganic stable analytes and terrestrial animals.

The following entries provide examples of the use of the DEBUG keyword:

```
DEBUG ANALYTES
DEBUG RADSUM
DEBUG OR_TA NR_TA OS_TA NS_TA
```

There are no quote strings associated with the DEBUG keyword.

4.4.4 DETAILS Keyword for the ECEM Code

The DETAILS keyword is used to control writing detailed data to the output details file for a variety of solution types. The following is this keyword's syntax:

```
DETAILS [modifier 1] {modifier 2}...{modifier 6}
```

Multiple DETAILS cards can be entered with combinations of modifiers, or a single card can be entered containing all of the modifiers. The modifiers can be entered in any order. Table 4.12 describes the modifiers associated with the DETAILS keyword.

Table 4.12 Modifiers Associated with the DETAILS Keyword in the ECEM Code

Modifier	Description
BURDEN	Presence of the BURDEN modifier initiates output of the body burden (tissue concentrations) for every species and analyte where the species output flag is used (see the SPECIES keyword).
CONCEN	Presence of the CONCEN modifier initiates output of the water, sediment, and soil concentration data used in the calculations. The media identifiers are: <ul style="list-style-type: none">• SW denotes surface water (river)• PW denotes pore water (river bottom)• GW denotes groundwater• SE denotes seep water (river bank)• SO denotes soil• SD denotes sediment (river bottom)
DOSDER	Presence of the DOSDER modifier initiates output of the dermal dose for terrestrial animal species and all analytes where the species output flag is used (see the SPECIES keyword).
DOSING	Presence of the DOSDER modifier initiates output of the ingestion dose for terrestrial animal species and all analytes where the species output flag is used (see the SPECIES keyword).
DOSINH	Presence of the DOSDER modifier initiates output of the inhalation dose for terrestrial animal species and all analytes where the species output flag is used (see the SPECIES keyword).

Modifier	Description
DOSHAZ	Presence of the DOSHAZ modifier initiates output of the inhalation dose for terrestrial animal species and all analytes where the species output flag is used (see the SPECIES keyword).
DOSRAD	Presence of the DOSRAD modifier initiates output of the radioactive dose for animal and plant species and all radioactive analytes where the species output flag is used (see the SPECIES keyword).
BMTISS	Presence of the BMTISS modifier initiates output of the benchmark comparison for animal and plant species exposed to radioactive analytes where the species output flag is used (see the SPECIES keyword).
SUMRAD	Presence of the DOSRAD modifier initiates output of the radioactive dose summed over all radioactive analytes for animal and plant species when the species output flag is used (see the SPECIES keyword).

The following entries provide examples of the use of the DETAILS keyword:

```
DETAILS DOSRAD SUMRAD
DETAILS SUMRAD
DETAILS DOSING DOSDER BURDEN
```

There are no quote strings associated with the DETAILS keyword.

4.4.5 END Keyword for the ECEM Code

The END keyword signifies the end of all keyword data. It should be the last keyword in the keyword file. All data in the keyword file after the END keyword will be ignored. The following is this keyword's syntax:

```
END
```

There are no modifiers or quote strings associated with the END keyword.

4.4.6 EXECUTE Keyword for the ECEM Code

The EXECUTE keyword signifies that the user wishes to perform problem execution. If this keyword is not entered, then the inputs are checked for consistency, but the problem will not be executed. This is useful if the run being set up is expected to take a significant amount of computation time. The following is this keyword's syntax:

```
EXECUTE
```

There are no modifiers or quote strings associated with the EXECUTE keyword.

4.4.7 FILE Keyword for the ECEM Code

The FILE keyword is used to enter the names of input and output files except for the report file. The names of the files providing concentration data are contained in the environmental scenario file rather than in the keyword file. The following is this keyword's syntax:

```
FILE [modifier1 "quote1"] {modifier2 "quote2"} ... {modifier5 "quote5"}
```

The file names are entered in quote strings, which must be enclosed in double quotation marks. Path names up to 200 characters long are supported. The file name associated with a modifier must be entered before the next modifier is entered. At least one FILE keyword is required for every run of the code. Table 4.13 describes the modifiers associated with the FILE keyword.

Table 4.13 Modifiers Associated with the FILE Keyword in the ECEM Code

Modifier	Description
DETAILS	Optional output file containing detailed solutions by realization.
ESD	Required input keyword file (environmental settings definitions) that contains problem definition information for the release and transport codes and information specific to the ECEM code.
HEADER	Required output file containing header type information associated with all of the other output files identified in this table.
THRESHOL	Optional output file containing exceedance probabilities for user-specified thresholds. See the THRESHOLD keyword (Section 4.4.18) for more detailed information.
STATISTI	Optional output file containing summary statistics for all calculations.
VALUES	Optional output file containing generated values for all stochastic variables. This file is recommended because it contains data required to support uncertainty analyses.

The following two entries define the file for detailed calculations and the header file for use by SACView:

```
FILE DETAILS "TestCase.det"  
FILE HEADER "/home/ANALYSIS/Median2/ecem/TestCase.hdr"
```

4.4.8 FOODS Keyword for the ECEM Code

The FOODS keyword is used to designate the location where the FCDA files are to be written and to identify the name of the map file associated with these FCDA files. The following is this keyword's syntax:

```
FOODS [PATH= "quote1"] [MAP= "quote2"] [SACVIEW= "quote3"]
```

The file names are entered in quote strings, which must be enclosed in double quotation marks. Path names up to 200 characters long are supported. The file name associated with a modifier must be entered before the next modifier is entered. At least one FOODS keyword is required for every run of the code. Table 4.14 describes the modifiers associated with the FOODS keyword.

Table 4.14 Modifiers Associated with the FOODS Keyword in the ECEM Code

Modifier	Description
PATH	The complete path name identifying the location to which FOOD files are to be written for use by the HUMAN code.
MAP	The name of the file containing the map of the FOOD file contents.
SACVIEW	The file name of the header file for the FOOD files needed for SACView.

The following entry defines the map file and data directory for food concentrations and the header file for use by SACView:

```
FOODS PATH="D:\SAC\CODES_1\ECEM\FOODS\  
MAP="ECEM_FCDA_Map.Dat"  
SACVIEW="ECEM_FCDA.Hdr"
```

4.4.9 GROWTH Keyword for the ECEM Code

The GROWTH keyword is used to define the parameters of the growth rate equation described in Section 4.1.2.1. The following is this keyword's syntax:

```
GROWTH DELTA=value1 BETA=value2
```

These modifiers can be entered in any order, together with their associated data. The following example illustrates the use of the GROWTH keyword:

```
GROWTH DELTA=0.002 BETA=0.25
```

4.4.10 LOCATION Keyword for the ECEM Code

The LOCATION keyword identifies the locations for ecological impact calculations that will be generated. Multiple LOCATION keywords are allowed. The locations must be a subset of the locations at which environmental data were computed and stored by the inventory, release, and transport modules. The list of desired locations builds sequentially with each LOCATION record. Upon program entry, no locations are active. The following is this keyword's syntax:

```
LOCATION [PRIMARY="quote 1"] {SECOND="quote 2"} (OUTPUT)
```

The ecological impacts module is activated at a location by entering the location ID string in association with the PRIMARY modifier. A separate LOCATION keyword is required for every desired location. The function of the SECOND modifier is to supply concentrations from other locations that may not be

computed at the primary location. If the SECOND location is not entered, impacts are calculated using only concentrations available at the primary location. Table 4.15 describes the modifiers associated with the LOCATION keyword.

Table 4.15 Modifiers Associated with the LOCATION Keyword in the ECEM Code

Modifier	Description
PRIMARY	The entry associated with the PRIMARY modifier is an ecological location identification string (up to six characters in length). The location ID entered must be one of the suite of locations identified in the environmental scenario file.
SECOND	The entry associated with the SECOND modifier is an ecological location identification string (up to six characters in length). The location ID entered must be one of the suite of locations identified in the environmental scenario file.
OUTPUT	The OUTPUT modifier is necessary for data to be output for the location.

For example, the primary location may be in the riparian zone, but a food chain including river species is being modeled. The primary location would be on land, and the secondary location should be chosen as the nearest river location. The following are example LOCATION keywords:

```
LOCATION PRIMARY="EL #001"  
LOCATION PRIMARY="EL #002" SECOND="EL #001"
```

4.4.11 REALIZATION Keyword for the ECEM Code

The REALIZATION keyword defines the number of realizations to generate. The following is this keyword's syntax:

```
REALIZATION value1
```

The integer value1 has a minimum value of 1 and a maximum of the number of realizations defined in the environmental settings definition file. If the number of realizations is less than the number of realizations in the concentration data files, then only the first realizations will be used.

The following keyword record sets the number of realizations to 10:

```
REALIZAT 10
```

4.4.12 REPORT Keyword for the ECEM Code

The REPORT keyword is used to define the name of the output report (log) file. It must be the first keyword entered in the keyword file. The following is this keyword's syntax:

```
REPORT ["quote"]
```

The name of the report file is entered in a quote string. File names up to 72 characters long are supported, and path names can be optionally included. The following is an example REPORT keyword record:

```
REPORT "G:\SAC\SystemCodes\ECEM\Test1.rpt"
```

4.4.13 RESPIRE Keyword for the ECEM Code

The RESPIRE keyword is used to define the parameters of the respiration rate equation described in Section 4.1.2.1. This respiration equation only applies to water-respiring species. The following is this keyword's syntax:

```
RESPIRE GAMMA=value1 PHI=value2
```

The two modifiers can be entered in any order, together with their associated data. The following example illustrates the use of the RESPIRE keyword:

```
RESPIRE PHI=0.032 GAMMA=0.2
```

4.4.14 SEED Keyword for the ECEM Code

The SEED keyword sets the value for the seed for the random number generator. The following is this keyword's syntax:

```
SEED Value1
```

The value for Value1 must be an integer or real number in the range 1 to 999999. The following is an example keyword record:

```
SEED 344443
```

There are no quote strings or modifiers associated with the SEED keyword.

4.4.15 SPECIES Keyword for the ECEM Code

The SPECIES keyword is used to select the species to be simulated in the ECEM code. The following is this keyword's syntax:

```
SPECIES [ID="quote1"] [SEDING=value] {OUTPUT}
```

A separate SPECIES keyword must be entered for every species being modeled. The ID modifier must be matched with a quote string containing a unique ID that matches one of the species defined in the ESD file (see the SPECIES keyword in Section 2.3.8). The optional OUTPUT modifier initiates output of all information invoked by the DETAILS and STATISTICS keywords for this specie. If no OUTPUT modifiers are entered for any species, then no summary statistics or detailed data will be output.

The modifier SEDING allows the user to override the value in the ESD keyword file for the fraction of diet for this species that comes from ingestion of sediment. This value applies only to animal species. The entered value must be in the range 0 to 1. The sum of all consumption for an animal species (see the CONSUME keyword in Section 4.4.2) must be 1 after sediment ingestion is added.

4.4.16 STATISTIC Keyword for the ECEM Code

The STATISTIC keyword is used to control writing summary statistics to the summary statistics file for a variety of solution types. The following is this keyword's syntax:

```
STATISTIC [modifier 1] {modifier 2}...{modifier 6}
```

Multiple STATISTIC cards can be entered with combinations of modifiers, or a single card can be entered containing all of the modifiers. The modifiers can be entered in any order. Table 4.16 describes the modifiers associated with the STATISTIC keyword.

Table 4.16 Modifiers Associated with the STATISTIC Keyword in the ECEM Code

Modifier	Description
DEFINE	The presence of this modifier controls the writing of stochastic variables to the report file.
GENERATE	The presence of this modifier controls the writing of statistics for generated values to the report file.
BURDEN	Presence of the BURDEN modifier initiates output of summary statistics of the body burden (tissue concentrations) for every species and analyte where the species output flag is used (see the SPECIES keyword).
CONCEN	Presence of the CONCEN modifier initiates output of summary statistics for the water, sediment, and soil concentration data used in the calculations. The media identifiers are: <ul style="list-style-type: none">• SW denotes surface water (river)• PW denotes pore water (river bottom)• GW denotes ground water• SE denotes seep water (river bank)• SO denotes soil• SD denotes sediment (river bottom)
DOSDER	Presence of the DOSDER modifier initiates output of summary statistics of the dermal dose for terrestrial animal species and all analytes where the species output flag is used (see the SPECIES keyword).
DOSING	Presence of the DOSING modifier initiates output of summary statistics of the ingestion dose for terrestrial animal species and all analytes where the species output flag is used (see the SPECIES keyword).

Modifier	Description
DOSINH	Presence of the DOSDER modifier initiates output of summary statistics of the inhalation dose for terrestrial animal species and all analytes where the species output flag is used (see the SPECIES keyword).
DOSHAZ	Presence of the DOSHAZ modifier initiates output of summary statistics of the inhalation dose for terrestrial animal species and all analytes where the species output flag is used (see the SPECIES keyword).
DOSRAD	Presence of the DOSRAD modifier initiates output of summary statistics of the radioactive dose for animal and plant species and all radioactive analytes where the species output flag is used (see the SPECIES keyword).
BMTISS	Presence of the BMTISS modifier initiates output of summary statistics of the benchmark tissue values for animal and plant species exposed to radioactive analytes where the species output flag is used (see the SPECIES keyword).
SUMRAD	Presence of the DOSRAD modifier initiates output of summary statistics of the radioactive dose summed over all radioactive analytes for animal and plant species when the species output flag is used (see the SPECIES keyword).

The following entries provide examples of the use of the STATISTIC keyword:

```

STATISTIC DOSRAD
STATISTIC DOSING BMTISS

```

There are no quote strings associated with the STATISTIC keyword.

4.4.17 STOCHASTIC Keyword for the ECEM Code

The STOCHASTIC keyword is used to enter the definition of a statistical distribution for stochastic variables. The following is this keyword's syntax:

```

STOCHASTIC ["Quote1"] [Dist_Index Parameters] {TRUNCATE U1 U2} {"Quote2"}

```

The entry for Quote1 must be a unique character string of up to 20 characters that will be used to identify this stochastic variable in subsequent uses. It is case sensitive and embedded spaces are significant. It is sometimes useful to make the character string some combination of a variable name and other data such that it can be recreated easily when stochastic data are needed. The entry for Quote2 is a description for the stochastic variable that can be up to 64 characters long. An entry for Quote2 is not required.

The entry for Dist_Index must be an integer in the range 1 to 11 that identifies the index of a statistical distribution. The available statistical distributions are defined in Section 0 Table 11.1. The word Parameters in the general syntax statement indicates the numerical values of parameters required for defining the statistical distribution. The additional modifier TRUNCATE can be used for all distribution types except 1, 3, and 10 (constant, discrete uniform, and user defined). If TRUNCATE is entered, it must be followed by two values in the interval 0 to 1, inclusive. The lower value must be less than the

upper value. These two values specify the tail probabilities at which to impose range truncation for the distribution. Truncation data must be entered after all of the other parameters that define the distribution.

The following is an example stochastic card for a bioconcentration factor that is normally distributed with a mean of 125 and a standard deviation of 5 for a frog exposed to carbon-14:

```
STOCHASTIC "BCFC14Frog" 7 125.0 5.0 "Example number 1"
```

Although this section gives the general form of a STOCHASTIC keyword entry, it does not describe the entire set of STOCHASTIC keywords required to run the ECEM code. Section 4.5 provides a more complete set of example STOCHASTIC keywords. Table 4.17 provides the example keywords grouped by variable type.

Table 4.17 Cross Reference to Example STOCHASTIC Keywords for the ECEM Code

Dependencies	Cross Reference
Analyte, Species	Table 4.20 Example ECEM Keywords for the Growth Model for Terrestrial Animals.
Analyte	Table 4.21 Example ECEM Keywords for the Root Uptake Model for Terrestrial Plants.
Species	Table 4.22 Example ECEM Keywords for the Time Fraction Aquatic Animals Spend Above Water.
Analyte, Species	Table 4.23 Example ECEM Keywords for the Depuration Rate for Animal Species.
Analyte, Species	Table 4.24 Example ECEM Keywords for the Chemical Assimilation for Aquatic Animal Species.
Analyte, Species	Table 4.25 Example ECEM Keywords for the Bioconcentration Factor for Aquatic Animal Species.
Analyte, Species	Table 4.26 Example ECEM Keywords for the Metabolism Loss Rate for Aquatic Species.
Species	Table 4.27 Example ECEM Keywords for Plant-Air Partition Coefficients.
Species	Table 4.28 Example ECEM Keywords for the Fraction of Time Aquatic Species Spend in Pore Water.

4.4.18 THRESHOLD Keyword for the ECEM Code

As an optional calculation, up to two threshold values can be provided by the user and used to compare calculated doses and body burdens. The values of the thresholds are entered using the THRESHOLD

keyword. Two types of threshold can be supplied. The SUMRAD modifier is used for a total radioactive dose only by species. For all other modifiers, the thresholds apply by analyte and species. The following is this keyword's syntax:

```
THRESHOLD [TYPE=[ BURDEN | DOSDER | DOSING | DOSINH | DOSRAD |
BMTISS | SUMRAD ]] [SPECIE="quote1"] {ANALYTE="quote2"}
{LIMIT1=value1} {LIMIT2=value2}
```

Table 4.18 describes the modifiers for the THRESHOLD keyword.

Table 4.18 Modifiers Associated with the THRESHOLD Keyword in the ECEM Code

Modifier	Description
ANALYTE	The quote string associated with the ANALYTE modifier is an analyte ID. If the SUMRAD modifier is used, the ANALYTE modifier should be omitted (it is ignored). The analyte ID must match with one of the analytes in the ESD file.
SPECIES	The quote string associated with the SPECIES modifier is a species ID that identifies the species for which this threshold applies.
TYPE	The quote string associated with the TYPE modifier identifies the type of solution for this threshold calculation. The following are valid entries for the quote string: <ul style="list-style-type: none"> • BURDEN: Body burden (tissue concentration) • DOSDER: Dermal dose • DOSRAD: Radioactive dose • DOSING: Ingestion dose • DOSINH: Inhalation dose • DOSDER: Dermal dose • BMTISS: Benchmark tissue value for aquatic species • SUMRAD: Sum of the radionuclide dose over analytes
LIMIT1	This modifier identifies a user-specified threshold for calculation of an exceedance probability. The limit is applicable to a specific combination of solution type, species, and analyte.
LIMIT2	This modifier identifies a second user-specified threshold for calculation of an exceedance probability. The limit is applicable to a specific combination of solution type, species, and analyte.

An example of a set of THRESHOLD keywords is given in the following:

```
THRESHOLD TYPE="BURDEN" ANALYTE="C14" SPECIE="CHCATF"
LIMIT1=0.005 LIMIT2=0.01
THRESHOLD TYPE="DOSRAD" ANALYTE="C14" SPECIE="CHCATF"
LIMIT1=0.04 LIMIT2=0.065
THRESHOLD TYPE="SUMRAD" SPECIE="CHCATF" LIMIT2=23.4
```

4.4.19 TIMES Keyword for the ECEM Code

The TIMES keyword identifies the times at which the calculations are to be performed. The following is this keyword's syntax:

```
TIMES [ [T1] {T2} ... {Tn} | {ALL} ]
```

The numerical entries T1, T2, ..., Tn are the times (whole number years) when outputs are desired. These times must be a subset of the times at which environmental data were computed and stored by the inventory, release, and transport modules. Multiple TIMES keywords can be entered. If the modifier ALL is used, results will be calculated for every time in the ESD keyword file. If the modifier ALL is used, no numerical values should be entered. The following is an example TIMES keyword that requests output for the three years 2020, 2075, and 3014:

```
TIMES 2020 2075 3014
```

There are no quote strings associated with the TIMES keyword.

4.4.20 TITLE Keyword for the ECEM Code

The TITLE keyword is used to define a single-line problem title. The problem title will be written to output files. If the title is not supplied, then the program will error terminate. The following is this keyword's syntax:

```
TITLE ["quote"]
```

The title is entered in a quote string, which must be enclosed in double quotation marks. Titles up to 72 characters long are supported. The following example defines a title for a run of the code:

```
TITLE "Example title line for the Ecological impacts code."
```

There are no modifiers associated with the TITLE keyword.

4.4.21 USER Keyword for the ECEM Code

The USER keyword is used to identify the user of the program. The user name will be written to output files. If the user name is not supplied, then the program will error terminate. The following is this keyword's syntax:

```
USER ["quote"]
```

The user name is entered in a quote string, which must be enclosed in double quotation marks. User names up to 16 characters long are supported. The following example defines John Q. Public as the user running the code:

```
USER "John Q. Public"
```

There are no modifiers associated with the USER keyword.

4.4.22 VARIABLE Keyword for the ECEM Code

The VARIABLE keyword is used to enter values for several variables that are constant rather than stochastic. The following is this keyword's syntax:

```
VARIABLE {TUPTAKE=V1} {COWHDFX=V2} {EXPOSI=V3} {GASCON=V4}  
        {RFRAC=V6} {AREA=V7} {LENGTH=V8}
```

Table 4.19 describes the modifiers associated with the VARIABLE keyword. Multiple VARIABLE keywords can be entered, each with a portion of the modifiers. If a modifier is entered more than once, the last definition is the one used in the calculations.

Table 4.19 Modifiers Associated with the VARIABLE Keyword in the ECEM Code

Modifier	Description
COWHDFX	Cowherd function for terrestrial plants and animals (unitless).
EXPOSI	Exposure interval for terrestrial plants and animals (seconds).
GASCON	Universal gas constant (pascal-m ³ /mole-K) used in terrestrial plant calculations.
RFRAC	Respirable fraction for terrestrial plants and animals (gram/m ² -hr).
AREA	Area of contamination for terrestrial plants and animals (cm ²).
LENGTH	Length of side of contaminated area for terrestrial plants and animals (m).

The following are example keywords defining this suite of variables for terrestrial plants:

```
VARIABLE COWHDFX      0.0497 EXPOSI      7.9E+8  
VARIABLE GASCON       8.314  
VARIABLE RFRAC        0.036  
VARIABLE AREA         500.0 LENGTH      1000.0
```

There are no quote strings associated with the VARIABLE keyword.

4.5 Example Stochastic Keywords for the ECEM Code

Typically, a large number of STOCHASTIC keywords are needed for a run of the ECEM code. For example, one run of the code with 10 analytes and 57 species required 4085 STOCHASTIC keywords. The exact number of keywords for a run depends on the number and type of analytes and the number and type of species. The general description of a STOCHASTIC keyword for the ECEM code is provided in Section 4.4.17. Additional information about statistical distributions is provided in Section 11.0.

The general description of the STOCHASTIC keyword uses two quote strings. The first quote string is used to associate a specific statistical distribution to a variable in the code. The second quote string is a descriptive phrase used only for labeling purposes in output files. The first quote string, which must be

unique, is a combination of analyte ID, species ID, and variable name. Character case and embedded spaces change the definition of the quote string. Table 4.20 gives example keywords for terrestrial species for a number of variables. In each case, the first quote string is the concatenation of the analyte ID (blank padded to six characters in length if necessary), the species ID (blank padded to six characters in length if necessary), and a variable name.

The first two example keywords in the table define the inhalation absorption factor (ALPHAVAP or α_{vapi}) for terrestrial animals (see Section 4.1.1.2.4). The second set of two example keywords defines the inhalation particulate absorption factor (ALPHAPAR or α_{pari}) for terrestrial animals (see Section 4.1.1.2.5). The third set of two example keywords defines the ingestion absorption factor (ALPHAING or α_{ingi}) for terrestrial animals (see Section 4.1.1.2.7). The fourth set of two example keywords defines the dermal permeability for soil (ALPHADS or α_{dci}) for terrestrial animals (see Section 4.1.1.2.1). The fifth set of two example keywords defines the dermal absorption for water (ALPHADW or K_{pi}) for terrestrial animals (see Section 4.1.1.2.2). If there were 10 analytes and 17 terrestrial animals, then five groups of 170 STOCHASTIC keywords would be required instead of the five groups of two example keywords.

Table 4.20 Example ECEM Keywords for the Growth Model for Terrestrial Animals

Analyte	Species	Variable	Description	Units	Statistical Distribution
CCl4	AMCOOT	ALPHAVAP (α_{vapi})	Inhalation absorption factor for CCl4 and AMCOOT	unitless	Triangular on Lower Limit .36, Mode .4, Upper Limit .44
STOCHASTIC "CCl4 AMCOOTALPHAVAP" 6 3.600E-01 4.000E-01 4.400E-01 "Inhalation absorption factor for CCl4 and AMCOOT"					
Cs137	COYOTE	ALPHAVAP (α_{vapi})	Inhalation absorption factor for Cs137 and COYOTE	unitless	Triangular on Lower Limit .421, Mode .468, Upper Limit .515
STOCHASTIC "Cs137 COYOTEALPHAVAP" 6 4.21E-01 4.68E-01 5.15E-01 "Inhalation absorption factor for Cs137 and COYOTE"					
CCl4	AMCOOT	ALPHAPAR (α_{pari})	Inhalation particulate absorption factor for CCl4 and AMCOOT	unitless	Triangular on Lower Limit .36, Mode .4, Upper Limit .44
STOCHASTIC "CCl4 AMCOOTALPHAPAR" 6 3.600E-01 4.000E-01 4.400E-01 "Inhalation particulate absorption factor for CCl4 and AMCOOT"					

Analyte	Species	Variable	Description	Units	Statistical Distribution
CrVI	CARP	ALPHAPAR (α_{pari})	Inhalation particulate absorption factor for CrVI and CARP	unitless	Triangular on Lower Limit .288, Mode .32, Upper Limit .352
STOCHASTIC "CrVI CARP ALPHAPAR" 6 2.88E-01 3.20E-01 3.52E-01 "Inhalation particulate absorption factor for CrVI and CARP"					
AMCOOT		ALPHAING (α_{ingi})	Ingestion absorption factor for CCl4 and AMCOOT	unitless	Triangular on Lower Limit .585, Mode .65, Upper Limit .715
STOCHASTIC "CCl4 AMCOOTALPHAING" 6 5.850E-01 6.500E-01 7.150E-01 "Ingestion absorption factor for CCl4 and AMCOOT"					
CrVI	CARP	ALPHAING (α_{ingi})	Ingestion absorption factor for CrVI and CARP	Unitless	Triangular on Lower Limit .027, Mode .03, Upper Limit .033
STOCHASTIC "CrVI CARP ALPHAING" 6 2.70E-02 3.00E-02 3.30E-02 "Ingestion absorption factor for CrVI and CARP"					
CCl4	AMCOOT	ALPHADS (α_{dei})	Dermal permeability (soil) for CCl4 and AMCOOT	unitless	Triangular on Lower Limit .009, Mode .01, Upper Limit .011
STOCHASTIC "CCl4 AMCOOTALPHADS " 6 9.000E-03 1.000E-02 1.100E-02 "Dermal permeability (soil) for CCl4 and AMCOOT"					
CrVI	CARP	ALPHADS (α_{dei})	Dermal permeability (soil) for CrVI and CARP	unitless	Triangular on Lower Limit .0031, Mode .00344, Upper Limit .00378
STOCHASTIC "CrVI CARP ALPHADS " 6 3.10E-03 3.44E-03 3.78E-03 "Dermal permeability (soil) for CrVI and CARP"					

Analyte	Species	Variable	Description	Units	Statistical Distribution
CCl4	AMCOOT	ALPHADW (K _{pi})	Dermal absorption (water) for CCl4 and AMCOOT	cm/hr	Triangular on Lower Limit .0198, Mode .022, Upper Limit .0242
STOCHASTIC "CCl4 AMCOOTALPHADW " 6 1.980E-02 2.200E-02 2.420E-02 "Dermal absorption (water) for CCl4 and AMCOOT"					
Cs137	COYOTE	ALPHADW (K _{pi})	Dermal absorption (water) for Cs137 and COYOTE	cm/hr	Constant 0
STOCHASTIC "Cs137 COYOTEALPHADW " 1 0 "Dermal absorption (water) for Cs137 and COYOTE"					

The model for converting root uptake of analytes to above-ground plant-tissue concentrations requires a value for the octanol-water partitioning coefficient (KOW or K_{ow}) (see Section 4.1.1.1.2). A STOCHASTIC keyword for the KOW variable is needed for every combination of terrestrial plant species and analyte. Table 4.21 provides example keywords for this variable. The first quote string for the STOCHASTIC keywords would hold the concatenation of the analyte ID (blank padded to six characters long, if necessary) and the variable name KOW. A STOCHASTIC keyword is also needed for every combination of terrestrial plant and analytes for the bioconcentration factor for vegetation (BCFVEG or Bv) (see Section 4.1.1.1.2). The first quote string for the STOCHASTIC keywords for bioconcentration values would hold the concatenation of the analyte ID (blank padded to six characters long, if necessary) and the variable name BCFVEG.

Table 4.21 Example ECEM Keywords for the Root Uptake Model for Terrestrial Plants

Analyte	Variable	Description	Units	Statistical distribution
CCl4	K _{ow}	Octanol-water partition coefficient for CCl4	Unitless	Lognormal on Mean – 436.0, Standard deviation of Logarithms 21.8
STOCHASTIC "CCl4 KOW" 7 436.0 21.8 "Octanol-water partition coefficient for CCl4"				
CrVI	K _{ow}	Octanol-water partition coefficient for CrVI	Unitless	Constant 1.0
STOCHASTIC "CrVI KOW" 1 1.0 "Octanol-water partition coefficient for CrVI"				

Analyte	Variable	Description	Units	Statistical distribution
Sr90	BCFVEG (Bv)	Bioconcentration factor for Sr90 in vegetation	kg-soil/kg-dry- plant	Triangular on Lower Limit 14.2, Mode 15.8, Upper Limit 17.4
STOCHASTIC "Sr90 BCFVEG" 6 1.42E+01 1.58E+01 1.74E+01 "Bioconcentration factor for Sr90 in vegetation"				
Tc99	BCFVEG (Bv)	Bioconcentration factor for Tc99 in vegetation	kg-soil/kg-dry- plant	Triangular on Lower Limit 19.1, Mode 21.2, Upper Limit 23.3
STOCHASTIC "Tc99 BCFVEG" 6 1.91E+01 2.12E+01 2.33E+01 "Bioconcentration factor for Tc99 in vegetation"				

Calculation of the external dose from contact with sediment for aquatic species requires information about the fraction of time the species spends above water. The equation for this calculation is given in Section 4.1.3.2.3. A distinct STOCHASTIC keyword is needed for every aquatic species for this variable, and three examples are given in Table 4.22. The first quote string for the STOCHASTIC keywords would hold the concatenation of the species ID (blank padded to six characters long, if necessary) and the variable name FABOVE.

Table 4.22 Example ECEM Keywords for the Time Fraction Aquatic Animals Spend Above Water

Species	Variable	Description	Units	Statistical Distribution
AMCOOT	FABOVE	Fraction of time spent above water for AMCOOT	Unitless	Constant 1.0
STOCHASTIC "AMCOOTFABOVE" 1 1.0 "Fraction of time spent above water for AMCOOT"				
AMKSTL	FABOVE	Fraction of time spent above water for AMKSTL	Unitless	Constant 1.0
STOCHASTIC "AMKSTLFABOVE" 1 1.0 "Fraction of time spent above water for AMKSTL"				

Calculation of doses for animal species from dermal contact with contaminants is dependent on the depuration rate of the species (see Section 4.1.1.2.1). A distinct STOCHASTIC keyword is needed for every animal species for this variable, and three examples are given in Table 4.23. The first quote string for the STOCHASTIC keywords would hold the concatenation of the analyte ID (blank padded to six characters in length, if necessary), the species ID (blank padded to 6 characters in length, if necessary) and the variable name DEPRATE.

Table 4.23 Example ECEM Keywords for the Depuration Rate for Animal Species

Analyte	Species	Variable	Description	Units	Statistical Distribution
CCl4	AMCOOT	DEPRATE (K_{ei})	Depuration rate of AMCOOT for CCl4	1/day	Triangular on Lower Limit .765, Mode .85, Upper Limit .935
STOCHASTIC "CCl4 AMCOOTDEPRATE" 6 7.650E-01 8.500E-01 9.350E-01 "Depuration rate of AMCOOT for CCl4"					
CrVI	CARP	DEPRATE (K_{ei})	Depuration rate of CARP for CrVI	1/day	Triangular on Lower Limit .0468, Mode .052, Upper Limit .0572
STOCHASTIC "CrVI CARP DEPRATE" 6 4.680E-02 5.200E-02 5.720E-02 "Depuration rate of CARP for CrVI"					
Cs137	COYOTE	DEPRATE (K_{ei})	Depuration rate of COYOTE for Cs137	1/day	Triangular on Lower Limit .072, Mode .08, Upper Limit .088
STOCHASTIC "Cs137 COYOTEDEPRATE" 6 7.200E-02 8.000E-02 8.800E-02 "Depuration rate of COYOTE for Cs137"					

Calculation of the body burden for aquatic animal species is dependent on the chemical assimilation of contaminants for the species (see Section 4.1.2.1). A distinct STOCHASTIC keyword is needed for every animal species for this variable, and three examples are given in Table 4.24. The first quote string for the STOCHASTIC keywords would hold the concatenation of the analyte ID (blank padded to six characters long, if necessary), the species ID (blank padded to six characters in length, if necessary) and the variable name ALPHAIJ.

Table 4.24 Example ECEM Keywords for the Chemical Assimilation for Aquatic Animal Species

Analyte	Species	Variable	Description	Units	Statistical Distribution
CCl4	CARP	ALPHAIJ (α_{ij})	Chemical assimilation efficiency of CARP for CCl4	g contaminant assimilated per g contaminant ingested	Constant 1
STOCHASTIC "CCl4 CARP ALPHAIJ" 1 1 "Chemical assimilation efficiency of CARP for CCl4"					
CrVI	CHCATF	ALPHAIJ (α_{ij})	Chemical assimilation efficiency of CHCATF for CrVI	g contaminant assimilated per g contaminant ingested	Triangular on Lower Limit .027, Mode .03, Upper Limit .033
STOCHASTIC "CrVI CHCATFALPHAIJ" 6 2.700E-02 3.000E-02 3.300E-02 "Chemical assimilation efficiency of CHCATF for CrVI"					

Analyte	Species	Variable	Description	Units	Statistical Distribution
CrVI	CLAMS	ALPHA _{ij}	Chemical assimilation efficiency of CLAMS for CrVI	g contaminant assimilated per g contaminant ingested	Triangular on Lower Limit .0243, Mode .027, Upper Limit .0297
STOCHASTIC "CrVI CLAMS ALPHA _{ij} " 6 2.430E-02 2.700E-02 2.970E-02 "Chemical assimilation efficiency of CLAMS for CrVI"					

Calculation of the body burden for aquatic animal species is dependent on the bioconcentration factor of contaminants for the species (see Section 4.1.2.1). A distinct STOCHASTIC keyword is needed for every combination of animal species and nonorganic analyte for this variable, and three examples are given in Table 4.25. The first quote string for the STOCHASTIC keywords would hold the concatenation of the analyte ID (blank padded to six characters long, if necessary), the species ID (blank padded to six characters long, if necessary), and the variable name BCF.

Table 4.25 Example ECEM Keywords for the Bioconcentration Factor for Aquatic Animal Species

Analyte	Species	Variable	Description	Units	Statistical Distribution
CrVI	CARP	BCF	Bioconcentration factor of CARP for CrVI	L/kg	Triangular on Lower Limit .018, Mode .02, Upper Limit .022
STOCHASTIC "CrVI CARP BCF" 6 1.800E-02 2.000E-02 2.200E-02 "Bioconcentration factor of CARP for CrVI"					
CrVI	CPBLSN	BCF	Bioconcentration factor of CPBLSN for CrVI	L/kg	Triangular on Lower Limit .09, Mode .1, Upper Limit .11
STOCHASTIC "CrVI CPBLSNBCF" 6 9.000E-02 1.000E-01 1.100E-01 "Bioconcentration factor of CPBLSN for CrVI"					
U238	MAYFLY	BCF	Bioconcentration factor of MAYFLY for U238	L/kg	Triangular on Lower Limit .000279, Mode .00031, Upper Limit .000341
STOCHASTIC "U238 MAYFLYBCF" 6 2.790E-04 3.100E-04 3.410E-04 "Bioconcentration factor of MAYFLY for U238"					

Calculation of the body burden for aquatic animal species is dependent on the metabolism loss rate of the analyte for the species (see Section 4.1.2.1). A distinct STOCHASTIC keyword is needed for every combination of animal species analyte for this variable, and three examples are given in Table 4.26. The first quote string for the STOCHASTIC keywords would hold the concatenation of the analyte ID (blank padded to six characters long, if necessary), the species ID (blank padded to six characters long, if necessary), and the variable name METBLOSS.

Table 4.26 Example ECEM Keywords for the Metabolism Loss Rate for Aquatic Species

Analyte	Species	Variable	Description	Units	Statistical Distribution
CCl4	CARP	METBLOSS (K _{mi})	Metabolism loss rate for CCl4 in CARP	1/day	Constant 0
STOCHASTIC "CCl4 CARP METBLOSS" 1 0 "Metabolism loss rate for CCl4 in CARP"					
Cs137	MAYFLY	METBLOSS (K _{mi})	Metabolism loss rate for Cs137 in MAYFLY	1/day	Constant 0
STOCHASTIC "Cs137 MAYFLYMETBLOSS" 1 0 "Metabolism loss rate for Cs137 in MAYFLY"					
I129	MAYFLY	METBLOSS (K _{mi})	Metabolism loss rate for I129 in MAYFLY	1/day	Constant 0
STOCHASTIC "I129 MAYFLYMETBLOSS" 1 0 "Metabolism loss rate for I129 in MAYFLY"					

The calculation of body burden for terrestrial plants includes the plant-air partition coefficient for air to above-ground plant parts for particulate-bound contaminants (K_{pa2}) and the plant-soil partition coefficient for rain splash (K_{ps1}). See Section 4.1.1.1.4 for a description of K_{pa2} and Section 4.1.1.1.1 for a description of K_{ps1}. A distinct STOCHASTIC keyword is needed for every terrestrial plant species analyte for this variable, and two examples are given in Table 4.27. The first quote string for the STOCHASTIC keywords would hold the concatenation of the species ID (blank padded to six characters long, if necessary), and the variable name KPS1 or KPA2.

Table 4.27 Example ECEM Keywords for Plant-Air Partition Coefficients

Species	Variable	Description	Units	Statistical Distribution
BLCTWD	KPS1	Plant-soil partition coefficient for BLCTWD	Kg soil/kg plant wet wt	Triangular on Lower Limit .00306, Mode .0034, Upper Limit .00374
STOCHASTIC "BLCTWDKPS1 " 6 3.060E-03 3.400E-03 3.740E-03 "Plant-Soil partition coefficient for BLCTWD"				
BLCTWD	KPA2	Plant-air partition coefficient for BLCTWD	m ³ /kg wet weight	Triangular on Lower Limit 2,970; Mode 3,300; Upper Limit 3,630
STOCHASTIC "BLCTWDKPA2 " 6 2.970E+03 3.300E+03 3.630E+03 "Plant-Air partition coefficient for BLCTWD"				

The calculation of body burden for aquatic species depends on the fraction of the time the species spends in pore water (see Section 4.1.2.1). A distinct STOCHASTIC keyword is needed for every aquatic species

for this variable, and two examples are given in Table 4.28. The first quote string for the STOCHASTIC keywords would hold the concatenation of the species ID (blank padded to six characters long, if necessary), and the variable name BPORE.

Table 4.28 Example ECEM Keywords for the Fraction of Time Aquatic Species Spend in Pore Water

Species	Variable	Description	Units	Statistical Distribution
CARP	BPORE	Relative exposure time to pore water for CARP	unitless	Triangular on Lower Limit .045, Mode .05, Upper Limit .055
STOCHASTIC "CARP BPORE " 6 4.500E-02 5.000E-02 5.500E-02 "Relative exposure time to pore water for CARP"				
CHCATF	BPORE	Relative exposure time to pore water for CHCATF	unitless	Triangular on Lower Limit .09, Mode .1, Upper Limit .11
STOCHASTIC "CHCATFBPORE " 6 9.000E-02 1.000E-01 1.100E-01 "Relative exposure time to pore water for CHCATF"				

5.0 Human Impact Model (HUMAN)

This section contains instructions for the use of the human exposure and risk models and provides the mathematical formulation for the model is provided.

5.1 Mathematical Formulation for the Human Risk Model

The human risk model is a screening-level chronic exposure model. It is intended for use in situations where the environmental contamination conditions are static or only slowly varying. These conditions are met with the SAC contaminant sources, which are slowly released to the accessible environment, primarily via groundwater transport. The models are not appropriate for estimating risks from short-term accidental releases.

The HUMAN code addresses pathways related to long-term contamination of surface water and groundwater, with the associated contaminated media of seeps, springs, and sediments. With these as starting points, the code estimates the contaminant concentrations in surface soil from irrigation, air from resuspension and volatilization, aquatic foods, terrestrial crops, and animal products. Both domestic animals and wild animals may be included. Exposure pathways explicitly modeled include external irradiation, dermal contact, inhalation, and ingestion. Special models are included for unique Native American exposure situations. The code deals with first-order decay of radionuclides but not with degradation processes for chemicals.

The HUMAN code provides flexibility in combining the various pathways into exposure scenarios. Scenarios are defined through the use of representative sets of input parameters to simulate annual average or lifetime average exposure conditions. The scenarios are focused on individual exposures. Individuals are assumed to spend the amounts of time specified in the scenario at the location of analysis; individual mobility throughout the analysis domain is not supported. Population risks are only addressed for the pathway of consumption of drinking water from the Columbia River.

The HUMAN code provides results for radioactive contaminants; non-radioactive but carcinogenic contaminants; and non-radioactive, non-carcinogenic, but still hazardous contaminants. Radiation impacts to people may be calculated as either radiation dose or risk; carcinogenic chemical risks are provided in terms of risk of fatal cancer; risks from hazardous chemicals are provided as Hazard Quotients – the dimensionless ratio of the estimated intake to a standard Reference Dose.

The HUMAN code is designed to accept multiple realizations of concentration of contaminants in the environment. It allows the definition of stochastic exposure parameters, which combine with the uncertainty in the input media concentrations to provide a full range of uncertainty on the final dose or risk to the hypothetical exposed individual.

The following sections provide the mathematical formulations for the human risk model. A more extensive discussion of this model is provided in Chapter 5 of DOE (1998). The equations have been reorganized from that in DOE (1998) and the concentration equations for terrestrial foods (Sections 4.1.1.1 and 4.1.1.2) have been modified and expanded.

5.1.1 Human Exposure Equations Derived by Pathway

The following equations represent the total exposure of a person to radionuclides or chemicals. These equations describe the exposure or intake and the risk resulting from those exposures. Note that the user may substitute groundwater for seep/spring water in some scenario definitions.

5.1.1.1 External Radiation Exposure

The radiation dose from external radiation sources is computed for a number of activities using the following equation:

$$\begin{aligned} \text{Dose}_{\text{ext}} = & C_{\text{river}} \times ET_{\text{swim}} \times EF_{\text{swim}} \times ED \times DF_{\text{swim}} + \\ & C_{\text{river}} \times ET_{\text{boat}} \times EF_{\text{boat}} \times ED \times DF_{\text{boat}} + \\ & C_{\text{soil}} \times SH_{\text{soil}} \times ET_{\text{soil}} \times EF_{\text{soil}} \times ED \times DF_{\text{soil}} + \\ & C_{\text{sed}} \times SH_{\text{sed}} \times ET_{\text{sed}} \times EF_{\text{sed}} \times ED \times DF_{\text{soil}} \end{aligned}$$

where

Dose_{ext}	=	dose from external radionuclides (rem)
C_{river}	=	radionuclide concentration in river water (pCi/L)
ET_{swim}	=	exposure time for swimming (hours/day)
EF_{swim}	=	exposure frequency for swimming (days/year)
ED	=	exposure duration (year)
DF_{swim}	=	dose conversion factor for swimming (rem/hr per pCi/L)
ET_{boat}	=	exposure time for boating (hours/day)
EF_{boat}	=	exposure frequency for boating (days/year)
DF_{boat}	=	dose conversion factor for boating (rem/hr per pCi/L)
C_{soil}	=	radionuclide concentration in soil (pCi/kg)
SH_{soil}	=	shielding factor for soil (unitless)
ET_{soil}	=	exposure time for soil (hours/day)
EF_{soil}	=	exposure frequency for soil (days/year)
DF_{soil}	=	dose conversion factor for soil and sediment (rem/hr per pCi/kg)
C_{sed}	=	radionuclide concentration in sediment (pCi/kg)
SH_{sed}	=	shielding factor for sediment (unitless)
ET_{sed}	=	exposure time for sediment (hours/day)
EF_{sed}	=	exposure frequency for sediment (days/year)

5.1.1.2 Dermal Exposure (Non-Carcinogenic, Non-Radioactive)

The hazard quotient from dermal contact with non-carcinogenic, non-radioactive materials is computed for a number of activities using the following equation:

$$\begin{aligned} \text{DAHQ} = & C_{\text{soil}} \times AF_{\text{soil}} \times ABS \times SA_{\text{soil}} \times EF_{\text{soil}} \times CF1 \times ED \times CF7 / (BW_{\text{adult}} \times AT \times RfD_{\text{ing}}) + \\ & C_{\text{sed}} \times AF_{\text{sed}} \times ABS \times SA_{\text{sed}} \times EF_{\text{sed}} \times CF1 \times ED \times CF7 / (BW_{\text{adult}} \times AT \times RfD_{\text{ing}}) + \\ & C_{\text{seep}} \times K_p \times SA_{\text{seep}} \times ET_{\text{seep}} \times EF_{\text{seep}} \times CF3 \times ED \times CF7 / (BW_{\text{adult}} \times AT \times RfD_{\text{ing}}) + \\ & C_{\text{swim}} \times K_p \times SA_{\text{river}} \times ET_{\text{river}} \times EF_{\text{river}} \times CF3 \times ED \times CF7 / (BW_{\text{adult}} \times AT \times RfD_{\text{ing}}) \end{aligned}$$

where

DAHQ	=	hazard quotient from dermal absorption (unitless)
C _{soil}	=	contaminant concentration in soil (µg/kg)
AF _{soil}	=	adherence factor for soil (mg/cm ² per day)
ABS	=	material-specific factor to convert administered to absorbed dose (unitless)
SA _{soil}	=	body surface area exposed to soil (cm ²)
EF _{soil}	=	exposure frequency to soil (days/year)
CF1	=	unit conversion factor (1E-6 kg/mg)
ED	=	exposure duration (year)
CF7	=	conversion factor (1E-3 mg/µg)
BW _{adult}	=	body weight factor of an adult (kg)
AT	=	averaging time (year × 365.25 days/year)
RfD _{ing}	=	reference dose for ingestion (mg/kg per day)
C _{sed}	=	contaminant concentration in sediment (µg/kg)
AF _{sed}	=	adherence factor for sediment (mg/cm ² per day)
SA _{sed}	=	body surface area exposed to sediment (cm ²)
EF _{sed}	=	exposure frequency to sediment (days/year)
C _{seep}	=	contaminant concentration in seep/spring water (µg/L)
K _p	=	permeability coefficient for a chemical in water through skin (cm/hour)
SA _{seep}	=	body surface area exposed to seep/spring water (cm ²)
ET _{seep}	=	exposure time to seep/spring water (hours/day)
EF _{seep}	=	exposure frequency to seep/spring water (days/year)
CF3	=	unit conversion factor (1E-3 L/cm ³)
C _{swim}	=	contaminant concentration in surface water for swimming (µg/L)
SA _{river}	=	body surface area exposed to river water (cm ²)
ET _{river}	=	exposure time to river water (hours/day)
EF _{river}	=	exposure frequency to river water (days/year)

5.1.1.3 Dermal Exposure (Carcinogenic, Non-Radioactive)

The risk from dermal contact with carcinogenic, non-radioactive materials is computed for a number of activities using the following equation:

$$\begin{aligned} \text{DAR} = & C_{\text{soil}} \times \text{AF}_{\text{soil}} \times \text{ABS} \times \text{SA}_{\text{soil}} \times \text{EF}_{\text{soil}} \times \text{CF1} \times \text{ED} \times \text{SF}_{\text{ing}} \times \text{CF7} / (\text{BW}_{\text{adult}} \times \text{AT}) + \\ & C_{\text{sed}} \times \text{AF}_{\text{sed}} \times \text{ABS} \times \text{SA}_{\text{sed}} \times \text{EF}_{\text{sed}} \times \text{CF1} \times \text{ED} \times \text{SF}_{\text{ing}} \times \text{CF7} / (\text{BW}_{\text{adult}} \times \text{AT}) + \\ & C_{\text{seep}} \times K_p \times \text{SA}_{\text{seep}} \times \text{ET}_{\text{seep}} \times \text{EF}_{\text{seep}} \times \text{CF3} \times \text{ED} \times \text{SF}_{\text{ing}} \times \text{CF7} / (\text{BW}_{\text{adult}} \times \text{AT}) + \\ & C_{\text{swim}} \times K_p \times \text{SA}_{\text{river}} \times \text{ET}_{\text{river}} \times \text{EF}_{\text{river}} \times \text{CF3} \times \text{ED} \times \text{SF}_{\text{ing}} \times \text{CF7} / (\text{BW}_{\text{adult}} \times \text{AT}) \end{aligned}$$

where

DAR	=	risk from dermal absorption (risk)
C _{soil}	=	contaminant concentration in soil (µg/kg)
AF _{soil}	=	adherence factor for soil (mg/cm ² per day)
ABS	=	material-specific factor to convert administered to absorbed dose (unitless)
SA _{soil}	=	body surface area exposed to soil (cm ²)
EF _{soil}	=	exposure frequency to soil (days/year)

CF1	=	unit conversion factor (1E-6 kg/mg)
ED	=	exposure duration (year)
SF _{ing}	=	slope factor (risk per mg/kg per day)
CF7	=	conversion factor (1E-3 mg/μg)
BW _{adult}	=	body weight factor of an adult (kg)
AT	=	averaging time (year × 365.25 days/year)
C _{sed}	=	contaminant concentration in sediment (μg/kg)
AF _{sed}	=	adherence factor for sediment (mg/cm ² per day)
SA _{sed}	=	body surface area exposed to sediment (cm ²)
EF _{sed}	=	exposure frequency to sediment (days/year)
C _{seep}	=	contaminant concentration in seep/spring water (μg/L)
K _p	=	permeability coefficient for a chemical in water through skin (cm/hour)
SA _{seep}	=	body surface area exposed to seep/spring water (cm ²).
ET _{seep}	=	exposure time to seep/spring water (hours/day)
EF _{seep}	=	exposure frequency to seep/spring water (days/year)
CF3	=	unit conversion factor (1E-3 L/cm ³)
C _{swim}	=	contaminant concentration in surface water for swimming (μg/L)
SA _{river}	=	body surface area exposed to river water (cm ²)
ET _{river}	=	exposure time to river water (hours/day)
EF _{river}	=	exposure frequency to river water (days/year)

5.1.1.4 Inhalation Exposure (Carcinogenic)

The risk from inhalation of carcinogenic materials is computed for a number of activities using the following equation:

$$\begin{aligned} \text{INHC} = & C_{\text{soil}} \times \text{ML} \times \text{ET}_{\text{soil}} \times \text{EF}_{\text{soil}} \times \text{ED} \times \text{IRATE} \times \text{SF}_{\text{inh}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{CF4}) + \\ & C_{\text{seep}} \times \text{VF} \times \text{ET}_{\text{seep}} \times \text{EF}_{\text{seep}} \times \text{ED} \times \text{IRATE} \times \text{SF}_{\text{inh}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{CF4}) + \\ & C_{\text{river}} \times \text{VF} \times \text{ET}_{\text{river}} \times \text{EF}_{\text{river}} \times \text{ED} \times \text{IRATE} \times \text{SF}_{\text{inh}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{CF4}) + \\ & C_{\text{air}} \times \text{ET}_{\text{air}} \times \text{EF}_{\text{air}} \times \text{ED} \times \text{IRATE} \times \text{SF}_{\text{inh}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{CF4}) + \\ & C_{\text{sweat}} \times \text{CF}_{\text{sweat}} \times \text{ET}_{\text{sweat}} \times \text{EF}_{\text{sweat}} \times \text{ED} \times \text{IRATE} \times \text{SF}_{\text{inh}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{CF4}) \end{aligned}$$

where

INHC	=	chronic inhalation risk from carcinogens (risk)
C _{soil}	=	contaminant concentration in soil (μg/kg)
ML	=	mass loading of soil in the air (kg/m ³)
ET _{soil}	=	exposure time for breathing soil (hours/day)
EF _{soil}	=	exposure frequency to soil (days/year)
ED	=	exposure duration (year)
IRATE	=	inhalation (breathing) rate (m ³ /day)
SF _{inh}	=	slope factor for inhalation (risk per mg/kg per day)
CF7	=	conversion factor (1E-3 mg/μg)
AT	=	averaging time (year × 365.25 days/year)
BW _{adult}	=	body weight (kg)

CF4	=	unit conversion factor (24 hours/day)
C _{seep}	=	contaminant concentration in seep/spring water (µg/L)
VF	=	volatilization factor (L/m ³)
ET _{seep}	=	exposure time for breathing volatilized seep/spring water (hours/day)
EF _{seep}	=	exposure frequency to volatilized seep/spring water (days/year)
C _{river}	=	contaminant concentration in river water (µg/L)
ET _{river}	=	exposure time for breathing volatilized river water (hours/day)
EF _{river}	=	exposure frequency to volatilized river water (days/year)
C _{air}	=	contaminant concentration in air (µg/m ³)
ET _{air}	=	exposure time for breathing contaminated air (hours/day)
EF _{air}	=	exposure frequency to volatilized air (days/year)
C _{sweat}	=	contaminant concentration in water used in a sweat lodge (µg/L)
CF _{sweat}	=	volatilization factor for water used in Native American sweat lodges (L/m ³)
ET _{sweat}	=	exposure time for breathing in a sweat lodge (hours/day)
EF _{sweat}	=	exposure frequency to a sweat lodge (days/year)

