

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue, Argonne, Illinois 60439

DERIVATION OF URANIUM AND CESIUM-137 RESIDUAL
RADIOACTIVE MATERIAL GUIDELINES FOR
THE NIAGARA FALLS STORAGE SITE

by

Charley Yu, John M. Peterson, and YuChien Yuan
Energy and Environmental Systems Division

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SUMMARY

Residual radioactive material guidelines were derived for uranium and cesium-137 for a large, homogeneously contaminated area at the Niagara Falls Storage Site (NFSS), Lewiston, New York. The derivation of the single-nuclide and total uranium guidelines was based on the requirement that the 50-year committed effective dose equivalent to a hypothetical individual who lives or works in the immediate vicinity of NFSS should not exceed a dose of 100 mrem/yr following decontamination of the vicinity properties. The RESRAD computer code, which implements the methodology described in the U.S. Department of Energy manual for implementing residual radioactive material guidelines, was used in this evaluation. The results of the evaluation indicate that the basic dose limit of 100 mrem/yr will not be exceeded within 1,000 years for either uranium or cesium-137, provided that the soil concentrations of these radionuclides in the vicinity of NFSS do not exceed the following: 1,800 pCi/g for uranium and 95 pCi/g for cesium-137 for Scenario A (the expected scenario); 440 pCi/g for uranium and 33 pCi/g for cesium-137 for Scenario B (a plausible scenario); and 67 pCi/g for uranium and 33 pCi/g for cesium-137 for Scenario C (a possible but unlikely scenario). The uranium guideline applies to the total activity concentration of uranium isotopes (i.e., uranium-238, uranium-234, and uranium-235 present in their natural activity concentration ratio of 1:1:0.046). Therefore, if uranium-238 is measured as the indicator radionuclide, the respective limits for Scenarios A, B, and C would be 880 pCi/g, 220 pCi/g, and 33 pCi/g, respectively.

1 INTRODUCTION AND BRIEF HISTORY

The Niagara Falls Storage Site (NFSS) is located in the town (township) of Lewiston, Niagara County, New York, about 30 km (19 mi) north of Buffalo, New York (Fig. 1). The 77-ha (190-acre) site is part of a former 610-ha (1,500-acre) Manhattan Engineer District (MED) site, which in turn was part of the former Lake Ontario Ordnance Works. Beginning in 1944, the MED used the site for storage of radioactive residues that resulted from the processing of uranium ores (pitchblende) during development of the atomic bomb. Additional residues were brought to the site for several years after World War II (U.S. Dept. Energy 1986).

Subsequent to MED, responsibility for the site has been transferred to the U.S. Atomic Energy Commission (AEC), the U.S. Energy Research and Development

