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# OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
# ANALYSIS/MODEL COVER SHEET

1. QA: QA



***Complete Only Applicable Items***

2. ☑ Analysis — Check all that apply

Type of Analysis:
- ☐ Engineering
- ☑ Performance Assessment
- ☐ Scientific

Intended Use of Analysis:
- ☐ Input to Calculation
- ☐ Input to another Analysis or Model
- ☑ Input to Technical Document
- ☑ Input to other Technical Products

Describe use:

3. ☑ Model — Check all that apply

Type of Model:
- ☑ Conceptual Model
- ☑ Mathematical Model
- ☐ Process Model
- ☐ Abstraction Model
- ☐ System Model

Intended Use of Model:
- ☑ Input to Calculation
- ☑ Input to another Model or Analysis
- ☑ Input to Technical Document
- ☑ Input to other Technical Products

Describe use:

4. Title:
Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP)

5. Document Identifier (including Rev. No. and Change No., if applicable):
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# OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
# ANALYSIS/MODEL COVER SHEET

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# OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
# ANALYSIS/MODEL REVISION RECORD

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| 4. Revision/Change No. | 5. Description of Revision/Change |
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| Rev 00 | Initial issue |

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## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AMR | Analysis and Model Report |
| BDCF | Biosphere Dose Conversion Factors |
| BIOMASS | Biosphere Modeling and Assessment |
| CFR | Code of Federal Regulations |
| CNWRA | Center for Nuclear Waste Regulatory Analysis |
| CRWMS | Civilian Radioactive Waste Management System |
| DOE | U.S. Department of Energy |
| EPA | Environmental Protection Agency |
| FEPs | Features, Events, and Processes |
| GENII-S | Hanford Environmental Dosimetry System (Generation II or GENII - Sensitivity and Uncertainty Analysis Shell) |
| IAEA | International Atomic Energy Agency |
| M&O | Management and Operating Contractor |
| NCRP | National Council on Radiation Protection and Measurements |
| NRC | U.S. Nuclear Regulatory Commission |
| PMR | Process Model Report |
| QA | Quality Assurance |
| QARD | Quality Assurance Requirement and Description |
| RIG | Revised Interim Guidance |
| SQR | Software Qualification Report |
| TSPA | Total System Performance Assessment |
| TSPA-VA | Total System Performance Assessment – Viability Assessment |
| WIPP | Waste Isolation Pilot Plant |
| YMP | Yucca Mountain Site Characterization Project |

# 1. PURPOSE

The purpose of this Analysis and Model Report (AMR), "Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEPs)" is to perform and document the screening analysis of FEPs that are potentially biosphere-related. This screening analysis includes the screen decision, screening argument, and recommended Total System Performance Assessment (TSPA) disposition for biosphere-related primary FEPs. This AMR also documents the adequacy of the scientific bases for the Yucca Mountain Site Characterization Project (YMP) biosphere model and demonstrates that model is appropriate and adequate for its intended use. This AMR is limited to the reference biosphere identified in Section 4.2.

Specific aspects of biosphere model development are discussed in this AMR. The YMP biosphere conceptual model is the aggregate of all those FEPs expected to influence dose to humans from radioactive materials that may ultimately be released from the potential repository and entering the biosphere. The Hanford Environmental Dosimetry System – Sensitivity and Uncertainty Analysis Shell (GENII-S) computer software (SNL 1998) used by the YMP embodies a generic mathematical model that, with proper selection of input variables, is applicable to a wide range of environmental transport and dose conditions. When parameter values derived from the YMP biosphere conceptual model are used as input for the GENII-S software, the ensuing analyses represent a YMP-specific biosphere model. This YMP biosphere model, i.e., the conceptual model as implemented in the GENII-S software, is subject to validation in accordance with AP-3.10Q, *Analyses and Models.*

## 1.1 SCOPE

The *Development Plan for the Evaluation of the Applicability of Biosphere-related Features, Events & Processes* (CRWMS M&O 2000a) identifies the scope of work and objectives for this AMR including evaluation of the applicability of the biosphere-related primary FEPs, and the approach for and the validation of the biosphere model.

Evaluation of the applicability of the biosphere-related primary FEPs assigned to the biosphere Process Model Report (PMR) is identified in the Development Plan (CRWMS M&O 2000a) in terms of the guidance provided in "Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission. (NRC) Regulations for Yucca Mountain Nevada" (Dyer 1999). The results of this analysis will be used in the compilation of a comprehensive list of FEPs that will be considered in total system performance assessment activities. The FEPs identified as being relevant to the biosphere process model are used to support the development of the biosphere model that will be used in assessing this aspect of the potential repository's performance, including calculation of BDCF.

### 1.1.1 Development of Features, Events, and Processes

*The Yucca Mountain Project (YMP) Features, Events, and Processes (FEP) Database* (CRWMS M&O 1999a) provides a list of FEPs potentially applicable to the Yucca Mountain Site Characterization Project (YMP). Freeze and Swift (1999) present a detailed summary of the development of that list of FEPs and its structure. This list is currently controlled under YAP SV.1Q, *Control of the Electronic Management of Data.* A detailed discussion on the

development of the database from compilation of the FEPs through categorization and mapping of the relationships between FEPs to development and screening of scenarios is presented in the TSPA. The following provides an overview of the development of the list of FEPs.

The first step in the identification of FEPs that might occur in the region of Yucca Mountain and that are relevant to the performance of the potential Yucca Mountain repository was accomplished by a review and compilation of FEPs previously identified as relevant to various radioactive waste disposal activities. This identification is based on a methodology developed by Cranwell et al. (1990) for the U.S. Nuclear Regulatory Commission. This same approach has been used, previously, by the Department of Energy (DOE) for the Waste Isolation Pilot Plant (DOE 1996). The database maintained by the Nuclear Energy Agency of the Organization for Economic Cooperation and Development was the initial starting point for this effort. This database is assumed to be the most comprehensive database that is available internationally. The database contains 1411 entries generated by organizations from 7 countries. The FEPs identified in the Nuclear Energy Agency database were then combined with 375 FEP entries generated as a result of the review of YMP-related documents and from YMP Workshops for a total of 1786 Yucca Mountain-related FEP entries. As a result of this combination, an initial list of potentially applicable FEPs was developed.

Each of the 1786 FEP entries was subsequently categorized/classified as either a primary or secondary FEPs. Primary FEPs are those FEPs for which the Project proposes to develop detailed screening arguments. The classification and description of primary FEPs are intended to encompass all the secondary FEPs that relate to the primary. Secondary FEPs are either FEPs that are completely redundant or that can be aggregated into a single primary FEP. This categorization resulted in the identification of 310 primary FEPs.

For the purpose of screening to determine applicability, each of the 310 primary FEPs were assigned to one or more Process Model Report (PMR) based on PMR subject, so that the analysis and resolution for screening decisions would be made. Primary FEPs have the potential to affect multiple aspects of the Project, may be relevant to more than one PMR, or may not fit neatly within the PMR structure. Of the 310 primary FEPs originally identified, 47 FEPs were considered relevant to the biosphere. These FEPs are listed in Table 1.

### 1.1.2 Model Validation Process

The Development Plan specifies that the model validation process is to be performed using a combination of methods. These methods include checking computer calculation results against hand calculations, review by an independent technical expert, and reconciliation of the YMP Biosphere Dose Conversion Factors (BDCF) with results of other environmental dose calculations. These BDCF are presented in *Non-Disruptive Event Biosphere Dose Conversion Factors* (CRWMS M&O 2000b) and *Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000c). The validation will document the determination of the adequacy of the scientific bases for the model, and demonstrate whether or not the model is appropriate for the intended use.

Table 1. Biosphere Features, Events, and Processes

| FEP NAME | FEP NUMBER |
|---|---|
| Erosion/denudation | 1.2.07.01.00 |
| Deposition | 1.2.07.02.00 |
| Climate change, global | 1.3.01.00.00 |
| Periglacial effects | 1.3.04.00.00 |
| Glacial and ice sheet effects, local | 1.3.05.00.00 |
| Human influences on climate | 1.4.01.00.00 |
| Greenhouse gas effects | 1.4.01.02.00 |
| Acid rain | 1.4.01.03.00 |
| Ozone layer failure | 1.4.01.04.00 |
| Altered soil or surface water chemistry | 1.4.06.01.00 |
| Water management activities | 1.4.07.01.00 |
| Wells | 1.4.07.02.00 |
| Social and institutional developments | 1.4.08.00.00 |
| Technological developments | 1.4.09.00.00 |
| Species evolution | 1.5.02.00.00 |
| Capillary rise | 2.2.07.03.00 |
| Soil type | 2.3.02.01.00 |
| Radionuclide accumulation in soils | 2.3.02.02.00 |
| Soil and sediment transport | 2.3.02.03.00 |
| Surface water transport and mixing | 2.3.04.01.00 |
| Marine features | 2.3.06.00.00 |
| Animal burrowing/intrusion | 2.3.09.01.00 |
| Precipitation | 2.3.11.01.00 |
| Surface runoff and flooding | 2.3.11.02.00 |
| Biosphere characteristics | 2.3.13.01.00 |
| Biosphere transport | 2.3.13.02.00 |
| Human characteristics (physiology, metabolism) | 2.4.01.00.00 |
| Diet and fluid intake | 2.4.03.00.00 |
| Human lifestyle | 2.4.04.01.00 |
| Dwellings | 2.4.07.00.00 |
| Wild and natural land and water use | 2.4.08.00.00 |
| Agricultural land use and irrigation | 2.4.09.01.00 |
| Animal farms and fisheries | 2.4.09.02.00 |
| Urban and industrial land and water use | 2.4.10.00.00 |
| Drinking water, foodstuffs and drugs, contaminant concentrations in | 3.3.01.00.00 |
| Plant uptake | 3.3.02.01.00 |
| Animal uptake | 3.3.02.02.00 |
| Bioaccumulation | 3.3.02.03.00 |
| Contaminated non-food products and exposure | 3.3.03.01.00 |
| Ingestion | 3.3.04.01.00 |
| Inhalation | 3.3.04.02.00 |
| External exposure | 3.3.04.03.00 |
| Radiation doses | 3.3.05.01.00 |
| Radiological toxicity/effects | 3.3.06.00.00 |
| Sensitization to radiation | 3.3.06.02.00 |
| Non-radiological toxicity/effects | 3.3.07.00.00 |
| Radon and radon daughter exposure | 3.3.08.00.00 |

## 2. QUALITY ASSURANCE

This analysis has been determined to be quality affecting in accordance with QAP-2-0, *Conduct of Activities*, because the information will be used to support performance assessment and other quality-affecting activities. This analysis is subject to the requirements of the *Quality Assurance Requirements and Description* (*QARD*) (DOE 2000). This analysis is covered by the *Activity Evaluation: Development of Biosphere Dose Conversion Factors* (CRWMS M&O 1999b). The primary implementing procedure for this work is Office of Civilian Radioactive Waste Management procedure AP-3.10Q, *Analyses and Models*. Several other procedures were used to support development of this AMR. These include the following:

- AP-2.1Q, Indoctrination and Training of Personnel.
- AP-2.2Q, Establishment and Verification of Required Education and Experience of Personnel.
- AP-2.13Q, Technical Product Development Planning.
- AP-2.14Q, *Review of Technical Products.*
- AP-3.4Q, *Level 3 Change Control.*
- AP-3.14Q, *Transmittal of Input*
- AP-3.15Q, *Managing Technical Inputs.*
- AP-6.1Q, *Controlled Documents.*
- AP-17.1Q, Record Source Responsibilities for Inclusionary Records.
- AP-SI.1Q, *Software Management.*
- AP-SIII.2Q, *Qualification of Unqualified Data and the Documentation of Rationale for Accepted Data.*
- AP-SIII.3Q, *Submittal and Incorporation of Data to the Technical Data Management System.*
- NLP-2-0, *Determination of Importance Evaluations*
- YAP-SV.1Q, *Control of the Electronic Management of Data*

Personnel performing work on this analysis were trained and qualified according to AP-2.1Q, *Indoctrination and Training of Personnel* and AP-2.2Q, *Establishment and Verification of Required Education and Experience of Personnel.* Preparation of this analysis does not require the classification of items in accordance with QAP-2-3, *Classification of Permanent Items.* This analysis is not a field activity. Therefore, a Determination of Importance Evaluation in accordance with NLP-2-0 is not required.

# 3. COMPUTER SOFTWARE AND MODEL USAGE

The *GENII-S V1.4.8.5* software code (SNL 1998) used in this AMR is a code for statistical and deterministic calculations of radiation doses to humans from radionuclides in the environment. This software was acquired from the Radiation Safety Information Computational Center, and qualified using test cases supplied by the software developer to verify that the software, as installed on YMP computers, produced outputs consistent with values expected for a prescribed set of inputs. At the time of acquisition of the GENII-S software, qualification requirements were specified in QAP-SI-0 Rev. 3, *Computer Software Qualification* (since superceded by AP-SI.1Q, *Software Management*). GENII-S was appropriate for this application and was used within the range of validation in accordance with AP-SI.1Q, *Software Management*, as described in the *GENII-S Software Qualification Report* (SQR) (CRWMS M&O 1998a).

The method and results of the GENII-S software qualification effort are detailed in the SQR (CRWMS M&O 1998a). All computer printouts generated by the test cases are provided as attachments to the SQR.

GENII-S is controlled under Configuration Management (Computer Software Configuration Item: 30034 V1.4.8.5). The copy of GENII-S software used for this analysis was obtained from Configuration Management and installed on a Gateway 2000 Personal Computer (Central Processing Unit # 111161). All analyses performed for this AMR used this computer.

# 4. INPUTS

## 4.1 DATA AND PARAMETERS

The calculation of Adjusted BDCF discussed in Section 6.2.4.3 of this AMR is based on the set of parameter values cited in Section 6.1 of *Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000c). Table 2 presents a list of the data titles and tracking numbers for parameters used. Some of these data sets are unqualified as identified in the information associated with the corresponding data tracking numbers. Per AP-3.10Q, unqualified data may be used in performance assessment activities when they are not directly relied upon to address safety and waste isolation issues. Two of the parameters were changed as shown in Table 3. Further discussion behind these changes is given in Section 6.2.4.3.

Table 3 identifies the input parameter value changes that were made as part of the model validation effort discussed in Section 6.2.4.3.

## 4.2 CRITERIA

At the present time there are no regulations in effect that provide criteria for evaluating the applicability of features, events, and processes to be used to assess the performance of the potential repository. As a result, guidance for evaluating the applicability of a FEP is provided by the DOE in *Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulator Commission Regulations* (Dyer 1999). This guidance is referred to as RIG throughout this document. The RIG provides specific guidance on the performance objectives for the repository after permanent closure (Section 113) and the associated performance requirements (Section 114). Guidance on the characteristics and limits of the reference biosphere and receptor of interest to be considered are provided in Section 115. The technical justifications for exclusion of a FEP from consideration on the basis of low probability and/or low consequence are provided in Section 114. Section 114 guidance, although specific to the geologic setting, was used in this analysis for the purpose of consistency with other AMRs. The RIG was used in lieu of specific criteria based on regulatory requirements until such time as regulations are promulgated.