5.1.1.5 Inhalation Exposure (Hazardous)

The hazard quotient from inhalation of non-carcinogenic, non-radioactive, materials is computed for a number of activities using the following equation:

$$\begin{aligned} \text{INHQ} = & C_{\text{soil}} \times \text{ML} \times \text{ET}_{\text{soil}} \times \text{EF}_{\text{soil}} \times \text{ED} \times \text{IRATE} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{CF4} \times \text{RfD}_{\text{inh}}) + \\ & C_{\text{seep}} \times \text{VF} \times \text{ET}_{\text{seep}} \times \text{EF}_{\text{seep}} \times \text{ED} \times \text{IRATE} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{CF4} \times \text{RfD}_{\text{inh}}) + \\ & C_{\text{river}} \times \text{VF} \times \text{ET}_{\text{river}} \times \text{EF}_{\text{river}} \times \text{ED} \times \text{IRATE} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{CF4} \times \text{RfD}_{\text{inh}}) + \\ & C_{\text{air}} \times \text{ET}_{\text{air}} \times \text{EF}_{\text{air}} \times \text{ED} \times \text{IRATE} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{CF4} \times \text{RfD}_{\text{inh}}) + \\ & C_{\text{sweat}} \times \text{CF}_{\text{sweat}} \times \text{ET}_{\text{sweat}} \times \text{EF}_{\text{sweat}} \times \text{ED} \times \text{IRATE} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{CF4} \times \\ & \text{RfD}_{\text{inh}}) \end{aligned}$$

where

INHQ	=	chronic inhalation hazard quotient (unitless)
C _{soil}	=	contaminant concentration in soil (µg/kg)
ML	=	mass loading of soil in the air (kg/m ³)
ET _{soil}	=	exposure time for breathing soil (hours/day)
EF _{soil}	=	exposure frequency to soil (days/year)
ED	=	exposure duration (year)
IRATE	=	inhalation rate (m ³ /day)
CF7	=	conversion factor (1E-3 mg/µg)
AT	=	averaging time (year × 365.25 days/year)
BW _{adult}	=	body weight (kg)
CF4	=	unit conversion factor (24 hours/day)
RfD _{inh}	=	reference dose for inhalation (mg/kg per day)
C _{seep}	=	contaminant concentration in seep/spring water (µg/L)
VF	=	volatilization factor (L/m ³)
ET _{seep}	=	exposure time for breathing volatilized seep/spring water (hours/day)
EF _{seep}	=	exposure frequency to volatilized seep/spring water (days/year)

C_{river}	=	contaminant concentration in river water ($\mu\text{g/L}$)
ET_{river}	=	exposure time for breathing volatilized river water (hours/day)
EF_{river}	=	exposure frequency to volatilized river water (days/year)
C_{air}	=	contaminant concentration in air ($\mu\text{g/m}^3$)
ET_{air}	=	exposure time for breathing contaminated air (hours/day)
EF_{air}	=	exposure frequency to contaminated air (days/year)
C_{sweat}	=	contaminant concentration in water used in a sweat lodge ($\mu\text{g/L}$)
CF_{sweat}	=	volatilization factor for water used in Native American sweat lodges (L/m^3)
ET_{sweat}	=	exposure time for breathing in a sweat lodge (hours/day)
EF_{sweat}	=	exposure frequency to a sweat lodge (days/year)

5.1.1.6 Inhalation Exposure (Radioactive)

The radiation dose from inhalation of radioactive materials is computed for a number of activities using the following equation:

$$\begin{aligned} \text{Dose}_{\text{inh}} = & C_{\text{soil}} \times \text{ML} \times ET_{\text{soil}} \times EF_{\text{soil}} \times \text{ED} \times \text{IRATE} \times \text{DF}_{\text{inh}} / \text{CF}_4 + \\ & C_{\text{seep}} \times \text{VF} \times ET_{\text{seep}} \times EF_{\text{seep}} \times \text{ED} \times \text{IRATE} \times \text{DF}_{\text{inh}} / \text{CF}_4 + \\ & C_{\text{river}} \times \text{VF} \times ET_{\text{river}} \times EF_{\text{river}} \times \text{ED} \times \text{IRATE} \times \text{DF}_{\text{inh}} / \text{CF}_4 + \\ & C_{\text{air}} \times ET_{\text{air}} \times EF_{\text{air}} \times \text{ED} \times \text{IRATE} \times \text{DF}_{\text{inh}} / \text{CF}_4 + \\ & C_{\text{sweat}} \times CF_{\text{sweat}} \times ET_{\text{sweat}} \times EF_{\text{sweat}} \times \text{ED} \times \text{IRATE} \times \text{DF}_{\text{inh}} / \text{CF}_4 \end{aligned}$$

where

Dose_{inh}	=	dose from inhalation of radionuclides (rem)
C_{soil}	=	radionuclide concentration in soil (pCi/kg)
ML	=	mass loading of soil in the air (kg/m^3)
ET_{soil}	=	exposure time for breathing volatilized soil (hours/day)
EF_{soil}	=	exposure frequency to volatilized soil (days/year)
ED	=	exposure duration (years)
IRATE	=	inhalation rate (m^3/day)
DF_{inh}	=	dose conversion factor for inhalation (rem/pCi)
CF_4	=	unit conversion factor (24 hours/day)
C_{seep}	=	radionuclide concentration in seep/spring water (pCi/L)
VF	=	volatilization factor (L/m^3)
ET_{seep}	=	exposure time for breathing volatilized seep/spring water (hours/day)
EF_{seep}	=	exposure frequency to volatilized seep/spring water (days/year)
C_{river}	=	radionuclide concentration in river water (pCi/L)
ET_{river}	=	exposure time for breathing volatilized river water (hours/day)
EF_{river}	=	exposure frequency to volatilized river water (days/year)
C_{air}	=	radionuclide concentration in air (pCi/ m^3)
ET_{air}	=	exposure time for breathing contaminated air (hours/day)
EF_{air}	=	exposure frequency to contaminated air (days/year)
C_{sweat}	=	radionuclide concentration in water used in a sweat lodge (pCi/L)
CF_{sweat}	=	volatilization factor for water used in Native American sweat lodges (L/m^3)
ET_{sweat}	=	exposure time for breathing materials suspended during cultural activities (hours/day)
EF_{sweat}	=	exposure frequency to materials resuspended during cultural activities (days/year)

5.1.1.7 Ingestion Exposure (Hazardous)

The hazard quotient from ingestion of non-carcinogenic, non-radioactive materials is computed for a number of activities using the following equation:

$$\begin{aligned} \text{INGQ} = & C_{\text{river}} \times \text{IR}_{\text{river}} \times \text{ED} \times \text{EF}_{\text{river}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{RfD}_{\text{ing}}) + \\ & C_{\text{ground}} \times \text{IR}_{\text{ground}} \times \text{ED} \times \text{EF}_{\text{ground}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{RfD}_{\text{ing}}) + \\ & C_{\text{seep}} \times \text{IR}_{\text{seep}} \times \text{ED} \times \text{EF}_{\text{seep}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{RfD}_{\text{ing}}) + \\ & C_{\text{soil}} \times \text{IR}_{\text{soilchild}} \times \text{ED}_{\text{child}} \times \text{EF}_{\text{soil}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{child}} \times \text{RfD}_{\text{ing}}) + \\ & C_{\text{soil}} \times \text{IR}_{\text{soiladult}} \times \text{ED}_{\text{adult}} \times \text{EF}_{\text{soil}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{RfD}_{\text{ing}}) + \\ & C_{\text{sed}} \times \text{IR}_{\text{sedchild}} \times \text{ED}_{\text{child}} \times \text{EF}_{\text{sed}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{child}} \times \text{RfD}_{\text{ing}}) + \\ & C_{\text{sed}} \times \text{IR}_{\text{sedadult}} \times \text{ED}_{\text{adult}} \times \text{EF}_{\text{sed}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{RfD}_{\text{ing}}) + \\ & C_{\text{leafy}} \times \text{IR}_{\text{leafy}} \times \text{ED} \times \text{EF}_{\text{leafy}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{RfD}_{\text{ing}}) + \\ & C_{\text{root}} \times \text{IR}_{\text{root}} \times \text{ED} \times \text{EF}_{\text{root}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{RfD}_{\text{ing}}) + \\ & C_{\text{meat}} \times \text{IR}_{\text{meat}} \times \text{ED} \times \text{EF}_{\text{meat}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{RfD}_{\text{ing}}) + \\ & C_{\text{milk}} \times \text{IR}_{\text{milk}} \times \text{ED} \times \text{EF}_{\text{milk}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{RfD}_{\text{ing}}) + \\ & C_{\text{bird}} \times \text{IR}_{\text{bird}} \times \text{ED} \times \text{EF}_{\text{bird}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{RfD}_{\text{ing}}) + \\ & C_{\text{fish}} \times \text{IR}_{\text{fish}} \times \text{ED} \times \text{EF}_{\text{fish}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{RfD}_{\text{ing}}) + \\ & C_{\text{fruit}} \times \text{IR}_{\text{fruit}} \times \text{ED} \times \text{EF}_{\text{fruit}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{RfD}_{\text{ing}}) + \\ & C_{\text{grain}} \times \text{IR}_{\text{grain}} \times \text{ED} \times \text{EF}_{\text{grain}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{RfD}_{\text{ing}}) + \\ & C_{\text{eggs}} \times \text{IR}_{\text{eggs}} \times \text{ED} \times \text{EF}_{\text{eggs}} \times \text{CF7} / (\text{AT} \times \text{BW}_{\text{adult}} \times \text{RfD}_{\text{ing}}) \end{aligned}$$

where

INGQ	=	chronic ingestion hazard quotient (unitless)
C_{river}	=	contaminant concentration in river water ($\mu\text{g/kg}$)
IR_{river}	=	ingestion rate of river water (kg/day)
ED	=	lifetime exposure duration (year)
EF_{river}	=	exposure frequency for river (days/year)
CF7	=	conversion factor ($1\text{E-}3 \text{ mg}/\mu\text{g}$)
AT	=	averaging time (year \times 365 days/yr)
BW_{adult}	=	body weight for adult (kg)
RfD_{ing}	=	reference dose for ingestion (mg/kg per day)
C_{ground}	=	contaminant concentration in groundwater ($\mu\text{g/kg}$)
$\text{IR}_{\text{ground}}$	=	ingestion rate of groundwater (kg/day)
$\text{EF}_{\text{ground}}$	=	exposure frequency for ground (days/year)
C_{seep}	=	contaminant concentration in seep/spring water ($\mu\text{g/kg}$)
IR_{seep}	=	ingestion rate of seep/spring water (kg/day)
EF_{seep}	=	exposure frequency for seep (days/year)
C_{soil}	=	contaminant concentration in soil ($\mu\text{g/kg}$)
$\text{IR}_{\text{soilchild}}$	=	ingestion rate of soil by a child (kg/day)
ED_{child}	=	exposure duration for a child (year)
EF_{soil}	=	exposure frequency for a bird (days/year)
BW_{child}	=	body weight for adult (kg)
$\text{IR}_{\text{soiladult}}$	=	ingestion rate of soil by an adult (kg/day)

ED _{adult}	=	exposure duration for an adult (year)
C _{sed}	=	contaminant concentration in sediment (µg/kg)
IR _{sedchild}	=	ingestion rate of sediment by a child (kg/day)
EF _{sed}	=	exposure frequency for sediment (days/year)
IR _{sedadult}	=	ingestion rate of sediment by an adult (kg/day)
C _{leafy}	=	contaminant concentration in above-ground vegetation (µg/kg)
IR _{leafy}	=	ingestion rate of above-ground vegetation (kg/day)
EF _{leafy}	=	exposure frequency for above-ground vegetation (days/year)
C _{root}	=	contaminant concentration in root vegetables (µg/kg)
IR _{root}	=	ingestion rate of root vegetables (kg/day)
EF _{root}	=	exposure frequency for a root (days/year)
C _{meat}	=	contaminant concentration in meat (µg/kg)
IR _{meat}	=	ingestion rate of meat (kg/day)
EF _{meat}	=	exposure frequency for meat (days/year)
C _{milk}	=	contaminant concentration in milk (µg/kg)
IR _{milk}	=	ingestion rate of milk (kg/day)
EF _{milk}	=	exposure frequency for milk (days/year)
C _{bird}	=	contaminant concentration in domestic and wild birds (µg/kg)
IR _{bird}	=	ingestion rate of domestic and wild birds (kg/day)
EF _{bird}	=	exposure frequency for a bird (days/year)
C _{fish}	=	contaminant concentration in fish (µg/kg)
IR _{fish}	=	ingestion rate of fish (kg/day)
EF _{fish}	=	exposure frequency for a fish (days/year)
C _{fruit}	=	contaminant concentration in fruit (µg/kg)
IR _{fruit}	=	ingestion rate of fruit (kg/day)
EF _{fruit}	=	exposure frequency for a fruit (days/year)
C _{grain}	=	contaminant concentration in grain (µg/kg)
IR _{grain}	=	ingestion rate of grain (kg/day)
EF _{grain}	=	exposure frequency for a grain (days/year)
C _{eggs}	=	contaminant concentration in eggs (µg/kg)
IR _{eggs}	=	ingestion rate of eggs (kg/day)
EF _{eggs}	=	exposure frequency for a eggs (days/year)

5.1.1.8 Ingestion Exposure (Carcinogenic)

The risk from ingestion of carcinogenic, non-radioactive materials is computed for a number of activities using the following equation:

$$\begin{aligned}
 INGR = & C_{river} \times IR_{river} \times ED \times EF_{river} \times SF_{ing} \times CF7 / (AT \times BW_{adult}) + \\
 & C_{ground} \times IR_{ground} \times ED \times EF_{ground} \times SF_{ing} \times CF7 / (AT \times BW_{adult}) + \\
 & C_{seep} \times IR_{seep} \times ED \times EF_{seep} \times SF_{ing} \times CF7 / (AT \times BW_{adult}) + \\
 & C_{soil} \times IR_{soilchild} \times ED_{child} \times EF_{soil} \times SF_{ing} \times CF7 / (AT \times BW_{child}) + \\
 & C_{soil} \times IR_{soiladult} \times ED_{adult} \times EF_{soil} \times SF_{ing} \times CF7 / (AT \times BW_{adult}) + \\
 & C_{sed} \times IR_{sedchild} \times ED_{child} \times EF_{sed} \times SF_{ing} \times CF7 / (AT \times BW_{child}) + \\
 & C_{sed} \times IR_{sedadult} \times ED_{adult} \times EF_{sed} \times SF_{ing} \times CF7 / (AT \times BW_{adult}) +
 \end{aligned}$$

$$\begin{aligned}
 &C_{\text{leafy}} \times IR_{\text{leafy}} \times ED \times EF_{\text{leafy}} \times SF_{\text{ing}} \times CF7 / (AT \times BW_{\text{adult}}) + \\
 &C_{\text{root}} \times IR_{\text{root}} \times ED \times EF_{\text{root}} \times SF_{\text{ing}} \times CF7 / (AT \times BW_{\text{adult}}) + \\
 &C_{\text{meat}} \times IR_{\text{meat}} \times ED \times EF_{\text{meat}} \times SF_{\text{ing}} \times CF7 / (AT \times BW_{\text{adult}}) + \\
 &C_{\text{milk}} \times IR_{\text{milk}} \times ED \times EF_{\text{milk}} \times SF_{\text{ing}} \times CF7 / (AT \times BW_{\text{adult}}) + \\
 &C_{\text{bird}} \times IR_{\text{bird}} \times ED \times EF_{\text{bird}} \times SF_{\text{ing}} \times CF7 / (AT \times BW_{\text{adult}}) + \\
 &C_{\text{fish}} \times IR_{\text{fish}} \times ED \times EF_{\text{fish}} \times SF_{\text{ing}} \times CF7 / (AT \times BW_{\text{adult}}) + \\
 &C_{\text{fruit}} \times IR_{\text{fruit}} \times ED \times EF_{\text{fruit}} \times SF_{\text{ing}} \times CF7 / (AT \times BW_{\text{adult}}) + \\
 &C_{\text{grain}} \times IR_{\text{grain}} \times ED \times EF_{\text{grain}} \times SF_{\text{ing}} \times CF7 / (AT \times BW_{\text{adult}}) + \\
 &C_{\text{eggs}} \times IR_{\text{eggs}} \times ED \times EF_{\text{eggs}} \times SF_{\text{ing}} \times CF7 / (AT \times BW_{\text{adult}})
 \end{aligned}$$

where

INGR	=	chronic ingestion cancer risk (risk)
C_{river}	=	contaminant concentration in river water ($\mu\text{g/kg}$)
IR_{river}	=	ingestion rate of river water (kg/day)
ED	=	lifetime exposure duration (years)
EF_{river}	=	exposure frequency for river (days/year)
SF_{ing}	=	slope factor for ingestion (risk per mg/kg per day)
CF7	=	conversion factor ($1\text{E-}3 \text{ mg}/\mu\text{g}$)
AT	=	averaging time (years \times 365 days/yr)
BW_{adult}	=	body weight for adult (kg)
C_{ground}	=	contaminant concentration in groundwater ($\mu\text{g/kg}$)
IR_{ground}	=	ingestion rate of groundwater (kg/day)
EF_{ground}	=	exposure frequency for ground (days/year)
C_{seep}	=	contaminant concentration in seep/spring water ($\mu\text{g/kg}$)
IR_{seep}	=	ingestion rate of seep/spring water (kg/day)
EF_{seep}	=	exposure frequency for seep (days/year)
C_{soil}	=	contaminant concentration in soil ($\mu\text{g/kg}$)
$IR_{\text{soilchild}}$	=	ingestion rate of soil by a child (kg/day)
ED_{child}	=	exposure duration for a child (years)
EF_{soil}	=	exposure frequency for a bird (days/year)
BW_{child}	=	body weight for adult (kg)
$IR_{\text{soiladult}}$	=	ingestion rate of soil by an adult (kg/day)
ED_{adult}	=	exposure duration for an adult (years)
C_{sed}	=	contaminant concentration in sediment ($\mu\text{g/kg}$)
IR_{sedchild}	=	ingestion rate of sediment by a child (kg/day)
EF_{sed}	=	exposure frequency for sediment (days/year)
IR_{sedadult}	=	ingestion rate of sediment by an adult (kg/day)
C_{leafy}	=	contaminant concentration in above-ground vegetation ($\mu\text{g/kg}$)
IR_{leafy}	=	ingestion rate of above-ground vegetation (kg/day)
EF_{leafy}	=	exposure frequency for above-ground vegetation (days/year)
C_{root}	=	contaminant concentration in root vegetables ($\mu\text{g/kg}$)
IR_{root}	=	ingestion rate of root vegetables (kg/day)
EF_{root}	=	exposure frequency for a root (days/year)
C_{meat}	=	contaminant concentration in meat ($\mu\text{g/kg}$)
IR_{meat}	=	ingestion rate of meat (kg/day)

EF_{meat}	=	exposure frequency for meat (days/year)
C_{milk}	=	contaminant concentration in milk ($\mu\text{g/kg}$)
IR_{milk}	=	ingestion rate of milk (kg/day)
EF_{milk}	=	exposure frequency for milk (days/year)
C_{bird}	=	contaminant concentration in domestic and wild birds ($\mu\text{g/kg}$)
IR_{bird}	=	ingestion rate of domestic and wild birds (kg/day)
EF_{bird}	=	exposure frequency for a bird (days/year)
C_{fish}	=	contaminant concentration in fish ($\mu\text{g/kg}$)
IR_{fish}	=	ingestion rate of fish (kg/day)
EF_{fish}	=	exposure frequency for a fish (days/year)
C_{fruit}	=	contaminant concentration in fruit ($\mu\text{g/kg}$)
IR_{fruit}	=	ingestion rate of fruit (kg/day)
EF_{fruit}	=	exposure frequency for a fruit (days/year)
C_{grain}	=	contaminant concentration in grain ($\mu\text{g/kg}$)
IR_{grain}	=	ingestion rate of grain (kg/day)
EF_{grain}	=	exposure frequency for a grain (days/year)
C_{eggs}	=	contaminant concentration in eggs ($\mu\text{g/kg}$)
IR_{eggs}	=	ingestion rate of eggs (kg/day)
EF_{eggs}	=	exposure frequency for a eggs (days/year)

5.1.1.9 Ingestion Exposure (Radioactive)

The dose from ingestion of radioactive materials is computed for a number of activities using the following equation:

$$\begin{aligned}
 \text{Dose}_{\text{ing}} = & C_{\text{seep}} \times IR_{\text{seep}} \times EF_{\text{seep}} \times ED \times DF6 + \\
 & C_{\text{river}} \times IR_{\text{river}} \times EF_{\text{river}} \times ED \times DF6 + \\
 & C_{\text{ground}} \times IR_{\text{ground}} \times EF_{\text{ground}} \times ED \times DF6 + \\
 & C_{\text{soil}} \times (IR_{\text{soilchild}} \times ED_{\text{child}} + IR_{\text{soiladult}} \times ED_{\text{adult}}) \times EF_{\text{soil}} \times DF6 + \\
 & C_{\text{sed}} \times (IR_{\text{sedchild}} \times ED_{\text{child}} + IR_{\text{sedadult}} \times ED_{\text{adult}}) \times EF_{\text{sed}} \times DF6 + \\
 & C_{\text{leafy}} \times IR_{\text{leafy}} \times EF_{\text{leafy}} \times ED \times DF6 + \\
 & C_{\text{root}} \times IR_{\text{root}} \times EF_{\text{root}} \times ED \times DF6 + \\
 & C_{\text{meat}} \times IR_{\text{meat}} \times EF_{\text{meat}} \times ED \times DF6 + \\
 & C_{\text{milk}} \times IR_{\text{milk}} \times EF_{\text{milk}} \times ED \times DF6 + \\
 & C_{\text{bird}} \times IR_{\text{bird}} \times EF_{\text{bird}} \times ED \times DF6 + \\
 & C_{\text{fish}} \times IR_{\text{fish}} \times EF_{\text{fish}} \times ED \times DF6 + \\
 & C_{\text{fruit}} \times IR_{\text{fruit}} \times EF_{\text{fruit}} \times ED \times DF6 + \\
 & C_{\text{grain}} \times IR_{\text{grain}} \times EF_{\text{grain}} \times ED \times DF6 + \\
 & C_{\text{eggs}} \times IR_{\text{eggs}} \times EF_{\text{eggs}} \times ED \times DF6
 \end{aligned}$$

where

Dose_{ing}	=	dose from ingestion (rem)
C_{seep}	=	radionuclide concentration in seep/spring water (pCi/kg)
IR_{seep}	=	ingestion rate of seep/spring water (kg/day)

EF _{seep}	=	exposure frequency of an adult to seep/spring water (days/year)
ED	=	exposure duration (year)
DF6	=	dose conversion factor for ingestion (rem/pCi)
C _{river}	=	radionuclide concentration in river water (pCi/kg)
IR _{river}	=	ingestion rate of river water (kg/day)
EF _{river}	=	exposure frequency of an adult to river water (days/year)
C _{ground}	=	radionuclide concentration in groundwater (pCi/kg)
IR _{ground}	=	ingestion rate of groundwater (kg/day)
EF _{ground}	=	exposure frequency of an adult to groundwater (days/year)
C _{soil}	=	radionuclide concentration in soil (pCi/kg)
IR _{soilchild}	=	ingestion rate of soil by a child (kg/day)
ED _{child}	=	exposure duration for a child (year)
IR _{soiladult}	=	ingestion rate of sediment by a child (kg/day)
ED _{adult}	=	exposure duration for an adult (year)
EF _{soil}	=	exposure frequency of an adult to soil (days/year)
C _{sed}	=	radionuclide concentration in sediment (pCi/kg)
IR _{sedchild}	=	ingestion rate of sediment by a child (kg/day)
IR _{sedadult}	=	ingestion rate of sediment by a child (kg/day)
EF _{sed}	=	exposure frequency of an adult to sediment (days/year)
C _{leafy}	=	radionuclide concentration in above-ground vegetation (pCi/kg)
IR _{leafy}	=	ingestion rate of above-ground vegetation (kg/day)
EF _{leafy}	=	exposure frequency of an adult to leafy vegetables (days/year)
C _{root}	=	radionuclide concentration in root vegetables (pCi/kg)
IR _{root}	=	ingestion rate of root vegetables (kg/day)
EF _{root}	=	exposure frequency of an adult to root vegetables (days/year)
C _{meat}	=	radionuclide concentration in meat (pCi/kg)
IR _{meat}	=	ingestion rate of meat (kg/day)
EF _{meat}	=	exposure frequency of an adult to meat (days/year)
C _{milk}	=	radionuclide concentration in milk (pCi/kg)
IR _{milk}	=	ingestion rate of milk (L/day)
EF _{milk}	=	exposure frequency of an adult to milk (days/year)
C _{bird}	=	radionuclide concentration in domestic and wild birds (pCi/kg)
IR _{bird}	=	ingestion rate of domestic and wild birds (kg/day)
EF _{bird}	=	exposure frequency of an adult to birds (days/year)
C _{fish}	=	radionuclide concentration in fish (pCi/kg)
IR _{fish}	=	ingestion rate of fish (kg/day)
EF _{fish}	=	exposure frequency of an adult to fish (days/year)
C _{fruit}	=	radionuclide concentration in fruit (pCi/kg)
IR _{fruit}	=	ingestion rate of fruit (kg/day)
EF _{fruit}	=	exposure frequency of an adult to fruit (days/year)
C _{grain}	=	radionuclide concentration in grain (pCi/kg)
IR _{grain}	=	ingestion rate of grain (kg/day)
EF _{grain}	=	exposure frequency of an adult to grain (days/year)
C _{eggs}	=	radionuclide concentration in eggs (pCi/kg)
IR _{eggs}	=	ingestion rate of eggs (kg/day)
EF _{eggs}	=	exposure frequency of an adult to eggs (days/year)

5.1.1.10 Conversion of Exposure to Risk for Radioactive Contaminants

The conversion of dose to risk for radioactive contaminants uses the following equation:

$$\text{Risk_Rad} = \text{Dose} \times \text{Dose2Risk}$$

where

$$\begin{aligned}\text{Dose} &= \text{any of the external, inhalation, and ingestion doses calculated above (rem)} \\ \text{Dose2Risk} &= \text{factor converting accumulated radiation dose to risk (risk/rem)}\end{aligned}$$

5.1.1.11 Concentrations for Special Native American Activities

The only unique Native American pathway defined in the SAC scenarios involves a sweat lodge. The assumption for the sweat lodge was that water would be collected and poured over hot rocks to create steam. The concentration in the sweat lodge water comes from the following expression:

$$C_{\text{sweat}} = C_{\text{water}}$$

where

$$\begin{aligned}C_{\text{sweat}} &= \text{analyte concentration for water in a sweat lodge (pCi/L or } \mu\text{g/L)} \\ C_{\text{water}} &= \text{analyte concentration in the water source (pCi/L or } \mu\text{g/L)}\end{aligned}$$

The code implementation allows the choice of groundwater, seep water, or surface river water for this calculation.

5.1.2 Population Dose and Risk for Radioactive Contaminants

The population radioactive dose is calculated as the sum of doses to individuals for a set of locations. With the limitation that the code only runs a single exposure scenario at a time, the activities of the people at the different locations can be different. For example, some could be drinking groundwater, and some could be drinking river water; however, they all would be drinking the same amount of water. The equation for this calculation is:

$$\text{Dose}_{\text{pop}} = \sum_{\text{loc}} (\text{Dose}_{\text{ind}} \times \text{Pop}_{\text{loc}})$$

where

$$\begin{aligned}\text{Dose}_{\text{pop}} &= \text{Population dose (person-rem)} \\ \text{Dose}_{\text{ind}} &= \text{Radioactive dose (rem) to an individual at a location} \\ \text{Pop}_{\text{loc}} &= \text{Number of people living at the location (persons)}\end{aligned}$$

The sum goes over all locations identified for the specific run of the HUMAN code (see the LOCATION keyword in Section 5.4.12 for further information).

The population risk from radioactive materials is calculated using the following equation:

$$\text{Risk}_{\text{pop}} = \text{Dose}_{\text{pop}} \times \text{Dose2Risk}$$

where

Risk_{pop} = number of people in the population that are expected to contract a fatal cancer

5.2 Code Execution Environment

5.2.1 Location in the Processing Sequence

The HUMAN code requires access to a number of data files developed by the SAC inventory, release, and transport codes (Eslinger et al. 2002). In particular, every code on the left side of Figure 1.1 must have been executed to build a suite of concentration data files before the HUMAN code can be used to calculate impacts. These concentration data files must have been developed under the control of the same ESD keyword file that the HUMAN code reads to determine processing options.

5.2.2 How the Code Is Invoked

HUMAN can run under either the Windows or the Linux operating system. Under the Windows operating system (Releases 98, NT, or 2000), HUMAN executes in a DOS box. A run of HUMAN is initiated by entering the following command line:

```
HUMAN "Keyfilename"
```

Under the Linux operating system HUMAN is executed through any of the following Bourne Shell or C Shell commands:

```
human.exe "Keyfilename"
```

For these commands, HUMAN or human.exe is the name of the executable program and "Keyfilename" is the name of a human scenario keyword file. Both the name of the executable program and the keyword file may contain path information. If HUMAN is invoked without entering the name of the keyword file, then the code will prompt the user for the file name. The keyword file, which should be prepared using an editor that can handle ASCII files without leaving embedded control codes, contains text control information describing the run. If HUMAN cannot open the keyword file, then the code will terminate execution after writing an error message to the standard output device.

5.2.3 Memory Requirements

The HUMAN code uses dynamic memory allocation, so the memory requirements depend on the problem being analyzed. A reasonably large example run where the HUMAN code required 3.84 MB of memory (on a Windows 2000 machine) used 7 analytes, 35 time steps, 25 realizations, and 1618 locations. It is expected that most, if not all, of the runs of the HUMAN code will require fewer than 5 MB of memory.

5.3 Data Files

The HUMAN code reads four or more input files and writes up to seven output files. The number of input files depends on the number of contaminants being analyzed. The number of output files depends on the options selected in the HUMAN code. These files are described in the following sections.

5.3.1 Input Files

The input files for the HUMAN code are keyword files and a suite of concentration-data-related files. One keyword file controls the case the HUMAN code will execute, and it points to the ESD keyword file. The suite of concentration data files are all identified in the ESD keyword file – the user of the HUMAN code only needs to identify the ESD keyword file. The following are the input files:

- **ESD Keyword File.** The ESD keyword file contains the control information the inventory and environmental transport codes use to generate concentration data files. Table 2.2 provides examples of keywords in the ESD file that control the impact codes, including the HUMAN code. Section 2.1 provides definitions for these keywords. Typically, the user of the HUMAN code will not modify the ESD keyword file.
- **HUMAN Keyword File.** The HUMAN Keyword file controls the scenario to be analyzed by the HUMAN code. The options and data available are constrained by the case defined in the ESD Keyword file. Section 5.4 describes the contents of the HUMAN keyword file. Table 5.1 provides excerpted records from a keyword file for the HUMAN code.
- **ECDA Concentration Files.** The ECDA concentration files contain all the concentration data available for the impact codes. The concentrations for all analytes are based on the same time and location data. There is a “map” file for the ECDA files containing indexing information for each of the concentration data files. In addition, there is a separate concentration data file for every analyte used in the impacts scenario. For example, when running a scenario with seven analytes, there will be one map file and seven concentration data files.
- **FCDA Concentration Files.** The FCDA concentration files contain all the food concentrations that are computed and written by the ECEM ecological impacts. The concentrations for all foods are based on the same time and location data. There is a “map” file for the FCDA files containing indexing information for each of the food concentration data files. In addition, there is a separate concentration data file for every food used in the impacts scenario. For example, when running a scenario with nine foods, there will be one map file and nine food concentration data files.

5.3.1.1 ESD Keyword File

The HUMAN code also reads keywords from the environmental settings file. These keywords are read from a different file and can have a different definition from a keyword defined for internal use in the HUMAN code. The environmental settings keywords are defined in Section 2.1. The following keywords are required:

- ANALYTE – definition of analytes in the environmental simulations
- END – end of the environmental settings keywords
- FILE – file names for the concentration file for each analyte

- LOCATION – locations at which concentrations were generated
- REALIZAT – number of realizations that were simulated
- SPECIES – species for which body burdens were generated
- TIMES – times at which concentrations were generated
- TITLE – environmental simulation title

5.3.1.2 HUMAN Keyword File

The HUMAN keyword definition file contains control information for the desired impact simulation. Individual keywords are defined in Section 5.4. Table 5.1 contains excerpted keywords from a keyword file for the HUMAN code. The complete file is 2925 lines long.

Table 5.1 Excerpted Records from a Keyword File for the HUMAN Code

```
! Report File (Must be first Entry)
REPORT "Farmer_CA1_median.Rpt"
! Other identification information
TITLE "SAC Rev. 1 - Composite Analysis Runs - CA1_Median"
USER "Carmen Arimescu"
EXECUTE
! Sweat lodge water source (GROUND, RIVER or SEEP options)
SWEAT RIVER
! File names (local directory names)
FILE STATS  "Farmer_CA1_median_Sta.csv" ! Risk summary statistics
FILE DETAIL  "Farmer_CA1_median_Dtl.csv" ! Risk detailed data
FILE VALUES "Farmer_CA1_median_Val.csv" ! Generated stochastic variables
FILE HEADER  "Farmer_CA1_median.Hdr"   ! Header file for SACVIEW
! Environmental keyword file
FILE ESD "/home/ANALYSIS4/CA1_median/ESD_CA1_median.key"
FOOD PATH="/home/ANALYSIS4/CA1_median/foods/"
  MAP ="Ecem_CA1_median_map_foods.dat
INGESTIO
  FISH  ="QSBASS"
...
  EGGS  ="UCHKEG"
!
FOODSOIL SOGW
! Output summary statistics
STATISTICS COMB_ANA ! Output risk detailed data at the combined analyte level
! Output detailed data
DETAILS COMB_ANA ! Output risk detailed data at the combined analyte level
...
DETAILS CONCEN ! Output concentration details
!
DEBUG FOOD
! Random Seed for Stochastics
SEED STOCHASTIC 421468
! Number of Realizations
REALIZATIONS 1
! Soil averaging time for irrigation (years)
```

```

SOIL 70.0
! Averaging time for exposure calculations (years)
AVERAGE 70.0
! Analyte definitions
ANALYTE ID="H3"    RADIOACT OUTPUT
...
ANALYTE ID="U238"    RADIOACT OUTPUT
!-----| ECDA Concentration Solution Times |-----!
TIMES
  1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 !
  12000 12050                                     !
!
LOCATION PRIMARY="UH0001" POP=0 BIRD="UH0001" MEAT="UH0001" FISH="QHP220" OUTPUT
...
LOCATION PRIMARY="UHR123" POP=0 BIRD="UHR123" MEAT="UHR123" FISH="QHP220" OUTPUT
!!!!!!!!!!!!!!!!!!!!!!!!!!!! Start of scenario-specific values !!!!!!!!!!!!!!!!!!!!!!!!!!!!!
! Comments    : Exposure frequencies
STOCHASTIC "EFBOAT"  1 0  "Exposure frequency for boating (day/yr)"
...
STOCHASTIC "EFFISH"  1 0  "Exposure frequency for fish (day/yr)"
! Comments    : Exposure time variables
STOCHASTIC "ETBOAT"  1 0  "Exposure time for boating (hr/day)"
...
STOCHASTIC "EDADULT" 1 32.5 "Exposure duration for an adult (yr)"
! Comments    : Ingestion rate variables
STOCHASTIC "IRATE"   1 22.5 "Inhalation rate (m^3/day)"
...
STOCHASTIC "IRGRAIN"  1 0    "Ingestion rate, grain (kg/day)"
! Comments    : Body variables
STOCHASTIC "BWCHILD" 1 16   "Body weight for a child (kg)"
STOCHASTIC "BWADULT" 1 70   "Body weight for an adult (kg)"
STOCHASTIC "SASOIL"  1 5000 "Body surface area - soils (cm^2)"
...
STOCHASTIC "SASWEAT" 1 20000 "Body surface area - sweat lodge (cm^2)"
! Comments    : Air concentration factor for sweat lodgeExposure frequencies
STOCHASTIC "CFSWEAT" 1 0.2 "Air concentration factor for sweat lodge (L/m^3)"
! Comments    : Soil and water variables
STOCHASTIC "SHIELDSOIL" 1 0.8    "Soil shielding factor (unitless)"
STOCHASTIC "SHIELDSOIL" 1 0.2    "Sediment shielding factor (unitless)"
STOCHASTIC "ML"        1 0.00000005 "Mass loading of soil in air (kg/m^3)"
STOCHASTIC "AFSOIL"    1 0.275 "Adherence factor for soil (mg/cm^2/day)"
STOCHASTIC "AFSED"     1 0.275 "Adherence factor for sediment (mg/cm^2/day)"
!
STOCHASTIC "DOSE2RISK" 1 1 "Sum of doses by nuclide"
!!!!!!!!!!!!!!!!!!!!!!!!!!!! End of scenario-specific values !!!!!!!!!!!!!!!!!!!!!!!!!!!!!
! Comments    : Radionuclide stochastic dose factors
STOCHASTIC "H3  DFSOIL" 1 0      "Deterministic H3 dose factor for soil (rem/hr per pCi/kg)"
STOCHASTIC "H3  DFSWIM" 1 0      "Deterministic H3 dose factor for swimming (rem/hr per pCi/L)"
STOCHASTIC "H3  DFBOAT" 1 0      "Deterministic H3 dose factor for boating (rem/hr per pCi/L)"
STOCHASTIC "H3  DFING"  1 6.401000E-11 "Deterministic H3 dose factor for ingestion (rem/pCi)"

```



```
STOCHASTIC "H3  DFINH" 1 6.401000E-11 "Deterministic H3 dose factor for inhalation (rem/pCi)"
! Comments : Stochastic volatilization factors
STOCHASTIC "H3  VF" 1 0 "Deterministic (reference) H3 Volatilization Factor [L/m3]"
!
STOCHASTIC "CCl4  VF" 1 0.01 "Deterministic (reference) CCL4 Volatilization Factor [L/m3]"
STOCHASTIC "CCl4  KP" 1 0.094868 "Deterministic (reference) CCL4 Skin Permeability Coefficient [cm/hr]"
STOCHASTIC "CCl4  ABS" 1 0.01 "Deterministic (reference) CCL4 Skin Absorption Factor [unitless]"
! End of Inputs
END
```

5.3.1.3 ECDA Concentration Files

The ECDA provides a central storage location for concentration data for all analytes at the environmental locations and times needed to perform social-cultural analyses. The ECDA files are described in Section 2.4.1.

5.3.1.4 FCDA Concentration Files

The FCDA provides a central storage location for food concentration data for all food species at the environmental locations and times needed to perform HUMAN impacts analyses. The FCDA files are described in Section 4.3.2.7.

5.3.2 Output Files

Up to seven output files can be written by the HUMAN code. The number of files depends on the options selected in the scenario being analyzed. The following are the output files:

- **Report File.** This required file contains a summary of the scenario being analyzed and contains any error messages. An example report file for the HUMAN code is provided in Table 5.2.
- **SACView Header File.** This required file contains information used by the interactive SACView program to allow easy extraction of subsets of the results computed by the HUMAN code. An example of this file is given in Table 5.3.
- **Stochastic Values File.** This optional file contains the values for every stochastic variable generated in the HUMAN code. The description of the VALUES modifier on the FILE keyword (see Section 5.4.7) explains how to activate writing this file. A subset of the data written to this file for a run using five realizations is provided in Table 5.4.
- **Risk Detailed Data.** This optional file contains the detailed values for the dose and risk values generated in the HUMAN code. The description of the DETAIL modifier on the FILE keyword (see Section 5.4.7) explains how to activate writing this file. A subset of the data written to this file for a run using five realizations is provided in Table 5.5.
- **Risk Summary Statistics.** This optional file contains the summary statistics for the dose and risk values generated in the HUMAN code. The description of the STATS modifier on the FILE keyword (see Section 5.4.7) explains how to activate writing this file. A subset of the data written to this file for a run using five realizations is provided in Table 5.6.

5.3.2.1 HUMAN Report File

Table 5.2 provides excerpted records from an example report file for the HUMAN code. This file contains information for a run of the HUMAN code using 4 analytes, 1 realization, 2873 locations, and 77 solution times. This example file is a typical size for the report file, provided that no debug options are selected. The size of this file grows rapidly when debug options are selected. For example, this file is about 12 KB in size. If the debug options are turned on, the file grows to 6.3 MB. A run using all debug options having a large number of locations, analytes, solution times, and realizations could generate a report file larger than 2 GB.

Table 5.2 Excerpted Records from an Example Report File for the HUMAN Code

H	H	U	U	M	M	AAAAA	N	N
H	H	U	U	MM	MM	A	A	NN
H	H	U	U	M	M	M	A	N
HHHHHHH	U	U	M	M	M	AAAAAAA	N	N
H	H	U	U	M	M	A	A	N
H	H	U	U	M	M	A	A	N
H	H	U	U	M	M	A	A	N
H	H	UUUUU	M	M	A	A	N	N
Human 3.00.A.3								
Last Modified on 26 Jun 2003								
Stochastic Human Risk Analysis								
Systems Assessment Capability (SAC), Revision 0								

Developed By Battelle								
Pacific Northwest National Laboratory								
Richland, Washington								

Current Run ID = 20030715091422 User Name = Paul W. Eslinger								
System Date = 07-15-2003 System Time = 09:14:22								
The software used to generate this output is experimental								
and has not been formally tested or peer reviewed.								
Review Signatures								
Input Prepared By: _____ Date: _____								
Input Reviewed By: _____ Date: _____								
===== Echo of the Problem Definition =====								
Title: Groundwater ingestion - no food consumption								
User: Paul W. Eslinger								
1 Realizations requested in this run								
1 Realizations available in the concentration files								
File Name for Input Keyword Data								
File: drink_gw.key								
File Name for use in SACVIEW								
File: Drink_GW.Hdr								
File Name for Summary Risk Data								
File: Drink_GW_Sta.csv								
...								
File Name for Media Concentrations for analyte with ID="H3"								
File: \Sac_1\AAAA\CON_H3.DAT								
...								
File Name for Media Concentrations for analyte with ID="I129"								
File: \Sac_1\AAAA\CON_I129.DAT								
Debug Flag Information								
No : Concentration Data								
...								
Yes : Stochastic Calculations								
No : Food concentrations								

```
Output Data Options Information
  Yes : Combined Analyte Risk Detailed Data
...
  No  : Media Level Concentrations

Averaging time for risk calculations
  Value = 25567.50  Units are days

Sweat lodge option is not used

Analyte Information based on 4 possible analytes.
  1 : H3      : NR : RAD : Tritium
  2 : Tc99    : NR : RAD : Technetium 99
  3 : U238    : NR : RAD : Uranium 238
  4 : I129    : NR : RAD : Iodine 129
A total of 4 analytes have been requested.

Soil type selection for for upland food
  SOGW : Groundwater irrigation

FOOD Information
  MILK : Not consumed
...
  ROOTVEG : Not consumed

Time Slices Requested: (Index, Calendar Year) based on 77 possible times.
  1 : 1944 : Included in this scenario
...
  77 : 2020 : Included in this scenario
A total of 77 times have been requested.
===== End of the Problem Definition =====
Starting Problem Execution
  Date: 07/15/2003
  Time: 09:14:29.692

Concentration data units conversion factors
  1 : H3      : NR : Ground water : 1.00000E+09 : From Ci/m^3      to pCi/L
...
  1 : H3      : NR : Air Concen.  : 1.00000E+12 : From Ci/m^3      to pCi/m^3

Ending Problem Execution
  Date: 07/15/2003
  Time: 09:15:32.443
Message originating in routine HUMAN
Message: Normal Termination
```

5.3.2.2 HUMAN SACView Header File

The SACView header file is an output file containing information used by the interactive SACView program to allow easy extraction of subsets of the results computed by the HUMAN code. This file is required for every run of the HUMAN code. An example of this file is given in Table 5.3. The file contains the following sections of information:

- A header section of basic run information
- Number of realizations processed
- Solution times selected
- Locations used
- Analytes processed

- Solutions selected
- Output file names

The user only specifies the name of this file; users should not modify the file after it is generated by the HUMAN code. See the instructions in Section 1.0 regarding the use of the SACView program. Because this file has at most a few hundred entries, the file size is always much smaller than 1 MB. File names for options not selected are set to null.

Table 5.3 Example Header File for the SACView Program

```

type: "Human"
title: "Agricultural Resident Scenario Using Local Groundwater - Covers"
user: "Paul W. Eslinger"
name: "Human"
version: "3.00.A.0"
date: "11 Mar 2003"
id: "20030314100334"
envfile: "ESD_Test.key"
realizations: 5
times: 198
1945
...
12050
locations: 4
"TH0007","TH0007 - Upland groundwater irrigated location"
"TH0008","TH0008 - Upland groundwater irrigated location"
"TH0013","TH0013 - Upland irrigated (both) location"
"TH0014","TH0014 - Upland irrigated (both) location"
analytes: 6
"CCl4  ","CAR","Carbon Tetrachloride"
"CrVI   ","CAR","Hexavalent Chromium"
"H3     ","RAD","Tritium"
"COMBIN","CAR","Combined carcinogenic analytes"
"COMBIN","HAZ","Combined hazardous analytes"
"COMBIN","RAD","Combined radioactive analytes"
solutions: 2
"AL","Analyte dose"
"CB","Combined dose for analyte type"
foods: 10
"CBIRD","Bird tissue concentration "
"CFISH","Fish tissue concentration"
"CLEAFVEG","Leafy vegetable concentration"
"CMEAT","Meat (deer) concentration"
"CMILK","Cow milk concentration"
"CROOTVEG","Root vegetable concentration"
"CFRUIT","Fruit concentration"
"CGRAIN","Grain concentration"
"CEGGS","Eggs concentration"
"CSOIL","Soil (upper layer) concentration"
statistics_impacts: "Farmer_Sta.csv"
detail_impacts: "Farmer_Dtl.csv"

```

5.3.2.3 HUMAN Stochastic Values File

The stochastic values file is an optional output file that contains the values for every stochastic variable generated in the HUMAN code. The description of the VALUES modifier on the FILE keyword (see Section 5.4.7) explains how to activate writing this file. The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file consists of the ID of the stochastic variable followed by a value for every generated realization. A subset of the data written to this file for a run using five realizations is provided in Table 5.4. Because this file has at most a few hundred entries, the file size is always much smaller than 1 MB.

Table 5.4 Excerpted Records from the Stochastic Values File

"DOSE2RISK",	6.63298E-04,	8.95216E-04,	4.28789E-04,	7.61322E-04,	3.24067E-04
"Sr90 DFSOIL",	3.90004E-10,	7.28447E-10,	2.60232E-10,	5.63547E-10,	5.15688E-10
"Sr90 DFINH",	3.00188E-07,	2.71429E-07,	6.30467E-07,	1.09017E-07,	1.41680E-07
"U HQINH",	1.00014E+00,	9.98158E-01,	9.94201E-01,	1.00092E+00,	1.00480E+00
"CC14 SFING",	4.34638E-01,	8.02780E-02,	1.85404E-01,	1.43329E-01,	2.62328E-02
"CC14 SFINH",	1.75551E-02,	3.65071E-01,	2.56433E-02,	7.24165E-02,	5.14025E-02
"EFBOAT",	2.44306E+01,	1.12904E+01,	1.78827E+01,	5.08665E+00,	2.99136E+01
"ETRIVER",	1.75214E+01,	1.53131E+01,	1.31528E+01,	1.10683E+01,	1.87175E+01
"ED",	1.44600E+01,	1.60701E+01,	6.21335E+01,	4.98780E+01,	2.99073E+01
"EFLEAFY",	3.60858E+02,	3.34866E+02,	2.94225E+02,	3.25261E+02,	2.76094E+02
"QPBIRD",	4.90110E-01,	4.32282E-01,	5.87973E-01,	5.38815E-01,	4.58023E-01
"QWBIRD",	2.22780E-01,	3.69238E-01,	2.49782E-01,	1.42156E-01,	2.92976E-01
"BWADULT",	6.21404E+01,	7.29195E+01,	8.22975E+01,	6.95193E+01,	8.40544E+01
"SASOIL",	5.00000E+03,	5.00000E+03,	5.00000E+03,	5.00000E+03,	5.00000E+03
"SARIVER",	2.00000E+04,	2.00000E+04,	2.00000E+04,	2.00000E+04,	2.00000E+04
"IRSEDCHILD",	2.47929E-04,	4.71712E-04,	3.42739E-05,	2.08821E-04,	3.33628E-04
"IRMEAT",	1.47307E+00,	2.16214E+00,	1.08884E-01,	2.99069E+00,	7.07404E-01
"IRATE",	3.38178E+01,	2.51633E+01,	2.98956E+01,	2.03503E+01,	2.78600E+01
"Sr90 TFDEER",	7.39602E-02,	4.40583E-02,	3.74697E-02,	1.29689E-02,	1.81908E-02
"Sr90 TFBIRD",	5.63319E-01,	2.14527E+00,	1.47448E+00,	2.64039E+00,	6.26559E-02
"IRGRATE",	9.07806E+02,	8.51027E+02,	6.27562E+02,	5.60488E+02,	7.31329E+02
"SHIELDSOIL",	8.00000E-01,	8.00000E-01,	8.00000E-01,	8.00000E-01,	8.00000E-01
"AFSED",	3.96716E-01,	1.41329E-01,	1.28814E-01,	4.29907E-01,	2.54937E-01

5.3.2.4 HUMAN Risk Detailed Data

The risk detailed data file is an optional output file that contains the detailed values for dose and risk generated in the HUMAN code. The description of the DETAIL modifier on the FILE keyword (see Section 5.4.7) explains how to activate writing this file. Section 5.4.4 describes the solution types that can be written to the file. The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file consists of six identifiers followed by a value for every generated realization. Table 5.5 provides a subset of the data written to this file for a run using five realizations. The following are the six identifiers on each line:

- Time: Year for which the data are valid
- Location ID: The location identifier where the data are valid
- Analyte ID: The identification of the analyte for which the data were computed
- Analyte Type: A flag for analyte type: 1=radioactive, 2=carcinogen, 3=noncarcinogen
- Solution type: A flag for solution type that has the following definition:

- o EX indicates external dose
- o IG indicates ingestion dose
- o IH indicates inhalation dose
- o AL indicates analyte dose
- o CB indicates combined dose for analyte type
- o DW indicates drinking water dose (radioactive)
- o PD indicates population dose (radioactive)
- o PR indicates population risk (radioactive)
- Units: The units associated with the computed data

Table 5.5 Excerpted Records from the Risks Detailed Data File

"Time","Location ID","Analyte ID","Analyte Type","Solution Type","Units","Values by realization"										
2000,"HL0413","H3","RAD","IG","Rem",	1.59834E-05,	5.09257E-05,	1.60365E-04,	6.87785E-05,	5.56380E-05					
2000,"HL0413","H3","RAD","IH","Rem",	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00					
2000,"HL0413","H3","RAD","EX","Rem",	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00					
2000,"HL0413","H3","RAD","DW","Rem",	9.67225E-07,	3.01822E-06,	2.21704E-06,	1.23771E-06,	1.58318E-06					
2000,"HL0413","H3","RAD","AL","Rem",	1.59834E-05,	5.09257E-05,	1.60365E-04,	6.87785E-05,	5.56380E-05					
2000,"HL0413","H3","RAD","PD","Rem",	3.28856E-02,	1.02619E-01,	7.53793E-02,	4.20823E-02,	5.38282E-02					
2000,"HL0413","H3","RAD","PR","Risk",	2.18130E-05,	9.18666E-05,	3.23219E-05,	3.20382E-05,	1.74439E-05					
...										
2000,"HL0414","COMBIN","RAD","CB","Rem",	1.51672E-02,	1.43815E-03,	4.61088E-03,	3.55055E-03,	1.01778E-03					
2000,"HL0414","COMBIN","RAD","DW","Rem",	1.87235E-02,	1.85456E-03,	1.82662E-03,	6.41806E-03,	7.02531E-04					
2000,"HL0414","COMBIN","RAD","PD","Rem",	5.99151E+02,	5.93458E+01,	5.84517E+01,	2.05378E+02,	2.24810E+01					
2000,"HL0414","COMBIN","RAD","PR","Risk",	3.97416E-01,	5.31273E-02,	2.50635E-02,	1.56359E-01,	7.28534E-03					
...										
2000,"HL0414","CC14","CAR","IG","Risk",	2.44771E-06,	8.10842E-08,	1.44645E-05,	1.51662E-05,	6.47176E-07					
2000,"HL0414","CC14","CAR","IH","Risk",	1.60686E-09,	4.94426E-09,	4.31426E-08,	1.44453E-09,	2.28790E-08					
2000,"HL0414","CC14","CAR","EX","Risk",	1.33223E-07,	4.05942E-09,	3.24008E-08,	7.81486E-08,	4.68123E-09					
2000,"HL0414","CC14","CAR","AL","Risk",	2.58254E-06,	9.00879E-08,	1.45400E-05,	1.52458E-05,	6.74737E-07					
...										
2000,"HL0414","COMBIN","CAR","CB","Risk",	2.58254E-06,	9.00879E-08,	1.45400E-05,	1.52458E-05,	1.84499E+00					
2000,"HL0414","U","HAZ","IG","Unitless",	8.05042E-06,	1.53466E-06,	6.57534E-05,	3.72276E-05,	7.38749E-06					
2000,"HL0414","U","HAZ","IH","Unitless",	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00					
2000,"HL0414","U","HAZ","EX","Unitless",	3.32978E-07,	1.90871E-07,	2.40724E-07,	8.16859E-06,	2.05838E-07					
2000,"HL0414","U","HAZ","AL","Unitless",	8.38340E-06,	1.72553E-06,	6.59941E-05,	4.53962E-05,	7.59333E-06					
2000,"HL0414","COMBIN","HAZ","CB","Unitless",	8.38340E-06,	1.72553E-06,	6.59941E-05,	4.53962E-05,	7.59333E-06					
...										
2100,"POPDOS","POPDOS","RAD","CB","Person-Rem",	6.39394E+02,	6.13426E+01,	7.99459E+01,	8.50341E+02,	1.23211E+02					
2100,"POPRSK","POPRSK","RAD","CB","Risk",	4.24109E-01,	5.49149E-02,	3.42799E-02,	6.47383E-01,	3.99285E-02					

This file can have up to nine rows of information for every combination of time, location, and analyte. Therefore, this file can become very large. As an example, a 227 KB file was generated for a case involving 11 locations, 10 analytes, 5 realizations, and 3 times. The file size directly scales with the number of analytes, locations, and times. The file size grows more slowly than a direct scaling by the number of realizations. As another example, a 463 MB file was generated for a case involving 1618 locations, 6 analytes, 11 realizations, and 35 times, using all details output options. The file size can be reduced by selecting fewer detailed solution types.

5.3.2.5 HUMAN Risk Summary Statistics

This optional file contains summary statistics for dose and risk values generated in the HUMAN code. The description of the STATS modifier on the FILE keyword (see Section 5.4.7) tells how to activate writing this file. The solution types that can be written to the file are described in Section 5.4.16. The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file consists of six identifiers followed by summary statistics (nine

percentiles, mean value, and standard deviation). Table 5.6 provides a subset of the data written to this file for a run using five realizations. The six identifiers on each line are the following:

- Time: Year for which the data are valid
- Location ID: The location identifier where the data are valid
- Analyte ID: The identification of the analyte for which the data were computed
- Analyte Type: A flag for analyte type: 1=radioactive, 2=carcinogen, 3=noncarcinogen
- Solution type: A flag for solution type that has the following definition:
 - EX indicates external dose
 - IG indicates ingestion dose
 - IH indicates inhalation dose
 - AL indicates analyte dose
 - CB indicates combined dose for analyte type
 - DW indicates drinking water dose (radioactive)
 - PD indicates population dose (radioactive)
 - PR indicates population risk (radioactive)
- Units: The units associated with the computed data

The data for each record in this file are too long to present without with line-wrapping in this document. Each record in the file occupies two lines in Table 5.6.

