OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL COVER SHEET
Complete Only Applicable Items

1. QA: QA

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:

Biosphere Dose Conversion Factors for nominal performance will be used for Performance Assessment of potential repository in TSPA-SR.

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:

Biosphere model is part of the Process Models used for Performance Assessment of potential repository in TSPA-SR.

4. Title:

Nominal Performance Biosphere Dose Conversion Factor Analysis

5. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-MGR-MD-000009 REV 01

6. Total Attachments:

6

7. Attachment Numbers - No. of Pages in Each:

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OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL REVISION RECORD
Complete Only Applicable Items

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3. Document Identifier (including Rev. No. and Change No., if applicable):

ANL-MGR-MD-000009 REV 01

4. Revision/Change No.	5. Description of Revision/Change
Revision 00	Initial issue
Revision 01	Revision to incorporate the analysis of the climate change effects on the Biosphere Dose Conversion Factors for nominal performance; add pathway and limited uncertainty analyses; append the list of radionuclides to include those important for up to 1 million years after the potential repository closure; remove bounding case; change the document title; and add biosphere model validation (moved from ANL-MGR-MD-000011 REV 00). Entire AMR has been revised because changes were extensive.

EXECUTIVE SUMMARY

The purpose of this report was to document the process leading to development of the Biosphere Dose Conversion Factors (BDCFs) for the postclodure nominal performance of the potential repository at Yucca Mountain. BDCF calculations concerned twenty-four radionuclides. This selection included sixteen radionuclides that may be significant nominal performance dose contributors during the compliance period of up to 10,000 years, five additional radionuclides of importance for up to 1 million years postclosure, and three relatively short-lived radionuclides important for the human intrusion scenario. Consideration of radionuclide buildup in soil caused by previous irrigation with contaminated groundwater was taken into account in the BDCF development. The effect of climate evolution, from the current arid conditions to a wetter and cooler climate, on the BDCF values was evaluated. The analysis included consideration of different exposure pathway's contribution to the BDCFs. Calculations of nominal performance BDCFs used the GENII-S computer code in a series of probabilistic realizations to propagate the uncertainties of input parameters into the output.

BDCFs for the nominal performance, when combined with the concentrations of radionuclides in groundwater allow calculation of potential radiation doses to the receptor of interest. Calculated estimates of radionuclide concentration in groundwater result from the saturated zone modeling. The integration of the biosphere modeling results (BDCFs) with the outcomes of the other component models is accomplished in the Total System Performance Assessment (TSPA) to calculate doses to the receptor of interest from radionuclides postulated to be released to the environment from the potential repository at Yucca Mountain.

CONTENTS

Page

CONTENTS (Continued)

Page

CONTENTS (Continued)

Page

FIGURES

TABLES

ACRONYMS

Acronyms

AMAD	Activity Median Aerodynamic Diameter
AMCG	Average Member of the Critical Group
AMR	Analysis Model Report
BDCF	Biosphere Dose Conversion Factor
CEDE	Committed Effective Dose Equivalent
CNWRA	Center for Nuclear Waste Regulatory Analyses
CRWMS M&O	Civilian Radioactive Waste Management System Management and Operating Contractor
CSNF	Commercial Spent Nuclear Fuel
DCF	Dose Conversion Factor
DF	Dose Factor
DHLW	Defense High Level Waste
DOE	U.S. Department of Energy
DSNF	DOE-owned Spent Nuclear Fuel
DTN	Data Tracking Number
EBS	Engineered Barrier System
FEP	Feature, Event, and Process
GENII-S	Hanford Environmental Dosimetry System (Generation II or GENII-Sensitivity and Uncertainty Analysis Shell)
KTI	Key Technical Issue
LHS	Latin Hypercube Sampling
MC	Monte Carlo (Sampling)
NRC	Nuclear Regulatory Commission
OCRWM	Office of Civilian Radioactive Waste Management
PA	Performance Assessment
PDF	Probability Distribution Function
SR	Site Recommendation
STD	Standard Deviation
SZ	Saturated Zone
TDMS	Technical Data Management System
TEDE	Total Effective Dose Equivalent

ACRONYMS (Continued)

TSPA	Total System Performance Assessment
TSPAI	Total System Performance Assessment and Integration
TSPA-SR	Total System Performance Assessment for the SR
UZ	Unsaturated Zone
YMP	Yucca Mountain Site Characterization Project

Abbreviations

Ac	Actinium
Am	Americium
At	Astatine
Bq	becquerel
C	Carbon
Ci	curie
cm	centimeter
Cs	Cesium
d	day
Eq.	equation
Fr	Francium
I	Iodine
in	inch
kg	kilogram
mo	month
Ni	Nickel
Np	Neptunium
Pa	Protactinium
pCi	picocurie
Pb	Lead
Pu	Plutonium
Ra	Radium
rem	unit of dose
Rn	Radon
Sr	Strontium
Sv	Sievert

ACRONYMS (Continued)

Tc	Technetium
Th	Thorium
U	Uranium
WA	Washington state
Y	Yttrium
yr	year

1. PURPOSE

Biosphere is one of the component process models of the Total System Performance Assessment (TSPA) model. The biosphere model considers the movement of radionuclides in the reference biosphere and human exposure to these radionuclides. The outcome of the biosphere model consists of radionuclide-specific biosphere dose conversion factors (BDCFs). BDCFs are included, together with other parameters, in the input for the TSPA code, which allows dose assessment from the postulated radionuclide releases from the potential repository.

The objective of biosphere modeling is to evaluate human exposure from radionuclides present in environmental media, such as water, soil, air, and food. Such exposures may be internal or external in origin. Internal exposure pathways under consideration in the biosphere model include ingestion and inhalation of radionuclides. The external exposure pathway considered external irradiation from contaminated soil. BDCFs for nominal performance quantify internal and external exposure to the receptor of interest resulting from the unit activity concentration of a radionuclide in groundwater introduced to the environment. The integration of the biosphere modeling results for nominal performance with the other models of the system is shown in Figure 1. The figure shows the diagram of the component models contributing to the TSPA. The BDCFs for nominal performance provide the means of conversion of radionuclide concentration in groundwater to annual doses to the human receptor of interest.

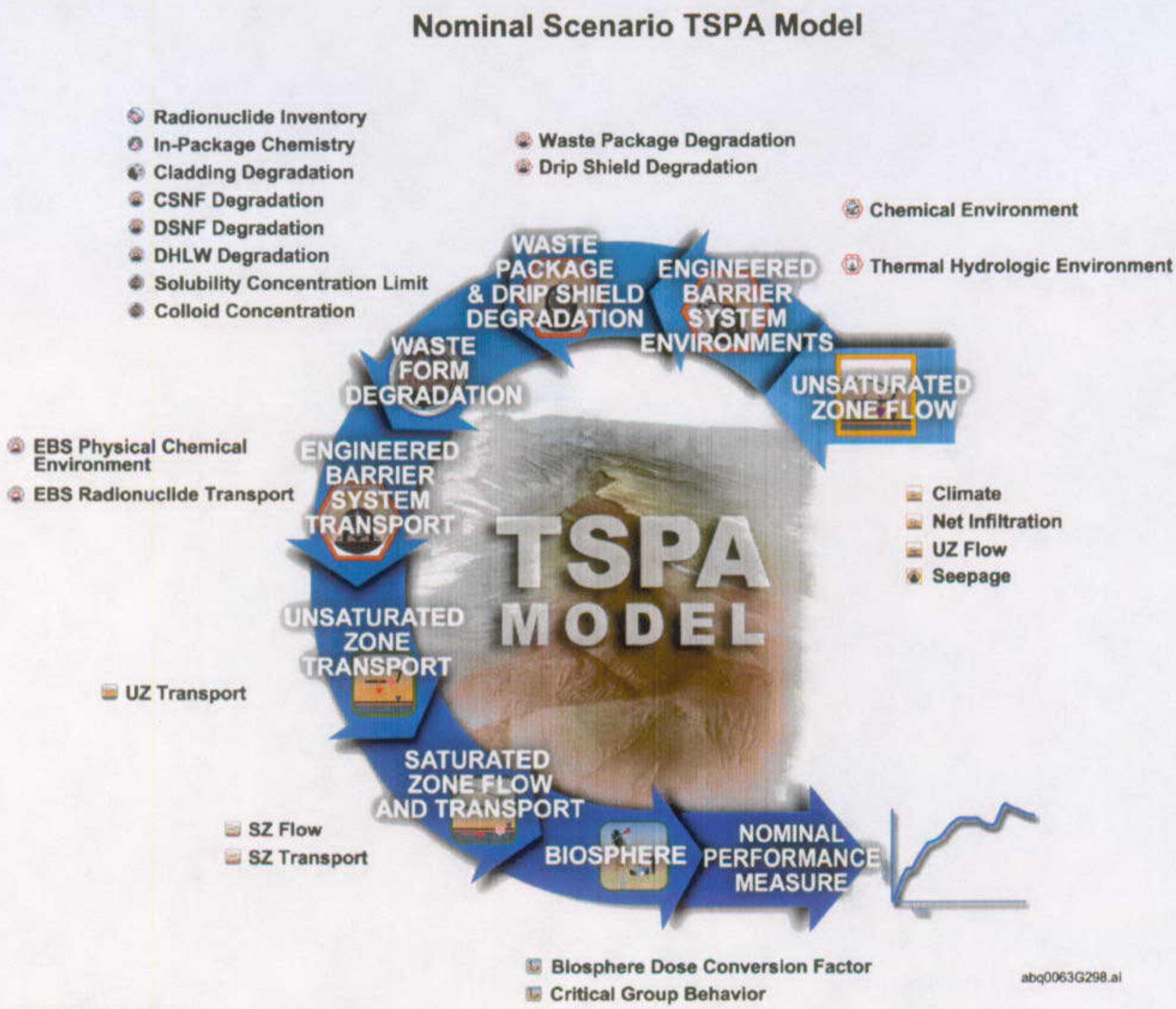
The assessments of nominal repository performance and of certain disruptive processes and events that may result in radionuclide releases into groundwater (e.g., intrusive volcanic event and human intrusion) share the same human exposure scenario. Therefore some additional radionuclides important from the perspective of disrupted performance were included in this analysis. They include relatively short-lived radionuclides, such as ^{90}Sr, ^{137}Cs, and ^{63}Ni, which are of interest for consideration of human intrusion.

The previously developed set of BDCFs for nominal performance (CRWMS M&O 2000a) was used as input to the TSPA-Site Recommendation (SR) Rev 0 (CRWMS M&O 2000b). This revision will be used in TSPA-SR Rev 1, which will support the Site Recommendation Report.

The current analysis supplements the preceding one with: (1) investigation of the effects of climate change on the Biosphere Dose Conversion Factors for nominal performance; (2) addition of pathway analysis; (3) expansion of the radionuclide list to include radionuclides important for up to 1 million years postclosure; (4) addition of radionuclides important for the human intrusion scenario. In addition, the bounding case considered previously has been removed. The analysis and model report (AMR) title has been modified to better reflect the contents of the document and to be consistent with Project-wide terminology.

The scope of the analysis encompasses development of radionuclide-specific nominal performance BDCFs for the twenty-four radionuclides of interest for the current conditions. The effects of the possible future climate on BDCFs are then evaluated. The analysis for the current climate includes consideration of radionuclide buildup in soil as the result of previous irrigation with contaminated groundwater. The analysis is augmented with the pathway and uncertainty studies. The model used to develop nominal performance BDCFs was appropriate for its intended use. It is analogous to the model used previously (CRWMS M&O 2000a).

This analysis was conducted in accordance with the Office of Civilian Radioactive Waste Management (OCRWM) AP-3.10Q procedure, *Analyses and Models* and the *Technical Work Plan for Biosphere Modeling and Expert Support* (CRWMS M&O 2000c).



(abq0063G298.ai)

Figure 1. Process Models Included in Total System Performance Assessment - Site Recommendation

2. QUALITY ASSURANCE

The activities documented in this AMR were evaluated in accordance with AP-2.21Q, *Quality Determination and Planning for Scientific, Engineering, and Regulatory Compliance Activities,* and were determined to be quality affecting and subject to the requirements of the U.S. Department of Energy (DOE) OCRWM *Quality Assurance Requirements and Description* (QARD) (DOE 2000). This evaluation is documented in the Technical Work Plan (CRWMS M&O 2000c). Consequently, the modeling or analysis activities documented in this AMR have been conducted in accordance with the Civilian Radioactive Waste Management System Management and Operating Contractor (CRWMS M&O) quality assurance program, using approved procedures.

The primary implementing procedure for this work is OCRWM procedure AP-3.10Q, *Analyses and Models*. To perform this work, several other procedures are invoked by AP-3.10Q. These include the following:

- AP-2.14Q, Review of Technical Products
- AP-2.21Q, Quality Determinations and Planning for Scientific, Engineering, and Regulatory Compliance Activities
- AP-3.4Q, Level 3 Change Control
- AP-3.14Q, Transmittal of Input
- AP-3.15Q, Managing Document Inputs
- AP-3.17Q, Impact Reviews
- 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
- AP-SIII.4Q, Development, Review, Online Placement, and Maintenance of Individual Reference Information Base Data Items
- AP-SV.1Q, Control of the Electronic Management of Data.

Personnel performing work on this analysis were trained and qualified according to OCRWM procedures 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 did not require the classification of items in accordance with CRWMS M&O procedure QAP-2-3, *Classification of Permanent Items.* This analysis is not a field activity. Therefore, a *Determination of Importance Evaluation* in accordance with CRWMS M&O procedure NLP-2-0 was not required.

Evaluation of electronic data management process control was performed and documented (CRWMS M&O 2000c) in accordance with AP-SV.1Q, *Control of the Electronic Management of Data* and was accomplished in accordance with the controls specified in the Technical Work Plan (CRWMS M&O 2000c). The control process ensuring accuracy and completeness as well as security of data included the following. Access to the data contained on the personal computer used to perform this work was controlled (password protected). The data were stored on the server drive, which was periodically backed up to the network and updated daily, as appropriate.

The development of BDCF did not depend on electronic data transfer for the model input. Upon completion of model runs, the files generated by the computer code were transferred to the Modeling Warehouse Database of the Technical Data Management System. To accomplish this transfer, the files were compressed, using the WinZip utility to maintain data security and integrity. The list of the transferred files, including filename, file size, and date when the file was generated is included in Attachment IV.

3. COMPUTER SOFTWARE AND MODEL USAGE

The computer code GENII-S V1.4.8.5 (Sandia National Laboratories 1998) was used to calculate nominal performance BDCFs. GENII-S is a computer program used to calculate statistical and deterministic values of radiation doses to humans from exposure to radionuclides in the environment. GENII-S is acquired software, which was qualified for use on the Yucca Mountain Project (CRWMS M&O 1998a). Justification for the selection of this software to perform calculation of radionuclide transport in the biosphere and uptake by a human receptor is documented in Harris (1997).

The GENII-S computer code consists of an executable program and auxiliary files, all of which are maintained under Configuration Management (CM) (CSCI: 30034 V1.4.8.5). The software was obtained from CM, it is appropriate for this application, and was used within the range of applicability in accordance with AP-SI.1Q, *Software Management*, as described in the software qualification report (CRWMS M&O 1998a). The analysis was performed using Gateway 2000 Personal Computers, CPU# 111161 and 111163 located in Building 3, Summerlin, in cubicles number 327D, and 327C, respectively.

The biosphere model used by GENII-S was validated in accordance with AP-3.10Q (see Attachment II for details) and was used within the range of validation. The documentation, inputs, and outputs for the biosphere model for the current and the evolved climates is located in the Technical Data Management System (TDMS) Model Warehouse, DTN MO0010MWDPBD09.006, *Biosphere Dose Conversion Factors for Nominal Performance.*

Prior irrigation periods (see Section 6.3.2, Table 3) were developed using Microsoft Excel version 97 SR-2. To calculate prior irrigation periods, standard Excel functions were used, as documented in Attachment V.

BDCF pathway contributions (see table and figures in Section 6.7) were also developed using Microsoft Excel version 97 SR-2. To accomplish this, portions of GENII-S output files were copied into the spreadsheet. Determination of pathway contributions to BDCFs was done using the *Pathway Contribution* software routine described in Attachment VI of this report.

4. INPUTS

4.1 DATA AND PARAMETERS

Input parameters used in this AMR report were developed in a series of AMRs listed in Table 1. The data sets used to develop nominal performance BDCFs are listed in Table 1. Selection of the values, ranges, and distributions of input parameters as well as justification of the applicability of the selected data to the specific exposure scenarios considered for the potential repository is described in the corresponding AMRs, which are also listed in Table 1 together with the corresponding data tracking numbers (DTNs). Some input parameters were developed in this analysis and are documented in this report. Input parameters developed in this report include selected ingestion pathway parameters (see Attachment III for details) and selected dose coefficients (see Section 6.5.2).

Input parameters listed as items 1 through 7 in Table 1 were developed specifically for the purpose of GENII-S analyses and are, therefore, appropriate for the use in this model. The values of dose conversion factors (DCFs) and dose coefficients (i.e., factors used to convert exposure to radionuclides to dose) apply to chronic low-level intakes and exposure conditions and are inappropriate for acute, high-level intakes and exposures. Therefore the BDCFs developed using such DCFs can not be applied to acute, high-level exposures to radionuclides.

4.2 CRITERIA

*Total System Performance Assess*ment and Integration (TSPAI) Nuclear Regulatory Commission (NRC) Key Technical Issue (KTI) (NRC 2000) includes subissues and the related technical acceptance criteria that are applicable to this work scope because the biosphere model is one of the TSPA component models. The TSPAI subissues include:

- Subissue 1, System Description and Demonstration of Multiple Barriers
- Subissue 2, Scenario Analysis
- Subissue 3, Model Abstraction
- Subissue 4, Demonstration of the Overall Performance Objective

The acceptance criteria associated with these subissues that are applicable to the development of BDCFs are relevant to several concepts which are addressed throughout this document. They include the following:

- The pedigree of data is clearly identified
- Input parameter development and basis for their selection is described
- Documents and reports are clear and consistent
- Data and model uncertainty is discussed
- Alternative modeling approaches are presented

Table 1. Input Data

No.	Data Tracking Number/ Document Identifier DTN/Document Title	Parameters/Comments
1	MO0010SPAPET07.004, Environmental Transport Parameters <u>Source of the DTN:</u> ANL-MGR-MD-000007 REV 00/ICN 1, *Environmental Transport Parameters Analysis* (CRWMS M&O 2000e)	Deposition velocity Crop resuspension factor Crop biomass Depth of surface soil Surface soil density Deep soil density Fraction of roots in surface soil Fraction of roots in deep soil Soil ingestion rate Weathering half-life Translocation factor Animal feed and water consumption rate Dry-to-wet ratio
2	MO0010SPAPTC08.005, Transfer Coefficients <u>Source of the DTN:</u> ANL-MGR-MD-000008 REV 00/ICN 2, *Transfer Coefficient Analysis* (CRWMS M&O 2000f)	Soil-to-plant transfer coefficients Soil-to-plant transfer scaling factor Animal feed-to-animal transfer coefficients Animal feed-to-animal transfer scaling factor Bioaccumulation factors
3	MO0010SPAAAM01.014, Input Parameter Values for External and Inhalation Radiation Exposure Analysis <u>Source of the DTN:</u> ANL-MGR-MD-000001 REV 01, *Input Parameter Values for External and Inhalation Radiation Exposure Analysis* (CRWMS M&O 2000g)	Mass loading Inhalation exposure time Chronic breathing rate Soil exposure time Home irrigation rate Duration of home irrigation

Table 1. Input Data (Continued)

No.	Data Tracking Number/Document Identifier DTN/Document Title	Parameters/Comments
4	MO0002RIB00068.000, Ingestion Exposure Parameter Values <u>Input and the source of the DTN:</u> ANL-MGR-MD-000006 REV 00/ICN 0, *Identification of Ingestion Exposure Parameters* (CRWMS M&O 2000h)	Irrigation water source Drinking water treatment Crop interception fraction Water contaminated fraction Irrigation water contamination fraction Aquatic food consideration Holdup time Storage time Dietary fraction Selected parameters from this data set (irrigation time, irrigation rate, food yield, grow time) were re-developed; in addition the additional set of ingestion exposure parameters for the evolved climate was developed as documented in Attachment III of this report.
5	MO0007SPADMM05.002, Distributions, Mean, Minimum and Maximum Consumption Levels of Locally Produced Food by Type and Tap Water for the Amargosa Valley Receptor of Interest <u>Source of the DTN:</u> CAL-MGR-MD-000005 REV 00/ICN 0, *Calculation: Values and Consumption Rates of Locally Produced Food and Tap Water for the Receptor of Interest* (CRWMS M&O 2000i)	Consumption rates for locally produced food and tap water
6	MO9912RIB00066.000, Parameter Values for Internal and External Dose Conversion Factors <u>Source of the DTN:</u> ANL-MGR-MD-000002 REV 00/ICN 0, Dose Conversion Factor Analysis: Evaluation of GENII-S Dose Assessment Methods (CRWMS M&O 1999)	Dose coefficients for exposure to contaminated soil (external dose conversion factors) External dose conversion factors for additional radionuclides have been developed in addition to coefficients included in this data set as described in Section 6.5.2.

Table 1. Input Data (Continued)

No.	Data Tracking Number/Document Identifier DTN/Document Title	Parameters/Comments
7	MO0004RIB00085.000, Soil and Radionuclide Removal by Erosion and Leaching Source of the DTN: ANL-NBS-MD-000009 REV 00/ICN 0, *Evaluate Soil/Radionuclide Removal by Erosion and Leaching* (CRWMS M&O 2000j)	Removal rates by leaching (leaching coefficients)
8	MO9912SPASUB02.001, Dose Coefficients for Air Submersion and Exposure to Contaminated Soil	The source of the data is Federal Guidance Report No. 12 (Eckerman and Ryman 1993).

4.3 CODES AND STANDARDS

At present, the regulatory framework for a potential repository at Yucca Mountain is evolving and the final applicable rules have not been released yet. Until the final rules become available, U.S. Department of Energy has issued interim guidance (Dyer 1999) pending the issuance of the NRC regulations. The interim guidance, which is based on the proposed rule 10 CFR 63 (64 FR 8640), *Disposal of High-level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada*, has been taken into consideration for the development of the nominal performance BDCFs. Of particular relevance to this analysis are: (1) Section 114 of the guidance which details requirements for performance assessment, including treatment of features, events and processes (FEPs) with regard to their inclusion or exclusion from the model, and (2) Section 115 of this rule which specifies required characteristics of the reference biosphere and critical group.

In parallel to the NRC rulemaking efforts, EPA is presently developing *Environmental Radiation Protection Standards for Yucca Mountain, Nevada* (64 FR 46976). Another proposed rule applicable to the potential repository at Yucca Mountain, is 10 CFR 963 (64 FR 67054), which outlines the Yucca Mountain site suitability guidelines.

5. ASSUMPTIONS

It was assumed that a dietary fraction of fresh forage for the evolved climate was equal to one. This means that livestock are sustained year-round on fresh forage even though the cooler weather conditions of the glacial transition climate would not permit such situation. This assumption is conservative because it overestimates the amount of radionuclides available for uptake by animals. In addition this assumption simplifies calculations of BDCFs. This assumption is used in Section 6.5.

The following assumptions were made to develop the parameter values for one climate evolution scenario, using Spokane, Washington as the analog site (see Attachment III):

1. No irrigation occurs during the period of November through February, because the precipitation rate exceeds the evapotranspiration rate during this period in Spokane, WA (see Tables III-4 and III-5).

2. The meteorological data for Spokane, WA were taken from the Western Regional Climate Center (1997) (see Table III-4).

3. Crop planting, growing and irrigation schedules for Spokane, WA were taken from Washington Agricultural Statistics Service (1992) or Hogan (1988) (see Table III-3).

4. Crop yields for Spokane, WA are the same as the ones for Amargosa Valley, except for alfalfa, because there are only three harvests and a shorter growing season in Spokane (Washington Agricultural Statistics Service 1999). A comparison made for some crop yields between the two locations indicates that those crop yields were very close (see Section III.2.1).

5. To maximize farmland use, two harvests were assumed if the planting period was longer than the growing time. Crops in this category include spinach, lettuce, and carrots, similar to the ones selected for Amargosa Valley (CRWMS M&O 2000h). The use of two harvests in one year for the same crop simplifies calculation of growing period and other irrigation parameters and is conservative.

The above assumptions concerning development of selected ingestion exposure parameters for the evolved climate were used in Sections 6.5.4.1 and 6.5.5.1.

It was assumed that the activity concentration of water used for the fish farm is the same as that of groundwater. The basis for this assumption is that it assures that well water is used for all local food production purposes. This assumption means that, for the GENII-S input, activity concentration of surface water is assumed to be equal to 1 pCi/L. This assumption is used in Tables 7 and 10.

A conservative assumption was made that the GENII-S beef consumption category included both beef and pork and that animal food-to-animal product transfer coefficients for beef can be applied to pork. This assumption allows including all types of locally produced meat using a single GENII-S food type category related to meat consumption. This assumption is used in Section 6.5.3.

Parameters represented by their probability distribution functions included in this analysis are assumed to vary independently (except for plant-to-soil and animal food-to-animal product transfer factors). Therefore, for this analysis the covariance among parameters was not included in the biosphere model. In general, the effect of neglecting covariances is to estimate slightly wider confidence intervals on BDCFs. In other words, ignoring positive correlations amongst input parameters, the uncertainty in the BDCFs will be underestimated. This assumption is used for entering GENII-S input (Sections 6.5.4.1 and 6.5.5.1).

6. ANALYSIS/MODEL

This chapter describes development of radionuclide- and exposure scenario-specific BDCF. First the context of analysis is presented in terms of selection of radionuclides of interest (Section 6.1), definition of the human receptor (Section 6.2) and the conditions of the receptor's exposure to radiation (Section 6.3). Application of the biosphere model, including the modeling inputs and outcomes, to calculate BDCFs for the current and the evolved climates are discussed in Section 6.4. Uncertainly and pathway analyses are discussed in Section 6.6 and 6.7, respectively. The last section of the chapter (Section 6.8) addresses alternative models.

Radionuclide-specific BDCFs developed in this analysis are expressed in terms of total effective dose equivalent (TEDE) (10 CFR 20) for the average member of the critical group resulting from an annual internal and external exposure to radionuclides in the environmental media, from unit of activity concentration of a radionuclide in groundwater released to the environment. Exposure pathways included in the BDCFs are specific to the exposure scenario under consideration. In general, they include ingestion, inhalation, and external exposure (see Section 6.3 for the description of exposure scenario and pathways). The BDCFs were calculated in a probabilistic analysis through multiple realizations of the model outcome from multiple sampling the model input parameters. The results of model realizations are subsequently abstracted into BDCF probability distribution functions, which is outside the scope of this model. The abstraction is carried out in *Abstraction of BDCF Distributions for Irrigation Periods,* ANL-NBS-MD-000007 REV 00/ICN 1 and in *Distribution Fitting to the Stochastic BDCF Data,* ANL-NBS-MD-000008 REV 00/ICN 1.

The biosphere model used in this analysis has been validated for the intended use in development of nominal performance BDCFs for the current and evolved climates. Model validation is discussed in Attachment II. The present analysis is analogous to the one conducted previously to develop non-disruptive event BDCFs (CRWMS M&O 2000a) and is appropriate for generation of input for the TSPA model.

6.1 RADIONUCLIDES OF INTEREST

BDCFs were developed for a combined list consisting of twenty-four radionuclides.

Sixteen radionuclides were identified as important for nominal performance during the compliance period of up to 10,000 years (CRWMS M&O 2000k). These are: ^{14}C, ^{99}Tc, ^{129}I, ^{127}Ac, ^{229}Th, ^{232}U, ^{233}U, ^{234}U, ^{236}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Am, and ^{243}Am.

It was recommended that for the assessment of the consequences of human intrusion the following nineteen radionuclides are considered (CRWMS M&O 2000k): ^{14}C, ^{63}Ni, ^{90}Sr, ^{99}Tc, ^{129}I, ^{137}Cs, ^{227}Ac, ^{229}Th, ^{232}U, ^{233}U, ^{234}U, ^{236}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Am, and ^{243}Am.

For estimating potential dose beyond the compliance period of 10,000 years to the expected time of peak dose or 1 million years, the following five radionuclides were included in addition to those listed above (CRWMS M&O 2000k): ^{210}Pb, ^{231}Pa, ^{226}Ra, ^{230}Th, and ^{242}Pu. This selection applies to both nominal performance and human intrusion scenarios.

6.2 RECEPTOR OF INTEREST

Receptor of interest is defined as a hypothetical individual for whom the dose consequences of the postulated radionuclide release from the potential repository are assessed. For this analysis an average member of the critical group is a receptor of interest. The critical group is defined as the group of individuals reasonably expected to receive the greatest exposure to radioactive releases from the potential repository over time, considering the circumstances under which the analysis is carried out.

The critical group used in this analysis has been developed in (CRWMS M&O (2000l). The critical group characterized in that report is a relatively homogeneously exposed group residing within a farming community. It is expected to receive the highest exposure for the exposure scenario under consideration (see Section 6.3 for the description of exposure scenario). It consists of full-time residents that are involved in agricultural activities for a significant part of the day; spending part of the day recreating outdoors; and consuming locally grown food, some of which is grown in their own gardens. The average member of the critical group defined in such a manner is an individual who represents the exposure scenario based on site-specific, but prudently conservative, exposure assumptions and parameter values. The average member of the critical group is represented by mean values of behaviors and characteristics, which were derived from each individual exposure parameter's frequency distribution for the critical group. In terms of the biosphere model outcome, BDCFs for the average member of the critical group are represented by the mean value of the BDCF probability distribution for the critical group.

The proposed NRC rule requires that, "The behaviors and characteristics of the average member of the critical group shall be based on the mean value of the critical group's variability range" (Dyer 1999, Section 115 (b)(4) of the attachment). In the previous revision of this analysis, for all exposure characteristics of the average member of the critical group, the mean fixed values were used, while the parameters associated with the environmental transport of radionuclides were allowed to be represented by probability distribution functions (see Sections 6.5.2 and 6.5.3 for the discussion of the model parameters). In the current analysis, exposure parameters (e.g., locally produced food consumption rates) for the critical group are represented by their probability distributions to include the uncertainty in these important parameters in the overall uncertainty of the modeling outcome. However, the mean values of the parameters distributions were calculated such that they coincide with either the food consumption survey mean values, in the case of food consumption rates, or with the best estimates of the parameter value in the case of other parameters. By doing so, the mean values of the BDCF distributions are the same as the mean values of the BDCF distributions calculated using fixed mean values of exposure parameters. However, the latter BDCFs distributions are broader because they include variability in behavioral characteristics.

6.3 EXPOSURE CONDITIONS

The main objective of biosphere modeling is to provide the numerical values of BDCFs, which represent annual doses to a human receptor of interest from a radionuclides under consideration per unit of activity concentration of this radionuclide postulated to be released to the environment in groundwater. The circumstances of human exposure to radionuclides present in the biosphere were defined in terms of features, events, and processes (FEPs) that were identified as applicable to the Yucca Mountain region.

One of the requirements that the reference biosphere must meet is that FEPs that describe the reference biosphere shall be consistent with present knowledge of the conditions in the region surrounding the Yucca Mountain site (Dyer 1999, Section 63.115 (a)(1) of the attachment; 64 FR 8640, Section 63.115 (a)(1)). The selection of applicable FEPs forms a basis of the definition of human exposure conditions. The selection should comprehensively address site-specific aspects of human exposure to radionuclides released to the environment from the potential repository. The list of FEPs potentially applicable to the Yucca Mountain Site Characterization Project has been constructed and described in detail (CRWMS M&O 2000m). The evaluation of the applicability of biosphere-related FEPs is being performed and the screening arguments for inclusion or exclusion of specific FEPs are being developed and documented (*Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP)*, ANL-MGR-MD-000011, REV 01). Table 2 lists FEPs that are addressed in this AMR and describes how and where a specific FEP is addressed within this document.

BDCFs, developed for the average member of the critical group, account for transfer of radionuclides through the human food chain and for human dosimetry. The mechanisms of radionuclide transfer through the biosphere, called exposure pathways, were first identified and then modeled. These exposure pathways are described in the following section.

Table 2. Consideration of Features, Events, and Processes Considered Applicable to YMP within the Biosphere Model for Calculation of Nominal Performance Biosphere Dose Conversion Factor

FEP Name	YMP FEP Database Number	Reference/Comment
Climate change, global	1.3.01.00.00	Climate change may affect the long-term performance of the repository. Consideration of climate change based on the geologic record from the Yucca Mountain region, has been included in the analysis. BDCFs for the evolved climate were developed (see Section 6.5.5).
Wells	1.4.07.02.00	This FEP is considered as the source of radionuclides entering the environment, here water for human use (e.g., drinking water) and agriculture (e.g., irrigation, animal watering). This FEP is a part of the exposure pathway selection described in Section 6.3.1.
Soil type	2.3.02.01.00	Soil type FEP is considered for the selection of the values for soil-to-plant transfer coefficient (values for sandy soils were selected, if available) controlling radionuclide transfer from soils to plants, as well as for the calculation of leaching factors, which quantify fraction of activity removed from the top soil layer by leaching, and development of soil-related parameters, such as soil density. (See Sections 6.5.3, 6.5.4.1, and 6.5.5.1 for the specific use of these parameters within the model.) These parameters were developed and documented in the AMRs and are used as input to this analysis.
Radionuclide accumulation in soils	2.3.02.02.00	Radionuclide accumulation in soil as the result continuing irrigation practices has been included in the model. See Section 6.3.2 for the description of the method and Sections 6.5.4.2 and 6.5.5.2 for calculation of buildup factors and incorporation of radionuclide buildup in soil into BDCFs for nominal performance.
Soil and sediment transport	2.3.02.03.00	Removal of radionuclides from top layer of soil by the process of wind erosion (aeolian processes) is addressed within the biosphere model when considering long-term effects of agricultural land use. This process is not directly included in the calculation of the nominal performance BDCFs, but rather it is applied within the TSPA model to modify/adjust the contamination source term.
Precipitation	2.3.11.01.00	Precipitation (precipitation rate) is a parameter which is not used directly in the model, but rather it is used to derive the values of other input parameters that depend on the overall water balance, such as leaching rate, irrigation rates for various crops, as well as home irrigation rate. The usage of precipitation is addressed in the AMRs, which document development of input parameters for the biosphere model. (See Sections 6.5.2, 6.5.3, 6.5.4.1, and 6.5.5.1 for the description of input and its sources).
Surface runoff and flooding	2.3.11.02.00	Evapotranspiration and infiltration are the factors in the water balance equation used to derive certain input parameters described above (see comment for FEP 2.3.11.01.00).
Biosphere characteristics	2.3.13.01.00	Biosphere characteristics such as climate, vegetation, fauna and flora are included in the model as the components of the reference biosphere. Specific relationships between these components form the foundation of the biosphere model used in this analysis and are shown in Figure 2.
Biosphere transport	2.3.13.02.00	See comment above, i.e., for FEP 2.3.13.01.00.
Human characteristics (physiology, metabolism)	2.4.01.00.00	Human characteristics, such as physiology and metabolism, are considered as elements of human dosimetry and they are inherent to dose conversion factors (conversion factors from radionuclide intake to dose). Selection of the specific set of dose conversion factors is discussed in Section 6.8.2. Also see Section 6.5.2 for the additional description of dosimetric input.

Table 2. Consideration of Features, Events, and Processes Considered Applicable to YMP within the Biosphere Model for Calculation of Nominal Performance Biosphere Dose Conversion Factor (Continued)

FEP Name	YMP FEP Database Number	Reference/Comment
Diet and fluid intake	2.4.03.00.00	Consumption rates of locally produced food and tap water for the critical group are included among the model input parameters which were developed in the input AMRs. See Sections 6.5.4.1 and 6.5.5.1 for the description of input and its sources for the current climate and for the glacial transition climate, respectively.)
Human lifestyle	2.4.04.01.00	Conditions of human exposure are based on the assumed lifestyle of the receptor of interest (farming community). This is apparent in the selection of specific values of exposure parameters (which, in addition to food and water consumption rates, include amount of time spent outdoor for work and recreation, inhalation exposure time) specific to the critical group's lifestyle. The human exposure parameters are described in the input AMR. (See Section 6.2 for the discussion of human receptor and Sections 6.5.4.1 and 6.5.5.1 for the description of input and its sources for the current climate and for the glacial transition climate, respectively.)
Dwellings	2.4.07.00.00	Type of dwellings and the habits of human receptor are addressed in the AMR, which develops the critical group. (See Section 6.2 for the discussion of human receptor and Sections 6.5.4.1 and 6.5.5.1 for the description of input and its sources for the current climate and for the glacial transition climate, respectively.)
Agricultural land use and irrigation	2.4.09.01.00	Agricultural land use by the human receptor is addressed in the AMRs that develops the critical group (see Section 6.2). Irrigation characteristics are included in biosphere model input. (See sections 6.5.4.1 and 6.5.5.1 for the description of input parameters and their sources for the current climate and for the glacial transition climate, respectively.)
Animal farms and fisheries	2.4.09.02.00	Contamination of animal products is considered in the model. (See mathematical representation of the biosphere model in Attachment I of this AMR for the description of submodels addressing radionuclide transfer to animal products and fish.)
Drinking water, foodstuffs and drugs, contaminant concentrations in	3.3.01.00.00	Consumption rates of locally produced food and tap water for the critical group are included among the model input parameters which were developed in the input AMRs. See Sections 6.5.4.1 and 6.5.5.1 for the description of input and its sources for the current climate and for the glacial transition climate, respectively.)
Plant uptake	3.3.02.01.00	Contamination of crops is considered in the model by using steady-state transfer factors. (See mathematical representation of the biosphere model in Appendix I for the description of submodels addressing radionuclide transfer to crops.)
Animal uptake	3.3.02.02.00	Contamination of animal products is considered in the model by using steady-state transfer factors. (See mathematical representation of the biosphere model in Appendix I for the description of submodels addressing radionuclide transfer to animal products.)
Bioaccumulation	3.3.02.03.00	The process of accumulation of radioactive contaminants in food products is considered in the model. See mathematical representation of the biosphere model in Appendix I for the description of submodels addressing radionuclide transfer to crops, animal products and fish.

Table 2. Consideration of Features, Events, and Processes Considered Applicable to YMP within the Biosphere Model for Calculation of Nominal Performance Biosphere Dose Conversion Factor (Continued)

FEP Name	YMP FEP Database Number	Reference/Comment
Ingestion	3.3.04.01.00	Ingestion of locally produced food and tap water is included in the model as one of the exposure pathways. Consumption rates of locally produced food and tap water for the critical group are included among the model input parameters which were developed in the input AMRs. See Sections 6.5.4.1 and 6.5.5.1 for the description of input and its sources for the current climate and for the glacial transition climate, respectively.
Inhalation	3.3.04.02.00	Inhalation of resuspended particular matter is included in the model as one of the pathways. See mathematical representation of the biosphere model in Attachment I. Parameters for the inhalation pathway are developed in the input AMR – see Sections 6.5.4.1 and 6.5.5.1 for the description of input parameters and their sources.
External exposure	3.3.04.03.00	External exposure pathway is includedin the model. (See mathematical representation of the biosphere model in Appendix I. Parameters for the external exposure pathway are developed in the input AMR – see Sections 6.5.4.1 and 6.5.5.1 for the description of input parameters and their sources.
Radiation doses	3.3.05.01.00	Calculation of radiation doses is carried out by the human dosimetry component of the biosphere model. (See mathematical representation of the biosphere model in Attachment I for the description of dosimetric component of the model.)

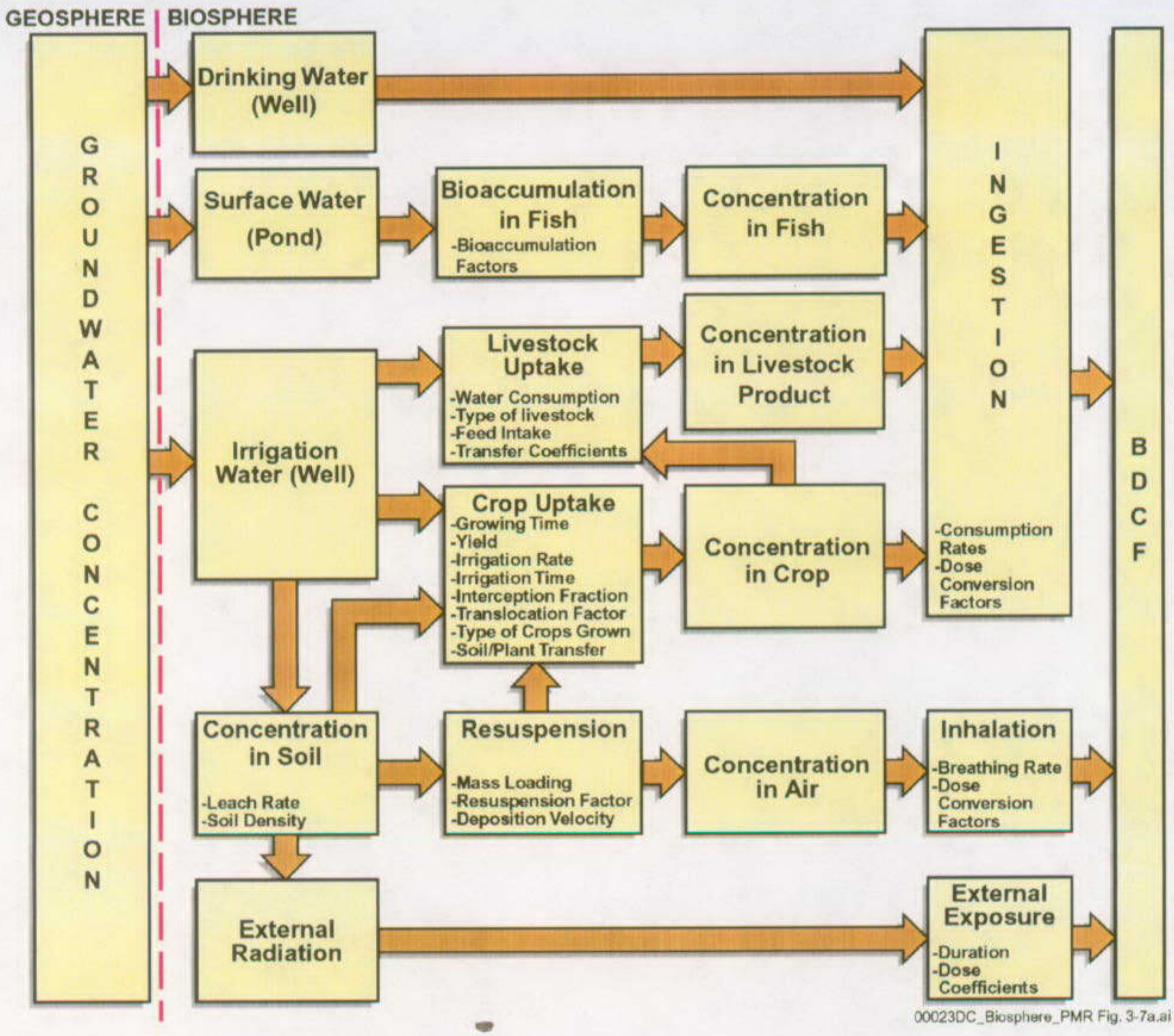
6.3.1 Exposure Pathway Identification and Modeling

Modeling the movement of radionuclides through the food chain is accomplished by identifying specific routes, called pathways, taken by radionuclides through the biosphere from the source of contamination to a human receptor. Current regional land use and other local current conditions influence pathways that are considered significant. The analysis considered pathways that are typical for the current conditions for the critical group residing within a hypothetical farming community in the vicinity of Yucca Mountain (64 FR 8640, Section 63.115 (a)(2) and Section 63.115 (b)). The farming critical group was selected because farming activities typically involve more exposure pathways than other human activities identified in the Yucca Mountain region (64 FR 8640, Section VI of the Supplementary Information). The exposure pathways included ingestion of contaminated water, crops, and animal products; inhalation, and external exposure from contaminated soil. Specifically, the following exposure pathways were considered for the development of the nominal performance BDCFs:

- Consumption of tap water
- Consumption of locally produced leafy vegetables
- Consumption of other locally produced vegetables
- Consumption of locally produced fruit
- Consumption of locally produced grain
- Consumption of locally produced meat
- Consumption of locally produced poultry
- Consumption of locally produced milk
- Consumption of locally produced eggs
- Consumption of locally produced fish
- Inadvertent soil ingestion
- Inhalation of resuspended particulate matter
- External exposure to contaminated soil

Pathway modeling is accomplished using simple mathematical formulations reflecting transfer compartments in the environment. This approach to biosphere modeling was used to calculate BDCFs and it is shown schematically in Figure 2. Modeling of radionuclide transport through the compartments of the biosphere model applied steady-state transfer factors, e.g., soil-to-plant and plant-to-animal product transfer coefficients, and bioaccumulation factors, e.g., bioaccumulation factor for fish. (See Appendix I for the numerical representation of the model, including the description of submodels and associated transfer parameters.)

