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YUCCA MOUNTAIN

YUCCA MOUNTAIN PROJECT

ENVIRONMENTAL PATHWAY ANALYSIS SCOPING STUDY FOR THE YUCCA MOUNTAIN PROJECT

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ENVIRONMENTAL PATHWAY ANALYSIS

SCOPING STUDY

FOR THE YUCCA MOUNTAIN SITE

March 1989

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EXECUTIVE SUMMARY

The Environmental Pathway Analysis Scoping Study (EPASS) for the Yucca Mountain site identifies and evaluates specific biota and hydrological pathways, as well as the radionuclides projected to be associated with the ingestion exposure mode for a region encompassing an approximately 50-mile (84-km) radius around Yucca Mountain. The study is designed to provide an initial indication of the critical environmental pathways and significant radionuclides that may require monitoring, sampling, or analysis as part of the radiological field program activities of the Yucca Mountain Project. Although the EPASS focuses on preclosure activities, it is a support document for the Radiological Monitoring Plan (RMP) and, as such, addresses data requirements for both the preclosure and postclosure phases of the repository project.

The emphasis of the EPASS is to adequately identify the significant pathways and radionuclides that should be addressed in the RMP without utilizing time- and cost-intensive modeling techniques for which little site-specific information is currently available. As a result, the study relies on the use of simplified hydrological and biota transport equations, adapted from existing modeling techniques, for evaluation of the ingestion pathways. All equations and associated data values used in the pathway model are accessed on a spreadsheet program to facilitate calculation of the many environmental parameters. Inhalation, immersion, and direct irradiation exposure pathways are not modeled because they are less difficult to evaluate by direct measurement or calculational techniques, and are routinely monitored as part of the radiological monitoring program.

In the interest of developing a comprehensive radiological monitoring program, significant pathways and radionuclides must also be evaluated for the postclosure period of the repository. To address specific RMP postclosure monitoring requirements, the EPASS identifies significant radionuclides for the groundwater pathway. Groundwater is specifically included in the EPASS model because, for postclosure monitoring purposes, it is considered to be the likely indicator path for potential radionuclide migration from the repository. In addition, because the emphasis of a postclosure radiological monitoring program is to provide assurance that there is adequate waste containment, the EPASS determines the significant monitoring pathways for those radionuclides listed in 40 CFR Part 191, Table 1, that have not been associated with a significant pathway already identified by the EPASS model (limiting case pathways). Since these radionuclides typically have long half-lives and are specifically identified in an EPA Standard, they are not only of interest for developing postclosure monitoring activities, but are considered to be of specific interest to the EPA with respect to postclosure repository isolation.

The EPASS model is composed of four simplistic submodels representing (1) air dispersion and surface deposition, (2) hydrology, (3) the biota, and (4) human age and consumption parameters. In general, results indicate that beef, cow milk, goat milk, venison, and leafy vegetation represent the significant pathways to humans. The primary significant radionuclide components for these pathways are C-14, Cs-137/Ba-137m, Sr-90/Y-90, Ni-63, Co-60, and Pu-241. For the postclosure period (at 10,000 yr), the significant radionuclides in the groundwater pathway include C-14, Ni-59, Tc-99, Zr-93, Pu-239, and Pu-241.

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1.0 INTRODUCTION

Prior to the implementation of a radiological monitoring program, an environmental pathways analysis is typically used to evaluate and provide an indication of the potential radiation exposure pathways to humans that may exist during the operation and decommissioning phases of a nuclear facility. In such an analysis, the following pathways are considered:

1. The airborne pathway (particulate and gaseous).
2. The hydrological pathway (surface and groundwater).
3. The terrestrial pathway (flora, fauna, and soils).

Evaluation of these pathways focuses on several modes of exposure, emphasizing the impact of these exposure modes on various environmental components and, ultimately, on humans (see Figure 1-1). Generally the exposure modes evaluated include inhalation, immersion, direct irradiation, and ingestion.

When analyzing environmental pathways, those exposure pathways that could result in an appreciable radiation dose to humans are considered critical pathways. In addition, those radionuclides that contribute to most of the dose along a critical path are considered critical or significant radionuclides. The determination of critical pathways and significant radionuclides is based on a facility's postulated release source term, environmental transport considerations, population distribution, and local use of the surrounding countryside. The primary purpose of a pathways analysis is to indicate those critical pathways and significant radionuclides that require monitoring as part of the radiological monitoring program.

The Environmental Pathway Analysis Scoping Study (EPASS) for the Yucca Mountain Project is narrower in scope than the standard pathways analysis. The purpose of the EPASS is to model and identify the critical biota/hydrological pathways and the significant radionuclides associated with the ingestion dose to humans living within an approximately 50-mile (84-km) radius (NRC, 1976) of Yucca Mountain (see Figure 1-2). The study is specifically designed to provide an initial indication of those pathways and radionuclides that (1) are significant contributors to a potential ingestion dose, and (2) may require monitoring, sampling, or analysis as part of a radiological monitoring program. Although the EPASS focuses on the preclosure period, it is a support document for the Radiological Monitoring Plan (RMP) (SAIC, 1988) and, as such, addresses data requirements for both the preclosure and postclosure phases of the repository project.

Generally, an in-depth evaluation of doses as a result of ingestion requires the use of complex modeling equations. The emphasis of the EPASS, however, is on adequately identifying the significant pathways and radionuclides that should be addressed in the RMP without utilizing the time- and cost-intensive modeling techniques for which little site-specific information is currently available. Consequently, the EPASS relies on the use of simplified hydrological and biota transport equations and, in some cases, default data for evaluation of the ingestion pathways. These equations and associated data values are set up on a Lotus 1-2-3 spreadsheet (Lotus Development Corporation, 1985) program to facilitate calculation of the many environmental parameters.

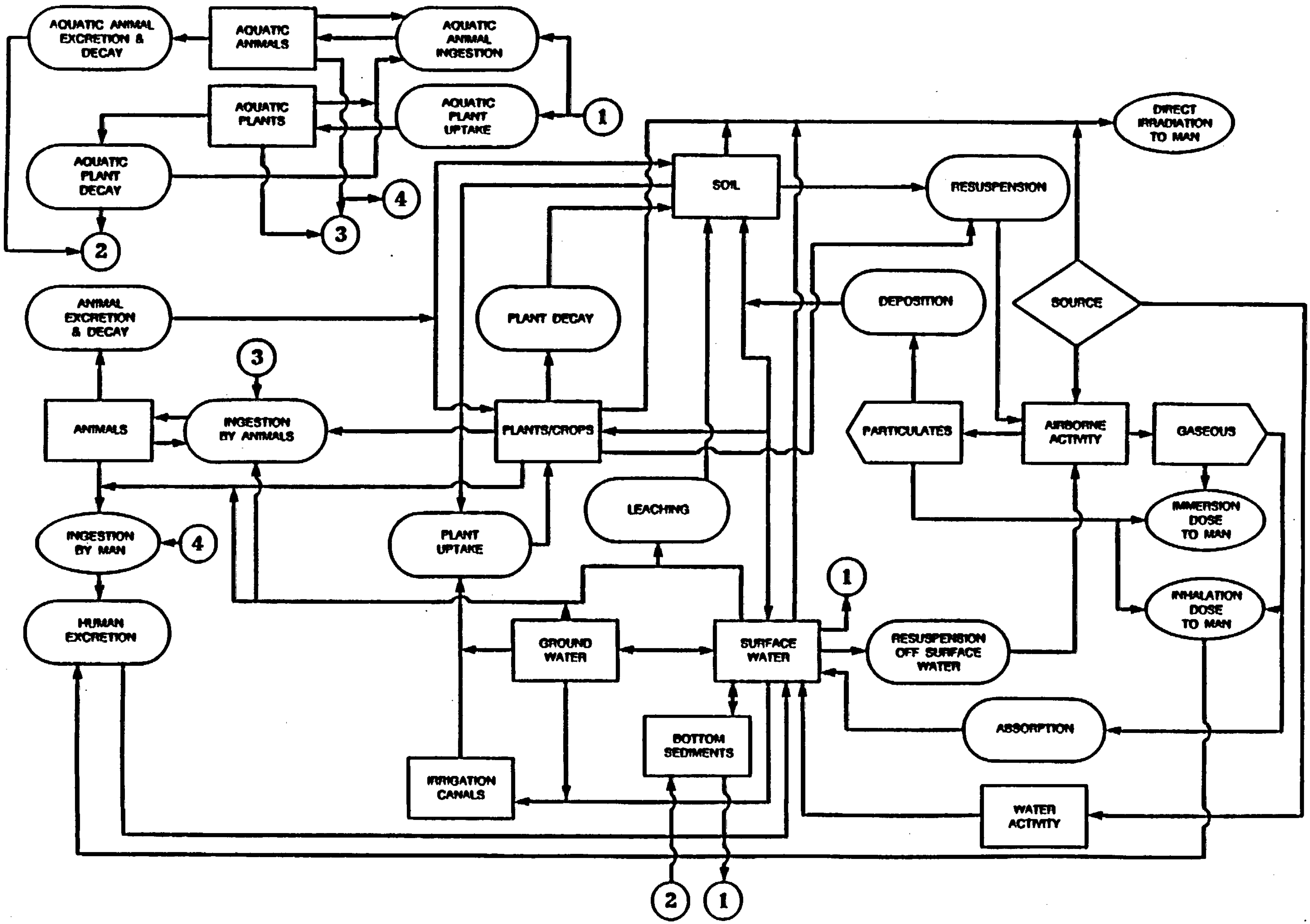

Figure 1-1. Typical environmental pathway model.

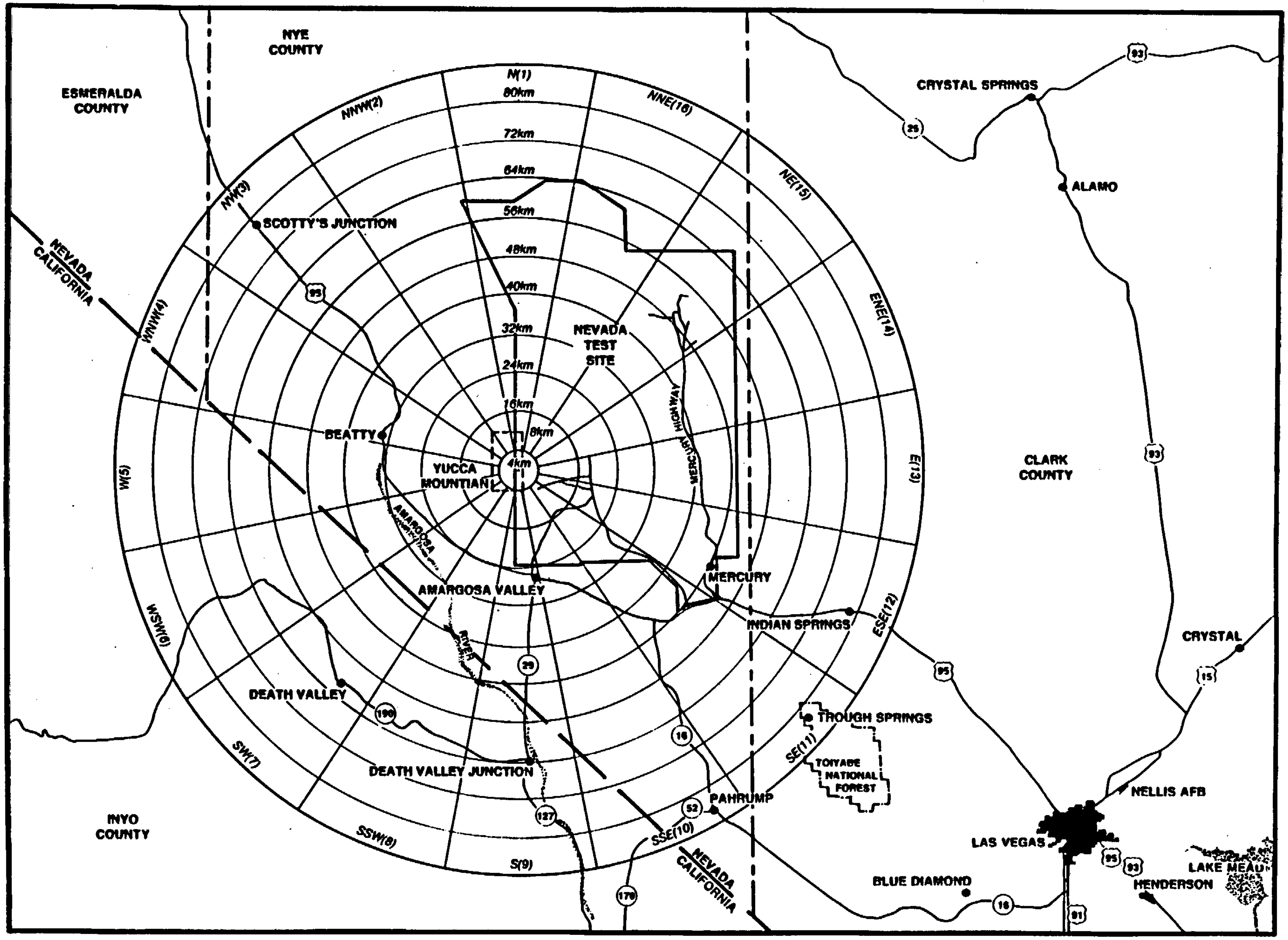

Figure 1-2. 84-kilometer Yucca Mountain environmental monitoring grid.

A detailed listing of the values used in the EPASS can be found in Appendix A. The inhalation, immersion, and direct irradiation exposure pathways are not modeled because they can be directly evaluated.

Woolfolk (1986) identifies many of the parameters to be evaluated as part of the EPASS. It is currently believed that the modeling and assumptions used in the EPASS are such that the significant pathways and radionuclides are not expected to change. However, as additional site-specific source term and environmental data become available, the pathway model and assumptions will be reevaluated in light of the new information.

2.0 REGULATORY GUIDANCE

Various levels of regulatory documentation exist that affect the activities of the Yucca Mountain Project. This documentation includes U.S. Nuclear Regulatory Commission (NRC) regulations, U.S. Environmental Protection Agency (EPA) standards, and U.S. Department of Energy (DOE) orders. At this phase of the repository project, the requirements for environmental surveillance are under the mandates of DOE directives, orders, policies, and guidance. If Yucca Mountain is selected as the repository, environmental surveillance requirements will be as specified by DOE and/or NRC criteria and will be consistent with the mandates of the Nuclear Waste Policy Act (NWPA), as amended.

Currently there are no regulations directly requiring a high-level waste (HLW) facility to implement a pathways analysis study. However, both the NRC and the EPA have issued guidance on the application of pathways analyses to specific cases (e.g., nuclear power plants and uranium mill tailings). For example, the NRC has presented detailed requirements for pathways analyses aimed at quantifying doses to humans from routine releases from nuclear power plant operations. The EPA has established some procedures for assessing doses to humans from various categories of facilities, including DOE-owned or operated and various types of NRC-licensed facilities. In addition, the DOE has issued some general guidance documentation in DOE (1988) and DOE (1987).

The EPASS was developed using available NRC, EPA, and DOE guides and standards. This documentation was used as a basis for developing many of the parameters and criteria used in the EPASS. In most instances where site-specific data was unavailable, guidance documentation provided default conservative case values. The following sections discuss the primary guidance documentation used to develop the EPASS.

2.1 NRC GUIDANCE

The principal source of NRC guidance for environmental pathways analyses is contained in NRC Regulatory Guide 1.109 (NRC, 1977a). This guide, entitled "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 50 Appendix I," contains the regulatory position on the evaluation of pathways analyses for power reactors. Although this reactor guidance may not be directly applicable, it is used primarily because (1) it is referenced by DOE guidance (DOE, 1981), and (2) similar regulatory guidance does not currently exist for a geologic repository. In general, Regulatory Guide 1.109 presents assumptions, methods, data, and equations for use in evaluating the following:

1. Doses from liquid effluent pathways, including ingestion of potable water, aquatic foods, and irrigated foods.

2. Air immersion--gamma and beta doses from noble gases discharged to the atmosphere.

3. Inhalation doses from radioiodines and other radionuclides released to the atmosphere.

4. External irradiation doses from ground deposition.

5. Doses due to the ingestion of contaminated foodstuff.

6. Integrated doses to the population from all significant pathways.

Regulatory Guide 1.109 also provides information for establishing the value used as the significant pathway screening limit in the EPASS. The guide states that

> A pathway is considered significant if a conservative evaluation yields an additional dose increment equal to or more than 10 percent of the total from all pathways considered....

In addition, the guide describes equations and some of the default data acceptable to the NRC (for use if site-specific information is not available) for performing environmental pathways analyses. The data include concentration factors for elements in environmental media, food chain transfer factors, air inhalation rates, and food and water consumption rates. Regulatory Guide 1.109 does not describe methods for predicting atmospheric dispersion; instead it references Regulatory Guide 1.111, "Methods for Estimating Atmospheric Transport and Dispersion for Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors" (NRC, 1977b), and Regulatory Guide 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants" (NRC, 1982).