Table 5.6 Excerpted Records from the Risk Summary Statistics File

"Time","Location ID","Analyte ID","Analyte Type","Solution Type","Units","Minimum","5th Percentile","10th Percentile","25th Percentile","Median","75th Percentile","90th Percentile","95th Percentile","Maximum","Mean","Standard Deviation"												
2000,"HL0413","H3","RAD","IG","Rem",	1.59834E-05,	1.59834E-05,	1.59834E-05,	1.59834E-05,	5.56380E-05,	5.56380E-05,	6.87785E-05,	6.87785E-05,	1.60365E-04,	7.03381E-05,	5.39783E-05,	
2000,"HL0413","H3","RAD","IH","Rem",	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	
2000,"HL0413","H3","RAD","EX","Rem",	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	
2000,"HL0413","H3","RAD","PD","Person-Rem",	3.28856E-02,	3.28856E-02,	3.28856E-02,	3.28856E-02,	5.38282E-02,	5.38282E-02,	7.53793E-02,	7.53793E-02,	1.02619E-01,	6.13590E-02,	2.80091E-02,	
2100,"HL0414","Tc99","RAD","IG","Rem",	7.90825E-08,	7.90825E-08,	7.90825E-08,	7.90825E-08,	8.38515E-07,	8.38515E-07,	7.16277E-06,	7.16277E-06,	1.32302E-04,	2.81574E-05,	5.82919E-05,	
2100,"HL0414","Tc99","RAD","IH","Rem",	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	
2100,"HL0415","U","HAZ","EX","Unitless",	2.13679E-07,	2.13679E-07,	2.13679E-07,	2.13679E-07,	6.95310E-07,	6.95310E-07,	1.37764E-06,	1.37764E-06,	1.67892E-05,	3.87023E-06,	7.23683E-06,	
2100,"HL0415","U","HAZ","AL","Unitless",	2.48891E-06,	2.48891E-06,	2.48891E-06,	2.48891E-06,	1.75020E-05,	1.75020E-05,	9.33037E-05,	9.33037E-05,	3.77678E-04,	9.97710E-05,	1.59648E-04,	
2100,"HL0415","COMBIN","HAZ","CB","Unitless",	2.48891E-06,	2.48891E-06,	2.48891E-06,	2.48891E-06,	1.75020E-05,	1.75020E-05,	9.33037E-05,	9.33037E-05,	3.77678E-04,	9.97710E-05,	1.59648E-04,	
2100,"HL3870","COMBIN","HAZ","CB","Unitless",	3.05987E-20,	3.05987E-20,	3.05987E-20,	3.05987E-20,	9.17589E-07,	9.17589E-07,	3.95330E-06,	3.95330E-06,	4.92935E-04,	9.95633E-05,	2.19907E-04,	
2100,"POPDOS","COMBIN","RAD","CB","Person-Rem",	6.13426E+01,	6.13426E+01,	6.13426E+01,	6.13426E+01,	6.13426E+01,	1.23211E+02,	1.23211E+02,	6.39394E+02,	6.39394E+02,	8.50341E+02,	3.50847E+02,	
2100,"POPRSK","COMBIN","RAD","CB","Risk",	3.42799E-02,	3.42799E-02,	3.42799E-02,	3.42799E-02,	5.49149E-02,	5.49149E-02,	4.24109E-01,	4.24109E-01,	6.47383E-01,	2.40123E-01,	2.81275E-01,	

This file can have up to nine rows of information for every combination of time, location, and analyte. Therefore, this file can become very large. As an example, a 398 KB file was generated for a case

involving 11 locations, 10 analytes, 5 realizations, and 3 times. The file size directly scales with the number of analytes, locations, and times. The file size grows more slowly than a direct scaling by the number of realizations. As another example, a 466 MB file was generated for a case involving 1618 locations, 6 analytes, 11 realizations, and 35 times, using all details output options. The file size can be reduced by selecting fewer statistics solutions types.

5.4 Keyword Descriptions for the HUMAN Code

In the following keyword descriptions, some data are optional and some are required. Data that are required are enclosed in square brackets. For AB to be required, it would be denoted by [AB]. If only one of the three items AB, BC, CD were required, it would be written as [AB|BC|CD]. The vertical bars indicate that the user must select one of the items in the list. Optional items are enclosed in normal brackets. For DE to be an optional entry, it would be denoted by {DE}. The { } or [] symbols indicate whether the data are required; the symbols do not need to be entered when the keyword is constructed. The keyword name can contain any number of characters; however, only the first eight characters are used (for example, REALIZAT = REALIZATION = REALIZATxxx).

In some instances, numerical values or quote strings are associated with a modifier. In this description, the association is indicated by using the equal (=) symbol. The = symbol is not required but may be used when the keyword is constructed. When a numerical value or quote string is associated with a modifier, it must be physically entered on the input line directly after the modifier.

In general, the keywords can be entered in any order. The following are the restrictions on keyword order:

- The REPORT keyword must be the first keyword in the file.
- The END keyword must be the last keyword in the file.

5.4.1 ANALYTE Keyword for the HUMAN Code

The ANALYTE keyword is used to define the analytes to be used in the simulation. The following is this keyword's syntax:

```
ANALYTE [ID="quote1"] [RADIOACTIVE | CARCINOGEN | NONCARCINOGEN] {OUTPUT}
```

The analytes requested must be a subset of the analytes for which environmental data were computed and stored by the inventory, release, and transport modules. Table 5.7 describes the modifiers associated with the ANALYTE keyword.

Table 5.7 Modifiers Associated with the ANALYTE Keyword in the HUMAN Code

Modifier	Description
ID	The quote string associated with the ID modifier is an analyte identification string up to six characters long. The analyte identification string is case sensitive, and spaces or hyphens change the definition. All data in the analyte identification strings must satisfy the following conventions: <ul style="list-style-type: none">• Only the first entry in the analyte identification string is capitalized• No embedded spaces or hyphens are used, even for radionuclides• Individual elements are defined using the standard element abbreviation
RADIOACTIVE	The presence of this modifier indicates to treat this analyte as a radioactive analyte.
CARCINOGEN	The presence of this modifier indicates to treat this analyte as a chemical carcinogen.
NONCARCINOGEN	The presence of this modifier indicates to treat this analyte as a noncarcinogenic hazardous chemical.
OUTPUT	If the modifier OUTPUT is entered, then outputs requested by the DETAILS and STATISTICS keywords will be written to the output files for this analyte. Otherwise, the calculations will occur, but no data will be output for this analyte.

Even though the HUMAN code can treat each analyte in three different fashions: as a radioactive analyte, as a noncarcinogenic hazardous chemical, and as a carcinogenic chemical. Each analyte can only be handled in one fashion in a given run of the code. Treating an analyte in all three fashions would require running the code three times.

The following is an example entry for a radioactive analyte:

```
ANALYTE ID="Np237" RADIOACTIVE
```

The following is an example entry for a carcinogenic analyte that has no imposed concentration limits:

```
ANALYTE ID="Cr" CARCINOGENIC
```

The following is an example entry for a noncarcinogenic (hazardous) analyte that has no imposed concentration limits:

```
ANALYTE ID="Kerosen" NONCARCINOGEN
```

5.4.2 AVERAGE Keyword for the HUMAN Code

The AVERAGE keyword is used to define averaging time for human risk calculations. The following is this keyword's syntax:

```
AVERAGE Value1
```

The entry for Value1 is the number of years in the averaging time. The averaging time has a default value of 70 years, and this record may be omitted if the default averaging time is desired. Before use in the human health calculations, the averaging time is converted to days by multiplying the input value by 365.25. The following record sets the averaging time to 50 years:

```
AVERAGE 50
```

There are no modifiers or quote strings associated with the AVERAGE keyword.

5.4.3 DEBUG Keyword for the HUMAN Code

The DEBUG keyword is used to activate dumping of intermediate calculations to the report file. It should be used sparingly and with only one or two realizations; otherwise, the volume of output could fill the user's hard drive. The following is this keyword's syntax:

```
DEBUG [modifier 1] {modifier 2}...{modifier 8}
```

Multiple DEBUG records can be entered with combinations of modifiers, or a single record can be entered containing all of the modifiers. The modifiers can be entered in any order. Table 5.8 describes the modifiers associated with the DEBUG keyword.

Table 5.8 Modifiers Associated with the DEBUG Keyword in the HUMAN Code

Modifier	Description
CARCINOGENIC	Intermediate outputs on calculations for carcinogenic analytes.
CONCENTR	Intermediate outputs on reading and processing media concentrations.
FOOD	Intermediate outputs on calculating concentrations in food items.
HAZARDOUS	Intermediate outputs on calculations for hazardous analytes.
RADIONUC	Intermediate outputs on calculations for radioactive analytes.
STOCHASTIC	Write out all generated stochastic values.
DEFINITE	Output the definition of all stochastic variables.
STATISTI	Output summary statistics for all generated stochastic variables.

The following entries are examples of the use of the DEBUG keyword:

```
DEBUG CARCINOGENIC RADIONUCLIDES STOCHASTIC  
DEBUG STOCHASTIC
```

There are no quote strings associated with the DEBUG keyword.

5.4.4 DETAILS Keyword for the HUMAN Code

The DETAILS keyword is used to control writing detailed data for all realizations to the output details file for a variety of solution types. The following is this keyword's syntax:

```
DETAILS {modifier 1} {modifier 2} ... {modifier13}
```

Multiple DETAILS cards can be entered with combinations of modifiers, or a single card can be entered containing all of the modifiers. The modifiers can be entered in any order. The modifiers associated with the DETAILS keyword are given in Table 5.9.

Table 5.9 Modifiers Associated with the DETAILS Keyword in the HUMAN Code

Modifier	Description
CONCEN	This modifier activates output of detailed media concentration data for those analytes and locations whose OUTPUT flags have been activated.
FOODS	This modifier activates output of detailed food concentration data for those analytes and locations whose OUTPUT flags have been activated.
COMB_ANA	This modifier activates output of the risk for combined pathways that is also combined over analytes of same type (radioactive, carcinogenic, or hazardous). Detailed information is written out for every time, location, and analyte type combination.
COMB_DWA	This modifier activates output of the risk from drinking water that is combined over all radioactive analytes. Detailed information is written out for every time and location combination.
COMB_PDS	This modifier activates output of the population dose from drinking water that is combined over all radioactive analytes. Detailed information is written out for every time step.
COMB_PRS	This modifier activates output of the population risk from drinking water that is combined over all radioactive analytes. Detailed information is written out for every time step.
EACH_ANA	This modifier activates output of the risk or impact for combined pathways for each analyte. Detailed information is written out for every time, location, and analyte combination.
EACH_PDS	This modifier activates output of the population dose from drinking water for each radioactive analyte. Detailed information is written out for every location, analyte, and time step combination.
EACH_PRS	This modifier activates output of the population risk from drinking water for each radioactive analyte. Detailed information is written out for every location, analyte, and time step combination.

Modifier	Description
PATH_ING	This modifier activates output of the ingestion pathway impact for each analyte. Detailed information is written out for this pathway for every location, analyte, and time step combination.
PATH_INH	This modifier activates output of the inhalation pathway impact for each analyte. Detailed information is written out for this pathway for every location, analyte, and time step combination.
PATH_EXT	This modifier activates output of the external exposure pathway impact for each analyte. Detailed information is written out for this pathway for every location, analyte, and time step combination.
PATH_DWA	This modifier activates output of the drinking water dose for radioactive analytes. Detailed information is written out for this pathway for every location, analyte, and time step combination.

The following entries provide examples of the use of the DETAILS keyword:

```
DETAILS COMB_ANA
DETAILS COMB_ANA COMB_PDS EACH_PDS
```

There are no quote strings associated with the DETAILS keyword.

5.4.5 END Keyword for the HUMAN Code

The END keyword signifies the end of all keyword data. It should be the last keyword in the keyword file. All data in the keyword file after the END keyword will be ignored. The following is this keyword's syntax:

```
END
```

There are no modifiers or quote strings associated with the END keyword.

5.4.6 EXECUTE Keyword for the HUMAN Code

The EXECUTE keyword signifies that the user wishes to perform problem execution. If this keyword is not entered, then the inputs are checked for consistency, but the problem will not be executed. This is useful if the run being set up is expected to take a significant amount of computation time. The following is this keyword's syntax:

```
EXECUTE
```

There are no modifiers or quote strings associated with the EXECUTE keyword.

5.4.7 FILE Keyword for the HUMAN Code

The FILE keyword is used to enter the names of input and output files except for the report file. The names of the files providing concentration data are contained in the environmental scenario file rather than in the keyword file. The following is this keyword's syntax:

```
FILE [modifier1="quote1"] {modifier2="quote2"} ... {modifier5="quote7" }
```

The file names are entered in quote strings, which must be enclosed in double quotation marks. Path names up to 72 characters long are supported. The file name associated with a modifier must be entered before the next modifier is entered. At least one FILE keyword is required for every run of the code. Table 5.10 describes the modifiers associated with the FILE keyword.

Table 5.10 Modifiers Associated with the FILE Keyword in the HUMAN Code

Modifier	Description
DETAIL	Output file containing the calculated risk for each analyte and segment for every realization of the code. The risks are written in tabular form so they can be imported easily into a spreadsheet or other software. This file is optional. It is required if any modifier is entered on the DETAILS keyword.
ESD	Input environmental settings definition file that contains the definition of the environmental runs from which impacts are to be calculated.
HEADER	Output file containing information needed by the SACView program to allow easy abstraction of the data output of the data code.
STATS	Output file containing summary statistics on the risks for every analyte at every location. This file is optional. It is required if any modifier is entered on the STATISTICS keyword.
VALUES	Output file containing the generated stochastic values for every stochastic variable used in the run. The values are written in tabular form so they can be imported easily into a spreadsheet or other software. This file is optional. Entry of this modifier and the file name initiates data output.

The following are two example entries:

```
FILE  HEADER  "TestCase.hdr"  
FILE  DETAIL  "TestCase.det"
```

The following set of two entries has the same effect as the single entry above.

```
FILE  HEADER="TestCase.hdr"  DETAIL="TestCase.det"
```

5.4.8 FOOD Keyword for the HUMAN Code

The FOOD keyword defines the path to the directory where all of the food files from a given run of ECEM reside. The MAP modifier identifies the record number map file for use with all food concentration (FCDA) data files. The following is this keyword's syntax:

```
FOOD [PATH = "Q1"]  
      [MAP = "Q2"]
```

The path to the directory is entered in a set of double quotes. The path name must end with a "\" for locations under a Windows operating environment or "/" for locations under a Linux operating environment. The path must be nonblank. An example for this keyword (for the Windows operating system) is the following:

```
FOOD PATH="C:\SAC_1\ECEM\FOODS\  
      MAP = "Food_Map.Dat"
```

5.4.9 FOODSOIL Keyword for the HUMAN Code

The FOODSOIL keyword is used to define the type of soil to be used in the exposure calculations. The following is this keyword's syntax:

```
FOODSOIL [ SODR | SOGW | SOSW ]
```

The same soil type is used for the entire run – and also determines the soil type used for the food calculations. Table 5.11 describes the modifiers associated with the FOODSOIL keyword.

Table 5.11 Modifiers Associated with the FOODSOIL Keyword in the HUMAN File

Modifier	Description
SODR	The food concentrations for the species were generated using dry land assumptions (no irrigation)
SOGW	The food concentrations for the species were generated using the assumption that the water source for irrigation was local groundwater.
SOSW	The food concentrations for the species were generated using the assumption that the water source for irrigation was surface water from the location identified in the ESD keyword file.

The following is an example entry for using food crops grown in soil irrigated with surface water:

```
FOODSOIL SOSW
```

5.4.10 FOODSOUR Keyword for the HUMAN Code

The FOODSOUR keyword is used to set a single source location for all food consumption for birds, meat, or fish. Use of the FOODSOUR keyword overrides and food source locations provided on individual LOCATION keywords. The following is this keyword's syntax:

FOODSOUR [BIRD= "Location ID 1" | FISH "Location ID 2" | MEAT"Location ID 3"]

Multiple FOODSOUR keywords can be entered. Table 5.12 describes the modifiers associated with the FOODSOUR keyword.

Table 5.12 Modifiers Associated with the FOODSOUR Keyword in the HUMAN File

Modifier	Description
BIRD	The quote string (location ID) associated with BIRD modifier indicates that food concentrations for the location identified by the location ID will be used at all locations in calculations where a human eats a bird.
FISH	The quote string (location ID) associated with FISH modifier indicates that food concentrations for the location identified by the location ID will be used at all locations in calculations where a human eats a fish.
MEAT	The quote string (location ID) associated with MEAT modifier indicates that food concentrations for the location identified by the location ID will be used at all locations in calculations where a human eats meat.

The following is an example entry for assigning the source location for meat and fish to be used as the food source:

FOODSOUR MEAT="UH1876" FISH="QHP013"

5.4.11 INGESTION Keyword for the HUMAN Code

The INGESTION keyword associates a food item for the HUMAN code with a concentration file prepared by the ECEM code for a food (species). The following is this keyword's syntax:

INGESTIO [BIRD= "Species ID 1"] [FISH= "Species ID 2"] [LEAFY= "Species ID 3"]
[MEAT= "Species ID 4"] [MILK= "Species ID 5"] [ROOT= "Species ID 6"]
[GRAIN= "Species ID 7"] [FRUIT= "Species ID 8"] [EGGS= "Species ID 9"]

Multiple INGESTIO keywords can be entered. Table 5.13 describes the modifiers associated with the INGESTIO keyword.

Table 5.13 Modifiers Associated with the INGESTIO Keyword in the HUMAN File

Modifier	Description
BIRD	The quote string (species ID) associated with BIRD modifier indicates that concentrations for the species identified by the species ID will be used in calculations where a human eats a bird.
FISH	The quote string (species ID) associated with FISH modifier indicates that concentrations for the species identified by the species ID will be used in calculations where a human eats a fish.
LEAFVEG	The quote string (species ID) associated with LEAFVEG modifier indicates that concentrations for the species identified by the species ID will be used in calculations where a human eats leafy vegetables.
MEAT	The quote string (species ID) associated with MEAT modifier indicates that concentrations for the species identified by the species ID will be used in calculations where a human eats meat.
MILK	The quote string (species ID) associated with MILK modifier indicates that concentrations for the species identified by the species ID will be used in calculations where a human drinks milk.
ROOTVEG	The quote string (species ID) associated with ROOTVEG modifier indicates that concentrations for the species identified by the species ID will be used in calculations where a human eats a root vegetable.
GRAIN	The quote string (species ID) associated with GRAIN modifier indicates that concentrations for the species identified by the species ID will be used in calculations where a human eats grain
FRUIT	The quote string (species ID) associated with FRUIT modifier indicates that concentrations for the species identified by the species ID will be used in calculations where a human eats fruits.
EGGS	The quote string (species ID) associated with EGGS modifier indicates that concentrations for the species identified by the species ID will be used in calculations where a human eats eggs.

The following is an example entry for assigning the ECEM species for meat, leafy vegetables, and fruit to be used as food sources:

```
INGESTIO MEAT="UH1876" LEAFVEG="QHP013" FRUIT="QHP013"
```

5.4.12 LOCATION Keyword for the HUMAN Code

The LOCATION keyword identifies the locations for human impact calculations that will be generated. Multiple LOCATION keywords are required if more than one location is requested. The locations must be a subset of the locations at which environmental data were computed and stored by the inventory,

release, and transport modules. The list of desired locations builds sequentially with each LOCATION record. Upon program entry, no locations are active. The following is this keyword's syntax:

```
LOCATION [PRIMARY="quote 1"] [SECOND="quote 2"] {POP=N1} {BIRD="quote 2"}
      {FISH="quote 3"} {MEAT="quote 4"} {OUTPUT}
```

The human impact module is activated at a location by entering the location ID string in association with the PRIMARY modifier. A LOCATION keyword is required at each location to activate calculations. Table 5.14 describes the modifiers associated with the LOCATION keyword.

Table 5.14 Modifiers Associated with the LOCATION Keyword in the HUMAN File

Modifier	Description
PRIMARY	The PRIMARY modifier is used to provide the ID for the assessment location. All results for this location will be associated with this location ID.
SECOND	The SECOND modifier is used to provide the ID for the optional secondary assessment location. Any environmental concentrations that are not available at the primary location are taken from the secondary location if they are available.
POP	The POP modifier is associated with the population at the primary location. If no POP modifier is present, the population from the ESD location keyword will be used for this location.
BIRD	The quote string (location ID) associated with BIRD modifier indicates that concentrations for the location identified by the location ID will be used in calculations where a human eats a bird.
FISH	The quote string (location ID) associated with FISH modifier indicates that concentrations for the species identified by the species ID will be used in calculations where a human eats a fish.
MEAT	The quote string (location ID) associated with MEAT modifier indicates that concentrations for the species identified by the species ID will be used in calculations where a human eats meat.
OUTPUT	If the modifier OUTPUT is entered, then outputs requested by the DETAILS and STATISTICS keywords will be written to the output files for this location. Otherwise, the calculations will occur, but no data will be output for this location.

The following are example LOCATION keywords:

```
LOCATION PRIMARY="UH0001" SECOND="QHP220" POP=0 BIRD="UH0001"
      MEAT="UH0001" FISH="QHP220" OUTPUT
LOCATION PRIMARY="RHP250" SECOND="RHP250" POP=0 BIRD="RHP250"
      MEAT="RHP250" FISH="QHP220" OUTPUT
```

5.4.13 REALIZATION Keyword for the HUMAN Code

The REALIZATION keyword defines the number of realizations to generate. The following is this keyword's syntax:

```
REALIZATION value1
```

The integer value1 has a minimum value of 1 and a maximum of the number of realizations defined in the environmental scenario definition file. If the number of realizations is fewer than the number of realizations in the concentration data files, then only the first realizations will be used.

The following keyword record sets the number of realizations to 10:

```
REALIZAT 10
```

5.4.14 REPORT Keyword for the HUMAN Code

The REPORT keyword is used to define the name of the output report (log) file. It must be the first keyword entered in the keyword file. The following is this keyword's syntax:

```
REPORT ["quote"]
```

The name of the report file is entered in a quote string. File names up to 72 characters long are supported, and path names can be included. The following is an example REPORT keyword record:

```
REPORT "/SAC/SystemCodes/Cultural/Test1.rpt"
```

5.4.15 SEED Keyword for the HUMAN Code

The SEED keyword sets the value for the seed for the random number generator. The following is this keyword's syntax:

```
SEED Value1
```

The value for Value1 must be an integer or real number in the range 1 to 999999. The following is an example keyword record:

```
SEED 344443
```

There are no modifiers or quote strings associated with the SEED keyword.

5.4.16 STATISTIC Keyword for the HUMAN Code

The STATISTIC keyword is used to control writing summary statistics to the output summary statistics file for a variety of solution types. The following is this keyword's syntax:

```
STATISTIC [modifier 1] {modifier 2}...{modifier 11}
```

Multiple STATISTIC cards can be entered with combinations of modifiers, or a single card can be entered containing all of the modifiers. The modifiers can be entered in any order. Table 5.15 describes the modifiers associated with the STATISTIC keyword.

Table 5.15 Modifiers Associated with the STATISTIC Keyword in the HUMAN Code

Modifier	Description
COMB_ANA	This modifier activates output of the risk for combined pathways that is also combined over analytes of same type (radioactive, carcinogenic, or hazardous). Summary statistics are written out for every time, location, and analyte type combination.
COMB_DWA	This modifier activates output of the risk from drinking water that is combined over all radioactive analytes. Summary statistics are written out for every time and location combination.
COMB_PDS	This modifier activates output of the population dose from drinking water that is combined over all radioactive analytes. Summary statistics are written out for every time step.
COMB_PRS	This modifier activates output of the population risk from drinking water that is combined over all radioactive analytes. Summary statistics are written out for every time step.
EACH_ANA	This modifier activates output of the risk or impact for combined pathways for each analyte. Summary statistics are written out for every time, location, and analyte combination.
EACH_PDS	This modifier activates output of the population dose from drinking water for each radioactive analyte. Summary statistics are written out for every location, analyte, and time step combination.
EACH_PRS	This modifier activates output of the population risk from drinking water for each radioactive analyte. Summary statistics are written out for every location, analyte, and time step combination.
PATH_ING	This modifier activates output of the ingestion pathway impact for each analyte. Summary statistics are written out for this pathway for every location, analyte, and time step combination.
PATH_INH	This modifier activates output of the inhalation pathway impact for each analyte. Summary statistics are written out for this pathway for every location, analyte, and time step combination.

Modifier	Description
PATH_EXT	This modifier activates output of the external exposure pathway impact for each analyte. Summary statistics are written out for this pathway for every location, analyte, and time step combination.
PATH_DWA	This modifier activates output of the drinking water dose for radioactive analytes. Summary statistics are written out for this pathway for every location, analyte, and time step combination.

The following entries provide examples of the use of the STATISTIC keyword:

```
STATISTIC COMB_ANA
STATISTIC COMB_ANA PATH_ING PATH_DWA EACH_PRS
```

There are no quote strings associated with the STATISTIC keyword.

5.4.17 STOCHASTIC Keyword for the HUMAN Code

The STOCHASTIC keyword is used to enter the definition of a statistical distribution for stochastic variables. The following is this keyword's syntax:

```
STOCHASTIC ["Quote1"] [Dist_Index Parameters] {TRUNCATE U1 U2}
{"Quote2" }
```

The entry for Quote1 must be a unique character string of up to 20 characters that will be used to identify this stochastic variable in subsequent uses. It is case sensitive and embedded spaces are significant. It is sometimes useful to make the character string some combination of a variable name and other data such that it can be recreated easily when stochastic data is needed. The entry for Quote2 is a description for the stochastic variable that can be up to 64 characters long. An entry for Quote2 is not required.

The entry for Dist_Index must be an integer in the range 1 to 13 that identifies the index of a statistical distribution. The statistical distributions are defined in Section 0. The word Parameters in the general syntax statement indicates the numerical values of parameters required for defining the statistical distribution. The additional modifier TRUNCATE can be used for all distribution types except 1, 3, and 10. If TRUNCATE is entered, it must be followed by two values in the interval 0 to 1, inclusive. The lower value must be less than the upper value. These two values specify the tail probabilities at which to impose range truncation for the distribution. Truncation data must be entered after all of the other parameters that define the distribution.

The following is an example stochastic record for the ingestion rate of soil for an adult that is uniformly distributed between 0.01 and 0.15:

```
STOCHASTIC "IRSOILADULT" 2 0.01 0.15 "Soil ingestion rate for an adult"
```

Although this section gives the general form of a STOCHASTIC keyword entry, it does not describe the entire set of STOCHASTIC keywords required to run the HUMAN code. A more complete set of example STOCHASTIC keywords is provided in Section 5.5. The example keywords are grouped by variable types as outlined in Table 5.16.

Table 5.16 Cross Reference to Example STOCHASTIC Keywords for the HUMAN Code

Cross-Reference	Multiple Dependencies	Type of Data Defined Using STOCHASTIC Keywords
Table 5.17	None	Exposure frequencies for different human activities.
Table 5.18	None	Exposure times for different human activities.
Table 5.19	None	Ingestion rates for water and food types.
Table 5.20	None	Miscellaneous variables.
Table 5.21	None	Data describing the body variability in humans.
Table 5.22	Analyte	Data for transfer of contaminants into food items.
Table 5.23	Analyte	Volatilization and Permeability Data.
Table 5.24	None	Animal food and water variables for computing concentration in animal food products.
Table 5.25	Analyte	Hazard quotients for inhalation and ingestion that are used to compare intake to levels of concern. These data are required only for the analytes modeled as hazardous constituents.
Table 5.26	Analyte	Dose factors for converting external exposure and intake of radionuclides to dose. These data are required only for the radioactive analytes.
Table 5.27	Analyte	Slope factors for inhalation and ingestion that are used to compare intake to risk. These data are required only for the analytes modeled as carcinogenic constituents.

5.4.18 SWEAT Keyword for the HUMAN Code

The SWEAT keyword is used to define the source of water to be used in the sweat lodge calculations. The following is this keyword's syntax:

```
SWEAT [ GROUND | RIVER | SEEP ]
```

If the SWEAT keyword is not used, then the sweat portion of the impact equations will yield a zero impact. The following is the keyword entry to select river water as the water source for sweat lodge calculations:

```
SWEAT RIVER
```

There are no quote strings or numerical values associated with the SWEAT keyword.

5.4.19 TIMES Keyword for the HUMAN Code

The TIMES keyword identifies the times at which the calculations are to be performed. The following is this keyword's syntax:

```
TIMES [ [T1] {T2} ... {Tn} | {ALL} ]
```

The numerical entries T1, T2, ..., Tn are the times (whole number years) when human impacts calculations are desired. These times must be a subset of the times at which environmental data were computed and stored by the inventory, release, and transport modules. Multiple TIMES keywords can be entered. If the modifier ALL is used, results will be calculated for every time in the ESD keyword file. If the modifier ALL is used, no numerical values should be entered. The following is an example TIMES keyword that requests output for the three years 2020, 2075, and 3014:

```
TIMES 2020 2075 3014
```

The following is an example TIMES keyword where all times from the ESD keyword file are requested:

```
TIMES ALL
```

There are no quote strings associated with the TIMES keyword.

5.4.20 TITLE Keyword for the HUMAN Code

The TITLE keyword is used to define a single-line problem title. The problem title will be written to output files. If the title is not supplied, then the program will error terminate. The following is this keyword's syntax:

```
TITLE ["quote"]
```

The title is entered in a quote string, which must be enclosed in double quotation marks. Titles up to 72 characters long are supported. The following example defines a title for a run of the code:

```
TITLE "Example title line for the human impacts code."
```

There are no modifiers associated with the TITLE keyword.

5.4.21 USER Keyword for the HUMAN Code

The USER keyword is used to identify the user of the program. The user name will be written to output files. If the user name is not supplied, then the program will error terminate. The following is this keyword's syntax:

```
USER ["quote"]
```

The user name is entered in a quote string, which must be enclosed in double quotation marks. User names up to 16 characters long are supported. The following example defines John Q. Public as the user running the code:

```
USER "John Q. Public"
```

There are no modifiers associated with the USER keyword.

5.5 Example Stochastic Keywords for the Human Code

The equations in Section 5.1.1 reference exposure frequencies for a number of activities. Table 5.17 provides example statistical distributions for these activities and the resulting keywords that implement the definitions.

Table 5.17 Example HUMAN Keywords for Entering Exposure Frequencies

Variable	Description	Units	Statistical Distribution
EF _{boat}	Exposure frequency for boating	day/yr	Constant of 5
STOCHASTIC "EFBOAT" 1 5 "Exposure frequency for boating"			
EF _{river}	Exposure frequency to volatile river water	day/yr	Uniform on 270 to 365
STOCHASTIC "EFRIVER" 2 270 365 "Exposure frequency to volatile river water"			
EF _{sed}	Exposure frequency for sediment	day/yr	Uniform on 1 to 20
STOCHASTIC "EFSED" 2 1 20 "Exposure frequency to sediment"			
EF _{seep}	Exposure frequency volatilized seep water	day/yr	Uniform on 270 to 365
STOCHASTIC "EFSEEP" 2 270 365 "Exposure frequency volatile seep water"			
EF _{soil}	Exposure frequency for soil	day/yr	Uniform on 270 to 365
STOCHASTIC "EFSOIL" 2 270 365 "Exposure frequency for soil"			
EF _{swim}	Exposure frequency for swimming	day/yr	Uniform on 1 to 20

Variable	Description	Units	Statistical Distribution
STOCHASTIC "EFSWIM" 2 1 20 "Exposure frequency for swimming"			
EF _{sweat}	Exposure frequency for sweat lodge	day/yr	Constant of 0
STOCHASTIC "EFSWEAT" 1 0 "Exposure frequency for sweat lodge"			
EF _{ground}	Exposure frequency for drinking groundwater	day/yr	Uniform on 270 to 365
STOCHASTIC "EFGROUND" 2 270 365 "Exposure frequency for drinking groundwater"			
EF _{leafy}	Exposure frequency for leafy vegetables	day/yr	Uniform on 270 to 365
STOCHASTIC "EFLEAFY" 2 270 365 "Exposure frequency for leafy vegetables"			
EF _{root}	Exposure frequency for eating root vegetables	day/yr	Uniform on 270 to 365
STOCHASTIC "EFROOT" 2 270 365 "Exposure frequency for eating root vegetables"			
EF _{meat}	Exposure frequency for eating meat	day/yr	Uniform on 270 to 365
STOCHASTIC "EFMEAT" 2 270 365 "Exposure frequency for eating meat"			
EF _{milk}	Exposure frequency for drinking milk	day/yr	Uniform on 270 to 365
STOCHASTIC "EFMILK" 2 270 365 "Exposure frequency for drinking milk"			
EF _{bird}	Exposure frequency for eating birds (poultry)	day/yr	Uniform on 270 to 365
STOCHASTIC "EFBIRD" 2 270 365 "Exposure frequency for eating birds (poultry)"			
EF _{fish}	Exposure frequency for eating fish	day/yr	Uniform on 270 to 365

Variable	Description	Units	Statistical Distribution
STOCHASTIC "EFFISH" 2 270 365	"Exposure frequency for eating fish"		

The equations in Section 5.1.1 reference exposure times and durations for a number of activities. Table 5.18 provides example statistical distributions for these activities and the resulting keywords that implement the definitions.

Table 5.18 Example HUMAN Keywords for Entering Exposure Times

Variable	Description	Units	Statistical Distribution
ET _{boat}	Exposure time for boating	hr/day	Constant of 0
STOCHASTIC "ETBOAT" 1 0 "Exposure time for boating"			
ET _{river}	Exposure time to volatile river water	hr/day	Uniform on 10 to 20
STOCHASTIC "ETRIVER" 2 10 20 "Exposure time to volatile river water"			
ET _{sed}	Exposure time for sediment	hr/day	Constant of 0
STOCHASTIC "ETSED" 1 0 "Exposure time for sediment"			
ET _{seep}	Exposure time volatile seep water	hr/day	Uniform on 10 to 24
STOCHASTIC "ETSEEP" 2 10 24 "Exposure time volatile seep water"			
ET _{soil}	Exposure time for soil	hr/day	Uniform on 8 to 24
STOCHASTIC "ETSOIL" 2 8 24 "Exposure time for soil"			
ET _{swim}	Exposure time for swimming	hr/day	Uniform on 0 to 8
STOCHASTIC "ETSWIM" 2 0 8 "Exposure time for swimming"			
ET _{sweat}	Exposure time for sweat lodge	hr/day	Uniform on 10 to 24
STOCHASTIC "ETSWEAT" 1 0 "Exposure time for sweat lodge"			

Variable	Description	Units	Statistical Distribution
ED _{child}	Exposure duration for a child	yr	Uniform on 1 to 6
STOCHASTIC "EDCHILD" 2 1 6 "Exposure duration for a child"			
ED _{adult}	Exposure duration for an adult	yr	Uniform on 1 to 64
STOCHASTIC "EDADULT" 2 1 64 "Exposure duration for an adult"			

The equations in Section 5.1.1 reference inhalation and ingestion rates for a number of foods. Table 5.19 provides example statistical distributions for these activities and the resulting keywords that implement the definitions.

Table 5.19 Example HUMAN Keywords for Entering Ingestion Rates

Variable	Description	Units	Statistical Distribution
IRATE	Inhalation rate	m ³ /day	Uniform on 15 to 30
STOCHASTIC "IRATE" 2 15 30 "Inhalation rate"			
IR _{soilchild}	Ingestion rate, soil child	kg/day	Uniform on 0.00002 to 0.0005
STOCHASTIC "IRSOILCHILD" 2 0.00002 0.00050 "Soil ingestion rate for a child"			
IR _{soiladult}	Ingestion rate, soil adult	kg/day	Uniform on 0.00001 to 0.00015
STOCHASTIC "IRSOILADULT" 2 0.00001 0.00015 "Soil ingestion rate for an adult"			
IR _{sedchild}	Ingestion rate, sediment – child	kg/day	Uniform on 0.00002 to 0.0005
STOCHASTIC "IRSEDCHILD" 2 0.00002 0.00050 "Sediment ingestion rate for a child"			
IR _{sedadult}	Ingestion rate, sediment – adult	kg/day	Uniform on 0.00001 to 0.00015
STOCHASTIC "IRSEDADULT" 2 0.00001 0.00015 "Sediment ingestion rate for an adult"			
IR _{river}	Ingestion rate, river water	L/day	Uniform on 0 to 3
STOCHASTIC "IRRIVER" 2 0 3 "River water ingestion rate"			

Variable	Description	Units	Statistical Distribution
IR _{ground}	Ingestion rate, ground water	L/day	Uniform on 0 to 3
STOCHASTIC "IRGROUND" 2 0 3 "Ground water ingestion rate"			
IR _{seep}	Ingestion rate, seep water	L/day	Constant of 0
STOCHASTIC "IRSEEP" 1 0 "Seep water ingestion rate"			
IR _{fish}	Ingestion rate, fish	kg/day	Uniform on 0 to 0.1
STOCHASTIC "IRFISH" 2 0 0.1 "Ingestion rate for fish"			
IR _{leafy}	Ingestion rate, leafy vegetables	kg/day	Uniform on 0 to 0.5
STOCHASTIC "IRLEAFY" 2 0 0.5 "Ingestion rate for leafy vegetables"			
IR _{root}	Ingestion rate, root vegetables	kg/day	Constant of 0
STOCHASTIC "IRROOT" 1 0 "Ingestion rate for root vegetables"			
IR _{meat}	Ingestion rate, meat	kg/day	Uniform on 0 to 0.25
STOCHASTIC "IRMEAT" 2 0 0.25 "Ingestion rate for meat"			
IR _{milk}	Ingestion rate, milk	L/day	Uniform on 0.1 to 1
STOCHASTIC "IRMILK" 2 0.1 1 "Milk ingestion rate"			
IR _{bird}	Ingestion rate, birds	kg/day	Constant of 0
STOCHASTIC "IRBIRD" 1 0 "Ingestion rate for bird meat"			

The equations in Section 5.1.1 reference several soil and air concentration related variables. Table 5.20 provides example statistical distributions for these activities and the resulting keywords that implement the definitions.

Table 5.20 Example HUMAN Keywords for Entering Concentration Variables

Variable	Description	Units	Statistical Distribution
ML	Mass loading of soil in air	kg/m ³	Constant of 0.00000005
STOCHASTIC "ML" 1 0.00000005 "Mass loading of soil in air"			
AF _{soil}	Adherence factor for soil	mg/cm ² /day	Uniform on 0.05 to 0.5
STOCHASTIC "AFSOIL" 2 0.05 0.50 "Adherence factor for soil"			
AF _{sed}	Adherence factor for sediment	mg/cm ² /day	Uniform on 0.05 to 0.5
STOCHASTIC "AFSED" 2 0.05 0.50 "Adherence factor for sediment"			
IRGRATE	Irrigation rate	L/m ² per yr	Uniform on 500 to 1000
STOCHASTIC "IRGRATE" 2 500 1000 "Irrigation rate"			
SHIELDSOIL	Soil shielding factor	unitless	Constant of 0.8
STOCHASTIC "SHIELDSOIL" 1 0.8 "Soil shielding factor"			
SHIELDSSED	Sediment shielding factor	unitless	Constant of 0.2
STOCHASTIC "SHIELDSSED" 1 0.2 "Sediment shielding factor"			
CF _{sweat}	Air concentration factor for sweat lodge	L/m ³	Uniform on 0.1 to 0.3
STOCHASTIC "CFSWEAT" 2 0.1 0.3 "Air concentration factor for sweat lodge"			

The equations in Section 5.1.1 reference several body size variables. Table 5.21 provides example statistical distributions for these activities and the resulting keywords that implement the definitions.

Table 5.21 Example Keywords for Entering Body Data in the HUMAN Code

Variable	Description	Units	Statistical Distribution
BW _{child}	Body weight for a child	kg	Constant of 16
STOCHASTIC "BWCHILD" 1 16 "Body weight for a child"			
BW _{adult}	Body weight for an adult	kg	Constant of 70
STOCHASTIC "BWADULT" 1 70 "Body weight for an adult"			
SA _{soil}	Body surface area – soils	cm ²	Constant of 5000
STOCHASTIC "SASOIL" 1 5000 "Body surface area for soil exposure"			
SA _{sed}	Body surface area – sediments	cm ²	Constant of 5000
STOCHASTIC "SASED" 1 5000 "Body surface area for sediment exposure"			
SA _{seep}	Body surface area - seep water	cm ²	Constant of 20000
STOCHASTIC "SASEEP" 1 20000 "Body surface area for seep water exposure"			
SA _{river}	Body surface area - river water	cm ²	Constant of 20000
STOCHASTIC "SARIVER" 1 20000 "Body surface area for river water exposure"			
SA _{other}	Body surface area - river water	cm ²	Constant of 0
STOCHASTIC "SAOTHER" 1 0 "Body surface area for other (Native American) activities"			
SA _{sweat}	Body surface area - sweat lodge	cm ²	Constant of 20000
STOCHASTIC "SASWEAT" 1 20000 "Body surface area sweat lodge calculations"			

The equations in Section 5.1.1 reference transfer factors for computing concentrations in human food items. These transfer factors must be defined for every analyte. Table 5.22 provides example statistical distributions for these activities and the resulting keywords that implement the definitions.

Table 5.22 Example HUMAN Keywords for Entering Food Transfer Factors

Analyte	Variable	Description	Units	Statistical Distribution
H3	TF _{milk}	Transfer factor for milk for tritium	day/Liter	Lognormal on Mean - 1.82391, Standard deviation of Logarithms 0.30103
STOCHASTIC "H3 TFMILK" 5 -1.82391 0.30103 "Transfer factor for milk for tritium"				
Pu239	TF _{milk}	Transfer factor for milk for Pu-239	day/Liter	Triangular on Lower Limit 3.0E-09, Mode 1.1E-06, Upper Limit 3.0E-06.
STOCHASTIC "Pu239 TFMILK" 6 3.00E-09 1.10E-06 3.00E-06 "Transfer factor for milk for Pu-239"				
CCl4	TF _{milk}	Transfer factor for milk for CCl4	day/Liter	Triangular on Lower Limit 0, Mode 3.60E-06, Upper Limit 1.00E-05
STOCHASTIC "CCl4 TFMILK" 6 0.0 3.60E-06 1.00E-05 "Transfer factor for milk for CCl4"				
CrVI	TF _{milk}	Transfer factor for milk for chromium	day/Liter	Lognormal on Mean -5, Standard Deviation of Logarithms 0.30103
STOCHASTIC "CrVI TFMILK" 5 -5.0 0.30103 "Transfer factor for milk for chromium"				
Tc99	TF _{meat}	Transfer factor for meat for Tc-99	day/kg	Loguniform on Lower Limit 1.00E-06, Upper Limit 1.00E-04
STOCHASTIC "Tc99 TFMEAT" 5 1.00E-06 1.00E-04 "Transfer factor for meat for Tc-99"				
Cs137	TF _{meat}	Transfer factor for meat for Cs-137	day/kg	Triangular on Lower Limit 0.01, Mode 0.05, Upper Limit 0.06
STOCHASTIC "Cs137 TFMEAT" 6 1.00E-02 5.00E-02 6.00E-02 "Transfer factor for meat for Cs-137"				

Analyte	Variable	Description	Units	Statistical Distribution
CCl4	TF _{meat}	Transfer factor for meat for CCl4	day/kg	Triangular on Lower Limit 0, Mode 1.10E-05, Upper Limit 2.00E-05
STOCHASTIC "CCl4 TFMEAT" 6 0.0 1.10E-05 2.00E-05 "Transfer factor for meat for CCl4"				
CrVI	TF _{meat}	Transfer factor for meat for chromium	day/kg	Lognormal on Mean - 2.04576, Standard Deviation of logarithms 0.30103
STOCHASTIC "CrVI TFMEAT" 5 -2.04576 0.30103 "Transfer factor for meat for chromium"				
H3	TF _{bird}	Transfer factor for birds for tritium	day/kg	Uniform on 0.5 to 1
STOCHASTIC "H3 TFBIRD" 2 0.5 1.0 "Transfer factor for birds for tritium"				
Tc99	TF _{bird}	Transfer factor for birds for Tc-99	day/kg	Triangular on Lower Limit 3.00E-02, Mode 3.50E-02, Upper Limit 2.00E-01
STOCHASTIC "Tc99 TFBIRD" 6 3.00E-02 3.50E-02 2.00E-01 "Transfer factor for birds for Tc-99"				
Pu239	TF _{bird}	Transfer factor for birds for Pu-239	day/kg	Loguniform on Lower Limit 2.00E-05, Upper Limit 3.00E-03
STOCHASTIC "Pu239 TFBIRD" 5 2.00E-05 3.00E-03 "Transfer factor for birds for Pu-239"				
CCl4	TF _{bird}	Transfer factor for birds for CCl4	day/kg	Triangular on Lower Limit 0, Mode 1.10E-05, Upper Limit 2.00E-05
STOCHASTIC "CCl4 TFBIRD" 6 0.00E+00 1.10E-05 2.00E-05 "Transfer factor for birds for CCl4"				
H3	BIO _{fish}	H3 bioaccumulation for fish	pCi/kg per pCi/L	Uniform on 0.6 to 1

Analyte	Variable	Description	Units	Statistical Distribution
STOCHASTIC "H3 BIOFISH" 2 0.6 1.0 "H3 bioaccumulation for fish"				
U238	BIO _{fish}	U-238 bioaccumulation for fish	pCi/kg per pCi/L	Triangular on Lower Limit 2, Mode 10, Upper Limit 50
STOCHASTIC "U238 BIOFISH" 6 2 10 50 "U-238 bioaccumulation for fish"				
CCl4	BIO _{fish}	CCl4 bioaccumulation for fish	pCi/kg per pCi/L	Uniform on 15 to 150
STOCHASTIC "CCl4 BIOFISH" 2 15 150 "CCl4 bioaccumulation for fish"				
CrVI	BIO _{fish}	Chromium bioaccumulation for fish	pCi/kg per pCi/L	Triangular on Lower Limit 40, Mode 200, Upper Limit 2000
STOCHASTIC "CrVI BIOFISH" 6 40 200 2000 "Chromium bioaccumulation for fish"				
H3	CR _{veg}	H3 soil-to-plant ratio	pCi/kg plant per pCi/kg soil	Triangular on Lower Limit 0.05, Mode 0.1, Upper Limit 0.2
STOCHASTIC "H3 CRVEG" 6 0.05 0.1 0.2 "H3 soil-to-plant ratio"				
Tc99	CR _{veg}	Tc99 soil-to-plant ratio	pCi/kg plant per pCi/kg soil	Triangular on Lower Limit 1, mode 10, Upper Limit 100
STOCHASTIC "Tc99 CRVEG" 6 1 10 100 "Tc99 soil-to-plant ratio"				
I129	CR _{veg}	I 129 soil-to-plant ratio	pCi/kg plant per pCi/kg soil	Triangular on Lower Limit 5.00E-05, Mode 5.00E-04, Upper Limit 5.00E-03
STOCHASTIC "I129 CRVEG" 6 5.00E-05 5.00E-04 5.00E-03 "I 129 soil-to-plant ratio"				

The equations in Section 5.1.1 reference volatilization, permeability, and skin absorption variables. Values for these variables must be entered for every analyte. Table 5.23 provides example statistical distributions for these activities and the resulting keywords that implement the definitions.

Table 5.23 Example HUMAN Keywords for Volatilization and Permeability Data

Analyte	Variable	Description	Units	Statistical Distribution
CCl4	VF	CCL4 Volatilization Factor	L/m ³	Loguniform on Lower Limit 0.001, Upper Limit 0.1
STOCHASTIC "CCl4 VF" 4 0.001 0.1 "CCL4 Volatilization Factor"				
CrVI	KP	Cr Skin Permeability Coefficient	cm/hr	Loguniform on Lower Limit 0.0003 Upper Limit 0.003
STOCHASTIC "CrVI KP" 4 0.0003 0.0030 "Cr Skin Permeability Coefficient"				
U	ABS	U Skin Absorption Factor	unitless	Loguniform on Lower Limit 0.0001, Upper Limit 0.01
STOCHASTIC "U ABS" 4 0.0001 0.0100 "U Skin Absorption Factor"				

The equations in Section 5.1.1 reference food and water intake by animals. Table 5.24 provides example statistical distributions for these activities and the resulting keywords that implement the definitions.

Table 5.24 Example HUMAN Keywords for Entering Animal Food and Water

Variable	Description	Units	Statistical Distribution
QP _{meat}	Quantity of plants eaten by meat animal	kg(wet)/day	Triangular on Lower Limit 58, Mode 68, Upper Limit 78
STOCHASTIC "QPMEAT" 6 58 68 78 "Quantity of plants eaten by meat animal"			
QP _{milk}	Quantity of plants eaten by milk animal	kg(wet)/day	Triangular on Lower Limit 45, Mode 55, Upper Limit 65
STOCHASTIC "QPMILK" 6 45 55 65 "Quantity of plants eaten by milk animal"			
QP _{bird}	Quantity of plants eaten by bird	kg(wet)/day	Triangular on Lower Limit 0.35, Mode 0.5, Upper Limit 0.65
STOCHASTIC "QPBIRD" 6 0.35 0.50 0.65 "Quantity of plants eaten by bird"			

Variable	Description	Units	Statistical Distribution
QW _{meat}	Quantity of water drunk by meat animal	Liter/day	Triangular on Lower Limit 25, Mode 68, Upper Limit 136
STOCHASTIC "QWMEAT" 6 25 68 136 "Quantity of water drunk by meat animal"			
QW _{milk}	Quantity of water drunk by milk animal	Liter/day	Triangular on Lower Limit 25, Mode 50, Upper Limit 100
STOCHASTIC "QWMILK" 6 25 50 100 "Quantity of water drunk by milk animal"			
QW _{bird}	Quantity of water drunk by bird	Liter/day	Triangular on Lower Limit 0.1, Mode 0.25, Upper Limit 0.4
STOCHASTIC "QWBIRD" 6 0.10 0.25 0.40 "Quantity of water drunk by bird"			

The equations in Section 5.1.1 reference hazard quotients (oral reference doses) for hazardous analytes. These values must be entered for every analyte. Table 5.25 provides example statistical distributions for these activities and the resulting keywords that implement the definitions.

Table 5.25 Example HUMAN Keywords for Entering Hazard Quotients

Analyte	Variable	Description	Units	Statistical Distribution
CrVI	HQ _{inh}	Cr(VI) hazard quotient for inhalation	mg(intake)/(kg(bodyweight) day)	Triangular on Lower Limit 1.00E-03, Mode 0.005, Upper Limit 0.015
STOCHASTIC "CrVI HQINH" 6 0.001 0.005 0.015 "Cr(VI) hazard quotient for inhalation"				
CrVI	HQ _{ing}	Cr(VI) hazard quotient for ingestion	mg(intake)/(kg(bodyweight) day)	Triangular on Lower Limit 0.001, Mode 0.005, Upper Limit 0.015
STOCHASTIC "CrVI HQING" 6 0.001 0.005 0.015 "Cr(VI) hazard quotient for ingestion"				
CCl4	HQ _{inh}	CCl4 hazard quotient for inhalation	mg(intake)/(kg(bodyweight) day)	Loguniform on Lower Limit 7.00E-06, Upper limit 7.00E-04
STOCHASTIC "CCL4 HQINH" 5 7.0E-06 7.0E-04 "CCl4 hazard quotient for inhalation"				

Analyte	Variable	Description	Units	Statistical Distribution
CC4	HQ _{ing}	CCl4 hazard quotient for ingestion	mg(intake)/(kg(bodyweight) day)	Loguniform on Lower Limit 7.00E-06, Upper Limit 7.00E-04
STOCHASTIC "CCL4 HQING" 5 7.0E-06 7.0E-04 "CCl4 hazard quotient for ingestion"				
U	HQ _{inh}	U hazard quotient for inhalation	mg(intake)/(kg(bodyweight) day)	Loguniform on Lower Limit 1.40E-06, Upper Limit 1.40E-03
STOCHASTIC "U HQINH" 5 1.4E-06 1.4E-03 "U hazard quotient for inhalation"				
U	HQ _{ing}	hazard quotient for ingestion	mg(intake)/(kg(bodyweight) day)	Loguniform on Lower Limit 3.00E-06, Upper Limit 3.00E-03
STOCHASTIC "U HQING" 5 3.0E-06 3.0E-03 "U hazard quotient for ingestion"				

The equations in Section 5.1.1 reference dose factors for radioactive analytes. The dose factors must be entered for every radioactive analyte. Table 5.26 provides example statistical distributions for these activities and the resulting keywords that implement the definitions.

Table 5.26 Example HUMAN Keywords for Entering Dose Factors

Analyte	Variable	Description	Units	Statistical Distribution
Cs137	DF _{soil}	Cs/Ba137 dose factor for soil	rem/hr per pCi/g	Triangular on Lower Limit 2.50E-08, Mode 5.00E-08, Upper Limit 1.00E-07
STOCHASTIC "U HQING" 5 3.0E-06 3.0E-03 "U hazard quotient for ingestion"				
Cs137	DF _{swim}	Cs/Ba137 dose factor for swimming	rem/hr per pCi/L	Triangular on Lower Limit 4.20E-10, Mode 8.30E-10, Upper Limit 1.70E-09
STOCHASTIC "Cs137 DFSWIM" 6 4.20E-10 8.30E-10 1.70E-09 "Cs/Ba137 dose factor for swimming"				
Cs137	DF _{boat}	Cs/Ba137 dose factor for boating	rem/hr per pCi/L	Triangular on Lower limit 2.10E-10, mode 4.20E-10, Upper Limit 8.30E-10

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Analyte	Variable	Description	Units	Statistical Distribution
STOCHASTIC "Cs137 DFBOAT" 6 2.10E-10 4.20E-10 8.30E-10 "Cs/Ba137 dose factor for boating"				
Cs137	DF _{ing}	Cs137 dose factor for ingestion	rem/pCi	Lognormal on Mean -7.30103, Standard Deviation of Logarithms 3.01E-01
STOCHASTIC "Cs137 DFING" 8 -7.30103E+00 3.01E-01 "Cs137 dose factor for ingestion"				
Cs137	DF _{inh}	Cs137 dose factor for inhalation	rem/pCi	Lognormal on Mean -7.49485, Standard Deviation of Logarithms 3.01E-01
STOCHASTIC "Cs137 DFINH" 8 -7.49485E+00 3.01E-01 "Cs137 dose factor for inhalation"				
H3	DF _{soil}	H3 dose factor for soil	rem/hr per pCi/g	Constant of 0
STOCHASTIC "H3 DFSOIL" 1 0 "H3 dose factor for soil"				
H3	DF _{swim}	H3 dose factor for swimming	rem/hr per pCi/L	Constant of 0
STOCHASTIC "H3 DFSWIM" 1 0 "H3 dose factor for swimming"				
H3	DF _{boat}	H3 dose factor for boating	rem/hr per pCi/L	Constant of 0
STOCHASTIC "H3 DFBOAT" 1 0 "H3 dose factor for boating"				
H3	DF _{ing}	H3 dose factor for ingestion	rem/pCi	Lognormal on Mean -10.1938, Standard Deviation of Logarithms 3.01E-01
STOCHASTIC "H3 DFING" 8 -1.01938E+01 3.01E-01 "H3 dose factor for ingestion"				
H3	DF _{inh}	H3 dose factor for inhalation	rem/pCi	Lognormal on Mean -10.0177, Standard Deviation of Logarithms 3.01E-01
STOCHASTIC "H3 DFINH" 8 -1.00177E+01 3.01E-01 "H3 dose factor for inhalation"				

The equations in Section 5.1.1 reference slope factors for carcinogenic analytes. The slope factors must be defined for every carcinogenic analyte. Table 5.27 provides example statistical distributions for these activities and the resulting keywords that implement the definitions.