### 4.2.1 Technical Criteria

This analysis applies RIG guidance for exclusion of a FEP from consideration; low probability and/or low consequence. Specifically, the guidance allows a FEP to be excluded from consideration if it is of low probability, i.e., less than one chance in 10,000 of occurring in 10,000 years or if occurrence of the FEPs can be shown to have no significant effect on expected annual dose. The low probability guidance is provided in Section 114 (d) of the RIG. This section explicitly states, "Consider only events that have at least one chance in 10,000 of occurring over 10,000 years."

Table 2. Input Parameters and Data Titles and Tracking Numbers

| Input Source Number | Data Title and Data Tracking Number | Parameter Name/ Input Description |
|---|---|---|
| 1 | Environmental Transport Parameter Values for Dose Assessment<br><br>MO9911RIB00064.000 | (1) Deposition velocity: particle for deposition on crops<br>(2) Resuspension factor<br>(3) Crop biomass for all crop types under consideration<br>(4) Basic soil data: depth of surface soil, fraction of plant root in surface soil, fraction of plant root in deep soil, surface soil density, bulk soil density.<br>(5) Soil ingestion rate<br>(6) Weathering half-life<br>(7) Translocation factor for all crop types/animal food products under consideration<br>(8) Animal feed and water consumption rates for all animal food products under consideration<br>(9) Dry-to-wet ratio for all crop types under consideration. |
| 2 | Parameter Values for Transfer Coefficients<br><br>MO9911RIB00065.000 | (1) Transfer parameters for elements and food types under consideration.<br>(2) Soil-to-plant transfer scale factor and animal uptake scale factor. |
| 3 | Input Parameter Values for External and Inhalation Radiation Exposure Analysis<br><br>MO9910RIB00061.000 | (1) Mass loading<br>(2) Inhalation exposure time, chronic breathing rate, and soil exposure time for the receptor of interest |
| 4 | Ingestion Exposure Parameter Values<br><br>MO0002RIB00068.000 | (1) Crop interception fraction<br>(2) Plant growing times<br>(3) Holdup times for plant and animal food products<br>(4) Feed storage time<br>(5) Animal dietary fractions<br>(6) Irrigation rates<br>(7) Irrigation times |
| 5 | Parameter Values for Consumption of Locally Produced Food and Tap Water<br><br>MO0002RIB00062.000 | Tap water and locally grown food consumption rates for the receptor of interest |
| 6 | Parameter Values for Internal and External Dose Conversion Factors<br><br>MO9912RIB00066.000 | (1) Dose coefficients for exposure to contaminated soil<br>(2) Dose coefficients for air submersion. |
| 7 | Revised Leaching Coefficients for GENII-S Code.<br><br>SN0002T0512299.003 | Leaching coefficients for elements under consideration |

Table 3. Adjusted Input Parameters and Values by Case

| Case Number | Soil Ingestion Rate (1) | Resuspension Factor |
|---|---|---|
| 1 | 410 | No Change |
| 2 | No Change | Lognormal Distribution<br>Min = 5.89 E-7<br>Max = 1.70-E-4 |
| 3 | 410 | Lognormal Distribution<br>Min = 5.89 E-7<br>Max = 1.70E-4 |

(1) Value in units of mg/d

Because the probability of any specific event depends strongly on how the event is defined, the probability criterion can only be applied at an appropriately broad scale. The guidance for low consequence screening arguments for FEPs is provided by the DOE in Section 114 (e-f) of the RIG. This guidance is as follows:

> " (e) Provide the technical basis for either inclusion or exclusion of specific features, events, and processes of the geologic setting in the performance assessment. Specific features, events, and processes of the geologic setting must be evaluated in detail if the magnitude and time of the resulting expected annual dose would be significantly changed by their omission.
>
> (f) Provide the technical basis for either exclusion or inclusion of degradation, deterioration or alteration processes of engineered barriers in the performance assessment, including those processes that would adversely affect the performance of natural barriers. Degradation, deterioration, or alternative processes of engineered barriers must be evaluated in detail if the magnitude and time of the result in expected annual dose would be significantly changed by their omission."

### 4.2.2 Qualitative Criteria

The RIG provides qualitative criteria that define the nature of the environment in which the receptor resides and the characteristics of the receptor of interest. This guidance is provided in Section 115 (a & b) and is identified as the required reference biosphere and the average member of the critical group.

#### 4.2.2.1 Reference Biosphere

The DOE guidance pertaining to the characteristics of the reference biosphere are presented in Sec. 115 (a)(1-2) of the RIG. This guidance is as follows:

> "(1) Features, events, and processes that describe the reference biosphere shall be consistent with present knowledge of the conditions in the region surrounding the Yucca Mountain site.
>
> (2) Biosphere pathways shall be consistent with arid or semi-arid conditions."

#### 4.2.2.2 Critical Group

The characteristics of the critical group to be considered in the dose assessment calculations are established by the DOE in Section 115 (b)(1-5). This guidance is as follows:

> "(1) The critical group shall reside within a farming community located approximately 20 km south from the underground facility (in the general location of U.S. Route 95 and Nevada Route 373).
>
> (2) The behaviors and characteristics of the farming community shall be consistent with current conditions of the region surrounding the Yucca Mountain site. Changes over time in the behaviors and characteristics of the critical group including, but not necessarily limited to, land use, lifestyle, diet, human physiology, or metabolics, shall not be considered.
>
> (3) The critical group resides within a farming community consisting of approximately 100 individuals, and exhibits behaviors or characteristics that will result in the highest expected annual doses.
>
> (4) The behaviors and characteristics of the average member shall be based on the mean value of the critical group's variability range. The mean value shall not be unduly biased based on the extreme habits of a few individuals.
>
> (5) The average member of the critical group shall be an adult. Metabolic and physiological consideration shall be consistent with present knowledge of adults."

## 4.3 CODES AND STANDARDS

There are no Codes or Standards directly applicable to this analysis.

# 5. ASSUMPTIONS

For the purpose of this analysis, it was assumed that the current lifestyle and behavior of the majority of the residents of Amargosa Valley is consistent with that of a modern, 20th century, community existing in an arid environment. An extremely low rainfall, that is insufficient to support agriculture, is assumed to characterize this environment. The bases for these assumptions are:

1 Modern utilities and services are available, i.e. electrical power to run pumps used to obtain water, provide lighting for homes and business, are available thereby eliminating the need to rely on locally derived power and heating sources.

2 Modern medical care and associated facilities are available, i.e. physicians, clinics, pharmacies, are available and reduce reliance on locally derived medicinal drugs.

3 Access to commercial services and products, i.e. supermarkets and retail stores, is available and minimizes the need for locally produced items such as tobacco and charcoal.

The characteristics of the arid environment are:

1 Low rainfall results in a surface environment that is devoid of year round surface water bodies i.e. rivers, lakes, streams, and man-made impoundments.

2 Springs and seeps, as a result of ground water up welling, occur infrequently and provide insufficient volumes of water to support agricultural and lifestyle activities of the community.

3 Low rainfall results in a high reliance on groundwater and as a result use of water for water consuming activities, i.e. growing a lawn, hyponic gardening, having a swimming pool, is minimized.

These assumptions are used throughout the document.

# 6. ANALYSIS/MODEL

This section documents the screening analysis of FEPs that are considered to be biosphere-related, and documents the adequacy of the scientific bases for the YMP biosphere model, and demonstrates that model is appropriate and adequate for its intended use.

## 6.1 SCREENING AND ANALYSIS OF THE BIOSPHERE-RELATED PRIMARY FEATURES, EVENTS, AND PROCESSES

The primary method used in this analysis was a screening of the biosphere-related primary FEPs and the associated secondary FEPs through use of the criteria identified in Section 4.2.

For FEPs that were excluded based on specific guidance (for example, FEPs that discuss the variation in location and/or composition of the critical group), the screening argument includes a reference to the appropriate section of the RIG and a short discussion of the reason for exclusion. For those that were excluded based on probability/consequence criteria, the screening argument includes a summary of the basis and results that indicate either low probability or low consequence. For FEPs that were included, in part or in total, a reference to the other biosphere AMR(s) that addresses that FEP is provided. These FEPs are ultimately used to support the TSPA.

The 47 primary FEPs, and the associated secondary FEPs, identified in Section 1.1.1 of this AMR were screened for inclusion or exclusion based on criteria provided in Section 4.2 of this AMR. A review of the secondary FEP's relationship to the primary FEP was conducted to determine if the primary FEP description captured the intent of the secondary FEP. That review indicated that for the 47 biosphere-related primary FEPs, the primary FEP description did capture the intent of the secondary FEP. However, it was also determined that not all secondary FEPs were applicable to Yucca Mountain biosphere. Secondary FEPs, which are considered not applicable, are identified in the "Screening Argument" column of Attachment I of this AMR. FEP, either primary or secondary, were considered excluded if:

- They are contrary to the qualitative criteria in DOE guidance.
- They can be shown to have a probability of occurrence less than $10^{-4}$ in $10^{4}$ years.
- Their occurrence can be demonstrated to have no significant effect on the overall performance of the system.

Attachment I identifies each of the 47 primary FEPs by YMP FEP No., YMP FEP Name, and YMP Primary FEP Description, and provides a screening decision for each FEP. For those FEPs recommended for exclusion from consideration, an exclusion argument is provided. Included FEPs have a TSPA disposition that identifies relevant AMRs associated with that FEP.

## 6.2 BIOSPHERE MODEL VALIDATION

### 6.2.1 YMP Biosphere Model Validation Activity

The validation activity documented here applies to all uses and applications of the YMP biosphere model, including the development of BDCF. A BDCF is a multiplier used to convert a radionuclide concentration at the geosphere/biosphere interface into a dose that a human would receive from all pathways. BDCF are expressed in units of annual dose per unit concentration in soil or water.

Application of the biosphere model to develop BDCF is documented in two AMRs: BDCF for groundwater contamination (a non-disruptive event) are developed in *Non-Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000b), and BDCF for soil contamination (a disruptive event) are developed in *Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000c). The biosphere model was also used to perform sensitivity analyses for groundwater BDCF in *Non-Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis* (CRWMS M&O 2000d), and soil contamination BDCF in *Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis* (CRWMS M&O 2000e). In addition, the model was used to support calculation of BDCF for an alternative receptor (CRWMS M&O 2000f ).

### 6.2.2 Approach to Model Validation

AP-3.10Q, *Analyses and Models* identifies model validation as "...a process to determine and document the adequacy of the scientific bases (i.e., confidence) for a model and to demonstrate the model is appropriate and adequate for its intended use." Validation may be accomplished by different means and to different degrees, depending on the exact nature and complexity of the phenomenon, process or system being modeled. For a simple system, the actual outcome, as reflected in data from laboratory experiments, field experiments or observations of natural or man-made analogs, may be compared with the predictions of the model. If such data are not available to support validation of the model, AP-3.10Q, *Analyses and Models* suggests alternate approaches including:

- Peer review or review by international collaborations.
- Technical review through publication in open literature.
- Review of model calibration parameters for reasonableness or consistency in explanation of relevant data.
- Comparison of analysis results with results from alternative conceptual models.
- Calibration and corroboration within experimental data sets.
- Comparison of analysis results with data attained during Performance Confirmation studies.

For the conditions being predicted with the YMP biosphere model (future exposure of humans to radioactive materials that may be released from the repository) direct observation of an actual outcome may never be possible. Accordingly, validation of the biosphere conceptual model as implemented using the GENII-S computer software was conducted using a combination of the alternative approaches suggested by AP-3.10Q, *Analyses and Models*.

### 6.2.3 Validation Method

The YMP biosphere model is a synthesis of the biosphere conceptual model and a generic mathematical model and submodels that are executed by the GENII-S computer code. The conceptual model considered in this validation was that of a farming community, located approximately 20 km south of the potential repository. The general climatic conditions are those of an arid/semi-arid environment. The individuals living in this community have a lifestyle consistent with present day behaviors and obtain a portion of the food and water they consume from local sources. The objective of this validation effort was to enhance confidence that the YMP biosphere model has an adequate scientific basis and is appropriate and adequate for the basic biosphere concept and this intended use. A validation process was developed, with predetermined validation criteria, to provide a high degree of confidence that:

- The GENII-S code, as installed, is operating correctly and gives results consistent with the inputs.
- The BDCF produced using GENII-S and the biosphere model are reasonable when compared with results of other calculations and conceptual models, and
- The pathways YMP biosphere were assessed and parameterized in a technically defensible manner.

The segments of this validation method are described in the following Sections (6.2.3.1–6.2.3.3). A detailed presentation of the results of the validation method is provided in Section 6.2.4.

#### 6.2.3.1 Segment 1: Software Qualification

The GENII-S code qualification is one segment of the YMP biosphere model validation. As part of qualification process in the SQR (CRWMS M&O 1998a), validation criteria were established for comparison of the GENII-S output with the results published in the software documentation or the results of hand calculations. Similar criterion are used to support model validation in this AMR.

Criterion 1.1: For test cases with numerical results, the GENII-S and expected (hand calculation or published) results agree within ±5%.

Criterion 1.2: For test cases with graphical output, actual and expected results agree (based on visual comparison).

Six validation test cases were executed as part of the software qualification discussed in the SQR (CRWMS M&O 1998a). Five were the sample cases (including both deterministic and

stochastic versions) provided with the GENII-S software package. The sample case results published in *User's Guide for GENII-S: A Code for Statistical and Deterministic Simulations of Radiation Doses to Humans from Radionuclides in the Environment* (Leigh et al. 1993) were used as the basis for comparison with results of the validation test runs. The sixth validation test case was an independent case specifically designed by the YMP staff to exercise all the pathways of interest. Hand calculations of the independent test case were done using the equations from the GENII-S mathematical model.

Each of the five sample test cases provided with the software was run in both stochastic and deterministic modes. The independent test case was run only in the deterministic mode. The results of each sample case were compared with the results published in Leigh et al. (1993). The results of the independent test case were compared with the hand-calculated doses.

For each test case, the numerical values produced by GENII-S fell within 5% of the published or hand-calculated value. It is concluded that validation criterion 1.1 was met.

For each test, case graphical outputs were consistent with the expected results. It is concluded that validation criterion 1.2 was met.

Meeting Criteria 1.1 and 1.2 demonstrates that the code was installed properly and is operating correctly.

#### 6.2.3.2 Segment 2: Comparison of the YMP BDCF with Results of Other GENII-S Calculations and Conceptual Models

The YMP BDCF produced using the YMP current biosphere model, as presented in CRWMS M&O (2000b) and CRWMS M&O (2000c), were compared and reconciled with results of other GENII-S calculations and conceptual models (LaPlante and Poor 1997, CRWMS M&O 1998b). Most features of the alternative models selected for comparison are very similar to the YMP biosphere model. However, the alternative calculations reflect the professional judgement of different analysts regarding the GENII-S input settings and parameter values that best represent the YMP biosphere features. Thus, this segment corresponds to one of the alternative validation approaches specified in AP-3.10Q, *Analyses and Models*.