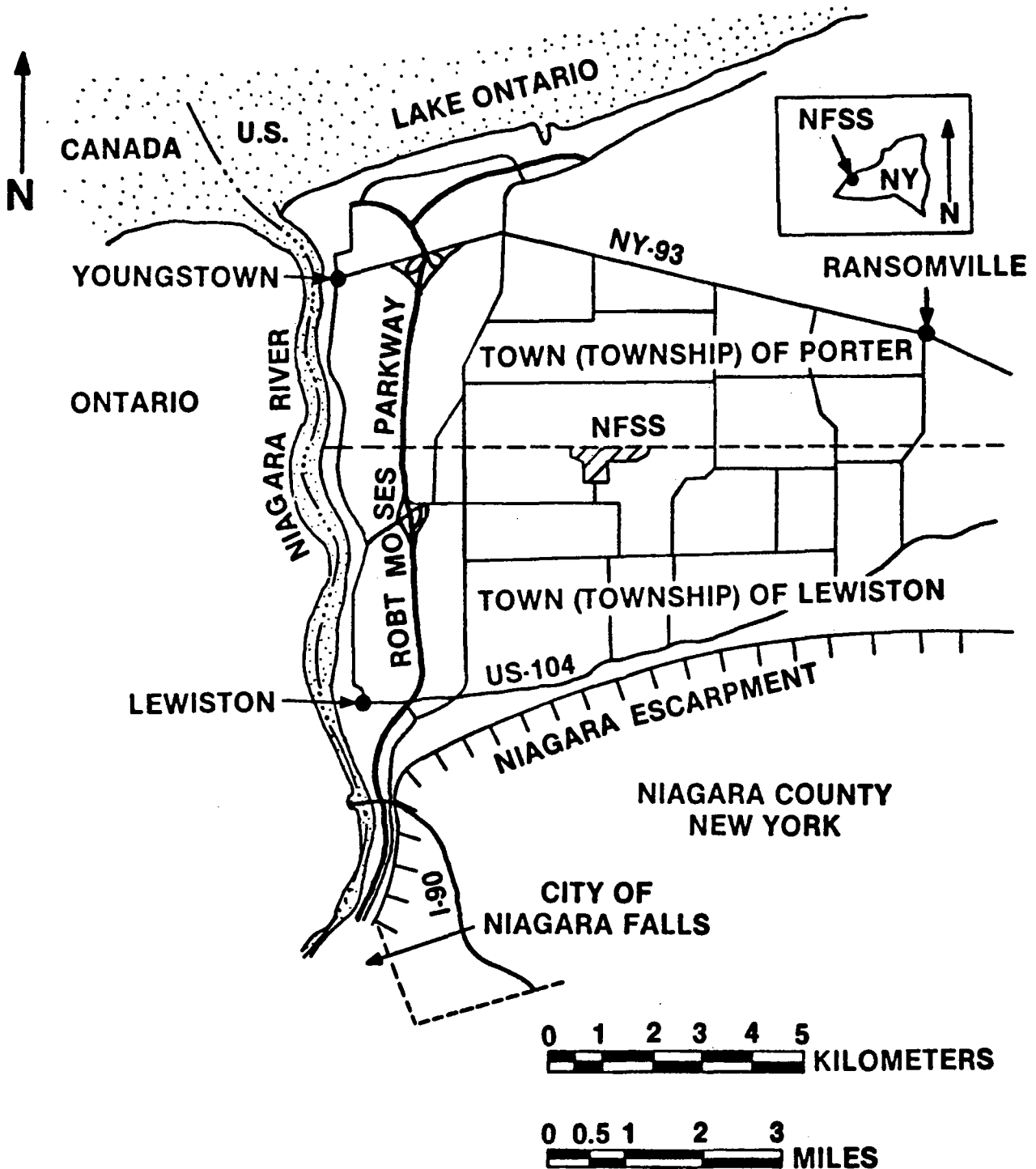


FIGURE 1 Location of the Niagara Falls Storage Site (Source: U.S. Dept. Energy 1986)

Administration (ERDA), and the U.S. Department of Energy (DOE). The site is currently administered by the Oak Ridge Operations Office of DOE and operated by Bechtel National, Inc. It is fenced and access is limited (U.S. Dept. Energy 1986).

Remedial actions are currently being conducted by Bechtel National, Inc.. These remedial actions consist of decontaminating portions of NFSS, as well as nearby off-site properties, to allow for unrestricted use of these areas (Bechtel Natl. 1987). Upon completion of remedial actions, all radioactively contaminated materials will be consolidated within a 3.4-ha (8.5-acre) containment area in the southwest corner of NFSS (U.S. Dept. Energy 1986). Current remedial actions are being guided by thorium and radium residual radioactive material guidelines (App. A). The purpose of this report is to derive the residual radioactive material guidelines for uranium (i.e., uranium-234, uranium-235, or uranium-238) and cesium-137 that are applicable to the remedial actions for NFSS, i.e., the residual concentration of uranium or cesium-137 in a homogeneously contaminated area that must not be exceeded if decontaminated portions of the site, as well as the vicinity properties, are to be released for unrestricted use. The total uranium guideline is also derived by assuming that uranium-238, uranium-234, and uranium-235 are present in their natural activity concentration ratio of 1:1:0.046. The derivation of site-specific uranium and cesium-137 guidelines for NFSS is based on a dose limit of 100 mrem/yr (App. A), assuming that uranium or cesium-137 is the only radionuclide present at an above-background concentration. The RESRAD computer code, which implements the methodology described in the DOE manual for implementing residual radioactive material guidelines (U.S. Dept. Energy 1988), was used to derive these guidelines.

2 SCENARIO DEFINITION

Three potential exposure scenarios are considered in this evaluation. All scenarios assume unrestricted use, at some time within 1,000 years, of the areas of NFSS that have been decontaminated. Scenario A (the expected scenario) assumes industrial use of the site. A hypothetical person is assumed to work in the NFSS area for 8 hours per day (6 hours outdoors and 2 hours indoors), 5 days per week, and 50 weeks per year. It is also assumed that 50% of the drinking water for the worker is taken from an on-site well and that the worker does not ingest plant foods or fish from the decontaminated area, or ingest meat and milk from livestock raised in the decontaminated area. Scenario B (plausible scenario) and Scenario C (possible but unlikely scenario) assume that a hypothetical person takes up residence in the immediate vicinity of NFSS, drinks water obtained from the decontaminated area, ingests plant foods grown in a garden in the decontaminated area, and ingests meat and milk from livestock raised in the decontaminated area. The differences in Scenarios B and C are (1) the source of water used by the individual -- including drinking water, irrigation water, and livestock feeding water and (2) the ingestion of fish from a nearby pond. Scenario B assumes that all water used by the individual is drawn from a deep (>15 m) well adjacent to the decontaminated area whereas Scenario C assumes that all water used by the individual is drawn from a pond adjacent to the decontaminated area and that the individual ingests fish taken from the nearby pond. A shallow well scenario is not considered because, although a shallow

groundwater system (brown sand) may exist in the decontaminated area, the yield of this groundwater system is usually low and the water quality is poor (U.S. Dept. Energy 1986). However, the NFSS has clayey soil of low permeability and poor drainage (U.S. Dept. Energy 1986), and a pond can be easily built at the site. Thus, deep well water and pond water are considered to be usable water sources in this evaluation.