Table 5.27 Example HUMAN Keywords for Entering Slope Factors

Analyte	Variable	Description	Units	Statistical
CCl4	SF _{inh}	CCl4 slope factor for inhalation	risk per mg(intake)/(kg(bodyweight)/day)	Lognormal on Mean - 1.27572, Standard Deviation of Logarithms 0.47712
STOCHASTIC "CCl4 SFINH" 8 -1.27572 0.47712 "CCl4 slope factor for inhalation"				
CCl4	SF _{ing}	CCl4 slope factor for ingestion	risk per mg(intake)/(kg(bodyweight)/day)	Lognormal Mean - 0.88606, Standard Deviation of Logarithms 0.47712
STOCHASTIC "CCl4 SFING" 8 -0.88606 0.47712 "CCl4 slope factor for ingestion"				
CrVI	SF _{inh}	Cr slope factor for inhalation	risk per mg(intake)/(kg(bodyweight)/day)	Triangular on Lower Limit 21, Mode 42, Upper Limit 290
STOCHASTIC "CrVI SFINH" 6 21 42 290 "Cr slope factor for inhalation"				
CrVI	SF _{ing}	Cr slope factor for ingestion	risk per mg(intake)/(kg(bodyweight)/day)	User-defined cumulative distribution function
STOCHASTIC "CrVI SFING" 10 "Cr slope factor for ingestion" 8 (0,0) (0.7999,0) (0.8,21) (0.8499,21) (0.85,42) (0.8999,42) (0.9,290) (1,290)				

6.0 Tri-Cities Economic Regional Model (TCERM)

6.1 Mathematical Formulation for the Economics Impact Model

The following sections give the mathematical formulations for the Tri-Cities Economic Risk Model (TCERM). TCERM is divided into three primary sections: TRIGGER calculations, EFFECTS calculations, and economic change (ECONCHG) calculations.

6.1.1 Trigger Mechanisms

The trigger mechanisms are the set of equations that use input environmental concentrations and user-specified threshold levels to determine if an economic effect is present. The cost of filtering or replacing a contaminated water supply is also calculated within the TRIGGER subroutine.

6.1.1.1 Comparison to Environmental Standards

The first function in the TRIGGER routine is to compare the environmental concentrations for a location to the standards selected for each contaminant. This information is then used in various combinations to set economic activity reduction factors used in the EFFECTS module of TCERM. The environmental concentrations provided for a site are surface water used as drinking water, surface water used for recreation (swimming, boating, etc.), surface water used for irrigation, groundwater used for drinking water, groundwater used for irrigation, and plant and animal tissue concentrations for selected species calculated by the ECEM model. Not all of these environmental concentrations need be supplied for a single location. For example, only one type of drinking water would be supplied, either surface water or groundwater, as appropriate.

6.1.1.1.1 Trigger for Drinking Water Concentrations

The trigger for surface water or groundwater drinking water is used in the calculation of the cost of filtering or replacing the drinking water supply. If the water concentration for an analyte exceeds the threshold, then the filtering cost for the analyte is added to the total cost of filtering the water supply. The drinking water source is specified as private or public surface water or groundwater.

$$FT_{DW}(L) = FT_{DW}(L) + FF_{DW}(L, C), \text{ If } C_{DW}(L, C) > AL_{DW}(C)$$

where

$$\begin{aligned} FT_{DW}(L) &= \text{total cost of filtering the drinking water supply at location L (\$/1,000 gal)} \\ FF_{DW}(L, C) &= \text{cost of filtering the drinking water supply for analyte C at location L (\$/1,000 gal)} \\ C_{DW}(L, C) &= \text{drinking water concentration for analyte C at location L (pCi/L or } \mu\text{g/L)} \\ AL_{DW}(C) &= \text{threshold for the drinking water concentration for analyte C (pCi/L or } \mu\text{g/L)} \end{aligned}$$

6.1.1.1.2 Trigger for Avoidance or Recreational Fishing and Hunting Due to Surface Water Concentrations

The surface water concentration specified for contact in recreational activities is used to determine the fishing and hunting reduction fractions.

$$\begin{aligned} \text{SWFT}_{\text{VA}}(\text{L}) &= 0, & \text{If } C_{\text{SW}}(\text{L}, \text{C}) < 0.01 \times \text{AL}_{\text{CON}}(\text{C}) \\ \text{SWFT}_{\text{VA}}(\text{L}) &= 1, & \text{If } 0.01 \times \text{AL}_{\text{CON}}(\text{C}) \leq C_{\text{SW}}(\text{L}, \text{C}) < \text{AL}_{\text{CON}}(\text{C}) \\ \text{SWFT}_{\text{VA}}(\text{L}) &= 2, & \text{If } C_{\text{SW}}(\text{L}, \text{C}) \geq \text{AL}_{\text{CON}}(\text{C}) \end{aligned}$$

where

$$\begin{aligned} \text{SWFT}_{\text{VA}}(\text{L}) &= \text{voluntary avoidance trigger for recreational fishing and hunting due to surface water contact concentration at location L (unitless)} \\ C_{\text{SW}}(\text{L}, \text{C}) &= \text{surface water contact concentration for analyte C at location L (pCi/L or } \mu\text{g/L)} \\ \text{AL}_{\text{CON}}(\text{C}) &= \text{threshold concentration for the surface water contact for analyte C (pCi/L or } \mu\text{g/L)} \end{aligned}$$

6.1.1.1.3 Trigger for Avoidance of Other Recreation due to Surface Water Concentrations

The surface water concentration specified for contact in other recreational activities used to determine the reduction fractions due to avoidance for other recreational activities.

$$\begin{aligned} \text{SWOT}_{\text{VA}}(\text{L}) &= 0, & \text{If } C_{\text{SW}}(\text{L}, \text{C}) < \text{AL}_{\text{CON}}(\text{C}) \\ \text{SWOT}_{\text{VA}}(\text{L}) &= 1, & \text{If } \text{AL}_{\text{CON}}(\text{C}) \leq C_{\text{SW}}(\text{L}, \text{C}) < 100.0 \times \text{AL}_{\text{CON}}(\text{C}) \\ \text{SWOT}_{\text{VA}}(\text{L}) &= 2, & \text{If } C_{\text{SW}}(\text{L}, \text{C}) \geq 100.0 \times \text{AL}_{\text{CON}}(\text{C}) \end{aligned}$$

where

$$\begin{aligned} \text{SWOT}_{\text{VA}}(\text{L}) &= \text{voluntary avoidance trigger for other recreation due to surface water contact concentration at location L (unitless)} \\ C_{\text{SW}}(\text{L}, \text{C}) &= \text{surface water contact concentration for analyte C at location L (pCi/L or } \mu\text{g/L)} \\ \text{AL}_{\text{CON}}(\text{C}) &= \text{threshold concentration for the surface water contact for analyte C (pCi/L or } \mu\text{g/L)} \end{aligned}$$

6.1.1.1.4 Trigger for Regulation of Recreation due to Surface Water Concentrations

The surface water concentration specified for contact in other recreational activities used to determine the reduction fractions due to avoidance for other recreational activities.

$$\begin{aligned} \text{SWOT}_{\text{RR}}(\text{L}) &= 0, & \text{If } C_{\text{SW}}(\text{L}, \text{C}) < 1000.0 \times \text{AL}_{\text{CON}}(\text{C}) \\ \text{SWOT}_{\text{RR}}(\text{L}) &= 2, & \text{If } C_{\text{SW}}(\text{L}, \text{C}) \geq 1000.0 \times \text{AL}_{\text{CON}}(\text{C}) \end{aligned}$$

where

$$\begin{aligned} \text{SWOT}_{\text{RR}}(\text{L}) &= \text{regulatory reduction trigger for other recreation due to surface water contact concentration at location L (unitless)} \\ C_{\text{SW}}(\text{L}, \text{C}) &= \text{surface water contact concentration for analyte C at location L (pCi/L or } \mu\text{g/L)} \\ \text{AL}_{\text{CON}}(\text{C}) &= \text{threshold concentration for the surface water contact for analyte C (pCi/L or } \mu\text{g/L)} \end{aligned}$$

6.1.1.1.5 Trigger for Avoidance of Irrigated Agricultural Products

The irrigation water concentration is used to determine the reduction fractions for agricultural activities. If the concentration in the surface water used for irrigation is more than one-half of the user-supplied threshold value but less than or equal to 90 percent of the threshold value, then there is a small avoidance of agricultural products. If the concentration in the surface water used for irrigation is more than 90 percent of the threshold value, then there is a greater avoidance of agricultural products.

$$\begin{aligned} \text{ISWT}_{\text{VA}}(L) &= 0, & \text{If } C_{\text{SW}}(L, C) < 0.5 \times \text{AL}_{\text{AG}}(C) \\ \text{ISWT}_{\text{VA}}(L) &= 1, & \text{If } 0.5 \times \text{AL}_{\text{AG}}(C) \leq C_{\text{SW}}(L, C) \leq 0.9 \times \text{AL}_{\text{AG}}(C) \\ \text{ISWT}_{\text{VA}}(L) &= 2, & \text{If } C_{\text{SW}}(L, C) > 0.9 \times \text{AL}_{\text{AG}}(C) \end{aligned}$$

where

$$\begin{aligned} \text{ISWT}_{\text{VA}}(L) &= \text{voluntary avoidance trigger for surface water irrigation at location L (unitless)} \\ C_{\text{SW}}(L, C) &= \text{irrigation surface water concentration for analyte C at location L (pCi/L or } \mu\text{g/L)} \\ \text{AL}_{\text{AG}}(C) &= \text{threshold concentration for the surface water contact for analyte C (pCi/L or } \mu\text{g/L)} \end{aligned}$$

If the concentration in the groundwater used for irrigation is more than one-half of the user-supplied threshold value but less than or equal to 90 percent of the threshold value, then there is a small avoidance of agricultural products. If the concentration in the groundwater used for irrigation is more than 90 percent of the threshold value, then there is a greater avoidance of agricultural products.

$$\begin{aligned} \text{IGWT}_{\text{VA}}(L) &= 0, & \text{If } C_{\text{GW}}(L, C) < 0.5 \times \text{AL}_{\text{AG}}(C) \\ \text{IGWT}_{\text{VA}}(L) &= 1, & \text{If } 0.5 \times \text{AL}_{\text{AG}}(C) \leq C_{\text{GW}}(L, C) \leq 0.9 \times \text{AL}_{\text{AG}}(C) \\ \text{IGWT}_{\text{VA}}(L) &= 2, & \text{If } C_{\text{GW}}(L, C) > 0.9 \times \text{AL}_{\text{AG}}(C) \end{aligned}$$

where

$$\begin{aligned} \text{IGWT}_{\text{VA}}(L) &= \text{voluntary avoidance trigger for surface water irrigation at location L (unitless)} \\ C_{\text{GW}}(L, C) &= \text{irrigation groundwater concentration for analyte C at location L (pCi/L or } \mu\text{g/L)} \\ \text{AL}_{\text{AG}}(C) &= \text{threshold concentration for the surface water contact for analyte C (pCi/L or } \mu\text{g/L)} \end{aligned}$$

6.1.1.1.6 Trigger for Regulation of Irrigated Agricultural Products

The surface water irrigation concentration is compared to a threshold surface water concentration to determine whether agricultural activities are regulated. If the concentration in the surface water used for irrigation is at or above the user-supplied threshold value, then agricultural activities are regulated.

$$\begin{aligned} \text{ISWT}_{\text{RR}}(L) &= 0, & \text{If } C_{\text{SW}}(L, C) < \text{AL}_{\text{AG}}(C) \\ \text{ISWT}_{\text{RR}}(L) &= 2, & \text{If } C_{\text{SW}}(L, C) \geq \text{AL}_{\text{AG}}(C) \end{aligned}$$

where

$$\begin{aligned} \text{ISWT}_{\text{RR}}(\text{L}) &= \text{regulatory reduction trigger for irrigation water at location L (unitless)} \\ \text{C}_{\text{SW}}(\text{L}, \text{C}) &= \text{irrigation water concentration for analyte C at location L (pCi/L or } \mu\text{g/L)} \\ \text{AL}_{\text{AG}}(\text{C}) &= \text{threshold concentration for the surface water for analyte C (pCi/L or } \mu\text{g/L)} \end{aligned}$$

The groundwater irrigation concentration is compared to a threshold surface water concentration to determine whether agricultural activities are regulated. If the concentration in the groundwater used for irrigation is at or above the user-supplied threshold value, then agricultural activities are regulated.

$$\begin{aligned} \text{IGWT}_{\text{RR}}(\text{L}) &= 0, & \text{If } \text{C}_{\text{GW}}(\text{L}, \text{C}) < \text{AL}_{\text{AG}}(\text{C}) \\ \text{IGWT}_{\text{RR}}(\text{L}) &= 2, & \text{If } \text{C}_{\text{GW}}(\text{L}, \text{C}) \geq \text{AL}_{\text{AG}}(\text{C}) \end{aligned}$$

where

$$\begin{aligned} \text{IGWT}_{\text{RR}}(\text{L}) &= \text{regulatory reduction trigger for irrigation water at location L (unitless)} \\ \text{C}_{\text{GW}}(\text{L}, \text{C}) &= \text{irrigation groundwater concentration for analyte C at location L (pCi/L or } \mu\text{g/L)} \\ \text{AL}_{\text{AG}}(\text{C}) &= \text{threshold concentration for the groundwater for analyte C (pCi/L or } \mu\text{g/L)} \end{aligned}$$

6.1.1.1.7 Trigger for Recreational Fishing and Hunting Animal Tissue Concentrations

For each species used for recreational fishing or hunting, the animal tissue concentrations calculated by ECEM are compared to user-specified threshold concentrations for each analyte. The variable BBT is set to one of two levels depending on the comparison to the body burden threshold for a given species S at a location L.

$$\begin{aligned} \text{BBT}(\text{L}, \text{S}) &= 0, & \text{If } \text{BB}(\text{L}, \text{S}, \text{C}) < \text{AL}_{\text{BB}}(\text{S}, \text{C}) \\ \text{BBT}(\text{L}, \text{S}) &= 2, & \text{If } \text{BB}(\text{L}, \text{S}, \text{C}) \geq \text{AL}_{\text{BB}}(\text{S}, \text{C}) \end{aligned}$$

where

$$\begin{aligned} \text{BBT}(\text{L}, \text{S}) &= \text{body burden trigger for species S at location L (unitless)} \\ \text{BB}(\text{L}, \text{S}, \text{C}) &= \text{body burden for analyte C in species S at location L (pCi/L or } \mu\text{g/kg)} \\ \text{AL}_{\text{BB}}(\text{S}, \text{C}) &= \text{threshold concentration for the body burden concentration for analyte C in species S (pCi/L or } \mu\text{g/kg)} \end{aligned}$$

At each location, the user specifies the fractional contribution to recreational fishing or hunting for each game species. If the body burden concentration for a species exceeds the user-specified threshold for at least one analyte, then the maximum body burden trigger for the species is 2, and the recreational hunting or fishing reduction fraction for the location is incremented by the contribution fraction for that game animal at that location.

$$\text{FRF}(\text{L}, \text{A}) = \text{FRF}(\text{L}, \text{A}) + \text{FWT}(\text{L}, \text{S})$$

where

$$\begin{aligned} \text{FRF}(\text{L}, \text{A}) &= \text{total reduction fraction for recreational activity A at location L (unitless)} \\ \text{FWT}(\text{L}, \text{S}) &= \text{percentage of the game animal at location L represented by species S (unitless)} \end{aligned}$$

6.1.1.1.8 Trigger for Agricultural Products Tissue Concentrations

For each species used as an agricultural product, the plant tissue concentrations calculated by ECEM are compared to user-specified threshold concentrations for each analyte. The variable tissue concentration threshold (TCT) is set to one of two levels depending on the comparison to the concentration threshold for a given species S at a location L.

$$\begin{aligned} \text{TCT}(L, P) &= 0, & \text{If } \text{TC}(L, P, C) < \text{AL}_{\text{TC}}(P, C) \\ \text{TCT}(L, P) &= 2, & \text{If } \text{TC}(L, P, C) \geq \text{AL}_{\text{TC}}(P, C) \end{aligned}$$

where

$$\begin{aligned} \text{TCT}(L, P) &= \text{trigger for tissue concentration in agricultural product P at location L (unitless)} \\ \text{TC}(L, P, C) &= \text{tissue concentration for analyte C in product P at location L (pCi/L or } \mu\text{g/kg)} \\ \text{AL}_{\text{TC}}(S, C) &= \text{threshold concentration for the tissue concentration for analyte C in product P} \\ &\quad \text{(pCi/L or } \mu\text{g/kg)} \end{aligned}$$

At each location, the user specifies the fractional contribution to agriculture for each farm, field, or orchard product. If the tissue concentration for a species exceeds the user-specified threshold for at least one analyte, then the maximum trigger for the product is 2, and the agricultural reduction fraction for the location is incremented by the contribution fraction for that game animal at that location.

$$\text{ARF}(L, P) = \text{ARF}(L, P) + \text{FWT}(L, P)$$

where

$$\begin{aligned} \text{ARF}(L, P) &= \text{total reduction fraction for agricultural product P at location L (unitless)} \\ \text{FWT}(L, P) &= \text{percentage of the agricultural crop at location L represented by product P} \\ &\quad \text{(unitless)} \end{aligned}$$

6.1.1.2 Calculation of Reduction Fractions

Reduction fractions for voluntary avoidance and regulatory reduction of recreational activities and agriculture are based on triggers that were set when environmental concentrations were compared to user-supplied threshold values. These triggers are used in combination to determine how much recreation and agriculture are reduced from a baseline level.

6.1.1.2.1 Reduction in Recreational Fishing and Hunting Due to Avoidance

Factors for reduction in fishing and hunting caused by voluntary avoidance are set based on the contact surface water trigger. All reduction fractions for voluntary avoidance of fishing and hunting are sampled from user-specified statistical distributions.

$$\begin{aligned} \text{RRF}_{\text{VA}}(L, A) &= 0, & \text{If } \text{Max}(\text{SWFT}_{\text{VA}}(L)) &= 0 \\ \text{RRF}_{\text{VA}}(L, A) &= \text{VAS1}_{\text{REC}}(L, A), & \text{If } \text{Max}(\text{SWFT}_{\text{VA}}(L)) &= 1 \\ \text{RRF}_{\text{VA}}(L, A) &= \text{VAS2}_{\text{REC}}(L, A), & \text{If } \text{Max}(\text{SWFT}_{\text{VA}}(L)) &= 2 \end{aligned}$$

where

- $RRF_{VA}(L,A)$ = reduction fraction for avoidance of recreational fishing or hunting due to surface water contact concentration at location L (unitless)
- $SWFT_{VA}(L)$ = voluntary avoidance trigger for recreational fishing and hunting due to surface water contact concentration at location L (unitless)
- $VAS1_{REC}(L,A)$ = stochastically generated step 1 fraction for avoidance of activity A at location L (unitless)
- $VAS2_{REC}(L,A)$ = stochastically generated step 2 fraction for avoidance of activity A at location L (unitless)

6.1.1.2.2 Reduction in Recreational Fishing and Hunting Due to Regulation

The reduction fractions for regulation of fishing and hunting are set based on the game body burden triggers. If the trigger for game body burden is greater than zero, then the reduction fraction for regulation of fishing or hunting is set equal to a stochastically generated reduction fraction times the total fraction of the local game species for that activity that exceed their body burden threshold.

$$RFF_{RR}(L,A) = 0, \quad \text{If } FRF(L,A) = 0$$

$$RFF_{RR}(L,A) = RR_{WQ}(L,A) \times FRF(L,A), \quad \text{If } FRF(L,A) > 0$$

where

- $RFF_{RR}(L,A)$ = reduction fraction due to regulation of fishing or hunting activity A at location L (unitless)
- $FRF(L,A)$ = total reduction fraction for recreational activity A at location L (unitless)
- $RR_{WQ}(L,A)$ = stochastically generated fraction based on water quality for activity A at location L (unitless)

6.1.1.2.3 Reduction in Other Recreational Activity Due to Avoidance

Factors for reduction in other recreation caused by voluntary avoidance are set based on the contact surface water trigger. All reduction fractions for contact water are sampled from user-specified statistical distributions.

$$RRF_{VA}(L,A) = SWOT_{VA}(L)$$

where

- $RRF_{VA}(L,A)$ = reduction fraction due to avoidance of other recreational activity A at location L (unitless)
- $SWOT_{VA}(L)$ = voluntary avoidance trigger for other recreation due to surface water contact concentration at location L (unitless)

6.1.1.2.4 Reduction in Other Recreational Activity Due to Regulation

Factors for reduction in other recreation caused by regulatory action are set based on the contact surface water trigger. All reduction fractions for contact water are sampled from user-specified statistical distributions.

$$RRF_{RR}(L, A) = RR_{WQ}(L, A) \quad , \quad \text{If } \text{Max}(SWOT_{RR}(L)) = 2$$

where

$$\begin{aligned} RRF_{RR}(L, A) &= \text{reduction fraction due to regulation of other recreational activity A at location L (unitless)} \\ RR_{WQ}(L, A) &= \text{stochastically generated fraction based on water quality for activity A at location L (unitless)} \\ SWOT_{RR}(L) &= \text{regulatory reduction trigger for other recreation due to surface water contact concentration at location L (unitless)} \end{aligned}$$

6.1.1.2.5 Reduction in Agricultural Value of Production Due to Avoidance

The voluntary avoidance reduction fractions for agriculture are based on both the surface water used for irrigation and the groundwater used for irrigation. If either the trigger for surface water irrigation or the trigger for groundwater irrigation are greater than zero, then the agricultural reduction fraction for voluntary avoidance is set equal to a stochastically generated reduction fraction.

$$\begin{aligned} ARF_{VA}(L, P) &= 0, \quad \text{If } ISWT_{VA}(L)=0 \text{ and } IGWT_{VA}(L)=0 \\ ARF_{VA}(L, P) &= VAS1(L, P), \quad \text{If } ISWT_{VA}(L)=1 \text{ or } IGWT_{VA}(L)=1 \\ ARF_{VA}(L, P) &= VAS2(L, P), \quad \text{If } ISWT_{VA}(L)=2 \text{ or } IGWT_{VA}(L)=2 \end{aligned}$$

where

$$\begin{aligned} ARF_{VA}(L, P) &= \text{reduction fraction based on avoidance of irrigated agricultural product P at location L (unitless)} \\ ISWT_{VA}(L) &= \text{voluntary avoidance trigger for surface water irrigation at location L (unitless)} \\ IGWT_{VA}(L) &= \text{voluntary avoidance trigger for groundwater irrigation at location L (unitless)} \\ VAS1(L, P) &= \text{stochastically generated step 1 fraction for product P at location L (unitless)} \\ VAS2(L, P) &= \text{stochastically generated step 2 fraction for product P at location L (unitless)} \end{aligned}$$

6.1.1.2.6 Reduction in Agricultural Supply Due to Regulation

The regulatory reduction fractions for agriculture are based on both the surface water used for irrigation and the groundwater used for irrigation. If the surface water for irrigation exceeds a threshold, then the agricultural reduction fraction is incremented by the product of a stochastically generated reduction fraction for surface water times the portion of agricultural product P that is irrigated with surface water at location L. If the groundwater for irrigation exceeds a threshold, then the agricultural reduction fraction is incremented by the product of a stochastically generated reduction fraction for groundwater times the portion of agricultural product P that is irrigated with groundwater at location L.

$$\begin{aligned} ARF_{RR}(L, P) &= 0, \quad \text{If } ISWT_{RR}(L)=0 \text{ and } IGWT_{RR}(L)=0 \\ ARF_{RR}(L, P) &= GVARF_{RR}(L, P) \times IRRFRAC_{GW}(L, P), \quad \text{If } ISWT_{RR}(L)=0 \text{ and } IGWT_{RR}(L)>0 \end{aligned}$$

$$\begin{aligned} \text{ARF}_{\text{RR}}(L, P) &= \text{SWARF}_{\text{RR}}(L, P) \times \text{IRRFRAC}_{\text{SW}}(L, P), \text{ IF } \text{ISWT}_{\text{RR}}(L) > 0 \text{ and } \text{IGWT}_{\text{RR}}(L) = 0 \\ \text{ARF}_{\text{RR}}(L, P) &= \text{SWARF}_{\text{RR}}(L, P) \times \text{IRRFRAC}_{\text{SW}}(L, P) \times \text{GWARF}_{\text{RR}}(L, P) \times \text{IRRFRAC}_{\text{GW}}(L, P), \\ &\text{ IF } \text{ISWT}_{\text{RR}}(L) > 0 \text{ and } \text{IGWT}_{\text{RR}}(L) > 0 \end{aligned}$$

where

$$\begin{aligned} \text{ARF}_{\text{RR}}(L, P) &= \text{reduction fraction based on regulation for irrigated agricultural product P at location L (unitless)} \\ \text{ISWT}_{\text{RR}}(L) &= \text{regulatory reduction trigger for surface water irrigation at location L (unitless)} \\ \text{IGWT}_{\text{RR}}(L) &= \text{regulatory reduction trigger for groundwater irrigation at location L (unitless)} \\ \text{GWARF}_{\text{RR}}(L, P) &= \text{stochastically generated fraction for reduction of groundwater irrigation of product P at location L (unitless)} \\ \text{IRRFRAC}_{\text{GW}}(L, P) &= \text{fraction of product P that is irrigated with groundwater at location L (unitless)} \\ \text{SWARF}_{\text{RR}}(L, P) &= \text{stochastically generated fraction for reduction of surface water irrigation of product P at location L (unitless)} \\ \text{IRRFRAC}_{\text{SW}}(L, P) &= \text{fraction of product P that is irrigated with surface water at location L (unitless)} \end{aligned}$$

6.1.1.3 Cost of Drinking Water Source Replacement

For the appropriate water type used for drinking water at location L, the annual cost of filtering and using the water for drinking water is:

$$\text{Cost}_{\text{FILT}}(L) = \text{FT}_{\text{DW}}(L) \times \text{FLOW}(L) \times 365.25$$

where

$$\begin{aligned} \text{Cost}_{\text{FILT}}(L) &= \text{total cost of filtering drinking water at location L (\$)} \\ \text{FT}_{\text{DW}}(L) &= \text{cost to filter drinking water at location L (\$/1,000 gal)} \\ \text{FLOW}(L) &= \text{flow rate of water supply at location L (1,000 gal/d)} \\ 365.25 &= \text{number of days per year (d)} \end{aligned}$$

The annualized cost of replacing the drinking water source at location L is:

$$\text{Cost}_{\text{REPL}}(L) = (\text{FLOW}(L) \times \text{COST}(L) \times \text{RATE}) / (1 - (1 + \text{RATE})^{-\text{YRS}})$$

where

$$\begin{aligned} \text{Cost}_{\text{REPL}}(L) &= \text{total cost to replace the drinking water supply at location L (\$)} \\ \text{FLOW}(L) &= \text{flow rate of water supply at location L (1,000 gal/d)} \\ \text{COST}(L) &= \text{replacement cost for the drinking water supply (\$/1,000 gal/d)} \\ \text{RATE} &= \text{annual discount rate (unitless)} \\ \text{YRS} &= \text{financing period (yr)} \end{aligned}$$

6.1.2 Economic Effects

The effects calculations are the set of equations that use the reduction fractions calculated in the TRIGGER subroutine to determine the costs associated with regulatory reduction or voluntary avoidance of recreational activities and agricultural products. These costs are then apportioned to industries and economic sectors for input to the ECONCHG subroutine.

6.1.2.1 Recreational Impact

Recreational impact is calculated for six activities: fishing, waterfowl hunting, upland hunting, boating, swimming, and water skiing. The value and effect are calculated for each activity, and then the effects are summed and allocated over the sectors of the regional economy.

6.1.2.1.1 Value of Recreational Activities

The value of the recreational activities is calculated separately for each requested time. The total value of an activity (\$) at a location is the daily value per person times the number of trips per person times the participating population for that activity.

$$V(L,A) = VD(A) \times Trips(A) \times Pop(L,A)$$

where

- $VD(A)$ = value per activity day of recreational activity A at location L (\$)
- $Trips(A)$ = number of recreational days per member of the population for activity A at location L (person⁻¹)
- $Pop(L,A)$ = participating population for recreational activity A at location L (persons)

The daily per person value of fishing and hunting are regression equations involving a base value and several measures of the quality of the fishing or hunting activity. The daily value of the other recreational activities is constant.

$$VD(L,A) = BV(A) + C_Q(A) \times SQF(L,A) + C_{SA}(A) \times SAF(L,A) + C_{COV}(A) \times COV(A) + C_{TT}(A) \times TT(L,A) + C_{SUBS}(A) \times SUBS(L,A) + C_{IOF}(A) \times IOF(L,A) + C_{HV}(A) \times HV(L,A)$$

where

- $BV(A)$ = base value of recreational activity A in the region (\$/d)
- $C_Q(A)$ = regression coefficient for site quality (unitless)
- $SQF(L,A)$ = regional site quality factor (unitless)
- $C_{SA}(A)$ = regression coefficient for specialized activity (unitless)
- $SAF(L,A)$ = specialized activity factor (unitless, 0 or 1)
- $C_{COV}(A)$ = regression coefficient for sample coverage (unitless)
- $COV(A)$ = sample coverage factor (unitless)
- $C_{TT}(A)$ = regression coefficient for travel time cost (unitless)
- $TT(L,A)$ = travel time cost factor (unitless)
- $C_{SUBS}(A)$ = regression coefficient for substitution (unitless)

SUBS(L,A) = substitution variable factor (unitless)
 $C_{IOF}(A)$ = regression coefficient for individual observation (unitless)
 IOF(L,A) = individual observation factor (unitless)
 $C_{HV}(A)$ = regression coefficient for household production (unitless)
 HV(L,A) = household production factor (unitless)

The number of trips at location L to pursue activity A on a per-person basis.

$$\text{Trips}(A) = \text{EXP} \left(C_{\text{base}}(A) + C_{\text{Dist}}(A) \times \text{LN}(\text{Dist}(L,A)) + C_{\text{QUAL}}(A) \times \text{LN}(\text{QUAL}(L,A)) + C_{\text{sub}}(A) \times \text{LN}(Q_{\text{sub}}(L,A)) \right)$$

where

$C_{\text{base}}(A)$ = base number of trips (person⁻¹)
 $C_{\text{Dist}}(A)$ = regression coefficient for travel distance (unitless)
 Dist(L,A) = travel distance factor (unitless)
 $C_{\text{QUAL}}(A)$ = regression coefficient for site quality (unitless)
 QUAL(L,A) = fishing or hunting quality for the site (unitless)
 $C_{\text{sub}}(A)$ = regression coefficient for substitute site (unitless)
 $Q_{\text{sub}}(L,A)$ = ratio of site quality to distance of substitute site (unitless)

6.1.2.1.2 Effect of Recreational Activities on the Regional Economy

The effect on the regional economy due to changes in recreational activity is measured by the change in expenditures on recreational activities due to contamination in the environment. The change in spending results in a reduced number of trips per person and is reduced by the maximum of the regulatory reduction and the voluntary avoidance factors calculated in the TRIGGER routine.

$$\text{ExpChg}(L,A) = -1 \times \text{Pop}(L,A) \times (\text{Trips}(A) \times \text{Max}(\text{RRF}_{\text{RR}}(L,A), \text{RRF}_{\text{VA}}(L,A)) \times \text{Spend}(L,A)$$

where

Pop(L,A) = participating population for recreational activity A at location L (persons)
 Trips(A) = number of recreational days per member of the population for activity A at location L (person⁻¹)
 $\text{RRF}_{\text{RR}}(L,A)$ = recreation reduction fraction due to regulation of activity A at location L (unitless)
 $\text{RRF}_{\text{VA}}(L,A)$ = recreation reduction fraction due to voluntary avoidance of activity A at location L (unitless)
 Spend(L,A) = spending per person per trip at location L on recreational activity A

The change in expenditures on recreation is allocated over economic industries in proportion to their contribution to the economy.

$$\text{RecEff}(L,A,I) = \text{ExpChg}(L,A) \times \text{RecIP}(A,I)$$

where

$\text{RecIP}(A, I)$ = percentage of total spending on activity A allocated to industry I (unitless)

The industry percentage for each activity is calculated by dividing the baseline recreational spending for an activity by the sum of the expenditures for the recreational activity over all industries.

$$\text{RecIP}(A, I) = \text{Base}(A, I) / \text{TotInd}(A)$$

where

$\text{Base}(A, I)$ = baseline spending in industry I on recreational activity A (\$).

$\text{TotInd}(A)$ = total spending on recreational activity A over all industries in the regional economy (\$)

The input to the final module of TCERM, ECONCHG, requires that the change in expenditures on recreation be allocated over economic sectors in proportion to their contribution to the economy. When each industry is defined, it is assigned to an economic sector. The sector totals are calculated by adding the baseline recreational spending for each industry assigned to the sector.

$$\text{RecEff}(L, A, S) = \text{ExpChg}(L, A) \times \text{RecSP}(A, S)$$

where

$\text{RecSP}(A, S)$ = percentage of total spending on activity A allocated to sector S (unitless)

6.1.2.2 Agricultural Impact

Agricultural impact is calculated for a number of agricultural products. The change in production, change in producer's surplus, revenue change, and cost change are calculated for each product, and then the effects are summed and allocated over the sectors of the regional economy. All agricultural impacts are calculated separately for each requested time.

6.1.2.2.1 Change in Value and Production of Agricultural Products

The change in production of agricultural products (bu or tons or cwt) is a reduction in production due to either regulatory action or voluntary avoidance. The minimum of these two alternatives is chosen because both will be negative numbers. This means that the maximum impact is selected.

$$\text{CHG}_{\text{PROD}}(L, P) = \text{Min}(\text{Prod}(L, P) \times (-\text{ARF}_{\text{RR}}(L, P)), \text{Prod}(L, P) \times \text{IFSW}(L, P) \times (-\text{ARF}_{\text{VA}}(L, P)))$$

where

$\text{Prod}(L, P)$ = total production of product P at location L (bu or tons or cwt)

$\text{ARF}_{\text{RR}}(L, P)$ = regulatory reduction fraction for agriculture (unitless)

$\text{IFSW}(L, P)$ = fraction of product P that is irrigated with surface water at location L (unitless)

$\text{ARF}_{\text{VA}}(L, P)$ = voluntary avoidance reduction fraction for agriculture (unitless)

The change in producer's surplus for agricultural product P at location L is an increase in the value of unsold product as a result of regulatory action or voluntary avoidance. If the value calculated for the change in producer's surplus is less than zero, then it is set to zero.

$$CHG_{PS}(L, P) = 0.5 \times \text{Min} \left((\text{Price}(P) - \text{LSP}(L, P)) \times \text{Prod}(L, P) \times (-\text{ARF}_{RR}(L, P)), (\text{Price}(P) - \text{LSP}(L, P)) \times \text{Prod}(L, P) \times \text{IFSW}(L, P) \times (-\text{ARF}_{VA}(L, P)) \right)$$

where

Price(P) = price of agricultural product P in the region (\$/bu or ton or cwt)
 LSP(L,P) = lowest supply price for agricultural product P at location L (\$/bu or ton or cwt)

The change in revenue from the sale of product P at location L is the price times the change in production.

$$CHG_{REV}(L, P) = \text{Price}(P) \times CHG_{PROD}(L, P)$$

The change in cost of product P at location L is the change in revenue minus the change in producer's surplus.

$$CHG_{COST}(L, P) = CHG_{REV}(L, P) - CHG_{PS}(L, P)$$

6.1.2.2.2 Effect of Agricultural Products on the Regional Economy

The two quantities needed to determine the impact on the regional economy of agriculture in the ECONCHG module are the change in procurements and the change in labor cost for agriculture.

$$CHG_{PROC}(L, P) = CHG_{COST}(L, P) \times (1 - \text{Labor})$$

where

CHG_{COST}(L,P) = change in cost of product P at location L
 Labor = percentage of the agricultural cost that is labor (unitless)

The change in the labor cost of agriculture is the change in cost times the labor percentage.

$$CHG_{LAB}(L, P) = CHG_{PS}(L, P) + CHG_{COST}(L, P) \times (\text{Labor})$$

where

CHG_{PS}(L,P) = change in producer's surplus for agricultural product P at location L
 CHG_{COST}(L,P) = change in cost of product P at location L
 Labor = percentage of the agricultural cost that is labor (unitless)

The changes in labor and non-labor expenditures on agriculture are allocated over economic industries in proportion to their contribution to final demand spending by consumers in the local economy (for labor) or for agricultural spending (non-labor).

$$\begin{aligned} AgEff_{PROC}(L, P, I) &= CHG_{PROC}(L, P) \times AgIP(I) \\ AgEff_{INC}(L, P, I) &= CHG_{LAB}(L, P) \times AgIP(I) \end{aligned}$$

where

$$\begin{aligned}\text{CHG}_{\text{PROC}}(\text{L}, \text{P}) &= \text{change in procurements for agriculture} \\ \text{AgIP}(\text{I}) &= \text{percentage of total spending on agriculture allocated to industry I (unitless)} \\ \text{CHG}_{\text{LAB}}(\text{L}, \text{P}) &= \text{change in the labor cost of agriculture}\end{aligned}$$

The industry percentage for each product is calculated by dividing the baseline agricultural spending on agriculture by the sum of the expenditures for agriculture over all industries.

$$\text{AgIP}(\text{I}) = \text{Base}(\text{I}) / \text{TotInd}$$

where

$$\begin{aligned}\text{Base}(\text{I}) &= \text{baseline spending in industry I by agriculture (\$M)} \\ \text{TotInd} &= \text{total spending by agriculture over all industries in the regional economy (\$M)}\end{aligned}$$

The input to the final module of TCERM, ECONCHG, requires that the change in procurements and income for agriculture be allocated over economic sectors in proportion to their contribution to the economy. When each industry is defined, it is assigned to an economic sector. The sector totals are calculated by adding the baseline agricultural spending for each industry assigned to the sector.

$$\begin{aligned}\text{AgEff}_{\text{PROC}}(\text{L}, \text{P}, \text{S}) &= \text{CHG}_{\text{PROC}}(\text{L}, \text{P}) \times \text{AgSP}(\text{S}) \\ \text{AgEff}_{\text{INC}}(\text{L}, \text{P}, \text{S}) &= \text{CHG}_{\text{INC}}(\text{L}, \text{P}) \times \text{AgSP}(\text{S})\end{aligned}$$

where

$$\text{AgSP}(\text{S}) = \text{percentage of total agricultural spending allocated to sector S (unitless)}$$

6.1.3 Economic Change Analysis

The economic change analysis is the set of equations that use the agricultural and recreational effects calculated in the EFFECTS subroutine to determine the impact on the regional economy in terms of changes in output, wages, and employment.

6.1.3.1 Change in Output

A sector-by-sector matrix M is provided in which the entries in each column represent purchases from each industry per dollar of output in the industry that defines the sector. The data for this matrix can be obtained from routine U.S. Department of Commerce, Bureau of Economic Analysis publications. The matrix M is subtracted from the identity matrix, and the resulting matrix is inverted using the LU decomposition method. The matrix M_{INV} is a square matrix of dimension number of sectors by number of sectors.

$$M_{\text{INV}} = (\text{I} - M)^{-1}$$

The change in output due to change in agricultural procurements is a matrix multiplication of the matrix M_{INV} and the vector of changes in the agricultural sector's non-labor procurements calculated in the EFFECTS routine.

$$\text{AgOut}_{\text{PROC}}(\text{L}, \text{S}) = M_{\text{INV}} \times \text{AgEff}_{\text{PROC}}(\text{L}, \text{S})$$

The change in output due to change in agricultural income is a matrix multiplication of the matrix M_{INV} and the vector of changes in spending of agricultural income calculated in the EFFECTS routine.

$$AgOut_{INC}(L, S) = M_{INV} \times AgEff_{INC}(L, S)$$

The change in output due to change in recreational spending is a matrix multiplication of the matrix M_{INV} and the vector of changes in recreational spending calculated in the EFFECTS routine. The change in recreational output is summed over all recreational activities.

$$RecOut(L, S) = \sum (M_{INV} \times RecEff(L, A, S)), A=1 \text{ to } NumAct$$

The total change in output for a sector is the sum of the changes in output due to changes in agricultural and recreational spending.

$$Output(L, S) = AgOut_{PROC}(L, S) + AgOut_{INC}(L, S) + RecOut(L, S)$$

6.1.3.2 Change in Wages

The change in wages is the product of the change in output and the base wages per dollar of output for a given sector.

$$Wages(L, S) = Output(L, S) \times BaseWage(S)$$

where

$$BaseWage(S) = \text{dollars of earnings per dollars of output for sector } S$$

6.1.3.3 Change in Employment

The change in employment is the product of the change in output and the base employment per million \$ of output for a given sector.

$$Employ(L, S) = Output(L, S) / 1.0E+6 \times BaseEmp(S)$$

where

$$BaseEmp(S) = \text{jobs per million dollars of output for sector } S.$$

6.2 Code Environment

6.2.1 Location in the Processing Sequence

The TCERM code requires access to a number of data files developed by the SAC inventory, release, and transport codes (Eslinger et al. 2004). In particular, every code on the left side of Figure 1.1 must have been executed to build a suite of concentration data files before the TCERM code can be used to calculate economic impacts. These concentration data files must have been developed under the control of the same ESD keyword file that the TCERM code reads to determine processing options.

6.2.2 How the Code Is Invoked

TCERM can run under either the Windows or the Linux operating system. Under the Windows operating system (Releases 98, NT, or 2000), TCERM executes in a DOS box. A run of TCERM is initiated by entering the following command line:

```
TCERM "Keyfilename"
```

Under the Linux operating system, TCERM is executed through the following Bourne Shell or C Shell command:

```
tcerm.exe "Keyfilename"
```

For these commands, TCERM or tcerm.exe is the name of the executable program and "Keyfilename" is the name of an economic scenario keyword file. Both the name of the executable program and the keyword file may contain path information. If TCERM is invoked without entering the name of the keyword file, the code will prompt the user for the file name. The keyword file, which should be prepared using an editor that can handle ASCII files without leaving embedded control codes, contains text control information describing the run. If TCERM cannot open the keyword file, then the code will terminate execution after writing an error message to the standard output device.

6.2.3 Memory Requirements

The TCERM code uses dynamic memory allocation, so the memory requirements depend on the problem being analyzed. An example run where the TCERM code required 1.9 MB of memory (on a Windows 2000 machine) used 10 analytes, 202 times steps, 1 realization, and 4 locations. It is expected that most if not all of the runs of the TCERM code will require fewer than 4 MB of memory.

6.3 Data Files

The TCERM code reads four or more input files and writes up to five output files. The number of input files depends on the number of contaminants being analyzed. The number of output files depends on the options selected in the TCERM code. These files are described in the following sections.

6.3.1 Input Files

The input files for the TCERM code are two keyword files and a suite of concentration data related files, plus a fish body burden file for scenarios that include recreational fishing. One keyword file controls the case the TCERM code will execute, and it points to the ESD keyword file. The suite of concentration data files are all identified in the ESD keyword file – the user of the TCERM only needs to identify the location and name of the ESD keyword file. The following are the input files:

- **TCERM Keyword File.** The TCERM Keyword file controls the scenario to be analyzed by the TCERM code. The options and data available are constrained by the case defined in the ESD Keyword file. Section 6.3.1.1 describes the contents of the TCERM keyword file.

- **ESD Keyword File.** The ESD keyword file contains the control information that the inventory and environmental transport codes use to generate concentration data files. Table 2.2 provides examples of keywords in the ESD file that control the impact codes, including the TCERM code. Section 2.1 provides definitions for these keywords. Typically, the user of the TCERM code will not modify the ESD keyword file.
- **ECDA Concentration Files.** The ECDA files contain all the concentration data available for the impact codes. The concentrations for all analytes are based on the same time and location data. There is a “map” file specific to the TCERM code containing indexing information for each of the concentration data files. In addition, there is a separate concentration data file for every analyte used in the impacts scenario. For example, when running a scenario with seven analytes there will be one map file and seven concentration data files. The structure of a concentration data file is described in Section 2.4.1.
- **ECЕМ Body Burden File.** Scenarios in TCERM that include recreational fishing and hunting require an additional input file. This file is generated by the ECEM code and contains the body burden for selected recreational species for all analytes to be modeled. Section 6.3.1.2 provides an example ECEM body burden file.

6.3.1.1 TCERM Keyword File

Table 6.1 provides excerpted records from a keyword file for TCERM. Data from each major section of the inputs are provided, but many lines were omitted to reduce the size of the file. This file was originally over 1350 lines long.

Table 6.1 Excerpted Records from a TCERM Keyword File

REPORT	"TCERM.Rpt"
TITLE	"Test run of the TCERM Code for SAC Rev. 1 Modifications"
USER	"Paul W. Eslinger"
!	
EXECUTE	
!	
!	Input file names
FILE ESD	"ESD_TCERM.key"
!	
!	FILE BURDEN "FISH_det.csv"
!	Output file names
FILE TRIGGERD	"TRIG_Det.csv"
FILE TRIGGERS	"TRIG_Sta.csv"
FILE EFFECTSD	"EFF_Det.csv"
FILE EFFECTSS	"EFF_Sta.csv"
FILE ECONCHGD	"ECHG_Det.csv"
FILE ECONCHGS	"ECHG_Sta.csv"
FILE HEADER	"TCERM.hdr"
!	
!	Food files from ECEM
FOODS MAP=	"Food_Map.Dat"
	PATH="\Projects\sac\TCERM\rev 1\Foods\"
!	
!	Output summary statistics

```
STATISTICS TRIGGER
STATISTICS EFFECTS
!
! Output detailed data
DETAILS TRIGGER
DETAILS EFFECTS
!
DEBUG EFFECTS
DEBUG FOOD
! Random Seed for Stochastics
SEED 445512
! Number of Realizations
REALIZATION 5
! Times to be used
TIMES 1950 2000 3000 5000 10000 12050
! Locations to be used
LOCATION ID="ECON01" NAME="Richland region"
  SWDW="L00001" SWCON="L00001" SWIRR="L00201" GWIRR="L00801"
  FISH="L00001" FOWL="L00401" GAME="L00801"
  FIELD="L00801" FARM="L00801" ORCHARD="L00801"
  INCOME=50000.0 DWSOURCE="PUBSW" SWFLWPUB=18000.0 SWCSTPUB=1000.0
  GWFLWPUB=2000.0 GWCSTPUB=0.0
...
LOCATION ID="ECON04" NAME="Snake to McNary region"
  SWDW="L00004" SWCON="L00004" SWIRR="L00204" GWIRR="L00804"
  FISH="L00008" FOWL="L00408" GAME="L00808"
  FIELD="L00808" FARM="L00808" ORCHARD="L00808"
  INCOME=50000.0 DWSOURCE="PVTSW" SWFLWPVT=2300.0 SWCSTPVT=67.0
  GWFLWPVT=2300.0 GWCSTPVT=45.0
!
! Analytes to be used
ANALYTE "CrVI" "H3" "I129" ! "U238"
!
! Fish species to be used
FISHSPC "SALMAD" "RTRTAD" "SMBASS" "CARP" "WSTRGN" "CRYFSH"
!
! Fish weighting factors by species and location
! These factors must sum to 1 for each location
FISHWT
  0.4 0.3 0.2 0.3 ! SALMAD
  0.1 0.1 0.2 0.1 ! RTRTAD
  0.2 0.2 0.2 0.2 ! SMBASS
  0.1 0.2 0.1 0.1 ! CARP
  0.1 0.1 0.2 0.2 !WSTRGN
  0.1 0.1 0.1 0.1 ! CRYFSH
!
! Waterfowl hunting species to be used
FOWLSPC "CQUAIL" "CANGOS"
!
! Waterfowl weighting factors by species and location
! These factors must sum to 1 for each location
```

```
FOWLWT
  0.7   0.8   0.6   0.4   ! QUAIL
  0.3   0.2   0.4   0.6   ! GOOSE
!
! Upland game hunting species to be used
GAMESPC "MULDER" "CQUAIU"
!
! Upland game weighting factors by species and location
! These factors must sum to 1 for each location
GAMEWT
  0.6   0.7   0.4   0.5   ! MULDER
  0.4   0.3   0.6   0.5   ! CQUAIU
!
! Recreational Activity Definitions
REACT ID="FISHNG" NAME="Fishing" CBASEVAL=33.769 SAMPCOV=1.0
CSITEQUAL=39.171
  CSPEACT=-0.679 CSAMPCOV=-11.759 CTRAVTIM=-13.333 CSUBVAR=10.831
CINDOBS=17.95
  CHOUSEVAL=9.499 CONSTANT=0.422 CDIST=-1.2377 CFISH=0.317 CSUB=-0.1269
  CINCOME=1.0 OUTPUT
...
REACT ID="SKIING" NAME="Water skiing" CBASEVAL=33.769 SAMPCOV=1.0
CSITEQUAL=39.171
  CSPEACT=-0.679 CSAMPCOV=-11.759 CTRAVTIM=-13.333 CSUBVAR=10.831
CINDOBS=17.95
  CHOUSEVAL=9.499 CONSTANT=0.422 CDIST=-1.2377 CFISH=0.317 CSUB=-0.1269
  CINCOME=1.0 OUTPUT
!
! Site quality for recreational activities by activity and location
SITEQUAL LOCATION="ECON01" REACT="FISHNG" 1.0
...
SITEQUAL LOCATION="ECON04" REACT="SKIING" 0.0
!
! Specialized activity flag by recreational activity and location
SPECACT LOCATION="ECON01" REACT="FISHNG" 1.0
...
SPECACT LOCATION="ECON04" REACT="SKIING" 0.0
!
! Travel time by recreational activity and location
TRAVTIM LOCATION="ECON01" REACT="FISHNG" 1.0
...
TRAVTIM LOCATION="ECON04" REACT="SKIING" 0.0
!
! Substitution variable by recreational activity and location
SUBVAR LOCATION="ECON01" REACT="FISHNG" 1.0
...
SUBVAR LOCATION="ECON04" REACT="SKIING" 0.0
!
! INDOBS variable by recreational activity and location
INDOBS LOCATION="ECON01" REACT="FISHNG" 1.0
...
```

```
INDOBS LOCATION="ECON04" REACT="SKIING" 0.0
!
! Property value by recreational activity and location
HOUSEVAL LOCATION="ECON01" REACT="FISHNG" 1.0
...
HOUSEVAL LOCATION="ECON04" REACT="SKIING" 0.0
!
! Property value by recreational activity and location
TRAVDIST LOCATION="ECON01" REACT="FISHNG" 1.0
...
TRAVDIST LOCATION="ECON04" REACT="SKIING" 1.0
!
! Property value by recreational activity and location
FISHQUAL LOCATION="ECON01" REACT="FISHNG" 1.0
...
FISHQUAL LOCATION="ECON04" REACT="SKIING" 1.0
!
! Property value by recreational activity and location
SUBDIST LOCATION="ECON01" REACT="FISHNG" 1.0
...
SUBDIST LOCATION="ECON04" REACT="SKIING" 1.0
!
! Spending on recreational activities by activity and location
SPEND LOCATION="ECON01" REACT="FISHNG" 38.6
...
SPEND LOCATION="ECON04" REACT="SKIING" 21.33
!
! Participating population in recreational activities by activity and
location
PARTIC LOCATION="ECON01" REACT="FISHNG" 37600.0
...
PARTIC LOCATION="ECON04" REACT="SKIING" 6000.0
!
! Discount rate for drinking water source replacement capital costs
DISCOUNT 0.07
!
! Drinking water filter cost ($/1000 gal/day)
FILTER LOCATION="ECON01" ANALYTE="CCl4" PUBSW=5.0
...
FILTER LOCATION="ECON04" ANALYTE="U238" PVTGW=5.0
!
! Agricultural Product Definitions
!
! Field crops
AGPROD ID="SPRWHT" NAME="Spring wheat" SPECIES="GRAIN" FIELD OUTPUT
...
AGPROD ID="SHPPRO" NAME="Sheep, lambs and wool" SPECIES="SHEEP" FARM
OUTPUT
!
! Percent of agricultural cost that is labor (unitless)
AGLABOR 0.55
```



```

!
! Lowest supply price and total production by location of agricultural
products
AGPARAM AGPROD="SPRWHT"  LOCATION="ECON01"  LOWPRICE=2.83
...
AGPARAM AGPROD="SHPPRO"  LOCATION="ECON04"  LOWPRICE=46.20
!
! Fraction of the agricultural product by location that is irrigated with
groundwater
IRRFRACG
  0.0   0.0   0.0   0.0   ! SPRWHT
...
  0.0   0.0   0.0   0.0   ! SHPPRO
!
! Fraction of the agricultural product by location that is irrigated with
surface water
IRRFRACS
  0.65  0.65  4.57  3.47  ! WINWHT
...
  0.0   0.0   0.0   0.0   ! SHPPRO
!
! Sector Definitions
SECTOR ID="AGRICU" NAME="Ag, Forestry, Fishery"
BASE_EMP=13.22937384  BASE_WAG=0.200201976  OUTPUT
...
SECTOR ID="GOVERN" NAME="Government"
BASE_EMP=21.98070593  BASE_WAG=0.833478636  OUTPUT
!
! Industry Definitions
! Recreational baseline order is Fishing, Boating/Skiing, Swimming
INDUSTRY ID="AGCRPS" NAME="AGG 1 AG CROPS"  SECTOR="AGRICU"
AGBASELINE=11.806  RECBASELINE=0.0  0.0  0.0  0.0  0.0  0.0  0.0
OUTPUT
...
INDUSTRY ID="GOVERN" NAME="AGG 90 GOVERNMENT"  SECTOR="GOVERN"
AGBASELINE=15.901  RECBASELINE=0.0  0.0  0.0  0.0  0.0  0.0  0.0
OUTPUT
!
! Sector by Sector Make-Use Matrix
! 1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16 17 18 19 20 21
22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
MAKEUSE
  0.024  0.0  0.0  0.0  0.086  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
3.8E-5  0.0  1.5E-6  0.0  0.016  0.0  5.1E-6
  2.3E-6  6.9E-5  1.6E-6  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
1.3E-6
...
  0.0024  0.0067  0.0059  0.0063  0.0036  0.0050  0.0045  0.0044  0.0072  0.0028  0.0036
0.0022
  0.0087  0.0072  0.0066  0.0053  0.0072  0.0070  0.014  0.011  0.015  0.0056  0.012
0.0030

```

```
!
! Threshold Concentrations
THRESHOLD ANALYTE="CCl4" DRINK      0.25      ! ug/L
...
THRESHOLD ANALYTE="U238" FARM      AGPROD="SHPPRO"      1.5E+3      ! ug/kg
!
! Lowest supply price
STOCHASTIC "SPRWHTPRICE"  6 2.83 3.82 4.95      "Price for spring wheat
($/bu )"
...
STOCHASTIC "SHPPROPRICE"  6 46.2 63.85 84.0      "Price for sheep and lambs
($/cwt)"
!
! Total production by location and agricultural product
STOCHASTIC"ECON01SPRWHTTOTPROD" 1 0.0      "Total production of Spring Wheat at
location ECON01 in bu"
...
STOCHASTIC"ECON04SHPPROTOTPROD" 1 0.0      "Total production of Sheep and Lambs
at location ECON04in cwt"
!
! Data from TCERM Params 10-30-00.xls sheet "RRAG_SW"
STOCHASTIC "ECON01SPRWHTRRAG_SW" 1 1.0      "Reg red in ag due to SW at ECON01
for SPRWHT"
...
STOCHASTIC "ECON04SHPPRORRAG_SW" 1 1.0      "Reg red in ag due to SW at ECON04
for SHPPRO"
!
! Data from TCERM Params 10-30-00.xls sheet "RRAG_GW"
STOCHASTIC "ECON01SPRWHTRRAG_GW" 1 1.0      "Reg red in ag due to GW at ECON01
for SPRWHT"
...
STOCHASTIC "ECON04SHPPRORRAG_GW" 1 1.0      "Reg red in ag due to GW at ECON04
for SHPPRO"
!
! Data from TCERM Params 10-30-00.xls sheet "VAAG_S1&S2"
STOCHASTIC "SPRWHTVAAG_S1" 6 0.0 0.05 0.25      "Vol avoid of ag step 1 for
SPRWHT"
...
STOCHASTIC "SHPPROVAAG_S1" 6 0.0 0.05 0.25      "Vol avoid of ag step 1 for
SHPPRO"
!
! Data from TCERM Params 10-30-00.xls sheet "VAAG_S1&S2"
STOCHASTIC "SPRWHTVAAG_S2" 6 0.2 0.3 0.8      "Vol avoid of ag step 2 for SPRWHT"
...
STOCHASTIC "SHPPROVAAG_S2" 6 0.2 0.3 0.8      "Vol avoid of ag step 2 for SHPPRO"
!
! Data from TCERM Params 10-30-00.xls sheet "Rec Reg Red & Vol Avoid"
STOCHASTIC "ECON01FISHNGRRREC_WQ" 6      0.6 0.8 0.9      "Reg red in rec due to
water quality at ECON01 for FISHNG"
...
STOCHASTIC "ECON04SKIINGRRREC_WQ" 6      0.6 0.8 0.9      "Reg red in rec due to
```

```
water quality at ECON04 for WSKING"
!
! Data from TCERM Params 10-30-00.xls sheet "Rec Reg Red & Vol Avoid"
STOCHASTIC "ECON01FISHNGVAREC_S1" 6 0.0 0.2 0.4 "Reg red in rec due to
water quality at ECON01 for FISHNG"
...
STOCHASTIC "ECON04SKIINGVAREC_S1" 6 0.1 0.25 0.5 "Reg red in rec due to
water quality at ECON04 for WSKING"
!
! Data from TCERM Params 10-30-00.xls sheet "Rec Reg Red & Vol Avoid"
STOCHASTIC "ECON01FISHNGVAREC_S2" 6 0.2 0.35 0.6 "Reg red in rec due to
water quality at ECON01 for FISHNG"
...
STOCHASTIC "ECON04SKIINGVAREC_S2" 6 0.2 0.5 0.8 "Reg red in rec due to
water quality at ECON04 for WSKING"
! End of Inputs
END
```

6.3.1.2 ESD Keyword File

The TCERM code also reads keywords from the environmental settings file. These keywords are read from a different file and can have a different definition from a keyword defined for internal use in the TCERM code. The environmental settings keywords are defined in Section 2.1. The following keywords are required:

- ANALYTE – Definition of analytes in the environmental simulations
- END – End of the environmental settings keywords
- FILE – File names for the concentration file for each analyte
- LOCATION – Locations at which concentrations were generated for the economic impact
- REALIZAT – Number of realizations that were simulated
- SPECIES – The species for which tissue concentrations were generated for the ecological impact
- TIMES – Times at which concentrations were generated for the economic impact
- TITLE – Environmental simulation title

6.3.1.3 ECEM Body Burden File

The TCERM code requires the analyte concentrations in game species (body burdens) for the recreational hunting and fishing activities calculations. These body burdens are input from an FCDA file written by ECEM (see Section 4.3.2.7).