2.2 EPA GUIDANCE

The primary source of EPA regulatory guidance useful for environmental pathways analyses is found in 40 CFR Part 191. This standard, entitled "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," provides dose limits for offsite releases as well as the release limits for containment requirements. Those radionuclides identified with specific postclosure containment release limits in 40 CFR Part 191, Table 1, typically have long half-lives and are, subsequently, not only of interest for developing the postclosure monitoring activities of the RMP (SAIC, 1988), but are considered to be of special interest to the EPA with respect to postclosure repository isolation. As a result, this information is used as a basis for evaluating some of the radionuclides examined in the EPASS.

2.3 DOE GUIDANCE

The principal source of DOE guidance for environmental pathways analysis modeling is found in a working draft of DOE (1988) as well as predecessor documents, DOE (1983) and DOE (1981). These documents effectively require that a critical pathway evaluation shall be used as the basis for establishing a radiological environmental sampling and analysis program. In addition to providing general modeling parameters useful to performing a pathway analysis, this DOE guidance recommends use of the modeling equations contained within Regulatory Guide 1.109 (NRC, 1977a). Consequently, the general equations contained in Regulatory Guide 1.109 formed the basis for the EPASS model.

3.0 THE ENVIRONMENTAL PATHWAY MODEL

Radionuclides discharged into the environment can result in radiation exposure of humans through a variety of mechanisms: inhalation, immersion, direct irradiation, and ingestion. Figure 1-1 depicts a generalized environmental pathway diagram displaying the many potential exposure pathways to humans. The most complex of these exposure routes involves those segments of the environment that impact the quality of media ingested by humans, specifically food (i.e., crops, animals, and dairy products) and water (i.e., irrigation and drinking water). This pathway complexity tends to fractionalize the original source term activity (e.g., portions of the radioactivity bioaccumulate in the soil, various plants, etc.). As a result, doses acquired via the ingestion pathway tend to be harder to accurately quantify than doses resulting from the more direct exposure paths of inhalation, direct irradiation, and immersion. In general, direct exposure path dose contributors are less difficult to evaluate by direct measurement or calculational techniques, and are routinely monitored as part of the radiological monitoring program. Consequently, the focus of the EPASS model is to define the critical pathway and radionuclide combinations associated with the ingestion dose to humans in support of the development of a comprehensive radiological monitoring program for the Yucca Mountain Project. Figure 3-1 illustrates the generalized EPASS model.

3.1 MODEL PARAMETERS

Because the EPASS is a scoping study, simplified modeling and transport equations are used. Woolfolk (1986) is used for establishing general guidance on parameters of interest, such as agricultural activity, types of wildlife, and elements of interest. In addition, Woolfolk (1986) provides a basis for establishing a limiting case pathway for specific elements, and for establishing the screening limits (the point at which the radionuclide does not significantly contribute to the dose) for the evaluation of significant radionuclides. Before the EPASS model can be used, however, specific information on radionuclides, as well as agricultural and wildlife parameters, must be established.

3.1.1 Radionuclides

Selection of specific radionuclides for evaluation in the EPASS is based on guidance or criteria established in Woolfolk (1986) and 40 CFR Part 191, Table 1. These radionuclides satisfy one or more of the following requirements:

1. They are generally present in nuclear fuel cycle waste in significant quantities and/or have a long half-life.

2. They are specifically referred to in 40 CFR Part 191, Table 1 and, therefore, are considered not only of interest for developing the postclosure monitoring activities of the RMP (SAIC, 1988), but of specific interest to the EPA.

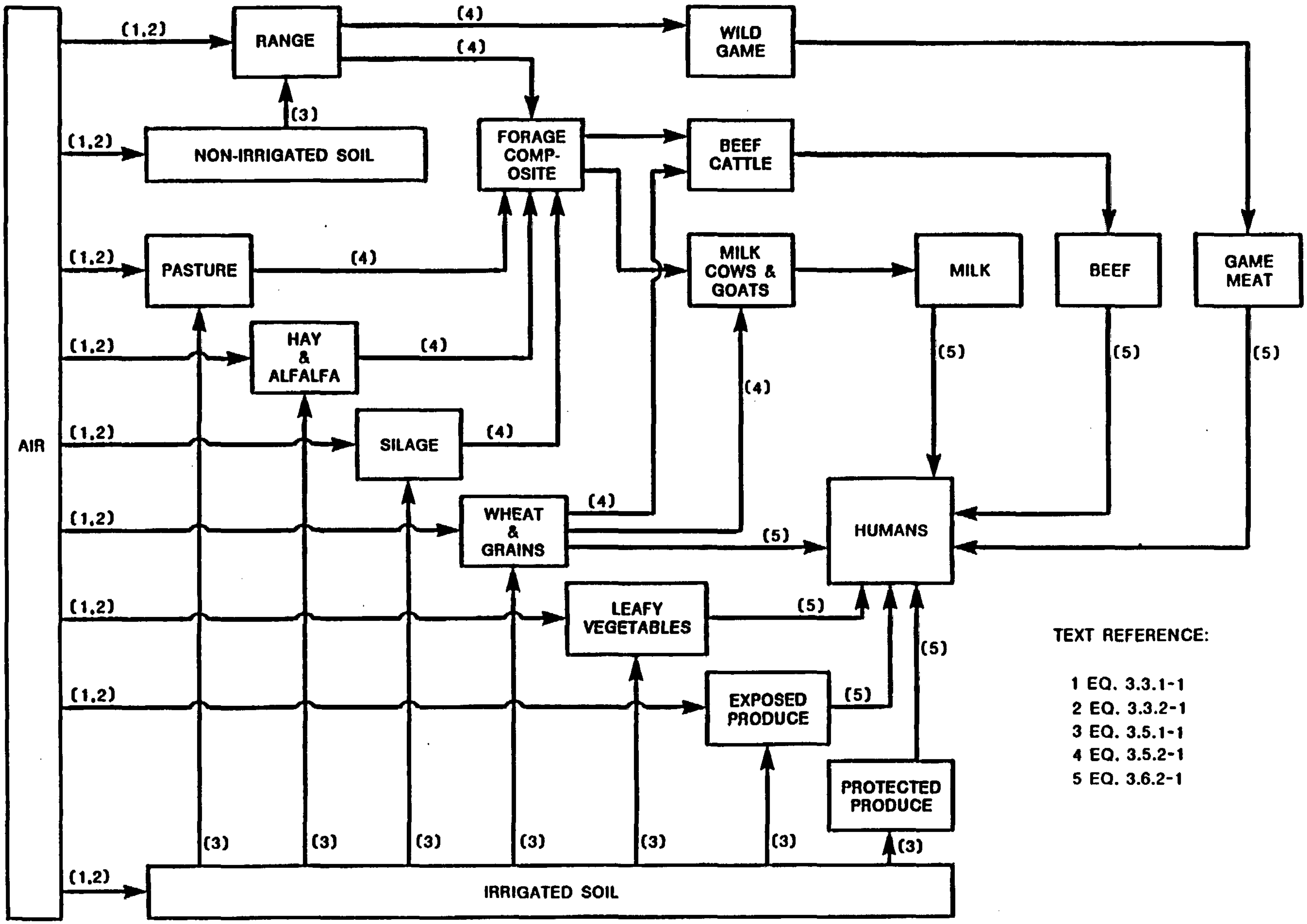

Figure 3-1. General EPASS model flow diagram.

3. They are daughter products with a long half-life and/or may be present in the waste in significant quantities.

Using these criteria, the radionuclides initially evaluated in the EPASS are H-3; C-14; Co-60; Ni-59, 63; Sr-89; Sr-90/Y-90; Zr-93; Tc-99; Sn-126; I-129; Cs-135; Cs-137/Ba-137m; Ra-226; Th-230, 232; U-233, 234, 235, 236, 238; Np-237; Pu-238, 239, 240, 241, 242; Am-241, 243; and Cm-244.

Once it has been demonstrated that a specific radionuclide is not a significant contributor to human exposure, the EPASS model does not continue to evaluate the potential radiological impacts of that radionuclide. The screening limits for exclusion are based on the percent contribution to total human exposure and are as follows: less than 0.1 percent for non-alpha emitting radionuclides, and less than 0.01 percent for alpha emitting radionuclides (Woolfolk, 1986). The exceptions to these limits are those radionuclides identified in Woolfolk (1986) and 40 CFR Part 191, Table 1 for which a limiting case pathway must be established (limiting case pathway radionuclides are those that will be monitored once the significant pathways have been determined).

In addition, an environmental pathway is not considered significant if it contributes less than 1 percent of the total dose to humans. This value is considered reasonably conservative with respect to guidance documentation, which allows pathway total dose screening limit ranges from 5 percent (DOE, 1987) to 10 percent (NRC, 1977a).

3.1.2 Additional Radionuclides

After the initial pathway and radionuclide evaluation, subsequent technical input and a reevaluation of the projected waste composition identified several additional radionuclides as potential significant pathway dose contributors, including Fe-55, Sb-125, Ce-144, Pm-147, Sm-151, Eu-154, and Eu-155. Although these radionuclides have relatively short half-lives (approximately 1 to 9 yr) and are generally considered difficult to measure in the environment, each exists in quantities greater than 0.1 percent of the total projected radionuclide inventory of the waste and, therefore, may be considered a possible significant radionuclide. The approach for evaluating this possibility was to determine (1) if chemical analogs had already been evaluated by the EPASS, and (2) if the typical monitoring techniques (e.g., gamma spectroscopy) and methods used for the radionuclides initially identified as significant would already measure or could easily be expanded to include the appropriate radioisotopes of Fe, Sb, Ce, Pm, Sm, and Eu.

Based on a study by the Electric Power Research Institute (EPRI, 1985), the chemical analogs of these radioisotopes are as follows:

1. Fe-55: Cobalt (Co) and nickel (Ni).

2. Sb-125: Arsenic (As).

3. Ce-144: Plutonium (Pu).

4. Pm-147: Cerium (Ce) and neodymium (Nd).

5. Sm-151: Europium (Eu) and ytterbium (Yb).

6. Eu-154: Ytterbium (Yb), samarium (Sm), and barium (Ba).

7. Eu-155: Ytterbium (Yb), samarium (Sm), and barium (Ba).

This information indicates that both Fe-55 and Ce-144 will act, in nature, chemically similar to cobalt/nickel and plutonium, respectively. Since cobalt, nickel, and plutonium have been directly evaluated by the EPASS model and the monitoring techniques are relatively established, Fe-55 and Ce-144 need only be monitored on a nonroutine basis, the actual frequency depending on the amount of Co-60, Ni-63, and various radioisotopes of plutonium detected in the environment. In fact, as part of the Project radiological monitoring activities (SAIC, 1988), Fe-55 and Ce-144 will be analyzed on such a nonroutine basis. The other radionuclides, with the exception of Sm-151, can and will be measured by gamma spectroscopy (SAIC, 1988). Because the analytical technique is difficult, and the chemical analog of Sm-151 is europium, Sm-151 will be analyzed only if significant quantities of Eu-154 and Eu-155 are indicated by gamma spectroscopy (SAIC, 1988). In short, since Fe-55, Sb-125, Ce-144, Pm-147, Sm-151, Eu-154, and Eu-155 have already been evaluated by chemical analog in the EPASS, or will be measured or analyzed as part of the radiological monitoring activities of the Project, they are not directly evaluated as part of the EPASS model.

3.1.3 Agriculture and wildlife

The agriculture parameters considered for the development of the EPASS model are those identified in attachments to Woolfolk (1986). For some parameters, the following simplifications were made:

1. The goat meat path is considered part of the beef pathway.

2. "Fruit" is considered to be apples.

3. "Nuts" are assumed to be pecans.

4. Greenhouse plants are considered to be mushrooms.

5. Big horn sheep, elk, and antelope are considered part of the large wild game source represented by deer.

6. Pheasants, grouse, and doves are considered part of the small upland game source represented by quail.

3.2 SOURCE TERM MODEL

Since the Project is in the initial phases of site characterization, the proposed Yucca Mountain repository is not an operating nuclear facility.

Therefore, in order to determine the significant pathways and radionuclides in the study region (within an 84-km radius of Yucca Mountain), a postulated annual release source term is developed. The source term is based on three simplified, hypothetical release cases, created and evaluated as part of the EPASS. It should be emphasized that the release cases are purely contrived mechanisms for the postulated release of radioactivity to the environment. These postulated radioactivity release quantities are significantly larger than those projected for an operating repository, and are developed only in order to predict which environmental pathways and radionuclides could be significant and should be monitored as part of the radiological monitoring program. They include a release to the atmosphere (the airborne case), a liquid release via the sanitary sewage system, and a potential underground liquid release. The equations for the calculation of the postulated releases are as follows:

$$Qair = MPC*CF*EPArat*Svol*RWF(a)*0.10 \quad (3.2\text{-}1)$$

$$Qwater = MPC*CF*EPArat*Wvol*RWF(l)*0.10 \quad (3.2\text{-}2)$$

$$Qdwater = MPC*CF*EPArat*Wspvol*RWF(l)*0.10 \quad (3.2\text{-}3)$$

where:
- Qair = postulated annual release of radioactivity to the atmosphere, Ci
- MPC = maximum permissible concentration value, µCi/ml
- CF = conversion factor (1000), Ci*ml/µCi*L
- EPArat = ratio, EPA to 10 CFR Part 20 whole body dose limits (25 mrem/500 mrem)
- Svol = annual ventilation stack exhaust volume, L
- RWF(a) = radionuclide weighting factor--airborne
- Qwater = postulated annual release via sewage, Ci
- Wvol = projected annual volume of contaminated sewage, L
- RWF(l) = radionuclide weighting factor--liquid
- Qdwater = postulated annual release of radioactivity to the groundwater from an underground liquid release, Ci
- Wspvol = volume of a postulated underground liquid release, L

The airborne and sanitary sewage releases are derived from Table 2 (general public) of 10 CFR Part 20, Appendix B, maximum permissible concentration (MPC) values. The underground liquid release case uses 10 CFR Part 20, Appendix B, Table 1 (occupational) MPC values, and assumes an occurrence probability of three times in the predicted 25-yr waste receiving operational lifetime of the facility. In addition, the MPC values are scaled by a ratio of the 40 CFR Part 191 to 10 CFR Part 20 general public whole body dose equivalent limits (25 mrem/500 mrem) to meet the EPA limits. Note that the above values are used only to develop a reasonable, potential release quantity in order to calculate the pathways and radionuclides of potential significance for monitoring. Since it is unlikely that facility operations will approach EPA offsite dose limits, the release values (Qair, Qwater, and Qdwater) are reduced by a factor of 0.10. Other factors include gaseous effluent and liquid annual release quantities, and a radionuclide weighting factor to equilibrate the release of specific radionuclides to dose consequences. In addition, a radionuclide class fraction, which considers the radionuclide composition for combinations of five different potential waste categories projected to be received at the Yucca Mountain facility (if it is selected as the repository site), is included as part of the source term model. The values for the source term model factors are listed in Appendix A, Section A.1, Table A.1.b and Section A.6, Table A.6.a of this report. Further discussion defining the radionuclide weighting factor and the radionuclide class fraction can be found in the following sections.

3.2.1 Radionuclide weighting factor

The radionuclide weighting factor (RWF) is a ratio of the effective whole body dose conversion factors (DCFs) for the radionuclides of interest to the DCF of U-233. The intent of the RWF is to relate the radiotoxic hazard (dose impacts) of each of the radionuclides under evaluation in the EPASS to a common radiotoxic hazard index (a single reference radionuclide under evaluation by the EPASS model). Selection of the reference radionuclide is not dependent on any specific criteria. For computational convenience, the EPASS model uses U-233, a radionuclide of high radiotoxicity (i.e., high DCF). In the EPASS calculational models, the RWF has specific limited applications. Since the pathway portion of the analysis is more dependent on dose than on the amount of activity of a radionuclide, the RWFs are used only to establish the relative significant environmental pathway(s), not the significant radionuclide(s). The weighting factor technique is useful in that it effectively normalizes the dose consequences of several radionuclides in each type or category of nuclear waste to a common denominator, thus enabling the significant pathway to humans to be determined without calculating the actual dose contribution from each individual radionuclide.

The general equation for determining the RWF is as follows:

$$RWF = DCFi/DCFu233 \qquad (3.2.1\text{-}1)$$

where: RWF = radionuclide weighting factor
DCFi = dose conversion factor for radionuclide i, rem/μCi
DCFu233 = dose conversion factor for U-233, rem/μCi

EPASS modeling requires two sets of weighting factors: airborne (RWF(a)) and liquid (RWF(l)). The DCFs for derivation of the RWFs are the effective whole body values obtained from WIPP (1985) (50-year ingestion values). In cases where a radionuclide has two DCFs, the factor associated with the larger f_1 value (the fraction that is absorbed into the blood) is utilized for RWF(a), while the smaller f_1 DCF is used for RWF(l). In effect, this means that the larger DCFs are used to derive the RWF values associated with the airborne pathway, which is considered to be a primary exposure pathway to humans (DOE, 1981). Appendix A, Table A.1.b provides a list of the radionuclides and their weighting factors.