This validation segment helps assure that no significant deficiencies have been made in describing the YMP biosphere or in implementing the model using GENII-S. If the YMP BDCF are shown to be consistent with results of other modeling efforts, additional confidence is gained in the appropriateness and adequacy of the YMP biosphere model and in the accuracy of its application. Selection of analyses for comparison was based on similarity of the pathways modeled and the documentation of the analysis inputs, both of which were necessary in order to compare and reconcile the results.

Validation Criteria 2.1 and 2.2 were established for comparison of the YMP BDCF with results of other calculations and conceptual models.

Criterion 2.1: For radionuclides in groundwater, differences between the YMP BDCF and the values inferred from other analyses can be explained by differences in the

pathway assumptions and values of input parameters used for the different analyses.

Criterion 2.2: For radionuclides in surface soil, differences between the YMP BDCF and the values inferred from other analyses can be explained by differences in the pathway assumptions and values of input parameters.

If values agree within about a factor of three, then they will be considered to be entirely consistent and no additional effort will be made to reconcile the differences. If the difference is greater than about a factor of three but less than a factor of ten, the values will be considered to be somewhat consistent, but no effort was made to explain the difference in terms of the values of the inputs used. If the difference is greater than a factor of ten, alternative calculations will be done to test the effect of different input parameter values and assumptions.

#### 6.2.3.3 Segment 3: Independent Review of the Biosphere Model

The third segment of the validation process was an independent review of the model by a qualified technical expert. The review was conducted to enhance confidence that the model has adequate scientific basis and is appropriate and adequate for its intended use as described in Section 6.2.3. Certain reviewer qualification criteria were deemed essential for the review to be credible, meaningful and constructive. Accordingly, it was determined that the independent reviewer must:

- Have had no prior involvement in the development of the YMP biosphere conceptual model.
- Be independent from the organization conducting the YMP biosphere modeling effort.
- Have broad experience in environmental dose assessment and biosphere model development.
- Possess detailed knowledge of the GENII-S code, its uses and limitations.

The following validation Criteria 3.1 – 3.4 were established for this independent review of the biosphere modeling effort.

Criterion 3.1: In the judgement of the independent reviewer, the pathways considered in the biosphere model and the manner in which they are applied is consistent with current environmental conditions in the Amargosa Valley and with the FEP of interest.

Criterion 3.2: In the judgement of the independent reviewer, the logic and analysis methods used to select values for the GENII-S input parameters are reasonable.

Criterion 3.3: In the judgement of the independent reviewer, the references and data sources cited by the YMP analysts are current and defensible.

Criterion 3.4: In the judgement of the independent reviewer, the values and ranges of the GENII-S input parameters used to develop BDCF are reasonable for the environmental conditions implicit in the biosphere conceptual model.

### 6.2.4 Validation Results

#### 6.2.4.1 Comparison of the YMP BDCF with Results of Other GENII-S Calculations and Conceptual Models

DOE guidance (Dyer 1999) and the nature of the YMP physical environment limit the possible processes by which radionuclides from the potential repository may enter the biosphere and the pathways by which humans may be exposed. As a result of the guidance cited in Section 4.2.4 of this analysis, no alternative conceptual models were identified. In other words, postulating future conditions, such as a radical increase in precipitation or return of continental glaciation, that would engender an alternative model of the biosphere would be contrary to the current DOE guidance. Comparison of the YMP BDCF with results of other GENII-S calculations for similar pathways and radionuclides is intended to enhance confidence in the YMP biosphere model and the integrity of the BDCF calculation process.

As a basis for this comparison, alternative calculations involving the same dose pathways and some of the same radionuclides were identified. The first of these calculations is documented in *Information and Analyses to Support Selection of Critical Groups and Reference Biospheres for Yucca Mountain Exposure Scenarios* (LaPlante and Poor 1997), prepared for the U.S. Nuclear Regulatory Commission by the Center for Nuclear Waste Regulatory Analyses (CNWRA). The second set of calculations is documented in CRWMS M&O (1998b). Although this analysis was prepared within the CRWMS M&O, it represents a different set of biosphere calculations.

The criteria that apply to the validation segments address the overall consistency of the YMP BDCF with results of other calculations. Substantial variation (for example, an order of magnitude or more) may be observed between different environmental dose calculation results that are fundamentally consistent in their conceptual treatment of a an issue. When the same calculational tool is used and the values for the input variables are documented, the effects of different inputs can be taken into account and the differences reconciled.

Full and exact agreement between the YMP BDCF as presented in CRWMS M&O (2000b) and CRWMS M&O (2000c), and the two other sets of calculations, reported in LaPlante and Poor (1997) and in CRWMS M&O (1998b) for all radionuclides was not expected. Whether or not the validation criteria were met was determined by the total weight of evidence presented by the alternative calculation results and not by any single BDCF comparison.

The following sections compare the BDCF values for groundwater contamination (CRWMS M&O 2000b), and BDCF values for soil contamination (CRWMS M&O 2000c) directly with the corresponding results of the alternative calculations. Values that agreed within about a factor of three were considered to be entirely consistent and no additional effort was made to reconcile the differences. If the difference was greater than about a factor of three but less than a factor of ten, the values were considered to be somewhat consistent, but no effort was made to explain the difference in terms of the values of the inputs used. If the difference was greater than a factor of

ten, alternative calculations were done to test the effect of different input parameter values and assumptions.

### 6.2.4.2 Comparison of Groundwater BDCF

Table 4 presents the BDCF values for groundwater (CRWMS M&O 2000b) which are identified in the table heading as YMP BDCF, the corresponding values from CRWMS M&O (1998b), identified in the table heading as TSPA-VA, and the ratio of the two values, YMP:TSPA-VA. The two sets of radionuclides considered in this table are those that have the potential to reach the biosphere, based on the referenced documents.

Table 4 shows that the groundwater YMP BDCF agree very well with the TSPA-VA values. The greatest observed difference is a factor of 1.44 and, for most radionuclides the agreement is even better. The TSPA-VA did not provide a BDCF value for one radionuclide (Uranium-232). This comparison strongly supports the finding that the validation criterion 2.1 is met.

Table 4. Comparison of YMP BDCF with TSPA-VA BDCF (Groundwater)

| Radionuclide | YMP BDCF[1] | TSPA-VA[1] | YMP BDCF:TSPA-VA Ratio |
|---|---|---|---|
| Actinium-227 | 1.81E+01 | 1.75E+01 | 1.03 |
| Americium-241 | 4.65E+00 | 4.50E+00 | 1.03 |
| Americium-243 | 4.64E+00 | 4.48E+00 | 1.04 |
| Carbon-14 | 4.06E-03 | 2.81E-03 | 1.44 |
| Iodine-129 | 3.61E-01 | 4.79E-01 | 0.75 |
| Neptunium-237 | 6.76E+00 | 6.57E+00 | 1.03 |
| Plutonium-238 | 4.11E+00 | 3.97E+00 | 1.04 |
| Plutonium-239 | 4.57E+00 | 4.41E+00 | 1.04 |
| Plutonium-240 | 4.56E+00 | 4.41E+00 | 1.03 |
| Technetium-99 | 4.02E-03 | 3.14E-03 | 1.28 |
| Thorium-229 | 4.59E+00 | 4.45E+00 | 1.03 |
| Uranium-232 | 1.71E+00 | [2] | [2] |
| Uranium-233 | 3.77E-01 | 3.65E-01 | 1.03 |
| Uranium-234 | 3.70E-01 | 3.58E-01 | 1.03 |
| Uranium-236 | 3.51E-01 | 3.40E-01 | 1.03 |
| Uranium-238 | 3.39E-01 | 3.28E-01 | 1.03 |

[1] All values in units of mrem/y per pCi/l
[2] BDCF Value for this radionuclide not included in TSPA-VA document.

Table 5 presents the BDCF values for groundwater (CRWMS M&O 2000b) which are identified in the table heading as YMP BDCF, the corresponding values from LaPlante and Poor (1997), and the ratio of the two values, YMP: LaPlante and Poor ratio. The two sets of radionuclides considered in this table are those that have the potential to reach the biosphere, based on the referenced documents.

Table 5 shows that except for plutonium isotopes, the groundwater YMP BDCF values agree with the values in LaPlante and Poor (1997) within a factor of about eight or less. The difference in the plutonium BDCF was examined to determine which input values might be responsible. The input pathway parameter values provided in LaPlante and Poor (1997) do not provide an

obvious reason for the difference. The relevant parameter values used in the two analyses are not significantly different.

Table 5. Comparison of YMP BDCF with LaPlante and Poor BDCF (Groundwater)

| Radionuclide | YMP BDCF[1] | LaPlante and Poor[1] | YMP BDCF: LaPlante and Poor Ratio |
|---|---|---|---|
| Actinium-227 | 1.81E+01 | 3.1E+01 | 0.58 |
| Americium-241 | 4.65E+00 | 7.9E+00 | 0.59 |
| Americium-243 | 4.64E+00 | [2] | [2] |
| Carbon-14 | 4.06E-03 | 1.9E-02 | 0.21 |
| Iodine-129 | 3.61E-01 | 3.1E+00 | 0.12 |
| Neptunium-237 | 6.76E+00 | 1.3E+01 | 0.52 |
| Plutonium-238 | 4.11E+00 | [2] | [2] |
| Plutonium-239 | 4.57E+00 | 1.1E-01 | 42 |
| Plutonium-240 | 4.56E+00 | 1.1E-01 | 42 |
| Technetium-99 | 4.02E-03 | 8.4E-03 | 0.48 |
| Thorium-229 | 4.59E+00 | 8.1E+00 | 0.57 |
| Uranium-232 | 1.71E+00 | 2.4E-01 | 7.1 |
| Uranium-233 | 3.77E-01 | 6.1E-02 | 6.2 |
| Uranium-234 | 3.70E-01 | 6.1E-02 | 6.1 |
| Uranium-236 | 3.51E-01 | 5.7E-02 | 6.2 |
| Uranium-238 | 3.39E-01 | 7.2E-02 | 4.7 |

[1] All values in units of mrem/y per pCi/l
[2] BDCF Value for this radionuclide not included in LaPlante and Poor (1997).

Because the difference between the plutonium BDCF could not be understood from differences in the input parameters, the pathway contributions to the plutonium BDCF was examined to see if additional confidence in the YMP BDCF value could be gained. The *Non-Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis* (CRWMS M&O 2000d) showed that more than half (61%) of the BDCF value was due to consumption of drinking water. The BDCF values were calculated using a fixed groundwater consumption rate of 752.8 l/y (CRWMS M&O 2000b). By applying the highest Plutonium-239 ingestion dose conversion factor (9.56E-7 Sv/Bq or 3.54E-3 mrem/pCi) from Federal Guidance Report 11 (Eckerman et al. 1988) to that groundwater consumption rate, a BDCF of 2.66 mrem/yr per pCi/l was calculated. Because groundwater consumption contributes 61% of the BDCF value, a BDCF value of about 5 mrem/y per pCi/l can be inferred. This value is very close to the YMP BDCF value for Plutonium-239 and suggests that the LaPlante and Poor (1997) results may have been calculated using lower values of dose per unit intake (dose conversion factors) for plutonium isotopes. LaPlante and Poor (1997) do not specify the dose per unit intake values used in their calculation.

Conclusion: Comparison of the YMP groundwater BDCF (CRWMS M&O 2000b) with the corresponding TSPA-VA values (CRWMS M&O 1998b) strongly supports a finding that validation criterion 2.1 was met. The comparison of the YMP groundwater BDCF (CRWMS M&O 2000b) and the LaPlante and Poor (1997) values shows fair agreement as discussed. Based on the weight of evidence presented by these comparisons, it was concluded that validation criterion 2.1 was met.

### 6.2.4.3 Comparison of Soil BDCF

Table 6 presents the BDCF values for soil contamination (CRWMS M&O 2000c) which are identified in the table heading as YMP BDCF, the corresponding values from CRWMS M&O (1998b), identified in the table heading as TSPA-VA, and the ratio of the two values, YMP BDCF:TSPA-VA ratio. The two sets of radionuclides considered in this table are those that may reach the biosphere, based on the referenced documents.

Table 6. Comparison of YMP BDCF with TSPA-VA BDCF (Soil Contamination)

| Radionuclide | YMP BDCF[1] | TSPA/VA[1] | YMP BDCF:TSPA/VA |
|---|---|---|---|
| Actinium-227 | 2.99E-09 | 8.49E-07 | 3.52E-03 |
| Americium-241 | 5.38E-10 | 2.14E-07 | 2.51E-03 |
| Americium-243 | 5.75E-10 | 2.14E-07 | 2.69E-03 |
| Cesium-137 | 1.81E-09 | [2] | [2] |
| Protactinium-231 | 1.59E-09 | 7.42E-07 | 2.14E-03 |
| Plutonium-238 | 3.62E-10 | 1.89E-07 | 1.92E-03 |
| Plutonium-239 | 4.02E-10 | 2.10E-07 | 1.91E-03 |
| Plutonium-240 | 4.01E-10 | 2.10E-07 | 1.91E-03 |
| Strontium-90 | 7.79E-09 | [2] | [2] |
| Thorium-229 | 9.44E-10 | 2.17E-07 | 4.35E-03 |
| Uranium-232 | 8.07E-10 | [2] | [2] |
| Uranium-233 | 1.77E-10 | 1.78E-08 | 9.94E-03 |

[1] All values in units of rem/y per pCi/m$^2$
[2] BDCF Value for this radionuclide not included in TSPA-VA document.

The ratios in Table 6 show that the YMP BDCF values for soil contamination (CRWMS M&O 2000c) are about 2 to 3 orders of magnitude lower than the TSPA-VA values (CRWMS M&O 1998b). A possible explanation for these differences can be found in the different input parameter values used in the two analyses.

First, the value of crop resuspension factor used in the TSPA-VA (CRWMS M&O 1998b) analysis (mean value of 1E-5 m$^{-1}$) was several orders of magnitude greater than that used to generate the YMP BDCF (mean value of 8.3E-11 m$^{-1}$) (CRWMS M&O 2000c). The significance of this difference is that, based on the BDCF sensitivity analysis results (CRWMS M&O 2000e), ingestion of crops contaminated by resuspended soil is an important dose pathway for most radionuclides of interest. Second, a value of 410 mg/d for inadvertent soil ingestion was used in the TSPA-VA analysis (CRWMS M&O 1998b) compared to the 50 mg/d value used in the YMP BDCF calculations (CRWMS M&O 2000c). The sensitivity analysis (CRWMS M&O 2000e) indicated that inadvertent soil ingestion accounts for a significant part (up to 77%) of the BDCF value for some radionuclides.