Potential radiation doses resulting from seven exposure pathways are analyzed: (1) direct exposure to external radiation from the decontaminated soil material, (2) internal radiation from inhalation of dust, (3) internal radiation from ingestion of plant foods grown in the decontaminated area and irrigated with water drawn from either a well or pond adjacent to the decontaminated area, (4) internal radiation from ingestion of meat from livestock fed with fodder grown in the decontaminated area and water drawn from an adjacent well or pond, (5) internal radiation from ingestion of milk from livestock fed with fodder grown in the decontaminated area and water drawn from an adjacent well or pond, (6) internal radiation from ingestion of aquatic food (fish) from a nearby pond, and (7) internal radiation from drinking water drawn from either a deep well or pond adjacent to the decontaminated area on the downgradient side.

The radiation dose to the hypothetical future resident or worker was calculated using the RESRAD computer code, based on the following specific assumptions:

- The resident spends 50% of his or her time indoors in the decontaminated area, 25% outdoors in the decontaminated area, and 25% away from the decontaminated area. The worker spends 2,000 hours per year on-site (25% indoors and 75% outdoors).
- The walls, floor, and foundation of the house or office building reduce external exposure by 30%; the indoor dust level is 40% of the outdoor dust level (U.S. Dept. Energy 1988).
- The size of the decontaminated area is sufficiently large that 50% of the plant food diet consumed by the resident is grown in a garden in the decontaminated area. The worker does not consume these plant foods.
- The size of the decontaminated area is large enough to provide sufficient meat and milk for the resident from livestock raised (i.e., foraging) in the decontaminated area. The worker does not consume this meat or milk.
- Vegetables are irrigated by, and livestock are provided with, water drawn from either a well (Scenario B) or a pond (Scenario C) located adjacent to the decontaminated area.
- An adjacent pond provides 50% of the aquatic food consumed by the resident for Scenario C. For Scenarios A and B, the worker or resident does not consume this aquatic food.

- An adjacent deep well provides 50% of the drinking water consumed by the worker (Scenario A); the deep well provides 100% of the drinking water consumed by the resident (Scenario B); or an adjacent pond provides 100% of the drinking water consumed by the resident (Scenario C).

All pathways considered for Scenarios A, B, and C are summarized in Table 1.

3 DOSE/SOURCE CONCENTRATION RATIOS

The dose/source concentration ratio $DSR_{ip}(t)$ for uranium or cesium-137 isotope i and pathway p at time t after decontamination was calculated using the RESRAD computer code (U.S. Dept. Energy 1988). The time frame considered in this analysis was 1,000 years. Radioactive decay and ingrowth were considered in deriving the dose/source concentration ratio. The various parameters used in the RESRAD code for this analysis are listed in App. B. The calculated maximum dose/source concentration ratios for all pathways are presented in Tables 2, 3, and 4 for Scenarios A, B, and C, respectively. Except for uranium isotopes for Scenario C, the maximum dose/source concentration ratios are at time 0 (immediately after decontamination). This is primarily because contaminants will not reach the (deep) groundwater table in 1,000 years. For Scenario C, the maximum dose/source concentration ratio for uranium isotopes occurs at 1,000 years after decontamination. The summation of $DSR_{ip}(t)$ for all pathways p is the $DSR_i(t)$ for the i^{th} isotope, i.e.,

$$DSR_i(t) = \sum_p DSR_{ip}(t) .$$

The total dose/source concentration ratio for total uranium can be calculated as

$$DSR(t) = \sum_i W_i DSR_i(t)$$

where W_i is the existing activity concentration fraction at the site for uranium-238, uranium-234, and uranium-235. For this analysis, W_i is assumed to be present in the natural activity concentration ratio of 1/2.046, 1/2.046, and 0.046/2.046 for uranium-238, uranium-234, and uranium-235, respectively. The total dose/source concentration ratios for single nuclides and total uranium are listed in Table 5. These ratios were used to determine the allowable residual radioactivity for uranium and cesium-137 in the vicinity of NFSS.

4 RESIDUAL RADIOACTIVE MATERIAL GUIDELINES

The residual radioactive material guideline is defined as the concentration of residual radioactive material that can remain in the decontaminated area and still allow for unrestricted use of that area. Using the annual radiation dose limit of 100 mrem/yr

TABLE 1 Summary of Pathways for Scenarios A, B, and C at NFSS

Pathway	Scenario A	Scenario B	Scenario C
1, External exposure	Yes	Yes	Yes
2, Inhalation	Yes	Yes	Yes
3, Ingestion of plant foods	No	Yes	Yes
4, Ingestion of meat	No	Yes	Yes
5, Ingestion of milk	No	Yes	Yes
6, Ingestion of fish	No	No	Yes
7, Ingestion of water ^a	Yes	Yes	Yes

^aSource of water used: Scenario A, 50% well water for drinking, no water for irrigation or livestock feeding; Scenario B, 100% well water for drinking, irrigation, and livestock feeding; Scenario C, 100% pond water for drinking, irrigation, and livestock feeding.