3.2.2 Radionuclide class fraction

Potential sources of radioactive waste to be shipped to a high-level waste repository consist of three primary types of radionuclides: fission products, activation products, and transuranic/actinides (TRU). These types are combined into five different waste categories, any combination of which could potentially be received at the Yucca Mountain facility. These categories of waste are as follows:

1. Crud (activation products)--found on the exterior of spent fuel.
2. High level waste (fission products).
3. Crud and actinide mix.
4. Damaged fuel (fission/crud/actinides).
5. Monitored retrievable storage fuel (fission products and actinides).

Because of the differing radionuclide component of the various waste categories, it is necessary to evaluate each of the above and determine whether a specific category has different significant pathways or radionuclide combinations. To accomplish this task, a waste source category table is developed. Based on the radionuclide quantities found in DOE (1979), a radionuclide fraction is developed for all radionuclides for each of the three radionuclide classes (i.e., fission products, activation products, and actinides). These fractions are then incorporated as a product term in the human model and used to determine the significant pathways and radionuclides for the five waste categories. In those instances where a waste category is based on a combination of two or three radionuclide classes, the human concentration values for the different radionuclide classes are summed. Appendix A, Table A.6.a provides a list of the radionuclide fractions of the waste source category table.

3.3 AIR DISPERSION AND SURFACE DEPOSITION MODEL

3.3.1 Air Dispersion

Since significant quantities of site-specific meteorological data are not available in sufficient detail to apply the more sophisticated air quality models, the EPASS uses a relatively simple airborne assessment model to predict the dispersal of the postulated airborne source term throughout the atmosphere in the study area. This model, essentially the plume centerline form of the Gaussian plume dispersion equation (AEC, 1968), requires only a few data inputs and the use of reasonably conservative assumptions to adequately predict the potential annual airborne release concentrations from the proposed Yucca Mountain facility. The plume centerline version of the Gaussian plume dispersion equation is used because it estimates the maximum concentration of a plume along a line radiating outward from the release point, providing a suitable level of conservatism in the results. The modified Gaussian plume dispersion equation used in the EPASS calculations is as follows:

```
Cairpart = [[Qair/(Pi*SIGy*SIGz*V)]*EXP                    (3.3.1-1)
           (-[(h*h)/2(SIGz*SIGz)])]*Fpart
```

where:

- Cairpart = airborne particulate radionuclide concentration, Ci/m^3
- Qair = total annual radioactivity released to the atmosphere, Ci
- Pi = 3.1415927
- SIGy = horizontal dispersion coefficient, m
- SIGz = vertical dispersion coefficient, m

V = average wind velocity, m/s
EXP = exponential function
h = release height (stack height), m
Fpart = fraction of the release that is in particulate form

For the purposes of model simplification, all radionuclides in the form of volatile gases and significant to the ingestion pathway are assumed to cling to airborne particulates. Therefore, Fpart is assumed to be equal to 1.0 and an airborne concentration of radioactive gases is not derived.

The potential airborne concentration for each radionuclide of interest is evaluated at a maximum-case and average-case distance. The maximum-case value is assumed to be at the location of the nearest point of human habitation to the Yucca Mountain facility release point. This location is estimated to be 20 km. Since there is no cropland in the immediate area, the EPASS model is used to calculate airborne concentration values (that could be deposited on the surface) for the purposes of establishing a maximally exposed individual case (e.g., with a home garden pathway). These maximum case calculations apply only to the drinking water and home vegetable gardening components of the pathway analysis. For the average case, however, cropland does exist in relatively significant quantities at further distances from the release point. In general, these areas are spread out due to the limited availability of water resources. Therefore, to evaluate the potential airborne concentrations of radionuclides that could be deposited on commercial cropland, an average distance is derived based on (1) the maximum distance of the region of interest, and (2) the nearest point of human habitation. Assuming that there is a nonuniform distribution of the release plume, the value of 52 km is obtained using the following equation:

$$[(Max - Min)/2] + Min = Avg \qquad (3.3.1\text{-}2)$$

where: Max = maximum distance of the region of interest, 84 km
Min = nearest point of human habitation, 20 km
Avg = average distance, km

Airborne concentrations calculated at this distance are applicable only to commercial foodcrop, forage, and surface water components of the pathway analysis.

Utilizing the above distance(s) and assuming very stable atmospheric conditions (Stability Class E from AEC, 1986) to maximize plume conditions, the horizontal (SIGy) and vertical (SIGz) dispersion coefficients can be obtained as described in Till (1983). From DOE (1984), an average annual wind velocity (for the Yucca Mountain area) of 3.0 m/s is derived. In addition, the stack release height is assumed to be 10 m, based on DOE (1980). The above data, equations, and assumptions are used to determine the postulated airborne concentration (Equation 3.3.1-1) of each radionuclide considered in the EPASS. These concentration values are then used to directly calculate surface deposition values.

3.3.2 Surface deposition

The climate of the Yucca Mountain site and the surrounding area is characterized by very little rainfall, low relative humidity, and large diurnal temperature ranges. As a result, wet deposition or scavenging is not considered in the surface deposition model of the EPASS. In effect, surface deposition is dependent only on airborne concentration (Equation 3.3.1-1) and deposition velocity:

$$Si = Cairpart * Vdep * CF \qquad (3.3.2\text{-}1)$$

where:
- Si = annual radionuclide surface deposition, Ci/m^2
- Cairpart = airborne radionuclide concentration, Ci/m^3
- Vdep = deposition velocity, m/s
- CF = correction factor, 3.15E+07 s/yr

For this evaluation, the deposition velocity (Vdep) is assumed to be equal to gravitational settling velocity (Vg). To conservatively maximize the travel distance of the plume, Vdep is calculated assuming a small, respirable particle size of 0.3 µm Activity Median Aerodynamic Diameters (AMAD). From Travis (1975), the model to calculate Vg (or Vdep, since it is assumed equal to Vg) is as follows:

$$Vg = ([(D*D)*g]/18u)*(Pp - P) \qquad (3.3.2\text{-}2)$$

where:
- Vg = Vdep, the gravitational settling velocity, 1.0E-04 m/s
- D = particle diameter, 0.3 µm
- g = gravitational acceleration, 9.806E+02 cm/s^2
- u = air viscosity at 18°C, 182.7E-06 g/cm*s
- Pp = particle density (assumed SiO_2, representative of sand), 2.30 g/cm^3
- P = density of air (room temperature), 1.293E-03 g/cm^3

The deposition equations presented above provide a model for determining the relationship between the airborne concentration and the rate of deposition on surfaces such as crops, plants, and surface water.

3.4 HYDROLOGY MODEL

The Yucca Mountain area consists primarily of desert terrain. As a result, there are no perennial sources of surface water (DOE, 1984) and the groundwater table is very deep (approximately 535 m (1755 ft) (DOE, 1984)). Travel time for radioactivity from the repository site to the accessible groundwater is presently projected to be approximately 10,000 yr (DOE, 1984). Although this travel time information suggests that a dose contribution via the hydrological pathway is very unlikely in the immediate future, the potential does exist for several small surface water sources to receive a small fraction of the postulated airborne activity. The EPASS model evaluates this possibility (Section 3.4.1). To address specific RMP postclosure monitoring requirements, the EPASS also identifies significant radionuclides for the groundwater pathway. Groundwater is specifically included in the EPASS model because, for postclosure monitoring purposes, it is considered to be the likely indicator path for potential radionuclide migration from the repository. To simplify the groundwater pathway radionuclide evaluation all parameters (e.g., population food consumption factors, etc.), with the exception of radioactive decay (10,000 yr), are assumed to remain constant.

3.4.1 Surface water

Four potential types of surface water may be encountered in the Yucca Mountain assessment area: reservoirs, playas, springs, and stock watering troughs. Because Crystal Reservoir (the only reservoir within the area of interest) is not used for irrigation or human consumption (Giampaoli, 1986), only springs and stock watering troughs are considered potential surface water paths to humans.

The EPASS surface water model is a simplification utilized to alleviate dependence on unavailable, detailed, site-specific data. It is based on the assumption that there are 120 stock watering troughs/springs in the area of interest, each comprising 25 square feet of area. Since stock watering troughs maintain the elevation of the surface water above ground level, and because Crystal Reservoir (the major contributor to surface water area) is not considered, activity contribution due to land surface runoff or scouring is ignored. The following equation describes the annual accumulation of activity in surface water:

$$Qsw = Si * Awater \qquad (3.4.1\text{-}1)$$

where: Qsw = annual activity accumulation in surface water, Ci
Si = annual radionuclide surface deposition, Ci/m^2
Awater = total area of surface water in the study area, m^2

To estimate the concentration of radioactivity in the surface water (surface water concentration), two cases are examined. The first case considered (Case A) uses surface water volume, activity released to the surface water, and the groundwater contribution (using the hypothetical 10,000-yr source term) for pathway evaluation. It is recognized that groundwater is not a significant dose contribution pathway prior to 10,000 yr; the intent is merely to introduce a factor of conservatism in the evaluation, since the surface water model is very simplistic. Case B is based on the specific activity of the radionuclide considered and the estimated solubility of the chemical element (in compound form) in water. Should the derived surface water concentration (Csw) for Case A be greater than the concentration for Case B, the Case B value is used (Case B is used as a limit of solubility for a given chemical element (in compound form) in water).

For surface water concentration, Case A and Case B are modeled as follows:

$$\text{CASE A:} \quad Csw_A = Qsw/Vsw + Cgw*Fspsw\text{-}gw \qquad (3.4.1\text{-}2)$$

$$\text{CASE B:} \quad Csw_B = Ksol*SpA \qquad (3.4.1\text{-}3)$$

where: $Csw_{A\&B}$ = radionuclide concentration in surface water, Ci/L
Qsw = annual accumulated activity in surface water via deposition, Ci

Vsw = volume of surface water, L
Cgw = radionuclide concentration in groundwater, Ci/L
Fspsw-gw = fraction of surface water supplied by groundwater sources
Ksol = solubility coefficient, g/L
SpA = specific activity of a given radionuclide, Ci/g

Due to a lack of specific data, the surface water volume (Vsw) is assumed to be 0.10 percent of the volume of Crystal Reservoir. The total quantity of water in Crystal Reservoir is approximately 3.0E+08 L (Giampaoli, 1986); therefore, Vsw = 3.0E+05 L. The fraction of surface water supplied by groundwater sources (Fspsw-gw) is assumed to be equal to 1.0 (DOE, 1984). The radionuclide concentration in groundwater (Cgw) is that derived by Equation 3.4.2-1. Solubility coefficients (Ksol) and specific activity (SpA) values can be found in Appendix A, Tables A.2.b and A.2.c.

3.4.2 Groundwater

To address specific RMP postclosure monitoring requirements, the EPASS identifies significant radionuclides for the groundwater pathway. Groundwater is specifically included in the EPASS model because, for postclosure monitoring purposes, it is considered to be the likely indicator path for potential radionuclide migration from the repository. In addition to postclosure monitoring needs, groundwater is evaluated because water resources are scarce in Nevada and both public and regulatory interest tend to focus on perceived concerns regarding repository containment and the potential for radiological impacts to groundwater sources. Consequently, even though DOE (1984) indicates that the general travel time of a radionuclide release to groundwater is approximately 10,000 yr, the EPASS evaluates two groundwater pathway cases: contributions from surface water sources (airborne deposition) to groundwater, and releases resulting from a contrived, postulated, underground release of contaminated liquid during the projected waste receiving operational lifetime of the facility. The purpose of these case evaluations is to attempt to determine which radionuclides, assuming the existence of a release mechanism, may be significant in the groundwater pathway and should be monitored as part of the postclosure monitoring program, assuming all other parameters (e.g., land use, agricultural, demographic) remain constant. Groundwater transport modeling is relatively complex, and requires detailed site-specific data that are not currently available. Consequently, simple modeling techniques are being used at this time. The following equation describes the postulated release of activity to the groundwater:

$$Qgw = (Qsw*Fsw\text{-}gw*EXP[(-Ttvswgw*0.693)/T]) + (Qdwater*Fdssw\text{-}gw*EXP[(-Ttvdswgw*0.693)/T])*Prob \quad (3.4.2\text{-}1)$$

where:
Qgw = activity accumulated in groundwater, Ci
Qsw = activity released to surface water, Ci
Fsw-gw = transfer fraction--surface to groundwater
EXP = exponential function
Ttvswgw = radionuclide travel time--surface to groundwater, yr
T = radionuclide half-life, yr

Qdwater	=	activity released--underground release to groundwater, Ci
Fdssw-gw	=	transfer fraction--underground release to groundwater
Ttvdswgw	=	travel time--underground release to groundwater, yr
Prob	=	postulated probability occurrence--underground liquid release, 3 in 25 yr

In Equation 3.4.2-1, the surface to groundwater transfer fraction (Fsw-gw) is assumed to be proportional to the fraction of groundwater recharge resulting from precipitation. For desert areas receiving approximately 12 in. of rainfall or less annually, recharge is less than 1 percent (Walker, 1963); therefore, Fsw-gw is assumed to be 0.01. Since, hypothetically, an underground postulated liquid release is relatively closer to the groundwater aquifer than a surface release, the underground release to groundwater transfer fraction (Fdssw-gw) is assumed to be 0.10. Note also that retardation coefficients are not considered; at this time, their effect on radionuclide transport in groundwater at Yucca Mountain has not been fully evaluated. The retardation values for radionuclides projected to be associated with the waste will be examined as more site-specific (transport/transmissivity) information becomes available.

As with the surface water model, the concentration of radioactivity in the groundwater is determined by considering two cases. The first case (Case A) considers groundwater volume and activity released to the groundwater (Qgw). Case B considers the specific activity of the radionuclide and the solubility of the radionuclide in water. If the derived concentration using Case A is greater than the concentration for Case B, the Case B value is used since Case B represents the estimated limit of solubility for a given radionuclide in water.

For groundwater concentration, Case A and Case B are modeled as follows:

$$\text{CASE A:} \quad Cgw_A = Qgw/Vgw \qquad (3.4.2\text{-}2)$$

$$\text{CASE B:} \quad Cgw_B = Ksol \times SpA \qquad (3.4.2\text{-}3)$$

where:

$Cgw_{A\&B}$	=	radionuclide concentration in groundwater, Ci/L
Qgw	=	annual accumulated activity in groundwater, Ci
Vgw	=	volume of groundwater, L
Ksol	=	solubility coefficient, g/L
SpA	=	specific activity of a given radionuclide, Ci/g

One of the largest groundwater aquifers in the area annually supplies approximately 17,000 acre-feet of water to the springs in Ash Meadows (Amargosa Valley) (Walker, 1963). Generally it is projected that the aquifers in the Yucca Mountain area do not supply these springs; however, because of the lack of specific data, the EPASS assumes the value for the Ash Meadow Spring system to be a crude but reasonable representation of the total annual, accessible groundwater that could hypothetically become contaminated. Obtaining the annual water use value of 10,580 acre-feet (1.30E+07 m^3) for the Amargosa Desert groundwater basin from DOE (1984) and extrapolating to 17,000 acre-feet gives an estimated Vgw value of 2.1E+10 L. Qgw is as derived previously. Appendix A, Tables A.2.b and A.2.c list Ksol and SpA values.

3.4.3 Drinking and irrigation water

In the EPASS evaluation area, almost all water for domestic use comes from springs or other groundwater sources (DOE, 1984). This implies that the potential dose contribution from surface water sources is negligible. Because of repository containment requirements regarding radionuclide travel time to accessible groundwater sources (10,000 yr), there is currently no credible scenario for the release of radioactivity to groundwater in excess of the limits specified in the regulations or standards for approximately 10,000 yr or more. Therefore, significant contribution to human dose as a result of the drinking or irrigation pathways is highly unlikely. However, because of the potential for increased public and regulatory scrutiny, the drinking and irrigation water pathways have been modeled and evaluated. These models consist of both surface and hypothetical (10,000-yr) groundwater components. Although the actual environmental condition is more complex, the EPASS uses a very simple model to evaluate the drinking and irrigation pathways:

For Drinking Water: $$Cpw = Csw*Fswpw + Cgw*Fgwpw \qquad (3.4.3\text{-}1)$$

For Irrigation Water: $$Cwir = Csw*Fswir + Cgw*Fgwir \qquad (3.4.3\text{-}2)$$

where:
- Cpw = radionuclide concentration in drinking water, Ci/L
- Csw = radionuclide concentration in surface water, Ci/L
- Fswpw = surface water, drinking fraction
- Cgw = radionuclide concentration in groundwater, Ci/L
- Fgwpw = groundwater, drinking fraction
- Cwir = radionuclide concentration in irrigation water, Ci/L
- Fswir = surface water, irrigation water fraction
- Fgwir = groundwater, irrigation water fraction

Based on information presented in DOE (1984), the surface water drinking fraction (Fswpw) is assumed to be effectively zero. In the case of the surface water irrigation fraction (Fswir), however, a value of 1.5E-05 can be derived from the ratio of the usable surface water volume (Vsw (Section 3.4.1)) to the groundwater volume (Vgw (Section 3.4.2)).