Pathway analysis results in determination of the total exposure of the individual to radionuclides. The human dosimetry element of the biosphere model was then involved to convert both internal exposure, through ingestion and inhalation, and external exposure from unit activity concentration in groundwater to TEDE for the human receptor resulting from an annual exposure.



(00023DC_Biosphere_PMR Fig. 3-7a.ai)

Figure 2. Block Diagram of Biosphere Conceptual Model for Nominal Performance of the Potential Repository

6.3.2 Radionuclide Buildup in Soil

The magnitude of radiation exposure from certain pathways depends on the radionuclide concentration in soil. The dynamics of the radionuclide concentration in the top layer of soil are governed by a conservation equation where the rate of change in radionuclide concentration in a volume of soil is equal to the quantity flowing in (from irrigation with contaminated groundwater) minus the amount being removed. Mechanisms of radionuclide removal from the soil considered in this analysis include radioactive decay, plant uptake, and leaching into the deeper soil layer.

To address this buildup effect, it was necessary to determine whether buildup caused any significant change in the BDCF. For those radionuclides where buildup did not occur to a significant degree, the periods of irrigation that were used for the calculation were of no consequence. However, for those radionuclides where buildup was shown to be significant, an approach was required that would allow the BDCFs to be determined for an arbitrary previous irrigation period. The technique adopted to determine the functional relationship between the value of the BDCF and the duration of previous irrigation was that of curve fitting (CRWMS M&O 2000n) with subsequent use of the fitted curve for interpolation or extrapolation. To accomplish this, the BDCFs were calculated for several periods of prior irrigation times. (The period of prior irrigation represents the number of years that the land has been irrigated with contaminated water before the intake occurs.)

The technique of curve fitting does not require that BDCFs be calculated for any specific time. The only requirement is that the dependent variable (BDCFs) is calculated over the range of the variable parameter of interest (irrigation periods). Considering this, the values of irrigation periods were calculated such that the series of BDCFs would be approximately equally spaced between the value for the first period and the asymptotic value after an infinitely long period of previous irrigation. Assuming the constant addition rate of radionuclide to soil via irrigation, BDCFs are proportional to the function *f*:

$$f = 1 - e^{-\lambda t} \qquad \text{(Eq. 1)}$$

where λ is the effective removal constant for each radionuclide in soil, and t is the duration of previous irrigation. The effective removal constant was approximated by the sum of the radioactive decay constant and the leaching factor. The range between the BDCF for no prior irrigation ($f = 0$) and the equilibrium value of the BDCF for an individual radionuclide ($f = 1$) was arbitrarily divided into the six equal intervals to obtain a sufficient number of data points for the future curve fitting. Then the irrigation time periods were calculated based on the effective removal rate of radionuclides from the top 15 cm of soil using the following formula:

$$t = \frac{\ln\left(\frac{1}{1-f}\right)}{\lambda} \qquad \text{(Eq. 2)}$$

where *f* is the fraction of the BDCF at equilibrium. For the six irrigation time periods, *f* is equal to 1/6, 2/6, 3/6, 4/6, and 5/6 for the second through the sixth irrigation period, respectively. The first time period corresponds to no prior irrigation with contaminated water. Irrigation time periods calculated using this method are provided in Table 3. The calculations were performed using an Excel spreadsheet as shown in Attachment V.

Table 3. Prior Irrigation Time Periods

Radionuclide	Removal constant, 1/y			Prior Irrigation Periods, y [a]					
	Radioactive Decay [b]	Leaching [c]	Effective [d]	1	2	3	4	5	6
^{14}C	1.21E-04	1.32E-01	1.32E-01	0	1	3	5	8	14
^{63}Ni	6.92E-03	1.69E-03	8.61E-03	0	21	47	80	128	208
^{90}Sr	2.42E-02	4.47E-02	6.89E-02	0	3	6	10	16	26
^{99}Tc [e]	3.25E-06	2.77E+00	2.77E+00	0	1	2	3	4	5
^{129}I [e]	4.42E-08	5.92E-01	5.92E-01	0	1	2	3	4	5
^{137}Cs	2.30E-02	2.42E-03	2.54E-02	0	7	16	27	43	71
^{210}Pb	3.11E-02	2.51E-03	3.36E-02	0	5	12	21	33	53
^{226}Ra	4.33E-04	1.35E-03	1.78E-03	0	102	227	389	616	1005
^{227}Ac	3.18E-02	1.50E-03	3.33E-02	0	5	12	21	33	54
^{229}Th	9.44E-05	2.12E-04	3.06E-04	0	595	1323	2262	3586	5848
^{230}Th	9.00E-06	2.12E-04	2.21E-04	0	825	1835	3136	4971	8108
^{231}Pa	2.11E-05	1.23E-03	1.25E-03	0	146	324	554	878	1432
^{232}U	9.63E-03	1.93E-02	2.89E-02	0	6	14	24	38	62
^{233}U	4.35E-06	1.93E-02	1.93E-02	0	9	21	36	57	93
^{234}U	2.84E-06	1.93E-02	1.93E-02	0	9	21	36	57	93
^{236}U	2.96E-08	1.93E-02	1.93E-02	0	9	21	36	57	93
^{238}U	1.55E-10	1.93E-02	1.93E-02	0	9	21	36	57	93
^{237}Np	3.24E-07	1.32E-01	1.32E-01	0	1	3	5	8	14
^{238}Pu	7.90E-03	1.23E-03	9.13E-03	0	20	44	76	120	196
^{239}Pu	2.87E-05	1.23E-03	1.26E-03	0	145	322	551	873	1423
^{240}Pu	1.06E-04	1.23E-03	1.34E-03	0	136	304	519	822	1341
^{242}Pu	1.84E-06	1.23E-03	1.23E-03	0	148	329	563	892	1455
^{241}Am	1.60E-03	3.56E-04	1.96E-03	0	93	207	354	561	915
^{243}Am	9.39E-05	3.56E-04	4.50E-04	0	405	901	1541	2442	3983

NOTES:
[a] Prior irrigation periods were calculated using Equation 2 in Excel spreadsheet (see Attachment V)
[b] Rittmann 1993, p. 2-5, Removal constant for radioactive decay = (ln 2)/(half-life)
[c] DTN: MO0004RIB00085.000
[d] Effective removal constant = Sum of radioactive decay and leaching removal constants
[e] Sixth irrigation period was less than five years, thus one year per period was conservatively assumed.

6.4 CONSIDERATION OF CLIMATE CHANGE

Geologic media provide the historical record of the types and periodicity of climate change in the Yucca Mountin region. The past-to-future climate analog forecasts that the modern-day climate at Yucca Mountain should persist from 400 to 600 yr., followed by a warmer and much wetter monsoon climate for 900 to 1,400 yr., followed by a cooler and wetter glacial transition climate for 8,000 to 8,700 yr. (CRWMS M&O 2000o, p. 6.5-3). The analysis performed to estimate climatic variables for the next 10,000 years (USGS 2000) identified representative meteorological stations selected to represent future climates. The stations selected provided an upper and lower climate bound for each future climate. The forecasted future climate states, analog sites (USGS 2000, Table 2) and the corresponding average long-term meteorological parameters (DTN GS000100001221.001) are listed in Table 4.

Table 4. Annual Average Meteorological Parameters for Potential Future Climate States at Yucca Mountain and the Analog Sites for the Climate Change Analysis

Climate State	Representative Meteorological Stations	Max Temperature (°F)	Min Temperature (°F)	Snowfall (inches)	Precipitation (inches)
Monsoon Climate Average Upper Bound	Nogales 6N, Arizona Hobbs, New Mexico	79.4 76.5	42.7 47.8	0.45 5.18	17.55 16.44
Monsoon Climate Average Lower Bound	Yucca Mountain site and regional meteorological stations (e.g. Amargosa Farms)	81.9	48.3	0.10	4.48
Glacial Transition Climate Average Upper Bound	Spokane, Washington Rosalia, Washington St. John, Washington	58.1 58.1 60.9	38.1 36.1 35.8	42.14 24.34 25.78	16.15 18.10 17.06
Glacial Transition Climate Average Lower Bound	Beowawe, Nevada Delta, Utah	65.0 65.4	30.8 34.8	14.39 25.15	8.64 7.79
Modern Interglacial Climate	Yucca Mountain site and regional meteorological stations (e.g. Amargosa Farms)	81.9	48.3	0.10	4.48

DTN: GS000100001221.001

Conditions representative of a glacial transition climate were selected to represent evolved climatic conditions at Yucca Mountain and evaluate the impact of climate change on BDCFs. A glacial transition climate was selected because it is predicted to occur for most of the next 10,000 years (CRWMS M&O 2000o, p. 6.5-3). Also, the conditions at the Spokane, Washington station differ the most from the current conditions in the Yucca Mountain region. In Spokane, the average maximum temperature is the lowest, and the amount of overall precipitation (including snow) is the greatest from among the selected analog sites. Therefore this site, being the coolest and wettest of the analog sites, was chosen to represent bounding future-climate conditions for the biosphere analysis.

To consider the effects of climate change on the biosphere modeling, BDCFs were developed for the two climate condition: (1) the current climate state, and (2) the evolved climate represented by the upper bound of the glacial transition climate, similar to that of Spokane, Washington.

6.5 DEVELOPMENT OF BIOSPHERE DOSE CONVERSION FACTORS

GENII-S, *A Code for Statistical and Deterministic Simulations of Radiation Doses to Humans from Radionuclides in the Environment* (Leigh et al. 1993), was chosen to support biosphere modeling for nominal performance. Using a comprehensive set of environmental pathways models, the code calculated the environmental transport of radionuclides following initial contamination of groundwater. Radionuclide concentrations in water, air, soil, and various foodstuffs, combined with human intake and external exposure conditions are then converted to internal and external radiation doses. A description of the environmental transport and uptake model implemented by the GENII-S code, which are important for biosphere modeling, is included in Attachment I.

Conversion of radionuclide intake by ingestion or inhalation is accomplished in GENII-S by application of dose conversion factors, which represent dose per unit activity intake by ingestion or by inhalation. Conversion factors depend on the chemical and physical form of chemical compound of the radionuclide. For conservatism, BDCFs for nominal performance were calculated using the set of dose conversion factors for inhalation and ingestion for those compounds that result in the highest doses.

The primary results from this analysis are radionuclide-specific BDCFs for the average member of the critical group for both current climate and the upper bound of the glacial transition climate. Each of these BDCF sets includes considerations of radionuclide buildup in soil due to previous irrigation. Probabilistic analysis was used to develop BDCF values, as described in the following section (Section 6.5.1). The general approach to the development of input parameters for the biosphere model is discussed in Section 6.5.2. The two following sections, Section 6.5.3 and Section 6.5.4, contain specific description of modeling input and output for the current climate and the glacial transition climate, respectively.

6.5.1 Probabilistic Analysis

To develop BDCFs, the probabilistic approach was taken which allows statistical sampling of parameter values described by their probability distribution functions (PDF). This method, called Monte Carlo analysis, provides a quantitative evaluation of uncertainty and its impacts on the modeling outcome represented by distributions of potential modeling results – BDCFs. When performing BDCF calculations, a large quantity of parameters is encountered. GENII-S has the capability of representing some of the model parameters by their PDFs. Parameter values were sampled using the Latin Hypercube sampling (LHS) scheme. With LHS, the probability distribution is divided into intervals of equal probability. The GENII-S code then samples a value from each interval, which results in more even and consistent sampling compared with the conventional Monte Carlo random sampling scheme.

There are more than 100 input parameters used in the GENII-S model (See Table 5). Some of these parameters can be represented by a distribution while the others are fixed.

Table 5. GENII-S Parameters

Parameter	Distribution	
	GENII-S	**Biosphere Selection**
RADIONUCLIDE CONCENTRATION IN SOIL		
Depth of Surface Soil	Variable	Fixed
Surface Soil Density	Variable	Fixed
Deep Soil Density	Variable	Fixed
Prior Irrigation Duration	Fixed	Fixed
Home Irrigation Rate	Variable	Variable
Home Irrigation Duration	Variable	Fixed
Leaching Factors	Fixed	Fixed
Crop Yields	Variable	Variable
RADIONUCLIDE CONCENTRATION IN AIR		
Deposition Velocity	Variable	Fixed
Mass Loading	Variable	Variable
RADIONUCLIDE CONCENTRATION IN PLANTS FOR HUMAN AND ANIMAL CONSUMPTION		
Resuspension Factor	Variable	Variable
Growing Time	Variable	Variable
Fraction of Roots in Upper Soil	Variable	Fixed
Fraction of Roots in Deep Soil	Variable	Fixed
Irrigation Rates	Variable	Variable
Irrigation Times	Variable	Variable
Interception Fraction (irrigation)	Variable	Variable
Weathering Half-life	Fixed	Fixed
Translocation Factors	Fixed	Fixed
Soil-to-Plant Transfer Factors	Fixed	Fixed
Soil-to-Plant Transfer Scaling Factor	Variable	Variable
Crop Biomass	Fixed	Fixed
Dry-to-Wet Ratio	Fixed	Fixed
RADIONUCLIDE CONCENTRATION IN ANIMAL PRODUCTS		
Feed Storage Time	Variable	Fixed
Dietary Fraction	Variable	Fixed
Contaminated Water Fraction	Variable	Fixed
Animal Feed and Water Consumption Rates	Fixed	Fixed
Transfer Coefficients for Animal Products	Fixed	Fixed
Animal Product Transfer Scaling Factor	Variable	Variable
Bioaccumulation Factors for Fish	Fixed	Fixed
HUMAN EXPOSURE		
Drinking Water Holdup	Variable	Fixed
Water Consumption Rates	Variable	Variable
Crop/Animal Product Holdup	Variable	Fixed
Food Consumption Rates	Variable	Variable
Soil Ingestion Rate	Variable	Fixed
Inhalation Exposure Time	Variable	Variable
Chronic Breathing Rate	Fixed	Fixed
Soil Exposure Time	Variable	Variable
DOSIMETRIC PARAMETERS		
Human Dose Scaling Factor	Variable	Fixed
Dose Commitment Period	Fixed	Fixed
DCFs/DFs	Fixed	Fixed
Organ/Tissue Weighting Factors	Fixed	Fixed

In general, parameters that could potentially be represented by a probability distribution function, but which were determined to have less influence on the final BDCF, were selected as fixed values. Such parameters include storage and holdup times (which are inconsequential for long-lived radionuclides), parameters related to properties of the soils (which were determined based on site-specific information), and parameters whose values were maximized for conservatism (e.g. home irrigation rate, fraction of contaminated water used for animal watering). Representing less important parameters as fixed values helped to alleviate the computational burden on the software and allowed increasing the maximum possible number of model realization, thus improving statistical representation of the outcome. (Model realization is one of the possible model outcomes obtained as a result of a single round of sampling of the model input parameters.) To obtain statistically valid results using LHS, the minimum number of realizations, has to be 1.33 times greater than the number of sampled parameters (LaPlante and Poor 1997, page 3-2). There were 37 sampled parameters in this analysis, which gives the minimum number of realization of about 50.

The code has a limitation on the combination of number of parameters represented by probability distributions and the number of realizations. That is, if more parameters are sampled from their probability distributions, the number of possible realizations decreases. The actual number of realizations that the code can process and produce output in a practical text format depends on the number of variables that are sampled and calculated. The code calculates 27 dependent variables, which when combined with 37 independent variables gives 64 variables whose values are included in the output file (MO0010MWDPBD09.006). It was determined that the maximum number of realizations can be calculated by dividing 10,000 by the number of variables. In this case the number of variables was 64, so the maximum number of realization would be 156. The number of realizations was therefore set to 150.

The statistical sampling technique described above produces a set of 150 single model results (BDCFs) from a set of sampled parameter values (inputs). The 150 model realizations are then statistically summarized and characterized to produce probability distributions of BDCFs that can be used in the TSPA model.

6.5.2 Development of Input Parameters

As noted before, GENII-S uses large number of input parameters. These parameters can be classified into two main groups: (1) the parameters that influence, or are related to, radionuclide transport and accumulation in the biosphere, and (2) the parameters related to characteristics of the human receptor. Input parameters, whether characterized as fixed constants or uncertain parameters with associated probability distributions, have been developed for each of the model runs. When available, site-specific data were used to determine input parameter values. However, for many parameters, the only available data were not completely representative of the reference biosphere and the population being assessed. In this case, developed parameter values reflect expert judgement regarding the degree to which each parameter is unknown. In this aspect, the resulting frequency distribution may be to some degree subjective and should not be considered to represent only natural variability. However, the selection of the parameter values was guided by the general assessment philosophy, which was to use generally conservative assumptions to ensure that the results are unlikely to underestimate the corresponding values of BDCFs for the considered radionuclide transport and uptake conditions and mechanisms.

A majority of the input parameters were developed in a series of analyses. The supporting documentation, including justification for the selection of parameter values, ranges, and distributions can be found in associated AMRs, as listed in Table 1. The remaining parameters are addressed below.

Ingestion Exposure Parameters

The previously developed set of ingestion exposure parameters (MO0002RIB00068.000) includes recommended values of thirteen parameters: water source, drinking water treatment, crop interception fraction, water contaminated fraction, irrigation water contamination fraction, irrigation time, irrigation rate, aquatic food consideration, food yield, grow time, holdup time, storage time, and dietary fraction. These parameters were developed for the current climate condition. If the weather becomes cooler and wetter, such as it is postulated for the evolved climate, the crop growing characteristics, such as the growing season or the irrigation rate will be affected.

Selected ingestion exposure parameters were developed to address a cooler and wetter weather conditions using Spokane, WA as an analog site. In addition, to correct inconsistencies found in the method used to develop *Ingestion Exposure Parameter Values* (MO0002RIB00068.000), additional calculations of the parameters for the current climate were carried out (see Attachment III for details). The summary is presented in Table 6.

Table 6. Summary of Ingestion Parameters for the Current and Evolved Climates

Parameter	Current Climate [a]				Evolved Climate [b]			
	Distribution	Reasonable Estimate	Minimum Value	Maximum Value	Distribution	Reasonable Estimate	Minimum Value	Maximum Value
Growing Time (day)								
Leafy vegetables	Uniform	57	45	68	Uniform	73	50	95
Root vegetables	Uniform	84	70	98	Uniform	122	75	168
Fruit	Uniform	136	88	184	Uniform	140	95	184
Grain	Fixed	244	244	244	Fixed	191	191	191
Fresh feed for beef	Triangular	47	46	135	Fixed	71	71	71
Stored feed for poultry	Fixed	140	140	140	Fixed	179	179	179
Fresh feed for milk	Triangular	47	46	135	Fixed	71	71	71
Stored feed for eggs	Fixed	140	140	140	Fixed	179	179	179
Irrigation Time (mo/yr)								
Leafy vegetables	Uniform	3.8	3.0	4.5	Uniform	4.8	3.3	6.2
Root vegetables	Uniform	3.9	3.2	4.6	Uniform	5.2	4.9	5.5
Fruit	Uniform	4.5	2.9	6.0	Uniform	4.6	3.1	6.0
Grain	Fixed	8.0	8.0	8.0	Fixed	6.2	6.2	6.2
Fresh feed for beef	Fixed	12	12	12	Fixed	7.0	7.0	7.0
Stored feed for poultry	Fixed	4.6	4.6	4.6	Fixed	5.7	5.7	5.7
Fresh feed for milk	Fixed	12	12	12	Fixed	7.0	7.0	7.0
Stored feed for eggs	Fixed	4.6	4.6	4.6	Fixed	5.7	5.7	5.7
Irrigation Rate (in/yr)								
Leafy vegetables	Uniform	36	28	43	Uniform	34	25	43
Root vegetables	Uniform	50	47	52	Uniform	40	39	41
Fruit	Uniform	38	30	45	Uniform	28	26	30
Grain	Fixed	56	56	56	Fixed	34	34	34
Fresh feed for beef	Fixed	95	95	95	Fixed	42	42	42
Stored feed for poultry	Fixed	75	75	75	Fixed	39	39	39
Fresh feed for milk	Fixed	95	95	95	Fixed	42	42	42
Stored feed for eggs	Fixed	75	75	75	Fixed	39	39	39

Table 6. Summary of Ingestion Parameters for the Current and Evolved Climates (Continued)

Parameter	Current Climate [a]				Evolved Climate [b]			
	Distribution	Reasonable Estimate	Minimum Value	Maximum Value	Distribution	Reasonable Estimate	Minimum Value	Maximum Value
Crop Yield (kg/m²)								
Leafy vegetables	Uniform	4.6	4.4	4.8	Uniform	4.6	4.4	4.8
Root vegetables	Uniform	7.0	4.1	9.8	Uniform	7.0	4.1	9.8
Fruit	Uniform	2.0	1.6	2.3	Uniform	2.0	1.6	2.3
Grain	Uniform	0.5	0.3	0.7	Uniform	0.5	0.3	0.7
Fresh feed for beef	Uniform	1.1	1.0	1.2	Fixed	0.5	0.5	0.5
Stored feed for poultry	Uniform	0.7	0.6	0.8	Uniform	0.7	0.6	0.8
Fresh feed for milk	Uniform	1.1	1.0	1.2	Fixed	0.5	0.5	0.5
Stored feed for eggs	Uniform	0.7	0.6	0.8	Uniform	0.7	0.6	0.8

NOTES: [a] From Table III-2 (Attachment III)
[b] From Table III-7 (Attachment III)

Dose Coefficients

A previously developed set of dose coefficients (DCs) for 15-cm layer of contaminated soil (MO9912RIB00066.000) was amended because the set did not include radionuclides considered important for up to 1 million years. For most radionuclides, their decay products must be taken into account in BDCF calculations. Decay products should match those considered in GENII-S for a given radionuclide. Following computational methods of GENII-S, DCs for some radionuclides include contributions from their own chains of short-lived radionuclides.

DCs were developed using the same method as that described in CRWMS M&O (1999), using accepted data from Federal Guidance Report No. 12 (FGR-12) (Eckerman and Ryman 1993) (MO9912SPASUB02.001) as the source of the data in Table 7. DCs in the FGR-12 are listed in units of Sv/s per Bq/m^3. GENII-S input should be in Sv/y per Bq/m^3. DC were therefore converted to the units used in GENII-S input file by multiplying FGR-12 DCs by the conversion factor of 3.15×10^7 s/y. In addition, for three radionuclides (^{222}Rn, ^{225}Ac, and ^{223}Ra), contributions from their short-lived decay products were added to the DC of a parent, in a process described in (CRWMS M&O 1999). DCs for radionuclides of interest and their decay products are summarized in Table 7.

Table 7. Dose Coefficients for 15-cm Layer of Contaminated Soil for Radionuclides of Interest (shown in bold type) and Their Decay Products

Radionuclide	Dose Coefficient for contaminated soil	
	Sv/s per Bq/m^3 [a]	Sv/y per Bq/m^3 [b]
^{14}C	7.20E-23	2.27E-15
^{63}Ni	0.00E+00	0.00E+00
^{90}Sr	3.72E-21	1.17E-13
^{90}Y	1.20E-19	3.78E-12
^{99}Tc	6.70E-22	2.11E-14
^{129}I	6.93E-20	2.19E-12
^{137}Cs + ^{137m}Ba	1.71E-17	5.39E-10
^{210}Pb	1.31E-20	4.13E-13
^{210}Bi	1.86E-20	5.86E-13
^{210}Po	2.45E-22	7.72E-15
^{226}Ra	1.65E-19	5.20E-12
^{222}Rn + decay products [c]	(1.14E-20)	1.58E-09
^{218}Po	(2.63E-22)	
^{214}Pb	(6.70E-18)	
^{214}Bi	(4.36E-17)	
^{214}Po	(2.40E-21)	
^{210}Pb [d]		
^{227}Ac	2.62E-21	8.25E-14

Table 7. Dose Coefficients for 15-cm Layer of Contaminated Soil for Radionuclides of Interest (shown in bold type) and Their Decay Products (Continued)

Radionuclide	Dose Coefficient for contaminated soil	
	Sv/s per Bq/m^3 [a]	Sv/y per Bq/m^3 [b]
^{229}Th	1.70E-18	5.36E-11
^{225}Ra	5.90E-20	1.86E-12
^{225}Ac + decay products [c]	(3.34E-19)	1.93E-10
^{221}Fr	(7.90E-19)	
^{217}At	(8.61E-21)	
^{213}Bi	(3.75E-18)	
^{213}Po at 97.84%	(0)	
^{209}Tl at 2.16%	(1.25E-18)	
^{209}Pb	(4.08E-21)	
^{230}Th	6.39E-21	2.01E-13
^{226}Ra [d]		
^{231}Pa	9.62E-19	3.03E-11
^{227}Th	2.65E-18	8.35E-11
^{223}Fr	1.01E-18	3.18E-11
^{223}Ra + decay products [c]	(3.10E-18)	2.36E-10
^{219}Rn	(1.54E-18)	
^{215}Po	(4.98E-21)	
^{211}Pb	(1.46E-18)	
^{211}Bi	(1.28E-18)	
^{207}Tl	(9.48E-20)	
^{232}U	4.77E-21	1.50E-13
^{233}U	7.24E-21	2.28E-13
^{229}Th [d]		
^{234}U	2.14E-21	6.74E-14
^{236}U	1.14E-21	3.59E-14
^{238}U	5.52E-22	1.74E-14
^{234}Th	1.29E-19	4.06E-12
^{234}Pa	5.38E-17	1.69E-09
^{237}Np	4.16E-19	1.31E-11
^{233}Pa	5.16E-18	1.63E-10
^{238}Pu	8.07E-22	2.54E-14
^{234}U [d]		
^{239}Pu	1.52E-21	4.79E-14
^{240}Pu	7.84E-22	2.47E-14
^{236}U [d]		
^{242}Pu	6.85E-22	2.16E-14
^{241}Am	2.34E-19	7.37E-12
^{237}Np [d]		

Table 7. Dose Coefficients for 15-cm Layer of Contaminated Soil for Radionuclides of Interest (shown in bold type) and Their Decay Products (Continued)

Radionuclide	Dose Coefficient for contaminated soil	
	Sv/s per Bq/m^{3} [a]	Sv/y per Bq/m^{3} [b]
^{243}Am	7.60E-19	2.39E-11
^{239}Np	3.90E-18	1.23E-10
^{239}Pu [d]		

NOTES: [a] MO9912SPASUB02.001

[b] (Sv/s per Bq/m^{3}) × (3.15 × 10^{7} s/y) = Sv/y per Bq/m^{3}

[c] Contribution from decay products listed below is added to the DC for this radionuclide

[d] The DCs for this radionuclide and its progeny, if applicable, have been listed earlier in this Table.

6.5.3 GENII-S Input

GENII input consists of parameters included in input files and parameters entered using menu-driven interface. Input files did not change between the current and evolved climates. The content of input files is shown, as images of the files, in Figures 3, 4, 5, and 6. Figure 3 shows the image of DEFSR.IN file containing input parameters for GENII-S simulations. (For some parameters, if the user does not enter a parameter value using a menu-driven interface, a value from the default file is assigned to this parameter. The file also contains certain conversion factors.) Parameters used in the calculation, included in this file, were developed in the AMR (CRWMS M&O 2000e) (MO0010SPAPET07.004) except for the chronic breathing rate (MO0010SPAAAM01.014). Parameters not used in the present analysis remained unchanged from the GENII-S original default file.

The image of the FTRANSR.DAT file containing food transfer factors developed in CRWMS M&O (2000f) (MO0010SPAPTC08.005) is shown in Figure 4. Food transfer factors for beef are assumped to apply to both beef and pork (see Section 5). This file also contains leaching factors developed in a separate report (CRWMS M&O 2000j) (MO0004RIB00085.000). Figure 5 shows the image of the BIOACSR.DAT file containing bioaccumulation factors (used for assessment of radionuclide transfer from water to fish for the aquatic food ingestion pathway) (MO0010SPAPTC08.005) while Figure 6 shows the image of the GRDFSR.DAT file containing dose coefficients for external exposure. The majority of dose coefficients were developed previously (CRWMS M&O 1999) (MO9912RIB00066.000). The remaining ones were developed in this analysis based on accepted data (MO9912SPASUB02.001) and are documented in this report (Section 6.5.2).

Among input parameters entered using menu-driven interface, many are specific to the exposure scenario. These parameters are listed in the subsequent sections dealing with the modeling input and output for the specific exposure scenarios.

```
INVENTORY PARAMETERS-----------------------------------------------------------
0.037, 3.7E4, 3.7E7, 3.7E10, 1.0          NVU      Source input conversion
1.0, 0.15, 225.0                          SVU      Soil source conversion
ENVIRONMENTAL PARAMETERS--------------------------------------------------------
0.008                                     ABSHUM   Absolute humidity (kg/m3)
2                                         PRCNTI   Air dispersion conserv. flag
0.001                                     DPVRES   Deposition vel./resuspension
4.7E-10                                   LEAFRS   Leaf resuspension factor
2.0,2.0,3.0,0.8,0.8,0.8,1.0,0.8,1.0,1.5   BIOMAS   BIOMA2 Biomass (kg/m2)
0.259                                     DEPFR2   Interception frac./irrigate
15.0                                      SURCM    Depth of surface soil (cm)
225.0                                     SLDN     Surface soil density (kg/m2)
1.5E3                                     SSLDN    Soil density (kg/m3)
True                                      HARVST   Harvest removal considered?
50.0                                      SOLING   Soil ingested (mg/da)
14.0                                      WTIM     Weathering time (da)
1.0, 0.1, 0.1, 0.1                        TRANS    Translocation, plants
0.1, 0.1, 0.1, 0.1, 1.0, 1.0              TRANSA   Translocation, animal food
68.0, 0.12, 55.0, 0.12, 68.0, 55.0        CONSUM   Animal Consumption (kg/da)
50.0, 0.3, 60.0, 0.3                      DWATER   Animal drinking water (L/da)
0.0, 0.8, 1.0, 0.8                        FRACUT   Acute fresh forage by season
0.2, 0.3, 0.5, 1.0                        SHORWI   Shore width factors
0.02                                      INGWAT   Swim water ingested (L/hr)
25295.0                                   TCWS     H2O/sed. transfer (L/m2/yr)
0.4,  5.0, 4.0                            YELDBT   BIOT: Veg. prod. (kg/m2/yr)
9.41E-4, 2*7.48E-4                        TOTEXC   BIOT: Excavation (m2/m3-yr)
1.0, 0.81, 0.19, 0.02, 0.008, 0.002,      EXCAV    BIOT: Frac. soil brought to
1.0, 0.9, 0.096, 0.006, 0.0005, 0.0005,            surface from within the
1.0, 0.9, 0.096, 0.006, 0.0005, 0.0005             waste by animal excavation
266.2                                     RINH     Chronic breathing (cm3/sec)
330.0                                     RINHA    Acute breathing (cm3/sec)
10                                        NDIST    Number of distances
805.0, 2414.0, 4023.0, 5632.0, 7241.0,
12068.0, 24135.0, 40255.0, 56315.0,
72405.0                                   X        JF/chi/Q/pop grid dist. (m)
0.1, 0.25, 0.18, 0.91, 0.18, 0.91, 0.18,
0.91, 2*0.20                              DRYFAC, DRYFA2 dry/wet ratio
METABOLIC PARAMETERS-----------------------------------------------------------
0.5, 50.0, 500.0                                         XDIV
0.5,  0.5,  0.95, 0.05,  0.8, 0.0, 0.0,   0.2, 0.0,      ADJ
0.1,  0.9,  0.5,  0.5,  0.15, 0.4, 0.4,  0.05, 0.0,
0.01, 0.99, 0.01, 0.99, 0.05, 0.4, 0.4, 0.135, 0.015
```

Figure 3. The Image of the DEFSR.IN File (Default Parameter Values and Conversion Factors)

Food Transfer Factors for SR Runs (09/09/00)

Ele-men	Dep Vel m/sec	Leafy Veg	Root Veg	Fruit --	Grain --	Beef day/kg	Poulty day/kg	Milk day/L	Egg day/kg	Leaching Factor
AC	1.0E-3	3.5E-3	3.5E-4	3.5E-4	3.5E-4	2.5E-5	4.0E-3	2.0E-5	2.0E-3	1.5E-03
AM	1.0E-3	2.0E-3	4.7E-4	4.1E-4	9.0E-5	2.0E-5	6.0E-3	2.0E-6	4.0E-3	3.6E-04
BI	1.0E-3	3.5E-2	5.0E-3	5.0E-3	5.0E-3	4.0E-4	4.0E-2	5.0E-4	4.0E-2	6.8E-03
C	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	1.3E-01
CS	1.0E-3	1.3E-1	4.9E-2	2.2E-1	2.6E-2	5.0E-2	4.4E+0	8.0E-3	4.0E-1	2.4E-03
FR	1.0E-3	2.0E-2	2.0E-2	2.0E-2	1.0E-2	3.0E-2	4.4E+0	7.0E-3	4.9E-1	0.0E-10
I	1.0E-2	3.4E-3	5.0E-2	5.0E-2	5.0E-2	7.0E-3	1.8E-2	1.0E-2	3.0E+0	5.9E-01
NI	1.0E-3	1.8E-1	6.0E-2	6.0E-2	3.0E-2	5.0E-3	1.0E-3	2.0E-2	1.0E-1	1.7E-03
NP	1.0E-3	3.7E-2	1.7E-2	1.7E-2	2.7E-3	1.0E-3	4.0E-3	5.0E-6	2.0E-3	1.3E-01
PA	1.0E-3	2.5E-3	2.5E-4	2.5E-4	2.5E-4	1.0E-5	4.0E-3	5.0E-6	2.0E-3	1.2E-03
PB	1.0E-3	4.5E-2	9.0E-3	9.0E-3	4.7E-3	4.0E-4	4.0E-2	3.0E-4	8.0E-1	2.5E-03
PO	1.0E-3	2.5E-3	7.0E-3	4.0E-4	4.0E-4	4.0E-3	4.5E-1	3.4E-4	7.0E+0	4.5E-03
PU	1.0E-3	3.9E-4	2.0E-4	1.9E-4	2.6E-5	1.0E-5	4.0E-3	1.1E-6	8.0E-3	1.2E-03
RA	1.0E-3	8.0E-2	1.3E-2	6.1E-3	1.2E-3	9.0E-4	3.0E-2	1.3E-3	2.0E-5	1.4E-03
SR	1.0E-3	2.0E+0	1.2E+0	2.0E-1	2.0E-1	8.0E-3	3.5E-2	1.5E-3	3.0E-1	4.5E-02
TC	1.0E-3	4.0E+1	6.6E+0	1.5E+0	7.3E-1	1.0E-4	3.0E-2	9.9E-3	3.0E+0	2.8E+00
TH	1.0E-3	4.0E-3	3.0E-4	2.1E-4	3.4E-5	6.0E-6	4.0E-3	5.0E-6	2.0E-3	2.1E-04
U	1.0E-3	8.5E-3	1.4E-2	4.0E-3	1.3E-3	3.0E-4	1.2E+0	6.0E-4	1.0E+0	1.9E-02
Y	1.0E-3	1.5E-2	6.0E-3	6.0E-3	6.0E-3	1.0E-3	1.0E-2	2.0E-5	2.0E-3	4.0E-03

Figure 4. The Image of the FTRANSR.DAT File (Food Transfer Coefficients and Leaching Factors)

Bioaccumulation Factor Library for SR Runs - (09-09-00 MAW)

Salt:	Fish	Crustacea	Molluscs	Plants	Fr:Fish	Crustacea	Molluscs	Plants	Cleanup
AC	1.0	1.0	1.0	1.0	25.0	1.0	1.0	1.0	0.7
AM	1.0	1.0	1.0	1.0	30.0	1.0	1.0	1.0	0.7
BI	1.0	1.0	1.0	1.0	15.0	1.0	1.0	1.0	0.9
C	1.0	1.0	1.0	1.0	50000.0	1.0	1.0	1.0	1.0
CS	1.0	1.0	1.0	1.0	2000.0	1.0	1.0	1.0	0.9
I	1.0	1.0	1.0	1.0	40.0	1.0	1.0	1.0	0.8
MO	1.0	1.0	1.0	1.0	10.0	1.0	1.0	1.0	0.9
NI	1.0	1.0	1.0	1.0	100.0	1.0	1.0	1.0	0.2
NP	1.0	1.0	1.0	1.0	30.0	1.0	1.0	1.0	0.7
PA	1.0	1.0	1.0	1.0	11.0	1.0	1.0	1.0	0.7
PB	1.0	1.0	1.0	1.0	300.0	1.0	1.0	1.0	0.9
PO	1.0	1.0	1.0	1.0	500.0	1.0	1.0	1.0	0.8
PU	1.0	1.0	1.0	1.0	30.0	1.0	1.0	1.0	0.7
RA	1.0	1.0	1.0	1.0	50.0	1.0	1.0	1.0	0.7
SR	1.0	1.0	1.0	1.0	60.0	1.0	1.0	1.0	0.2
TC	1.0	1.0	1.0	1.0	20.0	1.0	1.0	1.0	0.7
TH	1.0	1.0	1.0	1.0	100.0	1.0	1.0	1.0	0.7
U	1.0	1.0	1.0	1.0	10.0	1.0	1.0	1.0	0.7
Y	1.0	1.0	1.0	1.0	30.0	1.0	1.0	1.0	0.2

Figure 5. Image of the BIOACSR.DAT File (Bioaccumulation Factors)

FGR12 air,water,soil(15 CM) DCFs (Sv/yr per Bq/n) (9 Sep 2000 MAW)

n	Air Submersion m3	Water Surface L	Soil 15 cm "m3"	Buried 0.15 m m3	Buried 0.5 m m3	Buried 1.0m m3
C 14	7.06E-12	0.00E+00	2.27E-15	0.00E+00	0.00E+00	0.00E+00
NI63	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SR90	2.37E-10	0.00E+00	1.17E-13	0.00E+00	0.00E+00	0.00E+00
Y 90	5.99E-09	0.00E+00	3.78E-12	0.00E+00	0.00E+00	0.00E+00
TC99	5.11E-11	0.00E+00	2.11E-14	0.00E+00	0.00E+00	0.00E+00
I 129	1.20E-08	0.00E+00	2.19E-12	0.00E+00	0.00E+00	0.00E+00
CS137	9.08E-07	0.00E+00	5.39E-10	0.00E+00	0.00E+00	0.00E+00
TH230	5.49E-10	0.00E+00	2.02E-13	0.00E+00	0.00E+00	0.00E+00
RA226	9.93E-09	0.00E+00	5.20E-12	0.00E+00	0.00E+00	0.00E+00
RN222	2.79E-06	0.00E+00	1.59E-09	0.00E+00	0.00E+00	0.00E+00
PB210	1.78E-09	0.00E+00	4.13E-13	0.00E+00	0.00E+00	0.00E+00
BI210	1.04E-09	0.00E+00	5.87E-13	0.00E+00	0.00E+00	0.00E+00
PO210	1.31E-11	0.00E+00	7.73E-15	0.00E+00	0.00E+00	0.00E+00
U 232	4.48E-10	0.00E+00	1.50E-13	0.00E+00	0.00E+00	0.00E+00
TH232	2.75E-10	0.00E+00	8.76E-14	0.00E+00	0.00E+00	0.00E+00
RA228	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
AC228	1.51E-06	0.00E+00	8.69E-10	0.00E+00	0.00E+00	0.00E+00
TH228	2.90E-09	0.00E+00	1.32E-12	0.00E+00	0.00E+00	0.00E+00
RA224	1.55E-08	0.00E+00	8.62E-12	0.00E+00	0.00E+00	0.00E+00
PB212	2.17E-07	0.00E+00	1.14E-10	0.00E+00	0.00E+00	0.00E+00
BI212	2.30E-06	0.00E+00	1.27E-09	0.00E+00	0.00E+00	0.00E+00
PU242	1.26E-10	0.00E+00	2.16E-14	0.00E+00	0.00E+00	0.00E+00
NP238	8.57E-07	0.00E+00	4.98E-10	0.00E+00	0.00E+00	0.00E+00
U 234	2.41E-10	0.00E+00	6.75E-14	0.00E+00	0.00E+00	0.00E+00
U 236	1.58E-10	0.00E+00	3.60E-14	0.00E+00	0.00E+00	0.00E+00
PA231	5.42E-08	0.00E+00	3.03E-11	0.00E+00	0.00E+00	0.00E+00
AC227	1.84E-10	0.00E+00	8.26E-14	0.00E+00	0.00E+00	0.00E+00
TH227	1.54E-07	0.00E+00	8.36E-11	0.00E+00	0.00E+00	0.00E+00
FR223	7.22E-08	0.00E+00	3.19E-11	0.00E+00	0.00E+00	0.00E+00
RA223	4.30E-07	0.00E+00	2.36E-10	0.00E+00	0.00E+00	0.00E+00
NP237	3.25E-08	0.00E+00	1.31E-11	0.00E+00	0.00E+00	0.00E+00
PA233	2.95E-07	0.00E+00	1.63E-10	0.00E+00	0.00E+00	0.00E+00
U 233	5.14E-10	0.00E+00	2.28E-13	0.00E+00	0.00E+00	0.00E+00
TH229	1.21E-07	0.00E+00	5.36E-11	0.00E+00	0.00E+00	0.00E+00
RA225	8.80E-09	0.00E+00	1.86E-12	0.00E+00	0.00E+00	0.00E+00
AC225	3.40E-07	0.00E+00	1.94E-10	0.00E+00	0.00E+00	0.00E+00
U 238	1.08E-10	0.00E+00	1.74E-14	0.00E+00	0.00E+00	0.00E+00
TH234	3.33E-08	0.00E+00	1.73E-11	0.00E+00	0.00E+00	0.00E+00
PA234	2.95E-06	0.00E+00	1.70E-09	0.00E+00	0.00E+00	0.00E+00
PU238	1.54E-10	0.00E+00	2.54E-14	0.00E+00	0.00E+00	0.00E+00
PU240	1.50E-10	0.00E+00	2.47E-14	0.00E+00	0.00E+00	0.00E+00
AM241	2.58E-08	0.00E+00	7.38E-12	0.00E+00	0.00E+00	0.00E+00
PU237	6.36E-08	0.00E+00	2.72E-11	0.00E+00	0.00E+00	0.00E+00
AM243	6.87E-08	0.00E+00	2.40E-11	0.00E+00	0.00E+00	0.00E+00
NP239	2.43E-07	0.00E+00	1.23E-10	0.00E+00	0.00E+00	0.00E+00
PU239	1.34E-10	0.00E+00	4.79E-14	0.00E+00	0.00E+00	0.00E+00

Figure 6. Image of the GRDFSR.DAT File (Dose Coefficients for Soil Contaminated to 15 cm)

6.5.4 Biosphere Dose Conversion Factors for the Current Climate at Yucca Mountain

Present Yucca Mountain climate is arid to semi-arid and seasonally warm. Total rainfall is typically less than 10 in. The air temperatures range from over 40°C during summer days to below 0°C during some winter nights (CRWMS M&O 2000o, p. 6.2-4). BDCFs were developed for the climatic conditions corresponding to such precipitation and temperature characteristics. The receptor of interest was defined as an average member of the critical group, as described in Section 6.2. BDCFs were calculated in a series of GENII-S simulations for each of the 24 radionuclides (see Section 6.1). Each simulation resulted in 150 model realizations.