TABLE 2 Maximum Dose/Source Concentration Ratios for Scenario A at NFSS

Pathway	Dose/Source Concentration Ratio, ^a (mrem/yr)/(pCi/g)			
	Cesium- 137	Uranium- 234	Uranium- 235	Uranium- 238
1, External exposure	1.1×10^0	2.6×10^{-4}	1.9×10^{-1}	2.6×10^{-2}
2, Inhalation	1.0×10^{-5}	4.2×10^{-2}	4.0×10^{-2}	3.8×10^{-2}
3, Ingestion of plant foods	0	0	0	0
4, Ingestion of meat	0	0	0	0
5, Ingestion of milk	0	0	0	0
6, Ingestion of fish	0	0	0	0
7, Ingestion of water	0	0	0	0

^aAll values reported to two significant figures.

TABLE 3 Maximum Dose/Source Concentration Ratios for Scenario B at NFSS

Pathway	Dose/Source Concentration Ratio, ^a (mrem/yr)/(pCi/g)			
	Cesium- 137	Uranium- 234	Uranium- 235	Uranium- 238
1, External exposure	3.0×10^0	7.5×10^{-4}	5.3×10^{-1}	7.5×10^{-2}
2, Inhalation	2.6×10^{-5}	1.1×10^{-1}	1.0×10^{-1}	9.8×10^{-2}
3, Ingestion of plant foods	8.7×10^{-3}	6.2×10^{-2}	5.8×10^{-2}	5.6×10^{-2}
4, Ingestion of meat	1.3×10^{-2}	1.5×10^{-2}	1.4×10^{-2}	1.4×10^{-2}
5, Ingestion of milk	2.6×10^{-3}	2.2×10^{-3}	2.0×10^{-3}	2.0×10^{-3}
6, Ingestion of fish	0	0	0	0
7, Ingestion of water	0	0	0	0

^aAll values reported to two significant figures.

TABLE 4 Maximum Dose/Source Concentration Ratios for Scenario C at NFSS

Pathway	Dose/Source Concentration Ratio, ^a (mrem/yr)/(pCi/g)			
	Cesium- 137	Uranium- 234	Uranium- 235	Uranium- 238
1, External exposure	3.0×10^0	0	0	0
2, Inhalation	2.6×10^{-5}	2.3×10^{-3}	9.2×10^{-7}	3.3×10^{-6}
3, Ingestion of plant foods	8.7×10^{-3}	2.3×10^{-2}	3.3×10^{-2}	1.5×10^{-2}
4, Ingestion of meat	1.3×10^{-2}	5.6×10^{-2}	9.3×10^{-2}	5.0×10^{-2}
5, Ingestion of milk	2.6×10^{-3}	2.9×10^{-2}	2.7×10^{-2}	2.6×10^{-2}
6, Ingestion of fish	0	1.1×10^{-1}	1.2×10^0	9.5×10^{-2}
7, Ingestion of water	0	1.3×10^0	2.2×10^0	1.2×10^0

^aAll values reported to two significant figures.

TABLE 5 Total Dose/Source Concentration Ratios for Cesium-137 and Uranium at NFSS

Radionuclide	Dose/Source Concentration Ratio, ^a (mrem/yr)/(pCi/g)		
	Scenario A	Scenario B	Scenario C
Cesium-137	1.1	3.0	3.0
Uranium-234	0.043	0.19	1.5
Uranium-235	0.23	0.71	3.6
Uranium-238	0.064	0.24	1.4
Total uranium	0.057	0.23	1.5

^aAll values reported to two significant figures.

(App. A), the residual radioactive material guideline, G, for uranium or cesium-137 at NFSS may be calculated as

$$G = 100/DSR$$

where DSR is the total dose/source concentration ratio listed in Table 5. The calculated residual radioactive material guidelines for both single radionuclides (cesium-137, uranium-234, uranium-235, and uranium-238) and total uranium are presented in Table 6.

The guidelines for cesium-137 (reported to two significant figures) are 95 pCi/g, 33 pCi/g, and 33 pCi/g for Scenarios A, B, and C, respectively. The guidelines for total uranium (reported to two significant figures) are 1,800 pCi/g, 440 pCi/g, and 67 pCi/g for Scenarios A, B, and C, respectively; these guidelines assume that the activity concentration ratio of uranium-238, uranium-234, and uranium-235 is 1:1:0.046. If uranium-238 is measured as the indicator radionuclide, then the uranium-238 limits for total uranium can be calculated by dividing the total uranium guidelines by 2.046; the resulting limits for total uranium are 880 pCi/g, 220 pCi/g, and 33 pCi/g for Scenarios A, B, and C, respectively.