6.3.2 Output Files

Up to nine output files can be written by the TCERM code. The number of files depends on the options selected in the scenario being analyzed. The following are the output files:

- **Report File.** This required file contains a summary of the scenario being analyzed and contains any error messages. This file is described in Section 6.3.2.1.

- **SACView Header File.** This required file contains information used by the interactive SACView program to allow easy extraction of subsets of the results computed by the TCERM code. This file is described in Section 6.3.2.2.
- **Stochastic Values File.** This optional file contains the values for every stochastic variable generated in the TCERM code. This file is described in Section 6.3.2.3.
- **Trigger Detailed Data.** This optional file contains the detailed values for the economic change trigger data generated in the TCERM code. This file is described in Section 6.3.2.4.
- **Trigger Summary Statistics Data.** This optional file contains the summary statistics for the economic change trigger data generated in the TCERM code. This file is described in Section 6.3.2.5.
- **Effects Detailed Data.** This optional file contains the detailed values for the economic effects generated in the TCERM code. This file is described in Section 6.3.2.6.
- **Effects Summary Statistics Data.** This optional file contains the summary statistics for the economic effects generated in the TCERM code. This file is described in Section 6.3.2.7.
- **Economic Change Detailed Data.** This required file contains the detailed values for the economic change data generated in the TCERM code. This file is described in Section 6.3.2.8.
- **Economic Change Summary Statistics Data.** This required file contains the summary statistics for the economic change data generated in the TCERM code. This file is described in Section 6.3.2.9.

6.3.2.1 TCERM Report File

Table 6.2 provides excerpted records for an example report file for the TCERM code. This file contains information for a run of the TCERM code using 2 analytes, 4 locations, 31 agricultural products, and 62 industries in 36 sectors. This file is about 12 KB in size. The size of this file grows rapidly when debug options are selected. A run using all debug options having a large number of locations, analytes, solution times, and realizations could easily generate a report file of 2 GB or larger.

Table 6.2 Excerpted Records from a TCERM Report File

TTTTTTT	CCCCC	EEEEEEE	RRRRRR	MM	MM
T	C	C E	R	R M M	M M
T	C	E	R	R M	M M M
T	C	EEEE	RRRRRR	M	M M
T	C	E	R R	M	M
T	C	C E	R R	M	M
T	CCCCC	EEEEEEE	R	R M	M
TCERM Version 2.00.A.0					
Last Modified on 15 Apr 2003					

SAC Rev. 1 Economic Impacts Model					

Developed By Battelle Memorial Institute					
Pacific Northwest National Laboratories					
Richland, Washington					
Current Run ID = 20030528161226 User Name = Paul W. Eslinger					
System Date = 05-28-2003 System Time = 16:12:26.960					
The software used to generate this output is experimental					

and has not been formally tested or peer reviewed.

Review Signatures

Input Prepared By: _____ Date: _____

Input Reviewed By: _____ Date: _____

===== Echo of the Problem Definition =====

Title: Test run of the TCERM Code for SAC Rev. 1 Modifications

User: Paul W. Eslinger

5 Realizations requested in this run

5 Realizations available in the concentration files

File name for input keyword data

File: tcerm.key

File name for input ESD keyword data

File: ESD_TCERM.key

File name for this Report File

File: TCERM.Rpt

File name for the header data for SACVIEW

File: TCERM.hdr

File name for output detailed economic change data

File: ECHG_Det.csv

File name for output economic change summary statistics

File: ECHG_Sta.csv

File name for optional output detailed trigger data

File: TRIG_Det.csv

File name for optional output trigger summary statistics data

File: TRIG_Sta.csv

File name for optional output detailed economic change data

File: EFF_Det.csv

File name for optional output effects summary statistics data

File: EFF_Sta.csv

File Name for Media Concentrations for analyte with ID="CrVI"

File: \Projects\sac\tcerm\rev 1\test\CON_CrVI.DAT

File Name for Media Concentrations for analyte with ID="H3"

File: \Projects\sac\tcerm\rev 1\test\CON_H3.DAT

File Name for Media Concentrations for analyte with ID="I129"

File: \Projects\sac\tcerm\rev 1\test\CON_I129.DAT

Seed for random number generator = 445512.0

Debug Flag Information

No : Analyte concentration Data

No : Recreational computations

No : Agricultural computations

No : Trigger computations

Yes : Effects computations

No : Economic change computations

No : Stochastic variable definitions

No : Stochastic variable statistics

Analyte Information based on 5 possible analytes.

1	:	CCl4	:	==>	Not used
2	:	CrVI	:		Hexavalent Chromium
3	:	Cs137	:	==>	Not used
4	:	H3	:		Tritium
5	:	I129	:		Iodine 129

A total of 3 analytes have been requested.

Location Information

Index	:	ID	:	Location description
-------	---	----	---	----------------------

-----	:	-----	:	-----
1	:	ECON01	:	Richland region
2	:	ECON02	:	Kennewick region
3	:	ECON03	:	Pasco region
4	:	ECON04	:	Snake to McNary region

A total of 4 locations have been requested.

Agricultural Products

Index	:	ID	:	Product name
-------	---	----	---	--------------

-----	:	-----	:	-----
1	:	SPRWHT	:	Spring wheat
...	:		:	
31	:	SHPPRO	:	Sheep, lambs and wool

Recreational Activities

Index	:	ID	:	Activity name
-------	---	----	---	---------------

-----	:	-----	:	-----
1	:	FISHNG	:	Fishing
2	:	HUNTWF	:	Waterfowl hunting
3	:	HUNTUP	:	Upland game hunting
4	:	BOATNG	:	Boating
5	:	SWIMNG	:	Swimming
6	:	SKIING	:	Water skiing

Industry Definitions

Index	:	ID	:	Industry definition
-------	---	----	---	---------------------

-----	:	-----	:	-----
1	:	AGCRPS	:	AGG 1 AG CROPS
...	:		:	
62	:	GOVERN	:	AGG 90 GOVERNMENT

Sector Definitions

Index	:	ID	:	Sector definition
-------	---	----	---	-------------------

-----	:	-----	:	-----
1	:	AGRICU	:	Ag, Forestry, Fishery
...	:		:	
36	:	GOVERN	:	Government

Game Species

Index	:	ID	:	Species name
-------	---	----	---	--------------

-----	:	-----	:	-----
1	:	SALMAD	:	Salmon (adults)
...	:		:	
10	:	CQUAIU	:	California quail (Upland)

Time Slices Requested: (Index, Calendar Year) based on 30 possible times.

Index	:	Year	:	Use description
-------	---	------	---	-----------------

-----	:	-----	:	-----
1	:	1950	:	Included in this scenario
...	:		:	
30	:	12050	:	Included in this scenario

A total of 6 times have been requested.

```
===== End of the Problem Definition =====  
Ending Problem Execution  
  
Date: 05/28/2003  
Time: 16:12:29.867  
  
Message originating in routine TCERM  
Message: Normal Termination
```

6.3.2.2 TCERM SACView Header File

The SACView header file is an output file containing information used by the interactive SACView program to allow easy extraction of subsets of the results computed by the TCERM code. This file is generated by every run of the TCERM code. Table 6.3 provides an example of this file. The file contains the following sections of information:

- A header section of basic run information
- Number of realizations run
- Solution times selected
- Locations used
- Agricultural products used
- Recreational activities modeled
- Economic sectors modeled
- Economic change variables
- Trigger variables
- Effects variables
- Output file names

The user only specifies the name of this file; users should not modify the file after it is generated. See the instructions in Section 1.0 regarding the use of the SACView program. Because this file has at most a few hundred entries, the file size is always much smaller than 100 KB. File names for options not selected are set to null.

Table 6.3 Example Header File from TCERM for the SACView Program

```
type: "Economic"  
title: "Test run of the TCERM Code for SAC Rev. 1 Modifications"  
user: "Paul W. Eslinger"  
name: "TCERM"  
version: "2.00.A.0"  
date: "15 Apr 2003"  
id: "20030528161226"  
envfile: "ESD_TCERM.key"  
realizations: 5  
times: 6  
1950  
...  
12050  
locations: 4  
"ECON01", "Richland region"
```

```
"ECON02","Kennewick region"
"ECON03","Pasco region"
"ECON04","Snake to McNary region"
agprods: 31
"SPRWHT","Spring wheat"
...
"SHPPRO","Sheep, lambs and wool"
recacts: 6
"FISHNG","Fishing"
"HUNTWF","Waterfowl hunting"
"HUNTUP","Upland game hunting"
"BOATNG","Boating"
"SWIMNG","Swimming"
"SKIING","Water skiing"
sectors: 36
"AGRICU","Ag, Forestry, Fishery"
...
"GOVERN","Government"
echgvars: 3
"OUTPUT","Output in $"
"WAGES","Wages per $ of output"
"EMPLOY","Employment per $M of output"
trgvars: 6
"RRREC_FRAC","Regulatory reduction in recreational activity"
"VAREC_FRAC","Voluntary avoidance of recreational activity"
"RRAG_FRAC","Regulatory reduction in agricultural activity"
"VAAG_FRAC","Voluntary avoidance of agricultural products"
"FILTCOST","Cost to filter and use the present drining water supply"
"REPLCOST","Cost to replace the present drining water source"
effvars: 7
"DAYVAL","Value of a day of participation in a recreational activity"
"PERSONTRIP","Number of day trips per person participating in a
    recreational activity"
"TOTVAL","Total value of a recreational activity"
"PRODCHG","Change in production of an agricultural product"
"PRODSURPCHG","Producer surplus of an agricultural product"
"COSTCHG","Change in cost of an agricultural product"
"REVCHG","Change in revenue from an agricultural product"
echgsum: "ECHG_Sta.csv"
echgdet: "ECHG_Det.csv"
trigsum: "TRIG_Sta.csv"
trigdet: "TRIG_Det.csv"
effsum: "EFF_Sta.csv"
effdet: "EFF_Det.csv"
```

6.3.2.3 TCERM Stochastic Values File

The stochastic values file is an optional output file that contains the values for every stochastic variable generated in the TCERM code. The description of the STOCHAST modifier on the FILE keyword (see

Section 6.4.10) explains how to activate writing this file. The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file consists of the ID of the stochastic variable followed by a value for every generated realization. Table 6.4 provides a subset of the data written to this file for a run using one realization. Because this file has at most a few hundred entries, the file size is always smaller than 100 KB. For this example case, there were 2 analytes, 4 locations, 31 agricultural products, and 62 industries in 36 sectors. The resulting output file contained 513 stochastic variables.

Table 6.4 Excerpted Records from the TCERM Stochastic Values File

"SPRWHTPRICE",	4.39686E+00
"WINWHTPRICE",	4.11085E+00
"BARLEYPRICE",	2.63601E+00
"OATS PRICE",	1.38742E+00
"CORNGRPRICE",	3.15596E+00
"CORN SIPPRICE",	2.78145E+01
...	
"SPRWHTVAAG_S1",	5.15985E-02
"WINWHTVAAG_S1",	6.94639E-02
"BARLEYVAAG_S1",	9.13993E-02
"OATS VAAG_S1",	8.53741E-02
"CORNGRVAAG_S1",	5.36837E-02
...	
"GRPWINVAAG_S2",	3.00518E-01
"MILK VAAG_S2",	3.85969E-01
"BEEF VAAG_S2",	4.65310E-01
"HOGPIGVAAG_S2",	6.64737E-01
"SHPPROVAAG_S2",	4.65067E-01
"EN001 SPRWHTTTPROD",	0.00000E+00
"EN001 WINWHTTTPROD",	1.06814E+05

6.3.2.4 TCERM Trigger Detailed Data File

The trigger detailed data file is an optional output file that contains the detailed values for economic trigger calculations in the TCERM code. Output to this file is activated by entering the TRIGGER modifier on the DETAILS keyword (see Section 6.4.6). The file name for this file is entered using the TRIGGERD modifier on the FILE keyword (see Section 6.4.10). The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. After the one-line header, each line of the file consists of four identifiers followed by a value for every generated realization. Table 6.5 provides a subset of the data written to this file for a run using one realization. The following are the four identifiers:

- Time: Year for which the data are valid
- Location ID: The location identifier where the data are valid
- Solution Category: The identification of the solution category for which data were computed
- Solution Type: The identification of the solution type for which data were computed

Table 6.5 Excerpted Records from the TCERM Trigger Detailed Data File

"Time", "Location ID", "Solution Category", "Solution Type", "Values by realization"
1950, "ECON01", "FISHNG", "RRREC_FRAC", 6.67E-01, 7.98E-01, 7.33E-01, 7.89E-01
1950, "ECON01", "FISHNG", "VAREC_FRAC", 3.17E-01, 3.74E-01, 3.01E-01, 4.33E-01
1950, "ECON01", "HUNTWF", "RRREC_FRAC", 6.67E-01, 7.98E-01, 7.33E-01, 7.89E-01
1950, "ECON01", "HUNTWF", "VAREC_FRAC", 3.17E-01, 3.74E-01, 3.01E-01, 4.33E-01
1950, "ECON01", "HUNTUP", "RRREC_FRAC", 6.67E-01, 7.98E-01, 7.33E-01, 7.89E-01
1950, "ECON01", "HUNTUP", "VAREC_FRAC", 3.17E-01, 3.74E-01, 3.01E-01, 4.33E-01
1950, "ECON01", "BOATNG", "RRREC_FRAC", 6.67E-01, 7.98E-01, 7.33E-01, 7.89E-01
1950, "ECON01", "BOATNG", "VAREC_FRAC", 3.17E-01, 3.74E-01, 3.01E-01, 4.33E-01
1950, "ECON01", "SWIMNG", "RRREC_FRAC", 6.67E-01, 7.98E-01, 7.33E-01, 7.89E-01
1950, "ECON01", "SWIMNG", "VAREC_FRAC", 3.17E-01, 3.74E-01, 3.01E-01, 4.33E-01
1950, "ECON01", "SKIING", "RRREC_FRAC", 6.67E-01, 7.98E-01, 7.33E-01, 7.89E-01
1950, "ECON01", "SKIING", "VAREC_FRAC", 3.17E-01, 3.74E-01, 3.01E-01, 4.33E-01
1950, "ECON01", "SPRWHT", "RRAG_FRAC", 0.00E+00, 0.00E+00, 0.00E+00, 0.00E+00
1950, "ECON01", "SPRWHT", "VAAG_FRAC", 2.74E-01, 3.72E-01, 5.35E-01, 6.01E-01

This file can have several rows of information for every combination of time, location, and crop. For a typical run, this file is several thousand lines long.

6.3.2.5 TCERM Trigger Summary Statistics File

This optional file contains summary statistics for the detailed economic trigger data generated in the TCERM code. Output to this file is activated by entering the TRIGGER modifier on the STATISTICS keyword (see Section 6.4.33). The file name for this file is entered using the TRIGGERS modifier on the FILE keyword (see Section 6.4.10). The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file consists of four identifiers followed by summary statistics (nine percentiles, mean value, and standard deviation). Table 6.6 provides a subset of the data written to this file for a run using five realizations. The following are the four identifiers on each line:

- Time: Year for which the data are valid
- Location ID: The location identifier where the data are valid
- Solution Category: The identification of the solution category for which data were computed
- Solution Type: The identification of the solution type for which data were computed.

The data for each record in this file are too long to present without line-wrapping in this document. Each record in the file occupies two lines in Table 6.6.

Table 6.6 Excerpted Records from the TCERM Trigger Summary Statistics File

"Time", "Location ID", "Solution Category", "Solution Type", "Minimum", "5th Percentile", "10th Percentile", "25th Percentile", "Median", "75th Percentile", "90th Percentile", "95th Percentile", "Maximum", "Mean", "Standard Deviation"
2000, "EN001 ", "FISHNG", "RRREC_FRAC", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000, "EN001 ", "FISHNG", "VAREC_FRAC", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000, "EN001 ", "BOATNG", "RRREC_FRAC", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000, "EN001 ", "SPRWHT", "VAAG_FRAC", 5.95562E-01, 5.95562E-01, 5.95562E-01, 5.95562E-01, 5.95562E-01, 5.95562E-01, 5.95562E-01, 5.95562E-01, 5.95562E-01, 5.95562E-01, 5.95562E-01, 5.95562E-01, 0.00000E+00

```
2000,"EN001 ","WINWHT","RRAG_FRAC", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00,
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"EN001 ","WINWHT","VAAG_FRAC", 5.67366E-01, 5.67366E-01, 5.67366E-01, 5.67366E-01, 5.67366E-
01, 5.67366E-01, 5.67366E-01, 5.67366E-01, 5.67366E-01, 5.67366E-01, 0.00000E+00
2000,"EN001 ","BARLEY","RRAG_FRAC", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00,
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"EN001 ","BARLEY","VAAG_FRAC", 5.77696E-01, 5.77696E-01, 5.77696E-01, 5.77696E-01, 5.77696E-
01, 5.77696E-01, 5.77696E-01, 5.77696E-01, 5.77696E-01, 5.77696E-01, 0.00000E+00
2000,"EN001 ","OATS ","RRAG_FRAC", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00,
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
```

This file can have several rows of information for every combination of time, location, and crop. For a typical run, this file is several thousand lines long.

6.3.2.6 TCERM Economic Effects Detailed Data File

The economic effects detailed data file is an optional output file that contains the detailed values for economic effect calculations in the TCERM code. Output to this file is activated by entering the EFFECTS modifier on the DETAILS keyword (see Section 6.4.6). The file name for this file is entered using the EFFECTS modifier on the FILE keyword (see Section 6.4.10). The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. After the one-line header, each line of the file consists of four identifiers followed by a value for every generated realization. Table 6.7 provides a subset of the data written to this file for a run using one realization. The four identifiers are the following:

- Time: Year for which the data are valid
- Location ID: The location identifier where the data are valid
- Solution Category: The identification of the solution category for which data were computed
- Solution Type: The identification of the solution type for which data were computed.

Table 6.7 Excerpted Records from the TCERM Economic Effects Detailed Data File

"Time"	"Location ID"	"Solution Category"	"Solution Type"	"Values by realization"
1950	"ECON01"	"FISHNG"	"DAYVAL"	3.67790E+01, 3.67790E+01, 3.67790E+01
1950	"ECON01"	"FISHNG"	"PERSONTRIP"	1.52501E+00, 1.52501E+00, 1.52501E+00
1950	"ECON01"	"FISHNG"	"TOTVAL"	2.10892E+06, 2.10892E+06, 2.10892E+06
1950	"ECON01"	"FISHNG"	"RECEXPENDCHG"	-1.47740E+06, -1.76768E+06, -1.62302E+06
1950	"ECON01"	"HUNTWF"	"DAYVAL"	3.67790E+01, 3.67790E+01, 3.67790E+01
1950	"ECON01"	"HUNTWF"	"PERSONTRIP"	1.52501E+00, 1.52501E+00, 1.52501E+00
1950	"ECON01"	"HUNTWF"	"TOTVAL"	0.00000E+00, 0.00000E+00, 0.00000E+00
1950	"ECON01"	"HUNTWF"	"RECEXPENDCHG"	0.00000E+00, 0.00000E+00, 0.00000E+00
1950	"ECON01"	"HUNTUP"	"DAYVAL"	3.67790E+01, 3.67790E+01, 3.67790E+01
1950	"ECON01"	"HUNTUP"	"PERSONTRIP"	1.52501E+00, 1.52501E+00, 1.52501E+00
1950	"ECON01"	"HUNTUP"	"TOTVAL"	0.00000E+00, 0.00000E+00, 0.00000E+00
1950	"ECON01"	"HUNTUP"	"RECEXPENDCHG"	0.00000E+00, 0.00000E+00, 0.00000E+00
1950	"ECON01"	"BOATNG"	"DAYVAL"	1.47300E+01, 1.47300E+01, 1.47300E+01
1950	"ECON01"	"BOATNG"	"PERSONTRIP"	1.52501E+00, 1.52501E+00, 1.52501E+00
1950	"ECON01"	"BOATNG"	"TOTVAL"	2.47097E+04, 2.47097E+04, 2.47097E+04
1950	"ECON01"	"BOATNG"	"RECEXPENDCHG"	-1.64937E+04, -1.97343E+04, -1.81194E+04
1950	"ECON01"	"SWIMNG"	"DAYVAL"	6.60000E+00, 6.60000E+00, 6.60000E+00
1950	"ECON01"	"SWIMNG"	"PERSONTRIP"	1.52501E+00, 1.52501E+00, 1.52501E+00

```
1950,"ECON01","SWIMNG","TOTVAL", 0.00000E+00, 0.00000E+00, 0.00000E+00
1950,"ECON01","SWIMNG","RECEXPENDCHG", 0.00000E+00, 0.00000E+00, 0.00000E+00
1950,"ECON01","SKIING","DAYVAL", 2.13300E+01, 2.13300E+01, 2.13300E+01
1950,"ECON01","SKIING","PERSONTRIP", 1.52501E+00, 1.52501E+00, 1.52501E+00
1950,"ECON01","SKIING","TOTVAL", 0.00000E+00, 0.00000E+00, 0.00000E+00
1950,"ECON01","SKIING","RECEXPENDCHG", 0.00000E+00, 0.00000E+00, 0.00000E+00
1950,"ECON01","SPRWHT","PRODCHG", 0.00000E+00, 0.00000E+00, 0.00000E+00
1950,"ECON01","SPRWHT","PRODSURPCHG", 0.00000E+00, 0.00000E+00, 0.00000E+00
1950,"ECON01","SPRWHT","COSTCHG", 0.00000E+00, 0.00000E+00, 0.00000E+00
1950,"ECON01","SPRWHT","REVCHG", 0.00000E+00, 0.00000E+00, 0.00000E+00
```

This file can have several rows of information for every combination of time, location, and crop. For a typical run, this file is several thousand lines long.

6.3.2.7 TCERM Economic Effects Summary Statistics File

This optional file contains summary statistics for the detailed economic effects data generated in the TCERM code. Output to this file is activated by entering the EFFECTS modifier on the STATISTICS keyword (see Section 6.4.33). The file name for this file is entered using the EFFECTS modifier on the FILE keyword (see Section 6.4.10). The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file consists of four identifiers followed by summary statistics (nine percentiles, mean value, and standard deviation). Table 6.8 provides a subset of the data written to this file for a run using five realizations. The following are the four identifiers on each line:

- Time: Year for which the data are valid
- Location ID: The location identifier where the data are valid
- Solution Category: The identification of the solution category for which data were computed
- Solution Type: The identification of the solution type for which data were computed.

The data for each record in this file are too long to present without line-wrapping in this document. Each record in the file occupies two lines in Table 6.8.

Table 6.8 Excerpted Records from the TCERM Economic Effects Summary Statistics File

```
"Time","Location ID","Solution Category","Solution Type","Minimum","5th Percentile","10th
Percentile","25th Percentile","Median","75th Percentile","90th Percentile","95th
Percentile","Maximum","Mean","Standard Deviation"
2000,"EN001 ","FISHNG","DAYVAL", 6.49410E+01, 6.49410E+01, 6.49410E+01, 6.49410E+01, 6.49410E+01,
6.49410E+01, 6.49410E+01, 6.49410E+01, 6.49410E+01, 6.49410E+01, 0.00000E+00
2000,"EN001 ","FISHNG","PERSONTRIP", 1.16078E+01, 1.16078E+01, 1.16078E+01, 1.16078E+01, 1.16078E+01,
1.16078E+01, 1.16078E+01, 1.16078E+01, 1.16078E+01, 1.16078E+01, 0.00000E+00
2000,"EN001 ","FISHNG","TOTVAL", 2.83437E+07, 2.83437E+07, 2.83437E+07, 2.83437E+07, 2.83437E+07,
2.83437E+07, 2.83437E+07, 2.83437E+07, 2.83437E+07, 2.83437E+07, 0.00000E+00
2000,"EN001 ","BOATNG","DAYVAL", 2.61350E+01, 2.61350E+01, 2.61350E+01, 2.61350E+01, 2.61350E+01,
2.61350E+01, 2.61350E+01, 2.61350E+01, 2.61350E+01, 2.61350E+01, 0.00000E+00
2000,"EN001 ","BOATNG","PERSONTRIP", 9.19832E+00, 9.19832E+00, 9.19832E+00, 9.19832E+00, 9.19832E+00,
9.19832E+00, 9.19832E+00, 9.19832E+00, 9.19832E+00, 9.19832E+00, 0.00000E+00
2000,"EN001 ","BOATNG","TOTVAL", 2.64438E+05, 2.64438E+05, 2.64438E+05, 2.64438E+05, 2.64438E+05,
2.64438E+05, 2.64438E+05, 2.64438E+05, 2.64438E+05, 2.64438E+05, 0.00000E+00
2000,"EN001 ","SWIMNG","DAYVAL", 2.61350E+01, 2.61350E+01, 2.61350E+01, 2.61350E+01, 2.61350E+01,
2.61350E+01, 2.61350E+01, 2.61350E+01, 2.61350E+01, 2.61350E+01, 0.00000E+00
```

This file can have several rows of information for every combination of time, location, and crop. For a typical run, this file is several thousand lines long.

6.3.2.8 TCERM Economic Change Detailed Data File

The economic change detailed data file is a required output file that contains the detailed values for economic change calculations in the TCERM code. The file name for this file is entered using the ECONCHGD modifier on the FILE keyword (see Section 6.4.10). The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. After the one-line header, each line of the file consists of four identifiers followed by a value for every generated realization. Table 6.9 provides a subset of the data written to this file for a run using one realization. The following are the four identifiers:

- Time: Year for which the data are valid
- Location ID: The location identifier where the data are valid
- Solution Category: The identification of the solution category for which data were computed
- Solution Type: The identification of the solution type for which data were computed

Table 6.9 Excerpted Records from the TCERM Economic Change Detailed Data File

"Time",	"Location ID",	"Solution Category",	"Solution Type",	"Values by realization"
2000,"EN001 "	"AGRICU"	"OUTPUT"		-3.44122E+03
2000,"EN001 "	"AGRICU"	"WAGES"		-6.88939E+02
2000,"EN001 "	"AGRICU"	"EMPLOY"		-4.55252E-02
2000,"EN001 "	"AGSVCS"	"OUTPUT"		-8.75477E+02
2000,"EN001 "	"AGSVCS"	"WAGES"		-3.81511E+02
2000,"EN001 "	"AGSVCS"	"EMPLOY"		-4.00955E-02
2000,"EN001 "	"MINING"	"OUTPUT"		-8.76162E+00
2000,"EN001 "	"MINING"	"WAGES"		-3.32251E+00
2000,"EN001 "	"MINING"	"EMPLOY"		-9.04338E-05
2000,"EN001 "	"CONSTR"	"OUTPUT"		-2.85485E+03
2000,"EN001 "	"CONSTR"	"WAGES"		-1.21060E+03
2000,"EN001 "	"CONSTR"	"EMPLOY"		-3.65421E-02
2000,"EN001 "	"FODPRO"	"OUTPUT"		-1.79937E+04
2000,"EN001 "	"FODPRO"	"WAGES"		-3.01344E+03
2000,"EN001 "	"FODPRO"	"EMPLOY"		-8.27248E-02
2000,"EN001 "	"PRIPUB"	"OUTPUT"		-1.96714E+03
2000,"EN001 "	"PRIPUB"	"WAGES"		-6.47606E+02
2000,"EN001 "	"PRIPUB"	"EMPLOY"		-2.67759E-02
2000,"EN001 "	"CHEMIC"	"OUTPUT"		-5.18538E+03
2000,"EN001 "	"CHEMIC"	"WAGES"		-9.20565E+02
2000,"EN001 "	"CHEMIC"	"EMPLOY"		-1.54273E-02

This file can have several rows of information for every combination of time, location, and crop. For a typical run, this file will be several thousand lines long.

6.3.2.9 TCERM Economic Change Summary Statistics File

The economic change summary statistics file is a required output file that contains the detailed values for economic change calculations in the TCERM code. The file name for this file is entered using the ECONCHGS modifier on the FILE keyword (see Section 6.4.10). The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file consists of four identifiers followed by summary statistics (nine percentiles, mean value, and standard deviation). Table 6.10 provides a subset of the data written to this file for a run using five realizations. The four identifiers on each line are the following:

- Time: Year for which the data are valid
- Location ID: The location identifier where the data are valid
- Solution Category: The identification of the solution category for which data were computed
- Solution Type: The identification of the solution type for which data were computed.

The data for each record in this file are too long to present without line wrapping in this document. Each record in the file occupies two lines in Table 6.10.

Table 6.10 Excerpted Records from the TCERM Economic Change Summary Statistics File

"Time", "Location ID", "Solution Category", "Solution Type", "Minimum", "5th Percentile", "10th Percentile",										
"25th Percentile", "Median", "75th Percentile", "90th Percentile", "95th Percentile", "Maximum", "Mean", "Standard Deviation"										
2000, "EN001 "	"AGRICU",	"OUTPUT",	-3.44122E+03,	-3.44122E+03,	-3.44122E+03,	-3.44122E+03,	-3.44122E+03,	-3.44122E+03,	-3.44122E+03,	0.00000E+00
2000, "EN001 "	"AGRICU",	"WAGES",	-6.88939E+02,	-6.88939E+02,	-6.88939E+02,	-6.88939E+02,	-6.88939E+02,	-6.88939E+02,	-6.88939E+02,	0.00000E+00
2000, "EN001 "	"AGRICU",	"EMPLOY",	-4.55252E-02,	-4.55252E-02,	-4.55252E-02,	-4.55252E-02,	-4.55252E-02,	-4.55252E-02,	-4.55252E-02,	0.00000E+00
2000, "EN001 "	"AGSVCS",	"OUTPUT",	-8.75477E+02,	-8.75477E+02,	-8.75477E+02,	-8.75477E+02,	-8.75477E+02,	-8.75477E+02,	-8.75477E+02,	0.00000E+00
2000, "EN001 "	"AGSVCS",	"WAGES",	-3.81511E+02,	-3.81511E+02,	-3.81511E+02,	-3.81511E+02,	-3.81511E+02,	-3.81511E+02,	-3.81511E+02,	0.00000E+00
2000, "EN001 "	"AGSVCS",	"EMPLOY",	-4.00955E-02,	-4.00955E-02,	-4.00955E-02,	-4.00955E-02,	-4.00955E-02,	-4.00955E-02,	-4.00955E-02,	0.00000E+00
2000, "EN001 "	"MINING",	"OUTPUT",	-8.76162E+00,	-8.76162E+00,	-8.76162E+00,	-8.76162E+00,	-8.76162E+00,	-8.76162E+00,	-8.76162E+00,	0.00000E+00
2000, "EN001 "	"MINING",	"WAGES",	-3.32251E+00,	-3.32251E+00,	-3.32251E+00,	-3.32251E+00,	-3.32251E+00,	-3.32251E+00,	-3.32251E+00,	0.00000E+00
2000, "EN001 "	"MINING",	"EMPLOY",	-9.04338E-05,	-9.04338E-05,	-9.04338E-05,	-9.04338E-05,	-9.04338E-05,	-9.04338E-05,	-9.04338E-05,	0.00000E+00
2000, "EN001 "	"CONSTR",	"OUTPUT",	-2.85485E+03,	-2.85485E+03,	-2.85485E+03,	-2.85485E+03,	-2.85485E+03,	-2.85485E+03,	-2.85485E+03,	0.00000E+00
2000, "EN001 "	"CONSTR",	"WAGES",	-1.21060E+03,	-1.21060E+03,	-1.21060E+03,	-1.21060E+03,	-1.21060E+03,	-1.21060E+03,	-1.21060E+03,	0.00000E+00

This file can have several rows of information for every combination of time, location, and crop. For a typical run, this file will be several thousand lines long.

6.4 Keyword Descriptions for the TCERM Code

In the following descriptions, some data are optional and some are required. Data required are enclosed in square brackets. For AB to be required, it would be denoted by [AB]. If only one of the three items

AB, BC, CD were required, it would be written as [AB|BC|CD]. The vertical bars indicate to choose one of the items in the list. Optional items are enclosed in normal brackets. For DE to be an optional entry, it would be denoted by {DE}. The {} or [] symbols are indicators of whether the data are required; they are not actually entered when the keyword record is constructed.

In general, the order in which keywords are entered does not matter. However, the REPORT keyword must be the first keyword in the file and the END keyword must be the last keyword in the file.

6.4.1 AGLABOR Keyword for the TCERM Code

The AGLABOR keyword is used to determine the percentage of agricultural value generated that is labor cost. The following is this keyword's syntax:

```
AGLABOR value
```

The first value is the percentage of agricultural value that is labor. The following is an example of the AGLABOR keyword record:

```
AGLABOR 0.55
```

6.4.2 AGPARAM Keyword for the TCERM Code

The AGPARAM keyword is used to provide the lowest price for an agricultural product at a location. It is assumed that if the price drops below this price, then no product will be produced. The following is this keyword's syntax:

```
AGPARAM AGPROD="quote1" LOCATION="quote2" LOWPRICE=value
```

The first quote string contains an agricultural product ID. The second quote string contains a location ID. The lowest supply price for the product and location provided follows the LOWPRICE modifier on the AGPARAM keyword card. The following is an example of the AGPARAM keyword record:

```
AGPARAM AGPROD="SPRWHT" LOCATION="EN001" LOWPRICE=2.83
```

6.4.3 AGPROD Keyword for the TCERM Code

The AGPROD keyword is used to associate each agricultural product with a food species ID in the FCDA file and to indicate the whether the product is a farm, field, or orchard product. The following is this keyword's syntax:

```
AGPROD ID="quote1" NAME="quote2" SPECIES="quote3" [FARM | FIELD | ORCHARD]  
{OUTPUT}
```

The first quote string contains an agricultural product ID. The second quote string contains a product name. The third quote is a species ID as modeled in ECEM. The modifier OUTPUT is included if information for this agricultural product should be written to the output files. The following is an example of the AGPROD keyword record:

```
AGPROD ID="SHPPRO" NAME="Sheep, lambs, wool" SPECIES="SHEEP" FARM OUTPUT
```

6.4.4 ANALYTE Keyword for the TCERM Code

The ANALYTE keyword is used to define the analytes to be used in calculating economic risk metrics. The following is this keyword's syntax:

```
ANALYTE ["quote 1"] {"quote " }...{"quote n" }
```

The entry for each quote string must be an analyte identification string (up to six characters in length). The analyte identification string is case sensitive, and spaces or hyphens change the definition. Care must be taken that all data follow the convention that only the first entry in the analyte name is capitalized and that no embedded spaces or hyphens are used. The analytes selected must be a subset of the set of analytes identified in the environmental scenario file. Multiple analyte keywords can be entered. The following ANALYTE keyword selects the two analytes strontium-90 and zinc for analysis:

```
ANALYTE "Zinc" "Sr90"
```

6.4.5 DEBUG Keyword for the TCERM Code

The DEBUG keyword is used to activate dumping of intermediate calculations to the report file. It should be used sparingly and with only one or two realizations; otherwise, the volume of output could fill the user's hard drive. The following is this keyword's syntax:

```
DEBUG [modifier1] {modifier2}{modifier3}
```

Multiple DEBUG records can be entered with combinations of modifiers, or a single record can be entered containing all of the modifiers. The modifiers can be entered in any order. Table 6.11 describes the modifiers associated with the DEBUG keyword:

Table 6.11 Modifiers Associated with the DEBUG Keyword in the TCERM Code

Modifier	Description
TRIGGER	Intermediate outputs on calculations for area calculations.
EFFECTS	Intermediate outputs on calculations for distance calculations on specific sites.
ECONCHG	Intermediate outputs on calculations for generating map data.
ANALYTE	Media concentration data are output to the report file.
FOOD	FCDA concentrations are output to the report file.
VERBOSE	Writes a message to the report file each time a subroutine is called.
DEFINITION	Output the definition of all stochastic variables.
STATISTICS	Output summary statistics for all generated stochastic variables.

The following entries provide examples of the use of the DEBUG keyword:

```
DEBUG TRIGGER
DEBUG EFFECTS
DEBUG TRIGGER EFFECTS ECONCHG
DEBUG ANALYTE FOOD
DEBUG DEFINITION STATISTICS
```

6.4.6 DETAILS Keyword for the TCERM Code

The DETAILS keyword is used to activate reporting of calculations of TRIGGER or EFFECTS calculations by realization to output files. Details are always written for the ECONCHG calculations. The following is this keyword's syntax:

```
DETAILS {TRIGGER} {EFFECTS}
```

Multiple DETAILS keywords can be entered with combinations of modifiers, or a single record can be entered. The following is an example that activates reporting for detailed data for both trigger and effects calculations:

```
DETAILS TRIGGER EFFECTS
```

6.4.7 DISCOUNT Keyword for the TCERM Code

The DISCOUNT keyword is used to supply the discount rate for calculation of the capital cost of drinking water source replacement in the EFFECTS subroutine. The following is this keyword's syntax:

```
DISCOUNT value1
```

The entry for the value must be a fraction between 0 and 1. The fraction represents the interest rate in a payment calculation. The following is an example of the DISCOUNT keyword record:

```
DISCOUNT 0.07
```

6.4.8 END Keyword for the TCERM Code

The END keyword signifies the end of all keyword data. It should be the last keyword in the keyword file. All data in the keyword file after the END keyword will be ignored. The following is this keyword's syntax:

```
END
```

There are no modifiers or quote strings associated with the END keyword.

6.4.9 EXECUTE Keyword for the TCERM Code

The EXECUTE keyword signifies that the user wishes to perform problem execution. If this keyword is not entered, then the inputs are checked for consistency, but the problem will not be executed. This is useful if the run being set up is expected to take a significant amount of computation time. The following is this keyword's syntax:

EXECUTE

There are no modifiers or quote strings associated with the EXECUTE keyword.

6.4.10 FILE Keyword for the TCERM Code

The FILE keyword is used to enter the names of input and output files except for the report file. The names of the files providing concentration data are contained in the environmental scenario file rather than in the keyword file. The following is this keyword's syntax:

```
FILE [modifier1 "quote1"] {modifier2 "quote2"} ... {modifierk "quotek"}
```

The file names are entered in quote strings, which must be enclosed in double quotation marks. Path names up to 200 characters long are supported. The file name associated with a modifier must be entered before the next modifier is entered. At least one FILE keyword is required for every run of the code. Table 6.12 describes the modifiers associated with the FILE keyword.

Table 6.12 Modifiers Associated with the FILE Keyword in the TCERM Code

Modifier	Description
ESD	Input environmental scenario file that contains the definition of the environmental runs from which impacts are to be calculated.
HEADER	Output file containing header type information associated with all of the other output files identified in this table.
STOCHASTIC	Output file containing the generated values for all stochastic variables used in the run. This is an optional file that is recommended to support uncertainty analyses. Entry of this modifier and the file name activates output of the data.
TRIGGERD	Output file containing the calculated data, by realization, for each of the trigger calculations. This file is required only if the TRIGGER modifier is used on the DETAILS keyword.
TRIGGERS	Output file containing summary statistics for each of the trigger calculations. This file is required only if the TRIGGER modifier is used on the STATISTICS keyword.
EFFECTSD	Output file containing the calculated data, by realization, for each of the effects calculations. This file is required only if the EFFECTS modifier is used on the DETAILS keyword.

Modifier	Description
EFFECTSS	Output file containing summary statistics for each of the effects calculations. This file is required only if the EFFECTS modifier is used on the STATISTICS keyword.
ECONCHGD	Output file containing the calculated annual change in the economy by economic sector for each realization, location, and time. This file is always required.
ECONCHGS	Output file containing summary statistics for the annual economic change by economic sector for each location and time. This file is always required.

The following is an example entry:

```
FILE  HEADER "TestCase.hdr"  EFFECTSD "TestCase.efd"
```

The following set of two entries has the same effect as the single entry above.

```
FILE  EFFECTSD "TestCase.efd"
FILE  HEADER  "TestCase.hdr"
```

6.4.11 FILTER Keyword for the TCERM Code

The FILTER keyword is used to provide the cost of filtering the water supply at a location for a given analyte. The following is this keyword's syntax:

```
FILTER LOCATION="quote1" ANALYTE="quote2"
      [PUBSW | PUBGW | PVTSW | PVTGW] value1
```

The entry for the value is the filtration cost in \$/1000 gal/day. The following is an example of the FILTER keyword record:

```
FILTER LOCATION="EN003" ANALYTE="Sr90" PUBSW=5.0
```

6.4.12 FISHQUAL Keyword for the TCERM Code

The FISHQUAL keyword is used to provide the activity quality factor for each recreational activity for each location. The following is this keyword's syntax:

```
FISHQUAL LOCATION="quote1" REACT="quote2" value
```

The first quote string contains a location ID and is limited to six characters. The second quote string provides a recreational activity ID and is limited to 6 characters. The value is an activity quality factor for the given recreational activity. The following is an example for this keyword:

```
FISHQUAL LOCATION="ECON01" REACT="SKIING" 1.0
```

6.4.13 FISHSPC Keyword for the TCERM Code

The FISHSPC keyword is used to define the species from the FCDA file to be used for recreational fishing tissue concentrations. The following is this keyword's syntax:

```
FISHSPC  ["quote 1"] {"quote " }...{"quote n" }
```

The entry for each quote string must be a species identification string (up to six characters in length). The species selected must be a subset of the set of species identified in the environmental scenario file. Multiple FISHSPC keywords can be entered. The following FISHSPC keyword selects the two species adult salmon and adult trout for analysis:

```
FISHSPC "SALMAD" "RTRTAD"
```

6.4.14 FISHWT Keyword for the TCERM Code

The FISHWT keyword is used to input the matrix that identifies the relative importance of each species to recreational fishing at each location. There are no modifiers to the FISHWT keyword. The FISHWT keyword must be followed by NUMSPC lines, each containing NUMLOC values. The order of the species must match the number and order of species input through the SPECIES keyword. The values must match the order and number of the locations supplied in the LOCATION keyword. For each location (column of values), the weights must sum to 1 (100%). The following is an example of the FISHWT keyword:

```
FISHWT
  0.4    0.3    0.2    0.3    ! SALMAD weights
  0.1    0.1    0.2    0.1    ! TROUT weights
  0.2    0.2    0.2    0.2    ! BASS weights
  0.1    0.2    0.1    0.1    ! CARP weights
  0.1    0.1    0.2    0.2    ! STURGEON weights
  0.1    0.1    0.1    0.1    ! CRAYFISH weights
```

6.4.15 FOODS Keyword for the TCERM Code

The FOODS keyword is used to identify the path for the location of the FCDA files to be used and the name of the map file associated with these FCDA files. The following is this keyword's syntax:

```
FOODS [PATH= "quote1"] [MAP= "quote2"]
```

The file names are entered in quote strings, which must be enclosed in double quotation marks. Path names up to 200 characters long are supported. The file name associated with a modifier must be entered before the next modifier is entered.

6.4.16 FOWLSPC Keyword for the TCERM Code

The FOWLSPC keyword is used to define the species from the FCDA file to be used for recreational waterfowl hunting tissue concentrations. The following is this keyword's syntax:

```
FOWLSPC  ["quote 1"] {"quote " }...{"quote n" }
```

The entry for each quote string must be a species identification string (up to six characters in length). The species selected must be a subset of the set of species identified in the environmental scenario file. Multiple FOWLSPC keywords can be entered. The following FOWLSPC keyword selects the two species California quail and Canadian goose for analysis:

```
FOWLSPC "CQUAIL" "CANGOS"
```

6.4.17 FOWLWT Keyword for the TCERM Code

The FOWLWT keyword is used to input the matrix that identifies the relative importance of each species to recreational waterfowl hunting at each location. There are no modifiers to the FOWLWT keyword. The FOWLWT keyword must be followed by NUMSPC lines, each containing NUMLOC values. The order of the species must match the number and order of species input through the SPECIES keyword. The values must match the order and number of the locations supplied in the LOCATION keyword. For each location (column of values), the weights must sum to 1 (100%). The following is an example of the FOWLWT keyword:

```
FOWLWT
0.7    0.8    0.6    0.4    ! QUAIL
0.3    0.2    0.4    0.6    ! GOOSE
```

6.4.18 GAMESPC Keyword for the TCERM Code

The GAMESPC keyword is used to define the species from the FCDA file to be used for recreational upland hunting tissue concentrations. The following is this keyword's syntax:

```
GAMESPC  ["quote 1"] {"quote " }...{"quote n" }
```

The entry for each quote string must be a species identification string (up to six characters in length). The species selected must be a subset of the set of species identified in the environmental scenario file. Multiple GAMESPC keywords can be entered. The following GAMESPC keyword selects the two species mule deer and California quail for analysis:

```
GAMESPC "MULDER" "CQUAIU"
```

6.4.19 GAMEWT Keyword for the TCERM Code

The GAMEWT keyword is used to input the matrix that identifies the relative importance of each species to recreational upland hunting at each location. There are no modifiers to the GAMEWT keyword. The

GAMEWT keyword must be followed by NUMSPC lines, each containing NUMLOC values. The order of the species must match the number and order of species input through the SPECIES keyword. The values must match the order and number of the locations supplied in the LOCATION keyword. For each location (column of values), the weights must sum to 1 (100%). The following is an example of the GAMEWT keyword:

```
GAMEWT
0.6   0.7   0.4   0.5   ! MULDER
0.4   0.3   0.6   0.5   ! CQUAIU
```

6.4.20 HOUSEVAL Keyword for the TCERM Code

The HOUSEVAL keyword is used to provide the household production factor for each recreational activity for each location. The following is this keyword's syntax:

```
HOUSEVAL LOCATION="quote1" REACT="quote2" value
```

The first quote string contains a location ID and is limited to six characters. The second quote string provides a recreational activity ID and is limited to 6 characters. The value is a household production factor for the given recreational activity. The following is an example for this keyword:

```
HOUSEVAL LOCATION="ECON01" REACT="HUNTUP" 1.0
```

6.4.21 INDOBS Keyword for the TCERM Code

The INDOBS keyword is used to provide the individual observation factor for each recreational activity for each location. The following is this keyword's syntax:

```
INDOBS LOCATION="quote1" REACT="quote2" value
```

The first quote string contains a location ID and is limited to six characters. The second quote string provides a recreational activity ID and is limited to 6 characters. The value is an individual observation factor for the given recreational activity. The following is an example for this keyword:

```
INDOBS LOCATION="ECON04" REACT="FISHNG" 1.0
```

6.4.22 INDUSTRY Keyword for the TCERM Code

The INDUSTRY keyword is used to define the local industries. The following is this keyword's syntax:

```
INDUSTRY ID="quote1" NAME="quote2" SECTOR="quote3"
AGBASELINE=value1 RECBASELINE=value2 value3 value4 value5 value6 value7
{OUTPUT}
```

The first quote string contains an industry ID. The second quote string contains a short description of the industry. The first value is the baseline agricultural value for the industry. The second through seventh values are the baseline recreational values for the industry. One value is provided for each of the six

recreational activities, in the order in which they are supplied on the RECACT keyword card. The third quote string contains the sector ID identifying the sector to which this industry aggregates. The following is an example of the INDUSTRY keyword record:

```
INDUSTRY ID="FODSTR" NAME="Food Stores" SECTOR="FODSTO" AGBASELINE=52.349
RECBASELINE=15.573 15.573 15.573 14.381 0.0 14.381 OUTPUT
```

6.4.23 IRRFRACG Keyword for the TCERM Code

The IRRFRACG keyword is used to input the matrix that identifies the percentage of water supplied through irrigation for each agricultural product at each location. There are no modifiers to the IRRFRACG keyword. The IRRFRACG keyword must be followed by NUMAGP lines, each containing NUMLOC values. The order of the agricultural products must match the number and order of agricultural products input through the AGPROD keyword. The values must match the order and number of the locations supplied in the LOCATION keyword. The following is an example of the IRRFRACG keyword:

```
IRRFRACG
0.4    0.3    0.2    0.3    ! SPRWHT
0.1    0.1    0.2    0.1    ! WINWHT
0.2    0.2    0.2    0.2    ! ALFSED
0.1    0.2    0.1    0.1    ! ASPARA
0.1    0.1    0.2    0.2    ! SWTCHR
0.1    0.1    0.1    0.1    ! APPLES
```

6.4.24 IRRFRACS Keyword for the TCERM Code

The IRRFRACS keyword is used to input the matrix that identifies the percentage of water supplied through irrigation for each agricultural product at each location. There are no modifiers to the IRRFRACS keyword. The IRRFRACS keyword must be followed by NUMAGP lines, each containing NUMLOC values. The order of the agricultural products must match the number and order of agricultural products input through the AGPROD keyword. The values must match the order and number of the locations supplied in the LOCATION keyword. The following is an example of the IRRFRACS keyword:

```
IRRFRACS
0.4    0.3    0.2    0.3    ! SPRWHT
0.1    0.1    0.2    0.1    ! WINWHT
0.2    0.2    0.2    0.2    ! ALFSED
0.1    0.2    0.1    0.1    ! ASPARA
0.1    0.1    0.2    0.2    ! SWTCHR
0.1    0.1    0.1    0.1    ! APPLES
```

6.4.25 LOCATION Keyword for the TCERM Code

The LOCATION keyword is used to define the nodes to be used in calculating economic risk metrics. One LOCATION record must be entered for each node to be assessed. The following is this keyword's syntax:

```
LOCATION [ID="quote1"] [NAME="quote2"]
      SWDW="quote3" SWCON="quote4" SWIRR="quote6"
      GWDW="quote5" GWIRR="quote6"
      FISH="quote7" FOWL="quote8" GAME="quote9"
      FARM="quote10" FIELD="quote11" ORCHARD="quote12"
      SWFLOW_PUB=value1 GWFLOW_PUB=value2
      SWFLOW_PVT=value3 GWFLOW_PVT=value4
      SWCOST_PUB=value5 GWCOST_PUB=value6
      SWCOST_PVT=value7 GWCOST_PVT=value8
      DWSOURCE=[PUBSW | PUBGW | PVTSW | PVTGW] {OUTPUT}
```

The locations selected must be a subset of the set of locations identified in the environmental scenario file. Table 6.13 describes the modifiers associated with the LOCATION keyword.