This section contains a listing of the modeling input data and the summary of the model output followed by the discussion of the radionuclide buildup in soil caused by irrigation with contaminated groundwater.

6.5.4.1 Input Data

As noted previously, GENII-S input consists of input files and parameters entered during the model runs using menu-driven interface. The content of the input files was the same for both climate conditions considered in this analysis and it is given in Section 6.4.3. The set of input values for the current climate, entered using GENII-S menu-driven interface is shown in Table 8. The values and selections in the table are listed in the format that they are entered in GENII-S.

Table 8. GENII-S Menu-Accessible Input Parameters for the Current Climate

Menu(s)	Option/-Parameter, Unit	Selection	Values: Minimum	Values: Best Estimate	Values: Maximum	Distribution	Reference[a]/ Comments
PRE-GENII							
Edit Flags and Options	Scenario Options						
	- Near-Field Scenario	Y	NA [b]	NA	NA	NA	Near-field scenario
	- Population Dose	N	NA	NA	NA	NA	
	- Acute Release	N	NA	NA	NA	NA	
	Transport Options						No radionuclide transport
	- Air Transport	N	NA	NA	NA	NA	
	- 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						Pathway selection
	- External Finite Plume	N	NA	NA	NA	NA	
	- 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	Y	NA	NA	NA	NA	
	- Aquatic Food Ingestion	Y	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						Output selection
	- Both Committed and Cumulative	N	NA	NA	NA	NA	
	- EDE by Nuclide	N	NA	NA	NA	NA	
	- EDE by Pathway	N	NA	NA	NA	NA	
	Run Options						Unit selection, Run selection, Intake duration
	- Inventory Unit Index (1-5)	1, pCi	NA	NA	NA	NA	
	- 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	
Select Nuclides	Radionuclide selection	Y/N	-	-	-	-	Section 6.1

Table 8. GENII-S Menu-Accessible Input Parameters for the Current Climate (Continued)

Menu(s)	Option/-Parameter, Unit	Selection	Values: Minimum	Values: Best Estimate	Values: Maximum	Distribution	Reference[a]/ Comments
	PRE-GENII (Continued)						
Select Statistical Output	- Statistical Committed Dose Summary	Y	NA	NA	NA	NA	Output Selection
	- Statistical Committed Nuclide Dose	N	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	
	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)	150	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 #2
	- Animal Uptake Scale Factor, (-)	NA	0.117	—	8.51	Lognormal	Input #2
	- Human Dose Factor Scale Factor, (-)	NA	—	1	—	Fixed	Input #6
	- Dose Commitment Period, yr	NA	NA	50	NA	NA	
	- Surface Soil Depth, cm	NA	—	15	—	Fixed	Input #1
	- Surface Soil Density, kg/m^2	NA	—	225	—	Fixed	Input #1
	- Deep Soil Density, kg/m^3	NA	—	1500	—	Fixed	Input #1
	- Roots in Upper Soil, fraction	NA	—	1	—	Fixed	Input #1
	- Roots in Deep Soil, fraction	NA	—	0	—	Fixed	Input #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	Table 3
	Biotic Trans./Near Field Data Not used	—	—	—	—	—	—

Table 8. GENII-S Menu-Accessible Input Parameters for the Current Climate (Continued)

Menu(s)	Option/-Parameter, Unit	Selection	Values: Minimum	Values: Best Estimate	Values: Maximum	Distribution	Reference[a]/ 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	5793.5	6073.5	6353.5	Uniform	Input #3
	- Resuspension Model Flag (0-2)	1	NA	NA	NA	NA	Mass loading
	- Mass Loading, g/m^3	NA	3.8×10^{-5}	1.05×10^{-4}	1.73×10^{-4}	Normal	Input #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	2827	3387	3947	Uniform	Input #3
	- Home Irrigation Flag (0/1 = N/Y)	1	NA	NA	NA	NA	Contaminated
	- Irrigation Water Index (1-2)	1	NA	NA	NA	NA	water
	- Home Irrigation Rate, in/yr	NA	51	74	96	Uniform	Input #3
	- Home Irrigation Duration, mo/yr	NA	--	12	--	Fixed	Input #3
	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	1.7×10^{-10}	4.7×10^{-10}	7.7×10^{-10}	Normal	Input #1
	- Crop Deposition Velocity, m/s	NA	--	0.001	--	Fixed	Input #1
	- Crop Interception Fraction	NA	0.044	0.259	0.474	Normal	Input #4
	- Exported Food Dose (0/1 = N/Y)	0	NA	NA	NA	NA	Not used
	- Soil Ingestion Rate, mg/day	NA	--	50	--	Fixed	Input #1
	- Swim H2O Ingestion Rate, l/h	NA	--	0	--	Fixed	Not used
	- Population Ingesting Aquatic Food	0	NA	NA	NA	NA	Not used
	- Bioaccumulation Flag (0/1 = N/Y)	0	NA	NA	NA	NA	Not used
	- Population Drinking Contaminated Water	0	NA	NA	NA	NA	Whole population
	- Drink Water Source Index (0-3)	0	NA	NA	NA	NA	Groundwater
	- Drink Water Treated (0/1 = N/Y)	0	NA	NA	NA	NA	Input #4
	- Drink Water Holdup Time, days	NA	--	0	--	Fixed	Input #4
	- Drink Water Consumption, l/y	NA	0	752.85	1487.45	Uniform	Input #5

Table 8. GENII-S Menu-Accessible Input Parameters for the Current Climate (Continued)

Menu(s)	Option/-Parameter, Unit	Selection	Values			Distribution	Reference[a]/ Comments
			Minimum	Best Estimate	Maximum		
MAIN EDITING MENU (Continued)							
Array Data Input (cont.) Variable Distribution	**Aquatic Food Ingestion**						
	- Use (0/1 = F/T)	1	NA	NA	NA	NA	Input #5
	Fish	0	NA	NA	NA	NA	Input #5
	Mollusc	0	NA	NA	NA	NA	Input #5
	Crustacea	0	NA	NA	NA	NA	Input #5
	Plants						
	- Transit Time (hr)	NA	--	0	--	Fixed	
	Fish	NA	--	0	--	Fixed	
	Mollusc	NA	--	0	--	Fixed	
	Crustacea	NA	--	0	--	Fixed	
	Plants						
	- Production (kg/y)	NA	--	0	--	Fixed	
	Fish	NA	--	0	--	Fixed	
	Mollusc	NA	--	0	--	Fixed	
	Crustacea	NA	--	0	--	Fixed	Parameters
	Plants						not used
	- Holdup (days)	NA	--	0	--	Fixed	
	Fish	NA	--	0	--	Fixed	
	Mollusc	NA	--	0	--	Fixed	
	Crustacea	NA	--	0	--	Fixed	
	Plants						
	- Consumption (kg/yr)	NA	6.17E-8	0.47	8.79	Loguniform	Input #5
	Fish	NA	--	0	--		
	Mollusc	NA	--	0	--		
	Crustacea	NA	--	0	--		
	Plants						

Table 8. GENII-S Menu-Accessible Input Parameters for the Current Climate (Continued)

Menu(s)	Option/-Parameter, Unit	Selection	Values			Distribution	Reference[a]/ Comments
			Minimum	Best Estimate	Maximum		
MAIN EDITING MENU (Continued)							
Array Data Input (cont.) Variable Distribution	**Terrestrial Food Ingestion**						
	- Use (0/1 = F/T)						
	Leafy Vegetables	1	NA	NA	NA	NA	Input #5
	Root Vegetables	1	NA	NA	NA	NA	Input #5
	Fruit	1	NA	NA	NA	NA	Input #5
	Grain	1	NA	NA	NA	NA	Input #5
	- Growing Time, days						
	Leafy Vegetables	NA	45	57	68	Uniform	Attachment III
	Root Vegetables	NA	70	84	98	Uniform	Attachment III
	Fruit	NA	88	136	184	Uniform	Attachment III
	Grain	NA	--	244	--	Fixed	Attachment III
	- Water Source Flag (0-2)						
	Leafy Vegetables	1	NA	NA	NA	NA	|
	Root Vegetables	1	NA	NA	NA	NA	| Contaminated
	Fruit	1	NA	NA	NA	NA	| water
	Grain	1	NA	NA	NA	NA	|
	- Irrigation Rate, in/yr						
	Leafy Vegetables	NA	28	36	43	Uniform	Attachment III
	Root Vegetables	NA	47	50	52	Uniform	Attachment III
	Fruit	NA	30	38	45	Uniform	Attachment III
	Grain	NA	--	56	--	Fixed	Attachment III
	- Irrigation Time, mo/yr						
	Leafy Vegetables	NA	3.0	3.8	4.9	Uniform	Attachment III
	Root Vegetables	NA	3.2	3.9	4.6	Uniform	Attachment III
	Fruit	NA	2.9	4.5	6.0	Uniform	Attachment III
	Grain	NA	--	8.0	--	Fixed	Attachment III
	- Crop Yield, kg/m^2						
	Leafy Vegetables	NA	4.4	4.6	4.8	Uniform	Attachment III
	Root Vegetables	NA	4.1	7.0	9.8	Uniform	Attachment III
	Fruit	NA	1.6	2.0	2.3	Uniform	Attachment III
	Grain	NA	0.3	0.5	0.7	Uniform	Attachment III

Table 8. GENII-S Menu-Accessible Input Parameters for the Current Climate (Continued)

Menu(s)	Option/-Parameter, Unit	Selection	Values: Minimum	Values: Best Estimate	Values: Maximum	Distribution	Reference[a]/ Comments
MAIN EDITING MENU (Continued)							
Array Data Input (cont.) Variable Distribution	**Terrestrial Food Ingestion (Continued)**						
	- Production, kg/yr						
	Leafy Vegetables	NA	--	0	--	Fixed	Parameter not used
	Root Vegetables	NA	--	0	--	Fixed	
	Fruit	NA	--	0	--	Fixed	
	Grain	NA	--	0	--	Fixed	
	- Holdup, days						
	Leafy Vegetables	NA	--	1	--	Fixed	Input #4
	Root Vegetables	NA	--	14	--	Fixed	Input #4
	Fruit	NA	--	14	--	Fixed	Input #4
	Grain	NA	--	14	--	Fixed	Input #4
	- Consumption Rate, kg/yr						
	Leafy Vegetables	NA	1.16	15.14	59.68	Loguniform	Input #5
	Root Vegetables	NA	0.65	7.81	29.86	Loguniform	Input #5
	Fruit	NA	0.18	15.57	97.69	Loguniform	Input #5
	Grain	NA	8.79×10^{-11}	0.48	12.33	Loguniform	Input #5
	Animal Product Consumption						
	- Use (0/1 = F/T)						
	Beef	1	NA	NA	NA	NA	Input #5
	Poultry	1	NA	NA	NA	NA	Input #5
	Milk	1	NA	NA	NA	NA	Input #5
	Eggs	1	NA	NA	NA	NA	Input #5
	- Consumption Rate, kg/yr						
	Beef	NA	7.34×10^{-7}	2.93	53.11	Fixed	Input #5
	Poultry	NA	2.22×10^{-5}	0.80	10.50	Fixed	Input #5
	Milk	NA	2.91×10^{-9}	4.14	100.36	Fixed	Input #5
	Eggs	NA	0.23	6.68	33.34	Fixed	Input #5
	- Holdup, days						
	Beef	NA	--	20	--	Fixed	Input #4
	Poultry	NA	--	1	--	Fixed	Input #4
	Milk	NA	--	1	--	Fixed	Input #4
	Eggs	NA	--	1	--	Fixed	Input #4

Table 8. GENII-S Menu-Accessible Input Parameters for the Current Climate (Continued)

Menu(s)	Option/-Parameter, Unit	Selection	Values: Minimum	Values: Best Estimate	Values: Maximum	Distribution	Reference[a]/ Comments
MAIN EDITING MENU (Continued)							
Array Data Input (cont.) Variable Distribution	**Animal Product Consumption**						
	- Production, kg/yr						
	Beef	NA	--	0	--	Fixed	Parameter not used
	Poultry	NA	--	0	--	Fixed	Parameter not used
	Milk	NA	--	0	--	Fixed	Parameter not used
	Eggs	NA	--	0	--	Fixed	Parameter not used
	- Contaminated Water Fraction						
	Beef	NA	--	1	--	Fixed	Input #4
	Poultry	NA	--	1	--	Fixed	Input #4
	Milk	NA	--	1	--	Fixed	Input #4
	Eggs	NA	--	1	--	Fixed	Input #4
	Animal Products (Stored Feed Data)						
	- Dietary Fraction						
	Beef	NA	--	0	--	Fixed	Input #4
	Poultry (corn)	NA	--	1	--	Fixed	Input #4
	Milk	NA	--	0	--	Fixed	Input #4
	Eggs (corn)	NA	--	1	--	Fixed	Input #4
	- Growing Time, days						
	Beef	NA	--	0	--	Fixed	Input #4
	Poultry (corn)	NA	--	140	--	Fixed	Attachment III
	Milk	NA	--	0	--	Fixed	Input #4
	Eggs (corn)	NA	--	140	--	Fixed	Attachment III
	- Water Source Flag						
	Beef	0	NA	NA	NA	NA	Input #4
	Poultry (corn)	1	NA	NA	NA	NA	Input #4
	Milk	0	NA	NA	NA	NA	Input #4
	Eggs (corn)	1	NA	NA	NA	NA	Input #4
	- Irrigation Rate, in/yr						
	Beef	NA	--	0	--	Fixed	Input #4
	Poultry (corn)	NA	--	75	--	Fixed	Attachment III
	Milk	NA	--	0	--	Fixed	Input #4
	Eggs (corn)	NA	--	75	--	Fixed	Attachment III
	- Irrigation Time, mo/yr						
	Beef	NA	--	0	--	Fixed	Input #4
	Poultry (corn)	NA	--	4.6	--	Fixed	Attachment III
	Milk	NA	--	0	--	Fixed	Input #4
	Eggs (corn)	NA	--	4.6	--	Fixed	Attachment III

Table 8. GENII-S Menu-Accessible Input Parameters for the Current Climate (Continued)

Menu(s)	Option/-Parameter, Unit	Selection	Values			Distribution	Reference[a]/ Comments
			Minimum	Best Estimate	Maximum		
Array Data Input (cont.) Variable Distribution	**Animal Products (Stored Feed Data) cont.**						
	- Feed Yield, kg/m^2						
	Beef	NA	-	0	--	Fixed	Input #4
	Poultry (corn)	NA	0.6	0.7	0.8	Uniform	Attachment III
	Milk	NA	--	0	--	Fixed	Input #4
	Eggs (corn)	NA	0.6	0.7	0.8	Uniform	Attachment III
	- Storage, days						
	Beef	NA	--	0	--	Fixed	Input #4
	Poultry (corn)	NA	--	14	--	Fixed	Input #4
	Milk	NA	--	0	--	Fixed	Input #4
	Eggs (corn)	NA	--	14	--	Fixed	Input #4
	Animal Products (Fresh Forage Data)						
	- Dietary Fraction						
	Beef (alfalfa)	NA	--	1	--	Fixed	Input #4
	Milk (alfalfa)	NA	--	1	--	Fixed	Input #4
	- Grow Time, days						
	Beef (alfalfa)	NA	46	47	135	Triangular	Attachment III
	Milk (alfalfa)	NA	46	47	135	Triangular	Attachment III
	- H2O Source Flag						
	Beef (alfalfa)	0	NA	NA	NA	NA	Groundwater
	Milk (alfalfa)	0	NA	NA	NA	NA	
	- Irrigation Rate, in/yr						
	Beef (alfalfa)	NA	--	95	--	Fixed	Attachment III
	Milk (alfalfa)	NA	--	95	--	Fixed	Attachment III
	- Irrigation Time, mo/yr						
	Beef (alfalfa)	NA	--	12	--	Fixed	Attachment III
	Milk (alfalfa)	NA	--	12	--	Fixed	Attachment III
	- Feed Yield, kg/m^2						
	Beef (alfalfa)	NA	1.0	1.1	1.2	Uniform	Attachment III
	Milk (alfalfa)	NA	1.0	1.1	1.2	Uniform	Attachment III
	- Storage, days						
	Beef (alfalfa)	NA	--	0	--	Fixed	Input #4
	Milk (alfalfa)	NA	--	0	--	Fixed	Input #4

Table 8. GENII-S Menu-Accessible Input Parameters for the Current Climate (Continued)

Menu(s)	Option/-Parameter, Unit	Selection	Values			Distribution	Reference[a]/ 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	
	- Surface Soil, pCi/m^2	NA	--	1	--	Fixed	
	- Deep Soil, pCi/kg	NA	--	0	--	Fixed	
	- Ground Water, pCi/l	NA	--	0	--	Fixed	
	- Surface Water, pCi/l	NA	--	1	--	Fixed	Section 5

NOTES: [a] Input numbers identified in Reference/Comment column refer to input numbers in column 1 of Table 1.
[b] NA as an entry means that a given selection/option/value does not appear in GENII-S.

6.5.4.2 Modeling Output

The outcome of the BDCF statistical calculation consists of 150 results of individual model realizations for each radionuclide for every irrigation period. The corresponding means and standard deviations are listed in Table 9 for the first and the sixth irrigation period. The ratio of BDCFs for these two periods allows determination of the degree of radionuclide buildup in soil represented by the buildup factor. The buildup factor is a ratio of the mean value of period 6 (longest) to period 1 (no prior irrigation). Buildup factors are also listed in Table 9. For those radionuclides whose buildup factor was greater than 1.15, BDCFs were also calculated for the remaining irrigation periods, i.e., periods 2 through 5. Their means and standard deviations are listed in Table 10.

Table 9. Summary Results of Biosphere Dose Conversion Factor Modeling for the Current Climate for First and Sixth Irrigation Periods, and the Corresponding Buildup Factors

Radionuclide	BDCF, 1st Irrigation Period rem/y per pCi/L		BDCF, 6th Irrigation Period rem/y per pCi/L			Buildup Factor [c]
	Mean [a]	Standard Deviation [a]	Time, y [b]	Mean [a]	Standard Deviation [a]	
^{14}C	5.19E-5	1.40E-4	14	5.19E-5	1.40E-4	1.00
^{63}Ni	7.22E-7	4.20E-7	208	1.16E-6	1.04E-6	1.61
^{90}Sr	1.55E-4	8.21E-5	26	2.57E-4	2.57E-4	1.66
^{99}Tc	3.34E-6	2.26E-6	5	3.39E-6	2.34E-6	1.01
^{129}I	3.10E-4	1.62E-4	5	3.11E-4	1.62E-4	1.00
^{137}Cs	1.26E-4	1.47E-4	71	4.54E-4	1.72E-4	3.60
^{210}Pb	6.67E-3	4.02E-3	53	6.86E-3	4.08E-3	1.03
^{226}Ra	1.10E-3	5.61E-4	1005	1.81E-2	8.36E-3	16.5
^{227}Ac	1.54E-2	8.07E-3	54	1.64E-2	8.09E-3	1.06
^{229}Th	4.01E-3	2.14E-3	5848	4.91E-2	1.13E-2	12.2
^{230}Th	6.05E-4	3.23E-4	8108	3.97E-2	1.64E-2	65.6
^{231}Pa	1.15E-2	6.05E-3	1432	4.55E-2	1.10E-2	3.96
^{232}U	1.45E-3	7.49E-4	62	2.34E-3	7.87E-4	1.61
^{233}U	3.19E-4	1.66E-4	93	3.62E-4	1.68E-4	1.13
^{234}U	3.13E-4	1.63E-4	93	3.52E-4	1.65E-4	1.12
^{236}U	2.97E-4	1.54E-4	93	3.33E-4	1.56E-4	1.12
^{238}U	2.86E-4	1.49E-4	93	3.36E-4	1.51E-4	1.17
^{237}Np	5.76E-3	3.02E-3	14	5.84E-3	3.04E-3	1.01
^{238}Pu	3.50E-3	1.84E-3	196	3.73E-3	1.84E-3	1.07
^{239}Pu	3.88E-3	2.04E-3	1423	5.78E-3	2.14E-3	1.49
^{240}Pu	3.88E-3	2.04E-3	1341	5.66E-3	2.12E-3	1.46
^{242}Pu	3.61E-3	1.90E-3	1455	5.41E-3	1.99E-3	1.50
^{241}Am	3.96E-3	2.08E-3	915	5.28E-3	2.16E-3	1.33
^{243}Am	3.95E-3	2.08E-3	3983	1.44E-2	3.19E-3	3.65

NOTES: [a] The values were taken from GENII-S runs (see Attachment IV).
[b] Time for 6th irrigation period from Table 3.
[c] Ratio of mean BDCF for 6th irrigation period to mean BDCF for 1st (no prior irrigation) period.

Table 10. Summary Results of Biosphere Dose Conversion Factor Modeling for the Current Climate for Radionuclides with Buildup Factor Greater than 1.15

Radionuclide	Biosphere Dose Conversion Factor for Prior Irrigation Periods rem/y per pCi/L											
	1		2		3		4		5		6	
	Mean	STD	Mean	STD	Mean	STD	Mean	STD	Mean	STD	Mean	STD
^{63}Ni	7.22E-7	4.20E-7	8.10E-7	4.98E-7	8.98E-7	6.14E-7	9.84E-7	7.47E-7	1.07E-6	8.88E-7	1.16E-6	1.04E-6
^{90}Sr	15.5E-5	8.21E-5	1.78E-4	1.08E-4	1.97E-4	1.39E-4	2.16E-4	1.75E-4	2.38E-4	2.17E-4	2.57E-4	2.57E-4
^{137}Cs	1.26E-4	1.47E-4	1.90E-4	1.49E-4	2.57E-4	1.53E-4	3.21E-4	1.58E-4	3.86E-4	1.64E-4	4.54E-4	1.72E-4
^{226}Ra	1.10E-3	5.61E-4	4.38E-3	1.53E-3	7.86E-3	3.17E-3	1.13E-2	4.90E-3	1.48E-2	6.58E-3	1.81E-2	8.36E-3
^{229}Th	4.01E-3	2.14E-3	1.30E-2	3.19E-3	2.20E-2	5.02E-3	3.10E-2	7.03E-3	4.01E-2	9.20E-3	4.91E-2	1.13E-2
^{230}Th	6.05E-4	3.23E-4	5.19E-3	1.76E-3	1.30E-2	5.05E-3	2.18E-2	8.71E-3	3.07E-2	1.25E-2	3.97E-2	1.64E-2
^{231}Pa	1.15E-2	6.05E-3	1.73E-2	6.38E-3	2.43E-2	7.17E-3	3.13E-2	8.23E-3	3.83E-2	9.54E-3	4.55E-2	1.10E-2
^{232}U	1.45E-3	7.49E-4	1.58E-3	7.52E-4	1.77E-3	7.59E-4	1.96E-3	7.65E-4	2.15E-3	7.75E-4	2.34E-3	7.87E-4
^{238}U	2.86E-4	1.48E-4	2.96E-4	1.49E-4	3.06E-4	1.50E-4	3.16E-4	1.50E-4	3.26E-4	1.51E-4	3.36E-4	1.51E-4
^{239}Pu	3.88E-3	2.04E-3	4.26E-3	2.06E-3	4.63E-3	2.07E-3	5.01E-3	2.09E-3	5.39E-3	2.11E-3	5.78E-3	2.14E-3
^{240}Pu	3.88E-3	2.04E-3	4.23E-3	2.05E-3	4.59E-3	2.06E-3	4.94E-3	2.08E-3	5.29E-3	2.10E-3	5.66E-3	2.12E-3
^{242}Pu	3.61E-3	1.90E-3	3.97E-3	1.91E-3	4.33E-3	1.93E-3	4.69E-3	1.94E-3	5.05E-3	1.97E-3	5.41E-3	1.99E-3
^{241}Am	3.96E-3	2.08E-3	4.22E-3	2.10E-3	4.49E-3	2.11E-3	4.76E-3	2.12E-3	5.02E-3	2.14E-3	5.28E-3	2.16E-3
^{243}Am	3.95E-3	2.08E-3	6.03E-3	2.18E-3	8.10E-3	2.33E-3	1.02E-2	2.56E-3	1.23E-2	2.87E-3	1.44E-2	3.19E-3

Source: The values were taken from GENII-S runs (see Attachment IV).

The analysis of the model results indicates that for 10 radionuclides BDCFs increase only very insignificantly with the prior irrigation time (buildup factor is less than 1.15). Among these radionuclides were Technetium-99, Iodine-129, and Neptunium-237, which are considered the key radionuclides in the TSPA-SR analysis (CRWMS M&O 2000b, Figure 4.1-6). Buildup factor for the remaining 14 radionuclides ranged from 1.17 (Uranium-238) to 65.6 (Thorium-230). However, for radionuclides that show significant buildup, BDCFs for the sixth irrigation period were calculated assuming thousands of years of continuous prior irrigation on the same plot of land, although this is not a typical agricultural practice. In addition, radionuclide removal by soil erosion has not been factored in because this mechanism is addressed later in the abstraction phase of the biosphere modeling.

6.5.5 Biosphere Dose Conversion Factors for the Evolved Climate

To model the effect of the future climate variations on biosphere, BDCFs were developed for the climatic conditions corresponding to the upper bound of the glacial transition climate, as described in Section 6.3. An average member of the critical group represented the receptor of interest, as for the case of the modern climate. Also, following the same calculation technique as the one used for the current climate, BDCFs were calculated in a series of GENII-S simulations for each of the 24 radionuclides. Each simulation resulted in 150 model realizations.

This section contains a listing of the modeling input data and the summary of the model output followed by the discussion of the radionuclide buildup in soil caused by irrigation with contaminated water.

6.5.5.1 Input Data

The content of the input files, the same for both the current and the evolved climates, is presented in Section 6.4.3. The set of input values for the evolved climate, entered using GENII-S menu-driven interface, is shown in Table 11. The values and selections in the table are listed in the format that they are entered in GENII-S.

Table 11. GENII-S Menu-Accessible Input Parameters for the Evolved Climate

Menu(s)	Option/-Parameter, Unit	Selection	Values: Minimum	Values: Best Estimate	Values: Maximum	Distribution	Reference[a]/ Comments
PRE-GENII							
Edit Flags and Options	Scenario Options						
	- Near-Field Scenario	Y	NA [b]	NA	NA	NA	Near-field scenario
	- Population Dose	N	NA	NA	NA	NA	
	- Acute Release	N	NA	NA	NA	NA	
	Transport Options						No radionuclide transport
	- Air Transport	N	NA	NA	NA	NA	
	- 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						Pathway selection
	- External Finite Plume	N	NA	NA	NA	NA	
	- 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	Y	NA	NA	NA	NA	
	- Aquatic Food Ingestion	Y	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						Output selection
	- Both Committed and Cumulative	N	NA	NA	NA	NA	
	- EDE by Nuclide	N	NA	NA	NA	NA	
	- EDE by Pathway	N	NA	NA	NA	NA	
	Run Options						Unit selection, Run selection, Intake duration
	- Inventory Unit Index (1-5)	1, pCi	NA	NA	NA	NA	
	- 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	
Select Nuclides	Radionuclide selection	Y/N	-	-	-	-	Section 6.1

Table 11. GENII-S Menu-Accessible Input Parameters for the Evolved Climate (Continued)

Menu(s)	Option/-Parameter, Unit	Selection	Values: Minimum	Values: Best Estimate	Values: Maximum	Distribution	Reference[a]/ Comments
PRE-GENII (Continued)							
Select Statistical Output	- **Statistical Committed Dose Summary**	Y	NA	NA	NA	NA	Output Selection
	- Statistical Committed Nuclide Dose	N	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	
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)	150	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 #2
	- Animal Uptake Scale Factor, (-)	NA	0.117	--	8.51	Lognormal	Input #2
	- Human Dose Factor Scale Factor, (-)	NA	--	1	--	Fixed	Input #6
	- Dose Commitment Period, yr	NA	NA	50	NA	NA	
	- Surface Soil Depth, cm	NA	--	15	--	Fixed	Input #1
	- Surface Soil Density, kg/m^2	NA	--	225	--	Fixed	Input #1
	- Deep Soil Density, kg/m^3	NA	--	1500	--	Fixed	Input #1
	- Roots in Upper Soil, fraction	NA	--	1	--	Fixed	Input #1
	- Roots in Deep Soil, fraction	NA	--	0	--	Fixed	Input #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	Table 3
	Biotic Trans./Near Field Data Not used	—	—	—	—	—	—

Table 11. GENII-S Menu-Accessible Input Parameters for the Evolved Climate (Continued)

Menu(s)	Option/-Parameter, Unit	Selection	Values			Distribution	Reference[a]/ Comments
			Minimum	Best Estimate	Maximum		
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	5793.5	6073.5	6353.5	Uniform	Input #3
	- Resuspension Model Flag (0-2)	1	NA	NA	NA	NA	Mass loading
	- Mass Loading, g/m^3	NA	3.8×10^{-5}	1.05×10^{-4}	1.73×10^{-4}	Normal	Input #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	2827	3387	3947	Uniform	Input #3
	- Home Irrigation Flag (0/1 = N/Y)	1	NA	NA	NA	NA	Contaminated
	- Irrigation Water Index (1-2)	1	NA	NA	NA	NA	water
	- Home Irrigation Rate, in/yr	NA	26	37	48	Uniform	Input #3
	- Home Irrigation Duration, mo/yr	NA	--	6	--	Fixed	Input #3
	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	1.7×10^{-10}	4.7×10^{-10}	7.7×10^{-10}	Loguniform	Input #1
	- Crop Deposition Velocity, m/s	NA	--	0.001	--	Fixed	Input #1
	- Crop Interception Fraction	NA	0.044	0.259	0.474	Normal	Input #4
	- Exported Food Dose (0/1 = N/Y)	0	NA	NA	NA	NA	Not used
	- Soil Ingestion Rate, mg/day	NA	--	50	--	Fixed	Input #1
	- Swim H2O Ingestion Rate, l/h	NA	--	0	--	Fixed	Not used
	- Population Ingesting Aquatic Food	0	NA	NA	NA	NA	Not used
	- Bioaccumulation Flag (0/1 = N/Y)	0	NA	NA	NA	NA	Not used
	- Population Drinking Contaminated Water	0	NA	NA	NA	NA	Whole population
	- Drink Water Source Index (0-3)	0	NA	NA	NA	NA	Groundwater
	- Drink Water Treated (0/1 = N/Y)	0	NA	NA	NA	NA	Input #4
	- Drink Water Holdup Time, days	NA	--	0	--	Fixed	Input #4
	- Drink Water Consumption, l/y	NA	0	752.85	1487.45	Uniform	Input #4

Table 11. GENII-S Menu-Accessible Input Parameters for the Evolved Climate (Continued)

Menu(s)	Option/-Parameter, Unit	Selection	Values			Distribution	Reference[a]/ Comments
			Minimum	Best Estimate	Maximum		
MAIN EDITING MENU (Continued)							
Array Data Input (cont.) Variable Distribution	**Aquatic Food Ingestion**						
	- Use (0/1 = F/T)						
	Fish	1	NA	NA	NA	NA	Input #5
	Mollusc	0	NA	NA	NA	NA	Input #5
	Crustacea	0	NA	NA	NA	NA	Input #5
	Plants	0	NA	NA	NA	NA	Input #5
	- Transit Time (hr)						Parameters not used
	Fish	NA	--	0	--	Fixed	
	Mollusc	NA	--	0	--	Fixed	
	Crustacea	NA	--	0	--	Fixed	
	Plants	NA	--	0	--	Fixed	
	- Production (kg/y)						
	Fish	NA	--	0	--	Fixed	
	Mollusc	NA	--	0	--	Fixed	
	Crustacea	NA	--	0	--	Fixed	
	Plants	NA	--	0	--	Fixed	
	- Holdup (days)						
	Fish	NA	--	0	--	Fixed	
	Mollusc	NA	--	0	--	Fixed	
	Crustacea	NA	--	0	--	Fixed	
	Plants	NA	--	0	--	Fixed	
	- Consumption (kg/yr)						
	Fish	NA	6.17E-8	0.47	8.79	Loguniform	Input #5
	Mollusc	NA	--	0	--		
	Crustacea	NA	--	0	--		
	Plants	NA	--	0	--		

Table 11. GENII-S Menu-Accessible Input Parameters for the Evolved Climate (Continued)

Menu(s)	Option/-Parameter, Unit	Selection	Values			Distribution	Reference[a]/ Comments
			Minimum	Best Estimate	Maximum		
MAIN EDITING MENU (Continued)							
Array Data Input (cont.) Variable Distribution	**Terrestrial Food Ingestion**						
	- Use (0/1 = F/T)						
	Leafy Vegetables	1	NA	NA	NA	NA	Input #5
	Root Vegetables	1	NA	NA	NA	NA	Input #5
	Fruit	1	NA	NA	NA	NA	Input #5
	Grain	1	NA	NA	NA	NA	Input #5
	- Growing Time, days						
	Leafy Vegetables	NA	50	73	95	Uniform	Attachment III
	Root Vegetables	NA	75	122	168	Uniform	Attachment III
	Fruit	NA	95	140	184	Uniform	Attachment III
	Grain	NA	--	191	--	Fixed	Attachment III
	- Water Source Flag (0-2)						
	Leafy Vegetables	1	NA	NA	NA	NA	|
	Root Vegetables	1	NA	NA	NA	NA	| Contaminated
	Fruit	1	NA	NA	NA	NA	| water
	Grain	1	NA	NA	NA	NA	|
	- Irrigation Rate, in/yr						
	Leafy Vegetables	NA	25	34	43	Uniform	Attachment III
	Root Vegetables	NA	39	40	41	Uniform	Attachment III
	Fruit	NA	26	28	30	Uniform	Attachment III
	Grain	NA	--	34	--	Fixed	Attachment III
	- Irrigation Time, mo/yr						
	Leafy Vegetables	NA	3.3	4.8	6.2	Uniform	Attachment III
	Root Vegetables	NA	4.9	5.2	5.5	Uniform	Attachment III
	Fruit	NA	3.1	4.6	6.0	Uniform	Attachment III
	Grain	NA	--	6.2	--	Fixed	Attachment III
	- Crop Yield, kg/m^2						
	Leafy Vegetables	NA	4.4	4.6	4.8	Uniform	Attachment III
	Root Vegetables	NA	4.1	7.0	9.8	Uniform	Attachment III
	Fruit	NA	1.6	2.0	2.3	Uniform	Attachment III
	Grain	NA	0.3	0.5	0.7	Uniform	Attachment III

Table 11. GENII-S Menu-Accessible Input Parameters for the Evolved Climate (Continued)

Menu(s)	Option/-Parameter, Unit	Selection	Values			Distribution	Reference[a]/ Comments
			Minimum	Best Estimate	Maximum		
MAIN EDITING MENU (Continued)							
Array Data Input (cont.) Variable Distribution	**Terrestrial Food Ingestion (cont.)**						
	- Production, kg/yr						
	Leafy Vegetables	NA	--	0	--	Fixed	Parameter not used
	Root Vegetables	NA	--	0	--	Fixed	
	Fruit	NA	--	0	--	Fixed	
	Grain	NA	--	0	--	Fixed	
	- Holdup, days						
	Leafy Vegetables	NA	--	1	--	Fixed	Input #4
	Root Vegetables	NA	--	14	--	Fixed	Input #4
	Fruit	NA	--	14	--	Fixed	Input #4
	Grain	NA	--	14	--	Fixed	Input #4
	- Consumption Rate, kg/yr						
	Leafy Vegetables	NA	1.16	15.14	59.68	Loguniform	Input #5
	Root Vegetables	NA	0.65	7.81	29.86	Loguniform	Input #5
	Fruit	NA	0.18	15.57	97.69	Loguniform	Input #5
	Grain	NA	8.79×10^{-11}	0.48	12.33	Loguniform	Input #5
	Animal Product Consumption						
	- Use (0/1 = F/T)						
	Beef	1	NA	NA	NA	NA	Input #5
	Poultry	1	NA	NA	NA	NA	Input #5
	Milk	1	NA	NA	NA	NA	Input #5
	Eggs	1	NA	NA	NA	NA	Input #5
	- Consumption Rate, kg/yr						
	Beef	NA	7.34×10^{-7}	2.93	53.11	Fixed	Input #5
	Poultry	NA	2.22×10^{-5}	0.80	10.50	Fixed	Input #5
	Milk	NA	2.91×10^{-9}	4.14	100.36	Fixed	Input #5
	Eggs	NA	0.23	6.68	33.34	Fixed	Input #5
	- Holdup, days						
	Beef	NA	--	20	--	Fixed	Input #4
	Poultry	NA	--	1	--	Fixed	Input #4
	Milk	NA	--	1	--	Fixed	Input #4
	Eggs	NA	--	1	--	Fixed	Input #4

Table 11. GENII-S Menu-Accessible Input Parameters for the Evolved Climate (Continued)

Menu(s)	Option/-Parameter, Unit	Selection	Values			Distribution	Reference[a]/ Comments
			Minimum	Best Estimate	Maximum		
MAIN EDITING MENU (Continued)							
Array Data Input (cont.) Variable Distribution	**Animal Product Consumption**						
	- Production, kg/yr						
	Beef	NA	--	0	--	Fixed	Parameter not used
	Poultry	NA	--	0	--	Fixed	Parameter not used
	Milk	NA	--	0	--	Fixed	Parameter not used
	Eggs	NA	--	0	--	Fixed	Parameter not used
	- Contaminated Water Fraction						
	Beef	NA	--	1	--	Fixed	Input #4
	Poultry	NA	--	1	--	Fixed	Input #4
	Milk	NA	--	1	--	Fixed	Input #4
	Eggs	NA	--	1	--	Fixed	Input #4
	Animal Products (Stored Feed Data)						
	- Dietary Fraction						
	Beef	NA	--	0	--	Fixed	Input #4
	Poultry (corn)	NA	--	1	--	Fixed	Input #4
	Milk	NA	--	0	--	Fixed	Input #4
	Eggs (corn)	NA	--	1	--	Fixed	Input #4
	- Growing Time, days						
	Beef	NA	--	0	--	Fixed	Input #4
	Poultry (corn)	NA	--	179	--	Fixed	Attachment III
	Milk	NA	--	0	--	Fixed	Input #4
	Eggs (corn)	NA	--	179	--	Fixed	Attachment III
	- Water Source Flag						
	Beef	0	NA	NA	NA	NA	Input #4
	Poultry (corn)	1	NA	NA	NA	NA	Input #4
	Milk	0	NA	NA	NA	NA	Input #4
	Eggs (corn)	1	NA	NA	NA	NA	Input #4
	- Irrigation Rate, in/yr						
	Beef	NA	--	0	--	Fixed	Input #4
	Poultry (corn)	NA	--	39	--	Fixed	Attachment III
	Milk	NA	--	0	--	Fixed	Input #4
	Eggs (corn)	NA	--	39	--	Fixed	Attachment III
	- Irrigation Time, mo/yr						
	Beef	NA	--	0	--	Fixed	Input #4
	Poultry (corn)	NA	--	5.7	--	Fixed	Attachment III
	Milk	NA	--	0	--	Fixed	Input #4
	Eggs (corn)	NA	--	5.7	--	Fixed	Attachment III

Table 11. GENII-S Menu-Accessible Input Parameters for the Evolved Climate (Continued)

Menu(s)	Option/-Parameter, Unit	Selection	Values			Distribution	Reference[a]/ Comments
			Minimum	Best Estimate	Maximum		
MAIN EDITING MENU (Continued)							
Array Data Input (cont.) Variable Distribution	**Animal Products (Stored Feed Data) cont.**						
	- Feed Yield, kg/m^2	NA	-	0	--	Fixed	Input #4
	Beef	NA	0.6	0.7	0.8	Uniform	Attachment III
	Poultry (corn)	NA	--	0	--	Fixed	Input #4
	Milk	NA	0.6	0.7	0.8	Uniform	Attachment III
	Eggs (corn)						
	- Storage, days	NA	--	0	--	Fixed	Input #4
	Beef	NA	--	14	--	Fixed	Input #4
	Poultry (corn)	NA	--	0	--	Fixed	Input #4
	Milk	NA	--	14	--	Fixed	Input #4
	Eggs (corn)						
	Animal Products (Fresh Forage Data)						
	- Dietary Fraction						
	Beef (alfalfa)	NA	--	1 [c]	--	Fixed	Input #4
	Milk (alfalfa)	NA	--	1 [c]	--	Fixed	Input #4
	- Grow Time, days						
	Beef (alfalfa)	NA	--	71	--	Fixed	Attachment III
	Milk (alfalfa)	NA	--	71	--	Fixed	Attachment III
	- H2O Source Flag						
	Beef (alfalfa)	0	NA	NA	NA	NA	Groundwater
	Milk (alfalfa)	0	NA	NA	NA	NA	
	- Irrigation Rate, in/yr						
	Beef (alfalfa)	NA	--	42	--	Fixed	Attachment III
	Milk (alfalfa)	NA	--	42	--	Fixed	Attachment III
	- Irrigation Time, mo/yr						
	Beef (alfalfa)	NA	--	7.0	--	Fixed	Attachment III
	Milk (alfalfa)	NA	--	7.0	--	Fixed	Attachment III
	- Feed Yield, kg/m^2						
	Beef (alfalfa)	NA	--	0.5	--	Fixed	Attachment III
	Milk (alfalfa)	NA	--	0.5	--	Fixed	Attachment III
	- Storage, days						
	Beef (alfalfa)	NA	--	0	--	Fixed	Input #4
	Milk (alfalfa)	NA	--	0	--	Fixed	Input #4

Table 11. GENII-S Menu-Accessible Input Parameters for the Evolved Climate (Continued)

Menu(s)	Option/-Parameter, Unit	Selection	Values			Distribution	Reference[a]/ 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	
	- Surface Soil, pCi/m^2	NA	--	1	--	Fixed	
	- Deep Soil, pCi/kg	NA	--	0	--	Fixed	
	- Ground Water, pCi/l	NA	--	0	--	Fixed	
	- Surface Water, pCi/l	NA	--	1	--	Fixed	Section 5

NOTES: [a] Input numbers identified in Reference/Comment column refer to input numbers in column 1 of Table 1.

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

[c] Dietary fraction for fresh forage equal to 1 means that cattle is sustained year-round on fresh forage even though the weather conditions for the glacial transition climate may not permit it. However, this assumption is conservative and it simplifies calculations

6.5.5.2 Modeling Output

The outcome of the BDCF statistical calculation consists of 150 results of individual model realizations for each radionuclide for every irrigation period. The corresponding means and standard deviations for the evolved climate are listed in Table 12 for the first and the sixth irrigation period. To evaluate the degree of radionuclide buildup in soil, the buildup factors were calculated for each radionuclide. The buildup factor is a ratio of the mean value of period 6 (longest) to period 1 (no prior irrigation). Buildup factors are listed in Table 12. For those radionuclides whose buildup factor was greater than 1.15, BDCFs were also calculated for the remaining irrigation periods, i.e., periods 2 through 5. Their means and standard deviations are listed in Table 13.