3.5 BIOTA MODELS

The EPASS biota models utilize the environmental media concentrations resulting from atmospheric, surface water, and groundwater transport (described in Sections 3.3 and 3.4) as input. These models are used to predict the significance of the terrestrial and aquatic food chain pathways in terms of dose contribution to humans. To fulfill this task, the EPASS relies on three basic equations: the first to predict radionuclide content in terrestrial vegetation (both domestic and natural vegetation), the second to determine uptake in terrestrial animals (both domestic and wild), and the third to predict the radionuclide concentrations in aquatic animals. In order to simplify the biota models, both radioactive decay and transfer times (food to consumer) are conservatively ignored.

3.5.1 Vegetation

The concentration of radioactive material in vegetation results from deposition onto the plant foliage and uptake of radionuclides from contaminated soil. Both the airborne and irrigation water source terms are considered contributors. As a result, the equation for the vegetation model presented in this section of the study consists of two primary components. The first bracketed term in Equation 3.5.1-1 represents the concentration resulting from airborne deposition. The second bracketed term represents the irrigated water contribution. The total concentration is the sum of these two terms, represented as follows:

$$
\begin{aligned}
Cvt = \{[&Tgr*S*([(Fint*TL*[1-EXP(-Rw*SL)])/Cd*Rw*SL]-R*S*Dpl*Fint)*HW \\
&+ ((Fsoil*[1-EXP(-Rw*SL)])/Sd*Rw*SL)]\} + \\
&\{Tgr*Cwir*Rir*Fcrir*Fir*[([(Fint*TL*[1-EXP(-Rw*SL)])/Cd*Rw*SL]*HW) \\
&+ (Fsoil*[1-EXP(-Rw*SL)])/(Sd*RW*SL)]\}*Ai \qquad (3.5.1\text{-}1)
\end{aligned}
$$

where:
- Cvt = total radionuclide concentration in plants, Ci/kg
- Tgr = fraction of the year/growing season for crop
- S = annual radionuclide surface deposition, Ci/m^2
- Fint = crop interception fraction (the fraction of deposition material intercepted and immediately retained on foliage)
- TL = translocation factor (the factor for the translocation of externally deposited radionuclides to edible parts of plants)
- EXP = exponential function
- Rw = weathering removal rate constant, 1/d
- SL = growing season length, d
- Cd = agricultural productivity, wet weight, kg/m^2
- R = resuspension fraction (of particulate radioactivity from the surface of the plant), 1/m
- Dpl = plant (foliar) density, kg/m^3
- HW = washing/peeling/threshing factor (pertains only to the edible portions of foodcrops)
- Fsoil = radionuclide soil to plant transfer coefficient (dimensionless)
- Sd = areal soil density, kg/m^2
- Cwir = radionuclide concentration in irrigation water, Ci/L
- Rir = irrigation rate, L/m^2
- Fcrir = fraction of crops that are irrigated
- Fir = fraction of the growing season the crops are irrigated
- Ai = fraction of land area utilized for a specific crop (this value is used only for the commercial crops/average individual evaluations)

Since the total area of Nye County encompasses most of the EPASS evaluation area, the vegetation model utilizes specific data based on Nye County statistics when available. This data is then applied to the entire Southern Nevada area of interest (or EPASS evaluation area--see Figure 1-1). For incomplete or missing data, information is derived from sources considered to be a reasonable substitute for Nye County parameters (i.e., southern New Mexico agricultural data). For example, some agricultural productivity values

(Cd) are calculated from studies by the U.S. Department of Agriculture (1978) and U.S. Department of Commmerce (1982a); other values are obtained directly from Shor (1982). In addition, the crop growing season length (SL) and season fraction (Tgr) are derived from USDA (1978) and DOC (1982a). Soil uptake concentration factors (Fsoil) are calculated using information available in Figures 2.1 and 2.2 and Table 2.3 of Shor (1982). For the average-case individual, commercial feed-crop area fractions are developed based on the assumption that the total area of Nye County (see Figure 1-1) is effectively the total area of interest, since it encompasses two-thirds of the EPASS evaluation area. Area fractions are then derived by determining the area utilized by each type of crop (from USDA, 1978 and DOC, 1982a) and dividing the values by the total area of Nye County (DOC, 1982a). Other factors (i.e., Fint, Dpl, TL, Sd, Rw, Fir, Rir, and Fcrir) are obtained from more general sources, as discussed below.

The translocation factor (TL) is assumed to be equal to 1.0, based on the National Council on Radiation Protection and Measurements (1984). The crop interception fraction (Fint) relies on the assumption that all of the airborne activity is particulate. Based on an assumed deposition velocity of 0.1 cm/s, information in Hoffman (1979) indicates that Fint values for range grasses, pasture crops, and wheat are 0.57. NRC (1977a) provides a default value of 0.20 for leafy vegetables, fruit, berries, mushrooms, and peppers. For potatoes and pecans Fint is considered to be zero, since surface deposition is not applicable (the edible portions are in the form of a root or shell-covered seed).

Values such as the weathering removal constant (Rw) are derived by the use of simple equations such as the following:

$$Rw = 0.693/tw \qquad (3.5.1\text{-}2)$$

where tw is the weathering half-life, 14 days, based on NCRP (1984). Other factors, such as areal soil density (Sd) and the irrigation rate (Rir), are taken directly from NCRP (1984) and DOE (1984), respectively. The plant density (Dpl) is based on the density of cellulose/wood, and derived from the U.S. Department of Health, Education, and Welfare (1970). The fraction of the growing season that crops are irrigated (Fir) and the washing/peeling factor (HW) are assumed values. Terms such as the radionuclide concentration in irrigation water (Cwir) and the annual surface deposition (S) are those determined in Sections 3.3.2 and 3.4.3 of this report. For a complete list of the values used in the vegetation model, see Appendix A, Tables A.3.b through A.3.f.

3.5.2 Animals

Because of the buildup of radioactivity on the surfaces of plants and crops, the principal means of radionuclide entry into grazing animals is generally via the consumption of forage (Till, 1983). In effect, the radionuclide concentration in an animal or animal product is proportional to the quantity of contaminated feed or forage eaten by the animal and its intake of contaminated water. In the EPASS, the animal model includes both dairy (cow and goat) and meat products (domestic and wild). In Equation 3.5.2-1, the first term in brackets models the animal's radionuclide concentration resulting from the ingestion of contaminated food; the second bracketed term represents the contribution from the ingestion of water. The sum of both bracketed terms multiplied by the radionuclide transfer factor (Fupi) models the radionuclide concentration in a given animal, as follows:

$$Cani = \{[\sum_{n=1}^{j} Cvegn*FFin*FFanlocn*Rin] + [(Csw*Rwi*FFsw) + (Cgw*Rwi*FFgw)]\}*Fupi \quad (3.5.2\text{-}1)$$

where:
- Cani = concentration of the radionuclide in meat or milk, Ci/kg
- Cvegn = concentration of the radionuclide in each type of forage/feed n, Ci/kg
- FFin = fraction of daily forage/feed that is a specific type n
- FFanlocn = local food fraction (for each forage/feed type, n) fed to local domestic animals
- Rin = forage/feed consumption rate, kg/d (for each forage/feed type, n)
- Csw = concentration of the radionuclide in surface water, Ci/L
- Rwi = water consumption rate, L/d
- FFsw = fraction of daily water intake that is surface water
- Cgw = radionuclide concentration in groundwater, Ci/L
- FFgw = fraction of daily water intake that is groundwater
- Fupi = radionuclide transfer factor (meat or milk), d/kg or d/L

As in the vegetation model, the animal model relies on available Nye County data to model the Southern Nevada area of interest. If such data is incomplete or unavailable, information is derived from other sources. For example, consumption rates of food and water by animals (Ri and Rw values) are based on animal units defined in Brown (1954). Since the unit standard is a cow (animal unit fraction of 1.0), and the consumption rates for all other animals are in terms of cow fraction (Brown, 1954), only the consumption rates for a cow require defining. For this number, a default value of 50 kg/d and 60 L/d (food and water respectively) are used (NRC, 1977a). Other factors, such as the animal diet fractions (FFi values), are assumed values based on general reading of Stockman (1979). The FFi and the derived Ri values are, in turn, used to determine the fraction of locally grown food available for local area domestic animal consumption (Fanloc values).

The Fanloc fraction (for crops) is essentially based on a ratio of the total local agricultural production value for that crop to the total quantity of a specific type of crop consumed for all domestic animals of interest. Conservatively assuming that the total amount of crop produced is available for feed, the Fanloc equation is modeled as follows:

$$Fanloc = Qprod/Qcons \quad (3.5.2\text{-}2)$$

where:
- Qcons = quantity of food consumed by domestic animals, kg
- Qprod = quantity of a type of food produced locally, kg

and (using wheat/grain as an example);

$$Qconsw = \sum_{n=1}^{x} Atotn*Rin*FFin \qquad (3.5.2\text{-}3)$$

$$Qprodw = Cdw * A \qquad (3.5.2\text{-}4)$$

where:
- Qconsw = quantity of grain consumed by domestic animals, kg
- Atotn = total number of each type of animal n in Nye County
- Rin = food consumption quantity of each type of animal n, kg
- FFin = grain diet fraction for animal n
- Qprodw = total quantity of local wheat/grain produced, kg
- Cdw = agricultural productivity of wheat/grain, kg/m^2
- A = total local area allocated to wheat/grain crops, m^2

Contributors to animal diet such as range and pasture are assumed to be in constant supply; thus, their Fanloc values are 1.0.

Other factors, like the radionuclide transfer values (Fupi) for (1) cow and goat milk, (2) beef, and (3) chicken and pork, are found in NRC (1977a), Till (1983), and Shor (1982), respectively. FFsw and FFgw are conservatively assumed values. Tables A.4.c through A.4.e provide a list of animal model values.

3.5.3 Aquatic animals

Within an 84-km radius of Yucca Mountain, large bodies of water capable of supporting significant quantities of fish and other aquatic life are non-existent. There are, however, several small springs potentially inhabited by consumable fish. As a result, the EPASS evaluates the potential radionuclide concentration in the fish.

For the purposes of this evaluation, equilibrium between the radionuclide concentration in water and the concentration in fish is assumed to have been reached. In other words, the concentrations of radionuclides in aquatic foods are assumed to be directly related to the concentrations of radionuclides in surface water. This is modeled in the following manner:

$$Caan = Csw * Cfaan \qquad (3.5.3\text{-}1)$$

where:
- Caan = concentration of radionuclides in aquatic animals, Ci/kg
- Csw = concentration of radionuclides in surface water, Ci/L
- CFaan = radionuclide concentration factors for fish, L/kg

Appendix A, Table A.4.f provides a complete listing of the concentration factors used in the aquatic model as obtained from Till (1983).

3.6 HUMAN MODEL

To be consistent with the consumption rate and food data provided in NCRP (1984), four groups are evaluated in the human model: infants (< 1 yr), children (1 - 11 yr), teens (12 - 18 yr), and adults (> 18 yr). Significant pathways and radionuclides are determined primarily for the average-individual case (see Section 3.3.1 for the average case discussion). However, to determine whether or not additional pathways or radionuclides become significant under maximum ingestion conditions, a maximum individual case is also considered (maximum case and average case assumptions are presented in Appendix A, Table A.5.a).

3.6.1 Ingestion--human model

Although the inhalation exposure pathway is typically the principal means of radionuclide entry into humans (i.e., the inhalation pathway is the most significant dose pathway), the EPASS does not model this pathway because it can be directly evaluated. As a result, the concentration of radionuclides in humans is effectively proportional to the quantity of contaminated food and water ingested. In the pathway study, the equation used to model radionuclide concentration (or dose, since DCFs are included in the source term) is as follows:

$$Ahuman = \{ [\sum_{n=1}^{z} (Cfoodn*Dfoodn*Flocfoodn)*Ufood] + (Cmilk*Umilk*Dmilk)*Flocmilk + (Cwater*Uwater*Dwater)*Flocwater \}*RCF \quad (3.6.2\text{-}1)$$

where:
- Ahuman = amount of activity ingested by humans from local food sources, Ci
- Cfoodn = radionuclide concentration in each food type n, Ci/kg
- Dfoodn = diet fractions for each food type n
- Flocfoodn = fraction of each type of food consumed from local sources
- Ufood = intake quantity of food, kg/yr
- Cmilk = radionuclide concentration in goat and cow milk, Ci/L
- Umilk = intake quantity of goat and cow milk, L/yr
- Dmilk = diet fractions for goat and cow milk
- Flocmilk = fraction of goat and cow milk consumed from local sources
- Cwater = radionuclide concentration in drinking water, Ci/L
- Uwater = intake quantity of drinking water, L/yr
- Dwater = diet fraction for drinking water
- Flocwater = fraction of drinking water consumed from local sources
- RCF = radionuclide class fraction for each radionuclide under evaluation in the EPASS

As was the case for the animal and vegetation models, the human model relies on county-specific data when available. If such information is unavailable, reasonable default information is used. For example, human intake quantities (e.g., Ufood, Umilk, and Uwater), as well as most of the dietary fraction numbers (e.g., Dfoodn and Dmilk), are default values obtained or derived from NCRP (1984) (for both average and maximum individual cases). The human local food consumption factors (i.e., Flocfood and Flocmilk) are essentially derived in the same manner as the Fanloc values found in Section 3.5.2. Most of the Flocfood and Flocmilk values are based on a ratio of the total local agricultural production value (for each crop or animal) to the total quantity of each particular food group consumed for each population group (i.e., infant, child, teen, and adult). The population group data is based on Nye County information as obtained from DOC (1982b). The Flocwater value is assumed to be equal to 1.0. For a more detailed breakdown of the human model factors and assumptions, refer to Appendix A, Tables A.5.a through A.5.c.

4.0 ENVIRONMENTAL PATHWAY ANALYSIS EVALUATION

For the EPASS, computer spreadsheets are used to facilitate the numerous calculations required to predict the radiological significance of the ingestion pathways described in the previous sections of this report. Although radionuclide concentration values are derived, they should not be used to describe or determine potential radiological impacts in terms of dose. The values derived in the EPASS evaluation are not intended as absolute estimates, but as relative values only appropriate for use in indicating the projected major radionuclide contributors and significant ingestion pathways to humans in the Yucca Mountain area. These pathways and radionuclides will be monitored to assure that operations at Yucca Mountain are not providing a significant environmental or public health and safety hazard.

To determine the important pathways and radionuclides, the following four summary spreadsheets were developed:

1. Average individual--hypothetical groundwater component and radionuclide weighting factors not included.

2. Average individual--hypothetical groundwater component not included, radionuclide weighting factors included.

3. Average individual--hypothetical groundwater component included, radionuclide weighting factors not included.

4. Average individual--hypothetical groundwater component and radionuclide weighting factors included.

The above spreadsheets that include radionuclide weighting factors (Items 2 and 4) are used to determine the significant pathways; those without are used to determine the significant radionuclides. Maximum individual summary spreadsheets were not developed because the maximum individual case for the EPASS applies to only a very small portion of the population, limited to those individuals that have home gardens. Because of the site-specific considerations, the significant differences between the maximum and average cases are relatively few, thus allowing for the maximum individual results to be estimated on the basis of data for the average individual. The primary differences include the following:

1. A factor of 5 to 7 increase (for the maximum individual) to account for the increase in uptake quantities and diet fractions.

2. A 5 to 7 order of magnitude increase for the radionuclide concentrations in garden vegetables such as leafy vegetables, corn, apples, and melons (because of the elimination of the area fraction Ai in the vegetation model; see Section 3.5.1).

Assuming that the relative quantities of radionuclides in the maximum individual case remain proportional to those in the average case, significant pathways and radionuclides for both cases are easily determined.

For those radionuclides that require a limiting case pathway evaluation (Woolfolk, 1986) and that are not indicated as significant radionuclides in any of the identified significant pathways, each of the models on the spreadsheet (those without radionuclide weighting factors) are examined to determine the appropriate significant components of the biota pathway for each limiting case radionuclide.

4.1 SIGNIFICANT PATHWAYS

Significant pathways with and without the hypothetical groundwater source term component for both average and maximum individuals for each projected waste category were evaluated. Pathways are considered significant if their dose contribution to humans is greater than 1 percent. Unlike the average individual case, however, specific modeling is not performed for the maximum individual case. Maximum case significant pathways are determined by scaling the leafy vegetable, corn, apple, melon, mushroom, and pepper (potential garden plants) fractions for the average teen-HLW category by 5 to 7 orders of magnitude (the difference between average and maximum values for these components of the biota model) and recalculating the contribution fractions to determine whether any of the above pathways become significant. The average case (for teenage consumption rates) is used as the primary basis for pathway evaluation because significant quantities of almost all the foods under evaluation are consumed. The HLW category is of particular interest because of the broad spectrum of radionuclides included in it. Table 4-1 identifies the significant pathways of the average individual case for each waste category. In addition, Table 4-2 identifies the limiting case pathways for those radionuclides indicated in Woolfolk (1986) and not identified as significant radionuclide contributors in Table 4-3. In general, these radionuclides are perceived to be of specific interest to either the EPA (e.g., they have been identified in EPA containment release limit standards, 40 CFR Part 191, Table 1) or the general public. As a result, the limiting pathways must be determined in order to institute appropriate postclosure environmental sampling activities. The basic elements include C, Cs, I, Pu, Th, Sr, Tc, and U. A complete radionuclide breakdown can be found in Appendix A, Table A.7 of this report.