When implementing the derived radionuclide guidelines for decontamination of a site, the law of sum of fractions applies. That is, the summation of the fractions of radionuclide concentrations S_i remaining on-site, averaged over an area of 100 m² and a depth of 15 cm and divided by its guideline G_i , should not be greater than unity -- i.e.,

$$\sum_i S_i / G_i \leq 1 .$$

TABLE 6 Residual Radioactive Material Guidelines for NFSS

Radionuclide	Guideline (pCi/g)		
	Scenario A	Scenario B	Scenario C
Cesium-137	95	33	33
Uranium-234	2,300	530	65
Uranium-235	440	140	28
Uranium-238	1,600	410	72
Total uranium	1,800	440	67

^aAll values reported to two significant figures.

The derived guidelines listed in Table 6 are for a large, homogeneously contaminated area. For an isolated small area of contamination, the allowable concentration that can remain on-site may be larger than the homogeneous guideline, depending on the size of the area of contamination.

5 REFERENCES

Bechtel National, Inc., 1987, *Post-Remedial Action Report for the Niagara Falls Storage Site Vicinity Properties - 1985 and 1986*, Lewiston, New York, DOE/OR/20722-133, prepared for U.S. Department of Energy, Oak Ridge Operations Office (Jan.).

U.S. Department of Energy, 1986, *Final Environmental Impact Statement, Long-Term Management of the Existing Radioactive Wastes and Residues at the Niagara Falls Storage Site*, DOE/EIS-0109F, Washington, D.C. (April).

U.S. Department of Energy, 1988, unpublished information, Assistant Secretary for Nuclear Energy.

APPENDIX A

DOE GUIDELINES FOR RESIDUAL RADIOACTIVE MATERIAL

[reproduced from U.S. Department of Energy, 1987, *U.S. Department of Energy Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites* (Revision 2, March 1987)]

A. INTRODUCTION

This document presents U.S. Department of Energy (DOE) radiological protection guidelines for cleanup of residual radioactive material and management of the resulting wastes and residues. It is applicable to sites identified by the Formerly Utilized Sites Remedial Action Program (FUSRAP) and remote sites identified by the Surplus Facilities Management Program (SFMP).^{*} The topics covered are basic dose limits, guidelines and authorized limits for allowable levels of residual radioactive material, and requirements for control of the radioactive wastes and residues.

Protocols for identification, characterization, and designation of FUSRAP sites for remedial action; for implementation of the remedial action; and for certification of a FUSRAP site for release for unrestricted use are given in a separate document (U.S. Department of Energy 1986) and subsequent guidance. More detailed information on applications of the guidelines presented herein, including procedures for deriving site-specific guidelines for allowable levels of residual radioactive material from basic dose limits, is contained in "A Manual for Implementing Residual Radioactive Material Guidelines" (U.S. Department of Energy 1987), referred to herein as the "supplement".

"Residual radioactive material" is used in these guidelines to describe radioactive material derived from operations or sites over which DOE has authority. Guidelines or guidance to limit the levels of radioactive material and to protect the public and the environment are provided for (1) residual concentrations of radionuclides in soil,** (2) concentrations of airborne

^{*}A remote SFMP site is one that is excess to DOE programmatic needs and is located outside a major operating DOE research and development or production area.

^{**}"Soil" is defined herein as unconsolidated earth material, including rubble and debris that may be present in earth material.

radon decay products, (3) external gamma radiation levels, (4) surface contamination levels, and (5) radionuclide concentrations in air or water resulting from or associated with any of the above.

A "basic dose limit" is a prescribed standard from which limits for quantities that can be monitored and controlled are derived; it is specified in terms of the effective dose equivalent as defined by the International Commission on Radiological Protection (ICRP 1977, 1978). The basic dose limits are used for deriving guidelines for residual concentrations of radionuclides in soil. Guidelines for residual concentrations of thorium and radium in soil, concentrations of airborne radon decay products, allowable indoor external gamma radiation levels, and residual surface contamination concentrations are based on existing radiological protection standards (U.S. Environmental Protection Agency 1983; U.S. Nuclear Regulatory Commission 1982; and DOE Departmental Orders). Derived guidelines or limits based on the basic dose limits for those quantities are used only when the guidelines provided in the existing standards cited above are shown to be inappropriate.

A "guideline" for residual radioactive material is a level of radioactivity or radioactive material that is acceptable if use of the site is to be unrestricted. Guidelines for residual radioactive material presented herein are of two kinds: (1) generic, site-independent guidelines taken from existing radiation protection standards and (2) site-specific guidelines derived from basic dose limits using site-specific models and data. Generic guideline values are presented in this document. Procedures and data for deriving site-specific guideline values are given in the supplement. The basis for the guidelines is generally a presumed worst-case plausible-use scenario for the site.