Table 6.13 Modifiers Associated with the LOCATION Keyword in the TCERM Code

Modifier	Description
ID	The location identification string is entered using the ID modifier. This string is limited to 6 characters and must be unique. It is used to associate other data with a specific location.
NAME	A descriptive name for this location is entered using the NAME modifier. This quote string is limited to 72 characters. It is used only for output labeling purposes.
SWDW	The quote string (location ID) associated with SWDW modifier indicates the location from which surface drinking water concentrations will be taken.
SWCON	The quote string (location ID) associated with SWCON modifier indicates the location from which surface contact water concentrations will be taken.
SWIRR	The quote string (location ID) associated with SWIRR modifier indicates the location from which surface irrigation water concentrations will be taken.
GWDW	The quote string (location ID) associated with GWDW modifier indicates the location from which groundwater drinking water concentrations will be taken.
GWIRR	The quote string (location ID) associated with GWIRR modifier indicates the location from which groundwater irrigation water concentrations will be taken.
FISH	The quote string (location ID) associated with FISH modifier indicates the location from which fish concentrations for the species identified on the FISHSPC keyword will be taken.
FOWL	The quote string (location ID) associated with FOWL modifier indicates the location from which fish concentrations for the species identified on the FOWLSPC keyword will be taken.

Modifier	Description
GAME	The quote string (location ID) associated with GAME modifier indicates the location from which fish concentrations for the species identified on the GAMESPC keyword will be taken.
FARM	The quote string (location ID) associated with FARM modifier indicates the location from which farm agricultural product concentrations will be taken.
FIELD	The quote string (location ID) associated with FIELD modifier indicates the location from which field agricultural product concentrations will be taken.
ORCHARD	The quote string (location ID) associated with ORCHARD modifier indicates the location from which orchard agricultural product concentrations will be taken.
DWSOURCE	One of the modifiers PUBSW, PVTSW, PUBGW, PVTGW is used to indicate whether the drinking water at this location is surface water or groundwater and whether it's from a public or private source.
SWFLWPUB	The flow rate (1000 gal/day) for a public surface water supply.
GWFLWPUB	The flow rate (1000 gal/day) for a public groundwater supply.
SWFLWPVT	The flow rate (1000 gal/day) for a private surface water supply.
GWFLWPVT	The flow rate (1000 gal/day) for a private groundwater supply.
SWCSTPUB	The replacement cost (\$/(1000 gal/day)) for a public surface water supply.
GCSTPUB	The replacement cost (\$/(1000 gal/day)) for a public groundwater supply.
SWCSTPVT	The replacement cost (\$/(1000 gal/day)) for a private surface water supply.
GCSTPVT	The replacement cost (\$/(1000 gal/day)) for a private groundwater supply.
OUTPUT	The OUTPUT modifier is necessary for data to be output for the location.

The following LOCATION keyword selects the location ECON01 and defines the associated variables:

```
LOCATION ID="ECON01" NAME="Richland region"
  SWDW="L00001" SWCON="L00001" SWIRR="L00201" GWIRR="L00801"
  FISH="L00001" FOWL="L00401" GAME="L00801"
  FIELD="L00801" FARM="L00801" ORCHARD="L00801"
  DWSOURCE="PUBSW" SWFLWPUB=18000.0 SWCSTPUB=1000.0
  GWFLWPUB=2000.0 GCSTPUB=0.0
```

6.4.26 MAKEUSE Keyword for the TCERM Code

The MAKEUSE keyword is used to input the make-use matrix required by the ECONCHG routine. There are no modifiers to the MAKEUSE keyword. The MAKEUSE keyword must be followed by NUMSCT lines, each containing NUMSCT values. These values are the make-use fractions for the

economic sectors defined by the SECTOR keyword. The values must match the order and number of the sectors supplied in the SECTOR keyword. The following is an example of the MAKEUSE keyword:

```
MAKEUSE
  0      0.6    0.05    0.05    0
  0      0      0        0        0
  0      0.5    0         0         0
  0      1.0    0         0         0
  0      0      0.05    0.05    0
```

6.4.27 PARTIC Keyword for the TCERM Code

The PARTIC keyword is used to provide the number of people participating in each recreational activity for each location. The following is this keyword's syntax:

```
PARTIC LOCATION="quote1" REACT="quote2" value
```

The first quote string contains a location ID and is limited to six characters. The second quote string provides a recreational activity ID and is limited to 6 characters. The value is a number of persons at the given location that participate in the given recreational activity. The following is an example for this keyword:

```
PARTIC LOCATION="ECON01" REACT="FISHNG" 37600.0
```

6.4.28 REALIZATION Keyword for the TCERM Code

The REALIZATION keyword defines the number of realizations to generate. The following is this keyword's syntax:

```
REALIZATION value1
```

The integer value1 has a minimum value of 1 and a maximum of the number of realizations defined in the environmental settings definition file. If the number of realizations is less than the number of realizations in the concentration data files, then only the first realizations will be used.

The following keyword record sets the number of realizations to 10:

```
REALIZAT 10
```

6.4.29 REACT Keyword for the TCERM Code

The REACT keyword is used to determine the recreational activities to be analyzed and to provide the necessary input data by activity. The following is this keyword's syntax:

```
REACT ID="quote1" NAME="quote2" SPEND=value1 PARTIC=value2
```

The first quote string contains an activity ID. The second quote string contains a short description of the activity. The values are variables used in the economic effects calculations. Descriptions of the modifiers for the REACT keyword are given in Table 6.14.

Table 6.14 Modifiers Associated with the REACT Keyword in the TCERM Code

Modifier	Description
ID	The recreational activity identification string is entered using the ID modifier. This string is limited to 6 characters and must be unique. It is used to associate other data with a specific recreational activity.
NAME	A descriptive name for this recreational activity is entered using the NAME modifier. This quote string is limited to 72 characters. It is used only for output labeling purposes.
CBASEVAL	The base value for this activity (\$/d).
SAMPCOV	Sample coverage factor (unitless)
CSITEQUAL	A regression coefficient for site quality (unitless).
CSPECACT	A regression coefficient for site quality (unitless).
CSAMPCOV	A regression coefficient for sample coverage (unitless).
CTRAVTIM	A regression coefficient for the travel time cost (unitless).
CSUBVAR	A regression coefficient for the substitution variable (unitless).
CINDOBS	A regression coefficient for individual observation (unitless).
CHOUSEVAL	A regression coefficient for household production (unitless).
CONSTANT	The base number of trips to participate in this activity (person ⁻¹).
CDIST	A regression coefficient for travel distance (unitless).
CFISH	A regression coefficient for activity quality at this site (unitless).
CSUB	A regression coefficient for substitute site (unitless).
OUTPUT	The OUTPUT modifier is necessary for data to be output for the recreational activity.

The following is an example of the REACT keyword record:

```
REACT ID="HUNTUP" NAME="Upland game hunting" CBASEVAL=33.769 SAMPCOV=1.0
CSITEQUAL=39.171 CSPECACT=-0.679 CSAMPCOV=-11.759 CTRAVTIM=-13.333
CSUBVAR=10.831 CINDOBS=17.95 CHOUSEVAL=9.499 CONSTANT=0.422 CDIST=-
1.2377 CFISH=0.317 CSUB=-0.1269 CINCOME=1.0 OUTPUT
```

6.4.30 REPORT Keyword for the TCERM Code

The REPORT keyword is used to define the name of the output report (log) file. It must be the first keyword entered in the keyword file. The following is this keyword's syntax:

```
REPORT ["quote"]
```

The name of the report file is entered in a quote string. File names up to 72 characters long are supported, and path names can be included. The following is an example REPORT keyword record:

```
REPORT "/SAC/SystemCodes/Economic/Test1.rpt"
```

6.4.31 SECTOR Keyword for the TCERM Code

The SECTOR keyword is used to provide the sector definitions for aggregating from industries in the effects calculations. The following is this keyword's syntax:

```
SECTOR ID="quote1" NAME="quote2" BASE_EMPLOY=value2 BASE_WAGES=value3  
{OUTPUT}
```

Each economic sector is defined by entering a SECTOR keyword. The first quote string contains an identifying label for the sector and is limited to six characters. The second quote string provides a brief sector description and is limited to 72 characters. The list of sectors listed on SECTOR keyword records must exactly match the list, in order, of sectors listed in the sector make-use file. Sector data are provided through the use of modifiers on the sector keyword record. The following is an example for this keyword:

```
SECTOR ID="MISMFG" NAME="Other Manufacturing" BASE_EMP= 7.65973288  
BASE_WAG=0.260516434 OUTPUT
```

6.4.32 SEED Keyword for the TCERM Code

The SEED keyword is used to supply the random seed for stochastic variable generation. The following is this keyword's syntax:

```
SEED value1
```

6.4.33 SITEQUAL Keyword for the TCERM Code

The SITEQUAL keyword is used to provide the regional site quality factor for each recreational activity for each location. The following is this keyword's syntax:

```
SITEQUAL LOCATION="quote1" REACT="quote2" value
```

The first quote string contains a location ID and is limited to six characters. The second quote string provides a recreational activity ID and is limited to 6 characters. The value is a regional site quality factor for the given recreational activity. The following is an example for this keyword:

```
SITEQUAL LOCATION="ECON02" REACT="HUNTWF" 1.0
```

6.4.34 SPECACT Keyword for the TCERM Code

The SPECACT keyword is used to provide the specialized activity factor (0 or 1) for each recreational activity at each location. The following is this keyword's syntax:

```
SPECACT LOCATION="quote1" REACT="quote2" value
```

The first quote string contains a location ID and is limited to six characters. The second quote string provides a recreational activity ID and is limited to 6 characters. The value is a specialized activity factor for the given recreational activity. The following is an example for this keyword:

```
SPECACT LOCATION="ECON03" REACT="FISHNG" 1.0
```

6.4.35 SPEND Keyword for the TCERM Code

The SPEND keyword is used to provide the amount spent by a person each day of participating in a recreational activity at a location. The following is this keyword's syntax:

```
SPEND LOCATION="quote1" REACT="quote2" value
```

The first quote string contains a location ID and is limited to six characters. The second quote string provides a recreational activity ID and is limited to six characters. The value is a spending per person at the given location on the given recreational activity. The following is an example for this keyword:

```
SPEND LOCATION="ECON03" REACT="BOATNG" 14.73
```

6.4.36 STATISTICS Keyword for the TCERM Code

The STATISTICS keyword is used to activate reporting of summary statistics from calculations of TRIGGER or EFFECTS calculations to output files. The following is this keyword's syntax:

```
STATISTICS {TRIGGER} {EFFECTS}
```

Multiple STATISTICS keywords can be entered with combinations of modifiers, or a single record can be entered. The following is an example that activates reporting of summary statistics for both trigger and effects calculations:

```
STATISTICS TRIGGER EFFECTS
```

6.4.37 STOCHASTIC Keyword for the TCERM Code

The STOCHASTIC keyword is used to enter the definition of a statistical distribution for stochastic variables. The following is this keyword's syntax:

```
STOCHASTIC ["Quote1"] [Dist_Index Parameters] {TRUNCATE U1 U2} {"Quote2"}
```

The entry for Quote₁ must be a unique character string of up to 20 characters that will be used to identify this stochastic variable in subsequent uses. It is case sensitive and embedded spaces are significant. It is useful to make the character string some combination of a variable name and other character data such that it can be recreated easily when stochastic data are needed. The entry for Quote₂ is a description for the stochastic variable that can be up to 64 characters long. An entry for Quote₂ is not required.

The entry for Dist_Index must be an integer in the range 1 to 11 that identifies the index of a statistical distribution. The statistical distributions are defined in Section 0. The word Parameters in the general syntax statement indicates the numerical values of parameters required for defining the statistical distribution. The additional modifier TRUNCATE can be used for all distribution types except 1, 3, and 10. If TRUNCATE is entered, it must be followed by two values in the interval 0 to 1, inclusive. The lower value must be less than the upper value. These two values specify the tail probabilities at which to impose range truncation for the distribution. Truncation data must be entered after all of the other parameters that define the distribution.

The TCERM code uses a suite of STOCHASTIC keywords. The following paragraphs describe the required STOCHASTIC keywords by functional group. A run of TCERM using 4 recreational activities, 4 locations, and 31 agricultural products requires 513 STOCHASTIC keyword entries.

The lowest supply price for agricultural products is entered using the STOCHASTIC keyword. In this case, the value for Quote₁ is the agricultural product ID (blank filled to six spaces, if necessary) followed by the word PRICE. A separate STOCHASTIC keyword must be entered for every agricultural product. The following are example keywords:

```
STOCHASTIC "SPRWHTPRICE" 6 2.83 3.82 4.95 "Price for spring wheat ($/bu)"
STOCHASTIC "WINWHTPRICE" 6 2.5 3.67 4.81 "Price for winter wheat ($/bu)"
```

The total production is also entered using the STOCHASTIC keyword for each combination of location and agricultural products. In this case, the value for Quote₁ is the location ID (blank filled to six spaces, if necessary) followed by agricultural product ID (blank filled to six spaces, if necessary) followed by the word TOTPROD. A separate STOCHASTIC keyword must be entered for every combination of location and agricultural product. The following are example keywords:

```
STOCHASTIC "EN001 SPRWHTTOTPROD" 1 0.0
    "Total production of Spring Wheat at location EN001 in bu"
STOCHASTIC "EN002 WINWHTTOTPROD" 6 76011 101348 126685
    "Total production of Winter Wheat at location EN002 in bu"
```

The reduction fraction in total production due to regulatory limits being exceeded in surface water irrigation supplies is also entered using the STOCHASTIC keyword for each combination of location and

agricultural products. In this case, the value for Quote₁ is the location ID (blank filled to six spaces, if necessary) followed by agricultural product ID (blank filled to six spaces, if necessary) followed by the word RRA_{SW}. A separate STOCHASTIC keyword must be entered for every combination of location and agricultural product. The following are example keywords:

```
STOCHASTIC "EN001 SPRWHTRRAG_SW" 1 1.0
"Reg reduction in ag due to SW at EN001 for SPRWHT"
STOCHASTIC "EN004 SPRWHTRRAG_SW" 1 1.0
"Reg reduction in ag due to SW at EN004 for SPRWHT"
```

The reduction fraction in total production due to regulatory limits being exceeded in groundwater irrigation supplies is also entered using the STOCHASTIC keyword for each combination of location and agricultural products. In this case, the value for Quote₁ is the location ID (blank filled to six spaces, if necessary) followed by agricultural product ID (blank filled to six spaces, if necessary) followed by the word RRA_{SW}. A separate STOCHASTIC keyword must be entered for every combination of location and agricultural product. The following are example keywords:

```
STOCHASTIC "EN001 SPRWHTRRAG_GW" 1 1.0
"Reg reduction in ag due to GW at EN001 for SPRWHT"
STOCHASTIC "EN002 SPRWHTRRAG_GW" 1 1.0
"Reg reduction in ag due to GW at EN002 for SPRWHT"
```

The voluntary avoidance of agricultural products due to step 1 concentration limits being exceeded is also entered using the STOCHASTIC keyword for each agricultural product. In this case, the value for Quote₁ is the agricultural product ID (blank filled to six spaces, if necessary) followed by the word VAAG_{S1}. A separate STOCHASTIC keyword must be entered for every agricultural product. The following are example keywords:

```
STOCHASTIC "SPRWHTVAAG_S1" 6 0.0 0.05 0.25
"Voluntary avoid of ag step 1 for SPRWHT"
STOCHASTIC "WINWHTVAAG_S1" 6 0.0 0.05 0.25
"Voluntary avoid of ag step 1 for WINWHT"
```

The voluntary avoidance of agricultural products due to step 2 concentration limits being exceeded is also entered using the STOCHASTIC keyword for each agricultural product. In this case, the value for Quote₁ is the agricultural product ID (blank filled to six spaces, if necessary) followed by the word VAAG_{S2}. A separate STOCHASTIC keyword must be entered for every agricultural product. The following are example keywords:

```
STOCHASTIC "SPRWHTVAAG_S2" 6 0.2 0.3 0.8
"Voluntary avoid of ag step 2 for SPRWHT"
STOCHASTIC "WINWHTVAAG_S2" 6 0.2 0.3 0.8
"Voluntary avoid of ag step 2 for WINWHT"
```

The reduction fraction in recreation due to regulatory limits being exceeded in surface water is also entered using the STOCHASTIC keyword for each combination of location and recreational activity. In this case, the value for Quote₁ is the location ID (blank filled to six spaces, if necessary) followed by recreational activity ID (blank filled to six spaces, if necessary) followed by the word RRREC_{WQ}. A

separate STOCHASTIC keyword must be entered for every combination of location and recreational activity. The following are example keywords:

```
STOCHASTIC "EN001 FISHNGRRREC_WQ" 6 0.6 0.8 0.9
  "Regulatory red in rec due to water quality at EN001 for FISHNG"
STOCHASTIC "EN001 BOATNGRRREC_WQ" 6 0.6 0.8 0.9
  "Regulatory red in rec due to water quality at EN001 for BOATNG"
STOCHASTIC "EN001 SWIMNGRRREC_WQ" 6 0.6 0.8 0.9
  "Regulatory red in rec due to water quality at EN001 for SWIMNG"
STOCHASTIC "EN001 SKIINGRRREC_WQ" 6 0.6 0.8 0.9
  "Regulatory red in rec due to water quality at EN001 for WSKING"
```

The voluntary avoidance of recreational activities due to step 1 concentration limits being exceeded is also entered using the STOCHASTIC keyword for each combination of location and recreational activity. In this case, the value for Quote₁ is the location ID (blank filled to six spaces, if necessary) followed by recreational activity ID (blank filled to six spaces, if necessary) followed by the word VAREC_S1. A separate STOCHASTIC keyword must be entered for every combination of location and recreational activity. The following are example keywords:

```
STOCHASTIC "EN001 BOATNGVAREC_S1" 6 0.0 0.05 0.2
  "Voluntary avoid of rec step 1 at EN001 for BOATNG"
STOCHASTIC "EN001 SWIMNGVAREC_S1" 6 0.1 0.25 0.5
  "Voluntary avoid of rec step 1 at EN001 for SWIMNG"
```

The voluntary avoidance of recreational activities due to step 2 concentration limits being exceeded is also entered using the STOCHASTIC keyword for each combination of location and recreational activity. In this case, the value for Quote₁ is the location ID (blank filled to six spaces, if necessary) followed by recreational activity ID (blank filled to six spaces, if necessary) followed by the word VAREC_S2. A separate STOCHASTIC keyword must be entered for every combination of location and recreational activity. The following are example keywords:

```
STOCHASTIC "EN001 FISHNGVAREC_S2" 6 0.2 0.35 0.6
  "Voluntary avoid of rec step 1 at EN001 for FISHNG"
STOCHASTIC "EN001 BOATNGVAREC_S2" 6 0.0 0.1 0.5
  "Voluntary avoid of rec step 1 at EN001 for BOATNG"
```

6.4.38 SUBDIST Keyword for the TCERM Code

The SUBDIST keyword is used to provide the ratio of site quality to distance of a substitute site for each recreational activity at each location. The following is this keyword's syntax:

```
SUBDIST LOCATION="quote1" REACT="quote2" value
```

The first quote string contains a location ID and is limited to six characters. The second quote string provides a recreational activity ID and is limited to 6 characters. The value is the ratio of site quality to distance of a substitute site for the given recreational activity. The following is an example for this keyword:

```
SUBDIST LOCATION="ECON02" REACT="SKIING" 1.0
```


6.4.39 SUBVAR Keyword for the TCERM Code

The SUBVAR keyword is used to provide a substitution variable factor for each recreational activity at each location. The following is this keyword's syntax:

```
SUBVAR LOCATION="quote1" REACT="quote2" value
```

The first quote string contains a location ID and is limited to six characters. The second quote string provides a recreational activity ID and is limited to 6 characters. The value is a substitution variable factor for the given recreational activity. The following is an example for this keyword:

```
SUBVAR LOCATION="ECON02" REACT="SWIMNG" 0.0
```

6.4.40 THRESHOLD Keyword for the TCERM Code

The TRIGGER keywords reference thresholds for their calculations. The values of the thresholds are entered using the THRESHOLD keyword. The action levels apply by analyte, media, and usage. The following is this keyword's syntax:

```
THRESHOLD ANALYTE=["quote1"] [DRINK | SUR_CON | SUR_AG | FISH | FOWL |  
  GAME | FARM | FIELD | ORCHARD] {SPECIES="quote2"} {AGPROD="quote3"}  
[UNITS = "quote"] [N1]
```

The entry for the quote string is the analyte identification string. The modifiers for the THRESHOLD keyword are given in Table 6.15.

Table 6.15 Modifiers Associated with the THRESHOLD Keyword in the TCERM Code

Modifier	Description	
ANALYTE	The quote string associated with the ANALYTE modifier identifies the analyte to which the threshold will be assigned.	
MEDIUM	One of the following modifiers	
	DRINK	Drinking water concentration
	SUR_CON	Surface contact water concentration
	GRO_AG	Groundwater irrigation water concentration
	SUR_AG	Surface water for irrigation concentration
	FISH	Fish tissue concentration
	FOWL	Waterfowl tissue concentration
	GAME	Upland game tissue concentration
	FARM	Farm product tissue concentration
	FIELD	Field product tissue concentration
	ORCHARD	Orchard product tissue concentration

Modifier	Description
SPECIES	If a FISH, FOWL or GAME modifier is present, then the SPECIES modifier is used to provide a 6-character species ID for an ECEM species in the FCDA file.
AGPROD	If a FARM , FIELD or ORCHARD modifier is present, then the AGPROD modifier is used to provide a 6-character species ID for an ECEM species in the FCDA file.
VALUE	The numerical value associated with the VALUE modifier is the threshold value for the trigger calculations.
UNITS	The quote string associated with the UNITS modifier identifies the units associated with the threshold value.

The following are examples for this keyword:

```
THRESHOLD ANALYTE="Cs137" GRO_AG 160.0 ! pCi/L
THRESHOLD ANALYTE="CCl4" FOWL SPECIES="CANGOS" 82.0 ! ug/kg
THRESHOLD ANALYTE="H3" ORCHARD AGPROD="SWTCHR" 3.420E+4 ! pCi/L
```

6.4.41 TIMES Keyword for the TCERM Code

The TIMES keyword identifies the times at which the calculations are to be performed. The following is this keyword's syntax:

```
TIMES [T1] {T2} ... {Tn}
```

The numerical entries T1, T2, ..., Tn are the times (whole number years) when outputs are desired. These times must be a subset of the times at which environmental data were computed and stored by the inventory, release, and transport modules. Only one TIMES record should be entered. The times entered will apply to all AREA, SITE, and MAP calculations. The following is an example TIMES keyword that requests output for the three years 2020, 2075, and 3014:

```
TIMES 2020 2075 3014
```

There are no modifiers or quote strings associated with the TIMES keyword.

6.4.42 TITLE Keyword for the TCERM Code

The TITLE keyword is used to define a single-line problem title. The problem title will be written to output files. If the title is not supplied, then the program will error terminate. The following is this keyword's syntax:

```
TITLE ["quote"]
```

The title is entered in a quote string, which must be enclosed in double quotation marks. Titles up to 72 characters long are supported. The following example defines a title for a run of the code:

```
TITLE "Example title line for the economic impacts code - Test #1."
```

There are no modifiers associated with the TITLE keyword.

6.4.43 TRAVDIST Keyword for the TCERM Code

The TRAVDIST keyword is used to provide a travel distance factor for each recreational activity at each location. The following is this keyword's syntax:

```
TRAVDIST LOCATION="quote1" REACT="quote2" value
```

The first quote string contains a location ID and is limited to six characters. The second quote string provides a recreational activity ID and is limited to six characters. The value is a travel distance factor for the given recreational activity. The following is an example for this keyword:

```
TRAVDIST LOCATION="ECON03" REACT="HUNTUP" 1.0
```

6.4.44 TRAVTIM Keyword for the TCERM Code

The TRAVTIM keyword is used to provide a travel time cost factor for each recreational activity at each location. The following is this keyword's syntax:

```
TRAVTIM LOCATION="quote1" REACT="quote2" value
```

The first quote string contains a location ID and is limited to six characters. The second quote string provides a recreational activity ID and is limited to six characters. The value is a travel time cost factor for the given recreational activity. The following is an example for this keyword:

```
TRAVTIM LOCATION="ECON03" REACT="FISHNG" 1.0
```

6.4.45 USER Keyword for the TCERM Code

The USER keyword is used to identify the user of the program. The user name will be written to output files. If the user name is not supplied, then the program will error terminate. The following is this keyword's syntax:

```
USER ["quote"]
```

The user name is entered in a quote string, which must be enclosed in double quotation marks. User names up to 16 characters long are supported. The following example defines John Q. Public as the user running the code:

```
USER "John Q. Public"
```

There are no modifiers associated with the USER keyword.

7.0 Ecological Impacts Smoothing Model (MobileHome)

This section contains instructions for the use of the ecological impacts smoothing model and provides the mathematical formulation for the model.

7.1 Mathematical Formulation for the Ecological Impacts Smoothing Model

The MobileHome model is a post-processor to the ecological impacts model. The two functions of the MobileHome model are to spatially smooth ecological results, and to apply an occurrence mask to the ecological results so that results are not presented where species do not live.

7.1.1 Spatial Smoothing of Ecological Results

The spatial smoothing of ecological results is achieved in two steps. First, the distance from each location to all other locations of interest is calculated. Then all results of the same type are averaged for all locations whose distance from the location of interest is less than the current species' home range.

7.1.1.1 Distance Calculations

A linear distance formula is used to calculate the distance between any two locations. The formula to calculate the distance between location 1 and location 2 is:

$$D_{1,2} = \sqrt{(N_2 - N_1)^2 + (E_2 - E_1)^2}$$

where

N_2 = the northing of the second location (m)

N_1 = the northing of the first location (m)

E_2 = the easting of the second location (m)

E_1 = the easting of the first location (m)

7.1.1.2 Smoothing Calculations

An arithmetic average is used to calculate the smoothed result for like locations within a species' home range.

$$C_{SMTH} = \frac{R_1 + R_2 + \dots + R_n}{n}$$

where

R_1 to R_n = the results from locations 1 through n within the species' home range.

7.1.2 Occurrence Calculations

A mask indicating by location which species occur at each location can be applied to either the ECEM results or to the smoothed results. Occurrence is given as a matrix of 0's and 1's with size number of species by number of locations. The occurrence-masked result is the original result times the occurrence for that species and location.

7.2 Code Environment

7.2.1 Location in the Processing Sequence

The MOBILEHOME code requires access to the data files developed by the SAC ecological impacts model, ECEM. ECEM must have been executed to build a suite of ecological results files before the MOBILEHOME code can be used to smooth impacts. These ecological results files must have been developed under the control of the same ESD keyword file that the MOBILEHOME code reads to determine processing options.

7.2.2 How the Code Is Invoked

MOBILEHOME can run under either the Windows or the Linux operating system. Under the Windows operating system (Releases 98, NT, or 2000), MOBILEHOME executes in a DOS box. A run of MOBILEHOME is initiated by entering the following command line:

```
MOBILEHOME "Keyfilename"
```

Under the Linux operating system, MOBILEHOME is executed through the following Bourne Shell or C Shell command:

```
mobilehome-1.exe "Keyfilename"
```

For these commands, MOBILEHOME or mobilehome-1.exe is the name of the executable program and "Keyfilename" is the name of a smoothing scenario keyword file. Both the name of the executable program and the keyword file may contain path information. If MOBILEHOME is invoked without entering the name of the keyword file, the code will prompt the user for the file name. The keyword file, which should be prepared using an editor that can handle ASCII files without leaving embedded control codes, contains text control information describing the run. If MOBILEHOME cannot open the keyword file, then the code will terminate execution after writing an error message to the standard output device.

7.2.3 Memory Requirements

The MOBILEHOME code uses dynamic memory allocation, so the memory requirements depend on the problem being analyzed. An example run where the MOBILEHOME code required 1.8 MB of memory (on a Windows 2000 machine) used 3 analytes, 2 times steps, 25 realizations, 3 species and 12 locations. It is expected that most if not all of the runs of the MOBILEHOME code will require fewer than 4 MB of memory.

7.3 Data Files

The MOBILEHOME code reads four or more input files and writes up to five output files. The number of input files depends on the number of contaminants being analyzed. The number of output files depends on the options selected in the MOBILEHOME code. These files are described in the following sections.

7.3.1 Input Files

The input files for the MOBILEHOME code are two keyword files and a suite of concentration data related files, plus a fish body burden file for scenarios that include recreational fishing. One keyword file controls the case the MOBILEHOME code will execute, and it points to the ESD keyword file. The suite of concentration data files are all identified in the ESD keyword file – the user of the MOBILEHOME only needs to identify the location and name of the ESD keyword file. The following are the input files:

- **ESD Keyword File.** The ESD keyword file contains the control information that the inventory and environmental transport codes use to generate concentration data files. Table 2.2 provides examples of keywords in the ESD file that control the impact codes, including the ECEM code. Section 2.1 provides definitions for these keywords. Typically, the user of the MOBILEHOME code will not modify the ESD keyword file.
- **ECEM Keyword File.** The ECEM Keyword file controls the scenario to be analyzed by the MOBILEHOME code. The options and data available are constrained by the case defined in the ESD Keyword file. Section 4.3.1.3 describes the contents of the ECEM keyword file.
- **MOBILEHOME Keyword File.** The MOBILEHOME Keyword file controls the scenario to be analyzed by the MOBILEHOME code. The options and data available are constrained by the case defined in the ESD and ECEM Keyword files. Section 7.3.1.3 describes the contents of the MOBILEHOME keyword file.
- **ECEM Data File.** The MOBILEHOME code requires an input file that has been previously produced by the ECEM code. This file contains the selected ECEM output to be smoothed and/or occurrence-masked. The ECEM detailed data file is described in Section 4.3.2.4.

7.3.1.1 ESD Keyword File

The MOBILEHOME code reads keywords from the environmental settings file. These keywords are read from a different file and can have a different definition from a keyword defined for internal use in the MOBILEHOME code. The environmental settings keywords are defined in Section 2.1. The following keywords are required:

- ANALYTE – definition of analytes in the environmental simulations
- END – end of the environmental settings keywords
- LOCATION – locations at which concentrations were generated for the ecological impact
- SPECIES – definition of species for the ecological impact calculations
- TIMES – times at which concentrations were generated for the ecological impact

7.3.1.2 ECEM Keyword File

The MOBILEHOME code also reads keywords from the ECEM keyword file. These keywords are read from a different file and can have a different definition from a keyword defined for internal use in the MOBILEHOME code. The ECEM keywords are defined in Section 4.4. The following keywords are required:

- ANALYTE – definition of analytes in the environmental simulations
- DETAILS – definition of the solutions written to detailed data files
- END – end of the environmental settings keywords
- FILE – file names for the concentration file for each analyte
- LOCATION – locations at which concentrations were generated for the ecological impacts
- REALIZAT – number of realizations for which concentration data were generated for ecological impact calculations
- SPECIES – definition of species for the ecological impacts calculations
- TIMES – times at which concentrations were generated for the ecological impacts
- TITLE – environmental simulation title.

7.3.1.3 MOBILEHOME Keyword File

The MOBILEHOME keyword definition file contains control information for the desired impact simulation. Individual keywords are defined in Section 7.4. Table 7.1 provides an example keyword file for MOBILEHOME using 25 realizations, 12 locations, 3 analytes, 3 ecological species, and 3 ecological solutions.

Table 7.1 Example Keyword File for the MOBILEHOME Code

! MobileHome.KEY
!
! Report File (Must be first Entry)
REPORT "MobileHome.Rpt"
TITLE "Production run of the MobileHome Code for SAC Rev. 1"
USER "Terri B. Miley"
!
EXECUTE
!
! Input file names
FILE ESD "ESD_Test.key"
FILE ECEMK "ECEM.key"
FILE ECEMD "ECEM_det.csv"
! Output file names
FILE SMOOTHD "SMTH_Det.csv"
FILE SMOOTHS "SMTH_Sta.csv"
FILE OCCURD "OCC_Det.csv"
FILE OCCURS "OCC_Sta.csv"
FILE HEADER "MobileHome.hdr"
!
! Output detailed data

```
DETAILS SMOOTH
DETAILS OCCUR
!
! Output summary statistics
STATISTICS SMOOTH
STATISTICS OCCUR
!
!DEBUG ECEM
DEBUG LOGIC
!
! Times to be used
TIMES 2000 2100
!
! Analytes to be used
ANALYTE "CrVI" "H3"
!
! Species to be used
SPECIES "CARP"
SPECIES "MULDER"
SPECIES "BEAVER"
!
! Solutions to be used
SOLUTION "BURDEN" "SUMRAD" "DOSRAD"
!
! Home Range Definitions
RANGE SPECIES = "CARP" VALUE=50 UNITS="m" OUTPUT
RANGE SPECIES = "RTRTAD" VALUE=800 UNITS="m" OUTPUT
RANGE SPECIES = "SMBASS" VALUE=100 UNITS="m" OUTPUT
RANGE SPECIES = "CRYFSH" VALUE=20 UNITS="m" OUTPUT
RANGE SPECIES = "MULDER" VALUE=500 UNITS="m^2" OUTPUT
RANGE SPECIES = "BEAVER" VALUE=10 UNITS="ha" OUTPUT
!
! Occurrence mask data
OCCUR SPECIES="CARP" LOCATION AQUATIC
OCCUR SPECIES="SALMAD" LOCATION AQUATIC
OCCUR SPECIES="MULDER" LOCATION RIPARIAN
OCCUR SPECIES="BEAVER" LOCATION UPLAND
!
! Mixing recipe for carp
RECIPE SPECIES="CARP" LOCATION="TH0002" NUMCON=2
CONTRIBUTORS "TH0004" "TH0006"
! End of Inputs
END
```


7.3.2 Output Files

Up to six output files can be written by the MOBILEHOME code. The number of files depends on the options selected in the scenario being analyzed. The following are the output files:

- **Report File.** This required file contains a summary of the scenario being analyzed and contains any error messages. An example report file for the MOBILEHOME code is provided in Table 7.2.
- **SACView Header File.** This required file contains information used by the interactive SACView program to allow easy extraction of subsets of the results computed by the MOBILEHOME code. An example of this file is given in Table 7.3.
- **Smoothed Detailed Data.** This optional file contains the detailed values for the smoothed values generated in the MOBILEHOME code. The description of the SMOOTHD modifier on the FILE keyword (see Section 7.4.6) explains how to activate writing this file. A subset of the data written to this file for a run using five realizations is provided in Table 7.4.
- **Smoothed Data Summary Statistics.** This optional file contains the summary statistics for the smoothed values generated in the MOBILEHOME code. The description of the SMOOTHS modifier on the FILE keyword (see Section 7.4.6) explains how to activate writing this file. A subset of the data written to this file for a run using five realizations is provided in Table 7.5.
- **Occurrence-Masked Detailed Data.** This optional file contains the detailed values for the occurrence-masked values generated in the MOBILEHOME code. The description of the OCCURD modifier on the FILE keyword (see Section 7.4.6) explains how to activate writing this file. A subset of the data written to this file for a run using five realizations is provided in Table 7.6.
- **Occurrence-Masked Data Summary Statistics.** This optional file contains the summary statistics for the occurrence-masked values generated in the MOBILEHOME code. The description of the OCCURS modifier on the FILE keyword (see Section 7.4.6) explains how to activate writing this file. A subset of the data written to this file for a run using five realizations is provided in Table 7.7.

7.3.2.1 MOBILEHOME Report File

An example report file for the MOBILEHOME code is provided in Table 7.2. This file contains information for a run of the MOBILEHOME code using 3 analytes, 25 realizations, 3 species, 12 locations, 3 solutions and 2 solution times. The size of this file is about 6 KB in size. The size of this file grows rapidly when debug options are selected. A run using all debug options having a large number of locations, analytes, solution times, and realizations could easily generate a report file larger than the 2.1-GB file size limit under the Windows operating system.

Table 7.2 Example Report File for the MOBILEHOME Code

```

M      M      B      I L      H      H
MM MM      B      L      H      H
M MM M OO BBB I L EEE H H OO MM MM EEE
M      M O O B B I L E E HHHH O O M MM M E E
M      M O O B B I L EEEE H H O O M M EEEE
M      M O O B B I L E      H H O O M M E
M      M OO BBB I L EEE H H OO M M EEE

```

MobileHome Version 1.00.A.1
Last Modified on 2 Jun 2003

SAC Rev. 1 MobileHome Ecological
Post-Processor Model

Developed By Battelle Memorial Institute
Pacific Northwest National Laboratories
Richland, Washington

Current Run ID = 200306091156 User Name = Terri B. Miley
System Date = 06-09-2003 System Time = 11:56:35

The software used to generate this output is experimental
and has not been formally tested or peer reviewed.

Review Signatures

Input Prepared By: _____ Date: _____
Input Reviewed By: _____ Date: _____

===== Echo of the Problem Definition =====

Title: Production run of the MobileHome Code for SAC Rev. 1
User: Terri B. Miley
25 Realizations in the ECEM keyword file

File Name for this Report File
File: MobileHome.Rpt

File Name for MobileHome Input Keyword Data
File: mobilehome.key

File Name for ECEM Input Keyword Data
File: ECEM.key

File Name for ECEM Data
File: ECEM_Det.Csv

File Name for ESD Input Keyword Data
File: ESD_Test.key

File Name for the Output SACVIEW Header File
File: MobileHome.hdr

File Name for the Output SMOOTH Details File
File: SMTH_Det.csv

File Name for the Output SMOOTH Statistics File

File: SMTH_Sta.csv

File Name for the Output OCCUR Details File

File: OCC_Det.csv

File Name for the Output OCCUR Statistics File

File: OCC_Sta.csv

Analyte Information for 2 analytes.

```

1 : -Rads- : Sum of the radionuclide dose
2 : CrVI   : Hexavalent Chromium
3 : H3     : Tritium
4 : Cs137  : ==> Not used

```

Number of times requested is 2

Index Year

```

1  2000
2 : 2005 : ==> Not used
3 : 2015 : ==> Not used
4 : 2023 : ==> Not used
5  2100
6 : 2400 : ==> Not used
7 : 2700 : ==> Not used
8 : 3050 : ==> Not used

```

Number of species requested is 3

Index Species

```

1 : AMCOOT : ==> Not used
2 : AMCOUP : ==> Not used
3 : BEAVER
4 : CARP
5 : COYOTE : ==> Not used
6 : DAPMAG : ==> Not used
7 : DENSDG : ==> Not used
8 : DENSUP : ==> Not used
9 : FUNGI  : ==> Not used
10 : MULBRY : ==> Not used
11 : MULBUP : ==> Not used
12 : MULDER
13 : PERPHY : ==> Not used
14 : PHYPLK : ==> Not used

```

Number of solutions requested is 3

Index Solution

```

1  BURDEN
2  DOSRAD
3  SUMRAD

```

Index	Solution	Index	Analyte	Compute Flag
1	BURDEN	1	-Rads-	F
1	BURDEN	2	CrVI	T
1	BURDEN	3	H3	T
1	BURDEN	4	Cs137	T
2	DOSRAD	1	-Rads-	F
2	DOSRAD	2	CrVI	F
2	DOSRAD	3	H3	T
2	DOSRAD	4	Cs137	T
3	SUMRAD	1	-Rads-	T
3	SUMRAD	2	CrVI	F

```

3    SUMRAD      3    H3      F
3    SUMRAD      4    Cs137   F

===== End of the Problem Definition =====

Home Range data units conversion factors

3 : BEAVER : TA : RIPARIAN : From ha          to 1.78E+02 m
12 : MULDER : TA : UPLAND   : From m^2        to 1.26E+01 m

Range for species is less than distance to nearest node
Species index =      3  SPCID = "BEAVER"
Location index =      1  LOCID = "TH0001"

Range for species is less than distance to nearest node
Species index =      3  SPCID = "BEAVER"
Location index =      2  LOCID = "TH0003"

BGLOGIC Outputs
SOLN_COMP(BURDEN,-Rads-) = F
SOLN_COMP(DOSRAD,-Rads-) = F
SOLN_COMP(SUMRAD,-Rads-) = T
SOLN_COMP(BURDEN,CrVI ) = T
SOLN_COMP(DOSRAD,CrVI ) = F
SOLN_COMP(SUMRAD,CrVI ) = F
SOLN_COMP(BURDEN,H3   ) = T
SOLN_COMP(DOSRAD,H3   ) = T
SOLN_COMP(SUMRAD,H3   ) = F
SOLN_COMP(BURDEN,-Rads-) = F
SOLN_COMP(DOSRAD,-Rads-) = F
SOLN_COMP(SUMRAD,-Rads-) = T
SOLN_COMP(BURDEN,CrVI ) = T
SOLN_COMP(DOSRAD,CrVI ) = F
SOLN_COMP(SUMRAD,CrVI ) = F
SOLN_COMP(BURDEN,H3   ) = T
SOLN_COMP(DOSRAD,H3   ) = T
SOLN_COMP(SUMRAD,H3   ) = F

Run completed on:
Date: 06/09/2003
Time: 11:56:44

```

7.3.2.2 MOBILEHOME SACView Header File

The SACView header file is an output file containing information used by the interactive SACView program to allow easy extraction of subsets of the results computed by the MOBILEHOME code. This file is required for every run of the MOBILEHOME code. An example of this file is given in Table 7.3. The file contains the following sections of information:

- A header section of basic run information
- Number of realizations
- Solution times selected
- Locations used
- Analytes processed
- Species with output selected
- Solutions selected
- Output file names

The user only specifies the name of this file; users should not modify the file after it is generated by the MOBILEHOME code. See the instructions in Section 1.0 regarding the use of the SACView program. Because this file has at most a few hundred entries, the file size is always much smaller than 1 MB. File names for options not selected are set to null.

Table 7.3 Example Header File from MOBILEHOME for the SACView Program

```

type: "Ecological"
title: "Production run of the MobileHome Code for SAC Rev. 1"
user: "Terri B. Miley"
name: "MobileHome"
version: "1.00.A.1"
date: " 2 Jun 2003"
id: "20040916115213"
envfile: "ESD_Test.key"
realizations: 25
times: 8
    2000
    2100
locations: 12
"TH0001","TH0001 - Riparian - Pair with TH0002"
"TH0003","TH0003 - Riparian - Pair with TH0004"
"TH0005","TH0005 - River Only"
"TH0006","TH0006 - River Only"
"TH0007","TH0007 - Upland groundwater irrigated location"
"TH0008","TH0008 - Upland groundwater irrigated location"
"TH0009","TH0009 - Upland dry location"
"TH0010","TH0010 - Upland dry location"
"TH0011","TH0011 - Upland surface water irrigated location"
"TH0012","TH0012 - Upland surface water irrigated location"
"TH0013","TH0013 - Upland irrigated (both) location"
"TH0014","TH0014 - Upland irrigated (both) location"
analytes: 2
"-Rads-","NR","Sum of the radionuclide dose"
"CrVI  ","NS","Hexavalent Chromium"
"H3     ","NR","Tritium"
species: 3
"BEAVER","RIPARIAN","Beaver"
"CARP   ","AQUATIC ","Carp"
"MULDER","UPLAND   ","Mule deer"
solutions: 3
"BURDEN",""
"DOSRAD",""
"SUMRAD",""
summary: "SMTH_Sta.csv"
summary: "OCC_Sta.csv"
detail: "SMTH_Det.csv"
detail: "OCC_Det.csv"

```

7.3.2.3 MOBILEHOME Smoothed Detailed Data

The detailed data file for smoothed results is an optional output file that contains the detailed values for selected solutions generated in the ECEM code. The description of the SMOOTHD modifier on the FILE keyword (see Section 7.4.6) explains how to activate writing this file. The solution types that can be written to the file are described in Table 4.12 of the ECEM section. The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file consists of six identifiers followed by a value for every generated realization. A subset of the data written to this file for a run using two realizations is provided in Table 7.4. The header line occupies one line in the file even though it occupies two lines in the table. The following are the six identifiers on each line:

- Time: Year for which the data are valid
- Location ID: The location identifier where the data are valid
- Analyte ID: The identification of the analyte for which the data were computed
- Species ID: The identification for the species for which data were computed
- Solution type: A flag for solution type
- Units: The units associated with the computed data.

Table 7.4 Example Smoothed Detailed Data File for the MOBILEHOME Code

"Time", "LOC ID", "Soil", "ANA ID", "SPC ID", "Solution ID", "Units", "Values by realization"
2000,"TH0001","SORP","-Rads-","BEAVER","SUMRAD","rad/day", 2.29744E+03, 1.72897E+03, 2.11060E+03, 1.63428E+03, 1.05509E+03, 2.38094E+03, 6.47116E+02
2000,"TH0003","SORP","-Rads-","BEAVER","SUMRAD","rad/day", 2.02410E+03, 1.48567E+03, 2.55571E+03, 1.91338E+03, 1.31552E+03, 1.16129E+03, 1.48203E+03
2000,"TH0005","NONE","-Rads-","BEAVER","SUMRAD","rad/day", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"TH0006","NONE","-Rads-","BEAVER","SUMRAD","rad/day", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"TH0007","SODR","-Rads-","BEAVER","SUMRAD","rad/day", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"TH0007","SOGW","-Rads-","BEAVER","SUMRAD","rad/day", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"TH0008","SODR","-Rads-","BEAVER","SUMRAD","rad/day", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"TH0008","SOGW","-Rads-","BEAVER","SUMRAD","rad/day", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"TH0009","SODR","-Rads-","BEAVER","SUMRAD","rad/day", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"TH0010","SODR","-Rads-","BEAVER","SUMRAD","rad/day", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"TH0011","SODR","-Rads-","BEAVER","SUMRAD","rad/day", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"TH0011","SOSW","-Rads-","BEAVER","SUMRAD","rad/day", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"TH0012","SODR","-Rads-","BEAVER","SUMRAD","rad/day", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"TH0012","SOSW","-Rads-","BEAVER","SUMRAD","rad/day", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"TH0013","SODR","-Rads-","BEAVER","SUMRAD","rad/day", 0.00000E+00,

```
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"TH0013","SOGW","-Rads-","BEAVER","SUMRAD","rad/day", 0.00000E+00,
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"TH0013","SOSW","-Rads-","BEAVER","SUMRAD","rad/day", 0.00000E+00,
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"TH0014","SODR","-Rads-","BEAVER","SUMRAD","rad/day", 0.00000E+00,
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"TH0014","SOGW","-Rads-","BEAVER","SUMRAD","rad/day", 0.00000E+00,
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
2000,"TH0014","SOSW","-Rads-","BEAVER","SUMRAD","rad/day", 0.00000E+00,
0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
```

This file can have several rows of information for every combination of time, location, species, and analyte. Therefore, this file can become very large. As an example, a 2,800 KB file was generated for a case involving 14 locations, 10 analytes, 7 realizations, 12 times, and 4 output species. The file size directly scales with the number of analytes, locations, species, and times. The file size grows more slowly than a direct scaling by the number of realizations. The file size can be reduced by selecting fewer times, locations, output species, or solution types.

7.3.2.4 MOBILEHOME Smoothed Data Summary Statistics

This optional file contains summary statistics for smoothed data generated in the MOBILEHOME code. The description of the SMOOTHS modifier on the FILE keyword (see Section 7.4.6) explains how to activate writing this file. The solution types that can be written to the file are described in Table 4.12 of the ECEM section. The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file consists of six identifiers followed by summary statistics (nine percentiles, mean value, and standard deviation). A subset of the data written to this file for a run using five realizations is provided in Table 7.5. The following are the six identifiers on each line:

- Time: Year for which the data are valid
- Location ID: The location identifier where the data are valid
- Analyte ID: The identification of the analyte for which the data were computed
- Species ID: The identification for the species for which data were computed
- Solution type: A flag for solution type
- Units: The units associated with the computed data.

The data for each record in this file are too long to present without line-wrapping in this document. Each record in the file occupies two lines in Table 7.5.

Table 7.5 Excerpted Records from the MOBILEHOME Smoothed Data Summary Statistics File

"Time", "Location ID", "Specie ID", "Analyte ID", "Result Type", "Units", "Minimum", "5th Percentile", "10th Percentile", "25th Percentile", "Median", "75th Percentile", "90th Percentile", "95th Percentile", "Maximum", "Mean", "Standard Deviation"
1990, "EL0050", "RCANGS", "H3", "BURDEN", "pCi/kg", 2.54241E+01, 2.54241E+01, 2.54241E+01, 2.54241E+01, 2.73537E+04, 3.38985E+04, 4.51161E+04, 4.51161E+04, 8.01585E+04, 3.32611E+04, 2.48229E+04
1990, "EL0050", "RCANGS", "H3", "DOSRAD", "rad/day", 7.54994E-09, 7.54994E-09, 7.54994E-09, 7.54994E-09, 8.12296E-06, 1.00665E-05, 1.33977E-05, 1.33977E-05, 2.38039E-05, 9.87721E-06, 7.37140E-06
1990, "EL0050", "MAYFLY", "H3", "BURDEN", "pCi/kg", 1.22778E+01, 1.22778E+01, 1.22778E+01, 1.22778E+01, 6.70630E+03, 8.25514E+03, 1.05390E+04, 1.05390E+04, 1.76211E+04, 7.74609E+03, 5.44027E+03
1990, "EL0050", "MAYFLY", "H3", "BMTISS", "unitless", 1.23215E+01, 1.23215E+01, 1.23215E+01, 1.23215E+01, 6.88845E+03, 8.12850E+03, 1.02607E+04, 1.02607E+04, 1.80153E+04, 7.76516E+03, 5.52208E+03
1990, "EL0050", "MAYFLY", "H3", "DOSRAD", "rad/day", 3.64601E-09, 3.64601E-09, 3.64601E-09, 3.64601E-09, 1.99150E-06, 2.45145E-06, 3.12967E-06, 3.12967E-06, 5.23275E-06, 2.30028E-06, 1.61554E-06
1990, "EL0050", "SALMJV", "H3", "BURDEN", "pCi/kg", 6.28882E+00, 6.28882E+00, 6.28882E+00, 6.28882E+00, 1.38113E+03, 1.89246E+03, 2.46386E+03, 2.46386E+03, 4.66751E+03, 1.82576E+03, 1.46418E+03
1990, "EL0050", "SALMJV", "H3", "BMTISS", "unitless", 6.32028E+00, 6.32028E+00, 6.32028E+00, 6.32028E+00, 1.48005E+03, 1.87565E+03, 2.34242E+03, 2.34242E+03, 4.54303E+03, 1.81281E+03, 1.40662E+03
1990, "EL0050", "SALMJV", "H3", "DOSRAD", "rad/day", 1.86753E-09, 1.86753E-09, 1.86753E-09, 1.86753E-09, 4.10141E-07, 5.61986E-07, 7.31668E-07, 7.31668E-07, 1.38607E-06, 5.42179E-07, 4.34802E-07
1990, "EL0050", "HRVMSE", "H3", "BURDEN", "pCi/kg", 1.90977E+01, 1.90977E+01, 1.90977E+01, 1.90977E+01, 1.79798E+04, 2.42002E+04, 3.12386E+04, 3.12386E+04, 5.20661E+04, 2.18047E+04, 1.65240E+04
1990, "EL0050", "HRVMSE", "H3", "DOSRAD", "rad/day", 5.67125E-09, 5.67125E-09, 5.67125E-09, 5.67125E-09, 5.33928E-06, 7.18650E-06, 9.27663E-06, 9.27663E-06, 1.54616E-05, 6.47513E-06, 4.90697E-06
1990, "EL0050", "HRVMSE", "H3", "DOSDER", "rad/day", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
1990, "EL0050", "HRVMSE", "H3", "DOSING", "rad/day", 3.09753E+01, 3.09753E+01, 3.09753E+01, 3.09753E+01, 2.85303E+04, 3.52527E+04, 4.67677E+04, 4.67677E+04, 8.33295E+04, 3.45718E+04, 2.57908E+04
1990, "EL0050", "HRVMSE", "H3", "DOSINH", "rad/day", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
1990, "EL0050", "RCANGS", "CCI4", "BURDEN", "ug/kg", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
1990, "EL0050", "MAYFLY", "CCI4", "BURDEN", "ug/kg", 5.06943E-02, 5.06943E-02, 5.06943E-02, 5.06943E-02, 5.83496E-02, 6.45637E-02, 7.07093E-02, 7.07093E-02, 1.01457E-01, 6.48589E-02, 1.75829E-02
1990, "EL0050", "MAYFLY", "CCI4", "BMTISS", "unitless", 5.06943E-02, 5.06943E-02, 5.06943E-02, 5.06943E-02, 5.83496E-02, 6.45637E-02, 7.07093E-02, 7.07093E-02, 1.01457E-01, 6.48589E-02, 1.75829E-02
1990, "EL0050", "HRVMSE", "CCI4", "DOSINH", "ug/kg/day", 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00, 0.00000E+00
1990, "EL0050", "HRVMSE", "Rads-", "SUMRAD", "rad/day", 6.53884E-08, 6.53884E-08, 6.53884E-08, 6.53884E-08, 5.34093E-06, 7.32354E-06, 9.27913E-06, 9.27913E-06, 1.54730E-05, 6.51136E-06, 4.89722E-06
1990, "EL0050", "MAYFLY", "Rads-", "SUMRAD", "rad/day", 4.00539E-05, 4.00539E-05, 4.00539E-05, 4.00539E-05, 9.29692E-05, 1.36747E-04, 2.07406E-04, 2.07406E-04, 3.78735E-04, 1.40443E-04, 1.19386E-04
1990, "EL0050", "RCANGS", "Rads-", "SUMRAD", "rad/day", 7.54994E-09, 7.54994E-09, 7.54994E-09, 7.54994E-09, 8.12296E-06, 1.00665E-05, 1.33977E-05, 1.33977E-05, 2.38039E-05, 9.87721E-06, 7.37140E-06
1990, "EL0050", "SALMJV", "Rads-", "SUMRAD", "rad/day", 2.13907E-06, 2.13907E-06, 2.13907E-06, 2.13907E-06, 3.69897E-06, 5.16700E-06, 7.70061E-06, 7.70061E-06, 1.60394E-05, 5.71137E-06, 4.94818E-06

This file can have several rows of information for every combination of time, location, specie, and analyte. Therefore, this file can become very large. As an example, a 3,890 KB file was generated for a case involving 14 locations, 10 analytes, 7 realizations, 12 times, and 4 output species. The file size directly scales with the number of analytes, locations, species, and times. The file size grows more slowly than a direct scaling by the number of realizations. The file size can be reduced by selecting fewer times, locations, output species, or solution types.