4.2 SIGNIFICANT RADIONUCLIDES

For the significant pathways identified in Table 4-1, the primary radionuclide contributors were also determined. In addition, to address RMP postclosure monitoring requirements, the EPASS model determines the significant radionuclides for the groundwater pathway. Groundwater is specifically included in the EPASS because, for postclosure monitoring purposes, it is considered to be the likely indicator path for potential radionuclide migration from the repository. In the EPASS model an alpha-emitting radionuclide is considered a primary or significant contributor if it is greater than 0.01 percent of the total activity in a significant pathway. For beta and gamma emitters, this value is 0.1 percent. Tables 4-3 and 4-4 identify the significant radionuclides for the pathways derived by the EPASS model and the groundwater pathway, respectively.

Table 4-1. Significant pathways--Yucca Mountain[a]

Waste stream	Infant (< 1 yr)	Child (1-12 yr)	Teen (13-18 yr)	Adult (> 18 yr)
AVERAGE INDIVIDUAL (WITHOUT HYPOTHETICAL GROUNDWATER COMPONENT)				
Crud	M,B,GM,LV	M,B,GM,V,LV	M,B,GM,V,LV	M,B,V,LV
High-Level waste	M,B,GM,LV	M,B,GM,V,LV	M,B,GM,V,LV	M,B,GM,V,LV
Crud and actinide (little TRU[b])	M,B,GM,LV	M,B,GM,V,LV	M,B,GM,V,LV	M,B,V,LV
Damaged fuel	M,B,GM,LV	M,B,GM,V,LV	M,B,GM,V,LV	M,B,GM,V,LV
MRS[c] waste	M,B,GM,LV	M,B,GM,V,LV	M,B,GM,V,LV	M,B,GM,V,LV
AVERAGE INDIVIDUAL (WITH HYPOTHETICAL GROUNDWATER COMPONENT)				
Crud	M,B,GM,LV	M,B,GM,V,LV	M,B,GM,V,LV	M,B,V,LV
High-Level waste	M,B,GM,LV	M,B,GM,V,LV	M,B,GM,V,LV	M,B,GM,V,LV
Crud and actinide (little TRU)	M,B,GM,LV	M,B,GM,V,LV	M,B,GM,V,LV	M,B,V,LV
Damaged fuel	M,B,GM,LV	M,B,GM,V,LV	M,B,GM,V,LV	M,B,GM,V,LV
MRS waste	M,B,GM,LV	M,B,GM,V,LV	M,B,GM,V,LV	M,B,GM,V,LV

[a]M = milk/dairy, B = beef, GM = goat milk, V = venison, LV = leafy vegetables (leafy vegetables also become significant in the maximum individual (home gardening) case).

[b]TRU = transuranic waste.

[c]MRS = monitored retrievable storage.

Table 4-2. Limiting case pathways[a]

Radionuclide	Limiting pathway (ordered by decreasing significance)
Cs-135	1. Fish[b] 2. Duck/Geese[b] 3. Beef/Goat Milk 4. Deer 5. Lamb 6. Cow Milk
I-129	1. Fish[b] 2. Duck/Geese[b] 3. Beef/Goat Milk/Cow Milk 4. Deer
Pu-238	1. Fish[b] 2. Duck/Geese[b] 3. Beef/Deer[c] 4. Pork/Cow Milk 5. Goat Milk
Pu-239	1. Fish[b] 2. Duck/Geese[b] 3. Beef/Deer[c] 4. Pork/Cow Milk 5. Goat Milk
Pu-240	1. Fish[b] 2. Duck/Geese[b] 3. Beef/Deer[c] 4. Pork/Cow Milk 5. Goat Milk
Pu-242	1. Fish[b] 2. Duck/Geese[b] 3. Beef/Deer[c] 4. Pork/Cow Milk 5. Goat Milk
Th-230	1. Fish[b] 2. Duck/Geese[b] 3. Beef 4. Deer/Lamb/Cow Milk 5. Goat Milk 6. Pork
Th-232	1. Fish[b] 2. Duck/Geese[b] 3. Beef 4. Deer/Cow Milk/Lamb 5. Goat Milk
U-233	1. Fish[b] 2. Duck/Geese[b] 3. Beef/Cow Milk 4. Deer/Goat Milk
U-234	1. Fish[b] 2. Duck/Geese[b] 3. Beef/Cow Milk 4. Deer/Goat Milk
U-235	1. Fish[b] 2. Duck/Geese[b] 3. Beef/Cow Milk 4. Deer/Goat Milk
U-236	1. Fish[b] 2. Duck/Geese[b] 3. Beef/Cow Milk 4. Deer/Goat Milk
U-238	1. Fish[b] 2. Duck/Geese[b] 3. Beef/Cow Milk 4. Deer/Goat Milk

[a]For those radionuclides identified in Appendix A of Woolfolk (1986) and not identified in Table 4-3.
[b]Insufficient quantities in the environment to sample.
[c]Less than a factor of 5 difference.

Table 4-3. Significant radionuclides by pathway and waste category (for the model determined pathways)[a,b]

Pathway	Crud	High-level waste	Crud/actinide mix	Damaged fuel	Monitored retrievable storage waste
Milk/ dairy	Co-60 (6) Ni-59 (0.1) Ni-63 (5) C-14 (89)	H-3 (0.1) C-14 (3) Sr-90 (6) Tc-99 (0.1) Cs-137 (91)	C-14 (89) Co-60 (6) Ni-59 (0.1) Ni-63 (5)	C-14 (80) Co-60 (5) Ni-59 (0.1) Ni-63 (4) Sr-90 (0.5) Cs-137 (9)	H-3 (0.1) C-14 (3) Sr-90 (6) Cs-137 (91) Tc-99 (0.1)
Beef	Co-60 (2) Ni-63 (1) C-14 (96)	C-14 (22) Sr-90 (0.3) Cs-137 (78)	Co-60 (2) Ni-63 (1) C-14 (96)	C-14 (95) Co-60 (2) Ni-63 (1) Cs-137 (1)	C-14 (22) Sr-90 (0.3) Cs-137 (78)
Goat milk	Co-60 (8) Ni-63 (0.7) C-14 (99)	C-14 (0.6) Sr-90 (1) Cs-137 (98)	Co-60 (0.8) Ni-63 (0.7) C-14 (99)	C-14 (63) Co-60 (0.5) Ni-63 (0.4) Cs-137 (36) Sr-90 (0.5)	C-14 (0.6) Sr-90 (1) Cs-137 (98)
Venison	Co-60 (2) Ni-63 (1) C-14 (96)	C-14 (22) Sr-90 (0.3) Cs-137 (78)	Co-60 (2) Ni-63 (1) C-14 (96)	C-14 (95) Co-60 (2) Ni-63 (1) Cs-137 (1)	C-14 (22) Sr-90 (0.3) Cs-137 (78)
Leafy vege- tables	Co-60 (19) Ni-59 (0.8) Ni-63 (31) Zr-93 (0.8) C-14 (48)	C-14 (1) Sr-90 (21) Cs-137 (78)	Co-60 (19) C-14 (48) Ni-59 (0.7) Ni-63 (32) Zr-93 (0.8)	C-14 (26) Co-60 (10) Ni-59 (0.4) Ni-63 (17) Sr-90 (1) Zr-93 (0.4) Cs-137 (5) Pu-241 (40) Cm-244 (0.06)	C-14 (0.2) Sr-90 (3) Cs-137 (11) Pu-241 (85) Cm-244 (0.1)

[a]Adult case values used. Significant radionuclides for a pathway are not dependent on intake quantities or minor diet fraction differences.
[b]Values in parentheses indicate percentage contribution to the pathway.

Table 4.4. Significant radionuclides--groundwater pathway (adult--at 10,000 yrs)[a]

Crud	High-level waste	Crud/actinide mix	Damaged fuel	Monitored retrievable storage waste
C-14(15)	C-14(3)	C-14(15)	C-14(15)	C-14(1)
Ni-59(7)	Zr-93(20)	Ni-59(7)	Ni-59(7)	Zr-93(11)
Zr-93(77)	Tc-99(76)	Zr-93(77)	Zr-93(75)	Tc-99(40)
	Cs-135(0.5)		Tc-99(1)	Cs-135(0.3)
			U-236(0.01)	U-236(0.4)
			U-238(0.01)	U-238(0.4)
			Pu-239(0.1)	Np-237(0.05)
			Pu-240(0.7)	Pu-239(27)
			Am-243(0.02)	Pu-240(19)
				Pu-242(0.2)
				Am-243(0.7)

[a]Values in parentheses are percentages.

5.0 SUMMARY AND CONCLUSIONS

Based on the results of the EPASS model, the information summarized in Tables 4-1 and 4-2 indicate that, in general, beef, cow milk, goat milk, venison, and leafy vegetables represent the significant pathways to humans for most of the waste categories. Noted exceptions include the venison pathway for infants (venison is not part of an infant's diet) and the goat milk pathway for adults (for the crud and crud/actinide waste categories). Table 4-3 identifies the primary radionuclide components of the significant pathways as C-14, Cs-137/Ba-137m, Sr-90/Y-90, Ni-63, Co-60, and Pu-241. For the groundwater pathway (at 10,000 yr), Table 4-4 identifies the radionuclides as C-14, Ni-59, Tc-99, Zr-93, Pu-239, and Pu-240. It should be noted that the same radionuclides are significant regardless of a human's age. This is because radionuclide significance is derived relative to other radionuclides in a component of a human's diet, not the quantity consumed by the human.

Based on Tables 4-1 through 4-4 and the above information, it is currently recommended that the environmental monitoring program sample the following:

1. Range vegetation and leafy vegetation. These are the primary pathways for most of the limiting case radionuclides, as well as the bulk of the actinides. Since the vegetation pathways are sensitive to removal of surface deposition by washout due to precipitation, it is recommended that sampling of these pathways be conducted in conjunction with sampling of beef or milk (i.e., pathways that are almost as sensitive to the same radionuclides). In addition, it is important to sample those radionuclides representative of the projected waste category source spectrum for the Yucca Mountain facility. Recommended radionuclides include:

   a. Pu-239 and Pu-241. In general, actinides in the environment act in a similar manner; thus, Pu-239 and Pu-241 are chosen to represent the actinide portion of the limiting case radionuclides. In addition, these radionuclides appear as the dominant fraction of the actinides in the environmental model.

   b. Co-60, Cs-137/Ba-137m, Sr-90/Y-90 (primarily on leafy vegetables--home gardens). These radionuclides comprise a large portion of the non-actinide group of significant radionuclides and are fairly easy to monitor via beta and gamma spectroscopy.

   c. C-14 and Ni-63. These radionuclides are the primary components of the significant radionuclide group for this pathway. Despite the fact that the analytical technique required to quantify C-14 and Ni-63 is relatively complex and time-intensive, they should be monitored because of their dominance in the pathway.

2. Beef. This pathway is a significant one for monitoring the same types of radionuclides found in range or leafy vegetation. Beef has a tendency to accumulate many of the same radionuclides, and the results are not subject to variation due to precipitation/washout. It should also be noted that the model indicates that both the beef

and venison food chain pathway represent the same significant radionuclides. Although either pathway can be monitored, beef is recommended because (1) it is probably easier to obtain beef samples and (2) deer are too transient to be a good radionuclide indicator species for a relatively local area. If beef is not available, venison may be an acceptable alternative. Monitoring should include the following radionuclides:

a. Pu-239 and Pu-241. These radionuclides are chosen for essentially the same reasons stated in Item 1a. Although they are overshadowed by the fission and activation products in the beef/venison pathway, these radionuclides are significant when the others are not considered. Because beef activity levels are not affected by variations resulting from precipitation, as they are in vegetation, it is recommended that monitoring of Pu-239 and Pu-241 be performed for both the beef and vegetation pathways.

b. C-14. This radionuclide is the primary component of the significant radionuclide group for this pathway. Despite the fact that the analytical technique required to quantify C-14 is relatively complex, it should be monitored because of its dominance in the pathway.

c. Co-60, Cs-137/Ba-137m, and Sr-90/Y-90. These radionuclides, with the exception of Sr-90, are essentially the dominant radionuclide components of the beef pathway. Although Sr-90 does not appear as significant in some of the waste categories (and will appear more significant in the milk pathway), it is recommended that it be monitored to supplement monitoring of the vegetation pathways. Sr-90, as well as the other radionuclides, is relatively easy to measure via beta and gamma spectroscopy, although this should be supplemented by other radioanalytical methods.

3. Milk. Milk is the primary pathway for the nonactinide, limiting case radionuclides (e.g., iodine), as well as many of the fission and activation products. Although cow milk is preferred because it is a better indicator of the more soluble radioactive compounds and nuclides (e.g., tritium), goat milk can be monitored instead if it is more readily available. Recommended radionuclides for monitoring include:

a. Co-60, Cs-137/Ba-137m, and Sr-90/Y-90. The milk pathway is relatively sensitive to these radionuclides. They are also relatively easy to monitor via beta and gamma spectroscopy, although these should be supplemented by radioanalytical methods.

b. I-129. Although there are not significant quantities of this radionuclide in the waste, milk is the limiting case pathway and should be monitored for I-129.

c. C-14. This radionuclide is the primary component of the significant radionuclide group for this pathway. Despite the fact that the analytical technique required to quantify C-14 is relatively complex, it should be monitored because of its dominance in the pathway.

d. H-3. Although it is not a dominant component of the milk pathway, tritium is very mobile in the environment and a good indicator of a potential release. Thus, milk should periodically be analyzed for tritium content.

4. Groundwater. Although groundwater is not considered a significant dose pathway, it is recommended that it be monitored to provide a baseline to prove adequate isolation of the waste (if Yucca Mountain is chosen as the nation's first repository). Recommended radionuclides for monitoring include:

   a. H-3. This radioactive compound is recommended primarily because it is very mobile in the environment. Its short half-life (12.3 yrs), however, limits its usefulness as an indicator of a potential release from the repository to the period of time during operation and soon after closure of the repository.

   b. Tc-99, Ni-59, and Zr-93. These radionuclides are the primary significant radionuclides for the groundwater pathway. They are also relatively mobile in the environment and have a long half-life, making them useful long-term indicators of a potential release from the repository.

   c. Pu-239 and Pu-240. These radionuclides are the primary significant actinides for the groundwater pathway. Although in general they are not as mobile in the environment, they have a long half-life and are useful as indicators of potentially larger breaches in waste isolation.

The above pathways and radionuclides represent recommendations based on either currently available site-specific information or reasonable default values and assumptions where the required information is unavailable. Because the intent of the EPASS is to provide a reasonably conservative estimate of the radionuclides and environmental pathways that should be monitored, it is projected that the final results will not change significantly. Should additional site-specific source term and environmental data become available, the model and assumptions will be reevaluated in light of the new information as appropriate. Appendix A provides a detailed listing of the values used in the EPASS.

REFERENCES

AEC (U.S. Atomic Energy Commission), 1968. "Meteorology and Atomic Energy 1968," Office of Information Services.

Baes III, C. F., R. D. Sharp, et al., 1984. "A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture," ORNL-5786.

Brown, Dorothy, 1954. "Methods of Surveying and Measuring Vegetation," Bulletin 42, Commonwealth Bureau of Pastures and Field Crops.

DOC (U.S. Department of Commerce), 1982a. "1982 Census of Agriculture, Part 28, Nevada State and County Data."

DOC (U.S. Department of Commerce), Bureau of the Census, 1982b. "1980 Census of Population, Part 30, Nevada."

DOE (U.S. Department of Energy), 1979. "Technology of Commercial Radioactive Waste Management," Volume 1, DOE/ET-0028.

DOE (U.S. Department of Energy), 1980. "Final Environmental Impact Statement: Waste Isolation Pilot Plant," DOE/EIS-0026.

DOE (U.S. Department of Energy), 1981. "A Guide for: Environmental Radiological Surveillance at U.S. Department of Energy Installations," DOE/EP-0023.

DOE (U.S. Department of Energy), 1983. "A Guide for Effluent Radiological Measurements at DOE Installations," DOE/EP-0096.

DOE (U.S. Department of Energy), 1984. "Environmental Assessment: Yucca Mountain Site, Nevada Research and Development Area, Nevada," DOE/RW-0073, Volume 1.

DOE (U.S. Department of Energy), 1988. Draft Order 5480.XY, "Requirements for Radiological Effluent Monitoring and Environmental Surveillance."

DOE (U.S. Department of Energy), 1987. Draft Order 5480.XX, "Radiation Protection of the Public and Environment."

EPRI (Electric Power Research Institute), 1985. "Environmental Radiation Doses from Difficult to Measure Radionuclides," EPRI NP-3840.

Giampaoli, M. E., 1986. "Field Reconnaissance Itinerary," Enclosure to Letter M86-GEO-MEG-054.