GENII-S calculations were performed to evaluate the effect of the crop resuspension factor and inadvertent soil ingestion values on BDCF. The calculations used the higher values for crop resuspension factor and soil ingestion rate, but replicated the BDCF "reasonable representation" (stochastic) cases from CRWMNS M&O (2000c) in all other respects. Resuspension factor was represented as a lognormal distribution with minimum value of 5.89E-7, maximum of 1.70E-4 and mean of 1E-5 m$^{-1}$. Inadvertent soil ingestion was set at a fixed value of 410 mg/d. The calculation using the higher soil ingestion rate is designated Case 1 in Table 7. Case 2 is the

calculation using higher resuspension factor. Case 3 uses the higher values for both parameters. The results are presented in Table 7, including the ratio of Case 3 to the TSPA-VA BDCF.

Table 7. Comparison of TSPA BDCF and Adjusted YMP BDCF (Soil Contamination)

| Radionuclide | TSPA-VA | Case 1[2] Adjusted BDCF | Case 2[3] Adjusted BDCF | Case 3[4] Adjusted BDCF | Ratio: Case 3 YMP BDCF: TSPA-VA |
|---|---|---|---|---|---|
| Actinium-231 | 8.49E-07 | 1.12E-08 | 1.48E-06 | 1.48E-06 | 1.75 |
| Americium-241 | 2.14E-07 | 2.67E-09 | 3.79E-07 | 3.81E-07 | 1.78 |
| Americium-243 | 2.14E-07 | 2.70E-09 | 3.79E-07 | 3.81E-07 | 1.78 |
| Cesium-137 | [5] | 1.83E-09 | 1.47E-08 | 1.47E-08 | [5] |
| Protactinium-231 | 7.42E-07 | 7.86E-09 | 1.11E-06 | 1.12E-06 | 1.51 |
| Plutonium-238 | 1.89E-07 | 2.25E-09 | 3.35E-07 | 3.37E-07 | 1.78 |
| Plutonium-239 | 2.10E-07 | 2.50E-09 | 3.72E-07 | 3.74E-07 | 1.78 |
| Plutonium-240 | 2.10E-07 | 2.49E-09 | 3.71E-07 | 3.74E-07 | 1.78 |
| Strontium-90 | [5] | 7.86E-09 | 2.50E-08 | 2.51E-08 | [5] |
| Thorium-229 | 2.17E-07 | 3.01E-09 | 3.85E-07 | 3.87E-07 | 1.79 |
| Uranium-232 | [5] | 1.57E-09 | 1.46E-07 | 1.4E-07 | [5] |
| Uranium-233 | 1.78E-08 | 3.47E-10 | 3.21E-08 | 3.229E-08 | 1.81 |

[1] All values in units of rem/y per pCi/m$^2$
[2] Reasonable representation case with inadvertent soil ingestion set at a fixed value of 410 mg/d
[3] Reasonable representation" case with resuspension factor represented as a lognormal distribution with minimum value of 5.89E-7, maximum of 1.70E-4 and mean of 1E-5 m$^{-1}$
[4] Reasonable representation" case with both resuspension factor and soil ingestion set at the higher values used in cases 1 and 2.
[5] BDCF value for this radionuclide not included in TSPA-VA document.

As seen from the ratios in Table 7, the YMP BDCF for all radionuclides except the plutonium isotopes were within a factor of two of those produced by the TSPA-VA calculation if the differences in crop resuspension factor and soil ingestion rate are considered. Nearly all the difference in the two sets of BDCF values can be attributed to the large difference in the crop resuspension factor values used in the calculations. Agreement of the adjusted BDCF values within a factor of two or less strongly supports the conclusion that the validation Criterion 2.2 was met.

Table 8 presents the BDCF values for soil contamination (CRWMS M&O 2000c) which are identified in the table heading as YMP BDCF, the corresponding values from LaPlante and Poor (1997), and the ratio of the two values, YMP: LaPlante and Poor ratio.

Table 8 shows that the YMP BDCF are about 2 to 3 orders of magnitude lower than the LaPlante and Poor values. By review of the inputs used for both analyses, it was noted that the crop resuspension factor distribution used in the LaPlante and Poor analysis (mean value of 1E-5 m$^{-1}$, minimum of 1.66E-6 m$^{-1}$ and maximum of 6.03E-5 m$^{-1}$) was similar to that used in the TSPA-VA analysis (mean value of 1E-5, a minimum of 5.89E-7 and a maximum of 1.70E-4 m$^{-1}$), about five orders of magnitude greater than was used in the YMP BDCF calculation. Using the results of the "adjusted BDCF" case 2 from Table 7 for comparison, the differences between the two sets of calculations are presented in Table 9.

Table 8. Comparison of YMP BDCF with LaPlante and Poor BDCF (Soil Contamination)

| Radionuclide | YMP BDCF[1] | LaPlante and Poor[1] | YMP BDCF: LaPlante and Poor |
|---|---|---|---|
| Actinium-227 | 2.99E-09 | 2.7E-06 | 1.1E-03 |
| Americium-241 | 5.38E-10 | 7.0E-07 | 7.7E-04 |
| Americium-243 | 5.75E-10 | 7.0E-07 | 8.2E-04 |
| Cesium-137 | 1.81E-09 | 1.2E-07 | 1.5E-02 |
| Protactinium-231 | 1.59E-09 | 2.1E-06 | 7.6E-04 |
| Plutonium-238 | 3.62E-10 | [2] | [2] |
| Plutonium-239 | 4.02E-10 | 1.0E-08 | 4.0E-02 |
| Plutonium-240 | 4.01E-10 | 1.0E-08 | 4.0E-02 |
| Strontium-90 | 7.79E-09 | 7.3E-08 | 1.1E-01 |
| Thorium-229 | 9.44E-10 | 7.3E-07 | 1.3E-03 |
| Uranium-232 | 8.07E-10 | 1.8E-08 | 4.5E-02 |
| Uranium-233 | 1.77E-10 | 5.8E-09 | 3.1E-02 |

[1] All values in units of rem/y per pCi/m$^2$
[2] BDCF Value for this radionuclide not included in LaPlante and Poor (1997).

Table 9. Comparison of Adjusted YMP BDCF with LaPlante and Poor BDCF (Soil Contamination)

| Radionuclide | Adjusted YMP BDCF[1,2] | LaPlante and Poor[1] | Ratio: Adjusted YMP BDCF /LaPlante and Poor |
|---|---|---|---|
| Actinium-227 | 1.48E-06 | 2.7E-06 | 0.55 |
| Americium-241 | 3.79E-07 | 7.0E-07 | 0.54 |
| Americium-243 | 3.79E-07 | 7.0E-07 | 0.54 |
| Cesium-137 | 1.47E-08 | 1.2E-07 | 0.12 |
| Protactinium-231 | 1.11E-06 | 2.1E-06 | 0.53 |
| Plutonium-238 | 3.35E-07 | [3] | [3] |
| Plutonium-239 | 3.72E-07 | 1.0E-08 | 37 |
| Plutonium-240 | 3.7E-07 | 1.0E-08 | 37 |
| Strontium-90 | 2.53E-08 | 7.3E-08 | 0.34 |
| Thorium-229 | 3.85E-07 | 7.3E-07 | 0.53 |
| Uranium-232 | 1.46E-07 | 1.8E-08 | 8.1 |
| Uranium-233 | 3.21E-08 | 5.8E-09 | 5.5 |

[1] All values in units of rem/y per pCi/m2
[2] "Case 2" values from Table 7, YMP BDCF "Reasonable representation" case with resuspension factor represented as a lognormal distribution with minimum value of 5.89E-7, maximum of 1.70E-4 and mean of 1E-5 m$^{-1}$
[3] BDCF Value for this radionuclide not included in LaPlante and Poor (1997).

The ratios presented in Table 9 indicate that the YMP BDCF for all radionuclides except the plutonium isotopes are within a factor of about eight of those produced by LaPlante and Poor (1997) if the difference in crop resuspension factor is considered. The fact that the adjusted YMP BDCF values for both plutonium isotopes are higher than the LaPlante and Poor (1997) values by about a factor of 40 is consistent with the observation discussed in Section 6.2.4.2 with regard to the groundwater BDCF. The difference, which may be due to lower plutonium dose conversion factors by LaPlante and Poor (1997), can not be reconciled from the available documentation. Agreement of the adjusted BDCF values within a factor of three for six of the

radionuclides and within an order of magnitude for three supports the conclusion that validation Criterion 2.2 was met.

Conclusion: Comparison of the YMP BDCF values for soil contamination (CRWMS M&O 2000c) with the TSPA-VA values (CRWMS M&O 1998b) strongly supports a finding that validation criterion 2.2 was met. The comparison of the YMP soil BDCF and the LaPlante and Poor (1997) results shows fair agreement. Based on the weight of evidence presented by these comparisons, it is concluded that validation criterion 2.2 was met. Meeting these criteria demonstrates the appropriateness and adequacy of the model for the intended use.

#### 6.2.4.4 Independent Review of the Biosphere Model

The independent reviewer selected was Mr. Bruce Napier of Pacific Northwest National Laboratory, principal architect of the GENII computer code. Mr. Napier is a nationally-known expert in environmental dose assessment. In addition to developing GENII and collaborating in the creation of GENII-S, he has directed or participated in several other major environmental dose modeling efforts. He is currently in the process of completing the next generation of stochastic environmental exposure, dose, and risk computer codes for radionuclides for the U. S. Environmental Protection Agency (EPA). His experience and qualifications include:

- Technical Integrator and Chief Scientist for the Hanford Environmental Dose Reconstruction project.
- Principal investigator on the U. S. /Russia Joint Coordinating Committee on Radiation Effects Research Projects on reconstruction of dose to the public around the Russian Mayak (Chelyabinsk-65) nuclear materials production site in Siberia.
- U. S. Chair of the U. S./Belarus and U. S./Ukraine Bi-National Advisory Committees on Chernobyl Studies for the U. S. National Cancer Institute.
- Consultant to the International Atomic Energy Agency (IAEA) and a participant in the IAEA's Cooperative Research Program on Biosphere Modeling and Assessment (BIOMASS).
- Member of EPA Science Advisory Board.
- Member of National Council on Radiation Protection and Measurements (NCRP) Scientific Committee 64 on Radionuclides in the Environment, Task Group 7 on Contaminated Soil as a Source of Radioactive Exposure.

The review was conducted by Mr. Napier in February-March of 2000 (Napier 2000) using the most recent final and draft documents that describe the characteristics of the YMP biosphere and the associated receptor of interest. Those references and his findings with regard to the adequacy of the model are documented in a letter report (Napier 2000). Based on the information provided to him, he stated that, with minor exceptions:

- *The critical group consists of a farming community with members consuming locally-produced food as a substantial part of their diet. This combination is reasonable, appropriate for the surroundings, and justifiable. The pathways considered in the biosphere model and the manner in which they are applied is consistent with current environmental conditions in the Amargosa Valley and with the FEP of interest.* Criterion 3.1 is judged to be met.

- *The logic and analysis methods used to select values for the GENII-S input parameters for the resident farmer scenario are sound.* Criterion 3.2 is judged to be met.

- *The references and data sources cited by the YMP analysts are current and credible. The parameters selected are well-described and traceable.* Criterion 3.3 is judged to be met.

- *The approach to selecting values and ranges for the input parameters is sound. The documentation is complete and relatively easily followed. The values and ranges of the GENII-S input parameters used to develop BDCF are reasonable for the environmental conditions implicit in the biosphere conceptual model.* Criterion 3.4 is judged to be met.

Mr. Napier concluded that "...the conceptual model of the biosphere, as laid out in the documents reviewed, is reasonable and in keeping with both the draft regulatory requirements and the actual physical setting. The biosphere conceptual model is clear, appropriate, and well documented. The mean or central values of the BDCF estimated are reasonable and appropriate." In addition to the above conclusion, Mr. Napier offered a number of suggestions and insights regarding stochastic environmental dose modeling and specific biosphere model parameters (Napier 2000).

The results of the independent review indicate that the model is appropriate and adequate for the intended use.

# 7. CONCLUSIONS

## 7.1 BIOSPHERE MODEL VALIDATION SUMMARY AND CONCLUSIONS

A model validation approach was developed to determine and document the adequacy of the scientific bases (i.e., confidence) for the YMP biosphere model and to demonstrate the model is appropriate and adequate for its intended use in accordance with AP-3.10Q, *Models and Analyses.* The model validation approach consisted of three segments:

1. Qualification of the GENII-S code.

2. Comparison of the YMP BDCF with results of other GENII-S calculations and conceptual models.

3. Independent review of the biosphere model by a qualified technical expert.

Eight criteria, both quantitative and qualitative, were established for the validation effort. The validation effort was carried out in accordance with the planned approach and the results documented in this AMR. Each of the eight pre-determined validation criteria was determined to be substantially satisfied.

It was therefore concluded that the YMP biosphere model, as implemented using the GENII-S code, is validated for developing BDCF for use in TSPA for the calculation of radiation doses to humans from radioactive material that may be released from a potential Yucca Mountain high level waste repository. This model is also valid for modeling and evaluation of alternative receptors of interest that fall within the bounds of the conceptual model. Therefore, it was concluded that the validation effort demonstrated the adequacy of the scientific basis for the model, and the biosphere model is appropriate and adequate for the intended use.

Related applications of the YMP biosphere model, including assessment of alternative release scenarios, determination pathway significance and analysis of the sensitivity of calculated BDCF to variations in input parameter values are specifically included within the range of intended uses for which this validation was conducted. This validated model is used to support TSPA/SR and will be used to support analyses and calculations for license application activities.

## 7.2 EVALUATION OF THE APPLICABILITY OF BIOSPHERE-RELATED FEATURES, EVENTS, AND PROCESSES

Of the 47 primary FEPs identified in Table 1 of this report, it was concluded that 22 FEPs are applicable, in part or in total, to Yucca Mountain. For those FEPs for which the screening decision was "Include/Exclude", the screening against the criteria revealed that one or more of the secondary FEPs associated with the primary FEPs were applicable while one or more of the secondary were not. The FEPs that are currently assumed to be applicable are identified in Table 10.