An "authorized limit" is a level of residual radioactive material or radioactivity that must not be exceeded if the remedial action is to be considered completed and the site is to be released for unrestricted use. The authorized limits for a site will include (1) limits for each radionuclide or group of radionuclides, as appropriate, associated with residual radioactive material in soil or in surface contamination of structures and equipment, (2) limits for each radionuclide or group of radionuclides, as appropriate, in air or water, and, (3) where appropriate, a limit on external gamma radiation resulting from the residual material. Under normal circumstances, expected to occur at most sites, authorized limits for residual radioactive material or radioactivity are set equal to guideline values. Exceptional conditions for which authorized limits might differ from guideline values are specified in Sections D and F of this document. A site may be released for unrestricted use only if site conditions do not exceed the authorized limits or approved supplemental limits, as defined in Section F.1, at the time remedial action is completed. Restrictions and controls on use of the site must be established and enforced if site conditions exceed the approved limits, or if there is potential to exceed the basic dose limit if use of the site is not restricted (Section F.2). The applicable controls and restrictions are specified in Section E.

DOE policy requires that all exposures to radiation be limited to levels that are as low as reasonably achievable (ALARA). For sites to be released for unrestricted use, the intent is to reduce residual radioactive material to levels that are as far below authorized limits as reasonable considering technical, economic, and social factors. At sites where the residual material is not reduced to levels that permit release for unrestricted use, ALARA policy is implemented by establishing controls to reduce exposure to levels that are as low as reasonably achievable. Procedures for implementing ALARA policy are discussed in the supplement. ALARA policies, procedures, and actions shall be documented and filed as a permanent record upon completion of remedial action at a site.

B. BASIC DOSE LIMITS

The basic limit for the annual radiation dose received by an individual member of the general public is 100 mrem/yr. The internal committed effective dose equivalent, as defined in ICRP Publication 26 (ICRP 1977) and calculated by dosimetry models described in ICRP Publication 30 (ICRP 1978), plus the dose from penetrating radiation sources external to the body, shall be used for determining the dose. This dose shall be described as the "effective dose equivalent". Every effort shall be made to ensure that actual doses to the public are as far below the basic dose limit as is reasonably achievable.

Under unusual circumstances, it will be permissible to allow potential doses to exceed 100 mrem/yr where such exposures are based upon scenarios that do not persist for long periods and where the annual lifetime exposure to an individual from the subject residual radioactive material would be expected to be less than 100 mrem/yr. Examples of such situations include conditions that might exist at a site scheduled for remediation in the near future or a possible, but improbable, one-time scenario that might occur following remedial action. These levels should represent doses that are as low as reasonably achievable for the site. Further, no annual exposure should exceed 500 mrem.

C. GUIDELINES FOR RESIDUAL RADIOACTIVE MATERIAL

C.1 Residual Radionuclides in Soil

Residual concentrations of radionuclides in soil shall be specified as above-background concentrations averaged over an area of 100 m². Generic guidelines for thorium and radium are specified below. Guidelines for residual concentrations of other radionuclides shall be derived from the basic dose limits by means of an environmental pathway analysis using site-specific data where available. Procedures for these derivations are given in the supplement.

If the average concentration in any surface or below-surface area less than or equal to 25 m² exceeds the authorized limit or guideline by a factor of $(100/A)^{1/2}$, where A is the area of the elevated region in square meters,

limits for "hot spots" shall also be applicable. Procedures for calculating these hot spot limits, which depend on the extent of the elevated local concentrations, are given in the supplement. In addition, every reasonable effort shall be made to remove any source of radionuclide that exceeds 30 times the appropriate limit for soil, irrespective of the average concentration in the soil.

Two types of guidelines are provided, generic and derived. The generic guidelines for residual concentrations of Ra-226, Ra-228, Th-230, and Th-232 are:

- 5 pCi/g, averaged over the first 15 cm of soil below the surface
- 15 pCi/g, averaged over 15-cm-thick layers of soil more than 15 cm below the surface

These guidelines take into account ingrowth of Ra-226 from Th-230 and of Ra-228 from Th-232, and assume secular equilibrium. If either Th-230 and Ra-226 or Th-232 and Ra-228 are both present, not in secular equilibrium, the appropriate guideline is applied as a limit to the radionuclide with the higher concentration. If other mixtures of radionuclides occur, the concentrations of individual radionuclides shall be reduced so that (1) the dose for the mixtures will not exceed the basic dose limit or (2) the sum of the ratios of the soil concentration of each radionuclide to the allowable limit for that radionuclide will not exceed 1 ("unity"). Explicit formulas for calculating residual concentration guidelines for mixtures are given in the supplement.

C.2 Airborne Radon Decay Products

Generic guidelines for concentrations of airborne radon decay products shall apply to existing occupied or habitable structures on private property that are intended for unrestricted use; structures that will be demolished or buried are excluded. The applicable generic guideline (40 CFR Part 192) is: In any occupied or habitable building, the objective of remedial action shall be, and a reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL.* In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL. Remedial actions by DOE are not required in order to comply with this guideline when there is reasonable assurance that residual radioactive material is not the cause.

*A working level (WL) is any combination of short-lived radon decay products in one liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.