Grossman, R. F., S. C. Black, et al., 1986. "Off-Site Environmental Monitoring Report: Radiation Monitoring Around United States Nuclear Test Areas, Calendar Year 1985," EPA/600/4-86/022.

HEW (U.S. Department of Health, Education and Welfare), 1970. "Radiological Health Handbook."

Hoffman, F. O., C. F. Baes III (editors), 1979. "A Statistical Analysis of Selected Parameters for Predicting Food Chain Transport and Internal Dose of Radionuclides," ORNL/NUREG/TM-282.

Lotus Development Corporation, 1985. 1-2-3 Spreadsheet Program, Release 2.0.

NCLRS (Nevada Crop and Livestock Reporting Service), 1985. "1984 Nevada Agricultural Statistics."

NCRP (National Council on Radiation Protection and Measurements), 1984. NCRP Report No. 76, "Radiological Assessment: Predicting the Transport, Bioaccumulation, and Uptake by Man of Radionuclides Released to the Environment."

NRC (U.S. Nuclear Regulatory Commission), 1976. Regulatory Guide 4-2, "Preparation of Environmental Reports for Nuclear Power Stations."

NRC (U.S. Nuclear Regulatory Commission), 1977a. Regulatory Guide 1.109, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 50 Appendix I."

NRC (U.S. Nuclear Regulatory Commission), 1977b. Regulatory Guide 1.111, "Methods for Estimating Atmospheric Transport and Dispersion for Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors."

NRC (U.S. Nuclear Regulatory Commission), 1982. Regulatory Guide 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants."

Rai, Dhanpat, and T. L. Ryan, 1984. "Solubility Constraint: An Important Consideration in the Safety Assessment of Nuclear Waste Disposal," Material Resuspension Society Symposium Proceedings, Volume 26.

SAIC (Science Applications International Corporation), 1988. "Radiological Monitoring Plan for the NNWSI Project," DOE/NV-10576-6, SAIC-87/800.

Shor, R. W., C. F. Baes III, and R. D. Sharp, 1982. "Agricultural Production in the United States by County: A Compilation of Information from the 1974 Census of Agriculture for Use in Terrestrial Food-Chain Transport and Assessment Models," ORNL-5768.

Stewart, Donald C., 1985. <u>Data for Radioactive Waste Management and Nuclear Applications</u>.

<u>Stockman Breeder's Handbook, 1979</u>.

Sutter, S. L., 1982. "Accident Generated Particulate Materials and Their Characteristics -- A Review of Background Information," NUREG/CR-2651.

Till, John E., and H. Robert Meyer (editors), 1983. <u>Radiological Assessment: A Textbook on Environmental Dose Analysis</u>, NUREG-3332.

Travis, John R., 1975. "A Model for Predicting the Redistribution of Particulate Contaminants from Soil Surfaces."

USDA (U.S. Department of Agriculture) and the New Mexico Department of Agriculture, 1978. "New Mexico Agricultural Statistics."

Walker, George E., and Thomas E. Eakin, 1963. "Groundwater Resources - Reconnaissance Series, Report 14, Geology and Ground Water of Amargosa Desert Nevada - California."

West, Robert C., and Samuel M. Selby (editors), 1967. CRC Handbook of Chemistry and Physics, Volume 48.

WIPP (Waste Isolation Pilot Plant), 1985. "Estimates of Internal Dose Equivalents from Inhalation and Ingestion of Selected Radionuclides," WIPP-DOE-176, Revision 1.

Woolfolk, Steven W., 1986. Letter, "Radiological Task Data," Woolfolk to Belanger, M86-TSP-SWW-09.

CODE OF FEDERAL REGULATIONS

10 CFR Part 20, 1986. Title 10, "Energy", Part 20, "Standards for Protection Against Radiation", U.S. Government Printing Office, Washington, D.C.

40 CFR Part 191, 1986. Title 40, "Protection of Environment", Part 191, "Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," U.S. Government Printing Office, Washington, D.C.

Appendix A

PATHWAY ANALYSIS ASSUMPTIONS

This appendix provides a list of assumptions and references used in the development of the environmental model but which were not directly discussed in previous sections of the EPASS.

A.1 RELEASE SOURCE TERMS

a. General source data (assuming 1 yr of operations)

Variable name	Value	Reference
Svol	2.2E+12 L	Page 8-35, DOE (1980)
Wvol	4.5E+08 L	Table 5-9, DOE (1984) (10% of total water use)
Wspvol	1.0E+03 L	Assumed value

b. Radionuclide weighting factors (derived from WIPP, 1985)

Table A.1.b. Radionuclide weighting factors (RWF) (ingestion values)[a,b,c]

Radionuclide	WIPP-DOE 176(A)	WIPP-DOE176(L)	RWF(A)	RWF(L)
H-3[d]	6.00E-05	6.00E-05	2.31E-03	5.45E-05
C-14[e]	2.40E-05	2.10E-03	9.23E-04	1.91E-03
Co-60	2.70E-02	1.00E-02	1.04E+00	9.09E-03
Ni-59[f]	2.00E-04	2.00E-04	7.69E-03	1.82E-04
Ni-63	5.80E-04	5.80E-04	2.23E-02	5.27E-04
Sr-89	9.20E-03	9.20E-03	3.54E-01	8.36E-03
Sr-90	1.10E-02	1.30E-01	4.23E-01	1.18E-01
Zr-93[f]	1.60E-03	1.60E-03	6.15E-02	1.45E-03
Tc-99	1.50E-03	1.50E-03	5.77E-02	1.36E-03
Sn-126[f]	1.80E-02	1.80E-02	6.92E-01	1.64E-02
I-129	2.70E-01	2.70E-01	1.04E+01	2.45E-01
Cs-135	7.10E-03	7.10E-03	2.73E-01	6.45E-03
Cs-137	5.00E-02	5.00E-02	1.92E+00	4.55E-02
Ra-226	1.30E+00	1.30E+00	5.00E+01	1.18E+00
Th-230	5.20E-01	5.20E-01	2.00E+01	4.73E-01
Th-232	2.70E+00	2.70E+00	1.04E+02	2.45E+00
U-233	2.60E-02	1.10E+00	1.00E+00	1.00E+00

Table A.1.b. Radionuclide weighting factors (RWF) (ingestion values)[a,b,c] (continued)

Radionuclide	WIPP-DOE 176(A)	WIPP-DOE176(L)	RWF(A)	RWF(L)
U-234	2.60E-02	1.00E+00	1.00E+00	9.09E-01
U-235	2.70E-02	1.00E+00	1.04E+00	9.09E-01
U-236	2.40E-02	1.00E+00	9.23E-01	9.09E-01
U-238	2.30E-02	9.40E-01	8.85E-01	8.55E-01
Np-237	3.90E+01	3.90E+01	1.50E+03	3.55E+01
Pu-238	5.50E-02	4.00E-01	2.12E+00	3.64E-01
Pu-239	5.90E-02	4.40E-01	2.27E+00	4.00E-01
Pu-240	5.90E-02	4.40E-01	2.27E+00	4.00E-01
Pu-241	9.50E-04	8.70E-03	3.65E-02	7.91E-03
Pu-242	5.60E-02	4.20E-01	2.15E+00	3.82E-01
Am-241	2.20E+00	2.20E+00	8.46E+01	2.00E+00
Am-243	2.20E+00	2.20E+00	8.46E+01	2.00E+00
Cm-244	1.10E+00	1.10E+00	4.23E+01	1.00E+00

[a]Weighting factors ratioed to U-233.
[b]WIPP-DOE-176 Revision 1 values are ingestion dose conversion factors at 50 yr.
[c](A) = used in airborne pathway, (L) = used in liquid pathway.
[d]The solubility class for tritium is H_2O.
[e]The solubility classes used for carbon are CO_2 and ORG.
[f]Obtained from Till (1983), Table 7.21.

A.2 HYDROLOGY MODEL VALUES

a. General source data (assuming 1 yr of operations)

Variable name	Value	Reference
Fswpw	0.0	Page 3-31, DOE (1984)
Fgwpw	1.0	DOE (1984)

b. Solubility coefficients (g/L) (Ksol--obtained from West, 1967)

Table A.2.b. Solubility coefficients[a,b,c]

Element	Ksol (g/L) (H)	Ksol (g/L) (C)
H		
C	9.70E-01	3.48E+00
Co	8.30E+02	3.62E+02
Ni		2.39E+03
Sr	1.00E+03	7.09E+02
Zr[d]	2.00E-01	2.00E-01
Tc		
Sn	2.70E+03	8.39E+02
I		1.87E+03
Cs	2.20E+03	1.67E+03
Ra[e,f]	1.39E+02	1.39E+02
Th	6.64E+01	1.63E+01
U[f]	2.40E-06	2.30E-06
Np[f]	2.40E-03	2.40E-03
Pu[f]	2.40E-04	2.40E-04
Am[f]	2.40E-03	2.40E-03
Cm[f]	2.40E-03	2.40E-03

[a](H) = hot water--values used for surface water, (C) = cold water--values used for groundwater.

[b]For values not specifically indicated (blank spaces) 100 percent solubility was assumed.

[c]Ksol data obtained by utilizing the value for the element in its most soluble compound form.

[d]Insoluble--assumed 0.02.

[e]Assumed cold and hot water values are the same (lack of hot water data).

[f]Rai (1984) (for a pH range of 4-8).

c. Specific activity (Ci/g) (SpA--obtained from Stewart, 1985)

Table A.2.c. Specific activity and half-lives

Radionuclide	SpA (Ci/g)	T (yr)
H-3	9.65E+03	1.23E+01
C-14	4.46E+00	5.73E+03
Co-60	1.13E+03	5.27E+00
Ni-59	7.56E-02	8.00E+04
Ni-63	6.18E+01	9.20E+01
Sr-89	2.81E+04	1.42E-01
Sr-90	1.41E+02	2.81E+01
Zr-93	4.03E-03	9.50E+05
Tc-99	1.69E-02	2.13E+05
Sn-126	2.84E-02	1.00E+05
I-129	1.73E-04	1.60E+07
Cs-135	1.15E-03	2.30E+06
Cs-137	8.69E+01	3.00E+01
Ra-226	9.86E-01	1.60E+03
Th-230	1.94E-02	8.00E+04
Th-232	1.09E-07	1.41E+10
U-233	9.63E-03	1.59E+05
U-234	6.23E-03	2.45E+05
U-235	2.16E-05	7.04E+08
U-236	6.46E-05	2.34E+07
U-238	3.36E-07	4.47E+09
Np-237	7.04E-04	2.14E+06
Pu-238	1.71E+01	8.77E+01
Pu-239	6.20E-02	2.41E+04
Pu-240	2.21E-01	6.57E+03
Pu-241	1.03E+02	1.44E+01
Pu-242	3.92E-03	3.76E+05
Am-241	3.42E+01	4.33E+02
Am-243	1.99E-01	7.37E+03
Cm-244	8.08E+01	1.81E+01

A.3 VEGETATION MODEL VALUES

a. General source data (assuming 1 yr of operations)

Variable name	Value	Reference
R (1/m)	1.0E-05	Assumed based on Sutter (1982), Table 2.2-1
HW	0.50	Assumed value
Dpl (kg/m^3)	5.0E+02	Derived from cellulose density, HEW (1970)
Sd (kg/m^2)	240	NCRP (1984), Table 2.12
Rir $(1/m^2)$	1.5E+03	Derived, Page 3-32, DOE (1984)
Fir	1.00	Assumed value

b. Growing season length and fraction

Table A.3.b. Growing season length and growing fractions[a]

Vegetation	SL(d)	Tgr	Reference
Range	365	1.00	USDA (1978)[b]
Irrigated past.	365	1.00	USDA (1978)[b]
Wheat	288	0.79	USDA (1978)[b]
Leafy vegetables	243	0.67	USDA (1978)[b]
Corn	133	0.36	DOC (1982a)
Potatoes	168	0.46	USDA (1978)[b]
Apples (2 Crops)	152	0.42	USDA (1978)[b]
Berries	152	0.42	Assumed the same value as apples
Melons	152	0.42	Assumed the same value as apples
Pecans	153	0.41	USDA (1978)[b]
Hay, alfalfa	365	1.00	DOC (1982a)
Silage	133	0.36	DOC (1982a)
Alfalfa seed	133	0.36	DOC (1982a)
Peppers	214	0.59	USDA (1978)[b]
Mushrooms[c]	365	1.00	DOC (1982a)

[a]Values are assumed numbers based on the references. The typical approach was to maximize the values for conservatism.

[b]New Mexico data (Eddy County or other southern counties) were used where Nevada (Nye County) data were not readily available (the climates are assumed to be reasonably similar).

[c]Assumed to be in a greenhouse.

c. Agricultural productivity (Cd)

Table A.3.c. Agricultural productivity

Vegetation	Cd (kg/m^2)	Reference
Range	0.28	Hoffman (1979)
Irrigated pasture	1.31	NCLRS (1985), Nye County
Wheat	0.05	Shor (1982), Appendix C
Leafy vegetables	0.76	Shor (1982), Appendix B
Corn	0.67	Shor (1982), Appendix C
Potatoes	1.90	Hoffman (1979)
Apples (2 crops)	0.58	Derived, USDA (1978)
Berries	0.36	Assumed the same as Pecans
Melons	0.58	Assumed the same as Apples
Pecans	0.36	Peanut Value, USDA (1978)
Hay	1.31	NCLRS (1985), Nye County
Alfalfa	0.99	NCLRS (1985), Nye County
Silage	0.67	Shor (1982), Appendix C
Alfalfa seed	0.67	Shor (1982), Appendix C
Peppers	0.31	USDA (1978), '74 - '78
Mushrooms	0.36	Assumed the same as Berries

d. Soil to plant transfer coefficients (Fsoil)
(from Figures 2.1, 2.2, and 2.3 of Baes, 1984)

Table A.3.d. Soil to plant concentration factors

Element	Bv[a]	Br[b]
H[c]	4.8E+00	4.8E+00
C[c]	5.5E+00	5.5E+00
Co	2.0E-02	7.0E-03
Ni	6.0E-02	6.0E-02
Sr	2.5E+00	2.5E-01
Zr	2.0E-03	5.0E-04
Tc	9.5E+00	1.5E+00
Sn	3.0E-02	6.0E-03
I	1.5E-01	5.0E-02
Cs	8.0E-02	3.0E-02
Ra	1.5E-02	1.5E-03
Th[d]	8.5E-03	4.0E-03
U	8.5E-03	4.0E-03
Np	1.0E-01	1.0E-01
Pu	4.5E-04	4.5E-04
Am	5.5E-03	2.5E-04
Cm	8.5E-04	1.5E-05

[a]Bv values apply to the leafy stem portions of vegetation.
[b]Br values apply to the fruit and seeds of vegetation (Baes, 1984).
[c]Obtained from NRC (1977a).
[d]Information not available, used uranium values.

(i) Concentration correction factors (Baes, 1984)

Table A.3.d.i. Soil-plant concentration correction factors (CF) (dry to wet weight CF)

Plant/crop	(D) or (W)[a]	CF
Range	(D)	1.000
Irrigated pasture[b]	(W)	0.888
Wheat	(W)	0.875
Leafy vegetables[c]	(W)	0.070
Corn	(W)	0.261
Potatoes	(W)	0.222
Apples	(W)	0.159
Berries	(W)	0.151
Melons[d]	(W)	0.060
Pecans[e]	(W)	0.967
Hay	(D)	1.000
Alfalfa	(D)	1.000
Silage	(D)	1.000
Alfalfa seed	(D)	1.000
Peppers	(W)	0.074
Mushrooms[f]	(W)	0.222

[a] (D) is considered dry weight crop, (W) is considered wet weight crop.
[b] Used the average value.
[c] Used the asparagus value.
[d] Used the cantaloupe value.
[e] Used the tree nut value.
[f] Used the weighted average of protected produce.