Table 10. Features, Events, and Processes Considered Applicable to YMP

| FEP NAME | YMP FEP DATABASE NUMBER | SCREENING DECISION |
|---|---|---|
| Wells | 1.4.07.02.00 | Include/Exclude |
| Soil type | 2.3.02.01.00 | Include/Exclude |
| Radionuclide accumulation in soils | 2.3.02.02.00 | Include/Exclude |
| Soil and sediment transport | 2.3.02.03.00 | Include/Exclude |
| Precipitation | 2.3.11.01.00 | Include/Exclude |
| Surface runoff and flooding | 2.3.11.02.00 | Include/Exclude |
| Biosphere characteristics | 2.3.13.01.00 | Include/Exclude |
| Biosphere transport | 2.3.13.02.00 | Include/Exclude |
| Human characteristics (physiology, metabolism) | 2.4.01.00.00 | Include/Exclude |
| Diet and fluid intake | 2.4.03.00.00 | Include/Exclude |
| Human lifestyle | 2.4.04.01.00 | Include/Exclude |
| Dwellings | 2.4.07.00.00 | Include/Exclude |
| Agricultural land use and irrigation | 2.4.09.01.00 | Include/Exclude |
| Animal farms and fisheries | 2.4.09.02.00 | Include |
| Drinking water, foodstuffs and drugs, contaminant concentrations in | 3.3.01.00.00 | Include/Exclude |
| Plant uptake | 3.3.02.01.00 | Include/Exclude |
| Animal uptake | 3.3.02.02.00 | Include/Exclude |
| Bioaccumulation | 3.3.02.03.00 | Include |
| Ingestion | 3.3.04.01.00 | Include/Exclude |
| Inhalation | 3.3.04.02.00 | Include |
| External exposure | 3.3.04.03.00 | Include/Exclude |
| Radiation doses | 3.3.05.01.00 | Include/Exclude |

# 8. INPUTS AND REFERENCES

## 8.1 INPUTS CITED

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# ATTACHMENT I

# SUMMARY OF SCREENING DECISIONS FOR PRIMARY BIOSPHERE-RELATED FEATURES, EVENTS, AND PROCESSES

ATTACHMENT I

# SUMMARY OF SCREENING DECISIONS FOR PRIMARY BIOSPHERE-RELATED FEATURES, EVENTS AND PROCESSES

| YMP FEP NO. | YMP FEP NAME | YMP PRIMARY FEP DESCRIPTION | SCREENING DECISION | SCREENING ARGUMENT | TSPA DISPOSITION |
|---|---|---|---|---|---|
| 1.2.07.01.00 | Erosion/denudation | Erosion and denudation are processes, which cause significant changes in the present-day topography and thus affect local and regional hydrology and the biosphere. Erosion of surficial materials can occur by a variety of means, including physical weathering (including glacial and fluvial erosion), chemical weathering, erosion by wind (Aeolian erosion), and mass wasting (e.g., landslide) processes. The extent of erosion depends to a large extent on climate and uplift. | EXCLUDE | Inconsistent with section 115(a)(1) of the RIG which limits the Reference Biosphere to current conditions; therefore, this FEP is excluded. | |
| 1.2.07.02.00 | Deposition | Deposition and erosion are processes which cause significant changes in the present-day topography and thus affect local and regional hydrology and the biosphere. Deposition of surficial materials can occur by a variety of means, including fluvial, aeolian, and lacustrine deposition and redistribution of soil through weathering and mass wasting processes. | EXCLUDE | Inconsistent with section 115(a)(1) of the RIG which limits the Reference Biosphere to current conditions; therefore, this FEP is excluded. | |
| 1.3.01.00.00 | Climate change, global | Climate change may affect the long-term performance of the repository. This includes the effects on long-term change in global climate (e.g., glacial/interglacial cycles) and shorter-term change in regional and local climate. Climate is typically characterized by temporal variations in precipitation and temperature. | EXCLUDE | Inconsistent with section 115(a)(1) of the RIG which limits the Reference Biosphere to current conditions; therefore, this FEP is excluded. | |

| YMP FEP NO. | YMP FEP NAME | YMP PRIMARY FEP DESCRIPTION | SCREENING DECISION | SCREENING ARGUMENT | TSPA DISPOSITION |
|---|---|---|---|---|---|
| 1.3.04.00.00 | Periglacial effects | This category contains FEPs related to the physical processes and associated landforms in cold but ice-sheet-free environments. Permafrost and seasonal freeze/thaw cycles are characteristic of periglacial environments. | EXCLUDE | Inconsistent with section 115(a)(1) and (2) of the RIG, which limits the Reference Biosphere to current arid/semi-arid conditions; therefore, this FEP is excluded. | |
| 1.3.05.00.00 | Glacial and ice sheet effects, local | This category contains FEPs related to the effects of glaciers and ice sheets occurring within the region of the repository, including direct geomorphologic effects and hydrologic effects. These effects include changes in topography (due to glaciation and melt water), changes in flow fields, and isostatic depression and rebound. | EXCLUDE | Inconsistent with section 115(a)(1) and (2) of the RIG, which limits the Reference Biosphere to current arid/semi-arid conditions; therefore, this FEP is excluded. | |
| 1.4.01.00.00 | Human influences on climate | This category contains FEPs related to future human actions that could influence global, regional, or local climate. Human actions may be intentional or accidental. This FEP aggregates all human influences on climate into a single category. | EXCLUDE | Inconsistent with Sections 115(a) and (b) of the RIG which require that the Reference Biosphere be consistent with current conditions. As a result, this FEP is excluded. | |
| 1.4.01.02.00 | Greenhouse gas effects | The greenhouse effect refers to the presence of carbon dioxide and other gases in the atmosphere that tend to allow solar radiation through to the earth's surface and reflect heat back to it. Thus, these gases act much as the glass of a greenhouse, with the earth as the greenhouse. Human activities such as burning of fossil fuels, forest clearance, and industrial processes produce these greenhouse gases. The greenhouse effect could increase concentrations of carbon dioxide and other gases in the atmosphere, and lead to changes in climate such as global warming. | EXCLUDE | Inconsistent with Sections 115(a) and (b) of the RIG which require that the Reference Biosphere be consistent with current conditions; including current greenhouse gas effects and current climatic conditions. The effect of changing the greenhouse effect gas is therefore excluded. | |

| YMP FEP NO. | YMP FEP NAME | YMP PRIMARY FEP DESCRIPTION | SCREENING DECISION | SCREENING ARGUMENT | TSPA DISPOSITION |
|---|---|---|---|---|---|
| 1.4.01.03.00 | Acid rain | Human actions may result in acid rain on a local to regional scale. Acid rain can detrimentally affect aquatic and terrestrial life by interfering with the growth, reproduction, and survival of organisms. It can influence the behavior and transport of contaminants in the biosphere, particularly by affecting surface water and soil chemistry. | EXCLUDE | Section 115(a)(1) and (2) of the RIG, limits the Reference Biosphere to current arid/semi-arid conditions, which includes any existing acid rain. Human actions, which change acid rain characteristics, are therefore excluded. | |
| 1.4.01.04.00 | Ozone layer failure | Human actions (i.e., the use of certain industrial chemicals) may lead to destruction or damage to the earth's ozone layer. This may lead to significant changes to the climate, affecting properties of the geosphere such as groundwater flow patterns. | EXCLUDE | Inconsistent with section 115(a)(1) of the RIG, which limits the Reference Biosphere to current conditions; therefore, the processes in this FEP, which consider change, are excluded. | |
| 1.4.06.01.00 | Altered soil or surface water chemistry | Human activities (e.g., industrial pollution, agricultural chemicals) may produce local changes to the soil chemistry or to the chemistry of water infiltrating Yucca Mountain and could provide a plume of unspecified nature to interact with the repository and possibly with containers. | EXCLUDE | Section 115(b)(1) specifies the location of the critical group as 20 km south of Yucca Mountain. As a result, this FEP which deals with impacts on the repository is excluded. | |
| 1.4.07.01.00 | Water management activities | Water management is accomplished through a combination of dams, reservoirs, canals, pipelines, collection and storage facilities. Water management activities could have a major influence on the behavior and transport of contaminants in the biosphere. | EXCLUDE | Section 115(b) of the RIG specifies that the behavior and characteristics of the critical group be consistent with current conditions. Figure 2-2 of LaPlante and Poor (1997) indicates that there are no major water retention facilities within 20 km. of the location of the critical group specified in Section 115(b). As a result, this FEP is excluded | |

| YMP FEP NO. | YMP FEP NAME | YMP PRIMARY FEP DESCRIPTION | SCREENING DECISION | SCREENING ARGUMENT | TSPA DISPOSITION |
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| 1.4.07.02.00 | Wells | One or more wells drilled for human use (e.g., drinking water, bathing) or agricultural use (e.g. irrigation, animal watering) may intersect the contaminant plume. | INCLUDE (wells for human and agricultural use)<br><br>EXCLUDE (wells located at a point other than specified by RIG) | Section 115(b) specifies the location of the critical group as approximately 20 km. south of the repository. Therefore, FEPs 1.4.07.02.01, 1.4.07.02.02, 1.4.07.02.03, 1.4.07.02.05, 1.4.07.02.08 and 1.4.07;.02.09 are excluded. | This FEP is considered as the source of radionuclides entering the environment under the Non-disruptive scenario. See AMR entitled: *Groundwater Usage by the Proposed Farming Community* (CRWMS M&O 2000g), and *Non-Disruptive Event Biosphere Dose Conversion Factors* (CRWMS M&O 2000b). |
| 1.4.08.00.00 | Social and institutional developments | This category contains FEPs related to social and institutional developments that could affect the long-term performance of the repository. The most likely is social and institutional development resulting in new activities, communities, or cities in the vicinity of Yucca Mtn. | EXCLUDE | Inconsistent with section 115(b)(2) of the RIG, which specifies that the behavior and characteristics of the critical group be consistent with current conditions. Changes are not to be considered. Therefore, this FEP is excluded. | |
| 1.4.09.00.00 | Technological developments | Technological developments may affect the long-term performance of the repository. These include changes in the ability of man to intrude the site, and changes that might affect contaminant exposure and its health implications. | EXCLUDE | Inconsistent with section 115(b)(2) of the RIG, which specifies that the behavior, and characteristics of the critical group be consistent with current conditions. Change is, therefore, not to be considered. Therefore, this FEP is excluded. | |
| 1.5.02.00.00 | Species evolution | Species living at or near the repository, including humans, may evolve in the future and new behavior and characteristics of living organisms may affect their contaminant exposure and its health implications. | EXCLUDE | Inconsistent with section 115(b)(2) of the RIG, which specifies that the behavior and characteristics of the critical group be consistent with current conditions. Consideration of non-human receptors is precluded by the performance objective specified in Section 113 (b). Therefore, this FEP is excluded. | |

| YMP FEP NO. | YMP FEP NAME | YMP PRIMARY FEP DESCRIPTION | SCREENING DECISION | SCREENING ARGUMENT | TSPA DISPOSITION |
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| 2.2.07.03.00 | Capillary rise | Capillary rise involves the drawing up of water, above the water table or above locally saturated zones, in continuous pores of the unsaturated zone until the suction gradient is balanced by the gravitational pull downward. Capillary rise may provide a mechanism for radionuclides to reach the surface environment in locations where the water table is shallow. | EXCLUDE | Section 115(b) (1) specifies the location of the critical group; approximately 20 km south of the repository. Since depth to water in that area is in excess of 50 meters (LaPlante and Poor 1997), this FEP is excluded. | |
| 2.3.02.01.00 | Soil type | Soil type is determined by many different factors (e.g., formative process, geology, climate, vegetation, land-use). The physical and chemical attributes of the surficial soils (such as organic matter content, pH), may influence the mobility of contaminants. | INCLUDE (soil type)<br><br>EXCLUDE (soil development/ formation) | Section 115 of the RIG limits reference biosphere to current conditions. Therefore, formation and development of soils (FEPs 2.3.02.01.01 through 2.3.02.01.03) are excluded. | This FEP is considered in the transfer of radionuclides from well water to the food chain. It is also considered in the build-up of function of previous irrigation and time. See AMR entitled *Non-Disruptive Event Biosphere Dose Conversion Factors Analysis* (CRWMS M&O 2000b), *Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000c), and *Evaluate Soil/Radionuclide Removal by Erosion and Leaching* (CRWMS M&O 2000h) |
| 2.3.02.02.00 | Radionuclide accumulation in soils | Radionuclide accumulation in soils may occur as a result of upwelling of contaminated groundwater (leaching, evaporation at discharge location) or deposition of contaminated water or particulates (irrigation water, runoff, atmospheric deposition). | INCLUDE (Deposition)<br><br>EXCLUDE (Upwelling at other locations) | Section 115(b) of the RIG specifies the location of the critical group as 20 km south of repository. Therefore, consideration of upwelling/ discharging (FEP 2.3.02.02.02) at other locations is excluded. | Disposition of radionuclides in soil as a result of continuous irrigation is considered. See AMRs entitled: *Non-Disruptive Event Biosphere Dose Conversion Factors Analysis* (CRWMS M&O 2000b), and *Abstraction of BDCF Distributions for Irrigation Periods* (CRWMS M&O 2000i) |

| YMP FEP NO. | YMP FEP NAME | YMP PRIMARY FEP DESCRIPTION | SCREENING DECISION | SCREENING ARGUMENT | TSPA DISPOSITION |
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| 2.3.02.03.00 | Soil and sediment transport | Contaminated sediments can be transported by fluvial, glacial and, to a lesser extent, aeolian processes. In addition, sediment transport may occur through the actions of living organisms (i.e., bioturbation). Sediment transport and redistribution may cause concentration or dilution of radionuclides. | INCLUDE (aeolian)<br><br>EXCLUDE (Fluvial, glacial, bioturbation) | Section 115(a) of the RIG specifies that the Reference Biosphere be consistent with current conditions. As there are no fluvial or glacial processes current at work in the area, portions of FEP 2.3.02.03.03 are excluded from consideration.. | Removal of potentially contaminated soil is considered. Aeolian processes for current conditions are addressed in AMR entitled *Evaluate Soil/Radionuclide Removal by Erosion and Leaching* (CRWMS M&O 2000h) |
| 2.3.04.01.00 | Surface water transport and mixing | Contaminants released from an underground repository might enter the biosphere through discharge of deep groundwater into a lake or river. Transport and mixing within the surface water bodies affects the subsequent behavior and transport of contaminants in the biosphere. Transport and mixing includes dilution, sedimentation, aeration, streamflow, and river meander. | EXCLUDE | Sections 115(a) and (b) of the RIG specifies that the Reference Biosphere be consistent with current conditions. Figure 2-2 of LaPlante and Poor (1997) indicates there are no lakes and rivers within 20 km of the location of the critical group. As a result this FEP is excluded from consideration. | |
| 2.3.06.00.00 | Marine features | This category contains FEPs related to marine and coastal features and processes. Processes include erosion, sedimentation, deposition, sea-level change, and storms. | EXCLUDE | Section 115(a) of the RIG specifies that the Reference Biosphere be consistent with current conditions. Figure 2-2 of LaPlante and Poor (1997) indicates there are no marine or coastal features within 20 km of the location of the critical group. As a result this FEP is excluded from consideration. | |