Table 12. Summary Results of Biosphere Dose Conversion Factor Modeling for the Evolved Climate for the First and Sixth Irrigation Periods and their Corresponding Buildup Factors

Radionuclide	BDCF, 1st Irrigation Period rem/y per pCi/L		BDCF, 6th Irrigation Period rem/y per pCi/L			Buildup Factor [c]
	Mean [a]	Standard Deviation [a]	Time, y [b]	Mean [a]	Standard Deviation [a]	
^{14}C	5.11E-5	1.41E-4	14	5.11E-5	1.41E-4	1.00
^{63}Ni	6.60E-7	3.67E-7	208	9.72E-7	7.63E-7	1.47
^{90}Sr	1.41E-4	7.36E-5	26	2.23E-4	2.15E-4	1.58
^{99}Tc	3.00E-6	1.89E-6	5	2.99E-6	1.95E-6	1.00
^{129}I	2.81E-4	1.46E-4	5	2.82E-4	1.46E-4	1.00
^{137}Cs	1.13E-4	1.43E-4	71	2.81E-4	1.52E-4	2.49
^{210}Pb	6.24E-3	3.84E-3	53	6.38E-3	3.87E-3	1.02
^{226}Ra	1.01E-3	5.23E-4	1005	1.08E-2	6.88E-3	10.7
^{227}Ac	1.43E-2	7.55E-3	54	1.49E-2	7.56E-3	1.04
^{229}Th	3.74E-3	2.01E-3	5848	2.71E-2	6.57E-3	7.25
^{230}Th	5.66E-4	3.03E-4	8108	2.25E-2	1.35E-2	39.8
^{231}Pa	1.07E-2	5.66E-3	1432	2.84E-2	7.69E-3	2.65
^{232}U	1.34E-3	6.99E-4	62	1.80E-3	7.11E-4	1.34
^{233}U	2.96E-4	1.55E-4	93	3.19E-4	1.55E-4	1.08
^{234}U	2.90E-4	1.52E-4	93	3.12E-4	1.52E-4	1.08
^{236}U	2.75E-4	1.44E-4	93	2.95E-4	1.44E-4	1.07
^{238}U	2.65E-4	1.39E-4	93	2.92E-4	1.39E-4	1.10
^{237}Np	5.37E-3	2.82E-3	14	5.42E-3	2.82E-3	1.01
^{238}Pu	3.27E-3	1.72E-3	196	3.38E-3	1.72E-3	1.03
^{239}Pu	3.63E-3	1.91E-3	1423	4.59E-3	1.94E-3	1.26
^{240}Pu	3.62E-3	1.91E-3	1341	4.53E-3	1.93E-3	1.25
^{242}Pu	3.37E-3	1.78E-3	1455	4.29E-3	1.80E-3	1.27
^{241}Am	3.69E-3	1.95E-3	915	4.39E-3	1.98E-3	1.19
^{243}Am	3.69E-3	1.94E-3	3983	9.05E-3	2.38E-3	2.45

NOTES: [a] The values were taken from GENII-S runs (see Attachment IV).
[b] Time for 6th irrigation period from Table 3
[c] Ratio of mean BDCF for 6th irrigation period to mean BDCF for 1st (no prior irrigation) period

Table 13. Summary Results of Biosphere Dose Conversion Factor Modeling for the Evolved Climate for Radionuclides with Buildup Factor Greater than 1.15

Radionuclide	Biosphere Dose Conversion Factors for Prior Irrigation Periods rem/y per pCi/L											
	1		2		3		4		5		6	
	Mean	STD	Mean	STD	Mean	STD	Mean	STD	Mean	STD	Mean	STD
^{63}Ni	6.60E-7	3.69E-7	7.22E-7	4.08E-7	7.85E-7	4.75E-7	8.47E-7	5.62E-7	9.10E-7	6.60E-7	9.72E-7	7.63E-7
^{90}Sr	1.41E-4	7.36E-5	1.60E-4	9.34E-5	1.75E-4	1.17E-4	1.90E-4	1.47E-4	2.07E-4	1.81E-4	2.23E-4	2.15E-4
^{137}Cs	1.13E-4	1.43E-4	1.46E-4	1.44E-4	1.80E-4	1.45E-4	2.13E-4	1.47E-4	2.47E-4	1.49E-4	2.81E-4	1.52E-4
^{226}Ra	1.01E-3	5.23E-4	2.85E-3	1.28E-3	4.85E-3	2.65E-3	6.84E-3	4.05E-3	8.81E-3	5.41E-3	1.08E-2	6.88E-3
^{229}Th	3.74E-3	2.01E-3	8.39E-3	2.45E-3	1.30E-2	3.30E-3	1.77E-2	4.34E-3	2.24E-2	5.43E-3	2.71E-2	6.57E-3
^{230}Th	5.66E-4	3.03E-4	3.10E-3	1.40E-3	7.52E-3	2.66E-3	1.25E-2	7.11E-3	1.75E-2	1.03E-2	2.25E-2	1.35E-2
^{231}Pa	1.07E-2	5.66E-3	1.37E-2	5.79E-3	1.73E-2	6.07E-3	2.10E-2	6.52E-3	2.46E-2	7.05E-3	2.84E-2	7.69E-3
^{232}U	1.34E-3	6.99E-4	1.41E-7	7.00E-4	1.51E-3	7.02E-4	1.60E-3	7.05E-4	1.70E-3	7.07E-4	1.80E-3	7.11E-4
^{239}Pu	3.63E-3	1.91E-3	3.82E-3	1.91E-3	4.01E-3	1.92E-3	4.20E-3	1.92E-3	4.40E-3	1.93E-3	4.59E-3	1.94E-3
^{240}Pu	3.62E-3	1.91E-3	3.80E-3	1.91E-3	3.98E-3	1.92E-3	4.16E-3	1.92E-3	4.34E-3	1.93E-3	4.53E-3	1.93E-3
^{242}Pu	3.37E-3	1.78E-3	3.55E-3	1.78E-3	3.74E-3	1.78E-3	3.92E-3	1.79E-3	4.10E-3	1.80E-3	4.29E-3	1.80E-3
^{241}Am	3.69E-3	1.95E-3	3.83E-3	1.95E-3	3.97E-3	1.95E-3	4.11E-3	1.96E-3	4.25E-3	1.97E-3	4.39E-3	1.98E-3
^{243}Am	3.69E-3	1.94E-3	4.76E-3	1.98E-3	5.83E-3	2.04E-3	6.90E-3	2.23E-3	7.98E-3	2.26E-3	9.05E-3	2.38E-3

Source: The values were taken from GENII-S runs (see Attachment IV).

BDCFs for the evolved climate tend to increase with the duration of prior irrigation, similar to the BDCFs for the current climate. Out of the 24 radionuclides analyzed, 11 do not show significant radionuclide buildup in soil and their BDCFs remain relatively unchanged as the irrigation duration lengthens. The remaining 13 radionuclides show various degrees of buildup up to the maximum buildup factor value of 39.8 for ^{230}Th. Similar to the current climate case, radionuclides showing the greatest degree of buildup need very long times of continuous irrigation, on the order of thousands of years, to reach an equilibrium activity concentration in soil. However, if soil erosion is factored in, the equilibrium condition is obtained much sooner because of the additional removal mechanism and the corresponding equilibrium level of activity concentration in soil is much lower.

Comparison of the BDCFs for the current and the evolved climate is presented in Table 14 for the first and the sixth irrigation period. The BDCFs for the evolved climate are up to 10 percent lower than the BDCFs for the current climate, mainly due to the decreased irrigation rate. For the sixth irrigation period the difference is greater. The BDCFs for the evolved climate may be up to about 60 percent lower than the BDCFs for the current climate. The difference is the greatest for radionuclides such as isotopes of thorium that build up slowly in soil.

Table 14. Comparison of the BDCFs (in rem/yr per pCi/L) for the Current and Evolved Climate

Radionuclide	1st Irrigation Period			6th Irrigation Period		
	BDCF for Current Climate [a]	BDCF for Evolved Climate [b]	Evolved / Current BDCF ratio	BDCF for Current Climate [a]	BDCF for Evolved Climate [b]	Evolved / Current BDCF ratio
^{14}C	5.19E-05	5.11E-05	0.99	5.19E-05	5.11E-05	0.99
^{63}Ni	7.22E-07	6.60E-07	0.91	1.16E-06	9.72E-07	0.84
^{90}Sr	1.55E-04	1.41E-04	0.91	2.57E-04	2.23E-04	0.87
^{99}Tc	3.34E-06	3.00E-06	0.90	3.39E-06	2.99E-06	0.88
^{129}I	3.10E-04	2.81E-04	0.91	3.11E-04	2.82E-04	0.91
^{137}Cs	1.26E-04	1.13E-04	0.90	4.54E-04	2.81E-04	0.62
^{210}Pb	6.67E-03	6.24E-03	0.94	6.86E-03	6.38E-03	0.93
^{226}Ra	1.10E-03	1.01E-03	0.92	1.81E-02	1.08E-02	0.60
^{227}Ac	1.54E-02	1.43E-02	0.93	1.64E-02	1.49E-02	0.91
^{229}Th	4.01E-03	3.74E-03	0.93	4.91E-02	2.71E-02	0.55
^{230}Th	6.05E-04	5.66E-04	0.94	3.97E-02	2.25E-02	0.57
^{231}Pa	1.15E-02	1.07E-02	0.93	4.55E-02	2.84E-02	0.62
^{232}U	1.45E-03	1.34E-03	0.92	2.34E-03	1.80E-03	0.77
^{233}U	3.19E-04	2.96E-04	0.93	3.62E-04	3.19E-04	0.88
^{234}U	3.13E-04	2.90E-04	0.93	3.52E-04	3.12E-04	0.89
^{236}U	2.97E-04	2.75E-04	0.93	3.33E-04	2.95E-04	0.89
^{238}U	2.86E-04	2.65E-04	0.93	3.36E-04	2.92E-04	0.87
^{237}Np	5.76E-03	5.37E-03	0.93	5.84E-03	5.42E-03	0.93
^{238}Pu	3.50E-03	3.27E-03	0.93	3.73E-03	3.38E-03	0.91
^{239}Pu	3.88E-03	3.63E-03	0.94	5.78E-03	4.59E-03	0.79
^{240}Pu	3.88E-03	3.62E-03	0.93	5.66E-03	4.53E-03	0.80

Table 14. Comparison of the BDCFs (in rem/yr. per pCi/L) for the Current and Evolved Climate (Continued)

Radionuclide	1st Irrigation Period			6th Irrigation Period		
	BDCF for Current Climate [a]	BDCF for Evolved Climate [b]	Evolved / Current BDCF ratio	BDCF for Current Climate [a]	BDCF for Evolved Climate [b]	Evolved / Current BDCF ratio
^{242}Pu	3.61E-03	3.37E-03	0.93	5.41E-03	4.29E-03	0.79
^{241}Am	3.96E-03	3.69E-03	0.93	5.28E-03	4.39E-03	0.83
^{243}Am	3.95E-03	3.69E-03	0.93	1.44E-02	9.05E-03	0.63

NOTES: [a] Developed from Tables 8
[b] Developed from Table 11

6.6 UNCERTAINTY ANALYSIS

As with any modeling effort, uncertainty is inherent to the biosphere model. This means that the modeling results carry uncertainty resulting from both the uncertainties in the model itself as well as uncertainties in model parameters. Uncertainty analysis assists in interpreting the results of the BDCF development. The objective of the uncertainty analysis was to determine how the uncertainty in model parameters affects the model results.

6.6.1 Sources of Uncertainty

All assessments based on model calculations are inherently uncertain. This uncertainty arises from several factors, including: (1) the ability to adequately model the physical processes involved, (2) the degree to which exposure scenarios adequately represent individuals in the desired critical group, (3) the level of knowledge available to estimate appropriate values for parameters in the model, and (4) natural variability in various quantities used to estimate parameter values.

Uncertainty in the model refers to uncertainty regarding abstracting a real system (in this case the biosphere – its components and the radionuclide transport between the components of the biosphere, including humans) and its evolution into a form that can be mathematically modeled. Model uncertainty results from limitations in the ability to mathematically represent a complex system and its behavior. This uncertainty, in the case of complex systems, may be difficult to quantify in a rigorous numerical fashion. However, it is usually possible to bound the effects of model uncertainties by making credible assumptions about the selection of likely processes and their conceptual representations. The compartment model selected to represent radionuclide behavior in the biosphere is an example of bounding analysis. The submodels of such system, which represent individual processes occurring in the biosphere, can be characterized as reasonably conservative i.e., realistic, yet unlikely to underestimate their modeling outcome. Such conservative conceptual models are commonly used for demonstrating compliance with the regulatory standards.

Parameter uncertainty represents uncertainty in the data, parameters, and coefficients used in mathematical models and in the supporting computer codes, such as GENII-S, in the case of biosphere modeling. Parameter uncertainty originates from a number of sources including insufficient information, or lack of site-specific information, to accurately determine values of parameters and coefficients used in the biosphere model. Another source of uncertainty is associated with the temporal and spatial heterogeneity of the biosphere system. However, lack of knowledge about an input parameter typically contributes more to the uncertainty of the parameter values than does the natural variability of that parameter. Contribution of parameter uncertainty to the overall uncertainty of the modeling outcome can be more readily quantified than model uncertainty. This analysis does not attempt to quantify the relative contribution of model uncertainty to the overall DCF uncertainty.

6.6.2 Biosphere Dose Conversion Factor Uncertainty

As noted before, uncertainties are inherent in any modeling of a real system, such as the biosphere. These uncertainties include data uncertainty and model uncertainty. Data or parameter uncertainty is more readily quantified than model uncertainty. In this assessment the treatment of uncertainties is limited to parameter uncertainty.

The results of BDCF calculations consist of 150 outcomes of individual model simulation. These BDCF values can be represented as a probability distribution function. The shape of the probability distribution function, the range of values within the predetermined confidence limits, and the associated statistics characterize the spread of BDCF values generated by the model runs. Distributions of BDCF values are related to probability distribution of the key uncertain parameters. Representation of the parameter values by their probability distribution functions have their origin in either the uncertainty on the best estimate of the parameter's value or in the variability of the parameter in the sample. The examples of the latter include locally-produced food consumption rates which were obtained in the regional survey and thus represent variability of consumption rates in the surveyed population. On the other hand, soil-to-plant or animal food-to-animal product transfer scaling factors represent uncertainty in the best estimate of the parameter values. For the conditions of no prior irrigation, drinking water and leafy vegetable consumption rates are the key parameters contributing to the BDCF variance for almost all radionuclides. Therefore the distribution of BDCF values reflects predominantly variability in the consumption rates.

6.7 PATHWAY ANALYSIS

BDCFs include contributions from various radiological pathways through the biosphere, as described in Section 6.2.1. The evaluation of the degree to which various pathways contribute to BDCFs was the subject of an independent assessment. An analysis was first conducted separately for the current and evolved climates, including consideration of radionuclide buildup in soil. Then the results of each pathway analysis for the two climates were compared.

To determine the contributions of different exposure pathways to the BDCF values, a single GENII-S deterministic assessment was performed for each radionuclide. Deterministic GENII-S runs were carried out simultaneously with the stochastic runs using input values listed in the column labeled "Best Estimate" of Tables 7 and 10, for the current and evolved climates, respectively. The method of obtaining pathway BDCFs is decribed in Attachment VI of this report.

6.7.1 Pathway Analysis for the Current Climate

The results of pathway analysis for the current climate and no prior irrigation are summarized in Table 15. An Excel software routine is documented in Attachment VI. For all radionuclides, except ^{14}C and ^{137}Cs, consumption of drinking water is the dominant pathway accounting for 55 to 69 percent of the BDCF, depending on the radionuclide. Leafy vegetables consumption ranks second, contributing from 23 to 27 percent, depending on the radionuclide. Together, consumption of drinking water and leafy vegetables account for 82 to 96 percent of the BDCF values for these radionuclides. The remaining consumption pathways account for up to a few percent of the BDCFs. Inhalation and external exposure pathways are not significant, and neither of them contributes more than a few tenths of a percent for all radionuclides except ^{137}Cs (7.7%), and ^{226}Ra (2.5%). For ^{14}C consumption of fish is by far the most important pathway (93 percent of the BDCF). Pathway contributions to BDCF for ^{137}Cs include 23 percent from consumption of drinking water, 12 percent from leafy vegetables, 12 percent from meat, 36 percent from fish, and 8 percent from external exposure.

Contribution of the specific pathways to the BDCFs is affected by radionuclide buildup in soil. This is because some pathways depend on radionuclide concentration in soil. Among the pathways that are unaffected by radionuclide buildup in soil is consumption of drinking water, which is the major pathway for most radionuclides. Also, the contribution to BDCFs from consumption of fish and that fraction of the BDCF that results from activity deposition on a plant's surfaces from irrigation water are unrelated to radionuclide concentration in soil.

For many radionuclides, such as ^{99}Tc, ^{129}I, and ^{237}Np, for which the effect of radionuclide buildup in soil is insignificant (see Table 12), pathway contributions to BDCFs remain virtually unchanged regardless of the previous irrigation practices. This, however, is not the case for radionuclides whose levels in soil increase with prolonged irrigation.

Table 15. Percent Pathway Contribution to Nominal Performance Biosphere Dose Conversion Factors for Current Climate and No Prior Irrigation

Nuclide	Drinking Water	Leafy Vegetables	Other Vegetables	Fruit	Cereals	Meat	Poultry	Cow Milk	Eggs	Fish	Soil Ingestion	External Exposure	Inhalation
^{14}C	3.0	0.9	0.6	0.8	0.1	0.4	0.2	0.2	1.1	92.8	0.0	0.0	0.0
^{63}Ni	59.0	23.4	1.7	1.6	0.1	2.5	0.0	7.8	0.1	3.7	0.0	0.0	0.0
^{90}Sr	59.7	26.9	3.0	1.9	0.2	5.1	0.0	0.7	0.3	2.3	0.0	0.0	0.0
^{99}Tc	55.3	27.9	3.5	1.8	0.2	0.1	0.0	8.2	2.4	0.7	0.0	0.0	0.0
^{129}I	61.1	23.6	1.8	1.7	0.2	3.6	0.0	4.1	2.3	1.6	0.0	0.0	0.0
^{137}Cs	28.8	11.5	0.9	0.9	0.1	12.3	0.2	1.5	0.1	36.0	0.0	7.7	0.0
^{210}Pb	60.6	23.6	1.8	1.5	0.1	0.2	0.0	0.1	0.7	11.3	0.0	0.0	0.0
^{226}Ra	65.3	25.4	1.9	1.6	0.2	0.5	0.0	0.5	0.0	2.0	0.0	2.5	0.0
^{227}Ac	68.3	26.5	1.9	1.7	0.2	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.2
^{229}Th	65.5	26.1	2.0	1.7	0.2	0.0	0.0	0.0	0.0	4.1	0.0	0.1	0.3
^{230}Th	66.2	25.6	2.0	1.7	0.2	0.0	0.0	0.0	0.0	4.1	0.0	0.0	0.3
^{231}Pa	68.7	26.8	2.0	1.8	0.2	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.1
^{232}U	67.2	26.5	2.0	1.7	0.2	0.2	0.1	0.3	0.8	0.4	0.0	0.3	0.3
^{233}U	67.8	26.2	2.0	1.7	0.2	0.2	0.1	0.3	0.8	0.4	0.0	0.0	0.2
^{234}U	67.8	26.2	2.0	1.7	0.2	0.2	0.1	0.3	0.8	0.4	0.0	0.0	0.2
^{236}U	67.3	26.7	2.0	1.7	0.2	0.2	0.1	0.3	0.8	0.4	0.0	0.0	0.2
^{238}U	67.3	26.6	2.0	1.8	0.2	0.2	0.1	0.3	0.8	0.4	0.0	0.1	0.2
^{237}Np	67.9	26.2	2.0	1.7	0.2	0.6	0.0	0.0	0.0	1.3	0.0	0.0	0.1
^{238}Pu	68.3	26.4	2.0	1.7	0.2	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.1
^{239}Pu	68.4	26.3	2.0	1.8	0.2	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.1
^{240}Pu	68.4	26.3	2.0	1.8	0.2	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.1
^{242}Pu	68.1	26.7	2.0	1.8	0.2	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.1
^{241}Am	68.3	26.5	2.0	1.7	0.2	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.1
^{243}Am	68.5	26.1	2.0	1.8	0.2	0.0	0.0	0.0	0.0	1.3	0.0	0.1	0.1

NOTE: Pathway contributions were developed using software routine described in Attachment VI.

The effect of radionuclide buildup in soil was evaluated by examining pathway contributions to BDCFs for selected radionuclides whose BDCFs increase with the duration of prior irrigation. It must be noted again that this analysis was carried out assuming constant level of activity concentration in water for the entire length of time needed to obtain steady-state conditions of radionuclide concentration is soil (thousands of years in many cases). In addition, other removal mechanisms, such as soil removal by erosion, were not factored in because they are considered in the abstraction process. The addition of soil removal from erosion would considerably shorten the time needed to obtain an equilibrium radionuclide concentration in soil and make the analysis of the BDCFs for very long periods of prior irrigation (such as those for ^{230}Th) irrelevant.

The graph shown in Figure 7 represents percentage pathway contributions to BDCF for ^{239}Pu at different periods of prior irrigation. (Contributions to BDCF from consumption of all crop types and contributions from consumption of all animal products are portrayed as their respective category.) ^{239}Pu is a radionuclide that shows a moderate degree of radionuclide buildup in soil and is a good representative of the group of radionuclides whose concentration levels in soil increase somewhat with irrigation time. The graph shows the decreasing importance of the water consumption pathway with irrigation time and growing inhalation and soil ingestion components.

The pathway-specific BDCFs for ^{239}Pu, as a function of irrigation duration, are shown in Figure 8. As for the previous graph, BDCFs from consumption of all crops as well as BDCFs from consumption of all animal foods were represented as two categories. The Figure shows that the pathway BDCFs for inhalation, soil ingestion, and external exposure increase with irrigation time, while BDCFs for the remaining pathways either remain constant (e.g. drinking water) or are not significantly affected by an increasing duration of prior irrigation.

^{230}Th is the radionuclide with the greatest degree of radionuclide buildup in soil. The graph shown in Figure 9 illustrates percentage pathway contributions for this radionuclide. The significance of water consumption decreases from being the major contributor for no prior irrigation condition to only about 10% for the second period, decreasing even more for the subsequent period. External exposure becomes a dominant pathway, with inhalation being the second greatest contributor. These two pathways together account for up to about 85% of the BDCF with the balance resulting mainly from crop consumption and soil ingestion.

Analogous to the graph in Figure 8 for ^{239}Pu, Figure 10 shows pathway BDCFs as a function of irrigation duration for ^{230}Th. It must be noted that the time scales for Figures 8 and 10 are not the same. Irrigation periods are based on the effective removal constants, which are different for different radionuclides. In the case of ^{230}Th, radionuclides are removed from soil very slowly, compared to other radionuclides and it would take many thousands of years of continuous irrigation for the equilibrium radionuclide concentration in soil to be reached. Therefore the results presented in Figures 7 through 10 must be put into perspective as representing a potential general trend rather than the actual expected conditions.

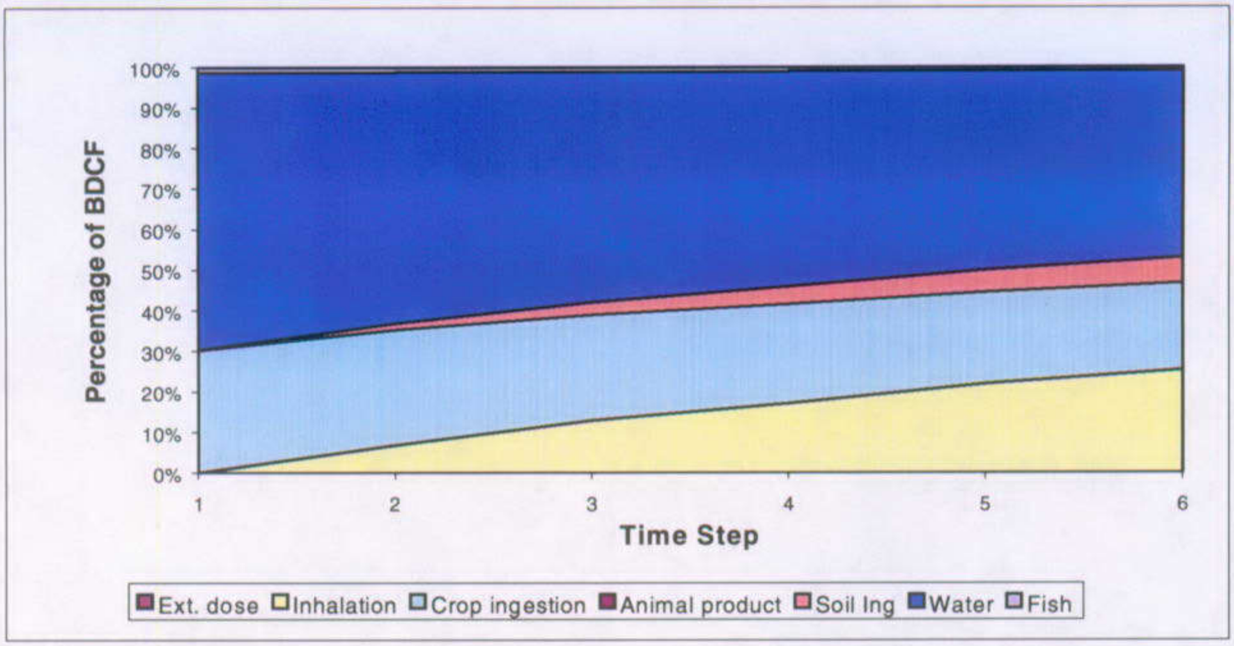


Figure 7. ^{239}Pu Pathway Contributions at Different Irrigation Periods (Time Steps)

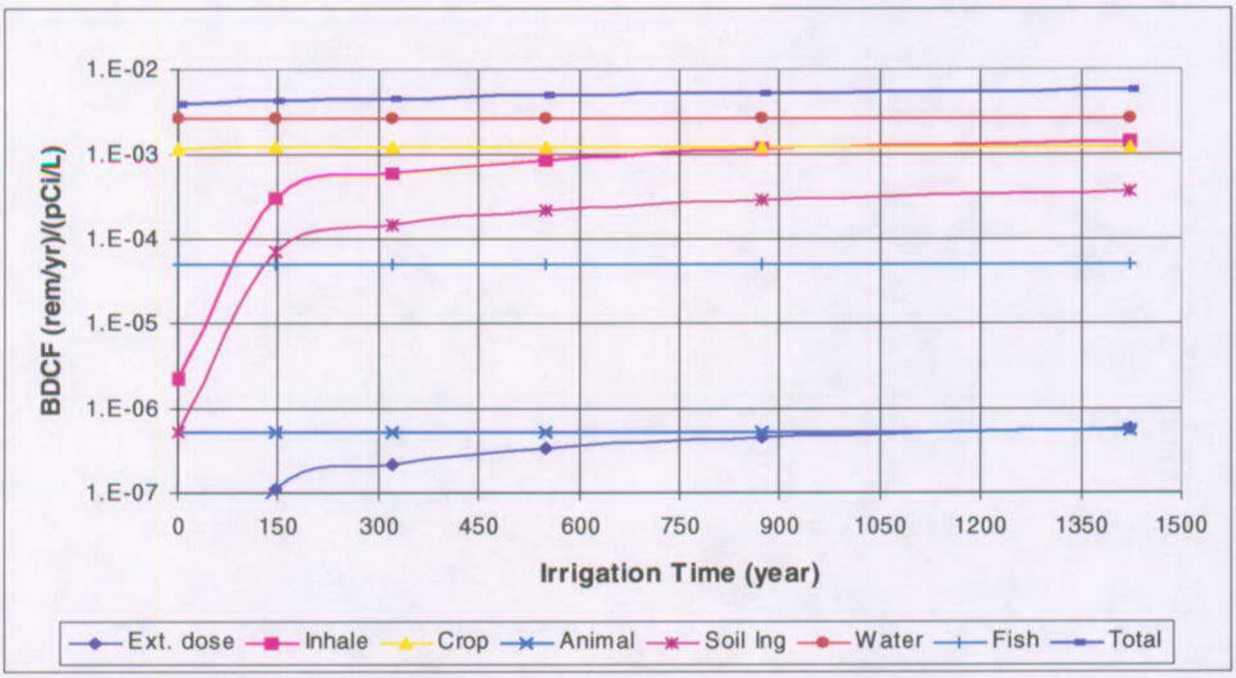


Figure 8. ^{239}Pu Pathway BDCFs as a Function of Irrigation Time

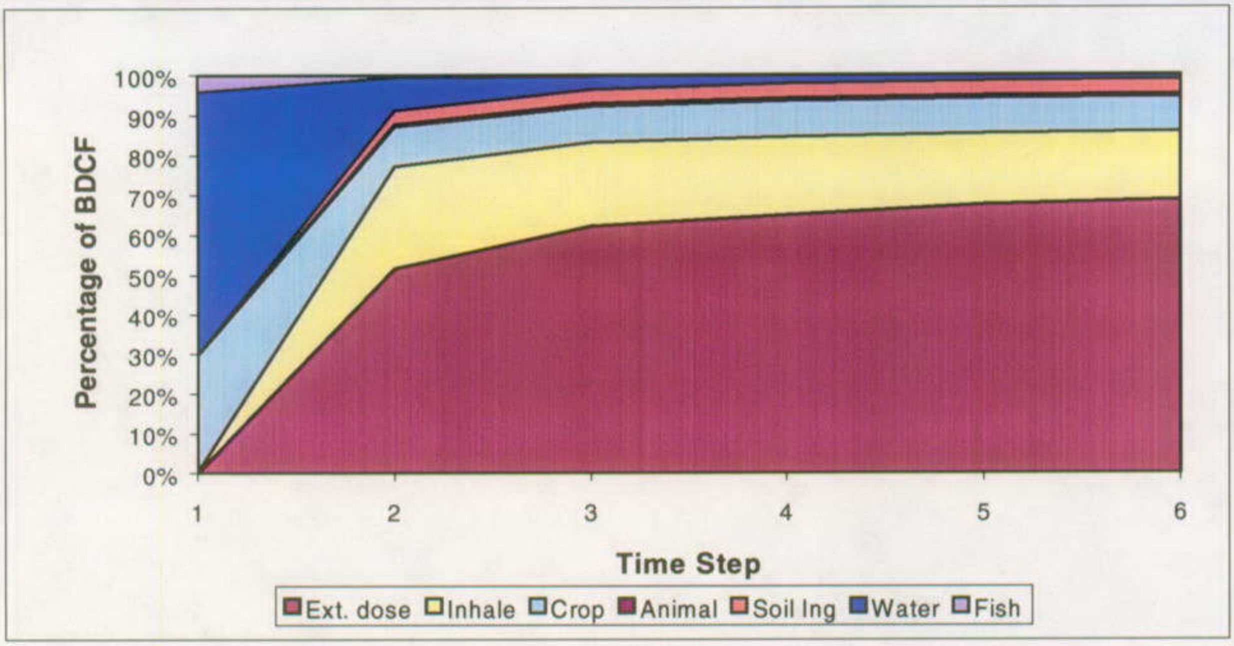


Figure 9. ^{230}Th Pathway Contributions at Different Irrigation Periods (Time Steps)

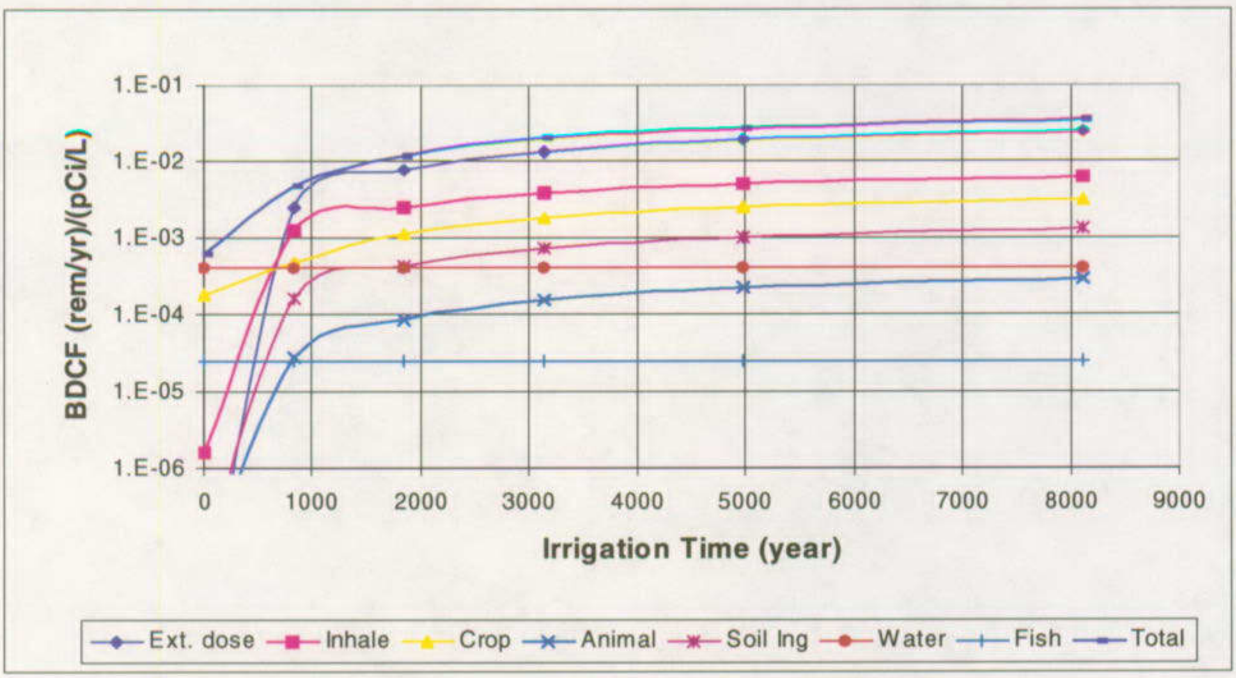


Figure 10. ^{230}Th Pathway BDCFs as a Function of Irrigation Time

6.7.2 Pathway Analysis for the Evolved Climate

As shown in Table 13, cooler and wetter conditions of the evolved climate result in a decrease in the magnitude of all BDCFs, as compared to the current climate. The decrease is not very significant, ranging from no more than 10

ercents for the first irrigation period to up to 45 percent for the sixth irrigation period. Because the BDCFs for the conditions of no prior irrigation are not affected very much by the climate change, neither are the pathway BDCFs. Therefore the results of the pathway analysis conducted for the current climate and no prior irrigation (first period) remain valid. Because the climate change does not affect the drinking water consumption pathway BDCF, which was a dominant pathway for the current climate, the overall BDCF decrease is due to the decrease of other pathway BDCFs. This results in even greater contribution of water consumption pathway BDCFs to the evolved climate BDCFs than it was the case of the current climate.

To analyze the combined effect on the BDCFs of prior irrigation and climate change, a graph was constructed that shows pathway BDCF ratios for the evolved and current climates for ^{239}Pu. This radionuclide exhibits a moderate degree of buildup and it was identified as one of the key radionuclides in the TSPA-SR analysis. The graph is shown in Figure 11. The ratios of pathway BDCFs for the evolved and current climate are less than one except for the water consumption and fish consumption pathways, which do not depend on radionuclide concentration in soil.

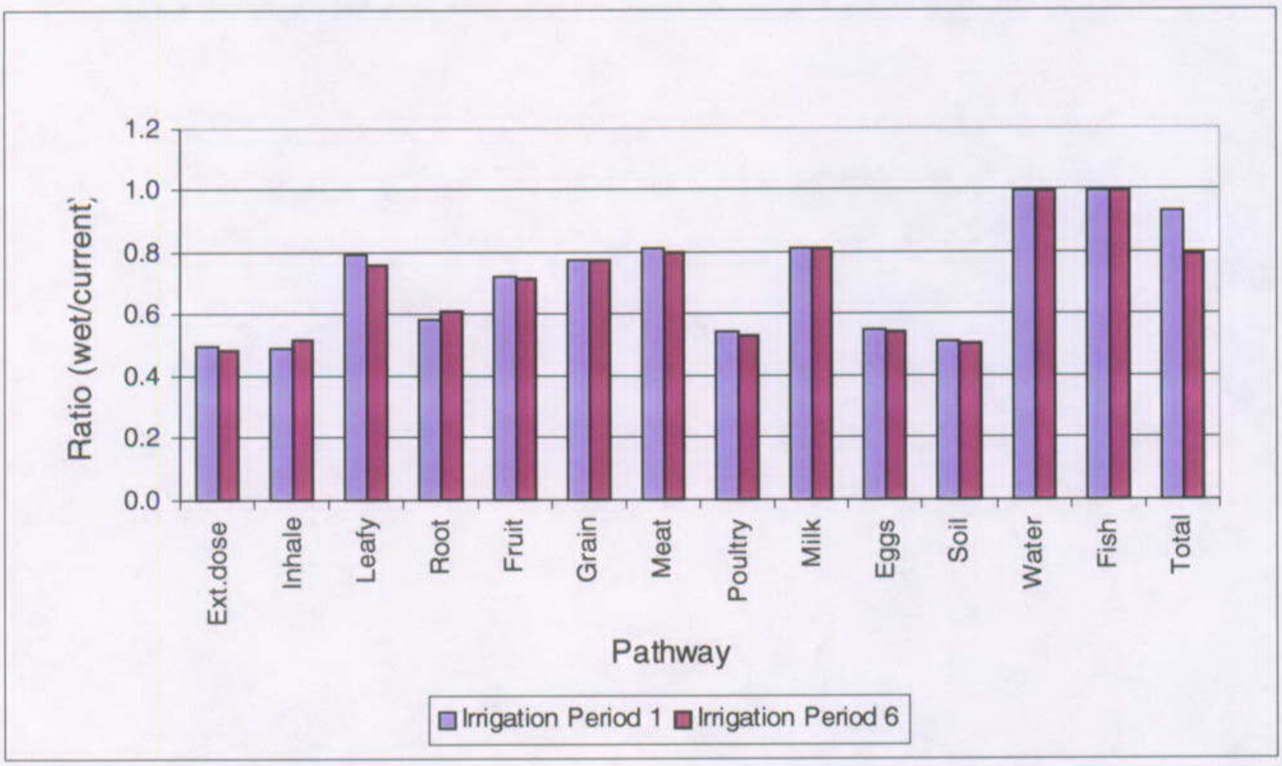


Figure 11. ^{239}Pu Pathway BDCF Ratio for Evolved and Current Climates

6.8 ALTERNATIVE MODELS

The strategy governing conceptual description of the biosphere system is consistent with similar activities being persued by the international scientific community. Several issues were identified that are relevant to the model components and warrant consideration in this analysis.

6.8.1 Alternative Exposure Scenarios

BDCF development was carried out for a specific exposure scenario. An exposure scenario is defined as one possible combination of specified FEPs affecting the biosphere system that could lead to radiological consequences. There are several alternative exposure scenarios that could be considered for the current biosphere. The proposed rules and the guidance limit the assessment to the exposure scenario associated with an adult farming receptor group based on the behaviors and characteristics of Amargosa Valley residents. Other exposure scenarios that could be conceivable include the exposure conditions of a subsistence farmer receptor group, a residential receptor group, or a group consisting of non-adult receptors.

The non-adult receptor group is not considered appropriate for the analysis of long-term performance of the potential repository. Considering the time scale of the assessment, it could be assumed that radioactive contamination of the biosphere due to releases from the repository is likely to remain constant over periods that are considerably longer that the human life span. It is then reasonable to calculate the annual dose averaged over the lifetime of the individuals, which means that it is not necessary to calculate doses to different age groups. This average can be adequately represented by the annual dose to an adult (ICRP 2000).

6.8.2 Alternative Dosimetric Models

The current assessment uses dosimetric models based in the conceptual approach recommended by the International Commission on Radiological Protection (ICRP) in Publication 26 (ICRP 1977) and the dosimetric methods outlined in Publication 30 (ICRP 1979, ICRP 1980, ICRP 1981). By using such model the outcome of the biosphere model expressed in terms of TEDE is compatible with the format of the proposed performance standard (Dyer 1999, Section 113(b)) which uses the same methodology.

Since the publication of the ICRP recommendations and models in the late 1970s and early 1980s the Commission updated both its recommendations (ICRP 1991) as well as its dosimetric methods. Of particular significance is a set of publications concerning age-dependent doses to the members of the public from intakes of radionuclides. The summary document for this set, ICRP Publication 72 (ICRP 1996), provides a listing of dose coefficients (dose conversion factors) for inhalation and ingestion of radionuclides by age group.

Dose conversion factors are a quintessence of dosimetric modeling, including metabolism of a specific radionuclide compound; possible deposition in various human organs and tissues; physical behavior, such as radioactive decay accompanied by the emission of ionizing radiation and production of radioactive progenies; irradiation of human organs and tissues by internally deposited radionuclides or radionuclides external to the human body; and the contribution of the radiation effects in the irradiated organs and tissues to the overall radiation effect.

Dose conversion factors in ICRP Publication 30 and ICRP Publication 72 were developed using different approaches (e.g., they are based on different tissue weighting factor values) and can not be interchanged. For some radionuclides, DCFs may differ considerably between the two dosimetric systems. However, comparing DCF values may be misleading in some cases because of the different bases for their calculation. In addition, application of ICRP-72 DCFs does not yield results compatible with the concept of ICRP-30-based TEDE, which is used in the proposed regulations to define performance standards for the repository.

7. CONCLUSIONS

The purpose of this analysis and model was to calculate BDCFs for the current and evolved climates. BDCFs for 24 radionuclides were developed for the receptor represented by the average member of the critical group. Analysis included evaluation of the general tendencies in all pathway BDCF values and individual pathway contributions following periods of prolonged irrigation with contaminated groundwater. BDCF development was accompanied by pathway, sensitivity, and uncertainty analyses. The resulting BDCFs are summarized in Tables 8 and 9 for the current climate, while the summary of the BDCFs for the evolved climate is presented in Tables 11 and 12. The results of biosphere modeling, abstracted into BDCF probability distribution functions, are used in the TSPA model to calculate doses for the nominal performance of the potential repository.

The analysis included consideration of radionuclide buildup in soil due to prior irrigation with contaminated groundwater. First, the buildup factors were evaluated, by producing a ratio of the sixth irrigation period to the first irrigation period BDCF for each radionuclide. If the buildup exceeded 15%, BDCFs were calculated for all the six irrigation periods shown in Table 3. Over 40% of radionuclides, including three of the four key radionuclides identified by the TSPA-SR analysis (^{99}Tc, ^{129}I, and ^{237}Np), do not show significant (less than 15%) radionuclide buildup in soil. The analysis of the BDCFs for the remaining radionuclides indicated that the increase in radionuclide concentrations in soil tend to affect inhalation and external exposure pathway contributions to the BDCFs the most, with the water consumption and fish consumption contributions to the BDCFs essentially unchanged, and the remaining pathway BDCFs affected to a lesser degree.

The comparison of the BDCFs for the current and evolved climate showed that BDCF values decrease for the cooler and wetter conditions of the evolved climate. The difference tends to be greater if the effect of radionuclide buildup in soil is included in the analysis.

Pathway analysis confirmed the earlier findings (CRWMS M&O 2000o) that ingestion of water and leafy vegetables are the two dominant pathways, which together contribute over 90 percent to the BDCFs for most radionuclides. The drinking water and leafy vegetable consumption pathways contributed at least 55 and 23 percent, respectively, to the BDCF for all radionuclides except ^{14}C and ^{137}Cs. However, the importance of other pathways, such as inhalation and external exposure increases with radionuclide buildup in soil for those radionuclides that show significant buildup effect.

The BDCFs developed in this AMR were obtained using current, updated inputs. If new input data become available, the BDCFs may be revised. The BDCF values presented in this report, as well as the conclusions from the pathway, and uncertainty analyses, differ from those developed previously (CRWMS M&O 2000a, CRWMS M&O 2000o) due to the differences in the input values.