(ii) Final soil to plant transfer coefficients (Bv or Br x CF, as appropriate) [Fsoil]

Table A.3.d.ii-a. Final soil to plant transfer coefficients (H,C,Co,Ni,Sr, and Zr)[a]

Crop	H	C	Co	Ni	Sr	Zr
Range (D)	4.80E+00	5.50E+00	2.00E-02	6.00E-02	2.50E+00	2.00E-03
Irg. past. (W)	4.26E+00	4.88E+00	1.78E-02	5.33E-02	2.22E+00	1.78E-03
Wheat (W)	4.20E+00	4.81E+00	6.13E-03	5.25E-02	2.19E-01	4.38E-04
L. vegs. (W)	3.36E-01	3.85E-01	1.40E-03	4.20E-03	1.75E-01	1.40E-04
Vegs. (W)	1.25E+00	1.44E+00	1.83E-03	1.57E-02	6.53E-02	1.31E-04
Rt. vegs. (W)	1.07E+00	1.22E+00	1.55E-03	1.33E-02	5.55E-02	1.11E-04
Cotton (D)	4.80E+00	5.50E+00	2.00E-02	6.00E-02	2.50E+00	2.00E-03
Fruit (Ap.) (W)	7.63E-01	8.75E-01	1.11E-03	9.54E-03	3.98E-02	7.95E-05
Fruit (Me.) (W)	2.88E-01	3.30E-01	4.20E-04	3.60E-03	1.50E-02	3.00E-05
Nuts (Pec.) (W)	4.64E+00	5.32E+00	6.77E-03	5.80E-02	2.42E-01	4.83E-04
Berries (W)	7.25E-01	8.31E-01	1.06E-03	9.06E-03	3.77E-02	7.55E-05
Hay (D)	4.80E+00	5.50E+00	2.00E-02	6.00E-02	2.50E+00	2.00E-03
Alfalfa (D)	4.80E+00	5.50E+00	2.00E-02	6.00E-02	2.50E+00	2.00E-03
Alf. Sd. (D)	4.80E+00	5.50E+00	7.00E-03	6.00E-02	2.50E-01	5.00E-04
Silage (D)	4.80E+00	5.50E+00	2.00E-02	6.00E-02	2.50E+00	2.00E-03
Peppers (W)	3.55E-01	4.07E-01	5.18E-04	4.44E-03	1.85E-02	3.70E-05
Mushrooms (W)	1.07E+00	1.22E+00	1.55E-03	1.33E-02	5.55E-02	1.11E-04

[a] (D) = dry weight value used, (W) = wet weight value used.

Table A.3.d.ii-b. Final soil to plant transfer coefficients (for Tc,Sn,I,Cs, Ra, and Th)[a]

Crop	Tc	Sn	I	Cs	Ra	Th
Range (D)	9.50E+00	3.00E-02	1.50E-01	8.00E-02	1.50E-02	8.50E-03
Irg. past. (W)	8.44E+00	2.66E-02	1.33E-01	7.10E-02	1.33E-02	7.55E-03
Wheat (W)	1.31E+00	5.25E-03	4.38E-02	2.62E-02	1.31E-03	3.50E-03
L. vegs. (W)	6.65E-01	2.10E-03	1.05E-02	5.60E-03	1.05E-03	5.95E-04
Vegs. (W)	3.92E-01	1.57E-03	1.31E-02	7.83E-03	3.92E-04	1.04E-03
Rt. vegs. (W)	3.33E-01	1.33E-03	1.11E-02	6.66E-03	3.33E-04	8.88E-04
Cotton (D)	9.50E+00	3.00E-02	1.50E-01	8.00E-02	1.50E-02	8.50E-03
Fruit (Ap.) (W)	2.39E-01	9.54E-04	7.95E-03	4.77E-03	2.38E-04	6.36E-04
Fruit (Me.) (W)	9.00E-02	3.60E-04	3.00E-03	1.80E-03	9.00E-05	2.40E-04
Nuts (Pec.) (W)	1.45E+00	5.80E-03	4.84E-02	2.90E-02	1.45E-03	3.87E-03
Berries (W)	2.27E-01	9.06E-04	7.55E-03	4.53E-03	2.27E-04	6.04E-04
Hay (D)	9.50E+00	3.00E-02	1.50E-01	8.00E-02	1.50E-02	8.50E-03
Alfalfa (D)	9.50E+00	3.00E-02	1.50E-01	8.00E-02	1.50E-02	8.50E-03
Alf. sd. (D)	1.50E+00	6.00E-03	5.00E-02	3.00E-02	1.50E-03	4.00E-03
Silage (D)	9.50E+00	3.00E-02	1.50E-01	8.00E-02	1.50E-02	8.50E-03
Peppers (W)	1.11E-01	4.44E-04	3.70E-03	2.22E-03	1.11E-04	2.96E-04
Mushrooms (W)	3.33E-01	1.33E-03	1.11E-02	6.66E-03	3.33E-04	8.88E-04

[a] (D) = dry weight value used, (W) = wet weight value used.

Table A.3.d.ii-c. Final soil to plant transfer coefficients (for U, Np, Pu, Am, and Cm)[a]

Crop	U	Np	Pu	Am	Cm
Range (D)	8.50E-03	1.00E-01	4.50E-04	5.50E-03	8.50E-04
Irg. past. (W)	7.55E-03	8.88E-02	4.00E-04	4.88E-03	7.55E-04
Wheat (W)	3.50E-03	8.75E-02	3.94E-04	2.19E-04	1.31E-05
L. vegs. (W)	5.95E-04	7.00E-03	3.15E-05	3.85E-04	5.95E-05
Vegs. (W)	1.04E-03	2.61E-02	1.17E-04	6.53E-05	3.92E-06
Rt. vegs. (W)	8.88E-04	2.22E-02	9.99E-05	5.55E-05	3.33E-06
Cotton (D)	8.50E-03	1.00E-01	4.50E-04	5.50E-03	8.50E-04
Fruit (Ap) (W)	6.36E-04	1.59E-02	7.16E-05	3.98E-05	2.39E-06
Fruit (Me.) (W)	2.40E-04	6.00E-03	2.70E-05	1.50E-05	9.00E-07
Nuts (Pec.) (W)	3.87E-03	9.67E-02	4.35E-04	2.42E-04	1.45E-05
Berries (W)	6.04E-04	1.51E-02	6.79E-05	3.78E-05	2.26E-06
Hay (D)	8.50E-03	1.00E-01	4.50E-04	5.50E-03	8.50E-04
Alfalfa (D)	8.50E-03	1.00E-01	4.50E-04	5.50E-03	8.50E-04
Alf. sd. (D)	4.00E-03	1.00E-01	4.50E-04	2.50E-04	1.50E-05
Silage (D)	8.50E-03	1.00E-01	4.50E-04	5.50E-03	8.50E-04
Peppers (W)	2.96E-04	7.40E-03	3.33E-05	1.85E-05	1.11E-06
Mushrooms (W)	8.88E-04	2.22E-02	9.99E-05	5.55E-05	3.33E-06

[a] (D) = dry weight value used, (W) = wet weight value used.

e. Fraction of crops that are irrigated (Fcrir)

Table A.3.e. Fraction of crops that are irrigated

Crop/vegetation	Fcrir	Reference
Range	0.0	Assumed value
Irrigated pasture	1.0	Table 15, DOC (1982a)
Hay	1.0	Table 15, DOC (1982a)
Alfalfa	1.0	Table 15, DOC (1982a)
Silage	1.0	Table 15, DOC (1982a)
Wheat/grains	1.0	Table 15, DOC (1982a)
Corn	1.0	Assumed value
Melons	1.0	Assumed value
Apples	1.0	Assumed value
Nuts/pecans	1.0	Assumed value
Potatoes	1.0	Table 15, DOC (1982a)
Alfalfa seed	1.0	Assumed value
Leafy vegetables	1.0	Assumed value
Peppers	1.0	Assumed value
Mushrooms	1.0	Assumed value
Berries	0.0	Not cash crop, DOC (1982a)

f. Cropland area--Nye County (used to develop area fractions--Ai)

where: Ai = Crop area/total Nye County area

Table A.3.f. Cropland vegetation area

Crop/vegetation	Area (m^2)	Reference
Total area--Nye	4.7E+10	DOC (1982b)
Range	1.4E+09	Table 1, DOC (1982a)
Irrigated pasture	6.8E+07	Table 2, DOC (1982a)
Wheat/grain	7.4E+05	Table 15, DOC (1982a)
Corn[a]	2.1E+04	Derived, Table 27, DOC (1982a)
Leafy vegetable[a]	3.1E+05	Derived, Table 27, DOC (1982a)
Apples	1.6E+05	Table 28, DOC (1982a)
Melons[a]	6.1E+05	Derived, Table 27. DOC (1982a)
Potatoes[b]	1.2E+05	Derived, Table 15, DOC (1982a)
Berries	2.0E+05	Table 29, DOC (1982a)
Alfalfa	3.1E+07	Table 26, DOC (1982a)
Alfalfa seed	1.5E+06	Table 26, DOC (1982a)
Hay	1.9E+07	Table 26, DOC (1982a)
Silage	1.8E+06	Table 26, DOC (1982a)
Peppers	2.5E+06	'70-'78 data, USDA (1978)
Mushrooms	1.6E+05	Table 30, DOC (1982a)

[a]Derived from state totals. Shor (1982), Appendices B and C, indicates that Nye County produces no more than 5 percent of the state total in any given crop category; thus, for corn, leafy vegetables, pecans, mushrooms, and melons approximately 5 percent of the state values were used.

[b]Value reflects one-fifth of the Washoe County value because Washoe County has five farms and Nye County has one. (Information on one farm is not reported.)

A.4 ANIMAL MODEL

a. General source data (assuming 1 yr of operations)

Variable name	Value	Reference
FFsw	0.90 domestic, 1.00 wild	Assumed value
FFgw	0.10 domestic, 0.00 wild	Assumed value

b. Animal consumption fractions and quantities (Ri) (from Brown, 1954)

Animal	Consumption unit (cow = 1.0)	Consumption Quantity (Ri) Food (kg/d)	Water (L/d)
Dairy cow	1.0	50	60
Beef cattle	1.0	50	50
Goats	0.2	10	12
Rabbit	0.006	0.3	0.36
Hogs	0.4	20	24
Poultry	0.004	0.2	0.24
Deer	0.25	12.5	15
Duck/geese	0.01	0.5	0.6
Quail	0.004	0.2	0.24
Sheep	0.2	10	12

c. Fraction of daily food that is a specific type (FFi values)
(assumed values based on general reading of Stockman, 1979)

Table A.4.c-a. FFi values by animal

Plant/crop	Variable name	Rabbit	Dairy cow	Cattle	Goat milk	Pig
Range	FFran	9.00E-01	1.00E-01	7.00E-01	3.00E-01	0.00E+00
Irg. past	FFir	5.00E-02	5.00E-01	5.00E-02	5.00E-01	0.00E+00
Wheat	FFwg	0.00E+00	1.50E-01	1.00E-01	0.00E+00	5.00E-01
L.vegs.(let.)	FFlvg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vegs. (corn)	FFvg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.00E-01
Rt. vegs. (potatoes)	FFrvg	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Aquatic plants	FFappl	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fruit (apples)	FFap	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fruit (melons)	FFmel	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nuts (pecans)	FFnut	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Berries	FFber	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hay	FFhay	3.00E-02	1.00E-01	1.00E-01	5.00E-02	0.00E+00
Alfalfa	FFalf	1.00E-02	3.00E-02	3.00E-02	5.00E-02	0.00E+00
Alfalfa seed	FFalfs	1.00E-02	1.00E-02	1.00E-02	5.00E-02	0.00E+00
Silage	FFsil	0.00E+00	1.00E-02	1.00E-02	5.00E-02	0.00E+00
Peppers	FFpep	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mushrooms	FFmush	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pollen/honey	FFhon	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table A.4.c-b. FFi values by animal

Plant/crop	Variable name	Poultry	Deer	Duck/ geese	Quail
Range	FFran	0.00E+00	9.00E-01	0.00E+00	9.00E-01
Irg. past	FFir	0.00E+00	5.00E-02	0.00E+00	5.00E-02
Wheat	FFwg	5.00E-01	0.00E+00	0.00E+00	0.00E+00
L.vegs.(let.)	FFlvg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vegs. (corn)	FFvg	5.00E-01	0.00E+00	0.00E+00	0.00E+00
Rt.vegs. (potatoes)	FFrvg	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Aquatic plants	FFapl	0.00E+00	0.00E+00	1.00E+00	0.00E+00
Fruit (apples)	FFap	0.00E+00	5.00E-03	0.00E+00	0.00E+00
Fruit (melons)	FFmel	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nuts (pecans)	FFnut	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Berries	FFber	0.00E+00	5.00E-03	0.00E+00	1.00E-02
Hay	FFhay	0.00E+00	2.00E-02	0.00E+00	2.00E-02
Alfalfa	FFalf	0.00E+00	2.00E-02	0.00E+00	1.00E-02
Alfalfa seed	FFalfs	0.00E+00	0.00E+00	0.00E+00	1.00E-02
Silage	FFsil	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Peppers	FFpep	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mushrooms	FFmush	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pollen/honey	FFhon	0.00E+00	0.00E+00	0.00E+00	0.00E+00

d. Radionuclide Transfer Parameters (d/kg or L/kg) (From Baes, 1984, except as noted).

Table A.4.d. Radionuclide transfer factors (Fupi)

Radionuclide	Fupmb (d/kg) (beef)	Fupmc (d/kg) (poultry)	Fupmp (d/kg) (pork)	Fupmk (d/L) (milk)	Fupmkg (d/L) (goat milk)
H-3[a]	1.20E-02	1.20E-02	1.20E-02	1.00E-02	1.70E-01
C-14[a]	3.10E-01	3.10E-01	3.10E-01	1.20E-02	1.00E-01
Co-60	2.00E-02	2.00E-02	2.00E-02	2.00E-03	2.00E-03
Ni-59	6.00E-03	6.00E-03	6.00E-03	1.00E-03	1.00E-03
Ni-63	6.00E-03	6.00E-03	6.00E-03	1.00E-03	1.00E-03
Sr-89[a,b]	3.00E-04	3.50E-02	3.90E-02	1.50E-03	1.40E-02
Sr-90[a,b]	3.00E-04	3.50E-02	3.90E-02	1.50E-03	1.40E-02
Zr-93	5.50E-03	5.50E-03	5.50E-03	3.00E-05	3.00E-05
Tc-99	8.50E-03	8.50E-03	8.50E-03	1.00E-02	1.00E-02
Sn-126	8.00E-02	8.00E-02	8.00E-02	1.00E-03	1.00E-03
I-129[a]	7.00E-03	7.00E-03	7.00E-03	1.00E-02	6.00E-02
Cs-135[c]	2.00E-02	1.00E-02	2.00E-02	7.00E-03	3.00E-01
Cs-137[c]	2.00E-02	1.00E-02	2.00E-02	7.00E-03	3.00E-01
Ra-226	2.50E-04	2.50E-04	2.50E-04	4.50E-04	4.50E-04
Th-230	6.00E-06	6.00E-06	6.00E-06	5.00E-06	5.00E-06
Th-232	6.00E-06	6.00E-06	6.00E-06	5.00E-06	5.00E-06
U-233	2.00E-04	2.00E-04	2.00E-04	6.00E-04	6.00E-04
U-234	2.00E-04	2.00E-04	2.00E-04	6.00E-04	6.00E-04
U-235	2.00E-04	2.00E-04	2.00E-04	6.00E-04	6.00E-04
U-236	2.00E-04	2.00E-04	2.00E-04	6.00E-04	6.00E-04
U-238	2.00E-04	2.00E-04	2.00E-04	6.00E-04	6.00E-04
Np-237	5.50E-05	5.50E-05	5.50E-05	5.00E-06	5.00E-06
Pu-238	5.00E-07	5.00E-07	5.00E-07	1.00E-07	1.00E-07
Pu-239	5.00E-07	5.00E-07	5.00E-07	1.00E-07	1.00E-07
Pu-240	5.00E-07	5.00E-07	5.00E-07	1.00E-07	1.00E-07
Pu-241	5.00E-07	5.00E-07	5.00E-07	1.00E-07	1.00E-07
Pu-242	5.00E-07	5.00E-07	5.00E-07	1.00E-07	1.00E-07
Am-241	3.50E-06	3.50E-06	3.50E-06	4.00E-07	4.00E-07
Am-243	3.50E-06	3.50E-06	3.50E-06	4.00E-07	4.00E-07
Cm-244	3.50E-06	3.50E-06	3.50E-06	2.00E-05	2.00E-05

[a]Goat milk value is from Regulatory Guide 1.109 Table E-2 (otherwise cow milk value is used).

[b]Chicken and pig values are from Till (1983).

[c]Chicken value is from Till (1983).

e. Total numbers of some domestic animals (Nye county) (Atot)

Table A.4.e. Domestic animal totals (Nye county)

Animal	Total number	Reference
Dairy cattle	46	Grossman (1986)
Beef cattle	24,500	Grossman (1986)
Goats	109	Grossman (1986)
Sheep	2000	Grossman (1986)
Chicken	180	Shor (1982), Appendix D[a]
Hogs	120	Assume approximately twice the values in Shor (1982), Appendix D

[a]Value given is the dressed weight number. The dress/live weight slaughter factor is 0.80 (from Shor, 1982, Table 16--turkey value). Also assumes that the average live weight is 2.0 kg.

f. Aquatic plants and animals concentration factors (from Table 5.41 of Till, 1983)

Table A.4.f. Aquatic plants and animals concentration factors

Element[a,b]	CFapl (L/kg)[c]	CFaan (L/kg)[c,d]
H	9.00E-01[e]	9.00E+01[e]
C	9.10E+03[e]	4.60E+03[e]
Co(60,58)	2.30E+03	1.25E+02
Ni(63)	1.00E+03[f]	1.25E+02
Sr(89,90)	6.40E+02	2.80E+01
Zr(95)	3.40E+04	2.60E+00
Tc(95m)	2.70E+02[f]	7.80E+01
Sn(assume like Sb)	1.40E+02	1.00E+02
I(131)	4.00E+02	4.40E+01
Cs(133,134,137)	2.00E+03	5.60E+03
Ra(226)	6.20E+03	3.80E+03
Th	1.20E+03[g]	8.00E+01
U[h]	1.20E+03	7.50E+00
Pu(239,240)	1.10E+04	8.00E+00
Np(assume like Pu)	1.10E+04	8.00E+00
Am(assume like Pu)	1.10E+04	8.00E+00
Cm(assume like Pu)	1.10E+04	8.00E+00

[a]Numbers in parentheses are atomic mass numbers.