| YMP FEP NO. | YMP FEP NAME | YMP PRIMARY FEP DESCRIPTION | SCREENING DECISION | SCREENING ARGUMENT | TSPA DISPOSITION |
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| 2.3.09.01.00 | Animal burrowing/intrusion | Burrowing animals may intrude into the repository, promoting release and spread of contamination. Burrowing animals may also contact or ingest contaminated soil. | EXCLUDE | Section 115 of the RIG specifies the location of the critical group and the reference biosphere. As a result, events directly involving the repository are excluded on the basis of inconsistency with the RIG. Ingestion or contact of burrowing animals with contaminated soil is excluded from consideration by the performance objectives in Section 114 which set one of the objectives as a dose to a human, not an animal. | |
| 2.3.11.01.00 | Precipitation | Precipitation is an important control on the amount of recharge. It transports solutes with it as it flows downward through the subsurface or escapes as runoff. The amount of precipitation depends on climate. | INCLUDE (precipitation)<br><br>EXCLUDE (recharge/and climate change) | Section 115(a) and (b) of the RIG specify that the reference biosphere must be consistent with current conditions and that the location of the critical group is 20 km south of the repository. FEPs 2.3.11.01.01 through 2.3.11.01.04 are therefore excluded. | Precipitation is considered a part of the overall water balance and is empirically considered in the amount of water used to support agricultural activities that may lead to an exposure. See AMRs entitled *Non-Disruptive Event Biosphere Dose Conversion Factors Analysis* (CRWMS M&O 2000b), and *Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000c). |

| YMP FEP NO. | YMP FEP NAME | YMP PRIMARY FEP DESCRIPTION | SCREENING DECISION | SCREENING ARGUMENT | TSPA DISPOSITION |
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| 2.3.11.02.00 | Surface runoff and flooding | Surface runoff and evapotranspiration are components in the water balance, together with precipitation and infiltration. They can also be important vehicles for the dispersion of contaminants. Surface runoff produces erosion, and can feed washes, arroyos, and impoundments, where flooding may lead to increased recharge. | INCLUDE (dispersion of contaminants, precipitation, and infiltration)<br><br>EXCLUDE (recharge, water balance) | Section 115(a) and (b) of the RIG specify that the reference biosphere must be consistent with current conditions and that the location of the critical group is 20 km south of the repository. Therefore, FEPs 2.3.11.02.02, 2.3.11.02.04 and 2.3.11.02.05 are inconsistent with the requirements of that Section and are excluded. | Dispersion of contaminants through erosion and leaching is addressed in AMR entitled *Evaluate Soil/Radionuclide Removal by Erosion and Leaching* (CRWMS M&O 2000h). |
| 2.3.13.01.00 | Biosphere characteristics | The conditions that exist in the biosphere are likely to vary over time in a largely unpredictable manner, due to both natural and anthropogenic events and/or processes. These biosphere conditions or characteristics can influence contaminant transport and can affect the long-term performance of the disposal system. Biosphere characteristics include climate, vegetation, plant and animal populations, and microbes. | INCLUDE (biosphere characteristics)<br><br>EXCLUDE (conditions vary over time.) | Changes over time are precluded from consideration by Sections 115(a)(1) & (2) of the RIG. FEP Numbers 2.3.13.01.03, 2.3.13.01.08, 2.3.13.01.09, 2.3.13.01.01, which address conditions that vary over time, and those characteristics not reflective of current conditions and/or incompatible with reference biosphere concept, FEP Numbers 2.3.13.01.01, 2.3.13.01.02, 2.3.13.02.06, are excluded. | Biosphere characteristics are considered, in support of the calculations of dose conversion factors, as part of the reference biosphere in the following AMRs: 1) *Identification of the Critical Group (Consumption of Locally Produced Food and Tap Water)* (CRWMS M&O 2000j), 2) *Groundwater Usage by the Proposed Farming Community* (CRWMS M&O 2000g), 3) *Input Parameter Values for External and Inhalation Radiation Exposure Analysis.* (CRWMS M&O 1999c), 4) *Identification of Ingestion Exposure Parameters* (CRWMS M&O 2000k), 5) *Environmental Transport Parameter Analysis* (CRWMS M&O 1999d), and 6) *Transfer Coefficient Analysis* (CRWMS M&O 1999e). |

| YMP FEP NO. | YMP FEP NAME | YMP PRIMARY FEP DESCRIPTION | SCREENING DECISION | SCREENING ARGUMENT | TSPA DISPOSITION |
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| 2.3.13.02.00 | Biosphere transport | Radionuclides contained in sediments and surface water bodies, and in the gaseous phase may be transferred to the biosphere by a variety of processes. Once in the biosphere, radionuclides may be transported and transferred through and between different compartments of the biosphere. Time-dependent chemical environments in the biosphere may promote or retard the transport and transfer processes, and consequently control exposure to the human population. | INCLUDE (transport & transfer through biosphere compartments)<br><br>EXCLUDE (radionuclide transfer to the biosphere via sediments, surface water, gas, and time dependent as well as chemical environment changes). | Radionuclides in gaseous form are assumed to be dispersed into the air as a result of irrigation or emanation from the ground. Dispersion will reduce the radionuclide concentration in air and as a result and will have a low consequence on the projected dose. Therefore they are excluded from consideration.<br>Since Section 115 limits the reference biosphere to current conditions, the impacts of both time-dependent and chemical-dependent environments, sedimentary transport and water bodies are excluded. Therefore, a portion of FEPs 2.3.13.02.01 and 2.3.13.02.02 are excluded. | Transport and transfer of radionuclides, entering the biosphere via a groundwater well and a volcanic eruption through various biosphere compartments are summarized in AMRs entitled *Non-Disruptive Event Biosphere Dose Conversion Factors* (CRWMS M&O 2000b) and *Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000c) |
| 2.4.01.00.00 | Human characteristics (physiology, metabolism) | This category contains FEPs related to human characteristics. These include physiology, metabolism, and variability among individual humans. | INCLUDE (Adult)<br><br>EXCLUDE (Non-adult) | Section 115(b)(5) specifies that the average member of the critical group is an adult. As a result, consideration of any other age receptor(FEP 2.4.02.00.00) is excluded. | The human receptor of interest is an adult as specified in the RIG. See AMR entitled *Dose Conversion Factor Analysis: Evaluation of GENII-S Dose Assessment Methods.* (CRWMS M&O 1999f). |

| YMP FEP NO. | YMP FEP NAME | YMP PRIMARY FEP DESCRIPTION | SCREENING DECISION | SCREENING ARGUMENT | TSPA DISPOSITION |
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| 2.4.03.00.00 | Diet and fluid intake | This category contains FEPs related to human diet and fluid intake. Consumption of food, water, soil, drugs, etc., will affect human exposure to radionuclides. Other influences include filtration of water, dilution of diet with uncontaminated food, and food preparation techniques. | INCLUDE (Diet, fluids, and intakes other than drugs)<br><br>EXCLUDE (Filtration of water and food preparation and intake of drugs.) | Effects of filtration and food preparation techniques (FEPs 2.4.03.01.05 and 2.4.03.01.06) are excluded on the basis of low consequence since these processes would tend to reduce the amount of radionuclides available for ingestion. Consumption of drugs (FEP 2.4.03.00.01) (locally produced) for medicinal purposes is inconsistent with current behaviors and is contrary to the requirements of Section 115 of the RIG. Therefore, those FEPs are excluded. | Applicable portions of this FEP are considered in the identification of the behavior of the critical group and its average member. See AMRs entitled *Identification of the Critical Group (Consumption of Locally Produced Food and Tap Water)* (CRWMS M&O 2000j), and *Identification of Ingestion Exposure Parameters* (CRWMS M&O 2000k). |
| 2.4.04.01.00 | Human lifestyle | Human lifestyle, including leisure activities, will influence the critical exposure pathways to man. | INCLUDE (Human lifestyle)<br><br>EXCLUDE (Hunter gathering) | Section 115(b) of the RIG specifies that the critical group is part of a farming community. Hunter gathering lifestyle (FEP 2.4.04.01.00) is inconsistent with the behavior of a farming community and is therefore excluded. | Lifestyle characteristics are considered in the development of the behavior and characteristics of the critical group. See AMRs entitled *Identification of the Critical Group (Consumption of Locally Produced Food and Tap Water)* (CRWMS M&O 2000j), *Identification of Ingestion Exposure Parameters* (CRWMS M&O 2000k), and *Input Parameter Values for External and Inhalation Radiation Exposure Analysis.* (CRWMS M&O 1999c). |

| YMP FEP NO. | YMP FEP NAME | YMP PRIMARY FEP DESCRIPTION | SCREENING DECISION | SCREENING ARGUMENT | TSPA DISPOSITION |
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| 2.4.07.00.00 | Dwellings | This category contains FEPs related to human dwellings, and the ways in which dwellings might affect human exposures. Exposure pathways might be influenced by building materials, location, and everyday household activities. | INCLUDE (household activities)<br><br>EXCLUDE (location, building material, gas and water leakage, and space heating) | Effects of different locations (FEP 2.4.07.00.02), is excluded from consideration since the location is specified in Section 115 of the RIG. Building material (FEP 2.4.07.00.01), gas and water leakage into basements (FEPs 2.4.07.00.03 & 2.4.07.00.04) and space heating (FEP 2.4.07.00.07) are inconsistent with current conditions as required in Section 115 of the RIG and are excluded. Based on U.S. Census Bureau (1999) data, dwellings in Amargosa Valley are predominately of a single type with no basements, and use non-locally produced heating materials is very common. As a result these FEP are excluded. | The effects of dwellings and household activities are implicitly considered in AMRs entitled *Non-Disruptive Event Biosphere Dose Conversion Factors* (CRWMS M&O 2000b) and *Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000c), and *Input Parameter Values for External and Inhalation Radiation Exposure Analysis.* (CRWMS M&O 1999c). |
| 2.4.08.00.00 | Wild and natural land and water use | This category contains FEPs related to human uses of wild and natural lands (forests, bush, coastlines) and water (lakes, rivers, oceans) that may affect the long-term performance of the repository. Wild and natural land use will be primarily controlled by natural factors (topography, climate, etc.) | EXCLUDE | Section 115(a) and (b) of the RIG specify that the critical group resides within a farming community. Use of wild and natural lands would remove the members of the critical group from the area of potential contamination. This will lower exposure, as a result this FEP is excluded on the basis of low consequence. | |

| YMP FEP NO. | YMP FEP NAME | YMP PRIMARY FEP DESCRIPTION | SCREENING DECISION | SCREENING ARGUMENT | TSPA DISPOSITION |
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| 2.4.09.01.00 | Agricultural land use and irrigation | Agricultural land use depends on many interrelated factors including climate, geology, topography, human lifestyle and economics. Land use includes traditional crop farming, greenhouses, and hydroponics. Agricultural activities may influence the long-term performance of the repository through contamination of the foodchain or alternative exposure pathways. Agricultural activities of concern include irrigation, ploughing, fertilization, crop storage, application of soil conditioners and agricultural chemicals, and fires. | INCLUDE (traditional crop and greenhouse farming)<br><br>EXCLUDE (hydroponic gardening, peat and leaf harvesting and the use of ashes and sewage sludge and fire) | Section 115(a) and (b) require consistency with current lifestyle and environmental conditions. FEPs 2.4.09.01.03, 2.409.01.04, 2.4.09.01.05, 2.4.09.01.06, and 2.4.09.01.13, they are excluded from consideration inconsistent with assumed current conditions. | The applicable portions of these FEPs, as they support calculation of the dose conversion factors, are considered. See AMRs entitled *Identification of the Critical Group (Consumption of Locally Produced Food and Tap Water)* (CRWMS M&O 2000j), and *Identification of Ingestion Exposure Parameters* (CRWMS M&O 2000k), and *Input Parameter Values for External and Inhalation Radiation Exposure Analysis.* (CRWMS M&O 1999c). |
| 2.4.09.02.00 | Animal farms and fisheries | Domestic livestock or fish could become contaminated through the intake of contaminated feed, water, or soil. Such contamination would then enter the foodchain. | INCLUDE | | This FEP is considered in the calculation of the dose conversion factors. See AMRs entitled *Identification of the Critical Group (Consumption of Locally Produced Food and Tap Water)* (CRWMS M&O 2000j), *Non-Disruptive Event Biosphere Dose Conversion Factors* (CRWMS M&O 2000b) and *Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000c), and *Transfer Coefficient Analysis* (CRWMS M&O 1999e). |

| YMP FEP NO. | YMP FEP NAME | YMP PRIMARY FEP DESCRIPTION | SCREENING DECISION | SCREENING ARGUMENT | TSPA DISPOSITION |
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| 2.4.10.00.00 | Urban and industrial land and water use. | This category contains FEPs related to urban and industrial uses of land and water (industry, urban development, earthworks, energy production, etc.) that may affect the long-term performance of the repository. Urban and industrial land use will be controlled by both natural factors (topography, climate, etc.) and human factors (economics, population density, etc.) | EXCLUDE | Inconsistent with section 115(a) and (b) of the RIG, which specifies that, the critical group resides within a farming community. Therefore this FEP is excluded. | |
| 3.3.01.00.00 | Drinking water, foodstuffs and drugs, contaminant concentrations in | This category contains FEPs related to human exposure to contaminants as a result of ingesting foodstuffs, water, or drugs. | INCLUDE (food stuff and water)<br><br>EXCLUDE (drugs, non-well water) | Consideration of use of locally produced drugs is inconsistent with current conditions as required by Section 115 of the RIG. As a result of this, a portion of the FEP is excluded. Given the depth to groundwater as presented in LaPlante and Poor (1997), well water is considered the most probable source of drinking water. Therefore, non-well water sources are excluded on the basis of inconsistency with current conditions. Use of locally produced drugs for medical purposes is inconsistent with assumed current conditions. | Applicable portions of these FEPs are considered in the calculation of biosphere dose conversion factors. See AMRs entitled *Identification of the Critical Group (Consumption of Locally Produced Food and Tap Water)* (CRWMS M&O 2000j), *Non-Disruptive Event Biosphere Dose Conversion Factors* (CRWMS M&O 2000b) and *Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000c). |
| 3.3.02.01.00 | Plant uptake | Uptake of contaminants by plants could affect the long-term performance of the disposal system. Some contaminants escaping from the repository are expected to eventually be able to reach natural outfalls (e.g., Franklin Lake Playa), where plant uptake would be possible. Particulate deposition onto plant surfaces is also possible. These plants may be used as feed for livestock and/or consumed directly by humans. | INCLUDE/ (radionuclide uptake)<br><br>EXCLUDE (natural outfalls) | Section 115 of the RIG specifies the location of the critical group. Based on the depth to groundwater presented in Figure 2-2 of LaPlante and Poor (1997) there are no natural outfalls in that area. Therefore, consideration of natural outfalls is excluded from consideration. | Plant uptake as a factor in the movement of radionuclides through biosphere compartments is considered in the calculation of biosphere dose conversion factors. Plant uptake is considered in AMRs entitled *Transfer Coefficient Analysis* (CRWMS M&O 1999e) |