8. INPUTS AND REFERENCES

8.1 DOCUMENTS CITED

CRWMS M&O 1998a. *Software Qualification Report (SQR) GENII-S 1.485 Environmental Radiation Dosimetry Software System Version 1.485.* CSCI: 30034 V1.4.8.5. DI: 30034-2003, Rev. 0. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980715.0029.

CRWMS M&O 1998b. *Yucca Mountain Site Characterization Project: Summary of Socioeconomic Data Analyses Conducted in Support of the Radiological Monitoring Program, April 1997 to April 1998.* Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980803.0064.

CRWMS M&O 1998c. "Biosphere." Chapter 9 of *Total System Performance Assessment-Viability Assessment (TSPA-VA) Analyses Technical Basis Document.* B00000000-01717-4301-00009 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981008.0009.

CRWMS M&O 1999. *Dose Conversion Factor Analysis: Evaluation of GENII-S Dose Assessment Methods.* ANL-MGR-MD-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991207.0215.

CRWMS M&O 2000a. *Non-Disruptive Event Biosphere Dose Conversion Factors.* ANL-MGR-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000307.0383.

CRWMS M&O 2000b. *Total System Performance Assessment for the Site Recommendation.* TDR-WIS-PA-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001005.0282.

CRWMS M&O 2000c. *Technical Work Plan for Biosphere Modeling and Expert Support.* TWP-MGR-MD-000009 REV 0. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001102.0378.

CRWMS M&O 2000d. Cancelled

CRWMS M&O 2000e. *Environmental Transport Parameters Analysis.* ANL-MGR-MD-000007 REV 00 ICN 01. Las Vegas, Nevada: CRWMS M&O. Submit to RPC URN-0733

CRWMS M&O 2000f. *Transfer Coefficient Analysis.* ANL-MGR-MD-000008 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001016.0005.

CRWMS M&O 2000g. *Input Parameter Values for External and Inhalation Radiation Exposure Analysis.* ANL-MGR-MD-000001 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001122.0005.

CRWMS M&O 2000h. *Identification of Ingestion Exposure Parameters.* ANL-MGR-MD-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000216.0104.

CRWMS M&O 2000i. *Calculation: Values and Consumption Rates of Locally Produced Food and Tap Water for the Receptor of Interest.* CAL-MGR-MD-000005 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000922.0092.

CRWMS M&O 2000j. *Evaluate Soil/Radionuclide Removal by Erosion and Leaching.* ANL NBS-MD-000009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000310.0057.

CRWMS M&O 2000k. *Inventory Abstraction.* ANL-WIS-MD-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000414.0643.

CRWMS M&O 2000l. *Identification of the Critical Group (Consumption of Locally Produced Food and Tap Water).* ANL-MGR-MD-000005 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: Submit to RPC. URN-0732

CRWMS M&O 2000m. *The Development of Information Catalogued in REV00 of the YMP FEP Database.* TDR-WIS-MD-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000705.0098.

CRWMS M&O 2000n. *Distribution Fitting to the Stochastic BDCF Data.* ANL-NBS-MD-000008 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000517.0258; MOL.20000601.0753.

CRWMS M&O 2000o. *Yucca Mountain Site Description.* TDR-CRW-GS-000001 REV 01 ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001003.0111.

CRWMS M&O 2000p. *Non-Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis.* ANL-MGR-MD-000010 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000420.0074.

CRWMS M&O 2000q. *Saturated Zone Flow and Transport Process Model Report.* TDR-NBS-HS-000001 REV 00 ICN 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001102.0067.

CRWMS M&O 2000r. *Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP).* ANL-MGR-MD-000011 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000420.0075.

CRWMS M&O 2000s. *Disruptive Event Biosphere Dose Conversion Factor Analysis.* ANL MGR-MD-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000303.0216.

CRWMS M&O 2000t. *Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis.* ANL-MGR-MD-000004 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000418.0826.

DOE (U.S. Department of Energy) 1997. *The 1997 "Biosphere" Food Consumption Survey Summary Findings and Technical Documentation.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19981021.0301.

DOE (U.S. Department of Energy) 2000. *Quality Assurance Requirements and Description.* DOE/RW-0333P, Rev. 10. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000427.0422.

Doorenbos, J. and Pruitt, W.O. 1977. *Crop Water Requirements.* FAO Irrigation and Drainage Paper 24. Rome, Italy: Food and Agriculture Organization of the United Nations. TIC: 245199.

Eckerman, K.F. and Ryman, J.C. 1993. *External Exposure to Radionuclides in Air, Water, and Soil, Exposure-to-Dose Coefficients for General Application, Based on the 1987 Federal Radiation Protection Guidance.* EPA 402-R-93-081. Federal Guidance Report No. 12. Washington, D.C.: U.S. Environmental Protection Agency, Office of Radiation and Indoor Air. TIC: 225472.

Eckerman, K.F.; Wolbarst, A.B.; and Richardson, A.C.B. 1988. *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion.* EPA 520/1-88-020. Federal Guidance Report No. 11. Washington, D.C.: U.S. Environmental Protection Agency. TIC: 203350.

Hogan, E. L., ed. 1988. "Plant Care: Vegetables." *Sunset Western Garden Book.* pp. 194-197. Menlo Park, California: Lane Publishing Co. TIC: 243490.

ICRP (International Commission on Radiological Protection) 1977. *Recommendations of the International Commission on Radiological Protection.* ICRP Publication 26. New York, New York: Pergamon Press. TIC: 221568.

ICRP (International Commission on Radiological Protection) 1979. *Limits for Intakes of Radionuclides by Workers.* Volume 2, No. 3/4 of *Annals of the ICRP.* Sowby, F.D., ed. ICRP Publication 30 Part 1. New York, New York: Pergamon Press. TIC: 4939.

ICRP (International Commission on Radiological Protection) 1980. *Limits for Intakes of Radionuclides by Workers.* Volume 4, No. 3/4 of *Annals of the ICRP.* ICRP Publication 30 Part 2. New York, New York: Pergamon Press. TIC: 4941.

ICRP (International Commission on Radiological Protection) 1981. *Limits for Intakes of Radionuclides by Workers.* Volume 6, No. 2/3 of *Annals of the ICRP.* ICRP Publication 30 Part 3, Including Addendum to Parts 1 and 2. New York, New York: Pergamon Press. TIC: 4943.

ICRP (International Commission on Radiological Protection) 1991. "1990 Recommendations of the International Commission on Radiological Protection." Volume 21, No. 1-3 of *Annals of the ICRP*. ICRP Publication 60. New York, New York: Pergamon Press. TIC: 235864.

ICRP (International Commission on Radiological Protection) 1996. *Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 5 Compilation of Ingestion and Inhalation Dose Coefficients.* Volume 26, No. 1 of *Annals of the ICRP*. Smith, H., ed. ICRP Publication 72. New York, New York: Pergamon Press. TIC: 235870.

ICRP (International Commission on Radiological Protection) 2000. *Radiation Protection Recommendations as Applied to the Disposal of Long-lived Solid Radioactive Waste. Annals of the ICRP*. ICRP Publication 81. New York, New York: Pergamon Press. On Order Library Tracking Number-249031

LaPlante, P.A. and Poor, K. 1997. *Information and Analyses to Support Selection of Critical Groups and Reference Biospheres for Yucca Mountain Exposure Scenarios.* CNWRA 97-009. San Antonio, Texas: Center for Nuclear Waste Regulatory Analyses. TIC: 236454.

Leigh, C.D.; Thompson, B.M.; Campbell, J.E.; Longsine, D.E.; Kennedy, R.A.; and Napier, B.A. 1993. *User's Guide for GENII-S: A Code for Statistical and Deterministic Simulations of Radiation Doses to Humans from Radionuclides in the Environment.* SAND91-0561. Albuquerque, New Mexico: Sandia National Laboratories. TIC: 231133.

Martin, D.L.; Gilley, J.R.; and Skaggs, R.W. 1991. "Appendix II: Evapotranspiration Equations." *Managing Nitrogen for Groundwater Quality and Farm Profitability, Proceedings of a Symposium Sponsored By Division A-5 of the American Society of Agronomy, Anaheim, California, 1988.* Follett, R.F.; Keeney, D.R.; Cruse, R.M., eds. 333-338. Madison, Wisconsin: Soil Science Society of America. TIC: 238376.

Napier, B.A.; Peloquin, R.A.; Strenge, D.L.; and Ramsdell, J.V. 1988. *Conceptual Representation.* Volume 1 of *GENII - The Hanford Environmental Radiation Dosimetry Software System.* PNL-6584. Richland, Washington: Pacific Northwest Laboratory. TIC: 206898.

Napier, B.A. 2000. *Review of the Yucca Mountain Biosphere Modeling Effort (Preliminary Report).* Richland, Washington: Pacific Northwest National Laboratory. TIC: 247141.

NRC (U.S. Nuclear Regulatory Commission) 2000. *Issue Resolution Status Report Key Technical Issue: Total System Performance Assessment and Integration.* Rev. 2. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 247614.

Rittmann, P.D. 1993. *Verification Tests for the July 1993 Revision to the GENII Radionuclide and Dose Increment Libraries.* WHC-SD-WM-TI-596. Richland, Washington: Westinghouse Hanford Company. TIC: 233965.

Till, J.E. and Meyer, H.R. 1983. *Radiological Assessment, A Textbook on Environmental Dose Analysis.* NUREG/CR-3332. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 223809.

USGS (U.S. Geological Survey) 2000. *Future Climate Analysis.* ANL-NBS-GS-000008 REV 00. Denver, Colorado: U.S. Geological Survey. ACC: MOL.20000629.0907.

Washington Agricultural Statistics Service 1992. "Spokane County, Washington." Washington, D.C.: National Agricultural Statistics Service, U.S. Department of Agriculture. Accessed 9/12/2000. TIC: 248846. http://www.nass.usda.gov/wa/counties/cnty063.htm

Washington Agricultural Statistics Service 1999. "1999 Annual Bulletin: Usual Planting & Harvesting Dates, Washington." Washington, D.C.: National Agricultural Statistics Service, U.S. Department of Agriculture. Accessed 8/23/00. TIC: 248851. http://www.nass.usda.gov/wa/annual99/plant99.htm

Western Regional Climate Center 1997. "Spokane, Washington: Normals, Means, and Extremes." Reno, Nevada: Western Regional Climate Center, Desert Research Institute. Accessed 8/23/00. TIC: 248857. http://www.wrcc.dri.edu/cgi-bin/clilcd.pl?wa24157

8.2 DATA CITED

GS000100001221.001. EarthInfo, Inc. Western US Meteorologic Station Weather Data - NCDC Summary of Day (West 1) and NCDC Summary of Day (West 2). Submittal date: 01/25/2000.

MO0002RIB00068.000. Ingestion Exposure Parameter Values. Submittal date: 02/03/2000.

MO0004RIB00085.000. Soil and Radionuclide Removal by Erosion and Leaching. Submittal date: 04/06/2000.

MO0007SPADMM05.002. Distributions, Mean, Minimum, and Maximum Consumption Levels of Locally Produced Food by Type and Tap Water for the Amargosa Valley Receptor of Interest. Submittal date: 07/31/2000.

MO0010MWDPBD09.006. Biosphere Dose Conversion Factors for Nominal Performance. Submittal date: 10/05/2000.

MO0010SPAAAM01.014. Input Parameter Values for External and Inhalation Radiation Exposure Analysis. Submittal date: 10/02/2000.

MO0010SPAPET07.004. Environmental Transport Parameters. Submittal date: 10/03/2000. Submit to RPC URN-0659

MO0010SPAPTC08.005. Transfer Coefficients. Submittal date: 10/03/2000. Submit to RPC URN-0660

MO9912RIB00066.000. Parameter Values for Internal and External Dose Conversion Factors. Submittal date: 12/03/99.

MO9912SPASUB02.001. Dose Coefficients for Air Submersion and Exposure to Contaminated Soil. Submittal date: 12/10/1999.

8.3 CORRESPONDENCE CITED

Dyer, J.R. 1999. "Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999), for Yucca Mountain, Nevada." Letter from J.R. Dyer (DOE/YMSCO) to D.R. Wilkins (CRWMS M&O), September 3, 1999, OL&RC:SB-1714, with enclosure, "Interim Guidance Pending Issuance of New NRC Regulations for Yucca Mountain (Revision 01).". ACC: MOL.19990910.0079.

Harris, M.W. 1997. "Recommendation of Models to be Used in the Biosphere Modeling Effort." Letter from M.W. Harris (CRWMS M&O) to W.R. Dixon (DOE/YMSCO), July 8, 1997, LV.ESR.CHT.07/97-125, with attachment. ACC: MOL.19971124.0033 MOL.19971124.0034.

8.4 CODES, STANDARDS, AND REGULATIONS

10 CFR 20. Energy: Standards for Protection Against Radiation. Readily available.

64 FR 46976. Environmental Radiation Protection Standards for Yucca Mountain, Nevada. Readily available.

64 FR 67054. Office of Civilian Radioactive Waste Management; General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories; Yucca Mountain Site Suitability Guidelines. Readily available.

64 FR 8640. Disposal of High-Level Radioactive Wastes in a Proposed Geologic Repository at Yucca Mountain, Nevada. Readily available.

8.5 PROCEDURES

AP-2.1Q, Rev. 1, ICN 0. *Indoctrination and Training of Personnel.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000629.0909.

AP-2.2Q, Rev. 0, ICN 0. *Establishment and Verification of Required Education and Experience of Personnel.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19990701.0618.

AP-2.14Q, Rev. 1, ICN 0. *Review of Technical Products.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20001211.0001.

AP-2.21Q, Rev. 0, ICN 0. *Quality Determination and Planning for Scientific, Engineering, and Regulatory Compliance Activities.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000802.0003.

AP-3.4Q, Rev. 2, ICN 0. *Level 03 Change Control.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20001213.0064.

AP-3.10Q, Rev. 2, ICN 3, *Analyses and Models.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000918.0282.

AP-3.14Q, Rev. 0, ICN 2. *Transmittal of Input.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20001122.0001.

AP-3.15Q, Rev. 2, ICN 0. *Managing Technical Product Inputs.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20001109.0051.

AP-3.17Q, Rev. 1, ICN 0. *Impact Reviews.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20001211.0003.

AP-6.1Q, Rev. 5, ICN 0. *Controlled Documents.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000608.0009.

AP-17.1Q, Rev. 1, ICN 3. *Record Source Responsibilities for Inclusionary Records.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20001120.0166.

AP-SI.1Q, Rev. 2, ICN 4, ECN 1. *Software Management.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20001019.0023.

AP-SIII.2Q. Rev. 0, ICN 3. *Qualification of Unqualified Data and the Documentation of Rationale for Accepted Data.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20001002.0152.

AP-SIII.3Q. Rev. 0, ICN 3. *Submittal and Incorporation of Data to the Technical Data Management System.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000418.0808.

AP-SIII.4Q. Rev. 0, ICN 1. *Development, Review, Online Placement, and Maintenance of Individual Reference Information Data Base Items.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19991214.0631.

AP-SV.1Q. Rev. 0, ICN 2. *Control of the Electronic Management of Data.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000831.0065.

NLP-2-0. Rev. 5, ICN 1. *Determination of Importance Evaluations.* Las Vegas, Nevada: Civilian Radioactive Waste Management System, Management and Operating Contractor. ACC: MOL.20000713.0360.

QAP-2-3. Rev. 10. *Classification of Permanent Items.* Las Vegas, Nevada: Civilian Radioactive Waste Management System, Management and Operating Contractor. ACC: MOL.19990316.0006.

8.6 SOFTWARE CITED

Sandia National Laboratories 1998. *Software Code: GENII-S V1.4.8.5*. V1.4.8.5. 30034 V1.4.8.5.

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ATTACHMENT I

MATHEMATICAL MODELS USED BY GENII-S

ATTACHMENT I

MATHEMATICAL MODELS USED BY GENII-S

This attachment describes selected models used in the GENII-S computer code, which are important from the perspective of mathematical biosphere modeling for performance assessment. Some components of the models are omitted in order to maintain focus on the main model features. For example, the radioactive decay factor is not included in the equations presented in this section, while GENII-S considers the decay and in-growth of radionuclides during transport through environmental media.

I.1 ENVIRONMENTAL TRANSPORT OF RADIONUCLIDES

The exposure scenarios under consideration are discussed in Section 6.2. In the case of the groundwater contamination scenario, radionuclide migration in the biosphere, and the subsequent human exposure, which is initiated when contaminated water is used for domestic and agricultural needs. The subsequent use of contaminated land, combined with the natural processes, causes radionuclide migration through the environment. As a result, radionuclides become redistributed from the initial source of contamination to other components of the biosphere, such as soil, air, plants, animals, and, eventually, humans.

I.1.1 Radionuclide Concentration in Soil

The soil model used in GENII-S is relatively simple. Although the code considers two soil strata: surface soil and deep soil, only contamination present in the surface soil layer is subject to resuspension and transfer to food products. The radionuclide concentration in the top layer of soil is governed by a conservation equation, where the rate of change in radionuclide concentration in a volume of soil is equal to the rate of activity addition from irrigation minus the rate of activity removal. GENII-S considers three mechanisms of potential radionuclide removal from the soil: radioactive decay, plant uptake, and leaching into the deeper soil layer where activity becomes unavailable to plants. A fourth mechanism of potential radionuclide removal, not incorporated into the GENII-S computer code, is physical loss of soil (i.e., erosion by wind and water). This process is modeled outside of the GENII-S code.

Primary calculations of radionuclide concentration in soil in GENII-S are based on an irrigation period of one year. It is assumed that radioactivity is initially distributed throughout the upper soil layer, which is where the plant's roots are assumed to be located. Radionuclide activity in soil per unit area, C_s, following irrigation with contaminated water is calculated using the following relationship (adapted from Napier et al. 1988, p. 4.57-4.58):

$$C_s = \frac{25.4\, C_w\, I}{\lambda_l}\left(1 - e^{-\lambda_l t}\right) \qquad \text{(Eq. I-1)}$$

where

C_s – radionuclide activity concentration in soil per unit area (Bq m^{-2})
C_w – activity concentration of radionuclide in water (Bq L^{-1})
I – irrigation rate (in y^{-1})
λ_l – leaching rate (y^{-1})
t – exposure time (equal to one year)
$25.4\ L\ in^{-1}\ m^{-2}$ – unit conversion factor (number of liters in one inch of water applied over one m^2 of soil surface

For irrigation periods longer than one year, GENII-S factors in removal of radionuclides from soil by harvest. Harvest removal calculations are based on radionuclide concentration in a plant and the plant's yield and are carried out cyclically for the assumed duration of prior irrigation with contaminated water.

I.1.2 Radionuclide Concentration in Air

The concentration of radionuclides in air, C_a, resulting from soil resuspension is calculated, from the definition of the resuspension factor, using the following equation (Napier et al. 1988, p. 4.63):

$$C_a = C_s \times M \qquad \text{(Eq. I-2)}$$

where

C_a – radionuclide concentration in air (Bq m^{-3})
M – resuspension factor (m^{-1})

I.1.3 Radionuclide Concentration in Plants

Four categories of edible plants are considered in GENII-S: leafy vegetables, other (root) vegetables, fruit, and grain. There are two main mechanisms of radionuclide transfer to a plant: direct deposition on plant surfaces and the root uptake. Deposition on plant surfaces may result from irrigation with contaminated water and from resuspension of contaminated soil.

In order to evaluate radionuclide deposition onto leaf surfaces, the deposition rates for irrigation and soil resuspension have to be calculated separately. The leaf deposition rate from irrigation, DR_{ir}, is calculated as follows (adapted from Napier et al. 1988, p. 4.57):

$$DR_{ir} = \frac{25.4 \times 12\, C_w\, I}{ID} \qquad \text{(Eq. I-3)}$$

where

DR_{ir} – leaf deposition rate from irrigation (Bq m^{-2} y^{-1})
ID – irrigation duration (months)
25.4 $l\ in^{-1}\ m^{-2}$ – unit conversion factor
12 $months\ y^{-}$ – unit conversion factor

The leaf deposition rate from resuspension, DR_{rs}, is calculated as follows (adapted from Napier et al. 1988, p. 4.57):

$$DR_{rs} = 3.154 \times 10^{7}\ C_a\ v_d \qquad \text{(Eq. I-4)}$$

where

DR_{rs} – leaf deposition rate from resuspension (Bq m^{-2} y^{-1})
v_d – deposition velocity (m s^{-1})
$3.154 \times 10^{7}\ s\ y^{-1}$ – unit conversion factor

Activity concentration in a plant, following leaf deposition of airborne radionuclides, $C_{p,d}$, is calculated as follows (adapted from Napier et al. 1988, p. 4.67):

$$C_{p,d} = \frac{(DR_{ir}\ r_w + DR_{rs}\ r_a)T}{365\ \lambda_w\ B}\left(1 - e^{-\lambda_w t_g}\right) \qquad \text{(Eq. I-5)}$$

where

$C_{p,d,}$ – activity concentration in a plant (Bq kg^{-1})
λ_w – weathering constant (d^{-1})
t_g – growing time (days)
r_w – irrigation interception fraction (dimensionless)
r_a – air interception fraction (dimensionless)
T – translocation factor (dimensionless)
365 d y^{-1} – unit conversion factor

Translocation factor, T, descries the fraction of radionuclide transferred from plant surfaces to edible parts of the plant. Irrigation interception fraction, r_w, and the air interception fraction, r_a represent the fraction of initial deposition retained on the plant.

The air interception fraction, r_a, was calculated as follows (adopted from Napier et al. 1988, p. 4.69):

$$r_a = 1.0 - e^{-a\ B\ DW} \qquad \text{(Eq. I-6)}$$

where

a – empirical factor ($m^2\,kg^{-1}{}_{dry\ mass}$)
B – biomass ($kg_{wet\ mass}\,m^{-2}$)
DW – plant dry-to-wet weight ratio ($kg_{dry\ mass}\,kg^{-1}{}_{wet\ mass}$)

Empirical factor, a, is equal to 3.6 for root vegetables and fruit and 2.9 for leafy vegetables, grain and grasses (Napier et al. 1988, p. 4.69).

Activity concentration in a plant which results from radionuclide uptake by a plant root system, $C_{p,r}$, is calculated using the following equation (adapted from Napier et al. 1988, p. 4.67):

$$C_{p,r} = \frac{C_s}{\rho_s} F_{s\to p}\, DW \qquad \text{(Eq. I-7)}$$

where

$C_{p,r}$ – activity concentration in a plant from root uptake ($Bq\ kg^{-1}$)
ρ_s – surface soil density ($kg\ m^{-2}$)
$F_{s\to p}$ – radionuclide soil-to-plant transfer factor ($Bq\ kg^{-1}{}_{dry\ plant}$ per $Bq\ kg^{-1}{}_{dry\ soil}$)

Total activity concentration in a plant, C_p, is the sum of deposition on plant surfaces and root uptake contributions (adapted from Napier et al. 1988, , p. 4.68):

$$C_p = C_{p,d} + C_{p,r} \qquad \text{(Eq. I-8)}$$

where

C_p – total activity concentration in a plant ($Bq\ kg^{-1}$)

Activity concentration of ^{14}C in plants was calculated using a different method (Napier et al. 1988, p. 4.86). It was assumed that the specific activity of ^{14}C in an environmental medium, such as a plant, was the same as that of the contaminating medium. The fractional content of carbon in a plant was then used to compute the concentration of ^{14}C in the food product under consideration. The following equation was used to determine ^{14}C activity concentration in plants (Napier et al. 1988, p. 4.86):

$$C_p = \frac{25.4 \times 12\, C_w I}{ID\ \lambda_I\ \rho_s} \times \frac{0.1}{0.01} \times FC_p \qquad \text{(Eq. I-9)}$$

where

0.1 – the assumed uptake of 10 ercents of plant carbon from soil
0.01 – the average fraction of soil that is carbon

FC_p – fraction of carbon in a plant

The assumption of uptake of 10 percent of plant carbon from the soil is conservative because plants acquire almost all of their carbon from the air (Napier et al. 1988, p. 4.86).

I.1.4 Radionuclide Concentration in Animal Products

Radionuclide transfer to animal products results from the ingestion of contaminated feed and contaminated water by the animal. Animal products considered include meat (beef and pork), milk, poultry, and eggs. Determination of radionuclide concentrations in animal products begins with the calculation of radionuclide concentrations in fresh forage and stored feed, C_f, using formulas similar to those described in Section I.1.3, but with parameter values characteristic of crops grown for animal consumption. Once the concentrations of radionuclides in fresh forage and stored feed were determined, the daily radionuclide intake by the animal is calculated which is then converted to the radionuclide concentration in animal product, C_{ap}, using the following formula (adapted from Napier et al. 1988, p. 4.70-4.72):

$$C_{ap} = \left(C_w \; CR_{a,w} + C_f \; CR_{a,f}\right) F_{ad \to ap} \qquad \text{(Eq. I-10)}$$

where

C_{ap} – radionuclide concentration in animal product (Bq kg^{-1} or Bq L^{-1})
$CR_{a,w}$ – animal consumption rate of water (L d^{-1})
C_f – activity concentration in fresh forage or stored feed (Bq kg^{-1})
$CR_{a,f}$ – animal consumption rate of fresh forage or stored feed (kg d^{-1})
$F_{ad \to ap}$ – radionuclide transfer factor from animal diet to animal product (d kg^{-1} or d L^{-1})

The concentration of ^{14}C in animal products is calculated using the following formula (Napier et al. 1988, p. 4.89):

$$C_{ap} = \frac{C_f \; CR_{a,f} + C_w CR_{a,w}}{FC_f \; CR_{a,f} + FC_w CR_{a,w}} \; FC_{ap} \qquad \text{(Eq. I-11)}$$

where

FC_{ap} – fraction of carbon in animal product
FC_f – fraction of carbon in animal feed

I.1.5 Radionuclide Concentration in Aquatic Food

The concentration of radionuclides in fish, C_f, is calculated using the following formula:

$$C_f = C_w \; BF \qquad \text{(Eq. I-12)}$$

where

BF – bioaccumulation factor in fish (Bq kg^{-1} per Bq L^{-1})

I.2 DOSE ASSESSMENT

Radiation doses to humans may result from internal intake of radionuclides by inhalation or ingestion or from external exposure to radionuclides present in the environment. Dose assessment in GENII-S is carried out by considering radionuclide concentrations in environmental media, factoring in human exposure conditions, and performing the conversion of exposure to dose. For internal exposure, radionuclide activity intake is calculated by combining the radioactivity concentration in environmental media (e.g., food, soil, air, and water) with the amount of environmental medium taken into the body. Then, using dosimetric models, radionuclide intake is converted into dose. To assess exposure from external sources, GENII-S uses dose coefficients that convert radionuclide concentrations in environmental media to doses for the duration of exposure.

Dose calculations performed by GENII-S are based on methods developed in ICRP-30 (ICRP 1979, ICRP 1980, ICRP 1981). The code calculates incremental organ dose equivalents for each year following an initial radionuclide intake. Committed dose equivalent (50-year organ dose following an intake) is then assembled from incremental dose equivalents to each organ over the commitment period. Committed effective dose equivalent is then calculated by producing a sum of the organ dose equivalents weighted by organ/tissue weighting factors.

Conceptually, calculation of doses from internally deposited radionuclides, D_{int}, can be considered as if the following relationship were used (adapted from Napier et al. 1988, pp. 4.63, 4.69, 4.72):

$$D_{\mathrm{int}} = IN \times DCF \qquad \text{(Eq. I-13)}$$

where

D_{int} – dose from annual radionuclide intake (Sv)
IN – annual radionuclide intake by inhalation or by ingestion (Bq)
DCF_{in} – dose conversion factor for internal radionuclide intake by inhalation or ingestion (Sv Bq^{-1})

Dose calculated as above is expressed in terms of committed effective dose equivalent (CEDE). To convert dose expressed in sieverts to rems, dose in sieverts should be multiplied by 100.

Annual intake, IN, is a product of activity concentration in a medium and the amount of this medium taken internally over one year. For annual intake with food, activity concentration in a food product is multiplied by the annual consumption rate for this food; for annual intake with water, activity concentration in water gets combined with the annual consumption rate of water; for inadvertent soil ingestion, activity concentration in soil is multiplied by the amount of soil ingested annually. To calculate intake by inhalation, the activity concentration in air is multiplied by the breathing rate and the amount of time a person is exposed to a given activity concentration in air.

GENII-S calculates the radiation doses from external exposures by considering radionuclide concentrations in soil or air and the duration of exposure to soil and air and combining them with dose coefficients to calculate radiation doses. For example, annual doses from external exposure, D_{ext}, to radionuclides in soil were calculated using the following relationship (adapted from Napier et al. 1988, pp. 4.84):

$$D_{ext} = C_{s,v} \; T_{ext} \, DCF_{soil} \qquad \text{(Eq. I-14)}$$

where

D_{ext} – annual dose from external exposure (Sv)
$C_{s,v}$ – activity concentration in soil per unit volume (Bq m^{-3})
T_{ext} – duration of external exposure to contaminated soil (h)
DCF_{soil} – dose coefficient for exposure to soil contaminated to a depth of 15 cm from FGR 12, (MO9912SPASUB02.001) (Eckerman and Ryman 1993) (Sv s^{-1} per Bq m^{-3})

Dose calculated as above is expressed in terms of effective dose equivalent (EDE).

Doses from exposure to internally deposited radionuclides are combined with doses from external irradiation to produce total all-pathway doses.

$$D_{tot} = D_{\text{int}} + D_{ext} \qquad \text{(Eq. I-15)}$$

where

D_{tot} – total dose (Sv)

Total dose, calculated using Eq. I-15 is expressed in terms of total effective dose equivalent (TEDE).

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ATTACHMENT II

BIOSPHERE MODEL VALIDATION

ATTACHMENT II

BIOSPHERE MODEL VALIDATION

II.1 INTRODUCTION

The biosphere system is the link between the geosphere system and the receptor and it is represented by the biosphere conceptual model. Typical scope of biosphere modeling includes the migration and accumulation of radionuclides in the biosphere and the evaluation of the potential radiological impacts on a human receptor. The specific case of the biosphere modeling for the potential repository at Yucca Mountain, described herein, differs from the conventional approach. The biosphere conceptual model in this case is limited to consideration of biosphere transport, and human intake and exposure, resulting from a unit of activity concentration present at the contamination source, such as groundwater. The model does not include evaluation of radiological impact or assessment of doses; it provides dose factors, called biosphere dose conversion factors (BDCFs), that enable such evaluations or assessments that are carried out in the TSPA model.

The biosphere system can be conceived as a set of specific biotic and abiotic components of the accessible environment and the relationships between these components. Typically, construction of the conceptual model of the biosphere is based on developing assumptions and hypotheses regarding these characteristics. This is followed by constructing a logical and comprehensive framework that combines those assumptions and hypotheses with relevant scientific understanding to enable calculations of radiological impact. The attention, therefore, is focused on the characteristics of the environment that are important from the perspective of contributing to BDCFs for exposure scenarios under consideration. The biosphere conceptual model constructed for the potential repository is representative of a reference biosphere system delineated by the proposed rules and the interim guidance (64 FR 46976, Section III.B.6; 64 FR 8640, 63.115; Dyer 1999, Section 115).

II.1.1 Description of Conceptual Model

The biosphere conceptual model for the region around Yucca Mountain consists of assumptions, simplifications, and idealizations that describe the essential aspects of the biosphere in the vicinity of Yucca Mountain. The model is used to evaluate the transport of radionuclides released from the source of contamination throughout the biosphere to the human receptor. The receptor of interest is discussed in Section II.1.2.1.

The biosphere conceptual model provides a mechanism for the evaluation of BDCFs from selected pathways to a defined receptor. The release scenario addressed here is that of pumping contaminated groundwater to be used in a hypothetical farming community under undisturbed, or nominal, repository performance.

The biosphere conceptual model includes the following components: surface soil above the lower bounds of the plant root zone, surface water, the atmosphere, flora and fauna. In other words, the lowest boundary of the biosphere conceptual model is at the bottom of the plant root zone, and it includes all biological components that may be a part of a potential pathway of radionuclides to humans. The biosphere conceptual model does not include processes related to atmospheric transport and dispersion of airborne radionuclides. The biosphere model does consider airborne radioactivity resulting from resuspension of contaminated soil. Therefore the contribution from inhalation of resuspended contaminated soil is included in the BDCFs.

The primary function of the biosphere conceptual model is to support calculations of BDCFs. The BDCFs account for: (1) environmental transport of radionuclides by converting radionuclide concentrations at the source, such as groundwater, to concentrations in relevant biosphere media such as plants and animals; and (2) radionuclide uptake via, and external exposure to, environmental media and resulting dose factors. BDCFs are therefore functions of environmental transfer factors, exposure factors and dosimetric factors. Environmental transfer factors convert radionuclide concentrations in water to concentrations in a biosphere medium (e.g., plants, meat, milk, eggs). Exposure factors include parameters such as ingestion rate and exposure time (e.g., how much beef a receptor eats per year, how much time a receptor spends outdoors). Dosimetric factors convert internal and external exposures to radiation to doses. They account for the biological effectiveness of various types of radiation and the different sensitivities of various body tissues to radiation. Dosimetric factors are specific to each radionuclide and the mechanism by which they expose the receptor (e.g., direct radiation, ingestion, and inhalation).

The objective of the biosphere modeling effort is to determine the values of BDCFs for those radionuclides expected to enter the biosphere, considering all of the important exposure pathways. Radionuclide-specific BDCFs quantify radionuclide transport, intake and external exposure, and the resulting doses per unit of activity concentration at the source. They are calculated for a specific receptor of interest and they combine contributions from various exposure pathways, such as ingestion of food, water, inadvertent ingestion of soil, inhalation, and exposure to radionuclides external to the body.

BDCFs are multipliers, or factors, used in the TSPA model to convert radionuclide concentration at the source of contamination into radiation dose that a human receptor would receive from exposure pathways under consideration. For the groundwater contamination scenario, annual doses are estimated by multiplying radionuclide concentration in groundwater by the appropriate BDCFs.

DCFs are expressed in terms of annual dose, i.e., TEDE or CEDE, per unit of activity concentration at the source of contamination. BDCFs are independent of the actual activity concentration in groundwater. Calculations of radionuclide concentrations in groundwater are developed in the TSPA code. They are based on the mass flux break-through curves, which are summarized in the *Saturated Zone Flow and Transport PMR* (CRWMS M&O 2000q).

II.1.1.1 Model Development

The biosphere system at Yucca Mountain is represented by the reference biosphere. A starting point for biosphere conceptual model development is the requirement that "[f]eatures, 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" (64 FR 8640, Section 63.115(a)(1), Dyer 1999, Section 115). To meet this requirement, any conceptual model of the biosphere around Yucca Mountain must be based on FEPs that are reflective of current conditions. A list of FEPs that have been identified as reflective of current conditions considered applicable to the conduct of performance assessment for Yucca Mountain has been developed. FEPs that are considered applicable to biosphere modeling are shown in Table II-1.

Table II-1. Features, Events, and Processes Applicable to Biosphere

FEP NAME	YMP FEP DATABASE NUMBER
Erosion/denudation	1.2.07.01.00
Deposition	1.2.07.02.00
Climate change, global	1.3.01.00.00
Wells	1.4.07.02.00
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
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
Dwelling	2.4.07.00.00
Agricultural land use and irrigation	2.4.09.01.00
Animal farms and fisheries	2.4.09.02.00
Drinking water, foodstuffs and drugs, contaminant	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
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

For the groundwater contamination scenario, the entry point for contaminants present in groundwater into the biosphere is a groundwater well head. It is assumed that the human receptor's water supply is extracted from a groundwater well that is similar to wells that currently exist.

II.1.1.2 Conceptual Model of the Biosphere

As discussed in the previous sections, the attributes of the current biosphere model are based on a set of FEPs that conform to the proposed rules. These attributes, while sometimes appearing to be abstract, reflect the elements of a semi-arid environment in the Yucca Mountain vicinity and the possible processes leading to radionuclide transport in this environment. Generally, the reference biosphere, where the hypothetical farming community exists, is located geohydrologically downgradient from the potential repository. Therefore, it is conceivable that in the future radionuclides may be present in the groundwater at the well head used by the receptor at the location approximately 20 km south from the potential repository.

For the groundwater contamination scenario, a farmer is assumed to use contaminated groundwater for irrigation and consumption. Contaminated groundwater used for irrigation causes contamination of soil, and, subsequently, contamination of edible crops, as well as animal feed. Contaminated animal feed results in contamination of animal food products, such as milk, meat and eggs. In addition, small particles of soil contaminated by irrigation may become resuspended. Resuspended contamination, if deposited on the crops, adds to the contamination caused by irrigation with contaminated water. A person may also inhale resuspended contamination. Contaminated soil is a source of external irradiation to a person from radionuclides emitting penetrating radiation, which are either present in soil or deposited on the soil surface.

Figure 2, of this document, presents an illustrative, but not comprehensive, block diagram of the biosphere conceptual model for the groundwater contamination scenario. The figure shows important mechanisms of radionuclide migration in the biosphere from the source of contamination to the human receptor for the primary pathways relevant to the groundwater scenario. Important parameters controlling radionuclide transport in the biosphere are also identified in the diagrams.

Ingestion, inhalation and external exposure are the major exposure pathways included in the conceptual model of the biosphere. The ingestion pathway includes drinking of contaminated water, consumption of locally produced crops that have been irrigated with contaminated groundwater, consumption of meat and dairy products from livestock that have been sustained on contaminated water, and ingestion of contaminated soil. The biosphere conceptual model allows for the assumption that livestock and poultry are sustained with some quantity of locally grown feed (e.g., pasture and seasonally harvested alfalfa). Thus, these animals are exposed to the radionuclides by consuming the radionuclides present in, or on, the plant tissues. Alfalfa is the predominant crop produced by the Amargosa Valley community and alfalfa and forage grasses comprise a major proportion of Nye County agricultural land (CRWMS M&O 1998b). Another component of the ingestion pathway is the inadvertent ingestion of soil.

The primary inhalation pathway is through breathing of resuspended soil during outdoor activities such as farming and recreation. The factors that determine the degree of exposure through dust resuspension is the annual average concentration of suspended particles in air and the amount of time exposed annually to that concentration.

The external pathway occurs as a result of direct exposure to the radiation emitted by radioactive materials external to the body (e.g., those present in the soil or on the soil surface). Duration of exposures depends on the activity concentration in soil and the amount of time spent indoors and outdoors.

The magnitude of exposure from a number of pathways described above depends on the radionuclide concentration in soil. The dynamics of the radionuclide concentration in the top layer of soil are governed by a conservation equation where the rate of change in radionuclide concentration in a volume of soil is equal to the quantity flowing in from irrigation minus the amount being removed. Mechanisms of potential radionuclide removal from the soil include radioactive decay, plant uptake, leaching into the deeper soil layer and physical loss of soil during crop harvesting. Continual land use with the attendant tilling may accelerate the erosion process.

Countering the removal of radionuclides from the soil is the continual addition of radionuclides from irrigation. For a given set of parameters, continual irrigation may cause an increase in the radionuclide concentration of the soil until a steady-state equilibrium is reached. Because all primary exposure pathways (i.e., ingestion, inhalation, and external exposure) are dependent in some way on the radionuclide concentration in soil, the BDCFs will increase as a function of continuing irrigation until the radionuclide concentration equilibrium is reached in soil.

II.1.2 Exposure Scenario

An exposure scenario establishes the circumstances of human exposure to radionuclides present in the biosphere. The groundwater contamination scenario includes the conditions of undisturbed performance as well as some disruptive events and processes that may lead to groundwater contamination, such as seismic events and human intrusion. Each exposure scenario would represent a different combination of FEPs and therefore would have different exposure pathways.

The exposure scenario was defined in a two-step process. First, the geosphere-biosphere interface was defined. The radionuclide entry point to the biosphere is a well head. Second, the conditions that would lead to radionuclide intake and external exposure were determined and the applicable exposure pathways were identified based on the site-specific environment and assumptions about the human receptor group. For all exposure scenarios, present-day practices by a farming community were considered, and commercial and industrial activities were excluded. Exclusion of activities other than farming was due to the fact that farming activities involve more exposure pathways than other known activities of the region, and that the large demand for groundwater for irrigation associated with farming increases the likelihood of contamination and uptake by humans.

II.1.2.1 Groundwater Contamination Scenario

The groundwater contamination scenario is used to evaluate the radiological consequences of both an undisturbed potential repository system performance as well as the consequences of selected disruptive processes and events. The latter include potential consequences of earthquakes and igneous intrusions as well as consequences following a stylized human intrusion event. Human intrusion is assumed to result in breaching of the potential repository's geologic and engineered barriers. The event involves drilling a borehole through a degraded waste container into the aquifer underlying the Yucca Mountain site. Water infiltration through the borehole enables radionuclide transport to the saturated zone. Radionuclides may enter the biosphere when the groundwater is used by humans. For this scenario, a groundwater well head is considered the source of drinking water; irrigation; animal watering and domestic uses, including gardening.

The groundwater contamination scenario is based on proposed rules (64 FR 8640, Section 63.115; 64 FR 46976, Section 197.21) and interim guidance (Dyer 1999, Section 115) that assumes that the affected hypothetical farming community is located in the Amargosa Valley region 20 km from the potential repository at Yucca Mountain. This location represents the area closest to the potential repository, downgradient for radionuclide releases in the groundwater, where the depth of the water table is accessible for agricultural practices. Contaminated well water is the only way that radionuclides from the potential repository reach this hypothetical farming community.

The receptor of interest is an average member of the critical group. The critical group is representative of individuals from a hypothetical farming community whose behavioral characteristics will result in the highest exposures among the individuals in the community. The average member of the critical group is an adult who lives year-round at this location, uses a well as the primary water source, and otherwise has habits (e.g., consumption of locally-produced foods) that are similar to those of the current population of the Amargosa Valley.

The routes taken by radionuclides through the biosphere from the source to a person are called exposure pathways. The analysis considered pathways that are typical for a hypothetical farming community. Farming activities usually involve more exposure pathways than other human activities in the Yucca Mountain region, including ingestion through consumption of contaminated water, crops and animal products; inhalation and direct exposure from surface contamination intensified by the significant outdoor activity of a farming lifestyle.

The following exposure pathways were considered for groundwater contamination scenario:

- Consumption of tap water
- Consumption of locally produced leafy vegetables
- Consumption of other (root) locally produced vegetables
- Consumption of locally produced fruit
- Consumption of locally produced grain
- Consumption of locally produced meat (beef and pork)
- Consumption of locally produced poultry
- Consumption of locally produced milk
- Consumption of locally produced eggs
- Consumption of fish
- Inadvertent soil ingestion
- Inhalation of resuspended particulate matter
- External exposure to contaminated soil.

Pathways related to sediments and surface water were not considered because the current environment in the Yucca Mountain region lacks these features.

The contribution to a BDCF from a specific pathway depends on the amount of contamination the human receptor comes in contact with, either through intake or through external exposure. Radioactivity intake may occur through inhalation or ingestion. The magnitude of the BDCF contribution from ingestion depends on the activity concentration in consumed products and the rate of consumption of these products. The magnitude of inhalation contribution to the BDCF (e.g., from breathing resuspended soil and dust during outdoor activities, such as gardening and recreation) is influenced by the amount of resuspended particulate matter in the air, breathing rate, as well as the amount of time a person is exposed to a given concentration of radioactivity in the air. BDCF component from the external exposure pathway results from exposure to radiation sources that are external to the body, such as contaminated soil. For this pathway, the contribution depends on the amount of time a person is exposed to activity in the soil.

II.2 BIOSPHERE MODEL VALIDATION

This attachment discusses the Biosphere Model Validation which was performed and originally presented in *Evaluation of the Applicability of Biosphere-related Features, Events, and Processes (FEP)* (CRWMS M&O 2000r). A model validation discussion will not be included in the revised document. An update to the model validation due to changes in input parameters is discussed in Section II.3.

II.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 BDCFs. 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. BDCFs are expressed in units of annual dose per unit concentration in soil or water.