C.3 External Gamma Radiation

The average level of gamma radiation inside a building or habitable structure on a site to be released for unrestricted use shall not exceed the background level by more than 20 μ R/h and shall comply with the basic dose limit when an appropriate-use scenario is considered. This requirement shall not necessarily apply to structures scheduled for demolition or to buried foundations. External gamma radiation levels on open lands shall also comply with the basic dose limit, considering an appropriate-use scenario for the area.

C.4 Surface Contamination

The generic surface contamination guidelines provided in Table 1 are applicable to existing structures and equipment. These guidelines are adapted from standards of the U.S. Nuclear Regulatory Commission (NRC 1982)* and will be applied in a manner that provides a level of protection consistent with the Commission's guidance. These limits apply to both interior and exterior surfaces. They are not directly intended for use on structures to be demolished or buried, but should be applied to equipment or building components that are potentially salvageable or recoverable scrap. If a building is demolished, the guidelines in Section C.1 are applicable to the resulting contamination in the ground.

C.5 Residual Radionuclides in Air and Water

Residual concentrations of radionuclides in air and water shall be controlled to levels required by DOE Environmental Protection Guidance and Orders, specifically DOE Order 5480.1A and subsequent guidance. Other Federal and/or state standards shall apply when they are determined to be appropriate.

D. AUTHORIZED LIMITS FOR RESIDUAL RADIOACTIVE MATERIAL

Authorized limits shall be established to (1) ensure that, as a minimum, the basic dose limits specified in Section B will not be exceeded under the worst-case plausible-use scenario consistent with the procedures and guidance provided or (2) be consistent with applicable generic guidelines, where such guidelines are provided. The authorized limits for each site and its vicinity properties shall be set equal to the generic or derived guidelines except where it can be clearly established on the basis of site-specific data -- including health, safety, and socioeconomic considerations -- that the guidelines are not appropriate for use at the specific site. Consideration should also be given to ensure that the limits comply with or provide a level of protection equivalent to other appropriate limits and guidelines (i.e., state or

*These guidelines are functionally equivalent to Section 4 -- Decontamination for Release for Unrestricted Use -- of NRC Regulatory Guide 1.86 (U.S. Atomic Energy Commission 1974), but they are applicable to non-reactor facilities.

TABLE 1 SURFACE CONTAMINATION GUIDELINES

Radionuclides ^b	Allowable Total Residual Surface Contamination (dpm/100 cm ²) ^a		
	Average ^{c,d}	Maximum ^{d,e}	Removable ^{d,f}
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
Th-Natural, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay products	5,000 α	15,000 α	1,000 α
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000 β - γ	15,000 β - γ	1,000 β - γ

^a As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

^b Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

^c Measurements of average contamination should not be averaged over an area of more than 1 m². For objects of less surface area, the average should be derived for each such object.

^d The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.

^e The maximum contamination level applies to an area of not more than 100 cm².

^f The amount of removable radioactive material per 100 cm² of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm² is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. The numbers in this column are maximum amounts.

other Federal). Documentation supporting such a decision should be similar to that required for supplemental limits and exceptions (Section F), but should be generally more detailed because the documentation covers the entire site.

Remedial action shall not be considered complete unless the residual radioactive material levels comply with the authorized limits. The only exception to this requirement will be for those special situations where the supplemental limits or exceptions are applicable and approved as specified in Section F. However, the use of supplemental limits and exceptions should be considered only if it is clearly demonstrated that it is not reasonable to decontaminate the area to the authorized limit or guideline value. The authorized limits are developed through the project offices in the field and are approved by the headquarters program office.

E. CONTROL OF RESIDUAL RADIOACTIVE MATERIAL AT FUSRAP AND REMOTE SFMP SITES

Residual radioactive material above the guidelines at FUSRAP and remote SFMP sites must be managed in accordance with applicable DOE Orders. The DOE Order 5480.1A and subsequent guidance or superceding Orders require compliance with applicable Federal and state environmental protection standards.

The operational and control requirements specified in the following DOE Orders shall apply to interim storage, interim management, and long-term management.

- a. 5000.3, Unusual Occurrence Reporting System
- b. 5440.1C, Implementation of the National Environmental Policy Act
- c. 5480.1A, Environmental Protection, Safety, and Health Protection Program for DOE Operations, as revised by DOE 5480.1 change orders and the 5 August 1985 memorandum from Vaughan to Distribution
- d. 5480.2, Hazardous and Radioactive Mixed Waste Management
- e. 5480.4, Environmental Protection, Safety, and Health Protection Standards
- f. 5482.1A, Environmental, Safety, and Health Appraisal Program
- g. 5483.1A, Occupational Safety and Health Program for Government-Owned Contractor-Operated Facilities
- h. 5484.1, Environmental Protection, Safety, and Health Protection Information Reporting Requirements
- i. 5820.2, Radioactive Waste Management