| YMP FEP NO. | YMP FEP NAME | YMP PRIMARY FEP DESCRIPTION | SCREENING DECISION | SCREENING ARGUMENT | TSPA DISPOSITION |
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| 3.3.02.02.00 | Animal uptake | Livestock and fish may accumulate radionuclides as a result of ingestion of water, feed and soil/sediment and inhalation of aerosols and particulates. Depending on the livestock, they may be used for human consumption directly, or their produce (milk, eggs, etc.) may be consumed. | INCLUDE (consumption of locally produced meat and associated produce)<br><br>EXCLUDE (Animal grooming & fighting, consumption of carcasses as well as scavengers and predators.) | Animal grooming and fighting (FEP 3.3.02.02.05) on the basis of low consequence since these are relatively short-term activities and are therefore excluded. Consumption of carcasses and scavengers and predators (FEPs 3.3.02.02.01 and 3.3.02.02.06) are not consistent with the behavior of a farming community as is required by Section 115. | Applicable portions of this FEP are considered in the calculation of biosphere dose conversion factors. See AMR entitled *Transfer Coefficient Analysis* (CRWMS M&O 1999e). |
| 3.3.02.03.00 | Bioaccumulation | Contaminants may accumulate in different organisms, including members of the critical group, affecting impacts. Bioconcentration and biomagnification are related processes. | INCLUDE | | This FEP is considered as applicable, in the calculation of biosphere dose conversion factors. See AMR entitled *Transfer Coefficient Analysis* (CRWMS M&O 1999e). |
| 3.3.03.01.00 | Contaminated non-food products and exposure | Contaminants may be concentrated in various products: clothing (e.g., hides, leather, linen, wool); furniture (e.g., wood, metal); building materials (e.g., stone, clay for bricks, wood, dung); fuel (e.g., peat), tobacco, pets. | EXCLUDE | Section 115(b)(2) specifies that the behavior and characteristics of the critical group shall be consistent with current conditions. The data regarding employment in Amargosa Valley (U.S. Census Bureau 1999) shows that relatively few local residents are employed in manufacturing industries. These data suggest that manufacturing of durable and non-durable goods for use by local residents is not a significant source of potential contamination. Therefore, this FEP is excluded. | |

| YMP FEP NO. | YMP FEP NAME | YMP PRIMARY FEP DESCRIPTION | SCREENING DECISION | SCREENING ARGUMENT | TSPA DISPOSITION |
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| 3.3.04.01.00 | Ingestion | Ingestion is human exposure to repository-derived radionuclides through eating contaminated foodstuffs or drinking contaminated water. | INCLUDE (consumption of food stuffs and water)<br><br>EXCLUDE (charcoal production, smoking, and treesap consumption) | Production of charcoal (FEP 3.3.03.01.01), treesap consumption (FEP 3.3.03.01.03), and smoking of locally grown tobacco (FEP 3.3.03.01.05) are activities that in consistent with assumed current conditions. | Applicable portions of these FEPs are considered as an input for the calculation of biosphere dose conversion factors. See AMRs entitled *Non-Disruptive Event Biosphere Dose Conversion Factors* (CRWMS M&O 2000b) and *Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000c). |
| 3.3.04.02.00 | Inhalation | Two inhalation pathways are likely. The first is inhalation of gases and vapors emanating directly from the ground after transport through the far-field. The second is inhalation of suspended, contaminated particulate matter, (e.g., daughter products of radon, dust, smoke, pollen, and soil particles). | INCLUDE | | See AMRs entitled *Non-Disruptive Event Biosphere Dose Conversion Factors* (CRWMS M&O 2000b) and *Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000c) |
| 3.3.04.03.00 | External exposure | External exposure is human exposure to repository-derived radionuclides by contact, use, or exposure to contaminated materials. The mode is typically through dermal sorption. | INCLUDE (external exposure to penetrating ionizing radiation)<br><br>EXCLUDE (dermal sorption and injection) | Dermal sorption of tritium and non-tritium radionuclides (FEPs 3.3.04.03.02 and 3.3.04.03.01), are excluded since dermal sorption is considered to be of low consequence relative to ingestion & inhalation. Similarly, injection (FEP 3.3.04.03.07) is considered to be low consequence considering other pathways. | See AMRs entitled *Non-Disruptive Event Biosphere Dose Conversion Factors* (CRWMS M&O 2000b) and *Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000c). |

| YMP FEP NO. | YMP FEP NAME | YMP PRIMARY FEP DESCRIPTION | SCREENING DECISION | SCREENING ARGUMENT | TSPA DISPOSITION |
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| 3.3.05.01.00 | Radiation doses | The radiation dose is calculated from exposure rates (external, inhalation and ingestion) and dose conversion factors. The latter are based upon radiation type, human metabolism, metabolism of the element of concern in the human body, duration of exposure. | INCLUDE (exposure rate/dose conversion factors)<br><br>EXCLUDE (WIPP specific FEP) | The RIG is specific to Yucca Mountain. FEPs 3.3.05.01.02 through 3.3.05.01.04 are therefore not applicable, but the issues associated with these FEPs are addressed. | See AMRs entitled *Non-Disruptive Event Biosphere Dose Conversion Factors* (CRWMS M&O 2000b) and *Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000c) |
| 3.3.06.00.00 | Radiological toxicity/effects | This category contains FEPs related to the estimation of human health effects resulting from radiation doses. | EXCLUDE | Section 113(b) of the RIG establishes a performance objective that is based on radiation dose; therefore, this FEP is excluded. | |
| 3.3.06.02.00 | Sensitization to radiation | Human and other organisms may become sensitized to radiation exposure so that its effects are more severe. | EXCLUDE | Section 115(b)(2) of the RIG precludes consideration of changes in physiology or metaboloics; therefore, this FEP is excluded. | |
| 3.3.07.00.00 | Non-radiological toxicity/effects | This category contains FEPs related to the estimation of human health effects resulting from the non-radiological toxicity of the waste. | EXCLUDE | Section 113(b) of the RIG establishes a performance objective that is based on radiation dose; therefore, this FEP is excluded. | |
| 3.3.08.00.00 | Radon and radon daughter exposure | This category contains FEPs related to human exposure to radon and radon decay products. Ra-226 occurs in nuclear fuel waste and it gives rise to radon (Rn-222) gas, the radioactive daughters of which can be harmful to humans and animals upon inhalation. | EXCLUDE | Based on the inventory data provided in CRWMS M&O (2000l), The Ra-226 parent radionuclide, Th-230 does not appear in the saturated zone within the first 10,000 years. As a result, generation of Rn-222 is precluded. | |

# ATTACHMENT II

## GENII-S MENU ACCESSIBLE INPUT PARAMETERS; STATISTICAL RUN, REASONABLE REPRESENTATION

Attachment II. GENII-S Menu-Accessible Input Parameters; Statistical Run, Reasonable Representation.

| Menu(s) | Option/ - Parameter, Unit | Selection | Values [a,b] Minimum | Best Estimate | Maximum | Distribution | Reference[c]/ Comments |
|---|---|---|---|---|---|---|---|
| PRE-GENII | | | | | | | |
| Edit Flags and Options | Scenario Options | | | | | | |
| | - Near-Field Scenario | Y | NA | NA | NA | NA | Assumptions |
| | - Population Dose | N | NA | NA | NA | NA | |
| | - Acute Release | N | NA | NA | NA | NA | |
| | Transport Options | | | | | | |
| | - Air Transport | N | NA | NA | NA | NA | Assumptions |
| | - Surface Water Transport | N | NA | NA | NA | NA | |
| | - Biotic Transport | N | NA | NA | NA | NA | |
| | - Waste From Degradation | N | NA | NA | NA | NA | |
| | Exposure Pathway Options | | | | | | |
| | - External Finite Plume | N | NA | NA | NA | NA | Assumptions |
| | - External Infinite Plume | N | NA | NA | NA | NA | |
| | - External Ground Exposure | Y | NA | NA | NA | NA | |
| | - External Recreational Exposure | N | NA | NA | NA | NA | |
| | - Inhalation Uptake | Y | NA | NA | NA | NA | |
| | - Drinking Water Ingestion | N | NA | NA | NA | NA | |
| | - Aquatic Food Ingestion | N | NA | NA | NA | NA | |
| | - Terrestrial Food Ingestion | Y | NA | NA | NA | NA | |
| | - Animal Product Ingestion | Y | NA | NA | NA | NA | |
| | - Inadvertent Soil Ingestion | Y | NA | NA | NA | NA | |
| | Deterministic Output Options | | | | | | |
| | - Both Committed and Cumulative | N | NA | NA | NA | NA | Assumptions |
| | - EDE by Nuclide | N | NA | NA | NA | NA | |
| | - EDE by Pathway | N | NA | NA | NA | NA | |
| | Run Options | | | | | | |
| | - Inventory Unit Index (1-5) | 1, pCi | NA | NA | NA | NA | Assumptions/ Unit selection |
| | - Soil Inventory Unit Index (1-3) | 1, per $m^2$ | NA | NA | NA | NA | |
| | - Inventory Input Option (1-3) | 2 | NA | NA | NA | NA | |
| | - Det Run/Stat Run/Both (1/2/3) | 2 | NA | NA | NA | NA | |
| | - Nuclide Intake Duration, yr | 1 | NA | NA | NA | NA | |

Attachment II. GENII-S Menu-Accessible Input Parameters; Statistical Run, Reasonable Representation (Continued).

| Menu(s) | Option/ - Parameter, Unit | Selection | Values [a,b] Minimum | Best Estimate | Maximum | Distribution | Reference[c]/ Comments |
|---|---|---|---|---|---|---|---|
| | **PRE-GENII (continued)** | | | | | | |
| Select Statistical Output | **- Statistical Committed Dose Summary** | | | | | | |
| | - Statistical Committed Nuclide Dose | Y | NA | NA | NA | NA | |
| | - Statistical Committed Pathway Dose | N | NA | NA | NA | NA | |
| | - Statistical Committed Organ Dose | N | NA | NA | NA | NA | |
| | - Statistical Cumulative Pathway Dose | N | NA | NA | NA | NA | |
| | - Statistical Cumulative Organ Dose | N | NA | NA | NA | NA | |
| | - Statistical External Dose Summary | N | NA | NA | NA | NA | |
| | | N | NA | NA | NA | NA | |
| | **MAIN EDITING MENU** | | | | | | |
| Titles And Run Controls | - Model Name | | NA | NA | NA | NA | |
| | - Title (2 lines) | | NA | NA | NA | NA | |
| | - Latin Hypercube (LHS) or Monte Carlo (MC) Sampling | LHS | NA | NA | NA | NA | |
| | - The Number of Trials (<=500) | 160 | NA | NA | NA | NA | |
| | - A Random Seed (0.0<=Seed<=1.0) | 0.333 | NA | NA | NA | NA | |
| Fixed Data Input Variable Distribution | **Population/Soil/Scenario Data** | | | | | | |
| | - Total Population | 1 | NA | NA | NA | — | Not used |
| | - Population Scale Factor | NA | -- | 1 | -- | Fixed | Not used |
| | - Soil/Plant Transfer Scale Factor, (-) | NA | 0.0275 | -- | 36.4 | Lognormal | Input source #2 |
| | - Animal Uptake Scale Factor, (-) | NA | 0.117 | -- | 8.51 | Lognormal | Input source #2 |
| | - Human Dose Factor Scale Factor, (-) | NA | -- | 1 | -- | Fixed | Input source #6 |
| | - Dose Commitment Period, yr | NA | NA | 50 | NA | NA | Assumption |
| | - Surface Soil Depth, cm | NA | -- | 15 | -- | Fixed | Input source #1 |
| | - Surface Soil Density, $kg/m^2$ | NA | -- | 225 | -- | Fixed | Input source #1 |
| | - Deep Soil Density, $kg/m^3$ | NA | -- | 1500 | -- | Fixed | Input source #1 |
| | - Roots in Upper Soil, fraction | NA | -- | 1 | -- | Fixed | Input source #1 |
| | - Roots in Deep Soil, fraction | NA | -- | 0 | -- | Fixed | Input source #1 |
| | - Air Release Time Before Intake, yr | NA | NA | 0 | NA | NA | Not used |
| | - H2O Release Time Before Intake, yr | NA | NA | 0 | NA | NA | Not used |
| | **Biotic Trans./Near Field Data** | | | | | | |
| | Not used | — | — | — | — | — | — |

Attachment II. GENII-S Menu-Accessible Input Parameters; Statistical Run, Reasonable Representation (Continued).

| Menu(s) | Option/ - Parameter, Unit | Selection | Values [a,b] Minimum | Best Estimate | Maximum | Distribution | Reference[c]/ Comments |
|---|---|---|---|---|---|---|---|
| **MAIN EDITING MENU (continued)** | | | | | | | |
| Fixed Data Input Variable Distribution | **External/Inhalation Exposure (cont.)** | | | | | | |
| | - Chronic Plume Exposure Time, hr | NA | -- | 0 | -- | Fixed | Not used |
| | - Acute Plume Exposure Time, hr/phr | NA | -- | 0 | -- | Fixed | Not used |
| | - Inhalation Exposure Time, hr/yr | NA | --- | 3,918.5 | --- | Fixed | Input source #3 |
| | - Resuspension Model Flag (0-2) | 1 | NA | NA | NA | NA | Mass loading |
| | **- Mass Loading, g/m$^3$** | NA | $7.4\times10^{-7}$ | $8.7\times10^{-6}$ | $6.4\times10^{-5}$ | Lognormal | Input source #3 |
| | **- Transit Time to Rec. Site, hr** | NA | -- | 0 | -- | Fixed | \| |
| | - Swimming Exposure Time, hr | NA | -- | 0 | -- | Fixed | \| |
| | - Boating Exposure Time, hr | NA | -- | 0 | -- | Fixed | \| Parameters |
| | - Shoreline Exposure Time, hr | NA | -- | 0 | -- | Fixed | \| not used |
| | - Type of Shoreline Index (1-4) | 0 | NA | NA | NA | NA | \| |
| | - H2O/Sediment Transfer1/m$^2$/yr | NA | -- | 0 | -- | Fixed | \| |
| | - Soil Exposure Time, hr | NA | --- | 827 | --- | Fixed | Input source #3 |
| | - Home Irrigation Flag (0/1 = N/Y) | 0 | NA | NA | NA | NA | \| |
| | - Irrigation Water Index (1-2) | | NA | NA | NA | NA | \| Water not |
| | - Home Irrigation Rate, in/yr | 1 | 52 | 69.5 | 87 | Uniform | \| contaminated |
| | - Home Irrigation Duration, mo/yr | NA | -- | 12 | -- | Fixed | \| |
| | | NA | | | | | |
| | **Ingestion Exposure** | | | | | | |
| | - Food Production Option | 0 | NA | NA | NA | NA | Not used |
| | - Food-Weighted Chi/Q, kg-s/m$^3$ | 0 | -- | 0 | -- | Fixed | Not used |
| | - Crop Resuspension Factor, 1/m | NA | $9.6\times10^{-12}$ | $8.3\times10^{-11}$ | $7.2\times10^{-10}$ | Lognormal | Input source #1 |
| | - Crop Deposition Velocity, m/s | NA | -- | 0.001 | -- | | Input source #1 |
| | - Crop Interception Fraction | NA | 0.044 | 0.259 | 0.474 | Fixed | Input source #4 |
| | - Exported Food Dose (0/1 = N/Y) | 0 | NA | NA | NA | Normal | Not used |
| | - Soil Ingestion Rate, mg/day | NA | -- | 50 | -- | NA | Input source #1 |
| | - Swim H2O Ingestion Rate, l/h | NA | -- | 0 | -- | Fixed | Not used |
| | - Population Ingesting Aquatic Food | 0 | NA | NA | NA | Fixed | Not used |
| | - Bioaccumulation Flag (0/1 = N/Y) | 0 | NA | NA | NA | NA | Not used |
| | - Population Drinking Contaminated Water | 0 | NA | NA | NA | NA | \| |
| | | | | | | NA | \| Drinking water |
| | - Drink Water Source Index (0-3) | 0 | NA | NA | NA | | \| not |
| | - Drink Water Treated (0/1 = N/Y) | 0 | NA | NA | NA | NA | \| contaminated |
| | - Drink Water Holdup Time, days | NA | -- | 0 | -- | NA | \| |
| | - Drink Water Consumption, l/y | NA | -- | 752.85 | -- | Fixed | \| |
| | | | | | | Fixed | |