Application of the biosphere model to develop BDCFs is documented in two AMRs: the BDCFs for groundwater contamination (a non-disruptive event) were originally developed in *Non-Disruptive Event Biosphere Dose Conversion Factors* (CRWMS M&O 2000a), and BDCFs for an extursive igneous disruptive event (a disruptive event) were originally developed in *Disruptive Event Biosphere Dose Conversion Factor Analysis* (CRWMS M&O 2000s). The biosphere model was also used to perform sensitivity analyses for groundwater BDCFs in *Non-Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis* (CRWMS M&O 2000o), and for the disruptive event BDCFs in *Disruptive Event Biosphere Dose Conversion Factor Sensitivity Analysis* (CRWMS M&O 2000t). In addition, the model was used to support calculation of BDCF for an alternative receptor (CRWMS M&O 2000o).

II.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*.

II.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 BDCFs produced using GENII-S and the biosphere model are reasonable when compared with results of other calculations and conceptual models, and
- The YMP biosphere pathways were assessed and parameterized in a technically defensible manner.

A detailed presentation of the results of the validation method is provided in Section II.2.4.

II.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 *Software Qualification Report (SQR) GENII-S 1.485* (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 of the six test cases, 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.

II.2.3.2 Segment 2*:* Comparison of the YMP BDCFs with Results of Other GENII-S Calculations and Conceptual Models

The YMP BDCFs produced using the YMP current biosphere model, as presented in *Non-Disruptive Event Biosphere Dose Conversion Factors* (CRWMS M&O 2000a) was compared and reconciled with results of other GENII-S calculations and conceptual models (LaPlante and Poor 1997 and CRWMS M&O 1998c). 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 BDCFs 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 Criterion 2.1 was established for comparison of the YMP BDCFs with results of other calculations and conceptual models.

Criterion 2.1: For radionuclides in groundwater, differences between the YMP BDCFs 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.

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.

II.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 II.2.3 of this document. 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 FEPs 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.

II.2.4 Validation Results

II.2.4.1 Comparison of the YMP BDCFs 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 through which humans may be exposed. As a result of the DOE guidance (Dyer 1999), no alternative conceptual models were identified. Comparison of the YMP BDCFs 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 the TSPA-VA (CRWMS M&O 1998c). Although this second 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 BDCFs 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 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 BDCFs as presented in CRWMS M&O (2000q), and the two other sets of calculations, reported in LaPlante and Poor (1997) and in CRWMS M&O (1998c) was not expected for all radionuclides. 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 2000a) 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.

II.2.4.2 Comparison of Groundwater BDCFs

Table II-2 presents the BDCF values for groundwater (CRWMS M&O 2000a, Table 4) 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 II-2 shows that the groundwater YMP BDCFs 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 much better. The TSPA-VA did not provide a BDCF value for one radionuclide (^{232}U). This comparison strongly supports the finding that the validation criterion 2.1 was met.

Table II-2. Comparison of YMP BDCFs with TSPA-VA BDCFs

Radionuclide	YMP BDCF[1,2]	TSPA-VA[1,3]	YMP BDCF:TSPA-VA Ratio
^{227}Ac	1.81E+01	1.75E+01	1.03
^{241}Am	4.65E+00	4.50E+00	1.03
^{243}Am	4.64E+00	4.48E+00	1.04
^{14}C	4.06E-03	2.81E-03	1.44
^{129}I	3.61E-01	4.79E-01	0.75
^{237}Np	6.76E+00	6.57E+00	1.03
^{238}Pu	4.11E+00	3.97E+00	1.04
^{239}Pu	4.57E+00	4.41E+00	1.04
^{240}Pu	4.56E+00	4.41E+00	1.03
^{99}Tc	4.02E-03	3.14E-03	1.28
^{229}Th	4.59E+00	4.45E+00	1.03
^{232}U	1.71E+00	[4]	[4]
^{233}U	3.77E-01	3.65E-01	1.03
^{234}U	3.70E-01	3.58E-01	1.03
^{236}U	3.51E-01	3.40E-01	1.03
^{238}U	3.39E-01	3.28E-01	1.03

NOTE: [1] All values in units of mrem/y per pCi/l
[2] CRWMS M&O 2000a
[3] CRWMS M&O 1998c
[4] BDCF Value for this radionuclide not included in TSPA-VA document (CRWMS M&O 1998c).

Table II-3 presents the BDCF values for groundwater (CRWMS M&O 2000a, Table 4) 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 II-3 shows that except for the 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 II-3. Comparison of YMP BDCFs with LaPlante and Poor BDCFs

Radionuclide	YMP BDCF[1,2]	LaPlante and Poor [1,3]	YMP BDCF*:* LaPlante and Poor Ratio
^{227}Ac	1.81E+01	3.1E+01	0.58
^{241}Am	4.65E+00	7.9E+00	0.59
^{243}Am	4.64E+00	[4]	[4]
^{14}C	4.06E-03	1.9E-02	0.21
^{129}I	3.61E-01	3.1E+00	0.12
^{237}Np	6.76E+00	1.3E+01	0.52
^{238}Pu	4.11E+00	[4]	[4]
^{239}Pu	4.57E+00	1.1E-01	42
^{240}Pu	4.56E+00	1.1E-01	42
^{99}Tc	4.02E-03	8.4E-03	0.48
^{229}Th	4.59E+00	8.1E+00	0.57
^{232}U	1.71E+00	2.4E-01	7.1
^{233}U	3.77E-01	6.1E-02	6.2
^{234}U	3.70E-01	6.1E-02	6.1
^{236}U	3.51E-01	5.7E-02	6.2
^{238}U	3.39E-01	7.2E-02	4.7

NOTE: [1] All values in units of mrem/y per pCi/l
[2] CRWMS M&O 2000a
[3] LaPlante and Poor 1997
[4] 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 2000o) 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 2000a). 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 2000a) with the corresponding TSPA-VA values (CRWMS M&O 1998c) strongly supports a finding that validation criterion 2.1 was met. The comparison of the YMP groundwater BDCF (CRWMS M&O 2000a) 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.

II.2.4.3 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 was 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 was 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 was 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 was 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.

II.3 BIOSPHERE MODEL VALIDATION UPDATE

As shown in previous sections, the Biosphere model was validated. However with the revision of the related AMRs, the validation needs to be revisited to ensure that the validation is still valid. AP-3.10Q, *Analyses and Models,* does not provide any direction as to when a validated model is no longer valid. To ensure that the validation is still sufficient, the revised YMP BDCFs were compared with the results of other modeling efforts to ensure that the criteria 2.1 and 2.2 are still being satisfied.

II.3.1 Software Qualification

The GENII-S code was qualified and has not been changed so the original qualification is still valid. The original criteria 1.1 and 1.2 are still being met.

II.3.2 Comparison of the Revised YMP BDCFs with Other Modeling Efforts

When comparing the groundwater BDCFs with the TSPA-VA BDCFs for groundwater (Table II-4), except for Carbon-14 the BDCFs were within a factor of three and agree very well with the TSPA-VA values. The Carbon-14 BDCF is higher because an incorrect leaching factor was found to have been used in earlier calculation of the Carbon-14 BDCF. This comparison supports the finding that the validation criteria 2.1 continues to be met.

Table II-4. Comparison of Revised YMP BDCFs with TSPA-VA BDCFs

Radionuclide	Revised YMP BDCF[1,2]	TSPA-VA[1,3]	YMP BDCF:TSPA-VA Ratio
^{227}Ac	1.54E+01	1.75E+01	0.88
^{241}Am	3.96E+00	4.50E+00	0.88
^{243}Am	3.95E+00	4.48E+00	0.88
^{14}C	5.19E-02	2.81E-03	18
^{129}I	3.10E-01	4.79E-01	0.65
^{237}Np	5.76E+00	6.57E+00	0.88
^{238}Pu	3.50E+00	3.97E+00	0.88
^{239}Pu	3.88E+00	4.41E+00	0.88
^{240}Pu	3.88E+00	4.41E+00	0.88
^{99}Tc	3.34E-03	3.14E-03	1.1
^{229}Th	4.01E+00	4.45E+00	0.90
^{232}U	1.45E+00	[4]	[4]
^{233}U	3.19E-01	3.65E-01	0.87
^{234}U	3.13E-01	3.58E-01	0.87
^{236}U	2.97E-01	3.40E-01	0.87
^{238}U	2.86E-01	3.28E-01	0.87

NOTE: [1] All values in units of mrem/y per pCi/L
[2] Table 8 of this document
[3] CRWMS M&O 1998
[4] BDCF Value for this radionuclide not included in TSPA-VA document (CRWMS M&O 1998).

Table II-4 shows that the revised groundwater YMP BDCF agree very well with the TSPA-VA values. The greatest observed difference is a factor of 18 for Carbon-14. For the other radionuclides the agreement is very good. 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 still being met.

Table II-5 presents the Revised YMP BDCF values for groundwater from Table 8 of this document 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 II-5 shows that except for the plutonium isotopes, the groundwater YMP BDCF values agree with the values in LaPlante and Poor (1997) within a factor of about six or less. The difference in the plutonium BDCF was examined previously as discussed in Section II.2.4.2 to determine which input values might be responsible. This earlier discussion is still applicable to the current ratio input pathway parameter values. The relevant parameter values used in the two analyses are not significantly different.

Table II-5. Comparison of Revised YMP BDCFs with LaPlante and Poor BDCFs

Radionuclide	Revised YMP BDCF[1,2]	LaPlante and Poor[1,3]	YMP BDCF: LaPlante and Poor Ratio
^{227}Ac	1.54E+01	3.1E+01	0.50
^{241}Am	3.96E+00	7.9E+00	0.50
^{243}Am	3.95E+00	[4]	[4]
^{14}C	5.19E-02	1.9E-02	2.7
^{129}I	3.10E-01	3.1E+00	0.10
^{237}Np	5.76E+00	1.3E+01	0.44
^{238}Pu	3.50E+00	[4]	[4]
^{239}Pu	3.88E+00	1.1E-01	35
^{240}Pu	3.88E+00	1.1E-01	35
^{99}Tc	3.34E-03	8.4E-03	0.40
^{229}Th	4.01E+00	8.1E+00	0.50
^{232}U	1.45E+00	2.4E-01	6.0
^{233}U	3.19E-01	6.1E-02	5.2
^{234}U	3.13E-01	6.1E-02	5.1
^{236}U	2.97E-01	5.7E-02	5.2
^{238}U	2.86E-01	7.2E-02	4.0

NOTE [1] All values in units of mrem/y per pCi/L
[2] Table 8 of this document
[3] LaPlante and Poor 1997
[4] BDCF Value for this radionuclide not included in LaPlante and Poor (1997).

In the original validation the difference between the plutonium BDCF could not be understood from differences in the input parameters. The pathway contributions to the plutonium BDCF were examined to see if additional confidence in the YMP BDCF value could be gained (see Section II.2.4.2). This prior discussion is still valid.

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

The model validation holds for the evolved climate because the ratio of the evolved to current climate BDCFs ranged from 0.90 to 0.99 (see Table 13 of this document) for the 1st irrigation period. This difference is insignificant and therefore the analysis and its concludions applicable to the revised current climate BDCFs also applies to the evolved climate BDCFs.

II.3.4 Independent Reviewer

The independent reviewer, Bruce Napier, concluded that all criteria, 3-1 through 3-4, had been met in the original model validation. For the validation update the independent reviewer was not contacted since primarily only the input parameters had changed and the comparison of the revised BDCFs with both the TSPA-VA (CRWMS M&O 1998c) and LaPlante and Poor (1997) data are good as shown in Tables II-4 and II-5. The other items included in the independent review have had minimum changes. In addition, the data being used for generating the BDCFs is qualified data.

ATTACHMENT III

INGESTION EXPOSURE PARAMETERS FOR NOMINAL CASE AND EVALUATION OF CLIMATE CHANGE

ATTACHMENT III

INGESTION EXPOSURE PARAMETERS FOR NOMINAL CASE AND EVALUATION OF CLIMATE CHANGE

The data set (RIB item) *Ingestion Exposure Parameter Values* (MO0002RIB00068.000) contains values for thirteen ingestion exposure pathway parameters including: irrigation water source, drinking water treatment, crop interception fraction, water contaminated fraction, irrigation water contamination fraction, irrigation time, irrigation rate, aquatic food consideration, food yield, grow time, holdup time, storage time, dietary fraction. These parameters were developed for the current climate conditions for the Yucca Mountain (Amargosa Valley). They are necessary to calculate radionuclide-specific BDCFs. Interim guidance requires evaluation of natural climate change in the region surrounding the Yucca Mountain site (Dyer 1999, Section 114(k)). Therefore, a new set of selected ingestion exposure parameters was developed to address a cooler/wetter weather condition, using Spokane, Washington as an analogous site.

In the process, several inconsistencies were found in the AMR *Identification of Ingestion Exposure Parameters* REV 00 (CRWMS M&O 2000h) which was used to develop RIB item MO0002RIB00068.000. They are as follows:

1. The food groupings were incorrect (CRWMS M&O 2000h, Table 2). Crops such as tomatoes, cucumbers and corn were categorized as leafy vegetables, which is inconsistent with the 1997 Biosphere Food Consumption Survey (DOE 1997) and other references, such as Till and Meyer (1983, p. 5-50).
2. Corn for grain was treated similarly to sweet corn, which has a shorter growing time (CRWMS M&O 2000h, Table 1).
3. Two harvests each year for corn were considered, with planting dates conflicting with growing times (CRWMS M&O 2000h, Table 1).
4. Some crop yields were developed using different crop types than those used to develop other parameters. For example, irrigation rate for fresh feed was based on alfalfa, while crop yield for fresh feed was based on alfalfa and other hays.
5. Only one-harvest yield was considered for some vegetables, which can potentially be harvested twice (CRWMS M&O 2000h, Table 1 and Table 6).

To develop a new set of data for Spokane, WA, the current data set had to be corrected for the above inconsistencies. The new data set could then be based on the same crop grouping.

III.1 DATA SET FOR AMARGOSA VALLEY

III.1.1 Selection of Input Data Set

To correct the inconsistencies listed above new values for growing time, irrigation time, irrigation rate and crop yield were developed based on the data listed in CRWMS M&O (2000h, Table 2). These data, as shown in Table III-1 below, include growing time, irrigation rate, annual crop evapotranspiration, precipitation and annual irrigation rate for the crop of interest. Crops, such as tomatoes, cucumbers, peppers, snap beans, and peas, previously categorized as leafy vegetables, were not used in this analysis. Corn data were also corrected by using one harvest per year. Growing time of 140 days for grain corn was selected for warm desert climate as suggested by Doorenbos and Pruitt (1977, p.42). The four growing stage periods (number of days needed for crop development) for corn were 25/40/45/30. Planting time was kept at the same date as that for spring corn used in the AMR. Irrigation rate was then calculated using the methods provided in Tables 3 through 5 of the AMR (CRWMS M&O 2000h). The new data for grain corn are also listed in Table III-1

Table III-1. Summary of Selected Ingestion Exposure Parameters

Crop	Crop Type	Growing Time (day)	Irrigation Time (mo/yr)	Annual ET (in/yr)	Precipi-tation (in/yr)	Annual Irrigation (in/yr)	Annual Crop Yield [1] (kg/m^2)
Spinach	Leafy vegetable	45	3.0	22.9	0.8	28	4.4
Lettuce	Leafy vegetable	68	4.5	38.5	1.2	43	4.8
Carrots	Root vegetable	70	4.6	46.7	1.1	52	7.8-9.8
Potatoes	Root vegetable	98	3.2	42.1	0.7	47	4.1
Melons	Fruit	88	2.9	39.8	0.4	45	1.9
Grapes	Fruit	184	6.0	N/A	N/A	30	1.6-2.3
Wheat	Grain	244	8.0	53.3	3.4	56	0.3-0.7
Corn	Stored feed for poultry and eggs	140	4.6	70.1	0.8	75	0.6-0.8
Alfalfa	Fresh feed for beef and milk	46-135	12	92.7	4.0	95	1.0-1.2

Source: CRWMS M&O 2000h.

Note: [1] The values for spinach, lettuce, and carrots yields were doubled because of the double harvest.

The value of the crop yield for a specific crop was used in the calculation only if the same crop was also considered for growing time, irrigation time and irrigation rate. Most of the crop yields were taken from (CRWMS M&O 2000h, Table 6), but their values were doubled for two-harvest crops (spinach, lettuce, and carrots) to become annual crop yields. Other crop yields were taken from (CRWMS M&O 2000h, Section 6.7). Since fresh feed was determined to be the only feed for beef cattle and milk cows, as recommended in (CRWMS M&O 2000h, Section 6.11), alfalfa was selected as a representative crop, and other hay was not included. All crop yields are shown in Table III-1.

III.1.2 Ingestion Exposure Parameters for Amargosa Valley

Based on data listed in Table III-1, the four ingestion exposure parameters for eight crop categories were developed as listed in Table III-2. Due to limited data available, if there were two values available for one parameter within the same crop type, a uniform distribution was assumed between the minimum and maximum values. Otherwise, a fixed value was used for the parameter. The only exception was growing time for forage. The same distribution and values were used as the ones developed previously (CRWMS M&O 2000h, Section 6.8).

Table III-2. Summary of Developed Ingestion Parameter Values for Amargosa Valley

Parameter	Distribution	Reasonable Estimate	Minimum Value	Maximum Value
Growing Time (day):				
Leafy vegetables	uniform	57	45	68
Root vegetables	uniform	84	70	98
Fruit	uniform	136	88	184
Grain	Fixed	244	244	244
Fresh feed for beef	Triangular	47	46	135
Stored feed for poultry	Fixed	140	140	140
Fresh feed for milk	Triangular	47	46	135
Stored feed for eggs	Fixed	140	140	140
Irrigation Time (mo/yr):				
Leafy vegetables	uniform	3.8	3.0	4.5
Root vegetables	uniform	3.9	3.2	4.6
Fruit	uniform	4.5	2.9	6.0
Grain	Fixed	8.0	8.0	8.0
Fresh feed for beef	Fixed	12	12	12
Stored feed for poultry	Fixed	4.6	4.6	4.6
Fresh feed for milk	Fixed	12	12	12
Stored feed for eggs	Fixed	4.6	4.6	4.6
Irrigation Rate (in/yr)				
Leafy vegetables	uniform	36	28	43
Root vegetables	uniform	50	47	52
Fruit	uniform	38	30	45
Grain	Fixed	56	56	56
Fresh feed for beef	Fixed	95	95	95
Stored feed for poultry	Fixed	75	75	75
Fresh feed for milk	Fixed	95	95	95
Stored feed for eggs	Fixed	75	75	75
Crop Yield (kg/m^2)				
Leafy vegetables	uniform	4.6	4.4	4.8
Root vegetables	uniform	7.0	4.1	9.8
Fruit	uniform	2.0	1.6	2.3
Grain	uniform	0.5	0.3	0.7
Fresh feed for beef	uniform	1.1	1.0	1.2
Stored feed for poultry	uniform	0.7	0.6	0.8
Fresh feed for milk	uniform	1.1	1.0	1.2
Stored feed for eggs	uniform	0.7	0.6	0.8

NOTE: Parameter values developed from Table III-1

III.2 DATA SET FOR SPOKANE, WA

To evaluate the BDCFs change due to climate evolution, the impact of the cooler/wetter weather on all parameters was examined. It was determined that many ingestion exposure parameters, such as crop growing time, irrigation time, and irrigation rate, were affected by climate change.

III.2.1 Crop Growing and Irrigation Requirements

Crop irrigation requirements differ between the Spokane climate and the Amargosa Valley climate. In Amargosa Valley, irrigation is needed year-around, although irrigation rate is lower during the winter season. In Spokane, no irrigation is necessary between November and February, because the precipitation exceeds evapotranspiration (see Table III-4 for the precipitation data and Table III-5 for the evapotranspiration calculation). In addition, there are few crops growing during that period of time in Spokane.

The same crops as those used for Amargosa Valley were evaluated for Spokane. The planting period and growing time are the important data, which are used to determine the irrigation time and irrigation rate. Two references were used as a source of information on planting periods and growing times: *Usual Planting and Harvesting Dates for Washington State* (Washington Agricultural Statistics Service 1999), and the *Sunset Western Garden Book* (Hogan 1988). Based on the Washington Agricultural Statistics Service, it was found that the growing times are longer in Spokane than those in Amargosa Valley for crops such as potatoes, corn for grain, and winter wheat. Therefore, growing times for other crops, including spinach, lettuce, carrots, and melons were based on the longest number of days to harvest listed in the *Sunset Western Garden Book*.

Both grapes and alfalfa are multi-year crops. The selected growing time for grapes was 184 days, conservatively assumed to be the same value as that used for Amargosa Valley (CRWMS M&O 2000h). Growing time for alfalfa was selected as 71 days, based on three harvests during the harvest period from May 15 to October 1 (Washington Agricultural Statistics Service 1999), assuming alfalfa starts to grow in early March in Spokane. The growing time and planting period for Spokane are shown in Table III-3.

If the planting period was longer than the growing time, two harvests were assumed. Crops in this category include spinach, lettuce, and carrots, similar to the ones selected for Amargosa Valley (CRWMS M&O 2000h). Although there could be only one harvest each year for a particular crop in Spokane, it was nevertheless assumed that another crop could be planted on the same land during the available planting season in order to maximize farmland use. The use of two harvests in one year for the same crop simplifies calculation of growing period and other irrigation parameters.

Planting date was assumed to fall in the middle of the planting period for each crop, which is the same approach as the one that was used previously (CRWMS M&O 2000h, Table 1). The irrigation period was then calculated based on the planting date(s) and the growing time. However, all irrigation periods were assumed to end on October 31, under the assumption of no irrigation between November and February, as discussed above. The planting dates, irrigation periods, and irrigation times for Spokane are listed in Table III-3.

Table III-3. Crop Planting, Growing and Irrigation Schedule for Spokane

Crop	Growing Time[a] (day)	Planting Period[a]	Planting Date[b]	Irrigation period[b]	Irrigation Time[c] (mo/yr)	Notes
Spinach	50	Apr. – May	4/6 and 5/26	4/6 – 7/14	3.3	
Lettuce	95	3/24 – 8/15	4/1 and 7/5	4/1 – 10/7	6.2	
Carrots	75	4/15 – 7/30	5/1 and 7/15	5/1 – 9/27	4.9	
Potatoes	168	3/15 – 5/15	4/16	4/16 – 9/30	5.5	
Melons	95	May – June	6/1	6/1 –9/3	3.1	
Grapes	184	Perennial crop	–	5/1 – 10/31	6.0	
Wheat, winter	312 (191)	9/1 – 10/30	10/1	10/1-10/31 3/1 – 8/7	6.2	No irrigation Nov.-Feb.
Corn for grain	179	4/15 – 6/5	5/11	5/11– 10/31	5.7	No irrigation after Oct.
Alfalfa	71	Perennial crop	–	3/1 – 10/1	7.0	

NOTES: [a] Washington Agricultural Statistics Service (1992) or Hogan (1988)
[b] Date and period were developed based on the growing time and plant period in the same table
[c] Values were converted from the irrigation period in the same table

Crop yields for Spokane were assumed to be the same as the ones for the Amargosa Valley, except for alfalfa, because it has only three harvests, and a shorter growing season in Spokane. An alfalfa yield of 0.5 kg/m^2 for Spokane was taken from Washington Agricultural Statistics Service (1992). In addition, this reference confirmed that some crop yields for Spokane were very close to the ones for the Amargosa Valley. For example, the yields of winter wheat, potatoes, and lettuce for Spokane were 0.5 kg/m^2, 4.6 kg/m^2 and 2.2 kg/m^2 (Washington Agricultural Statistics Service 1992) as compared with 0.3-0.7 kg/m^2, 4.1 kg/m^2 and 2.2 kg/m^2, respectively, for the Amargosa Valley (CRWMS M&O 2000h, Section 6.7).

III.2.2 Calculation of Reference Crop Evapotranspiration

To calculate the monthly average reference crop evapotranspiration, meteorological data are needed. The meteorological station selected was WBAN 24157 in Spokane, WA. The 30 year average meteorological data, including temperature, possible sunshine, relative humidity, precipitation, and wind speed were taken from the Western Regional Climate Center (1997). These monthly data are listed in Table III-4.

The temperature was converted to degrees Celsius (°C). Average monthly relative humidity was calculated using the four provided values at six hour intervals through the day. Average monthly wind speed was converted to meters per second (m/s).

Table III-4. Average Monthly Meteorological Data for Spokane, WA

Month	Average Monthly Temperature (°C)	Average Monthly Sunshine n/N	Average Monthly Relative Humidity (%)	Average Monthly Precipitation (in/mo)	Average Monthly Wind Speed (m/s)
January	-2.7	0.28	83	1.98	3.9
February	0.7	0.41	79	1.49	4.1
March	3.7	0.55	69	1.49	4.3
April	7.7	0.61	61	1.18	4.5
May	12.2	0.65	58	1.41	4.1
June	16.7	0.67	55	1.26	4.2
July	20.4	0.80	45	0.67	3.8
August	20.2	0.78	45	0.72	3.7
September	14.9	0.72	53	0.73	3.7
October	8.5	0.55	66	0.99	3.7
November	1.7	0.29	83	2.15	3.9
December	-2.3	0.23	86	2.42	3.9

Source: Western Regional Climate Center (1997)

Reference crop evapotranspiration was calculated using the radiation method suggested by Doorenbos and Pruitt (1977, Section 1.2). The Jensen-Haise method, previously used to estimate reference crop evapotranspiration (CRWMS M&O 2000h), was considered less applicable to semiarid and subhumid climates (Martin et al. 1991, p. 334). The radiation method, selected from among the four methods shown in Doorenbos and Pruitt (1977, Section 1), was determined to be the best method based on the available meteorological data. The calculation formula can be expressed as:

$$ET_0 = c\,(W \times Rs) = c \times ET \qquad \text{(Eq. III-1)}$$

where:

ET_0 – reference crop evapotranspiration in mm/day for the periods considered.

c – adjustment factor which depends on mean relative humidity and wind speed from Figure 2 in the Doorenbos and Pruitt (1977, p.14). Three different relative humidity cases with wind speed of 2 – 5 m/s were used in the calculation:

(II) RHmean = 40-55%: $ET_0 = 1.04\ ET - 0.4$ (Eq. III-2)

(III) RHmean = 55-70%: $ET_0 = 1.00\ ET - 0.6$ (Eq. III-3)

(IV) RHmean > 70%: $ET_0 = 0.87\ ET - 0.4$ (Eq. III-4)

W – weighting factor which depends on temperature and altitude. Values of W can be obtained from Table 4 in the Doorenbos and Pruitt (1977, p.13) based on measured temperature and 718 m altitude for Spokane.

Rs – solar radiation in units equivalent to evapotranspiration in mm/day, which can be calculated as:

$$Rs = (0.25 + 0.5\ n/N)\ Ra \qquad \text{(Eq. III-5)}$$

where:

Ra – extra terrestrial radiation (mm/day) as a function of latitude, values of *Ra* can be obtained from Table III-3 in the Doorenbos and Pruitt (1977, p.12) based on 48° northern latitude for Spokane.

n/N – ratio of actual measured bright sunshine to maximum possible sunshine, values of *n/N* can be obtained from average monthly possible sunshine measured in Spokane.

ET – evapotranspiration value calculated from $W \times Rs$

Table III-5. Reference Crop Evapotranspiration Calculation Using Radiation Method

Month	Ra Values for 48° Latitude [a] (mm/day)	W Values for 718 m and Monthly Temperature[a]	Calculated ET Values[b] (mm/day)	Conversion Formula [a]	Calculated Daily ET_0 [c] (mm/day)	Average Monthly ET_0 [d] (in/mo)
January	4.3	0.40	0.67	Eq. III-4	0.18	0.22
February	6.6	0.44	1.32	Eq. III-4	0.75	0.83
March	9.8	0.48	2.47	Eq. III-3	1.87	2.28
April	13.0	0.54	3.90	Eq. III-3	3.30	3.89
May	15.9	0.61	5.58	Eq. III-3	4.98	6.07
June	17.2	0.66	6.64	Eq. III-3	6.04	7.13
July	16.5	0.71	7.61	Eq. III-2	7.52	9.18
August	14.3	0.71	6.50	Eq. III-2	6.36	7.76
September	11.2	0.64	4.37	Eq. III-2	4.15	4.90
October	7.8	0.55	2.25	Eq. III-3	1.65	2.02
November	5.0	0.45	0.89	Eq. III-4	0.37	0.44
December	3.7	0.40	0.54	Eq. III-4	0.07	0.09

NOTES: [a] Doorenbos and Pruitt (1977)
[b] Calculated using Eq. 1 (W x Rs formula)
[c] Calculated using Equations III-1, III-2, III-3, and III-4
[d] Units of mm per day were converted to units of inch per month by multiplying the value in mm per day by the number of days in a month and dividing it by 25.4.

III.2.3 Calculation of Crop Irrigation Rate

Annual evapotranspiration value (*ET*) for each crop can be calculated based on its growing time by using reference crop evapotranspiration (ET_0). The calculation method was proposed by Doorenbos and Pruitt (1977, Section 2):

$$ET = \sum_i kc_i \times T_i \times ET_{di} \qquad \text{(Eq. III-6)}$$

where:

- ET – crop annual evapotranspiration (inch/year)
- i – index of crop growing stage (i = 1, 2, 3, 4), or index of month for alfalfa and grapes
- kc_i – crop coefficient for the growing stage
- T – length of the growing stage (day/year)
- ET_{di} – daily average reference crop evapotranspiration for the growing stage (inch/day).

Although the crop coefficients and stage lengths for all crops under consideration can be obtained from Doorenbos and Pruitt (1977, Section 2), the average recurrence interval of irrigation or significant rain for Spokane was unknown. This parameter is needed to determine crop coefficient for the first growing stage. Therefore, similar to the method used in the AMR (CRWMS M&O 2000h), one (1) was used for the crop coefficient for the first stage for all crops (except grapes and alfalfa, which will be explained later) as a conservative approach. It was recognized that once one (1) was used for crop coefficient of the first stage, the difference in crop coefficient values between stages was not very large (0.8 ~ 1.2). To simplify the calculation of crop annual evapotranspiration, it was assumed that the crop coefficient was equal to 1.1 for every stage of the plant growth. Therefore, Equation III-6 can be simplified as:

$$ET = \sum_i kc_i \times T_i \times ET_{di} = 1.1 \times \sum_j F_j \times ET_{0j} \qquad \text{(Eq. III-7)}$$

where:

- j – index of crop growing month
- F_j – fraction of the month that the crop is in its growing period (month/year)
- ET_{0i} – average monthly evapotranspiration for reference crop (inch/month), calculated in Table III-5.

The calculation of crop ET value consisted of summing reference crop ET_0 values for the growing period, and then multiplying by 1.1. The crop coefficient for alfalfa was selected at a peak value of 1.05, as a conservative approach, at the humid and moderate wind conditions for Spokane (Doorenbos and Pruitt 1977, p.45). The crop coefficient for grapes varies on a monthly basis, instead of distinct growing stages. A humid moderate wind condition was selected with crop coefficients of 0.5/0.65/0.75/0.8/0.75/0.65 for May through October, respectively.

Similar to crop annual evapotranspiration, crop annual precipitation was calculated by summing monthly precipitation during the crop growing period.

$$AP = \sum_j F_j \times PP_j \qquad \text{(Eq. III-8)}$$

where:

- AP – annual precipitation for a crop (inch/year)
- PP_j – monthly precipitation measured by local weather station (inch/month)

The calculated annual evapotranspiration and precipitation values are listed in Table III-6. The annual irrigation rate was then calculated based on 6 inches per year of deep percolation, which is the same approach as used previously (CRWMS M&O 2000h, Section 6.5), that is:

$$IR = ET - AP + DP \qquad \text{(Eq. III-9)}$$

where:

IR – crop annual irrigation rate (inch/year)
DP – deep percolation, or amount of overwatering (6 inch/year)

The calculated annual irrigation rates are shown in Table III-6.

Table III-6. Calculated Annual Crop Evapotranspiration and Precipitation Values, and Annual Irrigation Rates

Crop	Crop Type	Growing Time[a] (day)	Irrigation Time[a] (mo/y)	Annual ET[b] (in/yr)	Precipi-tation[c] (in/yr)	Annual Irrigation[d] (in/yr)	Annual Crop Yield[e] (kg/m^2)
Spinach	Leafy vegetable	50	3.3	22.7	4.0	25	4.4
Lettuce	Leafy vegetable	95	6.2	43.3	6.2	43	4.8
Carrots	Root vegetable	75	4.9	38.0	4.7	39	7.8-9.8
Potatoes	Root vegetable	168	5.5	40.7	5.4	41	4.1
Melons	Fruit	95	3.1	27.0	2.7	30	1.9
Grapes	Fruit	184	6.0	25.7	5.8	26	1.6-2.3
Wheat	Grain	191	6.2	35.6	7.2	34	0.3-0.7
Corn	Stored feed for poultry and eggs	179	5.7	38.6	5.3	39	0.6-0.8
Alfalfa	Fresh feed for beef and milk	71	7.0	43.3	7.5	42	0.5

NOTES: [a] Growing time and irrigation time were taken from Table III-3
[b] Crop annual ET were calculated using Eq. III-7
[c] Crop annual precipitation rates were calculated using Eq. III-8
[d] Crop annual irrigation rates were calculated using Eq. III-9
[e] Annual crop yields were taken from Table III-1, except alfalfa, see discussion in Section III.2.1

III.2.4 Ingestion Exposure Parameters for Spokane

Based on Table III-6, the four ingestion exposure parameters for eight crop categories were calculated for Spokane, WA, as listed in Table 7; by using the method similar to the one used to develop ingestion exposure parameters for Amargosa Valley, listed in Table III-2.

Table III-7. Summary of Four Ingestion Parameters for Spokane, WA

Parameter	Distribution	Reasonable Estimate	Minimum Value	Maximum Value
Growing Time (day):				
Leafy vegetables	Uniform	73	50	95
Root vegetables	Uniform	122	75	168
Fruit	Uniform	140	95	184
Grain	Fixed	191	191	191
Fresh feed for beef	Fixed	71	71	71
Stored feed for poultry	Fixed	179	179	179
Fresh feed for milk	Fixed	71	71	71
Stored feed for eggs	Fixed	179	179	179
Irrigation Time (mo/yr):				
Leafy vegetables	Uniform	4.8	3.3	6.2
Root vegetables	Uniform	5.2	4.9	5.5
Fruit	Uniform	4.6	3.1	6.0
Grain	Fixed	6.2	6.2	6.2
Fresh feed for beef	Fixed	7.0	7.0	7.0
Stored feed for poultry	Fixed	5.7	5.7	5.7
Fresh feed for milk	Fixed	7.0	7.0	7.0
Stored feed for eggs	Fixed	5.7	5.7	5.7
Irrigation Rate (in/yr)				
Leafy vegetables	Uniform	34	25	43
Root vegetables	Uniform	40	39	41
Fruit	Uniform	28	26	30
Grain	Fixed	34	34	34
Fresh feed for beef	Fixed	42	42	42
Stored feed for poultry	Fixed	39	39	39
Fresh feed for milk	Fixed	42	42	42
Stored feed for eggs	Fixed	39	39	39
Crop Yield (kg/m2)				
Leafy vegetables	Uniform	4.6	4.4	4.8
Root vegetables	Uniform	7.0	4.1	9.8
Fruit	Uniform	2.0	1.6	2.3
Grain	Uniform	0.5	0.3	0.7
Fresh feed for beef	Fixed	0.5	0.5	0.5
Stored feed for poultry	Uniform	0.7	0.6	0.8
Fresh feed for milk	Fixed	0.5	0.5	0.5
Stored feed for eggs	Uniform	0.7	0.6	0.8

Source: Parameter values developed from Table III-6.

III.3 DISCUSSION

Comparing Table III-7 with Table III-2, the following conclusions can be drawn:

- Crop growing times in Spokane are longer than in Amargosa Valley due to cooler weather, except for winter wheat, which was assumed not to grow during the winter.

- Most crop irrigation times in Spokane are longer than in Amargosa Valley, except for alfalfa and wheat, which do not grow during the winter.

- Irrigation rates in Spokane are 20 – 60% lower than in Amargosa Valley, except for leafy vegetables, which have comparable irrigation rates. This is because the growing requirements of leafy vegetables, especially as related to temperature, are similar for both areas, which results from different planting seasons for leafy vegetables.

- Crop yields in both areas are the same, except for alfalfa due to a shorter growing season in Spokane.

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ATTACHMENT IV

FILES GENERATED IN MODEL RUNS

ATTACHMENT IV

FILES GENERATED IN MODEL RUNS

The following file name notation was used:

File name: ABCDEFGH.*

A	N	– nominal performance
B	C	– current climate
	W	– evolved (wetter and cooler) climate
C	C	– average member of the critical group
D	1-6	– irrigation periods

EFGH notation for radionuclide name

e.g. CX14 for C-14
I129 for I-129
PU21 for Pu-241

* file extension (.inp and .flg are extensions for input files, while .out, .vec, .pti, and .txt are extensions for output files)

The model input and output files can be found in the Model Warehouse Database, DTN: MO0010MWDPBD09.006.

IV.1 GENII-S FILES FOR THE CURRENT CLIMATE

```
NCC1AC27 FLG         712  09-14-00  5:13p
NCC1AC27 INP      16,334  09-14-00  5:13p
NCC1AC27 OUT      17,636  09-14-00  5:14p
NCC1AC27 PTI       9,018  09-14-00  5:14p
NCC1AC27 TXT     150,273  09-14-00  5:15p
NCC1AC27 VEC      55,364  09-14-00  5:14p
NCC1AM21 FLG         712  09-14-00  5:15p
NCC1AM21 INP      16,334  09-14-00  5:16p
NCC1AM21 OUT      17,764  09-14-00  5:16p
NCC1AM21 PTI       9,018  09-14-00  5:16p
NCC1AM21 TXT     150,273  09-14-00  5:17p
NCC1AM21 VEC      55,364  09-14-00  5:16p
NCC1AM23 FLG         712  09-14-00  5:17p
NCC1AM23 INP      16,334  09-14-00  5:17p
NCC1AM23 OUT      17,563  09-14-00  5:18p
NCC1AM23 PTI       9,018  09-14-00  5:18p
NCC1AM23 TXT     150,273  09-14-00  5:18p
NCC1AM23 VEC      55,364  09-14-00  5:18p
```

NCC1CS17	FLG	712	09-14-00	5:18p
NCC1CS17	INP	16,334	09-14-00	5:19p
NCC1CS17	OUT	16,079	09-14-00	5:19p
NCC1CS17	PTI	9,018	09-14-00	5:19p
NCC1CS17	TXT	150,273	09-14-00	5:20p
NCC1CS17	VEC	55,364	09-14-00	5:19p
NCC1CX14	FLG	710	09-14-00	5:20p
NCC1CX14	INP	16,334	09-14-00	5:20p
NCC1CX14	OUT	16,079	09-14-00	5:20p
NCC1CX14	PTI	9,018	09-14-00	5:20p
NCC1CX14	TXT	150,273	09-14-00	5:21p
NCC1CX14	VEC	55,364	09-14-00	5:20p
NCC1I129	FLG	712	09-14-00	5:21p
NCC1I129	INP	16,334	09-14-00	5:21p
NCC1I129	OUT	16,079	09-14-00	5:22p
NCC1I129	PTI	9,018	09-14-00	5:22p
NCC1I129	TXT	150,273	09-14-00	5:22p
NCC1I129	VEC	55,364	09-14-00	5:22p
NCC1NI63	FLG	711	09-14-00	5:22p
NCC1NI63	INP	16,334	09-14-00	5:23p
NCC1NI63	OUT	16,265	09-14-00	5:23p
NCC1NI63	PTI	9,018	09-14-00	5:23p
NCC1NI63	TXT	150,273	09-14-00	5:24p
NCC1NI63	VEC	55,364	09-14-00	5:23p
NCC1NP27	FLG	712	09-14-00	5:24p
NCC1NP27	INP	16,334	09-14-00	5:24p
NCC1NP27	OUT	17,618	09-14-00	5:24p
NCC1NP27	PTI	9,018	09-14-00	5:24p
NCC1NP27	TXT	150,273	09-14-00	5:25p
NCC1NP27	VEC	55,364	09-14-00	5:24p
NCC1PA21	FLG	712	09-14-00	5:26p
NCC1PA21	INP	16,334	09-14-00	5:26p
NCC1PA21	OUT	17,837	09-14-00	5:26p
NCC1PA21	PTI	9,018	09-14-00	5:26p
NCC1PA21	TXT	150,273	09-14-00	5:27p
NCC1PA21	VEC	55,364	09-14-00	5:26p
NCC1PB20	FLG	712	09-14-00	5:27p
NCC1PB20	INP	16,334	09-14-00	5:27p
NCC1PB20	OUT	17,819	09-14-00	5:28p
NCC1PB20	PTI	9,018	09-14-00	5:28p
NCC1PB20	TXT	150,273	09-14-00	5:28p
NCC1PB20	VEC	55,364	09-14-00	5:28p
NCC1PU20	FLG	712	09-14-00	5:29p
NCC1PU20	INP	16,334	09-14-00	5:29p
NCC1PU20	OUT	17,618	09-14-00	5:29p
NCC1PU20	PTI	9,018	09-14-00	5:29p
NCC1PU20	TXT	150,273	09-14-00	5:30p
NCC1PU20	VEC	55,364	09-14-00	5:29p
NCC1PU22	FLG	712	09-14-00	5:30p
NCC1PU22	INP	16,334	09-14-00	5:30p
NCC1PU22	OUT	17,636	09-14-00	5:30p
NCC1PU22	PTI	9,018	09-14-00	5:30p
NCC1PU22	TXT	150,273	09-14-00	5:31p
NCC1PU22	VEC	55,364	09-14-00	5:30p
NCC1PU28	FLG	712	09-14-00	5:31p
NCC1PU28	INP	16,334	09-14-00	5:31p
NCC1PU28	OUT	17,618	09-14-00	5:32p

NCC1PU28	PTI	9,018	09-14-00	5:32p
NCC1PU28	TXT	150,273	09-14-00	5:32p
NCC1PU28	VEC	55,364	09-14-00	5:32p
NCC1PU29	FLG	712	09-14-00	5:33p
NCC1PU29	INP	16,334	09-14-00	5:33p
NCC1PU29	OUT	16,265	09-14-00	5:33p
NCC1PU29	PTI	9,018	09-14-00	5:33p
NCC1PU29	TXT	150,273	09-14-00	5:33p
NCC1PU29	VEC	55,364	09-14-00	5:33p
NCC1RA26	FLG	712	09-14-00	5:34p
NCC1RA26	INP	16,334	09-14-00	5:34p
NCC1RA26	OUT	18,024	09-14-00	5:34p
NCC1RA26	PTI	9,018	09-14-00	5:34p
NCC1RA26	TXT	150,273	09-14-00	5:35p
NCC1RA26	VEC	55,364	09-14-00	5:34p
NCC1SR90	FLG	711	09-14-00	5:35p
NCC1SR90	INP	16,334	09-14-00	5:35p
NCC1SR90	OUT	17,490	09-14-00	5:35p
NCC1SR90	PTI	9,018	09-14-00	5:35p
NCC1SR90	TXT	150,273	09-14-00	5:36p
NCC1SR90	VEC	55,364	09-14-00	5:35p
NCC1TC99	FLG	711	09-14-00	5:36p
NCC1TC99	INP	16,334	09-14-00	5:36p
NCC1TC99	OUT	16,265	09-14-00	5:37p
NCC1TC99	PTI	9,018	09-14-00	5:37p
NCC1TC99	TXT	150,273	09-14-00	5:37p
NCC1TC99	VEC	55,364	09-14-00	5:37p
NCC1TH20	FLG	712	09-14-00	5:39p
NCC1TH20	INP	16,334	09-14-00	5:39p
NCC1TH20	OUT	18,097	09-14-00	5:40p
NCC1TH20	PTI	9,018	09-14-00	5:40p
NCC1TH20	TXT	150,273	09-14-00	5:41p
NCC1TH20	VEC	55,364	09-14-00	5:40p
NCC1TH29	FLG	712	09-14-00	5:41p
NCC1TH29	INP	16,334	09-14-00	5:41p
NCC1TH29	OUT	17,563	09-14-00	5:41p
NCC1TH29	PTI	9,018	09-14-00	5:41p
NCC1TH29	TXT	150,273	09-14-00	5:42p
NCC1TH29	VEC	55,364	09-14-00	5:41p
NCC1U232	FLG	712	09-14-00	5:42p
NCC1U232	INP	16,334	09-14-00	5:43p
NCC1U232	OUT	18,056	09-14-00	5:43p
NCC1U232	PTI	9,018	09-14-00	5:43p
NCC1U232	TXT	150,273	09-14-00	5:44p
NCC1U232	VEC	55,364	09-14-00	5:43p
NCC1U233	FLG	712	09-14-00	5:44p
NCC1U233	INP	16,334	09-14-00	5:44p
NCC1U233	OUT	17,764	09-14-00	5:44p
NCC1U233	PTI	9,018	09-14-00	5:44p
NCC1U233	TXT	150,273	09-14-00	5:45p
NCC1U233	VEC	55,364	09-14-00	5:44p
NCC1U234	FLG	712	09-14-00	5:45p
NCC1U234	INP	16,334	09-14-00	5:45p
NCC1U234	OUT	16,265	09-14-00	5:46p
NCC1U234	PTI	9,018	09-14-00	5:46p
NCC1U234	TXT	150,273	09-14-00	5:46p
NCC1U234	VEC	55,364	09-14-00	5:46p