[b]Assumptions in parentheses indicate that no value for the element was found, so a value from an element assumed to act in a similar manner was chosen.

[c]Values are from the 84th Percentile of a log normal distribution.

[d]Freshwater fish only.

[e]From Regulatory Guide 1.109 Table A-1.

[f]Algae only.

[g]Plants only.

[h]Plant value assumed to be like Th.

A.5 HUMAN MODEL

a. Human uptake quantities--four human age groups (infant to adult), both average and maximum cases (from NCRP 1984, unless noted otherwise)

Table A.5.a. Total Uptake Quantities (Ufd, Uwater, Umilk) (kg/y) or (L/yr)[a]

AVERAGE INDIVIDUAL CASE[b]

Category	Infant (< 1 yr)	Child (1-11 yr)	Teen (12-18 yr)	Adult (> 18 yr)
Food	92	188	252	271
Liquid[c]	0	260	260	370
Milk/dairy[d]	544	419	394	207

MAXIMUM INDIVIDUAL CASE[e]

Category	Infant (< 1 yr)	Child (1-11 yr)	Teen (12-18 yr)	Adult (> 18 yr)
Food	0	596	757	720
Liquid[c]	330	510	510	730
Milk/dairy[d]	544[f]	419[f]	400	310

[a]Food includes the sum of the following (as defined in Table 5.3 NCRP (1984):

- Beef, pork, other and mixtures (meats).
- Poultry.
- Freshwater fish (trout).
- Potatoes.
- Leafy mixtures (lettuce), legumes (assume mushrooms).
  Other mixtures (corn) (vegetables).
- Other mixtures (apples, melons) (fruit).
- Grain.
- Eggs.

Those not included were either not found in the local area or not grown in significant quantities in the local area.

[b]From Table 5.3 and 5.1 NCRP (1984).

[c]Liquid includes tea, coffee, water, etc., as applicable.

[d]Includes milk products/calcium equivalent.

[e]From Table 5.2 NCRP (1984).

[f]Average values used because they were higher.

b. Dietary fractions (Dfoodn)

Average individual

The average individual diet fractions are primarily derived from Table 5.3 of NCRP (1984). For those food groups not specifically mentioned in Table 5.3, some assumptions were made and are noted. The dietary fraction is calculated as follows:

Example: Beef (Dfoodn) for an adult = Uptake of beef (kg/yr)/ Total food uptake (kg/yr)

For the purposes of this analysis, liquid is assumed to include water, tea, coffee, juice, soda, etc. Since there is no diet fraction breakdown in the liquid (water) category, the diet fraction for water is set to 1.0.

The milk/dairy category includes both cow and goat dairy products. Since most dairy products come from cows, the diet fractions are assumed to be 0.95 cow dairy products and 0.05 goat dairy products.

Table A.5.b-a. Average individual diet fractions (Dfoodn)[a]

Food	Variable name	Infant (< 1 yr)	Child (1-11 yr)	Teen (12-18 yr)	Adult (>18 yr)
Rabbit	Drab[b]	0.000	0.001	0.001	0.001
Dairy cow	Ddc	0.950	0.950	0.950	0.950
Cattle	Dcat	0.030	0.070	0.100	0.120
Goat milk	Dgm	0.050	0.050	0.050	0.050
Pig	Dp	0.020	0.080	0.100	0.100
Poultry	Dpo	0.010	0.030	0.040	0.040
Deer	Ddr[c]	0.000	0.040	0.040	0.060
Duck/geese	Dd/g[d]	0.000	0.015	0.015	0.015
Quail	Dql[e]	0.000	0.005	0.005	0.005
Lamb	Dlb[f]	0.000	0.020	0.020	0.025
Wheat	Dwg	0.200	0.170	0.160	0.130
L.vegs.(let.)	Dlvg	0.150	0.040	0.040	0.070
Vegs.(corn)	Dvg	0.300	0.110	0.120	0.130
Rt.Vegs.(pot.)	Drvg	0.150	0.100	0.100	0.090
Fruit (apples)	Dap[g]	0.040	0.110	0.085	0.060
Fruit (melons)	Dmel[g]	0.040	0.110	0.085	0.060
Nuts (pecans)	Dnut[h]	0.000	0.010	0.010	0.010
Berries	Dber[h]	0.010	0.010	0.010	0.010
Peppers	Dpep[i]	0.000	0.003	0.003	0.003
Mushrooms	Dmush[i]	0.000	0.003	0.003	0.003
Pollen/honey	Dhon[j]	0.001	0.001	0.001	0.001
Fish (frshwtr)	Dfish	0.000	0.001	0.001	0.001
Water	Dwater	1.000	1.000	1.000	1.000

[a]Derived from Table 5.3 of NCRP (1984).

[b]Assumed value, rabbit represents small game fraction of the food diet (part of the 8 to 10 percent fraction of the other meats category).

[c]Represents large wild game (big horn sheep, elk, antelope) fraction--assumed value. Large wild game is considered to be most of the wild game fraction (part of other meats category).

[d]Assumed value (small duck population), represents waterfowl fraction (part of other meats category).

[e]Assumed value, represents upland game (small part of diet) fraction (part of other meats category).

[f]Represents other domestic meat, assumed value, part of 8 to 10 percent other meat category.

[g]Melons and apples--assumed a 50/50 split of the other fruit category (NCRP, 1984).

[h]Pecans/nuts and berries--assumed value (lack of data).

[i]Peppers and mushrooms--assumed a 50/50 split of the legumes category (NCRP, 1984).

[j]Pollen honey--assumed value.

Maximum individual

The maximum individual case has a much more simplified diet as derived from Table 5.2 of NCRP (1984). It consists of the following:

Milk (assumes that all the dairy products are from cows), water, fish, leafy vegetables, meat and poultry (assumes all beef), and fruit, vegetables, apples, melons, corn, wheat and grains.

The above categories were used because they were considered to be the most dominant components of an overall diet.

The equation used to derive the maximum individual dietary fractions is the same as described for average dietary fractions.

Table A.5.b-b. Maximum individual case diet factions (Dfoodn)[a]

Food	Variable Name	Infant (< 1 yr)	Child (1-11 yr)	Teen (12-18 yr)	Adult (> 18 yr)
Rabbit	Drab	0.000	0.000	0.000	0.000
Dairy cow	Ddc	1.000	1.000	1.000	1.000
Cattle	Dcat	0.000	0.070	0.090	0.150
Goat milk	Dgm	0.000	0.000	0.000	0.000
Pig	Dp	0.000	0.000	0.000	0.000
Poultry	Dpo	0.000	0.000	0.000	0.000
Deer	Ddr	0.000	0.000	0.000	0.000
Duck/geese	Dd/g	0.000	0.000	0.000	0.000
Quail	Dql	0.000	0.000	0.000	0.000
Lamb	Dlb	0.000	0.000	0.000	0.000
Wheat	Dwg	0.000	0.218	0.208	0.180
L.vegs.(let.)	Dlvg	0.000	0.040	0.060	0.090
Vegs.(corn)	Dvg	0.000	0.218	0.208	0.180
Rt.vegs.(pot.)	Drvg	0.000	0.000	0.000	0.000
Fruit (apples)	Dap	0.000	0.218	0.208	0.180
Fruit (melons)	Dmel	0.000	0.218	0.208	0.180
Nuts (pecans)	Dnut	0.000	0.000	0.000	0.000
Berries	Dber	0.000	0.000	0.000	0.000
Peppers	Dpep	0.000	0.000	0.000	0.000
Mushrooms	Dmush	0.000	0.000	0.000	0.000
Pollen/honey	Dhon	0.000	0.000	0.000	0.000
Fish(frshwtr)	Dfish	0.000	0.010	0.020	0.030
Water	Dwater	1.000	1.000	1.000	1.000

[a]Derived from Table 5.2 of NCRP (1984).

c. The fraction of food consumed that is grown locally (Flocfood)

Nye County is considered to be the local area; therefore, the total affected population is assumed to be equal to the population in Nye County. From DOC (1982a), the total population breakdown is as follows: 71.2 percent > 18 yr and 28.7 percent < 18 yr (10,000 people). Based on this information, the following assumptions are made: 5 percent < 1 yr, 10 percent 1 to 11 yr, 13.7 percent 12 to 18 yr, and 71.2 percent > 18 yr. Using this information, the diet fractions (FFi) and consumption rate data (Ufood etc.), the total annual quantity of each food type consumed is calculated.

Table A.5.c-a. Annual consumption per food type (kg)[a]

Food Type	Infant (< 1 yr)	Children (1-11 yr)	Teen (12-18 yr)	Adult (> 18 yr)	Total consumed (kg)
Milk/dairy[b]	2.72E+05	4.19E+05	5.39E+05	1.47E+06	2.70E+06
Beef	1.38E+03	1.32E+04	3.45E+04	2.32E+05	2.80E+05
Pork	9.20E+02	1.50E+04	3.45E+04	1.92E+05	2.40E+05
Deer[c]	N/A	N/A	N/A	N/A	N/A
Rabbit[c]	N/A	N/A	N/A	N/A	N/A
Duck/geese[c]	N/A	N/A	N/A	N/A	N/A
Sheep	-0-	3.76E+03	6.90E+03	4.82E+04	5.90E+04
Quail[c]	N/A	N/A	N/A	N/A	N/A
Poultry	4.60E+02	5.64E+03	1.38E+04	7.72E+04	9.70E+04
Frsh.fish[c]	N/A	N/A	N/A	N/A	N/A
Potatoes	1.38E+03	1.88E+04	3.45E+04	1.74E+05	2.30E+05
L. vegs.	4.60E+02	7.52E+03	1.38E+04	1.35E+05	1.60E+05
Mushroom	-0-	3.76E+03	6.90E+03	2.89E+04	4.00E+04
Corn	1.06E+04	2.06E+04	4.14E+04	2.51E+05	3.20E+05
Apples	1.17E+04	2.07E+04	2.93E+04	1.16E+05	1.80E+05
Melons	1.17E+04	2.07E+04	2.93E+04	1.16E+05	1.80E+05
Wheat	4.60E+03	3.20E+04	5.52E+04	2.61E+05	3.40E+05
Honey[d]	N/A	N/A	N/A	N/A	N/A
Water	N/A	N/A	N/A	N/A	N/A

[a]N/A = not applicable.
[b]Milk/dairy includes dairy products and the goat dairy product contribution.
[c]Not raised domestically.
[d]Very little in local area.

The actual derivation of the fraction of local food consumed is based on a ratio of the annual quantity of a type of food produced to the total annual quantity of that food consumed.

Table A.5.c-b. Fraction of local food consumed (Flocfood, Flocmilk, Flocwater)

Food type	Animals sold	Total produced (L/y or kg/y)	Total consumed (L/y or kg/y)	Floc (Tprod/Tcons.)
Milk/dairy	46[a]	3.40E+05	2.70E+06	0.12
Beef	50[b,c]	1.40E+04	2.80E+05	0.34[f]
Pork	75[c,d]	5.90E+03	2.40E+05	0.025
Lamb/sheep	150[b,c]	3.40E+03	5.90E+04	0.06
Deer	N/A	N/A	N/A	0.50[g]
Poultry	160[c,e]	2.90E+02	9.70E+04	0.003
Rabbit	N/A	N/A	N/A	0.70[h]
Quail	N/A	N/A	N/A	0.70[h]
Freshwater fish	N/A	N/A	N/A	0.0001[i]
Potatoes	N/A	2.90E+05	2.30E+05	1.0
L. vegs.	N/A	2.20E+05	1.60E+05	1.0
Berries	N/A	7.30E+04	2.50E+04	1.0
Corn	N/A	1.40E+04	3.20E+05	0.04
Apples	N/A	9.40E+04	1.80E+05	0.52
Melons	N/A	5.80E+04	1.80E+05	0.32
Nuts	N/A	7.30E+03	2.50E+04	0.30
Peppers	N/A	7.70E+05	4.00E+04	1.00
Mushrooms	N/A	1.40E+04	4.00E+04	0.36
Honey	N/A	N/A	N/A	0.001[j]
Wheat	N/A	2.40E+04	3.40E+05	0.07
Water	N/A	N/A	N/A	1.0[k]
Goat milk		Assumed all local use		1.0
Duck/geese		Very little waterfowl in area		0.0001

[a]Assuming a production rate of 20 L/d per cow.
[b]2x the value in Shor (1982), Appendix D.
[c]Dressed weight values used, from Shor (1982), Tables 15 & 16.

Cow & beef	2.70E+02	kg/animal
Sheep	2.27E+01	kg/animal
Poultry	1.80E+00	kg/animal
Hog	7.80E+01	kg/animal

[d]1x the value in Shor (1982), Appendix D. 2x the value would be all the pigs in the county.
[e]Conservative, assumed value.
[f]National average value used from Section 4.2 of Shor (1982).
[g]Assumed value, few deer available in the Yucca Mountain area.
[h]Assumed value, most animals of this type would be obtained in the local area.
[i]Very little freshwater fish in the local area.
[j]Very little honey locally, assumed value.
[k]Water is assumed to come from predominantly local sources.

A.6. WASTE STREAM FRACTIONS

Radionuclide fraction

Because of the various potential waste streams (see Section 3.2.2), it is necessary to determine the significant pathways and radionuclides for each specific type of waste. To accomplish this task, a waste source category table is developed. In this table the radionuclide fraction (for each radionuclide) for the primary components of the waste streams are determined. These components include fission products, activation products, and crud--any combination of which make up the potential waste streams for Yucca Mountain. The data to derive the radionuclide fractions may be found in Tables 3.3.7, 3.3.8, and 3.3.10 of DOE (1979).

a. Three categories of high-level waste (HLW) considered:

Category I:	Crud (activation products) as defined in Table 3.3.7--DOE (1979).
Category II:	Fission products/spent fuel as defined in Table 3.3.8--DOE (1979).
Category III:	Actinides/spent fuel as defined in Table 3.3.10-- DOE (1979).

Category I	total activity at 6.5y:	1.00E+02[a]
Category II	total activity at 6.5y:	3.50E+05[a]
Category III	total activity at 6.5y:	8.89E+04[a]

[a]No waste will be less than 5 yr old--upon arrival at Yucca Mountain.

Table A.6.a. Waste category radionuclide fractions

Radionuclide	Crud	Fission products	Actinides
H-3	0.00E+00	8.86E-04	0.00E+00
C-14	6.00E-04	2.11E-06	0.00E+00
Co-60	8.00E-01	0.00E+00	0.00E+00
Ni-59	3.00E-04	0.00E+00	0.00E+00
Ni-63	4.00E-02	0.00E+00	0.00E+00
Sr-89	0.00E+00	3.14E-14	0.00E+00
Sr-90	0.00E+00	1.66E-01	0.00E+00
Zr-93	9.00E-04	4.86E-06	0.00E+00
Tc-99	0.00E+00	3.71E-05	0.00E+00
Sn-126	0.00E+00	1.37E-06	0.00E+00
I-129	0.00E+00	9.43E-08	0.00E+00
Cs-135	0.00E+00	7.71E-07	0.00E+00
Cs-137	0.00E+00	2.34E-01	0.00E+00
Ra-226[a]	0.00E+00	0.00E+00	8.32E-13
Th-230[a]	0.00E+00	0.00E+00	4.61E-11
Th-232[a]	0.00E+00	0.00E+00	1.24E-15
U-233	0.00E+00	0.00E+00	3.60E-10
U-234	0.00E+00	0.00E+00	5.74E-07
U-235	0.00E+00	0.00E+00	1.80E-07
U-236	0.00E+00	0.00E+00	3.60E-06
U-238	0.00E+00	0.00E+00	3.54E-06
Np-237	0.00E+00	0.00E+00	5.29E-06
Pu-238	0.00E+00	0.00E+00	3.42E-02
Pu-239	0.00E+00	0.00E+00	3.28E-03
Pu-240	0.00E+00	0.00E+00	5.08E-03
Pu-241	0.00E+00	0.00E+00	9.33E-01
Pu-242	0.00E+00	0.00E+00	1.69E-05
Am-241	0.00E+00	0.00E+00	1.25E-02
Am-243	0.00E+00	0.00E+00	1.52E-04
Cm-244	0.00E+00	0.00E+00	1.12E-02

[a]10 yr value used--long term significant growth contributor.

A.7 LIMITING CASE RADIONUCLIDES

Table A.7. Limiting case radionuclides[a]

Radionuclide
H-3
C-14
Cs-135
Cs-137
Sr-89
Sr-90
Tc-99
I-129
Th-230
Th-232
U-233
U-234
U-235
U-236
U-238
Pu-238
Pu-239
Pu-240
Pu-241
Pu-242

[a]As determined by Woolfolk (1986) and 40 CFR Part 191 (1986).