Attachment II. GENII-S Menu-Accessible Input Parameters; Statistical Run, Reasonable Representation (Continued).

| Menu(s) | Option/ - Parameter, Unit | Selection | Values [a,b] Minimum | Best Estimate | Maximum | Distribution | Reference[c]/ Comments |
|---|---|---|---|---|---|---|---|
| **MAIN EDITING MENU (continued)** | | | | | | | |
| Array Data Input (cont.) Variable Distribution | **Aquatic Food Ingestion Not used** | — | — | — | — | — | — |
| | **Terrestrial Food Ingestion** | | | | | | |
| | - Use (0/1 = F/T) | 1 | NA | NA | NA | NA | Input source #5 |
| | Leafy Vegetables | 1 | NA | NA | NA | NA | Input source #5 |
| | Root Vegetables | 1 | NA | NA | NA | NA | Input source #5 |
| | Fruit | 1 | NA | NA | NA | NA | Input source #5 |
| | Grain | | | | | | |
| | - Growing Time, days | NA | 45 | 64.5 | 75 | Triangular | Input source #4 |
| | Leafy Vegetables | NA | 70 | (84)[c] | 98 | Uniform | Input source #4 |
| | Root Vegetables | NA | 88 | (136) | 184 | Uniform | Input source #4 |
| | Fruit | NA | 75 | (159) | 244 | Uniform | Input source #4 |
| | Grain | | | | | | |
| | - Water Source Flag (0-2) | 0 | NA | NA | NA | NA | \| |
| | Leafy Vegetables | 0 | NA | NA | NA | NA | \| Water not |
| | Root Vegetables | 0 | NA | NA | NA | NA | \| contaminated |
| | Fruit | 0 | NA | NA | NA | NA | \| |
| | Grain | | | | | | |
| | - Irrigation Rate, in/yr | NA | 28.17 | 42.11 | 80.37 | Triangular | \| Input source #4 |
| | Leafy Vegetables | NA | 47.34 | (49.46) | 51.58 | Uniform | \| |
| | Root Vegetables | NA | 30.00 | (37.69) | 45.37 | Uniform | \| Water not |
| | Fruit | NA | 55.85 | (68.11) | 80.37 | Uniform | \| contaminated |
| | Grain | | | | | | |
| | - Irrigation Time, mo/yr | NA | 2.0 | 3.2 | 4.9 | Triangular | \| Input source #4 |
| | Leafy Vegetables | NA | 3.2 | (3.9) | 4.6 | Uniform | \| |
| | Root Vegetables | NA | 2.9 | (4.5) | 6.0 | Uniform | \| Water not |
| | Fruit | NA | 4.9 | (6.5) | 8.0 | Uniform | \| contaminated |
| | Grain | | | | | | |
| | - Crop Yield, kg/m$^2$ | NA | 0.59 | 1.82 | 4.11 | Triangular | Input source #4 |
| | Leafy Vegetables | NA | 1.73 | 4.33 | 5.87 | Triangular | Input source #4 |
| | Root Vegetables | NA | 1.57 | (1.91) | 2.25 | Uniform | Input source #4 |
| | Fruit | NA | 0.33 | (0.56) | 0.78 | Uniform | Input source #4 |
| | Grain | | | | | | |

Attachment II. GENII-S Menu-Accessible Input Parameters; Statistical Run, Reasonable Representation (Continued).

| Menu(s) | Option/ - Parameter, Unit | Selection | Values [a,b] Minimum | Best Estimate | Maximum | Distribution | Reference[c]/ Comments |
|---|---|---|---|---|---|---|---|
| **MAIN EDITING MENU (continued)** | | | | | | | |
| Array Data Input (cont.) Variable Distribution | **Terrestrial Food Ingestion (cont.)** | | | | | | |
| | - Production, kg/yr | | | | | | |
| | Leafy Vegetables | NA | -- | 0 | -- | Fixed | \| |
| | Root Vegetables | NA | -- | 0 | -- | Fixed | \| Parameter |
| | Fruit | NA | -- | 0 | -- | Fixed | \| not used |
| | Grain | NA | -- | 0 | -- | Fixed | \| |
| | - Holdup, days | | | | | | |
| | Leafy Vegetables | NA | -- | 1 | -- | Fixed | Input source #4 |
| | Root Vegetables | NA | -- | 14 | -- | Fixed | Input source #4 |
| | Fruit | NA | -- | 14 | -- | Fixed | Input source #4 |
| | Grain | NA | -- | 14 | -- | Fixed | Input source #4 |
| | - Consumption Rate, kg/yr | | | | | | |
| | Leafy Vegetables | NA | -- | 15.14 | -- | Fixed | Input source #5 |
| | Root Vegetables | NA | -- | 7.81 | -- | Fixed | Input source #5 |
| | Fruit | NA | -- | 15.57 | -- | Fixed | Input source #5 |
| | Grain | NA | -- | 0.48 | -- | Fixed | Input source #5 |
| | **Animal Product Consumption** | | | | | | |
| | - Use (0/1 = F/T) | | | | | | |
| | Beef | 1 | NA | NA | NA | NA | Input source #5 |
| | Poultry | 1 | NA | NA | NA | NA | Input source #5 |
| | Milk | 1 | NA | NA | NA | NA | Input source #5 |
| | Eggs | 1 | NA | NA | NA | NA | Input source #5 |
| | • Consumption Rate, kg/yr | | | | | | |
| | Beef | NA | -- | 2.93 | -- | Fixed | Input source #5 |
| | Poultry | NA | -- | 0.80 | -- | Fixed | Input source #5 |
| | Milk | NA | -- | 4.14 | -- | Fixed | Input source #5 |
| | Eggs | NA | -- | 6.68 | -- | Fixed | Input source #5 |
| | • Holdup, days | | | | | | |
| | Beef | NA | -- | 20 | -- | Fixed | Input source #4 |
| | Poultry | NA | -- | 1 | -- | Fixed | Input source #4 |
| | Milk | NA | -- | 1 | -- | Fixed | Input source #4 |
| | Eggs | NA | -- | 1 | -- | Fixed | Input source #4 |

Attachment II. GENII-S Menu-Accessible Input Parameters; Statistical Run, Reasonable Representation (Continued).

| Menu(s) | Option/ - Parameter, Unit | Selection | Values [a,b] Minimum | Best Estimate | Maximum | Distribution | Reference[c]/ Comments |
|---|---|---|---|---|---|---|---|
| **MAIN EDITING MENU (continued)** | | | | | | | |
| **Array Data Input (cont.) Variable Distribution** | **Animal Product Consumption** | | | | | | |
| | - Production, kg/yr | | | | | | |
| | Beef | NA | -- | 0 | -- | Fixed | \| |
| | Poultry | NA | -- | 0 | -- | Fixed | \| Parameter |
| | Milk | NA | -- | 0 | -- | Fixed | \| not used |
| | Eggs | NA | -- | 0 | -- | Fixed | \| |
| | - Contaminated Water Fraction | | | | | | |
| | Beef | NA | -- | 0 | -- | Fixed | \| |
| | Poultry (corn) | NA | -- | 0 | -- | Fixed | \| Water not |
| | Milk | NA | -- | 0 | -- | Fixed | \| contaminated |
| | Eggs (corn) | NA | -- | 0 | -- | Fixed | \| |
| | Animal Products (Stored Feed Data) | | | | | | |
| | - Dietary Fraction | | | | | | |
| | Beef | NA | -- | 0 | -- | Fixed | Input source #4 |
| | Poultry (corn) | NA | -- | 1 | -- | Fixed | Input source #4 |
| | Milk | NA | -- | 0 | -- | Fixed | Input source #4 |
| | Eggs (corn) | NA | -- | 1 | -- | Fixed | Input source #4 |
| | - Growing Time, days | | | | | | |
| | Beef | NA | -- | 0 | -- | Fixed | Input source #4 |
| | Poultry (corn) | NA | -- | 75 | -- | Fixed | Input source #4 |
| | Milk | NA | -- | 0 | -- | Fixed | Input source #4 |
| | Eggs (corn) | NA | -- | 75 | -- | Fixed | Input source #4 |
| | - Water Source Flag | | | | | | |
| | Beef | 0 | NA | NA | NA | NA | \| |
| | Poultry (corn) | 0 | NA | NA | NA | NA | \| Water not |
| | Milk | 0 | NA | NA | NA | NA | \| contaminated |
| | Eggs (corn) | 0 | NA | NA | NA | NA | \| |
| | - Irrigation Rate, in/yr | | | | | | |
| | Beef | NA | -- | 0 | -- | Fixed | \| Input source #4 |
| | Poultry (corn) | NA | -- | 80.37 | -- | Fixed | \| |
| | Milk | NA | -- | 0 | -- | Fixed | \| Water not |
| | Eggs (corn) | NA | -- | 80.37 | -- | Fixed | \| contaminated |
| | - Irrigation Time, mo/yr | | | | | | |
| | Beef | NA | -- | 0 | -- | Fixed | \| Input source #4 |
| | Poultry (corn) | NA | -- | 4.9 | -- | Fixed | \| |
| | Milk | NA | -- | 0 | -- | Fixed | \| Water not |
| | Eggs (corn) | NA | -- | 4.9 | -- | Fixed | \| contaminated |

Attachment II. GENII-S Menu-Accessible Input Parameters; Statistical Run, Reasonable Representation (Continued).

| Menu(s) | Option/ - Parameter, Unit | Selection | Values [a,b] Minimum | Best Estimate | Maximum | Distribution | Reference[c]/ Comments |
|---|---|---|---|---|---|---|---|
| **MAIN EDITING MENU (continued)** | | | | | | | |
| **Array Data Input (cont.) Variable Distribution** | **Animal Products (Stored Feed Data) cont.** | | | | | | |
| | - Feed Yield, kg/m$^2$ | | | | | | |
| | Beef | NA | -- | 0 | -- | Fixed | Input source #4 |
| | Poultry (corn) | NA | 0.59 | (0.69) | 0.78 | Uniform | Input source #4 |
| | Milk | NA | -- | 0 | -- | Fixed | Input source #4 |
| | Eggs (corn) | NA | 0.59 | (0.69) | 0.78 | Uniform | Input source #4 |
| | - Storage, days | | | | | | |
| | Beef | NA | -- | 0 | -- | Fixed | Input source #4 |
| | Poultry (corn) | NA | -- | 14 | -- | Fixed | Input source #4 |
| | Milk | NA | -- | 0 | -- | Fixed | Input source #4 |
| | Eggs (corn) | NA | -- | 14 | -- | Fixed | Input source #4 |
| | **Animal Products (Fresh Forage Data)** | | | | | | |
| | - Dietary Fraction | | | | | | |
| | Beef (alfalfa) | NA | -- | 1 | -- | Fixed | Input source #4 |
| | Milk (alfalfa) | NA | -- | 1 | -- | Fixed | Input source #4 |
| | - Grow Time, days | | | | | | |
| | Beef (alfalfa) | NA | 46 | 47 | 135 | Triangular | Input source #4 |
| | Milk (alfalfa) | NA | 46 | 47 | 135 | Triangular | Input source #4 |
| | - H2O Source Flag | | | | | | |
| | Beef (alfalfa) | 0 | NA | NA | NA | NA | I Water not |
| | Milk (alfalfa) | 0 | NA | NA | NA | NA | I contaminated |
| | - Irrigation Rate, in/yr | | | | | | |
| | Beef (alfalfa) | NA | -- | 94.66 | -- | Fixed | I Water not |
| | Milk (alfalfa) | NA | -- | 94.66 | -- | Fixed | I contaminated |
| | - Irrigation Time, mo/yr | | | | | | |
| | Beef (alfalfa) | NA | -- | 12 | -- | Fixed | I Water not |
| | Milk (alfalfa) | NA | -- | 12 | -- | Fixed | I contaminated |
| | - Feed Yield, kg/m$^2$ | | | | | | |
| | Beef (alfalfa) | NA | 0.25 | (0.7) | 1.15 | Uniform | Input source #4 |
| | Milk (alfalfa) | NA | 0.25 | (0.7) | 1.15 | Uniform | Input source #4 |
| | - Storage, days | | | | | | |
| | Beef (alfalfa) | NA | -- | 0 | -- | Fixed | Input source #4 |
| | Milk (alfalfa) | NA | -- | 0 | -- | Fixed | Input source #4 |

Attachment II. GENII-S Menu-Accessible Input Parameters; Statistical Run, Reasonable Representation (Continued).

| Menu(s) | Option/ - Parameter, Unit | Selection | Values [a,b] | | | Distribution | Reference[c]/ Comments |
|---|---|---|---|---|---|---|---|
| | | | Minimum | Best Estimate | Maximum | | |
| **MAIN EDITING MENU (continued)** | | | | | | | |
| **Array Data Input (cont.) Variable Distribution** | **Inventory – Basic Concentrations** | | | | | | |
| | - Air, pCi/m$^3$ | NA | -- | 0 | -- | Fixed | Assumption |
| | - Surface Soil, pCi/m$^2$ | NA | -- | 1 | -- | Fixed | |
| | - Deep Soil, pCi/kg | NA | -- | 0 | -- | Fixed | |
| | - Ground Water, pCi/l | NA | -- | 0 | -- | Fxed | |
| | - Surface Water, pCi/l | NA | -- | 0 | -- | Fixed | |

[a] NA as an entry means that a given selection/option/value does not appear in GENII-S.

[b] If data for best estimate value of uniform distribution was not provided by the input source, the average value was used (number in parentheses).

[c] Input source identification in Reference/Comment column (e.g. #1, #3) refers to input numbers in Table 2.