NCC1U236	FLG	712	09-14-00	5:46p
NCC1U236	INP	16,334	09-14-00	5:47p
NCC1U236	OUT	16,265	09-14-00	5:47p
NCC1U236	PTI	9,018	09-14-00	5:47p
NCC1U236	TXT	150,273	09-14-00	5:47p
NCC1U236	VEC	55,364	09-14-00	5:47p
NCC1U238	FLG	712	09-14-00	5:47p
NCC1U238	INP	16,334	09-14-00	5:48p
NCC1U238	OUT	17,691	09-14-00	5:48p
NCC1U238	PTI	9,018	09-14-00	5:48p
NCC1U238	TXT	150,273	09-14-00	5:49p
NCC1U238	VEC	55,364	09-14-00	5:48p
NCC2AM21	FLG	712	09-19-00	12:16p
NCC2AM21	INP	16,335	09-19-00	12:17p
NCC2AM21	OUT	17,848	09-19-00	12:17p
NCC2AM21	PTI	9,018	09-19-00	12:17p
NCC2AM21	TXT	150,273	09-19-00	12:17p
NCC2AM21	VEC	55,364	09-19-00	12:17p
NCC2AM23	FLG	712	09-14-00	7:32p
NCC2AM23	INP	16,336	09-14-00	7:32p
NCC2AM23	OUT	17,647	09-14-00	7:33p
NCC2AM23	PTI	9,018	09-14-00	7:33p
NCC2AM23	TXT	150,273	09-14-00	7:34p
NCC2AM23	VEC	55,364	09-14-00	7:33p
NCC2CS17	FLG	712	09-14-00	8:39p
NCC2CS17	INP	16,334	09-14-00	8:39p
NCC2CS17	OUT	16,163	09-14-00	7:34p
NCC2CS17	PTI	9,018	09-14-00	7:34p
NCC2CS17	TXT	150,273	09-14-00	8:39p
NCC2CS17	VEC	55,364	09-14-00	7:34p
NCC2NI63	FLG	711	09-19-00	2:00p
NCC2NI63	INP	16,335	09-19-00	2:00p
NCC2NI63	OUT	16,349	09-19-00	10:47a
NCC2NI63	PTI	9,018	09-19-00	10:47a
NCC2NI63	TXT	150,273	09-19-00	10:48a
NCC2NI63	VEC	55,364	09-19-00	10:47a
NCC2PA21	FLG	712	09-14-00	7:35p
NCC2PA21	INP	16,336	09-14-00	7:35p
NCC2PA21	OUT	17,921	09-14-00	7:36p
NCC2PA21	PTI	9,018	09-14-00	7:36p
NCC2PA21	TXT	150,273	09-14-00	7:36p
NCC2PA21	VEC	55,364	09-14-00	7:36p
NCC2PU20	FLG	712	09-19-00	11:50a
NCC2PU20	INP	16,336	09-19-00	11:51a
NCC2PU20	OUT	17,702	09-19-00	11:51a
NCC2PU20	PTI	9,018	09-19-00	11:51a
NCC2PU20	TXT	150,273	09-19-00	11:51a
NCC2PU20	VEC	55,364	09-19-00	11:51a
NCC2PU22	FLG	712	09-19-00	12:01p
NCC2PU22	INP	16,336	09-19-00	12:01p
NCC2PU22	OUT	17,720	09-19-00	12:02p
NCC2PU22	PTI	9,018	09-19-00	12:02p
NCC2PU22	TXT	150,273	09-19-00	12:02p
NCC2PU22	VEC	55,364	09-19-00	12:02p
NCC2PU29	FLG	712	09-19-00	11:39a
NCC2PU29	INP	16,336	09-19-00	11:39a
NCC2PU29	OUT	16,349	09-19-00	11:40a

NCC2PU29	PTI	9,018	09-19-00	11:40a
NCC2PU29	TXT	150,273	09-19-00	11:40a
NCC2PU29	VEC	55,364	09-19-00	11:40a
NCC2RA26	FLG	712	09-14-00	8:39p
NCC2RA26	INP	16,336	09-14-00	8:39p
NCC2RA26	OUT	18,108	09-14-00	7:37p
NCC2RA26	PTI	9,018	09-14-00	7:37p
NCC2RA26	TXT	150,273	09-14-00	8:40p
NCC2RA26	VEC	55,364	09-14-00	7:37p
NCC2SR90	FLG	711	09-19-00	2:03p
NCC2SR90	INP	16,334	09-19-00	2:03p
NCC2SR90	OUT	17,574	09-19-00	11:00a
NCC2SR90	PTI	9,018	09-19-00	11:00a
NCC2SR90	TXT	150,273	09-19-00	11:00a
NCC2SR90	VEC	55,364	09-19-00	11:00a
NCC2TH20	FLG	712	09-14-00	7:38p
NCC2TH20	INP	16,336	09-14-00	7:38p
NCC2TH20	OUT	18,181	09-14-00	7:41p
NCC2TH20	PTI	9,018	09-14-00	7:41p
NCC2TH20	TXT	150,273	09-14-00	7:41p
NCC2TH20	VEC	55,364	09-14-00	7:41p
NCC2TH29	FLG	712	09-14-00	7:41p
NCC2TH29	INP	16,336	09-14-00	7:41p
NCC2TH29	OUT	17,647	09-14-00	7:42p
NCC2TH29	PTI	9,018	09-14-00	7:42p
NCC2TH29	TXT	150,273	09-14-00	7:43p
NCC2TH29	VEC	55,364	09-14-00	7:42p
NCC2U232	FLG	712	09-19-00	11:12a
NCC2U232	INP	16,334	09-19-00	11:12a
NCC2U232	OUT	18,140	09-19-00	11:13a
NCC2U232	PTI	9,018	09-19-00	11:13a
NCC2U232	TXT	150,273	09-19-00	11:13a
NCC2U232	VEC	55,364	09-19-00	11:13a
NCC2U238	FLG	712	09-19-00	11:25a
NCC2U238	INP	16,334	09-19-00	11:25a
NCC2U238	OUT	17,775	09-19-00	11:26a
NCC2U238	PTI	9,018	09-19-00	11:26a
NCC2U238	TXT	150,273	09-19-00	11:26a
NCC2U238	VEC	55,364	09-19-00	11:26a
NCC3AM21	FLG	712	09-19-00	12:18p
NCC3AM21	INP	16,336	09-19-00	12:19p
NCC3AM21	OUT	17,848	09-19-00	12:19p
NCC3AM21	PTI	9,018	09-19-00	12:19p
NCC3AM21	TXT	150,273	09-19-00	12:20p
NCC3AM21	VEC	55,364	09-19-00	12:19p
NCC3AM23	FLG	712	09-14-00	7:43p
NCC3AM23	INP	16,336	09-14-00	7:43p
NCC3AM23	OUT	17,647	09-14-00	7:44p
NCC3AM23	PTI	9,018	09-14-00	7:44p
NCC3AM23	TXT	150,273	09-14-00	7:45p
NCC3AM23	VEC	55,364	09-14-00	7:44p
NCC3CS17	FLG	712	09-14-00	7:45p
NCC3CS17	INP	16,335	09-14-00	7:45p
NCC3CS17	OUT	16,163	09-14-00	7:46p
NCC3CS17	PTI	9,018	09-14-00	7:46p
NCC3CS17	TXT	150,273	09-14-00	7:47p
NCC3CS17	VEC	55,364	09-14-00	7:46p

NCC3NI63	FLG	711	09-19-00	2:01p
NCC3NI63	INP	16,335	09-19-00	2:01p
NCC3NI63	OUT	16,349	09-19-00	10:50a
NCC3NI63	PTI	9,018	09-19-00	10:50a
NCC3NI63	TXT	150,273	09-19-00	10:50a
NCC3NI63	VEC	55,364	09-19-00	10:50a
NCC3PA21	FLG	712	09-14-00	7:47p
NCC3PA21	INP	16,336	09-14-00	7:47p
NCC3PA21	OUT	17,921	09-14-00	7:48p
NCC3PA21	PTI	9,018	09-14-00	7:48p
NCC3PA21	TXT	150,273	09-14-00	7:48p
NCC3PA21	VEC	55,364	09-14-00	7:48p
NCC3PU20	FLG	712	09-19-00	11:52a
NCC3PU20	INP	16,336	09-19-00	11:53a
NCC3PU20	OUT	17,702	09-19-00	11:53a
NCC3PU20	PTI	9,018	09-19-00	11:53a
NCC3PU20	TXT	150,273	09-19-00	11:54a
NCC3PU20	VEC	55,364	09-19-00	11:53a
NCC3PU22	FLG	712	09-19-00	12:03p
NCC3PU22	INP	16,336	09-19-00	12:03p
NCC3PU22	OUT	17,720	09-19-00	12:04p
NCC3PU22	PTI	9,018	09-19-00	12:04p
NCC3PU22	TXT	150,273	09-19-00	12:05p
NCC3PU22	VEC	55,364	09-19-00	12:04p
NCC3PU29	FLG	712	09-19-00	11:42a
NCC3PU29	INP	16,336	09-19-00	11:42a
NCC3PU29	OUT	16,349	09-19-00	11:43a
NCC3PU29	PTI	9,018	09-19-00	11:43a
NCC3PU29	TXT	150,273	09-19-00	11:43a
NCC3PU29	VEC	55,364	09-19-00	11:43a
NCC3RA26	FLG	712	09-14-00	7:49p
NCC3RA26	INP	16,336	09-14-00	7:49p
NCC3RA26	OUT	18,108	09-14-00	7:50p
NCC3RA26	PTI	9,018	09-14-00	7:50p
NCC3RA26	TXT	150,273	09-14-00	7:50p
NCC3RA26	VEC	55,364	09-14-00	7:50p
NCC3SR90	FLG	711	09-19-00	2:04p
NCC3SR90	INP	16,334	09-19-00	2:04p
NCC3SR90	OUT	17,574	09-19-00	11:02a
NCC3SR90	PTI	9,018	09-19-00	11:02a
NCC3SR90	TXT	150,273	09-19-00	11:03a
NCC3SR90	VEC	55,364	09-19-00	11:02a
NCC3TH20	FLG	712	09-14-00	7:50p
NCC3TH20	INP	16,337	09-14-00	7:51p
NCC3TH20	OUT	18,181	09-14-00	7:55p
NCC3TH20	PTI	9,018	09-14-00	7:55p
NCC3TH20	TXT	150,273	09-14-00	7:56p
NCC3TH20	VEC	55,364	09-14-00	7:55p
NCC3TH29	FLG	712	09-14-00	7:56p
NCC3TH29	INP	16,337	09-14-00	7:56p
NCC3TH29	OUT	17,647	09-14-00	7:58p
NCC3TH29	PTI	9,018	09-14-00	7:58p
NCC3TH29	TXT	150,273	09-14-00	7:58p
NCC3TH29	VEC	55,364	09-14-00	7:58p
NCC3U232	FLG	712	09-19-00	11:15a
NCC3U232	INP	16,335	09-19-00	11:15a
NCC3U232	OUT	18,140	09-19-00	11:16a

NCC3U232	PTI	9,018	09-19-00	11:16a
NCC3U232	TXT	150,273	09-19-00	11:17a
NCC3U232	VEC	55,364	09-19-00	11:16a
NCC3U238	FLG	712	09-19-00	11:28a
NCC3U238	INP	16,335	09-19-00	11:31a
NCC3U238	OUT	17,775	09-19-00	11:31a
NCC3U238	PTI	9,018	09-19-00	11:31a
NCC3U238	TXT	150,273	09-19-00	11:32a
NCC3U238	VEC	55,364	09-19-00	11:31a
NCC4AM21	FLG	712	09-19-00	12:21p
NCC4AM21	INP	16,336	09-19-00	12:21p
NCC4AM21	OUT	17,848	09-19-00	12:22p
NCC4AM21	PTI	9,018	09-19-00	12:22p
NCC4AM21	TXT	150,273	09-19-00	12:22p
NCC4AM21	VEC	55,364	09-19-00	12:22p
NCC4AM23	FLG	712	09-14-00	7:58p
NCC4AM23	INP	16,337	09-14-00	7:59p
NCC4AM23	OUT	17,647	09-14-00	8:00p
NCC4AM23	PTI	9,018	09-14-00	8:00p
NCC4AM23	TXT	150,273	09-14-00	8:01p
NCC4AM23	VEC	55,364	09-14-00	8:00p
NCC4CS17	FLG	712	09-14-00	8:01p
NCC4CS17	INP	16,335	09-14-00	8:01p
NCC4CS17	OUT	16,163	09-14-00	8:01p
NCC4CS17	PTI	9,018	09-14-00	8:01p
NCC4CS17	TXT	150,273	09-14-00	8:02p
NCC4CS17	VEC	55,364	09-14-00	8:01p
NCC4NI63	FLG	711	09-19-00	2:01p
NCC4NI63	INP	16,335	09-19-00	2:01p
NCC4NI63	OUT	16,349	09-19-00	10:52a
NCC4NI63	PTI	9,018	09-19-00	10:52a
NCC4NI63	TXT	150,273	09-19-00	10:52a
NCC4NI63	VEC	55,364	09-19-00	10:52a
NCC4PA21	FLG	712	09-14-00	8:02p
NCC4PA21	INP	16,336	09-14-00	8:02p
NCC4PA21	OUT	17,921	09-14-00	8:04p
NCC4PA21	PTI	9,018	09-14-00	8:04p
NCC4PA21	TXT	150,273	09-14-00	8:04p
NCC4PA21	VEC	55,364	09-14-00	8:04p
NCC4PU20	FLG	712	09-19-00	11:55a
NCC4PU20	INP	16,336	09-19-00	11:55a
NCC4PU20	OUT	17,702	09-19-00	11:56a
NCC4PU20	PTI	9,018	09-19-00	11:56a
NCC4PU20	TXT	150,273	09-19-00	11:56a
NCC4PU20	VEC	55,364	09-19-00	11:56a
NCC4PU22	FLG	712	09-19-00	12:06p
NCC4PU22	INP	16,336	09-19-00	12:06p
NCC4PU22	OUT	17,720	09-19-00	12:07p
NCC4PU22	PTI	9,018	09-19-00	12:07p
NCC4PU22	TXT	150,273	09-19-00	12:07p
NCC4PU22	VEC	55,364	09-19-00	12:07p
NCC4PU29	FLG	712	09-19-00	11:44a
NCC4PU29	INP	16,336	09-19-00	11:44a
NCC4PU29	OUT	16,349	09-19-00	11:45a
NCC4PU29	PTI	9,018	09-19-00	11:45a
NCC4PU29	TXT	150,273	09-19-00	11:45a
NCC4PU29	VEC	55,364	09-19-00	11:45a

NCC4RA26	FLG	712	09-14-00	8:04p
NCC4RA26	INP	16,336	09-14-00	8:04p
NCC4RA26	OUT	18,108	09-14-00	8:05p
NCC4RA26	PTI	9,018	09-14-00	8:05p
NCC4RA26	TXT	150,273	09-14-00	8:06p
NCC4RA26	VEC	55,364	09-14-00	8:05p
NCC4SR90	FLG	711	09-19-00	11:04a
NCC4SR90	INP	16,335	09-19-00	11:04a
NCC4SR90	OUT	17,574	09-19-00	11:05a
NCC4SR90	PTI	9,018	09-19-00	11:05a
NCC4SR90	TXT	150,273	09-19-00	11:05a
NCC4SR90	VEC	55,364	09-19-00	11:05a
NCC4TH20	FLG	712	09-14-00	8:09p
NCC4TH20	INP	16,337	09-14-00	8:09p
NCC4TH20	OUT	18,181	09-14-00	8:17p
NCC4TH20	PTI	9,018	09-14-00	8:17p
NCC4TH20	TXT	150,273	09-14-00	8:18p
NCC4TH20	VEC	55,364	09-14-00	8:17p
NCC4TH29	FLG	712	09-14-00	8:40p
NCC4TH29	INP	16,337	09-14-00	8:40p
NCC4TH29	OUT	17,647	09-14-00	8:09p
NCC4TH29	PTI	9,018	09-14-00	8:09p
NCC4TH29	TXT	150,273	09-14-00	8:40p
NCC4TH29	VEC	55,364	09-14-00	8:09p
NCC4U232	FLG	712	09-19-00	11:18a
NCC4U232	INP	16,335	09-19-00	11:19a
NCC4U232	OUT	18,140	09-19-00	11:19a
NCC4U232	PTI	9,018	09-19-00	11:19a
NCC4U232	TXT	150,273	09-19-00	11:20a
NCC4U232	VEC	55,364	09-19-00	11:19a
NCC4U238	FLG	712	09-19-00	11:33a
NCC4U238	INP	16,335	09-19-00	11:33a
NCC4U238	OUT	17,775	09-19-00	11:33a
NCC4U238	PTI	9,018	09-19-00	11:33a
NCC4U238	TXT	150,273	09-19-00	11:34a
NCC4U238	VEC	55,364	09-19-00	11:33a
NCC5AM21	FLG	712	09-19-00	12:23p
NCC5AM21	INP	16,336	09-19-00	12:23p
NCC5AM21	OUT	17,848	09-19-00	12:25p
NCC5AM21	PTI	9,018	09-19-00	12:25p
NCC5AM21	TXT	150,273	09-19-00	12:25p
NCC5AM21	VEC	55,364	09-19-00	12:25p
NCC5AM23	FLG	712	09-14-00	8:18p
NCC5AM23	INP	16,337	09-14-00	8:18p
NCC5AM23	OUT	17,647	09-14-00	8:20p
NCC5AM23	PTI	9,018	09-14-00	8:20p
NCC5AM23	TXT	150,273	09-14-00	8:21p
NCC5AM23	VEC	55,364	09-14-00	8:20p
NCC5CS17	FLG	712	09-14-00	8:21p
NCC5CS17	INP	16,335	09-14-00	8:21p
NCC5CS17	OUT	16,163	09-14-00	8:21p
NCC5CS17	PTI	9,018	09-14-00	8:21p
NCC5CS17	TXT	150,273	09-14-00	8:22p
NCC5CS17	VEC	55,364	09-14-00	8:21p
NCC5NI63	FLG	711	09-19-00	2:02p
NCC5NI63	INP	16,336	09-19-00	2:02p
NCC5NI63	OUT	16,349	09-19-00	10:53a

NCC5NI63	PTI	9,018	09-19-00	10:53a
NCC5NI63	TXT	150,273	09-19-00	10:54a
NCC5NI63	VEC	55,364	09-19-00	10:53a
NCC5PA21	FLG	712	09-14-00	8:22p
NCC5PA21	INP	16,336	09-14-00	8:22p
NCC5PA21	OUT	17,921	09-14-00	8:24p
NCC5PA21	PTI	9,018	09-14-00	8:24p
NCC5PA21	TXT	150,273	09-14-00	8:25p
NCC5PA21	VEC	55,364	09-14-00	8:24p
NCC5PU20	FLG	712	09-19-00	11:57a
NCC5PU20	INP	16,336	09-19-00	11:57a
NCC5PU20	OUT	17,702	09-19-00	11:58a
NCC5PU20	PTI	9,018	09-19-00	11:58a
NCC5PU20	TXT	150,273	09-19-00	11:58a
NCC5PU20	VEC	55,364	09-19-00	11:58a
NCC5PU22	FLG	712	09-19-00	12:10p
NCC5PU22	INP	16,336	09-19-00	12:10p
NCC5PU22	OUT	17,720	09-19-00	12:11p
NCC5PU22	PTI	9,018	09-19-00	12:11p
NCC5PU22	TXT	150,273	09-19-00	12:14p
NCC5PU22	VEC	55,364	09-19-00	12:11p
NCC5PU29	FLG	712	09-19-00	11:47a
NCC5PU29	INP	16,336	09-19-00	11:47a
NCC5PU29	OUT	16,349	09-19-00	11:47a
NCC5PU29	PTI	9,018	09-19-00	11:47a
NCC5PU29	TXT	150,273	09-19-00	11:48a
NCC5PU29	VEC	55,364	09-19-00	11:47a
NCC5RA26	FLG	712	09-14-00	8:25p
NCC5RA26	INP	16,336	09-14-00	8:25p
NCC5RA26	OUT	18,108	09-14-00	8:26p
NCC5RA26	PTI	9,018	09-14-00	8:26p
NCC5RA26	TXT	150,273	09-14-00	8:27p
NCC5RA26	VEC	55,364	09-14-00	8:26p
NCC5SR90	FLG	711	09-19-00	11:06a
NCC5SR90	INP	16,335	09-19-00	11:07a
NCC5SR90	OUT	17,574	09-19-00	11:07a
NCC5SR90	PTI	9,018	09-19-00	11:07a
NCC5SR90	TXT	150,273	09-19-00	11:08a
NCC5SR90	VEC	55,364	09-19-00	11:07a
NCC5TH20	FLG	712	09-15-00	7:31a
NCC5TH20	INP	16,337	09-15-00	7:31a
NCC5TH20	OUT	18,181	09-14-00	9:43p
NCC5TH20	PTI	9,018	09-14-00	9:43p
NCC5TH20	TXT	150,273	09-15-00	7:31a
NCC5TH20	VEC	55,364	09-14-00	9:43p
NCC5TH29	FLG	712	09-14-00	8:27p
NCC5TH29	INP	16,337	09-14-00	8:28p
NCC5TH29	OUT	17,647	09-14-00	8:31p
NCC5TH29	PTI	9,018	09-14-00	8:31p
NCC5TH29	TXT	150,273	09-14-00	8:32p
NCC5TH29	VEC	55,364	09-14-00	8:31p
NCC5U232	FLG	712	09-19-00	11:21a
NCC5U232	INP	16,335	09-19-00	11:21a
NCC5U232	OUT	18,140	09-19-00	11:22a
NCC5U232	PTI	9,018	09-19-00	11:22a
NCC5U232	TXT	150,273	09-19-00	11:22a
NCC5U232	VEC	55,364	09-19-00	11:22a

NCC5U238	FLG	712	09-19-00	11:35a
NCC5U238	INP	16,335	09-19-00	11:35a
NCC5U238	OUT	17,775	09-19-00	11:36a
NCC5U238	PTI	9,018	09-19-00	11:36a
NCC5U238	TXT	150,273	09-19-00	11:36a
NCC5U238	VEC	55,364	09-19-00	11:36a
NCC6AC27	FLG	712	09-14-00	8:42p
NCC6AC27	INP	16,335	09-14-00	8:43p
NCC6AC27	OUT	17,720	09-14-00	8:43p
NCC6AC27	PTI	9,018	09-14-00	8:43p
NCC6AC27	TXT	150,273	09-14-00	8:44p
NCC6AC27	VEC	55,364	09-14-00	8:43p
NCC6AM21	FLG	712	09-14-00	8:44p
NCC6AM21	INP	16,336	09-14-00	8:44p
NCC6AM21	OUT	17,848	09-14-00	8:46p
NCC6AM21	PTI	9,018	09-14-00	8:46p
NCC6AM21	TXT	150,273	09-14-00	8:46p
NCC6AM21	VEC	55,364	09-14-00	8:46p
NCC6AM23	FLG	712	09-14-00	8:46p
NCC6AM23	INP	16,337	09-14-00	8:47p
NCC6AM23	OUT	17,647	09-14-00	8:50p
NCC6AM23	PTI	9,018	09-14-00	8:50p
NCC6AM23	TXT	150,273	09-14-00	8:51p
NCC6AM23	VEC	55,364	09-14-00	8:50p
NCC6CS17	FLG	712	09-14-00	8:51p
NCC6CS17	INP	16,335	09-14-00	8:51p
NCC6CS17	OUT	16,163	09-14-00	8:52p
NCC6CS17	PTI	9,018	09-14-00	8:52p
NCC6CS17	TXT	150,273	09-14-00	8:52p
NCC6CS17	VEC	55,364	09-14-00	8:52p
NCC6CX14	FLG	710	09-14-00	8:52p
NCC6CX14	INP	16,335	09-14-00	8:52p
NCC6CX14	OUT	16,163	09-14-00	8:53p
NCC6CX14	PTI	9,018	09-14-00	8:53p
NCC6CX14	TXT	150,273	09-14-00	8:53p
NCC6CX14	VEC	55,364	09-14-00	8:53p
NCC6I129	FLG	712	09-14-00	8:53p
NCC6I129	INP	16,334	09-14-00	8:54p
NCC6I129	OUT	16,163	09-14-00	8:54p
NCC6I129	PTI	9,018	09-14-00	8:54p
NCC6I129	TXT	150,273	09-14-00	8:54p
NCC6I129	VEC	55,364	09-14-00	8:54p
NCC6NI63	FLG	711	09-14-00	8:55p
NCC6NI63	INP	16,336	09-14-00	8:55p
NCC6NI63	OUT	16,349	09-14-00	8:55p
NCC6NI63	PTI	9,018	09-14-00	8:55p
NCC6NI63	TXT	150,273	09-14-00	8:56p
NCC6NI63	VEC	55,364	09-14-00	8:55p
NCC6NP27	FLG	712	09-14-00	8:56p
NCC6NP27	INP	16,335	09-14-00	8:56p
NCC6NP27	OUT	17,702	09-14-00	8:56p
NCC6NP27	PTI	9,018	09-14-00	8:56p
NCC6NP27	TXT	150,273	09-14-00	8:57p
NCC6NP27	VEC	55,364	09-14-00	8:56p
NCC6PA21	FLG	712	09-14-00	8:57p
NCC6PA21	INP	16,337	09-14-00	8:57p
NCC6PA21	OUT	17,921	09-14-00	9:00p

NCC6PA21	PTI	9,018	09-14-00	9:00p
NCC6PA21	TXT	150,273	09-14-00	9:01p
NCC6PA21	VEC	55,364	09-14-00	9:00p
NCC6PB20	FLG	712	09-14-00	9:01p
NCC6PB20	INP	16,335	09-14-00	9:01p
NCC6PB20	OUT	17,903	09-14-00	9:02p
NCC6PB20	PTI	9,018	09-14-00	9:02p
NCC6PB20	TXT	150,273	09-14-00	9:02p
NCC6PB20	VEC	55,364	09-14-00	9:02p
NCC6PU20	FLG	712	09-14-00	9:02p
NCC6PU20	INP	16,337	09-14-00	9:03p
NCC6PU20	OUT	17,702	09-14-00	9:03p
NCC6PU20	PTI	9,018	09-14-00	9:03p
NCC6PU20	TXT	150,273	09-14-00	9:04p
NCC6PU20	VEC	55,364	09-14-00	9:03p
NCC6PU22	FLG	712	09-14-00	9:04p
NCC6PU22	INP	16,337	09-14-00	9:04p
NCC6PU22	OUT	17,720	09-14-00	9:06p
NCC6PU22	PTI	9,018	09-14-00	9:06p
NCC6PU22	TXT	150,273	09-14-00	9:07p
NCC6PU22	VEC	55,364	09-14-00	9:06p
NCC6PU28	FLG	712	09-14-00	9:08p
NCC6PU28	INP	16,336	09-14-00	9:08p
NCC6PU28	OUT	17,702	09-14-00	9:08p
NCC6PU28	PTI	9,018	09-14-00	9:08p
NCC6PU28	TXT	150,273	09-14-00	9:09p
NCC6PU28	VEC	55,364	09-14-00	9:08p
NCC6PU29	FLG	712	09-14-00	9:09p
NCC6PU29	INP	16,337	09-14-00	9:09p
NCC6PU29	OUT	16,349	09-14-00	9:10p
NCC6PU29	PTI	9,018	09-14-00	9:10p
NCC6PU29	TXT	150,273	09-14-00	9:10p
NCC6PU29	VEC	55,364	09-14-00	9:10p
NCC6RA26	FLG	712	09-14-00	9:10p
NCC6RA26	INP	16,337	09-14-00	9:11p
NCC6RA26	OUT	18,108	09-14-00	9:12p
NCC6RA26	PTI	9,018	09-14-00	9:12p
NCC6RA26	TXT	150,273	09-14-00	9:13p
NCC6RA26	VEC	55,364	09-14-00	9:12p
NCC6SR90	FLG	711	09-14-00	9:14p
NCC6SR90	INP	16,335	09-14-00	9:14p
NCC6SR90	OUT	17,574	09-14-00	9:14p
NCC6SR90	PTI	9,018	09-14-00	9:14p
NCC6SR90	TXT	150,273	09-14-00	9:15p
NCC6SR90	VEC	55,364	09-14-00	9:14p
NCC6TC99	FLG	711	09-14-00	9:15p
NCC6TC99	INP	16,334	09-14-00	9:15p
NCC6TC99	OUT	16,349	09-14-00	9:15p
NCC6TC99	PTI	9,018	09-14-00	9:15p
NCC6TC99	TXT	150,273	09-14-00	9:16p
NCC6TC99	VEC	55,364	09-14-00	9:15p
NCC6TH20	FLG	712	09-15-00	7:31a
NCC6TH20	INP	16,337	09-15-00	7:31a
NCC6TH20	OUT	18,181	09-14-00	6:09p
NCC6TH20	PTI	9,018	09-14-00	6:09p
NCC6TH20	TXT	150,273	09-15-00	7:32a
NCC6TH20	VEC	55,364	09-14-00	6:09p

NCC6TH29	FLG	712	09-14-00	9:23p
NCC6TH29	INP	16,337	09-14-00	9:23p
NCC6TH29	OUT	17,647	09-14-00	9:29p
NCC6TH29	PTI	9,018	09-14-00	9:29p
NCC6TH29	TXT	150,273	09-14-00	9:29p
NCC6TH29	VEC	55,364	09-14-00	9:29p
NCC6U232	FLG	712	09-14-00	9:16p
NCC6U232	INP	16,335	09-14-00	9:16p
NCC6U232	OUT	18,140	09-14-00	9:17p
NCC6U232	PTI	9,018	09-14-00	9:17p
NCC6U232	TXT	150,273	09-14-00	9:18p
NCC6U232	VEC	55,364	09-14-00	9:17p
NCC6U233	FLG	712	09-14-00	9:18p
NCC6U233	INP	16,335	09-14-00	9:18p
NCC6U233	OUT	17,848	09-14-00	9:19p
NCC6U233	PTI	9,018	09-14-00	9:19p
NCC6U233	TXT	150,273	09-14-00	9:19p
NCC6U233	VEC	55,364	09-14-00	9:19p
NCC6U234	FLG	712	09-14-00	9:20p
NCC6U234	INP	16,335	09-14-00	9:20p
NCC6U234	OUT	16,349	09-14-00	9:20p
NCC6U234	PTI	9,018	09-14-00	9:20p
NCC6U234	TXT	150,273	09-14-00	9:20p
NCC6U234	VEC	55,364	09-14-00	9:20p
NCC6U236	FLG	712	09-14-00	9:21p
NCC6U236	INP	16,335	09-14-00	9:21p
NCC6U236	OUT	16,349	09-14-00	9:21p
NCC6U236	PTI	9,018	09-14-00	9:21p
NCC6U236	TXT	150,273	09-14-00	9:22p
NCC6U236	VEC	55,364	09-14-00	9:21p
NCC6U238	FLG	712	09-14-00	9:22p
NCC6U238	INP	16,335	09-14-00	9:22p
NCC6U238	OUT	17,775	09-14-00	9:23p
NCC6U238	PTI	9,018	09-14-00	9:23p
NCC6U238	TXT	150,273	09-14-00	9:23p
NCC6U238	VEC	55,364	09-14-00	9:23p

IV.2 GENII-S FILES FOR THE EVOLVED CLIMATE

NWC1AC27	FLG	712	09-15-00	8:32a
NWC1AC27	INP	16,326	09-15-00	8:33a
NWC1AC27	OUT	17,636	09-15-00	8:33a
NWC1AC27	PTI	9,018	09-15-00	8:33a
NWC1AC27	TXT	140,841	09-15-00	8:34a
NWC1AC27	VEC	50,964	09-15-00	8:33a
NWC1AM21	FLG	712	09-15-00	8:34a
NWC1AM21	INP	16,326	09-15-00	8:34a
NWC1AM21	OUT	17,764	09-15-00	8:34a
NWC1AM21	PTI	9,018	09-15-00	8:34a
NWC1AM21	TXT	140,841	09-15-00	8:35a
NWC1AM21	VEC	50,964	09-15-00	8:34a
NWC1AM23	FLG	712	09-15-00	8:35a
NWC1AM23	INP	16,326	09-15-00	8:35a
NWC1AM23	OUT	17,563	09-15-00	8:35a
NWC1AM23	PTI	9,018	09-15-00	8:35a

NWC1AM23	TXT	140,841	09-15-00	8:36a
NWC1AM23	VEC	50,964	09-15-00	8:35a
NWC1CS17	FLG	712	09-15-00	8:36a
NWC1CS17	INP	16,326	09-15-00	8:36a
NWC1CS17	OUT	16,079	09-15-00	8:37a
NWC1CS17	PTI	9,018	09-15-00	8:37a
NWC1CS17	TXT	140,841	09-15-00	8:40a
NWC1CS17	VEC	50,964	09-15-00	8:37a
NWC1CX14	FLG	710	09-15-00	8:40a
NWC1CX14	INP	16,326	09-15-00	8:40a
NWC1CX14	OUT	16,079	09-15-00	8:41a
NWC1CX14	PTI	9,018	09-15-00	8:41a
NWC1CX14	TXT	140,841	09-15-00	8:43a
NWC1CX14	VEC	50,964	09-15-00	8:41a
NWC1I129	FLG	712	09-15-00	8:44a
NWC1I129	INP	16,326	09-15-00	8:45a
NWC1I129	OUT	16,079	09-15-00	8:45a
NWC1I129	PTI	9,018	09-15-00	8:45a
NWC1I129	TXT	140,841	09-15-00	8:46a
NWC1I129	VEC	50,964	09-15-00	8:45a
NWC1NI63	FLG	711	09-15-00	8:46a
NWC1NI63	INP	16,326	09-15-00	8:46a
NWC1NI63	OUT	16,265	09-15-00	8:46a
NWC1NI63	PTI	9,018	09-15-00	8:46a
NWC1NI63	TXT	140,841	09-15-00	8:47a
NWC1NI63	VEC	50,964	09-15-00	8:46a
NWC1NP27	FLG	712	09-15-00	8:47a
NWC1NP27	INP	16,326	09-15-00	8:47a
NWC1NP27	OUT	17,618	09-15-00	8:47a
NWC1NP27	PTI	9,018	09-15-00	8:47a
NWC1NP27	TXT	140,841	09-15-00	8:48a
NWC1NP27	VEC	50,964	09-15-00	8:47a
NWC1PA21	FLG	712	09-15-00	8:48a
NWC1PA21	INP	16,326	09-15-00	8:48a
NWC1PA21	OUT	17,837	09-15-00	8:49a
NWC1PA21	PTI	9,018	09-15-00	8:49a
NWC1PA21	TXT	140,841	09-15-00	8:49a
NWC1PA21	VEC	50,964	09-15-00	8:49a
NWC1PB20	FLG	712	09-15-00	8:49a
NWC1PB20	INP	16,326	09-15-00	8:49a
NWC1PB20	OUT	17,819	09-15-00	8:50a
NWC1PB20	PTI	9,018	09-15-00	8:50a
NWC1PB20	TXT	140,841	09-15-00	8:50a
NWC1PB20	VEC	50,964	09-15-00	8:50a
NWC1PU20	FLG	712	09-15-00	8:50a
NWC1PU20	INP	16,326	09-15-00	8:51a
NWC1PU20	OUT	17,618	09-15-00	8:51a
NWC1PU20	PTI	9,018	09-15-00	8:51a
NWC1PU20	TXT	140,841	09-15-00	8:51a
NWC1PU20	VEC	50,964	09-15-00	8:51a
NWC1PU22	FLG	712	09-15-00	8:52a
NWC1PU22	INP	16,326	09-15-00	8:52a
NWC1PU22	OUT	17,636	09-15-00	8:52a
NWC1PU22	PTI	9,018	09-15-00	8:52a
NWC1PU22	TXT	140,841	09-15-00	8:53a
NWC1PU22	VEC	50,964	09-15-00	8:52a
NWC1PU28	FLG	712	09-15-00	8:53a

NWC1PU28	INP	16,326	09-15-00	8:53a
NWC1PU28	OUT	17,618	09-15-00	8:53a
NWC1PU28	PTI	9,018	09-15-00	8:53a
NWC1PU28	TXT	140,841	09-15-00	8:54a
NWC1PU28	VEC	50,964	09-15-00	8:53a
NWC1PU29	FLG	712	09-15-00	8:54a
NWC1PU29	INP	16,326	09-15-00	8:54a
NWC1PU29	OUT	16,265	09-15-00	8:54a
NWC1PU29	PTI	9,018	09-15-00	8:54a
NWC1PU29	TXT	140,841	09-15-00	8:55a
NWC1PU29	VEC	50,964	09-15-00	8:54a
NWC1RA26	FLG	712	09-15-00	8:56a
NWC1RA26	INP	16,326	09-15-00	8:56a
NWC1RA26	OUT	18,024	09-15-00	8:57a
NWC1RA26	PTI	9,018	09-15-00	8:57a
NWC1RA26	TXT	140,841	09-15-00	8:57a
NWC1RA26	VEC	50,964	09-15-00	8:57a
NWC1SR90	FLG	711	09-15-00	8:58a
NWC1SR90	INP	16,326	09-15-00	8:58a
NWC1SR90	OUT	17,490	09-15-00	8:58a
NWC1SR90	PTI	9,018	09-15-00	8:58a
NWC1SR90	TXT	140,841	09-15-00	8:59a
NWC1SR90	VEC	50,964	09-15-00	8:58a
NWC1TC99	FLG	711	09-15-00	8:59a
NWC1TC99	INP	16,326	09-15-00	8:59a
NWC1TC99	OUT	16,265	09-15-00	8:59a
NWC1TC99	PTI	9,018	09-15-00	8:59a
NWC1TC99	TXT	140,841	09-15-00	9:00a
NWC1TC99	VEC	50,964	09-15-00	8:59a
NWC1TH20	FLG	712	09-15-00	9:00a
NWC1TH20	INP	16,326	09-15-00	9:00a
NWC1TH20	OUT	18,097	09-15-00	9:01a
NWC1TH20	PTI	9,018	09-15-00	9:01a
NWC1TH20	TXT	140,841	09-15-00	9:01a
NWC1TH20	VEC	50,964	09-15-00	9:01a
NWC1TH29	FLG	712	09-15-00	9:02a
NWC1TH29	INP	16,326	09-15-00	9:02a
NWC1TH29	OUT	17,563	09-15-00	9:02a
NWC1TH29	PTI	9,018	09-15-00	9:02a
NWC1TH29	TXT	140,841	09-15-00	9:03a
NWC1TH29	VEC	50,964	09-15-00	9:02a
NWC1U232	FLG	712	09-15-00	9:03a
NWC1U232	INP	16,326	09-15-00	9:03a
NWC1U232	OUT	18,056	09-15-00	9:03a
NWC1U232	PTI	9,018	09-15-00	9:03a
NWC1U232	TXT	140,841	09-15-00	9:05a
NWC1U232	VEC	50,964	09-15-00	9:03a
NWC1U233	FLG	712	09-15-00	9:05a
NWC1U233	INP	16,326	09-15-00	9:05a
NWC1U233	OUT	17,764	09-15-00	9:05a
NWC1U233	PTI	9,018	09-15-00	9:05a
NWC1U233	TXT	140,841	09-15-00	9:06a
NWC1U233	VEC	50,964	09-15-00	9:05a
NWC1U234	FLG	712	09-15-00	9:06a
NWC1U234	INP	16,326	09-15-00	9:07a
NWC1U234	OUT	16,265	09-15-00	9:07a
NWC1U234	PTI	9,018	09-15-00	9:07a

NWC1U234	TXT	140,841	09-15-00	9:08a
NWC1U234	VEC	50,964	09-15-00	9:07a
NWC1U236	FLG	712	09-15-00	9:14a
NWC1U236	INP	16,326	09-15-00	9:14a
NWC1U236	OUT	16,265	09-15-00	9:09a
NWC1U236	PTI	9,018	09-15-00	9:09a
NWC1U236	TXT	140,841	09-15-00	9:14a
NWC1U236	VEC	50,964	09-15-00	9:09a
NWC1U238	FLG	712	09-15-00	9:11a
NWC1U238	INP	16,326	09-15-00	9:11a
NWC1U238	OUT	17,691	09-15-00	9:11a
NWC1U238	PTI	9,018	09-15-00	9:11a
NWC1U238	TXT	140,841	09-15-00	9:12a
NWC1U238	VEC	50,964	09-15-00	9:11a
NWC2AM21	FLG	712	09-19-00	1:48p
NWC2AM21	INP	16,327	09-19-00	1:49p
NWC2AM21	OUT	17,848	09-19-00	1:49p
NWC2AM21	PTI	9,018	09-19-00	1:49p
NWC2AM21	TXT	140,841	09-19-00	1:50p
NWC2AM21	VEC	50,964	09-19-00	1:49p
NWC2AM23	FLG	712	09-15-00	9:20a
NWC2AM23	INP	16,328	09-15-00	9:20a
NWC2AM23	OUT	17,647	09-15-00	9:21a
NWC2AM23	PTI	9,018	09-15-00	9:21a
NWC2AM23	TXT	140,841	09-15-00	9:22a
NWC2AM23	VEC	50,964	09-15-00	9:21a
NWC2CS17	FLG	712	09-15-00	9:22a
NWC2CS17	INP	16,326	09-15-00	9:22a
NWC2CS17	OUT	16,163	09-15-00	9:22a
NWC2CS17	PTI	9,018	09-15-00	9:22a
NWC2CS17	TXT	140,841	09-15-00	9:23a
NWC2CS17	VEC	50,964	09-15-00	9:22a
NWC2NI63	FLG	711	09-19-00	12:31p
NWC2NI63	INP	16,327	09-19-00	12:32p
NWC2NI63	OUT	16,349	09-19-00	12:32p
NWC2NI63	PTI	9,018	09-19-00	12:32p
NWC2NI63	TXT	140,841	09-19-00	12:33p
NWC2NI63	VEC	50,964	09-19-00	12:32p
NWC2PA21	FLG	712	09-15-00	9:23a
NWC2PA21	INP	16,328	09-15-00	9:23a
NWC2PA21	OUT	17,921	09-15-00	9:24a
NWC2PA21	PTI	9,018	09-15-00	9:24a
NWC2PA21	TXT	140,841	09-15-00	9:24a
NWC2PA21	VEC	50,964	09-15-00	9:24a
NWC2PU20	FLG	712	09-19-00	1:26p
NWC2PU20	INP	16,328	09-19-00	1:26p
NWC2PU20	OUT	17,702	09-19-00	1:26p
NWC2PU20	PTI	9,018	09-19-00	1:26p
NWC2PU20	TXT	140,841	09-19-00	1:27p
NWC2PU20	VEC	50,964	09-19-00	1:26p
NWC2PU22	FLG	712	09-19-00	1:36p
NWC2PU22	INP	16,328	09-19-00	1:36p
NWC2PU22	OUT	17,720	09-19-00	1:37p
NWC2PU22	PTI	9,018	09-19-00	1:37p
NWC2PU22	TXT	140,841	09-19-00	1:37p
NWC2PU22	VEC	50,964	09-19-00	1:37p
NWC2PU29	FLG	712	09-19-00	1:14p