7.3.2.5 MOBILEHOME Occurrence-Masked Detailed Data

The detailed data file for occurrence-masked results is an optional output file that contains the detailed values for selected solutions after a map of occurrence has been applied. These solutions can be either smoothed solutions or solutions generated in the ECEM code. The description of the OCCURD modifier on the FILE keyword (see Section 7.4.6) explains how to activate writing this file. The solution types that can be written to the file are described in Table 4.12 of the ECEM section. The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file consists of six identifiers followed by a value for every generated realization. A subset of the data written to this file for a run using two realizations is provided in Table 7.6. The header line occupies one line in the file even though it occupies two lines in the table. The following are the six identifiers on each line:

- Time: Year for which the data are valid
- Location ID: The location identifier where the data are valid
- Analyte ID: The identification of the analyte for which the data were computed
- Species ID: The identification for the species for which data were computed
- Solution type: A flag for solution type
- Units: The units associated with the computed data

Table 7.6 Example Occurrence-Masked Detailed Data File for the MOBILEHOME Code

"Time",	"LOC ID",	"Soil",	"ANA ID",	"SPC ID",	"Solution ID",	"Units",	"Values by realization"
2000,"TH0001",	"SORP",	"-Rads-",	"BEAVER",	"SUMRAD",	"rad/day",	"",	2.29744E+03,
1.72897E+03,	2.11060E+03,	1.63428E+03,	1.05509E+03,	2.38094E+03,	6.47116E+02		
2000,"TH0003",	"SORP",	"-Rads-",	"BEAVER",	"SUMRAD",	"rad/day",	"",	2.02410E+03,
1.48567E+03,	2.55571E+03,	1.91338E+03,	1.31552E+03,	1.16129E+03,	1.48203E+03		
2000,"TH0005",	"NONE",	"-Rads-",	"BEAVER",	"SUMRAD",	"rad/day",	"",	0.00000E+00,
0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00		
2000,"TH0006",	"NONE",	"-Rads-",	"BEAVER",	"SUMRAD",	"rad/day",	"",	0.00000E+00,
0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00		
2000,"TH0007",	"SODR",	"-Rads-",	"BEAVER",	"SUMRAD",	"rad/day",	"",	0.00000E+00,
0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00		
2000,"TH0007",	"SOGW",	"-Rads-",	"BEAVER",	"SUMRAD",	"rad/day",	"",	0.00000E+00,
0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00		
2000,"TH0008",	"SODR",	"-Rads-",	"BEAVER",	"SUMRAD",	"rad/day",	"",	0.00000E+00,
0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00		
2000,"TH0008",	"SOGW",	"-Rads-",	"BEAVER",	"SUMRAD",	"rad/day",	"",	0.00000E+00,
0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00		
2000,"TH0009",	"SODR",	"-Rads-",	"BEAVER",	"SUMRAD",	"rad/day",	"",	0.00000E+00,
0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00		
2000,"TH0010",	"SODR",	"-Rads-",	"BEAVER",	"SUMRAD",	"rad/day",	"",	0.00000E+00,
0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00		
2000,"TH0011",	"SODR",	"-Rads-",	"BEAVER",	"SUMRAD",	"rad/day",	"",	0.00000E+00,
0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00		
2000,"TH0011",	"SOSW",	"-Rads-",	"BEAVER",	"SUMRAD",	"rad/day",	"",	0.00000E+00,
0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00		
2000,"TH0012",	"SODR",	"-Rads-",	"BEAVER",	"SUMRAD",	"rad/day",	"",	0.00000E+00,
0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00		
2000,"TH0012",	"SOSW",	"-Rads-",	"BEAVER",	"SUMRAD",	"rad/day",	"",	0.00000E+00,
0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00,	0.00000E+00		

```
2000,"TH0013","SODR","-Rads-","BEAVER","SUMRAD","rad/day",0.00000E+00,
0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,
2000,"TH0013","SOGW","-Rads-","BEAVER","SUMRAD","rad/day",0.00000E+00,
0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,
2000,"TH0013","SOSW","-Rads-","BEAVER","SUMRAD","rad/day",0.00000E+00,
0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,
2000,"TH0014","SODR","-Rads-","BEAVER","SUMRAD","rad/day",0.00000E+00,
0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,
2000,"TH0014","SOGW","-Rads-","BEAVER","SUMRAD","rad/day",0.00000E+00,
0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,
2000,"TH0014","SOSW","-Rads-","BEAVER","SUMRAD","rad/day",0.00000E+00,
0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00
```

This file can have several rows of information for every combination of time, location, species, and analyte. Therefore, this file can become very large. As an example, a 2,800 KB file was generated for a case involving 14 locations, 10 analytes, 7 realizations, 12 times, and 4 output species. The file size directly scales with the number of analytes, locations, species, and times. The file size grows more slowly than a direct scaling by the number of realizations. The file size can be reduced by selecting fewer times, locations, output species, or solution types.

7.3.2.6 MOBILEHOME Occurrence-Masked Data Summary Statistics

This optional file contains summary statistics for occurrence-masked data generated in the MOBILEHOME code. The data to which an occurrence mask are applied can be smoothed data produced by the MOBILHOME code or solutions generated by the ECEM code. The description of the OCCURS modifier on the FILE keyword (see Section 7.4.6) explains how to activate writing this file. The solution types that can be written to the file are described in Table 4.12 of the ECEM section. The values are written as text in comma-separated format so they can be imported easily into a spreadsheet or other software. Each line of the file consists of six identifiers followed by summary statistics (nine percentiles, mean value, and standard deviation). A subset of the data written to this file for a run using five realizations is provided in Table 7.7. The following are the six identifiers on each line:

- Time: Year for which the data are valid
- Location ID: The location identifier where the data are valid
- Analyte ID: The identification of the analyte for which the data were computed
- Species ID: The identification for the species for which data were computed
- Solution type: A flag for solution type
- Units: The units associated with the computed data

The data for each record in this file are too long to present without line-wrapping in this document. Each record in the file occupies two lines in Table 7.7.

Table 7.7 Excerpted Records from the MOBILEHOME Occurrence-Masked Data Summary Statistics File

"Time","Location ID","Specie ID","Analyte ID","Result Type","Units","Minimum","5th Percentile","10th Percentile", "25th Percentile","Median","75th Percentile","90th Percentile","95th Percentile","Maximum","Mean","Standard Deviation"
1990,"EL0050","RCANGS","H3","BURDEN","pCi/kg",2.54241E+01,2.54241E+01,2.54241E+01,2.54241E+01, 2.73537E+04,3.38985E+04,4.51161E+04,4.51161E+04,8.01585E+04,3.32611E+04,2.48229E+04
1990,"EL0050","RCANGS","H3","DOSRAD","rad/day",7.54994E-09,7.54994E-09,7.54994E-09,7.54994E-09, 8.12296E-06,1.00665E-05,1.33977E-05,1.33977E-05,2.38039E-05,9.87721E-06,7.37140E-06
1990,"EL0050","MAYFLY","H3","BURDEN","pCi/kg",1.22778E+01,1.22778E+01,1.22778E+01,1.22778E+01, 6.70630E+03,8.25514E+03,1.05390E+04,1.05390E+04,1.76211E+04,7.74609E+03,5.44027E+03
1990,"EL0050","MAYFLY","H3","BMTISS","unitless",1.23215E+01,1.23215E+01,1.23215E+01,1.23215E+01, 6.88845E+03,8.12850E+03,1.02607E+04,1.02607E+04,1.80153E+04,7.76516E+03,5.52208E+03
1990,"EL0050","MAYFLY","H3","DOSRAD","rad/day",3.64601E-09,3.64601E-09,3.64601E-09,3.64601E-09, 1.99150E-06,2.45145E-06,3.12967E-06,3.12967E-06,5.23275E-06,2.30028E-06,1.61554E-06
1990,"EL0050","SALMJV","H3","BURDEN","pCi/kg",6.28882E+00,6.28882E+00,6.28882E+00,6.28882E+00, 1.38113E+03,1.89246E+03,2.46386E+03,2.46386E+03,4.66751E+03,1.82576E+03,1.46418E+03
1990,"EL0050","SALMJV","H3","BMTISS","unitless",6.32028E+00,6.32028E+00,6.32028E+00,6.32028E+00, 1.48005E+03,1.87565E+03,2.34242E+03,2.34242E+03,4.54303E+03,1.81281E+03,1.40662E+03
1990,"EL0050","SALMJV","H3","DOSRAD","rad/day",1.86753E-09,1.86753E-09,1.86753E-09,1.86753E-09, 4.10141E-07,5.61986E-07,7.31668E-07,7.31668E-07,1.38607E-06,5.42179E-07,4.34802E-07
1990,"EL0050","HRVMSE","H3","BURDEN","pCi/kg",1.90977E+01,1.90977E+01,1.90977E+01,1.90977E+01, 1.79798E+04,2.42002E+04,3.12386E+04,3.12386E+04,5.20661E+04,2.18047E+04,1.65240E+04
1990,"EL0050","HRVMSE","H3","DOSRAD","rad/day",5.67125E-09,5.67125E-09,5.67125E-09,5.67125E-09, 5.33928E-06,7.18650E-06,9.27663E-06,9.27663E-06,1.54616E-05,6.47513E-06,4.90697E-06
1990,"EL0050","HRVMSE","H3","DOSDER","rad/day",0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00, 0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00
1990,"EL0050","HRVMSE","H3","DOSING","rad/day",3.09753E+01,3.09753E+01,3.09753E+01,3.09753E+01, 2.85303E+04,3.52527E+04,4.67677E+04,4.67677E+04,8.33295E+04,3.45718E+04,2.57908E+04
1990,"EL0050","HRVMSE","H3","DOSINH","rad/day",0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00, 0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00
1990,"EL0050","RCANGS","CC14","BURDEN","ug/kg",0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00, 0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00
1990,"EL0050","MAYFLY","CC14","BURDEN","ug/kg",5.06943E-02,5.06943E-02,5.06943E-02,5.06943E-02, 5.83496E-02,6.45637E-02,7.07093E-02,7.07093E-02,1.01457E-01,6.48589E-02,1.75829E-02
1990,"EL0050","MAYFLY","CC14","BMTISS","unitless",5.06943E-02,5.06943E-02,5.06943E-02,5.06943E-02, 5.83496E-02,6.45637E-02,7.07093E-02,7.07093E-02,1.01457E-01,6.48589E-02,1.75829E-02
1990,"EL0050","HRVMSE","CC14","DOSINH","ug/kg/day",0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00, 0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00,0.00000E+00
1990,"EL0050","HRVMSE","-Rads-","SUMRAD","rad/day",6.53884E-08,6.53884E-08,6.53884E-08,6.53884E-08, 5.34093E-06,7.32354E-06,9.27913E-06,9.27913E-06,1.54730E-05,6.51136E-06,4.89722E-06
1990,"EL0050","MAYFLY","-Rads-","SUMRAD","rad/day",4.00539E-05,4.00539E-05,4.00539E-05,4.00539E-05, 9.29692E-05,1.36747E-04,2.07406E-04,2.07406E-04,3.78735E-04,1.40443E-04,1.19386E-04
1990,"EL0050","RCANGS","-Rads-","SUMRAD","rad/day",7.54994E-09,7.54994E-09,7.54994E-09,7.54994E-09, 8.12296E-06,1.00665E-05,1.33977E-05,1.33977E-05,2.38039E-05,9.87721E-06,7.37140E-06
1990,"EL0050","SALMJV","-Rads-","SUMRAD","rad/day",2.13907E-06,2.13907E-06,2.13907E-06,2.13907E-06, 3.69897E-06,5.16700E-06,7.70061E-06,7.70061E-06,1.60394E-05,5.71137E-06,4.94818E-06

This file can have several rows of information for every combination of time, location, specie, and analyte. Therefore, this file can become very large. As an example, a 3,890 KB file was generated for a case involving 14 locations, 10 analytes, 7 realizations, 12 times, and 4 output species. The file size directly scales with the number of analytes, locations, species, and times. The file size grows more slowly than a direct scaling by the number of realizations. The file size can be reduced by selecting fewer times, locations, output species, or solution types.

7.4 Keyword Descriptions for the MOBILEHOME Code

In the following keyword descriptions, some data are optional and some are required. Data that are required are enclosed in square brackets. For AB to be required, it would be denoted by [AB]. If only one of the three items AB, BC, CD were required, it would be written as [AB|BC|CD]. The vertical bars indicate that the user must select one of the items in the list. Optional items are enclosed in normal brackets. For DE to be an optional entry, it would be denoted by {DE}. The { } or [] symbols indicate whether the data are required; the symbols do not need to be entered when the keyword is constructed. The keyword name can contain any number of characters; however, only the first eight characters are used (for example, REALIZAT = REALIZATION = REALIZATxxx).

In some instances, numerical values or quote strings are associated with a modifier. In this description, the association is indicated by using the equal (=) symbol. The = symbol is not required but may be used when the keyword is constructed. When a numerical value or quote string is associated with a modifier, it must be physically entered on the input line directly after the modifier.

In general, the keywords can be entered in any order. The following are the restrictions on keyword order:

- The REPORT keyword must be the first keyword in the file.
- The END keyword must be the last keyword in the file.

7.4.1 ANALYTE Keyword for the MOBILEHOME Code

The ANALYTE keyword is used to define the analytes to be used in post-processing ecological results. The following is this keyword's syntax:

```
ANALYTE ["quote 1"] {"quote " }...{"quote n" }
```

The entry for each quote string must be an analyte identification string (up to six characters in length). The analyte identification string is case sensitive, and spaces or hyphens change the definition. Care must be taken that all data follow the convention that only the first entry in the analyte name is capitalized and that no embedded spaces or hyphens are used. The analytes selected must be a subset of the set of analytes identified in the environmental scenario file. Multiple analyte keywords can be entered. The following ANALYTE keyword selects the two analytes technetium-99 and tritium for analysis:

```
ANALYTE "Tc99" "H3"
```

7.4.2 DEBUG Keyword for the MOBILEHOME Code

The DEBUG keyword is used to activate writing of intermediate calculations to the report file. It should be used sparingly and with only one or two realizations; otherwise, the volume of output could fill the user's hard drive. The following is this keyword's syntax:

```
DEBUG [modifier 1] {modifier 2 }...{modifier k }
```

Multiple DEBUG cards can be entered with combinations of modifiers, or a single card can be entered containing all of the modifiers. The modifiers can be entered in any order. Table 7.8 describes the modifiers associated with the DEBUG keyword.

Table 7.8 Modifiers Associated with the DEBUG Keyword in the MOBILEHOME Code

Modifier	Description
ECM	Echo ecological results read from the input ECM data file.
LOGIC	Intermediate outputs tracking program execution flow logic.
DIST	Intermediate outputs on calculations for distance calculations.
RECIPE	Intermediate outputs on calculations for recipe calculations.
SMOOTH	Intermediate outputs on calculations for smoothing calculations.
OCCUR	Intermediate outputs on calculations for occurrence calculations.

The following entries provide examples of the use of the DEBUG keyword:

```
DEBUG LOGIC
DEBUG RECIPE
DEBUG ECM RECIPE SMOOTH
```

There are no quote strings associated with the DEBUG keyword.

7.4.3 DETAILS Keyword for the MOBILEHOME Code

The DETAILS keyword is used to activate reporting of calculations of SMOOTH or OCCUR calculations by realization to output files. The following is this keyword's syntax:

```
DETAILS {SMOOTH} {OCCUR}
```

Multiple DETAILS keywords can be entered with combinations of modifiers, or a single card can be entered. The following is an example that turns on reporting for detailed data for both smoothing and occurrence calculations:

```
DETAILS SMOOTH OCCUR
```

7.4.4 END Keyword for the MOBILEHOME Code

The END keyword signifies the end of all keyword data. It should be the last keyword in the keyword file. All data in the keyword file after the END keyword will be ignored. The following is this keyword's syntax:

```
END
```

There are no modifiers or quote strings associated with the END keyword.

7.4.5 EXECUTE Keyword for the MOBILEHOME Code

The EXECUTE keyword signifies that the user wishes to perform problem execution. If this keyword is not entered, then the inputs are checked for consistency, but the problem will not be executed. This is useful if the run being set up is expected to take a significant amount of computation time. The following is this keyword's syntax:

EXECUTE

There are no modifiers or quote strings associated with the EXECUTE keyword.

7.4.6 FILE Keyword for the MOBILEHOME Code

The FILE keyword is used to enter the names of input and output files except for the report file. The names of the files providing concentration data are contained in the environmental scenario file rather than in the keyword file. The following is this keyword's syntax:

FILE [modifier1 "quote1"] {modifier2 "quote2"} ... {modifier5 "quote5"}

The file names are entered in quote strings, which must be enclosed in double quotation marks. Path names up to 200 characters long are supported. The file name associated with a modifier must be entered before the next modifier is entered. At least one FILE keyword is required for every run of the code. Table 7.9 describes the modifiers associated with the FILE keyword.

Table 7.9 Modifiers Associated with the FILE Keyword in the MOBILEHOME Code

Modifier	Description
ECEMKEY	Input data file containing ecological results produced by the ECEM code.
ECEMD	Input ecological keyword file that contains the definition of the ECEM runs from which smoothed and/or masked results are to be calculated.
HEADER	Output file containing header type information associated with all of the other output files identified in this table.
SMOOTHD	Output file containing the calculated data, by realization, for each of the smoothed results. This file is required only if the SMOOTH modifier is used on the DETAILS keyword.
SMOOTH S	Output file containing summary statistics for each of the smoothed results. This file is required only if the SMOOTH modifier is used on the STATISTICS keyword.
OCCURD	Output file containing the calculated data, by realization, for the occurrence-masked results. This file is required only if the OCCUR modifier is used on the DETAILS keyword.
OCCUR S	Output file containing summary statistics for the occurrence-masked results. This file is required only if the OCCUR modifier is used on the STATISTICS keyword.

7.4.7 RANGE Keyword for the MOBILEHOME Code

The RANGE keyword is used to provide the size of the home range of a given species. The RANGE can be entered as either the radius of a circular home range or as an area. Range units are provided and the range is converted to a radius in meters if it is provided in area. The following is this keyword's syntax:

```
RANGE SPECIES="quote1"  VALUE=value1  UNITS=[ m | ha | m^2 | km^2 ]
```

The first quote string contains the ID for an ecological species for which results were calculated in the ECEM run being smoothed. Value1 is the roaming distance or area for the species. The second quote string contains the units of the RANGE value. The following is an example of the RANGE keyword record:

```
RANGE SPECIES="QCARPS"  VALUE=50  UNITS="m"
```

7.4.8 RECIPE Keyword for the MOBILEHOME Code

The RECIPE keyword is used to provide the size of the home range of a given species. The RECIPE can be entered as either the radius of a circular home range or as an area. Range units are provided and the range is converted to a radius in meters if it is provided in area. The following is this keyword's syntax:

```
RECIPE SPECIES="quote 1"  LOCATION="quote 2"  NUMCON=value1  
CONTRIBUTORS="quote 3" ... "quote k"
```

The first quote string contains the ID for an ecological species for which results were calculated in the ECEM run being smoothed. The second quote string contains the location for which the RECIPE is being entered. Value1 is the number of locations over which the smoothing is to be done for this species and location combination. The quote strings following the modifier CONTRIBUTORS are the location ID's for the locations whose results are to be averaged with this location. The following is an example of the RECIPE keyword record:

```
RECIPE SPECIES="QCARPS"  LOCATION="TH0002"  NUMCON=2  CONTRIBUTORS  
"TH0004" "TH0006"
```

7.4.9 REPORT Keyword for the MOBILEHOME Code

The REPORT keyword is used to define the name of the output report (log) file. It must be the first keyword entered in the keyword file. The following is this keyword's syntax:

```
REPORT ["quote"]
```

The name of the report file is entered in a quote string. File names up to 72 characters long are supported, and path names can be included. The following is an example REPORT keyword record:

```
REPORT "/SAC/SystemCodes/MobileHome/Test1.rpt"
```

7.4.10 SOLUTION Keyword for the MOBILEHOME Code

The SOLUTION keyword is used to select the ECEM solutions for which smoothed or occurrence-masked results are to be calculated in the MOBILEHOME code. The following is this keyword's syntax:

```
SOLUTION ["quote 1"] {"quote " }...{"quote n" }
```

The entry for each quote string must be a solution identification string (up to six characters in length). The solution identification string is case sensitive, and spaces or hyphens change the definition. The solutions selected must be a subset of the set of solutions identified in the corresponding ECEM keyword file. The following SOLUTION keyword selects the two SOLUTIONS, burden and dosrad, for analysis:

```
SOLUTION "BURDEN" "DOSRAD"
```

7.4.11 SPECIES Keyword for the MOBILEHOME Code

The SPECIES keyword is used to select the species for which smoothed or occurrence-masked results are to be calculated in the MOBILEHOME code. The following is this keyword's syntax:

```
SPECIES ["quote 1"] {"quote " }...{"quote n" }
```

The entry for each quote string must be a species identification string (up to six characters in length). The species identification string is case sensitive, and spaces or hyphens change the definition. The species selected must be a subset of the set of species identified in the corresponding ECEM keyword file. The following SPECIES keyword selects the two species, carp and smallmouth bass, for analysis:

```
SPECIES "QCARPS" "QSMBAS"
```

7.4.12 STATISTICS Keyword for the MOBILEHOME Code

The STATISTICS keyword is used to activate reporting of summary statistics from calculations of SMOOTH or OCCUR calculations to output files. The following is this keyword's syntax:

```
STATISTICS {SMOOTH} {OCCUR}
```

Multiple STATISTICS keywords can be entered with combinations of modifiers, or a single record can be entered. The following is an example that activates reporting of summary statistics for both smoothing and occurrence-masking calculations:

```
STATISTICS SMOOTH OCCUR
```

7.4.13 TIMES Keyword for the MOBILEHOME Code

The TIMES keyword identifies the times at which the calculations are to be performed. The following is this keyword's syntax:

```
TIMES [T1] {T2} ... {Tn}
```


The numerical entries T1, T2, ..., Tn are the times (whole number years) when outputs are desired. These times must be a subset of the times at which environmental data were computed and stored by the inventory, release, and transport modules. Only one TIMES record should be entered. The times entered will apply to all SMOOTH and OCCUR calculations. The following is an example TIMES keyword that requests output for the three years 2020, 2075, and 3014:

```
TIMES 2020 2075 3014
```

There are no modifiers or quote strings associated with the TIMES keyword.

7.4.14 TITLE Keyword for the MOBILEHOME Code

The TITLE keyword is used to define a single-line problem title. The problem title will be written to output files. If the title is not supplied, then the program will error terminate. The following is this keyword's syntax:

```
TITLE ["quote"]
```

The title is entered in a quote string, which must be enclosed in double quotation marks. Titles up to 72 characters long are supported. The following example defines a title for a run of the code:

```
TITLE "Example of the ecological impacts post-processor code - Test #1."
```

There are no modifiers associated with the TITLE keyword.

7.4.15 USER Keyword for the MOBILEHOME Code

The USER keyword is used to identify the user of the program. The user name will be written to output files. If the user name is not supplied, then the program will error terminate. The following is this keyword's syntax:

```
USER ["quote"]
```

The user name is entered in a quote string, which must be enclosed in double quotation marks. User names up to 16 characters long are supported. The following example defines John Q. Public as the user running the code:

```
USER "John Q. Public"
```

There are no modifiers associated with the USER keyword.

8.0 SAC Data Viewer (SACView)

This section contains instructions for using the SACView data extraction tool. SACView has a Windows user interface and simplifies viewing the contents of environmental concentration data files and the results files generated by all of the impacts programs. SACView allows creation of smaller customized data sets from the large data files that can be further analyzed using a spreadsheet or graphical analysis tool. SACView assists the user in defining the customized data set by presenting screens that allow the user to select from the various elements within the larger data set.

The following are references to other parts of this document that will help clarify the data types that can be retrieved by SACView:

- Concentration analysis will consist of selecting information from binary files that were created by the inventory, release, and transport codes. This data will be viewed through concentration analysis and the files are considered to reside in the ECDA. (see Sections 2.4 and 2.4.1).
- Foods analysis will consist of selecting information from binary files that were created as a result of the ecological impact analysis. This data will be viewed through concentration analysis and the files are considered to reside in the FCDA. (see Section 4.3.2.7)
- Cultural analysis will consist of selecting information from files that were created by cultural impacts model (see Section 3.3.2).
- Ecological analysis will consist of selecting information from files that were created by the ecological impacts model (see Section 4.3.2).
- Human analysis will consist of selecting information from files that were created by the human impacts model (see Section 5.3.2).
- Economic analysis will consist of selecting information from files that were created by the Tri-Cities economic regional model (see Section 6.3.2).

The following conventions are used in the descriptions for using the SACView tool:

- Screen names are capitalized (SAC SELECTION).
- Button and check box names appear in bold (**Human, Summary Data**).
- Framed categories (sections of a screen) and tab labels appear in italics (*Level of Analysis*).

8.1 Getting Started

SACView is written in Visual Basic and runs only under the Windows operating system; however, the data files to be viewed can reside either on a Windows system or a Linux system. SACView is launched from the Windows Start menu. The first screen displays a series of buttons, along with the version, date, and time the SACView application was built. This screen is called SAC SELECTION. Use the buttons that appear in the center of this screen (see Figure 8.1) to select the impact type or to select concentrations (ECDA/FCDA).



Figure 8.1 Selecting a Data Type in SACView

SACView can receive input from the impact codes (human, ecological, economic, and cultural) and can read concentration data that resides in the Environmental Concentration Data Accumulator (see Section 2.4) or concentration data that resides in the Food Concentration Data Accumulator (see Section 4.3.2.7). When you click on one of the data types found on the SAC Selection screen you will immediately launch the LOCATING FILES screen which will be described next. To terminate the SACView run from this screen, click the **Exit** button. To exit the program after you have continued to other screens, click the **Cancel** button found on that screen. SACView will state that selections will be lost and then return to the SAC SELECTION screen where you can click **Exit**. SACView will require you to verify that you do indeed wish to exit.

8.2 The Locating Files Screen

After selecting one of the impact types or concentrations, you will select a header file that contains information based on this data type. The purpose of the LOCATING FILES screen is to navigate to the header file that contains details about this data set. Examples of header files are found in the following tables:

- Table 3.3 for the cultural impact model.
- Table 4.4 for the ecological impact model.
- Table 5.3 for the human impact model.
- Table 6.3 for the economic impact model.
- Table 2.13 of Eslinger et al. (2004) for the ECDA model.
- Table 4.8 for the FCDA model.

A *Select Drive* window, a *Select Directory* window, and a *Select File* window will assist in navigating to the header file. Before selecting the header file consider modifying some file type and path options. The next two sections describe properties that help guide the navigation to the input header file.

8.2.1 Header File Details

In the upper left hand corner, in the frame labeled *Header File Details* is the *Select Drive* and the *extension filter* windows (Figure 8.2).

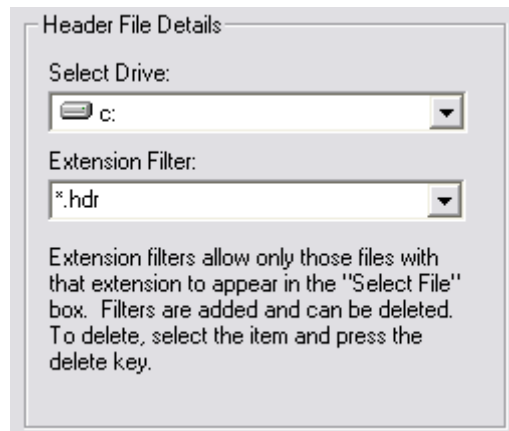


Figure 8.2 Drive Selection and Extension Filter

Set up the file filter and select the drive:

- To select a drive, open the drop-down list and highlight the desired drive.
- To control the file types that appear in the *file selection* window select the desired extension to filter out all other file types that may appear in this window. The list starts with the default file type that has an .hdr extension. The result is that only files with the .hdr extension will appear in the list. Others may be added by entering a file name or type in the *Extension Filter* box (for example, *.* and *.txt). The selected file should be the header file that defines the desired data set.

8.2.2 Setting up the Path to the Data

The next figure, *Setting Path to Data Files*, provides options for directing SACView to the location of the data. If the user intends to use SACView across the network, the path to the data read from the header file may not be correct. (There are references to tables at the beginning of Section 8.2 that give examples of header files. The data path locations are found near the bottom of the table.) There are three options for selecting the correct path on this screen (Figure 8.3):

1. Do nothing and the path that is found in the header file will be used as the path to the data. This option is valid when the system that is hosting SACView is the same system where both the header file and the data files were originally created.
2. Click to **Use same path as header file**. SACView will set the path to the data files to be the same as that of the header file. If all the files are in the same directory this is a valid option.

3. Click **Use special path**. If the header file and the data are not located in the same directory and neither of the previous two options can provide an acceptable path for the computer system that is currently accessing the data, the user is given the opportunity to provide the exact path to the data. SACView is capable of using a relative path to navigate to the data files, such as: “\\SAC\data.sac\ECDA“. If you enter a path it will be saved by SACView for future use when **OK** is pressed.

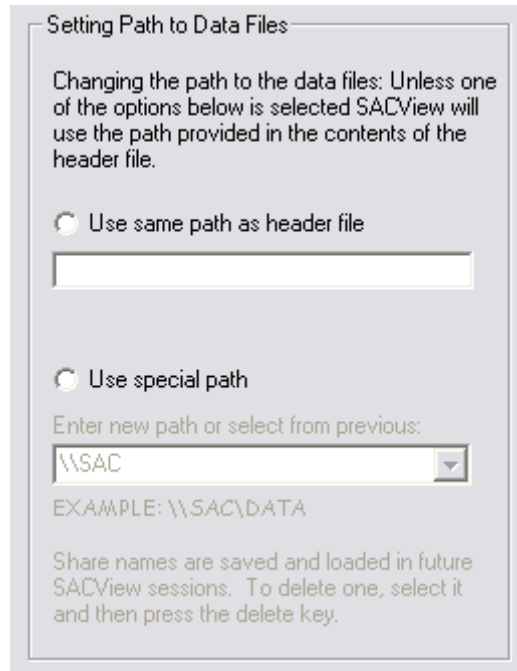


Figure 8.3 Setting Path to Data Files

To clean up this list under **Use special path**, select a path and press the delete key. The list will be updated when **OK** is pressed. If you press **cancel** from this screen the list will not be updated.

8.2.3 Selecting the Header File

The last step will be to select the header file from the *Select File* window (see Figure 8.4). Once the desired directory has been located and opened (double click each directory to open it) the file window will be populated with the available files that have an extension matching the extension set by the filter under *Header File Details* (see Section 8.2.1). Select a file and open it in one of two ways:

- Single-click the file name and click **OK**.
- Double-click the file name.

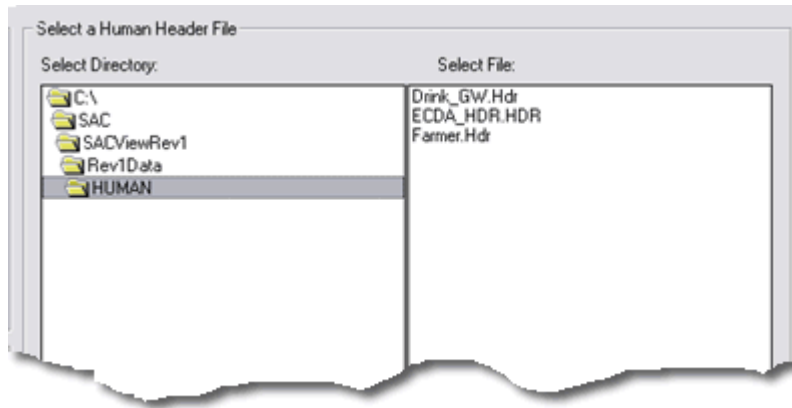


Figure 8.4 Navigating to the Header File in SACView

SACView will verify that you have selected a file that matches the selection you made on the SAC SELECTION screen. If the selected header file does not match that data type, an error message will appear (Figure 8.5):

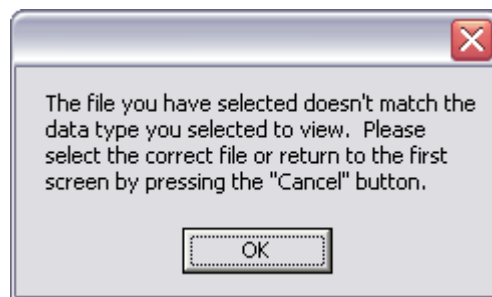


Figure 8.5 Selected Header File doesn't match data type.

After you click the **OK** button in the message box, SACView will remain at the LOCATING FILES screen to allow you to select a header file that matches your previous selections. If the type of data you selected is incorrect, click **Cancel** to return to the SAC SELECTION screen and select the correct data type.

8.3 Displaying the Contents of the Header File

Once you have selected the correct header file type, click **OK**. The HEADER CONTENTS screen will open. A label at the top of the screen confirms the data type that was selected on the SAC SELECTION screen.

8.3.1 Summary Run Information

Several blocks of information are displayed at the top of the screen that define the data set described in the header file. Table 8.1 describes the data from an example run.

Table 8.1 Summary Information from Header File displayed by SACView

Name	ECEM
User:	Paul W. Eslinger
Title:	SACView Rev 0 Initial case – 11 realizations
Version:	2.00.A.9
Date of Run:	4 Feb 2002
Run ID:	20020220133056
Realizations:	11

8.3.2 Level of Analysis and Other Options for Selection

At the bottom of the HEADER CONTENTS screen, you must make two selections that further define the data to be extracted. The *Level of Analysis* determines whether summary or detailed data are to be extracted. You must select the *Level of Analysis* first: **Summary Data** or **Detailed Data**. The *Other Options* vary depending on the impact type you selected. When changing the *Level of Analysis*, any *Other Options* that were selected will not be preserved.

Figure 8.6 shows the Human Model options. Neither **SummaryData** or **Detailed Data** data have *Other Options* available.

Level of Analysis

☒ Summary Data

☐ Detailed Data

Other Options

(NONE)

Disabled options indicate a valid file was not found for this option.

Figure 8.6 Human Model Options in SACView

For the Ecological Model, as displayed in Figure 8.7, there are no *Other Options* currently available for either **SummaryData** or **Detailed Data**.

Level of Analysis

☒ Summary Data

☐ Detailed Data

Other Options

(NONE)

Disabled options indicate a valid file was not found for this option.

Figure 8.7 Ecological Model Options in SACView

Figure 8.8 shows the Economic Model options. Both **Summary Data** and **Detailed Data** can have all three *Other Options* available — **Triggers**, **Effects**, and **Economic Change**.

Level of Analysis	Other Options
<input checked="" type="radio"/> Summary Data	<input checked="" type="radio"/> Triggers
<input type="radio"/> Detailed Data	<input type="radio"/> Effects
	<input type="radio"/> Economic Change

Disabled options indicate a valid file was not found for this option.

Figure 8.8 Economic Model Options in SACView

Figure 8.9 and Figure 8.10 demonstrate the Cultural Model options. Summary data and detailed data can have Sites or Areas as *Other Options*. Map data has no *Other Options*.

Level of Analysis	Other Options
<input checked="" type="radio"/> Summary Data	<input checked="" type="radio"/> Sites
<input type="radio"/> Detailed Data	<input type="radio"/> Areas
<input type="radio"/> Map Data	

Disabled options indicate a valid file was not found for this option.

Figure 8.9 Cultural Model Options for **Summary** and **Detailed Data** in SACView

Level of Analysis	Other Options
<input type="radio"/> Summary Data	(NONE)
<input type="radio"/> Detailed Data	
<input checked="" type="radio"/> Map Data	

Disabled options indicate a valid file was not found for this option.

Figure 8.10 Cultural Model Options for **Map Data** in SACView

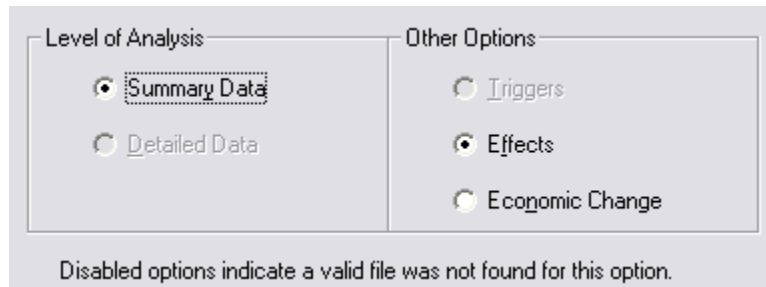
Figure 8.11 shows Concentration data options. The data found in the ECDA can only be viewed at the **Detailed Data** *Level of Analysis*, and there are no *Other Options* available.

Level of Analysis	Other Options
<input type="radio"/> Summary Data	(NONE)
<input checked="" type="radio"/> Detailed Data	

Disabled options indicate a valid file was not found for this option.

Figure 8.11 Concentration Data Options in SACView

Often, a set of data may not have all the options available as indicated in Figure 8.12. This is determined by the choices made when the particular impacts data set was created. For this SAC run there was no **Detailed Data** file or **Triggers** created.



Level of Analysis	Other Options
<input checked="" type="radio"/> Summary Data	<input type="radio"/> Triggers
<input type="radio"/> Detailed Data	<input checked="" type="radio"/> Effects
	<input type="radio"/> Economic Change

Disabled options indicate a valid file was not found for this option.

Figure 8.12 Unavailable Options for *Level of Analysis* and *Other Options*

At the bottom of the HEADER CONTENTS screen, click the **OK** button to bring up the next screen which will present the next set of items to select from. To return to the main screen, SAC SELECTION, click the **Cancel** button; all selections made to this point will be lost.

8.4 Impact/Concentration Screens

Although the next screen will be referred to by the name IMPACT SCREEN, one of the following names will appear at the top of the screen. The name that appears depends on the data type selection made on the SAC SELECTION screen.

- Human Impact
- Ecological Impact
- Economic Impact
- Cultural Impact
- ECDA Concentrations
- FCDA Concentrations

SACView is now prepared to display the information found in the header file selected by the user and described in Section 8.3.2. The data to be displayed reflects the type of data (impacts or concentrations), the *level of analysis* (**detailed**, **summary** or **map**), and *other options* that were selected.

The name of the header file appears in the lower left corner along with the number of realizations that make up this data set. All impact screens are designed around a series of tabs. On each tab are lists of elements that describe the data set. Specific directions are given here about how to make selections from these lists. The purpose of this process is to refine the data set that will be extracted. The information is displayed in tabular design as indicated in Figure 8.13.

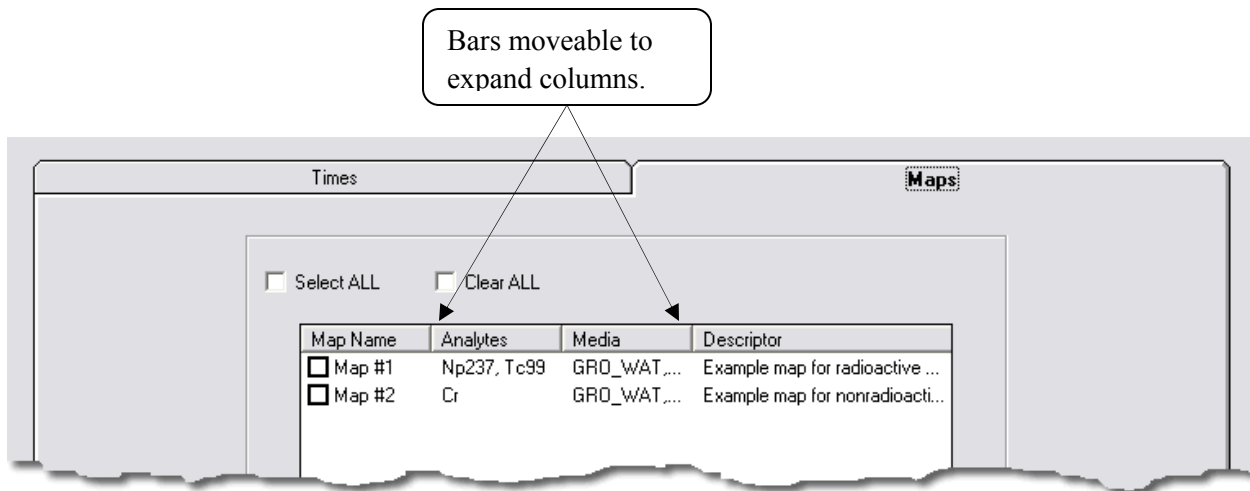


Figure 8.13 Tabular Design to Categorize the Information

The lists that appear on the tabs sometimes have columns to display multiple sets of information concerning the topic. There are four columns in the example above. Often the data displayed in a column is longer than the default column width. You may drag the bars left or right to widen the viewing area to display a greater portion of the information in the column. Often, scroll bars are available to make viewing a long list possible.

You must make selections on each tab. Some tabs, particularly *Analytes* and *Species*, may have more than one list. If a required selection is not made and the user attempts to extract the data by selecting **OK**, SACView will not continue; instead, a warning message will be displayed to notify the user that the selection process is not complete. Click the **OK** button in the warning box and SACView will return to the tab that needs completing. Make a selection, and click the **OK** button again. Further details will be given below defining the specific item selections for each type of data—Human, Ecological etc.

Most tabs on the IMPACT SCREEN will have **Select ALL** and **Clear ALL** options. (For FCDA Concentrations, the *Analytes* and *Foods* tabs are an exception. Only one item may be selected.) When the checkbox for **Select ALL** is checked, all options that appear in the tab will become selected. A strategy that can be used to select most of the items is to choose **Select ALL** and then uncheck individual items that are not to be included. The **Clear ALL** checkbox will remove all selected items (Figure 8.14).

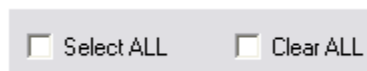


Figure 8.14 Select ALL or Clear ALL Options for Lists

8.4.1 Human Impact Selections

While selecting the *Level Of Analysis* and *Other Options* on the previous HEADER CONTENTS screen as described in Section 8.3.2, if you select **Summary Data** or **Detailed Data** and **Human Impacts**. The

IMPACT SCREEN display has three tabs: *Times*, *Locations*, and *Analytes and Solutions*. You must make at least one selection on each tab except for the *Analytes and Solutions* tab. The analytes have been categorized into three separate lists (see Figure 8.15) to help you in the selection process. The lists are *Radioactive Analytes*, *Hazardous Analytes*, and *Carcinogenic Analytes*. At least one selection must be made in one of the three lists. At least one selection must be made in *Solution Types*. Therefore, a minimum of two selections must be made on this tab.

The figure displays four panels for selecting analytes and solution types:

- Radioactive Analytes:** Includes checkboxes for 'Select ALL' and 'Clear ALL'. The list contains: ☐ Cesium 137, ☐ Tritium, ☐ Iodine 129, and ☐ Combined radioactive analytes.
- Hazardous Analytes:** Includes checkboxes for 'Select ALL' and 'Clear ALL'. The list contains: ☐ Combined hazardous analytes.
- Carcinogenic Analytes:** Includes checkboxes for 'Select ALL' and 'Clear ALL'. The list contains: ☐ Carbon Tetrachloride, ☐ Hexavalent Chromium, and ☐ Combined carcinogenic analytes.
- Solution Types:** Includes checkboxes for 'Select ALL' and 'Clear ALL'. The list contains: ☐ External dose, ☐ Ingestion dose, ☐ Inhalation dose, ☐ Analyte dose, ☐ Combined dose for analyte type, and ☐ Drinking water dose (radioactive).

Figure 8.15 Selection Analytes and Solution Types for the Human Impact

8.4.2 Ecological Impact Selections

The Ecological IMPACT SCREEN has only one set of tabs because there were no *Other Options* to select on the previous HEADER CONTENTS screen. The tabs that are displayed on the IMPACT SCREEN for both **Summary Data** and **Detailed Data** will be *Times*, *Locations*, *Analytes*, *Species*, and *Media and Solutions*.

The *Analytes* are grouped into the following categories:

- Organic radioactive analytes
- Non-organic (inorganic) radioactive analytes
- Organic stable analytes
- Non-organic (inorganic) stable analytes

The *Species* are grouped into the following categories:

- Terrestrial plants
- Aquatic plants
- Terrestrial animals
- Aquatic animals

The following are the available *Media Types*:

- AIRC denotes air concentration
- AIRD denotes air deposition
- GWAT denotes ground water concentration
- PWAT denotes pore water concentration (river bottom)
- SEDI denotes sediment concentration (river bottom).
- SEEP denotes seep water concentration (river bank)
- SODR denotes dry (non-irrigated) soil concentration
- SOGW denotes groundwater irrigated soil concentration
- SORP denotes riparian soil concentration
- SOSW denotes surface water irrigated soil concentration
- SWAT denotes surface water (river)

The following are the available *Solution Types*: (See Table 4.12)

- BURDEN – Body burden
- DOSDER – Dermal Dose
- DOSING – Ingestion Dose
- DOSINH – Inhalation Dose
- BMTISS – Benchmark Tissue Value
- CONCEN – Media Concentration (paired with the Media Types listed above)
- DOSRAD – Radioactive Dose
- SUMRAD – Sum of Radioactive Dose.

The rules for selecting ecological data are more complex than for other impact types:

- A *Time* and *Location* must always be selected.
- If the goal is to view concentrations only, then one or more *Analytes*, one or more *Media Type*, and the **CONCEN** *Solution Type* must be selected. This will allow viewing of the concentration data used in the calculations.
- If the goal is to view species data, then one or more *Analytes*, one or more *Species*, and one or more *Solution Types* must be selected. Occasionally, the user may only be interested in viewing the summed radionuclide dose. In this case, select only *Species* and the **SUMRAD** *Solution Type*. The output will consist of the radioactive dose summed over all radioactive analytes for the animal and/or plant species that are selected.

- Other combinations can be made. An *Analyte*, *Species*, **SUMRAD**, **CONCEN**, and other *Solution Types* may be selected simultaneously. Please note, however, if a *Species* is selected, then there must always be a *Solution Type* selected. The media types and **CONCEN** are tied together (see Figure 8.16). When selecting **CONCEN**, all items in the *Media Type* list will be selected. When selecting a media type, then the **CONCEN** solution will become selected.

The screenshot displays two selection panels. The top panel, titled 'Media Type', contains 'Select ALL' and 'Clear ALL' buttons above a table with columns 'Media' and 'Descriptor'. The table lists six media types, all of which are checked: AIRC (Air concentration), AIRD (Air deposition), GWAT (Groundwater concentration), PWAT (Pore water concentration), SEDI (Sediment concentration), and SFFP (Seep (sprink) water concentration). The bottom panel, titled 'Solution Type', also has 'Select ALL' and 'Clear ALL' buttons above a table with columns 'Solution' and 'Descriptor'. This table lists three solution types: DOSRAD (Radioactive dose), CONCEN (Media concentration), and SUMRAD (Sum of radioactive dose). Only the 'CONCEN' checkbox is checked.

Figure 8.16 Selections of Media Type and Solution Type

Table 8.2 summarizes the grouping of ecological selections.

Table 8.2 Summary of Ecological Selection Options

Analyte Selected	Species Selected	Media Type Selected	Solution Type	Data Viewed
Yes	No	Yes	CONCEN	Concentration data only.
No	Yes	No	SUMRAD	Radioactive dose summed over all radioactive analytes for the selected species.
Yes	Yes	No	See other solutions in Table 4.12	Results listed per analyte, species, and solution combinations selected.

Analyte Selected	Species Selected	Media Type Selected	Solution Type	Data Viewed
Yes	Yes	Yes	CONCEN plus another solution or SUMRAD	Data will be included as defined in the previous three table rows.

8.4.3 Economic Impact Selections

Four tabs will appear on the IMPACT SCREEN if **Summary Data** or **Detailed Data** and **Triggers** are selected on the previous HEADER CONTENTS screen when choosing the *Level Of Analysis* and *Other Options* as described in Section 8.3.2. The tabs will be labeled *Times*, *Locations*, *Products and Activities*, and *Triggers*. At least one selection is required on each tab except for the *Products and Activities* tab, which requires at least one selection for each list *Agricultural Product* and *Recreational Activity*. On the final tab, a *Trigger* must be selected.

If **Effects** is selected instead of **Triggers** on the previous HEADER CONTENTS screen, then the tabs will look the same as described above except for the fourth tab, which will now have *Effects* instead of *Triggers*. At least one selection must be made from each list just as described for *Triggers*.

If **Economic Changes** is selected instead of **Triggers** on the previous HEADER CONTENTS screen, the tabs will be labeled *Times*, *Locations*, *Sectors*, and *Impacts*. There will be only one list per tab and a selection will be required in each list.

8.4.4 Cultural Impact Selections

The Cultural Impact screen has only two tabs no matter what selections are made on the previous screen.

8.4.4.1 Cultural Summary and Detailed Selections

If **Summary Data** or **Detailed Data** and **Sites** are selected on the HEADER CONTENTS screen, there will be tabs containing lists of *Times* and *Sites*. One selection must be made on each tab. If, however, **Areas** is selected, there will be lists of *Times* and *Areas*. One selection must be made on each tab.

8.4.4.2 Cultural Map Selections

If the *Level of Analysis* selected is **Maps**, two tabs will display *Times* and *Maps*. One selection must be made on each tab.

8.4.5 Concentration Selections

To view concentration data, select from data sets that were created during the execution of the inventory, release, and transport codes represented by the left side of the diagram shown in Figure 1.1. The results created by these codes are in binary format and can be read by SACView. There are two types of concentration files that can be opened by SACView: Environmental Concentration Data Accumulator (ECDA) files and Food Concentration Data Accumulator (FCDA) files. The display will be slightly different for each type.

8.4.5.1 ECDA Concentrations

As mentioned in Section 2.4, a separate data file is created for each analyte. The ECDA CONCENTRATIONS screen will display *Times*, *Locations*, and *Analytes and Media* and a selection is required in each list. Figure 8.17 is an example of the *Analytes and Media* tab for ECDA concentration data.

The screenshot shows the 'Analytes and Media' tab selected. The 'Media Type' section includes a table with the following data:

Media	Descriptor
<input type="checkbox"/> GWAT	Groundwater concentrations
<input type="checkbox"/> SEEP	Seep water (riparian zone) concentrati...
<input type="checkbox"/> SWAT	Surface water (river) concentrations
<input type="checkbox"/> PWAT	Pore water (river bottom) concentrations
<input type="checkbox"/> SEDI	Sediment (river bottom) concentrations
<input type="checkbox"/> SORP	Soil (riparian zone) concentrations
<input type="checkbox"/> SODR	Non-irrigated upland soil concentrations
<input type="checkbox"/> SOGW	Groundwater irrigated upland soil conc...
<input type="checkbox"/> SOSW	Surface water irrigated upland soil con...
<input type="checkbox"/> AIRC	Air concentrations
<input type="checkbox"/> AIRD	Air deposition rates

The 'Contaminating Medium' section has a list box titled 'Analyte Name' with the following items:

- ☐ Carbon Tetrachloride
- ☐ Hexavalent Chromium
- ☐ Cesium 137
- ☐ Tritium
- ☐ Iodine 129

Figure 8.17 Analytes and Media Tab for ECDA Concentrations

8.4.5.2 FCDA Concentrations

In FCDA Concentrations there is a data file created for each analyte and food type pair. The FCDA CONCENTRATIONS screen will display *Times*, *Locations*, *Analytes* and *Foods*. These files were created by the ECEM (See Section 4.3.2.7) program. There is a small difference in the selection process on the *Analytes* and *Foods* tabs. Only one item per tab may be selected. Figure 8.18 is an example of the *Foods* tab. Notably absent are the check boxes to select all and clear all.

Times Locations Analytes **Foods**

Terrestrial Plants

Food Name

- ☐ Dense sedge
- ☐ Dense sedge - upland
- ☐ Fungi
- ☐ Mulberry
- ☐ Mulberry - upland
- ☐ Generic grain species

Aquatic Plants

Food Name

- ☐ Periphyton
- ☐ Phytoplankton

Terrestrial Animals

Food Name

- ☐ American coot
- ☐ American coot - upland
- ☐ Chicken eggs - upland
- ☐ Coyote
- ☐ Mule deer
- ☐ Milk cow

Aquatic Animals

Food Name

- ☐ Daphnia magna

Please select only ONE on this page.

Figure 8.18 Foods Tab for FCDA Concentrations

8.5 Saving the Data to File (SACView output files)

At the bottom of each IMPACT SCREEN, there is a button that provides the capability for saving the extracted data to a file that can be opened by a spreadsheet or other analysis program. All output data are in ASCII comma-delimited format. Data will not be saved until a file name is provided. A warning is displayed on the screen to remind you that this information has not yet been provided (Figure 8.19).

Note

ECDA_HDR.HDR
Number of Realizations: 25

Data WILL be saved.

Save As Excel Data Cancel OK

Figure 8.19 Saving the Data to File

To save the selected data in SACView, use the FILE NAME REQUEST screen to locate the drive and directory and enter a file name (Figure 8.20).