NWC2PU29	INP	16,328	09-19-00	1:15p
NWC2PU29	OUT	16,349	09-19-00	1:15p
NWC2PU29	PTI	9,018	09-19-00	1:15p
NWC2PU29	TXT	140,841	09-19-00	1:15p
NWC2PU29	VEC	50,964	09-19-00	1:15p
NWC2RA26	FLG	712	09-15-00	9:24a
NWC2RA26	INP	16,328	09-15-00	9:24a
NWC2RA26	OUT	18,108	09-15-00	9:25a
NWC2RA26	PTI	9,018	09-15-00	9:25a
NWC2RA26	TXT	140,841	09-15-00	9:26a
NWC2RA26	VEC	50,964	09-15-00	9:25a
NWC2SR90	FLG	711	09-19-00	12:43p
NWC2SR90	INP	16,326	09-19-00	12:44p
NWC2SR90	OUT	17,574	09-19-00	12:44p
NWC2SR90	PTI	9,018	09-19-00	12:44p
NWC2SR90	TXT	140,841	09-19-00	12:45p
NWC2SR90	VEC	50,964	09-19-00	12:44p
NWC2TH20	FLG	712	09-15-00	9:26a
NWC2TH20	INP	16,328	09-15-00	9:26a
NWC2TH20	OUT	18,181	09-15-00	9:28a
NWC2TH20	PTI	9,018	09-15-00	9:28a
NWC2TH20	TXT	140,841	09-15-00	9:29a
NWC2TH20	VEC	50,964	09-15-00	9:28a
NWC2TH29	FLG	712	09-15-00	9:29a
NWC2TH29	INP	16,328	09-15-00	9:29a
NWC2TH29	OUT	17,647	09-15-00	9:30a
NWC2TH29	PTI	9,018	09-15-00	9:30a
NWC2TH29	TXT	140,841	09-15-00	9:31a
NWC2TH29	VEC	50,964	09-15-00	9:30a
NWC2U232	FLG	712	09-19-00	1:01p
NWC2U232	INP	16,326	09-19-00	1:03p
NWC2U232	OUT	18,140	09-19-00	1:04p
NWC2U232	PTI	9,018	09-19-00	1:04p
NWC2U232	TXT	140,841	09-19-00	1:05p
NWC2U232	VEC	50,964	09-19-00	1:04p
NWC3AM21	FLG	712	09-19-00	1:51p
NWC3AM21	INP	16,328	09-19-00	1:52p
NWC3AM21	OUT	17,848	09-19-00	1:52p
NWC3AM21	PTI	9,018	09-19-00	1:52p
NWC3AM21	TXT	140,841	09-19-00	1:53p
NWC3AM21	VEC	50,964	09-19-00	1:52p
NWC3AM23	FLG	712	09-15-00	9:32a
NWC3AM23	INP	16,328	09-15-00	9:32a
NWC3AM23	OUT	17,647	09-15-00	9:34a
NWC3AM23	PTI	9,018	09-15-00	9:34a
NWC3AM23	TXT	140,841	09-15-00	9:34a
NWC3AM23	VEC	50,964	09-15-00	9:34a
NWC3CS17	FLG	712	09-15-00	9:34a
NWC3CS17	INP	16,327	09-15-00	9:34a
NWC3CS17	OUT	16,163	09-15-00	9:35a
NWC3CS17	PTI	9,018	09-15-00	9:35a
NWC3CS17	TXT	140,841	09-15-00	9:35a
NWC3CS17	VEC	50,964	09-15-00	9:35a
NWC3NI63	FLG	711	09-19-00	12:34p
NWC3NI63	INP	16,327	09-19-00	12:34p
NWC3NI63	OUT	16,349	09-19-00	12:35p
NWC3NI63	PTI	9,018	09-19-00	12:35p

NWC3NI63	TXT	140,841	09-19-00	12:35p
NWC3NI63	VEC	50,964	09-19-00	12:35p
NWC3PA21	FLG	712	09-15-00	9:35a
NWC3PA21	INP	16,328	09-15-00	9:37a
NWC3PA21	OUT	17,921	09-15-00	9:38a
NWC3PA21	PTI	9,018	09-15-00	9:38a
NWC3PA21	TXT	140,841	09-15-00	9:41a
NWC3PA21	VEC	50,964	09-15-00	9:38a
NWC3PU20	FLG	712	09-19-00	1:28p
NWC3PU20	INP	16,328	09-19-00	1:28p
NWC3PU20	OUT	17,702	09-19-00	1:29p
NWC3PU20	PTI	9,018	09-19-00	1:29p
NWC3PU20	TXT	140,841	09-19-00	1:29p
NWC3PU20	VEC	50,964	09-19-00	1:29p
NWC3PU22	FLG	712	09-19-00	1:38p
NWC3PU22	INP	16,328	09-19-00	1:38p
NWC3PU22	OUT	17,720	09-19-00	1:39p
NWC3PU22	PTI	9,018	09-19-00	1:39p
NWC3PU22	TXT	140,841	09-19-00	1:40p
NWC3PU22	VEC	50,964	09-19-00	1:39p
NWC3PU29	FLG	712	09-19-00	1:16p
NWC3PU29	INP	16,328	09-19-00	1:16p
NWC3PU29	OUT	16,349	09-19-00	1:17p
NWC3PU29	PTI	9,018	09-19-00	1:17p
NWC3PU29	TXT	140,841	09-19-00	1:17p
NWC3PU29	VEC	50,964	09-19-00	1:17p
NWC3RA26	FLG	712	09-15-00	9:41a
NWC3RA26	INP	16,328	09-15-00	9:41a
NWC3RA26	OUT	18,108	09-15-00	9:42a
NWC3RA26	PTI	9,018	09-15-00	9:42a
NWC3RA26	TXT	140,841	09-15-00	9:43a
NWC3RA26	VEC	50,964	09-15-00	9:42a
NWC3SR90	FLG	711	09-19-00	12:53p
NWC3SR90	INP	16,326	09-19-00	12:53p
NWC3SR90	OUT	17,574	09-19-00	12:54p
NWC3SR90	PTI	9,018	09-19-00	12:54p
NWC3SR90	TXT	140,841	09-19-00	12:54p
NWC3SR90	VEC	50,964	09-19-00	12:54p
NWC3TH20	FLG	712	09-15-00	9:43a
NWC3TH20	INP	16,329	09-15-00	9:43a
NWC3TH20	OUT	18,181	09-15-00	9:48a
NWC3TH20	PTI	9,018	09-15-00	9:48a
NWC3TH20	TXT	140,841	09-15-00	9:49a
NWC3TH20	VEC	50,964	09-15-00	9:48a
NWC3TH29	FLG	712	09-15-00	9:49a
NWC3TH29	INP	16,329	09-15-00	9:49a
NWC3TH29	OUT	17,647	09-15-00	9:50a
NWC3TH29	PTI	9,018	09-15-00	9:50a
NWC3TH29	TXT	140,841	09-15-00	9:51a
NWC3TH29	VEC	50,964	09-15-00	9:50a
NWC3U232	FLG	712	09-19-00	1:06p
NWC3U232	INP	16,327	09-19-00	1:06p
NWC3U232	OUT	18,140	09-19-00	1:07p
NWC3U232	PTI	9,018	09-19-00	1:07p
NWC3U232	TXT	140,841	09-19-00	1:07p
NWC3U232	VEC	50,964	09-19-00	1:07p
NWC4AM21	FLG	712	09-19-00	1:54p

NWC4AM21	INP	16,328	09-19-00	1:54p
NWC4AM21	OUT	17,848	09-19-00	1:55p
NWC4AM21	PTI	9,018	09-19-00	1:55p
NWC4AM21	TXT	140,841	09-19-00	1:55p
NWC4AM21	VEC	50,964	09-19-00	1:55p
NWC4AM23	FLG	712	09-15-00	9:52a
NWC4AM23	INP	16,329	09-15-00	9:53a
NWC4AM23	OUT	17,647	09-15-00	9:54a
NWC4AM23	PTI	9,018	09-15-00	9:54a
NWC4AM23	TXT	140,841	09-15-00	9:55a
NWC4AM23	VEC	50,964	09-15-00	9:54a
NWC4CS17	FLG	712	09-15-00	9:55a
NWC4CS17	INP	16,327	09-15-00	9:55a
NWC4CS17	OUT	16,163	09-15-00	9:55a
NWC4CS17	PTI	9,018	09-15-00	9:55a
NWC4CS17	TXT	140,841	09-15-00	9:56a
NWC4CS17	VEC	50,964	09-15-00	9:55a
NWC4NI63	FLG	711	09-19-00	12:37p
NWC4NI63	INP	16,327	09-19-00	12:37p
NWC4NI63	OUT	16,349	09-19-00	12:37p
NWC4NI63	PTI	9,018	09-19-00	12:37p
NWC4NI63	TXT	140,841	09-19-00	12:38p
NWC4NI63	VEC	50,964	09-19-00	12:37p
NWC4PA21	FLG	712	09-15-00	9:56a
NWC4PA21	INP	16,328	09-15-00	9:56a
NWC4PA21	OUT	17,921	09-15-00	9:57a
NWC4PA21	PTI	9,018	09-15-00	9:57a
NWC4PA21	TXT	140,841	09-15-00	9:58a
NWC4PA21	VEC	50,964	09-15-00	9:57a
NWC4PU20	FLG	712	09-19-00	1:30p
NWC4PU20	INP	16,328	09-19-00	1:30p
NWC4PU20	OUT	17,702	09-19-00	1:31p
NWC4PU20	PTI	9,018	09-19-00	1:31p
NWC4PU20	TXT	140,841	09-19-00	1:31p
NWC4PU20	VEC	50,964	09-19-00	1:31p
NWC4PU22	FLG	712	09-19-00	1:41p
NWC4PU22	INP	16,328	09-19-00	1:41p
NWC4PU22	OUT	17,720	09-19-00	1:42p
NWC4PU22	PTI	9,018	09-19-00	1:42p
NWC4PU22	TXT	140,841	09-19-00	1:43p
NWC4PU22	VEC	50,964	09-19-00	1:42p
NWC4PU29	FLG	712	09-19-00	1:19p
NWC4PU29	INP	16,328	09-19-00	1:19p
NWC4PU29	OUT	16,349	09-19-00	1:19p
NWC4PU29	PTI	9,018	09-19-00	1:19p
NWC4PU29	TXT	140,841	09-19-00	1:20p
NWC4PU29	VEC	50,964	09-19-00	1:19p
NWC4RA26	FLG	712	09-15-00	9:58a
NWC4RA26	INP	16,328	09-15-00	9:58a
NWC4RA26	OUT	18,108	09-15-00	9:59a
NWC4RA26	PTI	9,018	09-15-00	9:59a
NWC4RA26	TXT	140,841	09-15-00	10:00a
NWC4RA26	VEC	50,964	09-15-00	9:59a
NWC4SR90	FLG	711	09-19-00	12:55p
NWC4SR90	INP	16,327	09-19-00	12:56p
NWC4SR90	OUT	17,574	09-19-00	12:56p
NWC4SR90	PTI	9,018	09-19-00	12:56p

NWC4SR90	TXT	140,841	09-19-00	12:56p
NWC4SR90	VEC	50,964	09-19-00	12:56p
NWC4TH20	FLG	712	09-15-00	10:00a
NWC4TH20	INP	16,329	09-15-00	10:00a
NWC4TH20	OUT	18,181	09-15-00	10:08a
NWC4TH20	PTI	9,018	09-15-00	10:08a
NWC4TH20	TXT	140,841	09-15-00	10:08a
NWC4TH20	VEC	50,964	09-15-00	10:08a
NWC4TH29	FLG	712	09-15-00	10:09a
NWC4TH29	INP	16,329	09-15-00	10:09a
NWC4TH29	OUT	17,647	09-15-00	10:11a
NWC4TH29	PTI	9,018	09-15-00	10:11a
NWC4TH29	TXT	140,841	09-15-00	10:11a
NWC4TH29	VEC	50,964	09-15-00	10:11a
NWC4U232	FLG	712	09-19-00	1:08p
NWC4U232	INP	16,327	09-19-00	1:08p
NWC4U232	OUT	18,140	09-19-00	1:09p
NWC4U232	PTI	9,018	09-19-00	1:09p
NWC4U232	TXT	140,841	09-19-00	1:09p
NWC4U232	VEC	50,964	09-19-00	1:09p
NWC5AM21	FLG	712	09-19-00	1:56p
NWC5AM21	INP	16,328	09-19-00	1:57p
NWC5AM21	OUT	17,848	09-19-00	1:58p
NWC5AM21	PTI	9,018	09-19-00	1:58p
NWC5AM21	TXT	140,841	09-19-00	1:59p
NWC5AM21	VEC	50,964	09-19-00	1:58p
NWC5AM23	FLG	712	09-15-00	10:13a
NWC5AM23	INP	16,329	09-15-00	10:13a
NWC5AM23	OUT	17,647	09-15-00	10:15a
NWC5AM23	PTI	9,018	09-15-00	10:15a
NWC5AM23	TXT	140,841	09-15-00	10:16a
NWC5AM23	VEC	50,964	09-15-00	10:15a
NWC5CS17	FLG	712	09-15-00	10:16a
NWC5CS17	INP	16,327	09-15-00	10:16a
NWC5CS17	OUT	16,163	09-15-00	10:16a
NWC5CS17	PTI	9,018	09-15-00	10:16a
NWC5CS17	TXT	140,841	09-15-00	10:17a
NWC5CS17	VEC	50,964	09-15-00	10:16a
NWC5NI63	FLG	711	09-19-00	12:39p
NWC5NI63	INP	16,328	09-19-00	12:39p
NWC5NI63	OUT	16,349	09-19-00	12:40p
NWC5NI63	PTI	9,018	09-19-00	12:40p
NWC5NI63	TXT	140,841	09-19-00	12:40p
NWC5NI63	VEC	50,964	09-19-00	12:40p
NWC5PA21	FLG	712	09-15-00	10:17a
NWC5PA21	INP	16,328	09-15-00	10:17a
NWC5PA21	OUT	17,921	09-15-00	10:19a
NWC5PA21	PTI	9,018	09-15-00	10:19a
NWC5PA21	TXT	140,841	09-15-00	10:19a
NWC5PA21	VEC	50,964	09-15-00	10:19a
NWC5PU20	FLG	712	09-19-00	1:32p
NWC5PU20	INP	16,328	09-19-00	1:32p
NWC5PU20	OUT	17,702	09-19-00	1:33p
NWC5PU20	PTI	9,018	09-19-00	1:33p
NWC5PU20	TXT	140,841	09-19-00	1:34p
NWC5PU20	VEC	50,964	09-19-00	1:33p
NWC5PU22	FLG	712	09-19-00	1:43p

NWC5PU22	INP	16,328	09-19-00	1:44p
NWC5PU22	OUT	17,720	09-19-00	1:45p
NWC5PU22	PTI	9,018	09-19-00	1:45p
NWC5PU22	TXT	140,841	09-19-00	1:45p
NWC5PU22	VEC	50,964	09-19-00	1:45p
NWC5PU29	FLG	712	09-19-00	1:22p
NWC5PU29	INP	16,328	09-19-00	1:22p
NWC5PU29	OUT	16,349	09-19-00	1:23p
NWC5PU29	PTI	9,018	09-19-00	1:23p
NWC5PU29	TXT	140,841	09-19-00	1:23p
NWC5PU29	VEC	50,964	09-19-00	1:23p
NWC5RA26	FLG	712	09-15-00	10:20a
NWC5RA26	INP	16,328	09-15-00	10:20a
NWC5RA26	OUT	18,108	09-15-00	10:21a
NWC5RA26	PTI	9,018	09-15-00	10:21a
NWC5RA26	TXT	140,841	09-15-00	10:22a
NWC5RA26	VEC	50,964	09-15-00	10:21a
NWC5SR90	FLG	711	09-19-00	12:57p
NWC5SR90	INP	16,327	09-19-00	12:57p
NWC5SR90	OUT	17,574	09-19-00	12:58p
NWC5SR90	PTI	9,018	09-19-00	12:58p
NWC5SR90	TXT	140,841	09-19-00	12:58p
NWC5SR90	VEC	50,964	09-19-00	12:58p
NWC5TH20	FLG	712	09-15-00	10:26a
NWC5TH20	INP	16,329	09-15-00	10:26a
NWC5TH20	OUT	18,181	09-15-00	10:38a
NWC5TH20	PTI	9,018	09-15-00	10:38a
NWC5TH20	TXT	140,841	09-15-00	10:39a
NWC5TH20	VEC	50,964	09-15-00	10:38a
NWC5TH29	FLG	712	09-15-00	10:22a
NWC5TH29	INP	16,329	09-15-00	10:22a
NWC5TH29	OUT	17,647	09-15-00	10:25a
NWC5TH29	PTI	9,018	09-15-00	10:25a
NWC5TH29	TXT	140,841	09-15-00	10:26a
NWC5TH29	VEC	50,964	09-15-00	10:25a
NWC5U232	FLG	712	09-19-00	1:11p
NWC5U232	INP	16,327	09-19-00	1:11p
NWC5U232	OUT	18,140	09-19-00	1:12p
NWC5U232	PTI	9,018	09-19-00	1:12p
NWC5U232	TXT	140,841	09-19-00	1:12p
NWC5U232	VEC	50,964	09-19-00	1:12p
NWC6AC27	FLG	712	09-15-00	10:41a
NWC6AC27	INP	16,327	09-15-00	10:41a
NWC6AC27	OUT	17,720	09-15-00	10:41a
NWC6AC27	PTI	9,018	09-15-00	10:41a
NWC6AC27	TXT	140,841	09-15-00	10:42a
NWC6AC27	VEC	50,964	09-15-00	10:41a
NWC6AM21	FLG	712	09-15-00	10:42a
NWC6AM21	INP	16,328	09-15-00	10:42a
NWC6AM21	OUT	17,848	09-15-00	10:43a
NWC6AM21	PTI	9,018	09-15-00	10:43a
NWC6AM21	TXT	140,841	09-15-00	10:44a
NWC6AM21	VEC	50,964	09-15-00	10:43a
NWC6AM23	FLG	712	09-15-00	10:44a
NWC6AM23	INP	16,329	09-15-00	10:44a
NWC6AM23	OUT	17,647	09-15-00	10:48a
NWC6AM23	PTI	9,018	09-15-00	10:48a

NWC6AM23	TXT	140,841	09-15-00	10:48a
NWC6AM23	VEC	50,964	09-15-00	10:48a
NWC6CS17	FLG	712	09-15-00	10:48a
NWC6CS17	INP	16,327	09-15-00	10:49a
NWC6CS17	OUT	16,163	09-15-00	10:49a
NWC6CS17	PTI	9,018	09-15-00	10:49a
NWC6CS17	TXT	140,841	09-15-00	10:49a
NWC6CS17	VEC	50,964	09-15-00	10:49a
NWC6CX14	FLG	710	09-15-00	10:49a
NWC6CX14	INP	16,327	09-15-00	10:50a
NWC6CX14	OUT	16,163	09-15-00	10:50a
NWC6CX14	PTI	9,018	09-15-00	10:50a
NWC6CX14	TXT	140,841	09-15-00	10:50a
NWC6CX14	VEC	50,964	09-15-00	10:50a
NWC6I129	FLG	712	09-15-00	10:50a
NWC6I129	INP	16,326	09-15-00	10:51a
NWC6I129	OUT	16,163	09-15-00	10:51a
NWC6I129	PTI	9,018	09-15-00	10:51a
NWC6I129	TXT	140,841	09-15-00	10:52a
NWC6I129	VEC	50,964	09-15-00	10:51a
NWC6NI63	FLG	711	09-15-00	10:52a
NWC6NI63	INP	16,328	09-15-00	10:52a
NWC6NI63	OUT	16,349	09-15-00	10:52a
NWC6NI63	PTI	9,018	09-15-00	10:52a
NWC6NI63	TXT	140,841	09-15-00	10:53a
NWC6NI63	VEC	50,964	09-15-00	10:52a
NWC6NP27	FLG	712	09-15-00	10:53a
NWC6NP27	INP	16,327	09-15-00	10:53a
NWC6NP27	OUT	17,702	09-15-00	10:53a
NWC6NP27	PTI	9,018	09-15-00	10:53a
NWC6NP27	TXT	140,841	09-15-00	10:54a
NWC6NP27	VEC	50,964	09-15-00	10:53a
NWC6PA21	FLG	712	09-15-00	10:54a
NWC6PA21	INP	16,329	09-15-00	10:54a
NWC6PA21	OUT	17,921	09-15-00	10:57a
NWC6PA21	PTI	9,018	09-15-00	10:57a
NWC6PA21	TXT	140,841	09-15-00	10:58a
NWC6PA21	VEC	50,964	09-15-00	10:57a
NWC6PB20	FLG	712	09-15-00	10:58a
NWC6PB20	INP	16,327	09-15-00	10:58a
NWC6PB20	OUT	17,903	09-15-00	10:58a
NWC6PB20	PTI	9,018	09-15-00	10:58a
NWC6PB20	TXT	140,841	09-15-00	10:59a
NWC6PB20	VEC	50,964	09-15-00	10:58a
NWC6PU20	FLG	712	09-15-00	10:59a
NWC6PU20	INP	16,329	09-15-00	10:59a
NWC6PU20	OUT	17,702	09-15-00	11:00a
NWC6PU20	PTI	9,018	09-15-00	11:00a
NWC6PU20	TXT	140,841	09-15-00	11:00a
NWC6PU20	VEC	50,964	09-15-00	11:00a
NWC6PU22	FLG	712	09-15-00	11:00a
NWC6PU22	INP	16,329	09-15-00	11:01a
NWC6PU22	OUT	17,720	09-15-00	11:02a
NWC6PU22	PTI	9,018	09-15-00	11:02a
NWC6PU22	TXT	140,841	09-15-00	11:03a
NWC6PU22	VEC	50,964	09-15-00	11:02a
NWC6PU28	FLG	712	09-15-00	11:03a

NWC6PU28	INP	16,328	09-15-00	11:03a
NWC6PU28	OUT	17,702	09-15-00	11:04a
NWC6PU28	PTI	9,018	09-15-00	11:04a
NWC6PU28	TXT	140,841	09-15-00	11:04a
NWC6PU28	VEC	50,964	09-15-00	11:04a
NWC6PU29	FLG	712	09-15-00	11:04a
NWC6PU29	INP	16,329	09-15-00	11:05a
NWC6PU29	OUT	16,349	09-15-00	11:05a
NWC6PU29	PTI	9,018	09-15-00	11:05a
NWC6PU29	TXT	140,841	09-15-00	11:07a
NWC6PU29	VEC	50,964	09-15-00	11:05a
NWC6RA26	FLG	712	09-15-00	11:07a
NWC6RA26	INP	16,329	09-15-00	11:07a
NWC6RA26	OUT	18,108	09-15-00	11:09a
NWC6RA26	PTI	9,018	09-15-00	11:09a
NWC6RA26	TXT	140,841	09-15-00	11:27a
NWC6RA26	VEC	50,964	09-15-00	11:09a
NWC6SR90	FLG	711	09-15-00	11:27a
NWC6SR90	INP	16,327	09-15-00	11:27a
NWC6SR90	OUT	17,574	09-15-00	11:28a
NWC6SR90	PTI	9,018	09-15-00	11:28a
NWC6SR90	TXT	140,841	09-15-00	11:28a
NWC6SR90	VEC	50,964	09-15-00	11:28a
NWC6TC99	FLG	711	09-15-00	11:28a
NWC6TC99	INP	16,326	09-15-00	11:29a
NWC6TC99	OUT	16,349	09-15-00	11:29a
NWC6TC99	PTI	9,018	09-15-00	11:29a
NWC6TC99	TXT	140,841	09-15-00	11:29a
NWC6TC99	VEC	50,964	09-15-00	11:29a
NWC6TH20	FLG	712	09-15-00	11:38a
NWC6TH20	INP	16,329	09-15-00	11:38a
NWC6TH20	OUT	18,181	09-15-00	11:57a
NWC6TH20	PTI	9,018	09-15-00	11:57a
NWC6TH20	TXT	140,841	09-15-00	12:36p
NWC6TH20	VEC	50,964	09-15-00	11:57a
NWC6TH29	FLG	712	09-15-00	12:36p
NWC6TH29	INP	16,329	09-15-00	12:37p
NWC6TH29	OUT	17,647	09-15-00	12:42p
NWC6TH29	PTI	9,018	09-15-00	12:42p
NWC6TH29	TXT	140,841	09-15-00	12:43p
NWC6TH29	VEC	50,964	09-15-00	12:42p
NWC6U232	FLG	712	09-15-00	11:30a
NWC6U232	INP	16,327	09-15-00	11:30a
NWC6U232	OUT	18,140	09-15-00	11:31a
NWC6U232	PTI	9,018	09-15-00	11:31a
NWC6U232	TXT	140,841	09-15-00	11:31a
NWC6U232	VEC	50,964	09-15-00	11:31a
NWC6U233	FLG	712	09-15-00	11:31a
NWC6U233	INP	16,327	09-15-00	11:31a
NWC6U233	OUT	17,848	09-15-00	11:32a
NWC6U233	PTI	9,018	09-15-00	11:32a
NWC6U233	TXT	140,841	09-15-00	11:32a
NWC6U233	VEC	50,964	09-15-00	11:32a
NWC6U234	FLG	712	09-15-00	11:32a
NWC6U234	INP	16,327	09-15-00	11:33a
NWC6U234	OUT	16,349	09-15-00	11:33a
NWC6U234	PTI	9,018	09-15-00	11:33a

NWC6U234	TXT	140,841	09-15-00	11:33a
NWC6U234	VEC	50,964	09-15-00	11:33a
NWC6U236	FLG	712	09-15-00	11:34a
NWC6U236	INP	16,327	09-15-00	11:34a
NWC6U236	OUT	16,349	09-15-00	11:34a
NWC6U236	PTI	9,018	09-15-00	11:34a
NWC6U236	TXT	140,841	09-15-00	11:34a
NWC6U236	VEC	50,964	09-15-00	11:34a
NWC6U238	FLG	712	09-15-00	11:35a
NWC6U238	INP	16,327	09-15-00	11:35a
NWC6U238	OUT	17,775	09-15-00	11:35a
NWC6U238	PTI	9,018	09-15-00	11:35a
NWC6U238	TXT	140,841	09-15-00	11:36a
NWC6U238	VEC	50,964	09-15-00	11:35a

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ATTACHMENT V

DETERMINATION OF PRIOR IRRIGATION PERIODS

ATTACHMENT V

DETERMINATION OF PRIOR IRRIGATION PERIODS

The prior irrigation periods were calculated using standard functions of Microsoft Excel version 97 SR-2. The calculations are documented in this attachment.

To address the effect of radionuclide buildup in soil, it was necessary to determine whether buildup caused any significant change in the BDCFs. For those radionuclides where buildup did not occur to any significant degree, the periods of irrigation that were used for the calculation were of no consequence. However, for those radionuclides where buildup was shown to be significant, an approach was required that would allow the BDCFs to be determined for an arbitrary previous irrigation period. The technique adopted to determine the functional relationship between the value of the BDCF and the duration of previous irrigation was that of curve fitting (CRWMS M&O 2000n) with subsequent use of the fitted curve for interpolation or extrapolation. To accomplish this, the BDCFs were calculated for several periods of prior irrigation times. (The period of prior irrigation represents the number of years that the land has been irrigated with contaminated water before the intake occurs.)

The technique of curve fitting does not require that BDCFs be calculated for any specific time. The only requirement is that the dependent variable (BDCFs) is calculated over the range of the variable parameter of interest (irrigation periods). Considering this, the values of irrigation periods were calculated such that the series of BDCFs would be approximately equally spaced between the value for the first period and the asymptotic value after an infinitely long period of previous irrigation. Assuming the constant addition rate of radionuclide to soil via irrigation, BDCFs are proportional to the function f:

$$f = 1 - e^{-\lambda t} \qquad \text{(Eq. V-1)}$$

where λ is the effective removal constant for each radionuclide in soil, and t is the duration of previous irrigation. The effective removal constant was approximated by the sum of the radioactive decay constant and the leaching factor. The range between the BDCF for no prior irrigation ($f = 0$) and the equilibrium value of the BDCF for an individual radionuclide ($f = 1$) was arbitrarily divided into the six equal intervals to obtain a sufficient number of data points for the future curve fitting. Then the irrigation time periods were calculated based on the effective removal rate of radionuclides from the top 15 cm of soil using the following formula:

$$t = \frac{\ln\left(\frac{1}{1-f}\right)}{\lambda} \qquad \text{(Eq. V-2)}$$

where f is the fraction of the BDCF at equilibrium. For the six irrigation time periods, f is equal to 1/6, 2/6, 3/6, 4/6, and 5/6 for the second through the sixth irrigation period, respectively. The first time period corresponds to no prior irrigation with contaminated water.

The Excel spreadsheet that was used to calculate irrigation periods is shown below.

Calculation of irrigation periods

BDCF is proportional to 1-exp(lambda * t)
where lambda is the effective removal constant, t is duration of prior irrigation
The effective removal constant is the sum of the radioactive decay constant and the leacing factor.

0.17 0.33 0.50 0.67 0.83 <----- Equally spaced intervals (one sixths)
f = 1-exp(-lambda*t) <----- Solve for t
f - fraction of equilibrium BDCF equal to 1/6, 2/6, 3/6, 4//6, and 5/6 for the six irrigation periods

t = ln(1/(1-f))/lambda <----- Equation is used to calculate irrigation periods

	Removal constant, 1/y			Irrigation periods, years				
Radionuclide	**Rad.decay**	**Leaching**	**Effective**					
Carbon-14	1.21E-04	1.32E-01	1.32E-01	1	3	5	8	14
Nickel-63	7.22E-03	1.69E-03	8.91E-03	20	46	78	123	201
Strontium-90	2.38E-02	4.47E-02	6.85E-02	3	6	10	16	26
Technetium-99	3.25E-06	2.77E+00	2.77E+00	0	0	0	0	1
Iodine-129	4.41E-08	5.92E-01	5.92E-01	0	1	1	2	3
Cesium-137	2.31E-02	2.42E-03	2.55E-02	7	16	27	43	70
Lead-210	3.11E-02	2.51E-03	3.36E-02	5	12	21	33	53
Radium-226	4.33E-04	1.35E-03	1.78E-03	102	227	389	616	1005
Actinium-227	3.18E-02	1.50E-03	3.33E-02	5	12	21	33	54
Thorium-229	9.44E-05	2.12E-04	3.06E-04	595	1323	2262	3586	5848
Thorium-230	9.00E-06	2.12E-04	2.21E-04	825	1835	3136	4971	8108
Protactinium-231	2.12E-05	1.23E-03	1.25E-03	146	324	554	878	1432
Uranium-232	9.63E-03	1.93E-02	2.89E-02	6	14	24	38	62
Uranium-233	4.37E-06	1.93E-02	1.93E-02	9	21	36	57	93
Uranium-234	2.83E-06	1.93E-02	1.93E-02	9	21	36	57	93
Uranium-236	2.96E-08	1.93E-02	1.93E-02	9	21	36	57	93
Uranium-238	1.55E-10	1.93E-02	1.93E-02	9	21	36	57	93
Neptunium-237	3.24E-07	1.32E-01	1.32E-01	1	3	5	8	14
Plutonium-238	7.90E-03	1.23E-03	9.13E-03	20	44	76	120	196
Plutonium-239	2.88E-05	1.23E-03	1.26E-03	145	322	551	873	1423
Plutonium-240	1.06E-04	1.23E-03	1.34E-03	136	304	519	822	1341
Plutonium-242	1.84E-06	1.23E-03	1.23E-03	148	329	563	892	1455
Americium-241	1.60E-03	3.56E-04	1.96E-03	93	207	354	561	915
Americium-243	9.39E-05	3.56E-04	4.50E-04	405	901	1541	2442	3983

Figure V-1. The Image of the Excel Spreadsheet Showing Calculation of Irrigation Periods

ATTACHMENT VI

DETERMINATION OF PATHWAY CONTRIBUTION

ATTACHMENT VI

DETERMINATION OF PATHWAY CONTRIBUTION

A software routine, *Pathway Contribution* REV 0, built into a Microsoft Excel version 97 SR-2 spreadsheet, was used to automate the determination of contribution to the BDCF by each pathway.

PATHWAY CONTRIBUTION, REV. 0

Set-up and Operation of Software Routine:

An example of the application is provided to assist the user in understanding the organization and function of the routine used to determine the contribution to the BDCF by each pathway. Figure VI-1 is a representation of the spreadsheet for ^{99}Tc, under the current climate with no prior irrigation. The spreadsheet has been divided into three areas (i.e., A, B and C) for ease of explanation.

All data imported from the GENII-S output files is obtained by blocking and copying the desired data and then pasting it into the appropriate section of the spreadsheet. Inserting the data into the spreadsheet is accomplished by using the "Paste" command and the "Text to columns" submenu item under "Data" from the tool bar to arrange the data into individual cells.

Area "A" is a table imported directly from the GENII-S output file which shows the contributions to the annual committed effective dose equivalent from internal exposure by inhalation and ingestion and the external exposure. GENII-S calculates internal doses by multiplying the committed dose equivalent to each organ times the weighting factor for that organ, then summing the weighted organ dose equivalents. The sum of the internal dose (committed effective dose equivalent) from annual intake and the external dose (effective dose equivalent) from annual exposure yields the annual total effective dose equivalent.

The upper portion of area "B" is a table imported directly from the GENII-S output file. This table contains the committed dose equivalent to each organ from each individual pathway. The totals at the bottom of the organ columns are the same as the values shown in the committed dose equivalent column from the table shown in area "A". In order to determine the contribution by pathway to the annual total effective dose equivalent it is necessary to calculate the weighted dose equivalent to each organ from each pathway. This is done by multiplying the values in the upper table by each organ's weighting factor. The results are contained in the table in the lower portion of area "B". The total contribution for each pathway is obtained by summing the weighted organ committed dose equivalents. The results are found in the lower right corner of area "B" under the column titled "Total".

In area "C" the total percentage contributions to the BDCF are presented. The percentage contributions from each pathway were calculated by dividing the pathway contribution by the annual total effective dose equivalent and multiplying the result by 100.

Confirmation of Correct Operation:

The individual calculations have been spot checked with hand calculations to ensure that correct results are being produced. Also, as a spot check for each use of the routine, the total from the lower right hand corner of area "B" is compared to the "Internal Effective Dose Equivalent" value from the bottom right hand corner of area "A". These values should be almost the same.

DC-BDCFs: Average 1x, Tc-99

Committed Dose Equivalent by Exposure Pathway

A Organ	Committed Dose Equivalen	Weightin Factors	Weighted Dose Equivalent
Gonads	3.20E-07	2.50E-01	7.90E-08
Breast	3.20E-07	1.50E-01	4.70E-08
R Marrow	3.70E-07	1.20E-01	4.50E-08
Lung	3.20E-07	1.20E-01	3.80E-08
Thyroid	8.00E-06	3.00E-02	2.40E-07
Bone Sur	3.70E-07	3.00E-02	1.10E-08
Stomach	3.40E-05	6.00E-02	2.00E-06
LL Int.	5.50E-06	6.00E-02	3.30E-07
UL Int.	2.10E-06	6.00E-02	1.20E-07
S Int.	6.00E-07	6.00E-02	3.60E-08
Liver	4.30E-07	6.00E-02	2.60E-08
Internal Effective Dose Equival			3.00E-06
External Dose			1.20E-10
Annual Effective Dose Equivale			3.00E-06

Pathway	Lung	Stomach	S Int.	UL Int.	LL Int.	Bone Su	R Marro	Testes	Ovaries	Muscle	Thyroid	Liver	B
Inhale	1.10E-10	2.90E-11	4.50E-13	1.40E-12	3.60E-12	3.10E-13	3.10E-13	2.60E-13	2.60E-13	2.60E-13	6.90E-12	3.50E-13	
Leaf Veg	8.90E-08	9.60E-06	1.70E-07	5.80E-07	1.50E-06	1.00E-07	1.00E-07	8.90E-08	8.90E-08	8.90E-08	2.20E-06	1.20E-07	
Oth. Veg	1.10E-08	1.20E-06	2.00E-08	7.00E-08	1.90E-07	1.30E-08	1.30E-08	1.10E-08	1.10E-08	1.10E-08	2.70E-07	1.50E-08	
Fruit	5.80E-09	6.30E-07	1.10E-08	3.80E-08	1.00E-07	6.80E-09	6.80E-09	5.80E-09	5.80E-09	5.80E-09	1.50E-07	8.00E-09	
Cereals	5.80E-10	6.30E-08	1.10E-09	3.80E-09	1.00E-08	6.80E-10	6.80E-10	5.80E-10	5.80E-10	5.80E-10	1.50E-08	8.00E-10	
Meat	2.80E-10	3.00E-08	5.30E-10	1.80E-09	4.90E-09	3.30E-10	3.30E-10	2.80E-10	2.80E-10	2.80E-10	7.10E-09	3.80E-10	
Poultry	8.90E-12	9.60E-10	1.70E-11	5.80E-11	1.50E-10	1.00E-11	1.00E-11	8.90E-12	8.90E-12	8.90E-12	2.20E-10	1.20E-11	
Cow Milk	2.60E-08	2.80E-06	4.90E-08	1.70E-07	4.50E-07	3.00E-08	3.00E-08	2.60E-08	2.60E-08	2.60E-08	6.50E-07	3.50E-08	
Eggs	7.50E-09	8.10E-07	1.40E-08	4.90E-08	1.30E-07	8.80E-09	8.80E-09	7.50E-09	7.50E-09	7.50E-09	1.90E-07	1.00E-08	
Soil Ing	1.20E-11	1.30E-09	2.30E-11	7.70E-11	2.10E-10	1.40E-11	1.40E-11	1.20E-11	1.20E-11	1.20E-11	3.00E-10	1.60E-11	
Water	1.70E-07	1.90E-05	3.30E-07	1.10E-06	3.10E-06	2.10E-07	2.10E-07	1.70E-07	1.70E-07	1.70E-07	4.40E-06	2.40E-07	
Fish	2.20E-09	2.40E-07	4.20E-09	1.40E-08	3.80E-08	2.60E-09	2.60E-09	2.20E-09	2.20E-09	2.20E-09	5.60E-08	3.00E-09	
Total	3.20E-07	3.40E-05	6.00E-07	2.10E-06	5.50E-06	3.70E-07	3.70E-07	3.20E-07	3.20E-07	3.20E-07	8.00E-06	4.30E-07	
Weightin	1.20E-01	6.00E-02	6.00E-02	6.00E-02	6.00E-02	3.00E-02	1.20E-01	2.50E-01		1.50E-01	3.00E-02	6.00E-02	
CEDE													Total
Inhale	1.32E-11	1.74E-12	2.70E-14	8.40E-14	2.16E-13	9.30E-15	3.72E-14	6.50E-14	0.00E+00	3.90E-14	2.07E-13	2.10E-14	1.56E-11
Leaf Veg	1.07E-08	5.76E-07	1.02E-08	3.48E-08	9.00E-08	3.00E-09	1.20E-08	2.23E-08	0.00E+00	1.34E-08	6.60E-08	7.20E-09	8.45E-07
Oth. Veg	1.32E-09	7.20E-08	1.20E-09	4.20E-09	1.14E-08	3.90E-10	1.56E-09	2.75E-09	0.00E+00	1.65E-09	8.10E-09	9.00E-10	1.05E-07
Fruit	6.96E-10	3.78E-08	6.60E-10	2.28E-09	6.00E-09	2.04E-10	8.16E-10	1.45E-09	0.00E+00	8.70E-10	4.50E-09	4.80E-10	5.58E-08
Cereals	6.96E-11	3.78E-09	6.60E-11	2.28E-10	6.00E-10	2.04E-11	8.16E-11	1.45E-10	0.00E+00	8.70E-11	4.50E-10	4.80E-11	5.58E-09
Meat	3.36E-11	1.80E-09	3.18E-11	1.08E-10	2.94E-10	9.90E-12	3.96E-11	7.00E-11	0.00E+00	4.20E-11	2.13E-10	2.28E-11	2.66E-09
Poultry	1.07E-12	5.76E-11	1.02E-12	3.48E-12	9.00E-12	3.00E-13	1.20E-12	2.23E-12	0.00E+00	1.34E-12	6.60E-12	7.20E-13	8.45E-11
Cow Milk	3.12E-09	1.68E-07	2.94E-09	1.02E-08	2.70E-08	9.00E-10	3.60E-09	6.50E-09	0.00E+00	3.90E-09	1.95E-08	2.10E-09	2.48E-07
Eggs	9.00E-10	4.86E-08	8.40E-10	2.94E-09	7.80E-09	2.64E-10	1.06E-09	1.88E-09	0.00E+00	1.13E-09	5.70E-09	6.00E-10	7.17E-08
Soil Ing	1.44E-12	7.80E-11	1.38E-12	4.62E-12	1.26E-11	4.20E-13	1.68E-12	3.00E-12	0.00E+00	1.80E-12	9.00E-12	9.60E-13	1.15E-10
Water	2.04E-08	1.14E-06	1.98E-08	6.60E-08	1.86E-07	6.30E-09	2.52E-08	4.25E-08	0.00E+00	2.55E-08	1.32E-07	1.44E-08	1.68E-06
Fish	2.64E-10	1.44E-08	2.52E-10	8.40E-10	2.28E-09	7.80E-11	3.12E-10	5.50E-10	0.00E+00	3.30E-10	1.68E-09	1.80E-10	2.12E-08
Total	3.84E-08	2.04E-06	3.60E-08	1.26E-07	3.30E-07	1.11E-08	4.44E-08	8.00E-08	0.00E+00	4.80E-08	2.40E-07	2.58E-08	3.02E-06

pathway	rem/yr	mrem/yr	C	%
Inhale	1.56E-11	1.56E-08		0.0%
Leaf Veg	8.45E-07	8.45E-04		27.9%
Oth. Veg	1.05E-07	1.05E-04		3.5%
Fruit	5.58E-08	5.58E-05		1.8%
Cereals	5.58E-09	5.58E-06		0.2%
Meat	2.66E-09	2.66E-06		0.1%
Poultry	8.45E-11	8.45E-08		0.0%
Cow Milk	2.48E-07	2.48E-04		8.2%
Eggs	7.17E-08	7.17E-05		2.4%
Soil Ing	1.15E-10	1.15E-07		0.0%
Water	1.68E-06	1.68E-03		55.3%
Fish	2.12E-08	2.12E-05		0.7%
Ext. dose	1.20E-10	1.20E-07		0.0%
Total	3.03E-06	3.03E-03		100%

Figure VI-1. The Image of Excel Spreadsheet Showing Calculation of Pathway Contributions to BDCFs

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