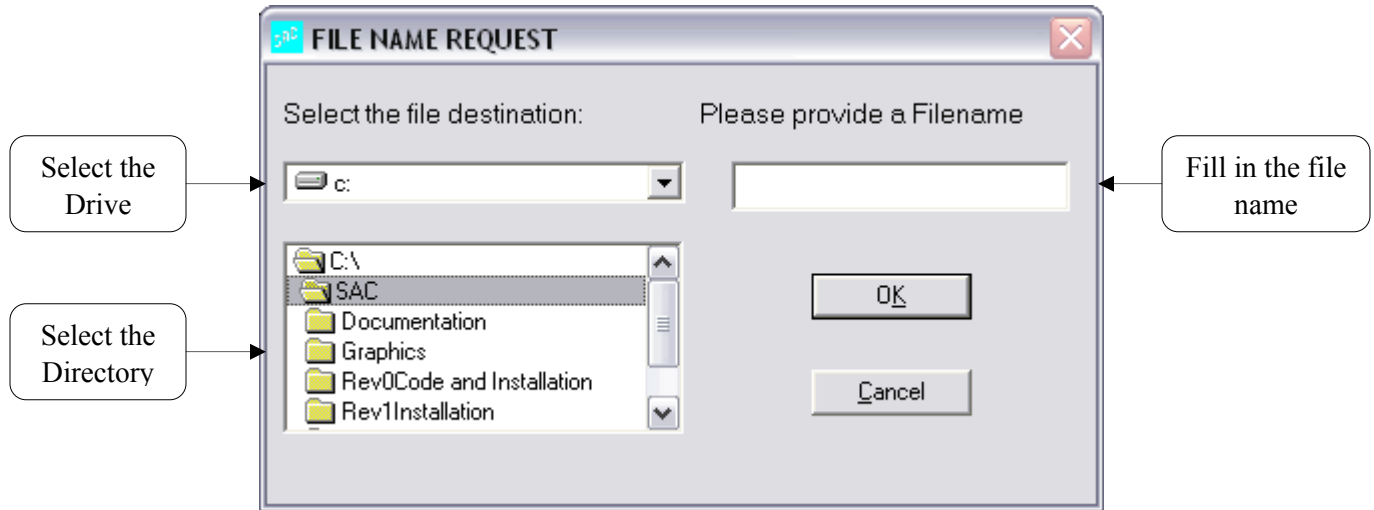


Figure 8.20 FILE NAME REQUEST Screen

The lists on the left of the screen are designed to assist in locating where the file is to be saved. In the input box located in the upper right corner, enter the file name to be used. The output is a comma-delimited file in ASCII format. If the “.csv” extension is used, the file can be imported without further conversions into Microsoft Excel.

After you provide a file name and click “OK,” SACView will return to the IMPACT SCREEN. The warning that appears above the **Save** button is changed to read “Data WILL be saved” as shown In Figure 8.21.

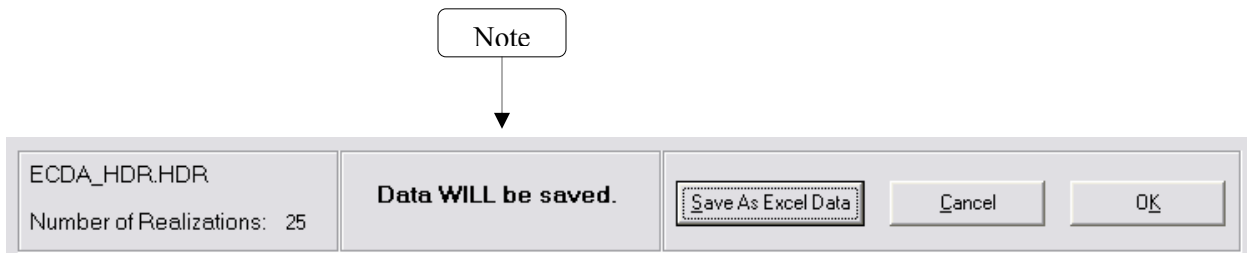


Figure 8.21 Verification Screen for the Data Save Option

If the impact type is Cultural and the **Map Data** option is selected, the **Save** button will display the caption “Save As Map Data.” In this case, data are output using comma-separated triple pairs: the first two entries of the triple are the easting and northing coordinates, and the last entry is the data value. The coordinates are expressed as meters in the Lambert Projection on the Washington State Plane (NAD 83).

8.6 Data Display Screen

While SACView is loading the results that reflect the user's selections several messages are displayed to inform the user that SACView is working to compile the results. Figure 8.22 through Figure 8.25 demonstrate the messages that will appear:

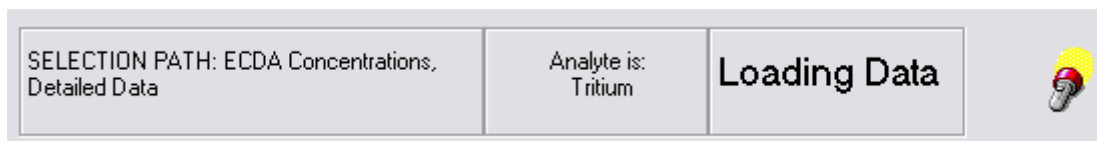


Figure 8.22 Inform User Data is being loaded

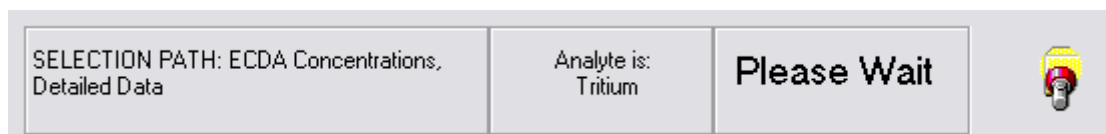


Figure 8.23 Reminder to "Please Wait"

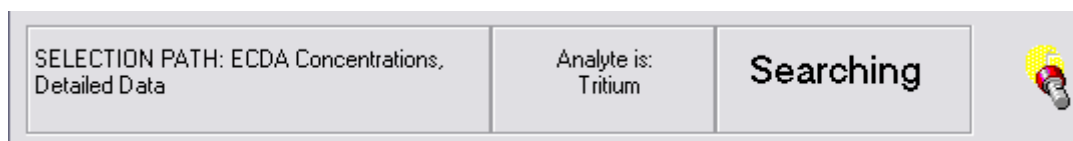
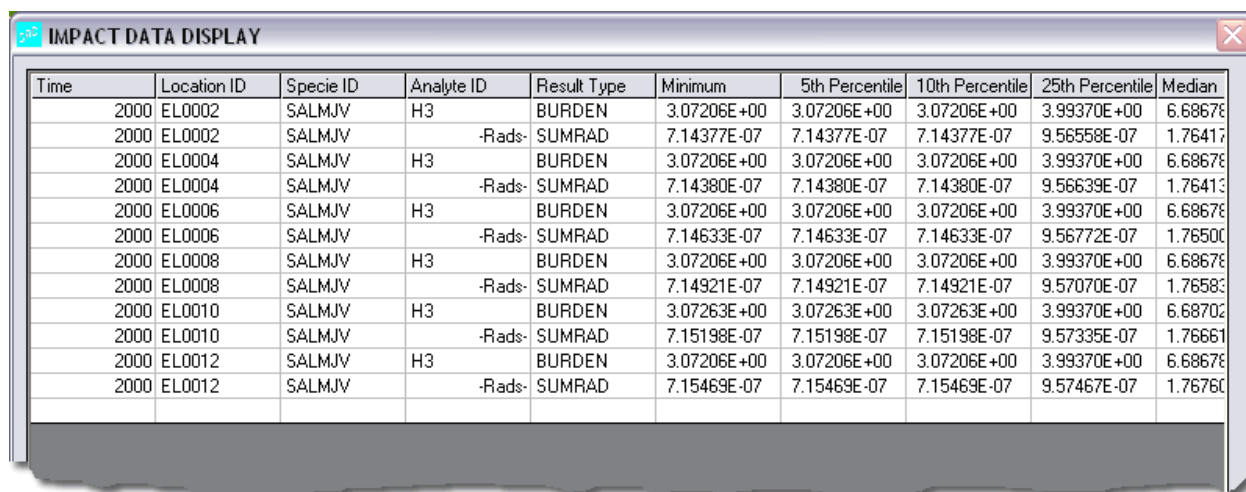


Figure 8.24 SACView searching for results



Figure 8.25 Loading of data is now complete.

The results are output to a grid on a screen labeled either IMPACT DATA DISPLAY or CONCENTRATIONS DATA DISPLAY. Scroll bars are available to make viewing the entire list possible. The columns in this display are not adjustable. Data that do not fit in the columns can be viewed by saving to a file and reviewing the data in a spreadsheet tool. A maximum of 3,000 lines of data is displayed on the grid, and all lines of data will be saved to the file if a file name is provided. Figure 8.26 shows an example of a **summary** impact data display.



Time	Location ID	Specie ID	Analyte ID	Result Type	Minimum	5th Percentile	10th Percentile	25th Percentile	Median
2000	EL0002	SALMJV	H3	BURDEN	3.07206E+00	3.07206E+00	3.07206E+00	3.99370E+00	6.6867E
2000	EL0002	SALMJV	-Rads-	SUMRAD	7.14377E-07	7.14377E-07	7.14377E-07	9.56558E-07	1.76417
2000	EL0004	SALMJV	H3	BURDEN	3.07206E+00	3.07206E+00	3.07206E+00	3.99370E+00	6.6867E
2000	EL0004	SALMJV	-Rads-	SUMRAD	7.14380E-07	7.14380E-07	7.14380E-07	9.56639E-07	1.76413
2000	EL0006	SALMJV	H3	BURDEN	3.07206E+00	3.07206E+00	3.07206E+00	3.99370E+00	6.6867E
2000	EL0006	SALMJV	-Rads-	SUMRAD	7.14633E-07	7.14633E-07	7.14633E-07	9.56772E-07	1.76500
2000	EL0008	SALMJV	H3	BURDEN	3.07206E+00	3.07206E+00	3.07206E+00	3.99370E+00	6.6867E
2000	EL0008	SALMJV	-Rads-	SUMRAD	7.14921E-07	7.14921E-07	7.14921E-07	9.57070E-07	1.76583
2000	EL0010	SALMJV	H3	BURDEN	3.07263E+00	3.07263E+00	3.07263E+00	3.99370E+00	6.68702
2000	EL0010	SALMJV	-Rads-	SUMRAD	7.15198E-07	7.15198E-07	7.15198E-07	9.57335E-07	1.76661
2000	EL0012	SALMJV	H3	BURDEN	3.07206E+00	3.07206E+00	3.07206E+00	3.99370E+00	6.6867E
2000	EL0012	SALMJV	-Rads-	SUMRAD	7.15469E-07	7.15469E-07	7.15469E-07	9.57467E-07	1.76760

Figure 8.26 Example of Extraction Results Displayed in SACView

Summary information about the selections that were made is displayed at the bottom of the screen. In the frame to the left, the composite selection path that was taken to get to this point is summarized. The total number of records that are displayed in the grid is reported in the center frame. A frame that informs the user of the processing status indicates **Loading Complete** in Figure 8.25.

Occasionally, a message will appear informing that no data can be found. In this case, you have selected a set of options that does not match with any computed data. In this case, you should try a different set of selection options. For example, ECEM (ecological) can compute equivalent water concentrations, which apply only to aquatic animals. The same run could also compute body burdens that apply to both aquatic and terrestrial animals. It is possible to select options that identify a harvest mouse and the equivalent water concentration solution. However, because the harvest mouse is a terrestrial animal, the equivalent water concentration solution does not apply. No results will be displayed.

8.6.1 Media Units

When concentration data are being extracted, a button is displayed to provide access to the units that were used in the calculations for the various media types. This button is illustrated in Figure 8.27.

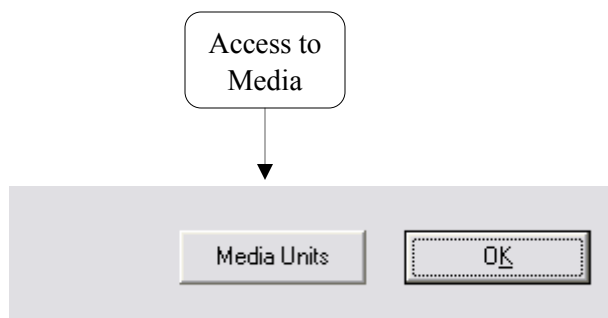


Figure 8.27 Accessing the Media Units

Click the **Media Units** button to open a small screen that lists the data units for each media type (Figure 8.28).



Figure 8.28 Display of Data Units for Media Concentrations

8.7 Reselect/Exit

Figure 8.29 shows the terminal screen that appears following the extraction of a customized data set in SACView. Four options are presented:

- **New Impact** – Click this button to discard all selections except the impact type and return to the IMPACT SELECTION screen described in Section 8.1. A new impact may be selected as well as the type of data to extract.
- **Summary / Detailed** – Click this button to discard all elemental selections made on the IMPACT SCREEN and return to the HEADER CONTENTS screen described in Section 8.3. A new *Level of Analysis* and/or *Other Options* may be selected to continue the extraction process. At this level, the current impact and type of data (impacts or concentrations) remain the same.
- **Elemental Selections** – Click this button to save all selections within SACView and return to the IMPACT DISPLAY screen described in Section 8.4. New selections may be made from these same lists that define the current impact type.
- **Exit** – Click this button to exit the application. In order to prevent inadvertent loss of work, SACView will ask you to confirm the requested action.

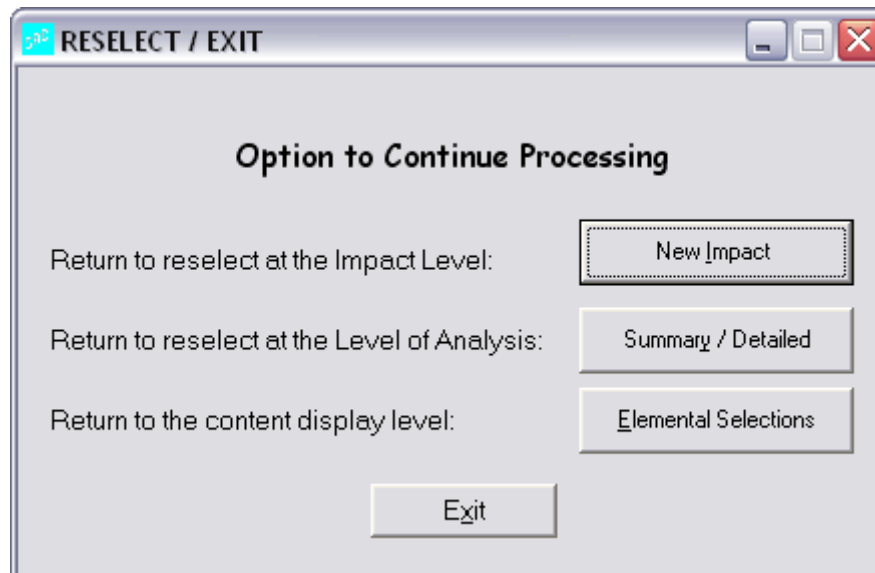


Figure 8.29 Reselect or Exit Screen

9.0 Impact Differencing Tool (ImDiff)

9.1 Overview

The river transport model in the SAC Rev. 1 computer codes can be run with or without background concentrations from upriver sources. A typical method of analyzing a Hanford-related problem is to run the river code with two data sets. First, a transport run is made using background values, but no source term from the Hanford Site is introduced. Then, another transport run is made that is identical to the first run except a Hanford source term is introduced. If the impact codes are run using these two data sets, then their results can be differenced to determine the contribution from Hanford sources.

The differencing does not currently apply to impacts based on groundwater concentrations. The groundwater model in SAC, Rev. 1, is not set up to model background concentrations.

A utility code called ImDiff is provided to facilitate differencing the results from the impact models. This code handles all four impact models: cultural, ecological, economic, and human. Two computer runs of an impacts model are required to use ImDiff. The impact runs to be differenced must be identical with the exception of the concentration files they use.

9.1.1 Location in the Processing Sequence

The ImDiff code requires access only to data files developed by the SAC impact codes. In particular, every code on the left side of Figure 1.1 must have been executed to build a suite of concentration data files, and then one or more impact codes from the right side of Figure 1.1 must also have been executed.

9.1.2 How the Code Is Invoked

ImDiff can run under either the Windows or the Linux operating system. Under the Windows operating system (Releases 98, NT, or 2000), ImDiff executes in a DOS box. A run of ImDiff is initiated by entering the following command line:

```
ImDiff "Keyfilename"
```

Under the Linux operating system, ImDiff is executed through the following Bourne Shell or C Shell command:

```
imdiff.exe "Keyfilename"
```

For these commands, ImDiff or imdiff.exe is the name of the executable program and "Keyfilename" is the name of a differencing scenario keyword file. Both the name of the executable program and the keyword file may contain path information. If ImDiff is invoked without entering the name of the keyword file, then the code will prompt the user for the file name. The keyword file, which should be prepared using an editor that can handle ASCII files without leaving embedded control codes, contains text control information describing the run. If ImDiff cannot open the keyword file, then the code will terminate execution after writing an error message to the standard output device.

9.1.3 Memory Requirements

The ImDiff code uses dynamic memory allocation, so the memory requirements depend on the problem being analyzed. It is expected that most if not all of the runs of the ImDiff code will require fewer than 1.2 MB of memory.

9.2 File Definitions

The ImDiff keyword file and the report file are unique to the ImDiff code. All other files used by ImDiff were generated by an impacts code (CULTURE, ECEM, HUMAN, or TCERM) or have the same format as files generated by the impact codes.

9.2.1 Input Files

The input files for the ImDiff code are a keyword file and a suite of impact files. The following are the input files:

- **ImDiff Keyword File.** The ImDiff keyword file defines which impacts are to be differenced and controls the differencing. An example ImDiff keyword file that differences results for all four impacts models is provided in Table 9.1. Section 9.3 provides definitions for these keywords.
- **CULTURAL Model Files.** The top-level input files for the cultural impact code are the header files for SACView (see Section 3.3.2.2) for both the background and combined data runs. These files point to the other input files needed for the AREA, MAP, and SITE computation options.
- **ECOLOGICAL Model Files.** The top-level input files for the ecological impact code are the header files for SACView (see Section 4.3.2.3) for both the background and combined data runs. These files point to the other input files needed for the RESULTS computation option.
- **HUMAN Model Files.** The top-level input files for the human impact code are the header files for SACView (see Section 5.3.2.2) for both the background and combined data runs. These files point to the other input files needed for the FOOD and IMPACTS computation options.
- **ECONOMIC Model Files.** The top-level input files for the economics impact code are the header files for SACView (see Section 6.3.2.2) for both the background and combined data runs. These files point to the other input files needed for the CHANGE, EFFECTS, and TRIGGER computation options.

Table 9.1 provides an example ImDiff keyword file that differences results for all four impacts models. The ImDiff code can be used to difference results from any combination of impact models during a single run.

Table 9.1 Example Keyword File for the ImDiff Code

REPORT "Test_01.rpt"
USER "Paul W. Eslinger"
TITLE "Test differencing for all impact models in the ImDiff code"
EXECUTE
!
MODEL HUMAN
BACKGROUND HEADER = "\\Test_01\Human\Human_Background.Hdr"

```
COMBINED      HEADER = "\\Test_01\\Human\\Human_Combined.Hdr"
DIFFERENCED  HEADER = "\\Test_01\\Human\\Human_Differenced.Hdr"
OPTION FOOD
  DETAILS     = "\\Test_01\\Human\\Human_Differenced_Food.Csv"
  STATISTICS  = "\\Test_01\\Human\\Human_Differenced_Food_Statistics.Csv"
OPTION IMPACTS
  DETAILS     = "\\Test_01\\Human\\Human_Differenced_Impacts.Csv"
  STATISTICS  = "\\Test_01\\Human\\Human_Differenced_Impacts_Statistics.Csv"
ENDMODEL
!
MODEL ECOLOGICAL
BACKGROUND   HEADER= "\\Test_01\\Ecologic\\Ecologic_Background.Hdr"
COMBINED      HEADER= "\\Test_01\\Ecologic\\Ecologic_Combined.Hdr"
DIFFERENCED  HEADER= "\\Test_01\\Ecologic\\Ecologic_Differenced.Hdr"
OPTION RESULTS
  DETAILS     = "\\Test_01\\Ecologic\\Ecologic_Dif_Results.Csv"
  STATISTICS  = "\\Test_01\\Ecologic\\Ecologic_Dif_Results_Statistics.Csv"
ENDMODEL
!
MODEL ECONOMIC
BACKGROUND   HEADER= "\\Test_01\\Economic\\Econ_Bck.hdr"
COMBINED      HEADER= "\\Test_01\\Economic\\Econ_Com.Hdr"
DIFFERENCED  HEADER= "\\Test_01\\Economic\\Econ_Dif.Hdr"
OPTION CHANGE
  DETAILS= "\\Test_01\\Economic\\ECHG_01_Dif_Det.Csv"
  STATISTICS= "\\Test_01\\Economic\\ECHG_01_Dif_Sta.Csv"
OPTION EFFECTS
  DETAILS= "\\Test_01\\Economic\\EFF_01_Dif_Det.Csv"
  STATISTICS= "\\Test_01\\Economic\\EFF_01_Dif_Sta.Csv"
OPTION TRIGGER
  DETAILS= "\\Test_01\\Economic\\TRIG_01_Dif_Det.Csv"
  STATISTICS= "\\Test_01\\Economic\\TRIG_01_Dif_Sta.Csv"
ENDMODEL
!
MODEL CULTURAL
BACKGROUND   HEADER= "\\Test_01\\Cultural\\Cult_Bck.hdr"
COMBINED      HEADER= "\\Test_01\\Cultural\\Cult_Com.hdr"
DIFFERENCED  HEADER= "\\Test_01\\Cultural\\Cult_Dif.hdr"
OPTION AREA
  DETAILS= "\\Test_01\\Cultural\\Cult_Dif_Det_Area.Csv"
  STATISTICS= "\\Test_01\\Cultural\\Cult_Dif_Sta_Area.Csv"
OPTION MAP
  DETAILS= "\\Test_01\\Cultural\\Cult_Dif_Det_Map.Csv"
OPTION SITE
  DETAILS= "\\Test_01\\Cultural\\Cult_Dif_Det_Sites.Csv"
  STATISTICS= "\\Test_01\\Cultural\\Cult_Dif_Sta_Sites.Csv"
ENDMODEL
END
```


9.2.2 Output Files

The output files for the ImDiff code are a report file and a suite of impacts files. The following are the output files:

- **ImDiff Report File.** The ImDiff report file echoes information from the run of the code. Table 9.2 provides an example ImDiff report file for a run that differences results for all four impacts models.
- **CULTURAL Model Files.** The following are the output differenced files for the economic impacts code:
 - **Header File for SACView** – This file format is described in Section 3.3.2.2
 - **Area Detailed Data** – This file format is described in Section 3.3.2.3
 - **Area Summary Statistics** – This file format is described in Section 3.3.2.4
 - **Map Detailed Data** – This file format is described in Section 3.3.2.5
 - **Site Detailed Data** – This file format is described in Section 3.3.2.6
 - **Site Summary Statistics** – This file format is described in Section 3.3.2.7
- **ECOLOGICAL Model Files.** The following are the output differenced files for the ecological impacts code:
 - **Header File for SACView** – This file format is described in Section 4.3.2.2
 - **Results Detailed Data** – This file format is described in Section 4.3.2.4
 - **Results Summary Statistics** – This file format is described in Section 4.3.2.5
- **HUMAN Model Files.** The following are the output differenced files for the human impacts code:
 - **Header File for SACView** – This file format is described in Section 5.3.2.2
 - **Risk Detailed Data** – This file format is described in Section 5.3.2.4
 - **Risk Summary Statistics** – This file format is described in Section 5.3.2.5
- **ECONOMIC Model Files.** The following are the output differenced files for the economic impacts code:
 - **Header File for SACView** – This file format is described in Section 6.3.2.2
 - **Economic Change Detailed Data** – This file format is described in Section 6.3.2.8
 - **EconomicChange Summary Statistics** – This file format is described in Section 6.3.2.9
 - **Effects Detailed Data** – This file format is described in Section 6.3.2.6
 - **Effects Summary Statistics** – This file format is described in Section 6.3.2.7
 - **Trigger Detailed Data** – This file format is described in Section 6.3.2.4
 - **Trigger Summary Statistics** – This file format is described in Section 6.3.2.5

Table 9.2 Example ImDiff Report File That Differences All Four Impacts Models

I I I I I I I I	M M	M M	D D D D	I I I I I I I I	F F F F F F F F	F F F F F F F F
I	M M M M		D D	I	F	F
I	M M M		D D	I	F	F
I	M M M		D D	I	F F F F	F F F F
I	M	M	D D	I	F	F
I	M	M	D D	I	F	F
I I I I I I I I	M	M	D D D D	I I I I I I I I	F	F
ImDiff Version 1.00.A.5						

Last Modified on 19 Feb 2002
Hanford and Background Impacts Differencing

Systems Assessment Capability, Rev. 0
Stochastic Ecological Pathways Risk Analysis

Developed By Battelle Memorial Institute
Pacific Northwest National Laboratories
Richland, Washington

Current Run ID = 20020219131143 User Name = Paul W. Eslinger
System Date = 02-19-2002 System Time = 13:11:43.441

The software used to generate this output is experimental
and has not been formally tested or peer reviewed.

Review Signatures

Input Prepared By: _____ Date: _____

Input Reviewed By: _____ Date: _____

Problem title for this run

Title: Test a the Economics Model in the ImDiff code

Keyword file for this run

File: "Test_01.key"

User name for this run

User: Paul W. Eslinger

Cultural model information -----

Cultural background header

File: "F:\Sac\Codes\ImDiff\Test_01\Cultural\Cult_Bck.hdr"

Cultural combined header

File: "F:\Sac\Codes\ImDiff\Test_01\Cultural\Cult_Com.hdr"

Cultural differenced header

File: "F:\Sac\Codes\ImDiff\Test_01\Cultural\Cult_Dif.hdr"

Ecological model information -----

Ecological background header

File: "F:\Sac\Codes\ImDiff\Test_01\Ecologic\Ecologic_Background.Hdr"

Ecological combined header

File: "F:\Sac\Codes\ImDiff\Test_01\Ecologic\Ecologic_Combined.Hdr"

Ecological differenced header

File: "F:\Sac\Codes\ImDiff\Test_01\Ecologic\Ecologic_Differenced.Hdr"

Economic model information -----

Economic background header

File: "F:\Sac\Codes\ImDiff\Test_01\Economic\Econ_Bck.hdr"

Economic combined header

File: "F:\Sac\Codes\ImDiff\Test_01\Economic\Econ_Com.Hdr"

Economic differenced header

File: "F:\Sac\Codes\ImDiff\Test_01\Economic\Econ_Dif.Hdr"

Human model information -----

Human background header

File: "F:\Sac\Codes\ImDiff\Test_01\Human\Human_Background.Hdr"

Human combined header

File: "F:\Sac\Codes\ImDiff\Test_01\Human\Human_Combined.Hdr"

Human differenced header

File: "F:\Sac\Codes\ImDiff\Test_01\Human\Human_Differenced.Hdr"

----- Cultural model information processing -----

. . . (Deleted records)

25 Lines Processed in PROCESS_CULTURAL_AREAS

161 Lines Processed in PROCESS_CULTURAL_MAPS

9 Lines Processed in PROCESS_CULTURAL_SITES

----- Economic model information processing -----

. . . (Deleted records)

8 Lines Processed in PROCESS_ECONOMIC_CHANGE

1152 Lines Processed in PROCESS_ECONOMIC_TRIGGER

2176 Lines Processed in PROCESS_ECONOMIC_EFFECTS

----- Ecological model information processing -----

. . . (Deleted records)

10051 Lines Processed in PROCESS_ECOLOGIC_RESULTS

----- Human model information processing -----

```
. . .  
97 Lines Processed in PROCESS_HUMAN_FOOD  
51 Lines Processed in PROCESS_HUMAN_IMPACTS
```

9.3 Keyword Definitions for the ImDiff Code

This section defines keywords needed to control the ImDiff code directly. The order in which keywords are entered does not matter for many keywords. Two keywords have a required order of appearance:

- The REPORT keyword must be the first keyword in the file.
- The END keyword must be the last keyword in the file.

The MODEL and ENDMODEL keywords must be paired. The BACKGROUND, COMBINED, DIFFERENCED, and OPTION keywords must be nested within a MODEL ... ENDMODEL pair of keywords. Other keywords cannot be used within a MODEL ... ENDMODEL pair of keywords.

In the following keyword descriptions, some data are optional and some are required. Required data are enclosed in square brackets. For AB to be required, it would be denoted by [AB]. If only one of the three items AB, BC, CD were required, it would be written as [AB|BC|CD]. The vertical bars indicate a choice of one of the items in the list. Optional items are enclosed in curly brackets; for example, the optional item DE would be denoted by {DE}. The {} or [] symbols are not entered when the keyword is constructed.

In some instances, numerical values or quote strings are associated with a modifier. In this description, the association is indicated by using the equal (=) symbol. The = symbol is not required but may be used when the keyword is constructed. When a numerical value or quote string is associated with a modifier, it must be physically entered on the input line directly after the modifier.

9.3.1 BACKGROUND Keyword for the ImDiff Code

The BACKGROUND keyword is used to point to the header file defining a data set that was generated using only background concentrations in the impact calculations. The following is this keyword's syntax:

```
BACKGROUND [HEADER="quote 1"]
```

The data set is defined by information contained in the header file developed for use by the SACView program. The name of the header file is entered in the quote string.

This keyword is only valid when entered between a MODEL and ENDMODEL pair of keywords and then applies only to the single model type. The following is an example use of this keyword for the human impacts model:

```
MODEL HUMAN  
BACKGROUND HEADER= "F:\SAC\Test_01\Human\Human_01.Hdr"  
COMBINED keyword  
DIFFERENCED keyword  
ENDMODEL
```

9.3.2 COMBINED Keyword for the ImDiff Code

The COMBINED keyword is used to point to the header file defining a data set that was generated using both Hanford derived analytes and background analytes in the impact calculations. The following is this keyword's syntax:

```
COMBINED [HEADER="quote 1"]
```

The data set is defined by information contained in the header file developed for use by the SACView program. The name of the header file is entered in the quote string.

This keyword is only valid when entered between a MODEL and ENDMODEL pair of keywords and then applies only to the single model type. The following is an example use of this keyword for the economic impact model:

```
MODEL ECONOMIC  
COMBINED HEADER="F:\SAC\Test_01\Economic\Economic_01.Hdr"  
BACKGROUND keyword  
DIFFERENCED keyword  
ENDMODEL
```

9.3.3 DEBUG Keyword for the ImDiff Code

The DEBUG keyword is used to initiate intermediate data output statements. The following is this keyword's syntax:

```
DEBUG
```

This keyword should not be used when a large data set is being processed because it may result in a very large output file. There are no modifiers or quote strings associated with the DEBUG keyword.

9.3.4 DIFFERENCED Keyword for the ImDiff Code

The DIFFERENCED keyword is used to define the header file that will be created for the difference between a data set that has both Hanford-derived analytes and background analytes in the impact calculations and the data set that has only Hanford-derived analytes. The following is this keyword's syntax:

```
DIFFERENCED [HEADER="quote 1"]
```

The modifier HEADER identifies a file name ("quote 1") for the header file for the differenced data set. SACView can use this header file for data extraction purposes.

This keyword is only valid when entered between a MODEL and ENDMODEL pair of keywords and then applies only to the single model type. The following is an example use of this keyword for the economic impact model:

```
MODEL ECONOMIC
DIFFERENCED HEADER="F:\SAC\Test_01\Economic\Economic_01.Hdr"
BACKGROUND keyword
COMBINED keyword
ENDMODEL
```

The differenced data is computed by subtracting the data from the background-only run from the correspond data for the combined run. Up to numerical accuracy of the solutions, the differences should be greater than or equal to zero.

9.3.5 END Keyword for the ImDiff Code

The END keyword signifies the end of all keyword data. It should be the last keyword in the keyword file. All data in the keyword file after the END keyword will be ignored. The following is this keyword's syntax:

```
END
```

There are no modifiers or quote strings associated with the END keyword.

9.3.6 ENDMODEL Keyword for the ImDiff Code

The ENDMODEL keyword is used to terminate impact model type associations initiated by a MODEL keyword. The following is the general syntax for the ENDMODEL keyword:

```
ENDMODEL
```

There are no quote strings or modifiers associated with the ENDMODEL keyword.

9.3.7 EXECUTE Keyword for the ImDiff Code

The EXECUTE keyword signifies that the user wishes to perform problem execution. If this keyword is not entered, the inputs are checked for consistency, but the problem will not be executed. This is useful if the run being set up is expected to take a significant amount of computation time. The following is this keyword record's syntax:

```
EXECUTE
```

There are no modifiers or quote strings associated with the EXECUTE keyword.

9.3.8 MODEL Keyword for the ImDiff Code

The MODEL keyword is used to select an impact model type that applies to model associations with the following keywords. The following is the keyword's general syntax:

```
MODEL [HUMAN|ECONOMIC|CULTURAL|ECOLOGICAL]
```

The MODEL keyword must always be paired with an ENDMODEL keyword. Once a MODEL keyword is entered, all BACKGROUND, COMBINED, DIFFERENCED, and OPTION keywords apply only to the chosen model. The following is an example use of this keyword to define inputs for the human impacts model:

```
MODEL HUMAN
```

There are no quote strings associated with the MODEL keyword.

9.3.9 OPTION Keyword for the ImDiff Code

The OPTION keyword is used to define the options for data differencing. The following is the general syntax for the keyword:

```
OPTION [MODIFIER1] [DETAILS= "quote1"] {STATISTICS="quote2" }
```

This keyword is only valid when entered between a MODEL and ENDMODEL pair of keywords and then applies only to the single model type. Table 9.3 describes the modifiers associated with the OPTION keyword.

Table 9.3 Modifiers Associated with the OPTION Keyword in the ImDiff Code

Model	Modifier	Action
Human	IMPACTS	Differencing will be conducted for all of the human impact metrics that were calculated in the previous runs of the HUMAN code. The detailed differenced data will be written to the file name entered in quote1. If the STATISTICS modifier is entered, summary statistics for the differenced data will be computed and written to the file name entered in quote2.
Cultural	AREA	Differencing will be conducted for all of the area calculations that were evaluated in previous runs of the CULTURE code. The detailed differenced data will be written to the file name entered in quote1. If the STATISTICS modifier is entered, summary statistics for the differenced data will be computed and written to the file name entered in quote2.

Model	Modifier	Action
Cultural	MAP	Differencing will be conducted for all of the map calculations that were evaluated in previous runs of the CULTURE code. The detailed differenced data will be written to the file name entered in quote1. If the STATISTICS modifier is entered, summary statistics for the differenced data will be computed and written to the file name entered in quote2.
Cultural	SITE	Differencing will be conducted for all of the site proximity calculations that were evaluated in previous runs of the CULTURE code. The detailed differenced data will be written to the file name entered in quote1. If the STATISTICS modifier is entered, summary statistics for the differenced data will be computed and written to the file name entered in quote2.
Ecological	RESULTS	Differencing will be conducted for all of the ecological impact metrics that were calculated in the previous runs of the ECEM code. The detailed differenced data will be written to the file name entered in quote1. If the STATISTICS modifier is entered, summary statistics for the differenced data will be computed and written to the file name entered in quote2.
Economic	CHANGE	Differencing will be conducted for all of the economic change calculations that were evaluated in previous runs of the TCERM code. The detailed differenced data will be written to the file name entered in quote1. If the STATISTICS modifier is entered, summary statistics for the differenced data will be computed and written to the file name entered in quote2.
Economic	EFFECTS	Differencing will be conducted for all of the economic effect calculations that were evaluated in previous runs of the TCERM code. The detailed differenced data will be written to the file name entered in quote1. If the STATISTICS modifier is entered, summary statistics for the differenced data will be computed and written to the file name entered in quote2.
Economic	TRIGGER	Differencing will be conducted for all of the economic trigger calculations that were evaluated in previous runs of the TCERM code. The detailed differenced data will be written to the file name entered in quote1. If the STATISTICS modifier is entered, summary statistics for the differenced data will be computed and written to the file name entered in quote2.

The following is an example set of option keywords for the economic model. In this suite of keywords, summary statistics are not computed for the economic change differenced data.

```
MODEL ECONOMIC
DIFFERENCED keyword
BACKGROUND keyword
COMBINED keyword
```



```
OPTION EFFECTS DETAILS= "Dif_Eff_Det.csv"  
STATISTICS="Dif_Eff_Sta.csv"  
OPTION TRIGGER DETAILS= "Dif_Trig_Det.csv"  
STATISTICS="Dif_Trig_Sta.csv"  
OPTION CHANGE DETAILS= "Dif_Chan_Det.csv"  
ENDMODEL
```

9.3.10 REPORT Keyword for the ImDiff Code

The REPORT keyword is used to define the name of the output report (log) file. It must be the first keyword entered in the keyword file. The following is this keyword record's syntax:

```
REPORT ["quote"]
```

The name of the report file is entered in a quote string. The following is an example REPORT keyword record:

```
REPORT "/SAC/SystemCodes/ECEM/Test1.rpt"
```

There are no modifiers associated with the REPORT keyword.

9.3.11 TITLE Keyword for the ImDiff Code

The TITLE keyword is used to define a single-line problem title. The problem title will be written to output files. If the title is not supplied, then the program will error terminate. The following is this keyword record's syntax:

```
TITLE ["quote"]
```

The title is entered in a quote string, which must be enclosed in double quotation marks. Titles up to 72 characters long are supported. The following example defines a title for a run of the code:

```
TITLE "Example title line for the ImDiffcode."
```

There are no modifiers associated with the TITLE keyword.

9.3.12 USER Keyword for the ImDiff Code

The USER keyword is used to identify the user of the program. The user name will be written to output files. If the user name is not supplied, then the program will error terminate. The following is this keyword record's syntax:

```
USER ["quote"]
```

The user name is entered in a quote string, which must be enclosed in double quotation marks. User names up to 16 characters long are supported. The following example defines John Q. Public as the user running the code:

```
USER "John Q. Public"
```

There are no modifiers associated with the USER keyword.

10.0 Keyword Language Syntax

Each line of a keyword data file is parsed into numeric and character data. These are interpreted to set up control information and define input parameters. An input line can contain up to 256 characters of information. Lines longer than 256 characters are truncated to 180 characters.

Every line of the input data file is considered a keyword record, continuation record, or a comment record. Keyword records contain a keyword beginning in column 1. The keyword is used to determine the purpose of the subsequent data. Continuation records are used when a keyword record requires too much data to be placed on one line. Comment lines are ignored by the reading software but are useful for annotating the input file.

The information from each keyword record and subsequent continuation lines is moved into storage arrays. Data that can be deciphered as numeric values are placed into a numeric array. Other data are classified either as “secondary keywords” (called “modifiers”) or “quote strings.” Secondary keywords are stored as character images in an array. All such keywords or modifiers read from the input file are changed to uppercase before being stored. Quote strings are text strings that are enclosed in double quotation marks. These are stored exactly as they are read from the input file.

10.1 Keyword Records

Keyword records start in column 1 with any letter from A to Z, in either upper- or lowercase. The first eight letters of a keyword are stored in a variable and are used by the modeling software to determine the actions desired by the program user. All subsequent lines of text that do not have an alphabetic character or comment character in column 1 are treated as continuation lines. The following is an example keyword record (where SAMPLEKEY starts in column 1):

```
SAMPLEKEY 2 0 500 1 100
```

The word SAMPLEKEY is the keyword. The numbers 2, 0, 500, 1, and 100 are numeric data.

10.2 Continuation Records

Continuation records start with any valid separator character (except a double quotation mark). These are treated as additional data to the previous keyword record. Section 5.5 identifies valid separator characters. The combined data on a keyword line and on the subsequent continuation line(s) are treated as a single block of information. All numeric values and character strings on those lines are used as input data relevant to the keyword of the keyword line. The two following keyword entries contain the same information:

```
SAMPLEKEY 2 0 500 1 100
```

```
SAMPLEKEY 2 0  
500 1 100
```

10.3 Comment Records

Any line with the characters \$, !, /, or * in column 1 will be treated as a comment record. These lines are ignored by the input data record reader. Both the \$ and the ! can also be used to signify in-line comments (not in column 1). Any information that follows a \$ or a ! will be ignored. The * and / characters indicate a comment only if one is the first character on the input line. The * character is also used as a repetition factor in the input. The following are some examples of comment lines:

```
$This is a comment line  
/This is a comment line  
!This is a comment line  
*This is a comment line
```

The following are some examples of in-line comments:

```
SAMPLEKEY 3 4.0 5.0 !Trailing information is ignored after the !  
SAMPLEKEY 3 4.0 5.0 $Trailing information is ignored after the $
```

10.4 Input Data Handling

Each line of the input is read and parsed into numeric and character values. All numeric values are converted to real numbers (as opposed to FORTRAN integer). All data that cannot be interpreted as numeric information are stored as character values.

Numeric data can include a leading sign (+ or -), integer characters 0 through 9, a decimal point, and an exponent indication ("E" or "e"). The FORTRAN "double precision" exponent indicator "D" is not valid. A maximum of ten digits is allowed when entering numeric data.

Secondary keywords, or modifiers, are character strings that could not be interpreted as numeric values. These are converted to uppercase, where necessary, and stored in an array. The number of secondary keywords that are moved into the array is stored for internal use.

Only the first eight characters of any keyword are significant. Keywords fewer than eight characters long are left justified and blank-filled.

10.4.1.1 Quote Strings

Quote strings are strings of literal text that must be used exactly as given in the input line. They are enclosed by double quotation marks and are typically used for passing file names into a program. Only the first 200 characters of a quote string are saved. Each quote string must begin and end on a single line of the input file. When an unclosed quote is encountered, an implied quote is created at the end of that line. The following is an example of quote string usage:

```
FILE "c:\apps\human\test.dat"
```

10.4.1.2 Data Separators

Keywords, numeric data, and secondary keywords must be separated by any one of the following data “separators”: space character, comma, equal sign, colon, semicolon, left parenthesis, right parenthesis, single quotation mark, double quotation mark, and tab character.

Also, any character with a ASCII character storage code of less than 10 is treated as a separator character. This is used mainly to identify the ASCII tab character as a data separator. Double quotation marks are used differently than the other separators. They indicate text strings that are stored without conversion by the program. As an illustration of the use of separator characters, the following keyword records all contain the same information:

```
SAMPLEKEY 3 4.5 5.6 6.7
SAMPLEKEY 3 (4.5,5.6,6.7)
SAMPLEKEY 3 ( 4.5=5.6'6.7 )
SAMPLEKEY 3:4.5 5.6:6.7
```

11.0 Stochastic Variable Generation

Many of the codes in SAC, Rev. 1 generate values for stochastic variables. All of the codes use the same suite of statistical routines to do this generation. The following are some major considerations for this process:

- Each distribution is generated using the Probability Integral Transformation method (Mood et al. 1974, p. 202).
- The uniform number generator uses a linear congruential method (Lewis et al 1969).
- Stratified sampling is used when the number of values to be generated is greater than 1.
- Most distributions may be truncated between two limits that are specified as limits in the uniform domain on the interval 0 to 1.
- The user may specify a cumulative distribution function in the form of a table of values.
- Information about a stochastic variable is linked to a unique character ID. Access to all information about the variable is available through use of the variable ID.

The following are the available statistical distributions:

- Constant value
- Uniform distribution between two limits
- Discrete uniform distribution on a set of contiguous integers
- Loguniform (base 10) distribution between two limits
- Loguniform (base e) distribution between two limits
- Triangular distribution defined using a lower limit, mode, and an upper limit
- Normal distribution with a mean and standard deviation
- Lognormal (base 10) distribution specified by the mean and standard deviation of the logarithms of the data
- Lognormal (base e) distribution specified by the mean and standard deviation of the logarithms of the data
- User-specified cumulative distribution function input as a table of probabilities and exceedance values
- Beta distribution that can be shifted and scaled from the standard (0,1) interval
- Log-ratio from a normal distribution
- Hyperbolic arcsine from a normal distribution

11.1 Stochastic Keyword

The STOCHASTIC keyword is used in each of the impact codes to enter the definition of a statistical distribution for stochastic variables. The following is the general syntax for the STOCHASTIC record:

```
STOCHASTIC ["Quote1"] [Dist_Index Parameters] {TRUNCATE U1 U2} {"Quote2" }
```

The entry for Quote1 must be a unique character string of up to 20 characters that will be used to identify this stochastic variable in subsequent uses. It is case sensitive and embedded spaces are significant. It is

sometimes useful to make the character string some combination of a variable name and other data so that it can be recreated easily when stochastic data is needed. The entry for Quote2 is a description for the stochastic variable that can be up to 64 characters long and is used for output labeling purposes. The entry for Quote2 is optional.

The entry for Index must be an integer in the range 1 to 13 that identifies the index of a statistical distribution. The statistical distributions are defined in Table 11.1. The word Parameters in the general syntax statement indicates the numerical values of parameters required for defining the statistical distribution. The additional modifier TRUNCATE can be used for all distribution types except 1, 3, and 10. If TRUNCATE is entered, it must be followed by two values in the interval 0 to 1, inclusive. The lower value must be less than the upper value. These two values specify the tail probabilities at which to impose range truncation for the distribution. Truncation data must be entered after all of the other parameters that define the distribution.

Table 11.1 Statistical Distributions Available in All Impact Codes

Index	Distribution	Truncate	Parameters Required
1	Constant	No	Single value.
2	Uniform	Yes	Lower limit, upper limit.
3	Discrete Uniform	No	Smallest integer, largest integer.
4	Loguniform (base 10)	Yes	Lower limit, upper limit.
5	Loguniform (base e)	Yes	Lower limit, upper limit.
6	Triangular	Yes	Lower limit, mode, upper limit.
7	Normal	Yes	Mean, standard deviation.
8	Lognormal (base 10)	Yes	Mean, standard deviation of logarithms.
9	Lognormal (base e)	Yes	Mean, standard deviation of logarithms.
10	User Defined	Yes	Number of pairs, data for pairs of values (Prob(X_i), X_i).
11	Beta	Yes	Alpha, beta, lower limit, upper limit. The mean of the distribution would be $\alpha/(\alpha+\beta)$ if the limits were 0 and 1.
12	Log ratio	Yes	Mean, standard deviation (of normal), lower limit, upper limit.
13	Hyperbolic arcsine	Yes	Mean, standard deviation (of normal).

The following is an example stochastic keyword for a variable assigned a constant of 234.432:

```
STOCHASTIC "Unique1" 1 234.432 "Define a constant distribution"
```

The constant can take any value.

The following is an example stochastic keyword for a variable assigned a uniform distribution on -2 to 7:

```
STOCHASTIC "Unique2" 2 -2.0 7 "Define a uniform distribution on -2 to 7"
```

The two limits can take any values as long as the second value is strictly greater than the first value.

The following is an example stochastic keyword for a variable assigned a discrete uniform distribution on the integers 6 to 70:

```
STOCHASTIC "Unique3" 3 6 70 "Discrete uniform distribution on 6 to 70"
```

The two limits must be integers where the second integer is strictly greater than the first integer.

The following is an example stochastic keyword for a variable assigned a loguniform (base 10) distribution on the interval 10^{-7} to 10^{-3} :

```
STOCHASTIC "Unique4" 4 1.0E-7 1.0E-3  
"Define a loguniform (base 10) distribution on 0.0000001 to 0.001"
```

The two limits must both be greater than zero and the second limit must be greater than the first limit.

The following is an example stochastic keyword for a variable assigned a loguniform (base e) distribution on the interval $1.0E+3$ to $1.0E+6$:

```
STOCHASTIC "Unique5" 5 1.0E3 1E+6  
"Define a loguniform (base e) distribution on 1000 to 1000000"
```

The two limits must both be greater than zero and the second limit must be greater than the first limit.

The following is an example stochastic keyword for a variable assigned a triangular distribution with a minimum of 2, a mode of 3, and a maximum of 7:

```
STOCHASTIC "Unique6" 6 2 3 7 "Triangular distribution on (2,3,6)"
```

The three values that define the triangular must all be different, and they must be entered in increasing order.

The following is an example stochastic keyword for a bioconcentration factor that is normally distributed with a mean of 125 and a standard deviation of 5 for a frog exposed to carbon-14:

```
STOCHASTIC "BCFC14Frog" 7 125.0 5.0 "Example normally distributed frog"
```

The mean value can be any number, but the standard deviation must be greater than zero.

The following keyword would define a different stochastic variable from the one just entered because the identification string (Quote1) is case sensitive:

```
STOCHASTIC "BCFC14FROG" 7 125.0 5.0 "Example normally distributed frog"
```

The following keyword entry would define a lognormal (base 10) distribution where the mean and standard deviation (of the logarithms) are -2.0 and 0.5:

```
STOCHASTIC "Unique8" 8 -2 0.5 "Lognormal (base 10) variable"
```

The mean value can be any number, but the standard deviation must be greater than zero.

The following keyword entry would define a lognormal (base e) distribution where the mean and standard deviation (of the logarithms) are -2.0 and 0.5. In addition, the lognormal distribution will be truncated between the lower 0.025 and upper 0.99 probabilities.

```
STOCHASTIC "Unique9" 9 -2 .5 TRUNCATE 0.025 0.99  
"Example for a truncated lognormal variable"
```

The mean value can be any number, but the standard deviation must be greater than zero.

The following keyword entry illustrates the use of the user-defined distribution (distribution type 10). This example entry uses seven pairs of values. The first pair of numbers uses a probability of 0 to define the lower limit of the distribution at 8.4 E-7. The last pair of numbers uses a probability of 1 to define the upper limit of the distribution at 1.73E-6. The other values are associated with the probability levels of .025, .167, .5, .833, and .975. The probability data and distribution percentiles must be entered in strictly increasing order.

```
STOCHASTIC "Sr90Con" 10 7  
0 8.40E-7  
2.50E-02 9.20E-7  
1.67E-01 1.06E-6  
5.00E-01 1.21E-6  
8.33E-01 1.37E-6  
9.75E-01 1.58E-6  
1 1.73E-6
```

The first pair of numbers uses a probability of 0 to define the lower limit of the distribution. The last pair of numbers uses a probability of 1 to define the upper limit of the distribution. The intervening pairs define probability levels and the associated data values. The probabilities and data values must be entered in strictly increasing order.

The following keyword entry would define a beta distribution with parameters 1.1 and 2.1 on the interval (0,1):

```
STOCHASTIC "Unique11-1" 11 1.1 2.1 0.0 1.0  
"Beta (1.1,2.1) on the interval 0,1"
```


Let the first parameter be denoted by α and the second parameter be denoted by β . The mean of the beta distribution would be $\alpha / (\alpha + \beta)$ if the limits were 0 and 1. Both α and β must be greater than zero. The lower limit must be less than the upper limit.

The following keyword entry would define a beta distribution with parameters 1.1 and 2.1 but on the interval -2 to 4:

```
STOCHASTIC "Unique11-2" 11 1.1 2.1 -2.0 4.0
"Beta (1.1,2.1) on the interval (-2,4) "
```

The following keyword entry would define a log ratio distribution from a normal (-1.459,1.523) distribution on the interval -5.756 to 4.33:

```
STOCHASTIC "Test1203" 12 -1.459 1.523 -5.756 4.330
"Log ratio from Normal (-1.4,1.5) on (-5.756,4.330) "
```

The entry for the normal standard deviation (a value of 1.523 in this example) must be greater than zero. The last two numerical values define the interval for the generated values, so the lower limit must be smaller than the upper limit.

The following keyword entry would define a hyperbolic arcsine distribution from a normal (0.189,0.146) distribution:

```
STOCHASTIC "Test1302" 13 0.189 0.146
"Hyperbolic Arcsine from Normal (0.189,0.146) "
```

The entry for the normal standard deviation (a value of 0.189 in this example) must be greater than zero.

11.2 Probability Concepts

The distribution of a continuous random variable X (the term *continuous* indicates that the random variable is defined over a continuum of values) is completely described by its probability density function, $f(x)$. The interpretation of the probability density function is that the area under $f(x)$, for an interval $a < x < b$, equals the probability that the random variable, X , will fall in the interval (a,b) , denoted $P[a < X < b]$. One cannot make the statement $P[X=t]$, because there is no area under the probability density function at any given point. Two axioms of probability theory (Mood et al. 1974, p. 22) are that the probability of any event is between zero and one, and the integral of the probability density function over the entire support (the interval $[L,U]$) of X equals 1. The integral of the probability density function from the lower bound L to some value x (suppose it is less than the upper bound U) represents the probability that X will be observed in the interval (L,x) . This integral operation defines the cumulative distribution function for the random variable X . The cumulative distribution function is denoted by $F(x)$ (the capital F for the cumulative distribution function corresponds to the lowercase f for the probability density function) and mathematically is represented by:

$$F(x) = \int_L^U f(s)ds$$

The inverse cumulative distribution function, $[F^{-1}(\bullet)]$, is single-valued if x is in the interval (L,U) . Hence if $p'=F(x')$ is known, in theory $x'=F^{-1}(p')$ can be obtained.

11.3 Probability Integral Transform Method

Generation of a random variable from a given distribution typically involves the use of information either about f or F . There are two philosophical approaches to generating random numbers: exact methods and approximate methods. The algorithms embedded in SAC employ exact methods. Exact methods can be further categorized into probability integral transform methods and functional methods. The probability integral transform method is employed in SAC.

In the probability integral transform method, the random variable of interest is expressed as a function of a $U(0,1)$ random variable, where $U(0,1)$ denotes the continuous random variable ranging uniformly over the interval $(0,1)$. The probability density function of the uniform random variable is $g(u)=1$ if $u \in (0,1)$ and is zero elsewhere. The cumulative distribution function for this random variable takes the exceedingly simple form $G(u)=u$. It can be shown that any cumulative distribution function evaluated at a random value X (instead of being evaluated at a known value x as in the previous discussion) is distributed uniformly over the interval $(0,1)$ (Mood et al. 1974, p. 202). Therefore, given a realization u of the $U(0,1)$ random variable and a selected statistical distribution (known cumulative distribution function), one can set $u=F(x)$ and solve to obtain $x=F^{-1}(u)$. The value x thus obtained is a random realization from the selected statistical distribution.

In principle, one can obtain an exact solution for x given any specific cumulative distribution function and value u . In reality, there exist some distributions, such as the normal and beta distributions, for which no closed-form analytical expression for F^{-1} exists, and hence approximation methods must be applied.

The probability integral transform method allows efficient sampling from a subregion of the interval (L,U) , such as (c,d) , where $L < c < d < U$. In this case one would find the corresponding interval in the uniform domain, say (c',d') , and sample uniformly over that interval, by sampling from the rescaled uniform distribution [for example, $u'=(d-c)u+c$] and then obtaining x as usual using $x=F^{-1}(u')$. The rescaled uniform distribution takes the form $g(u)=1/(d'-c')$ for $u \in (c',d')$ and is zero elsewhere. For any distribution with probability density function $f(x)$ and cumulative distribution function $F(x)$, the probability density function, under truncation to the interval (c,d) , is $f_T(x) = f(x)/[F(d)-F(c)]$. The divisor ensures that $f_T(x)$ integrates to unity.

11.4 Stratified Sampling

Stratified sampling can easily be implemented when generating random deviates using the probability integral transform method. This is accomplished by dividing the uniform interval $(0,1)$ into subintervals, or strata, and sampling a specified number of times within each stratum, each time obtaining the corresponding value of x . Within SAC, the strata intervals are assigned equal probability, and exactly one value is sampled within each stratum. The method generates samples from each stratum, and then randomly shuffles the entire set of realizations using a variation of the Quicksort algorithm (Singleton 1969). The primary purpose of stratified sampling is to achieve more evenly spaced (in a probability sense) samples from the distribution of a random variable than would result from randomly sampling over

the whole range of the distribution. Iman and Conover (1982) have shown that stratified sampling can result in more efficient estimation of simulation results for a variety of estimators than when using simple random sampling.

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