E.1 Interim Storage

- a. Control and stabilization features shall be designed to ensure, to the extent reasonably achievable, an effective life of 50 years and, in any case, at least 25 years.
- b. Above-background Rn-222 concentrations in the atmosphere above facility surfaces or openings shall not exceed (1) 100 pCi/L at any given point, (2) an annual average concentration of 30 pCi/L over the facility site, and (3) an annual average concentration of 3 pCi/L at or above any location outside the facility site (DOE Order 5480.1A, Attachment XI-1).
- c. Concentrations of radionuclides in the groundwater or quantities of residual radioactive material shall not exceed existing Federal or state standards.
- d. Access to a site shall be controlled and misuse of on-site material contaminated by residual radioactive material shall be prevented through appropriate administrative controls and physical barriers -- active and passive controls as described by the U.S. Environmental Protection Agency (1983--p. 595). These control features should be designed to ensure, to the extent reasonable, an effective life of at least 25 years. The Federal government shall have title to the property or shall have a long-term lease for exclusive use.

E.2 Interim Management

- a. A site may be released under interim management when the residual radioactive material exceeds guideline values if the residual radioactive material is in inaccessible locations and would be unreasonably costly to remove, provided that administrative controls are established to ensure that no member of the public shall receive a radiation dose exceeding the basic dose limit.
- b. The administrative controls, as approved by DOE, shall include but not be limited to periodic monitoring as appropriate, appropriate shielding, physical barriers to prevent access, and appropriate radiological safety measures during maintenance, renovation, demolition, or other activities that might disturb the residual radioactive material or cause it to migrate.
- c. The owner of the site or appropriate Federal, state, or local authorities shall be responsible for enforcing the administrative controls.

E.3 Long-Term Management

Uranium, Thorium, and Their Decay Products

- a. Control and stabilization features shall be designed to ensure, to the extent reasonably achievable, an effective life of 1,000 years and, in any case, at least 200 years.
- b. Control and stabilization features shall be designed to ensure that Rn-222 emanation to the atmosphere from the wastes shall not (1) exceed an annual average release rate of 20 pCi/m²/s and (2) increase the annual average Rn-222 concentration at or above any location outside the boundary of the contaminated area by more than 0.5 pCi/L. Field verification of emanation rates is not required.
- c. Prior to placement of any potentially biodegradable contaminated wastes in a long-term management facility, such wastes shall be properly conditioned to ensure that (1) the generation and escape of biogenic gases will not cause the requirement in paragraph b. of this section (E.3) to be exceeded and (2) biodegradation within the facility will not result in premature structural failure in violation of the requirements in paragraph a. of this section (E.3).
- d. Groundwater shall be protected in accordance with appropriate Departmental Orders and Federal and state standards, as applicable to FUSRAP and remote SFMP sites.
- e. Access to a site should be controlled and misuse of on-site material contaminated by residual radioactivity should be prevented through appropriate administrative controls and physical barriers -- active and passive controls as described by the U.S. Environmental Protection Agency (1983--p. 595). These controls should be designed to be effective to the extent reasonable for at least 200 years. The Federal government shall have title to the property.

Other Radionuclides

- f. Long-term management of other radionuclides shall be in accordance with Chapters 2, 3, and 5 of DOE Order 5820.2, as applicable.

F. SUPPLEMENTAL LIMITS AND EXCEPTIONS

If special site-specific circumstances indicate that the guidelines or authorized limits established for a given site are not appropriate for a portion of that site or for a vicinity property, then the field office may request that supplemental limits or an exception be applied. In either case, the field office must justify that the subject guidelines or authorized limits are not appropriate and that the alternative action will provide adequate

protection, giving due consideration to health and safety, the environment, and costs. The field office shall obtain approval for specific supplemental limits or exceptions from headquarters as specified in Section D of these guidelines and shall provide to headquarters those materials required for the justification as specified in this section (F) and in the FUSRAP and SFMP protocols and subsequent guidance documents. The field office shall also be responsible for coordination with the state or local government of the limits or exceptions and associated restrictions as appropriate. In the case of exceptions, the field office shall also work with the state and/or local governments to ensure that restrictions or conditions of release are adequate and mechanisms are in place for their enforcement.

F.1 Supplemental Limits

The supplemental limits must achieve the basic dose limits set forth in this guideline document for both current and potential unrestricted uses of a site and/or vicinity property. Supplemental limits may be applied to a vicinity property or a portion of a site if, on the basis of a site-specific analysis, it is determined that (1) certain aspects of the vicinity property or portion of the site were not considered in the development of the established authorized limits and associated guidelines for that vicinity property or site and, (2) as a result of these unique characteristics, the established limits or guidelines either do not provide adequate protection or are unnecessarily restrictive and costly.

F.2 Exceptions

Exceptions to the authorized limits defined for unrestricted use of a site or vicinity property may be applied to a vicinity property or a portion of a site when it is established that the authorized limits cannot be achieved and restrictions on use of the vicinity property or portion of the site are necessary to provide adequate protection of the public and the environment. The field office must clearly demonstrate that the exception is necessary and that the restrictions will provide the necessary degree of protection and will comply with the requirements for control of residual radioactive material as set forth in Section E of these guidelines.

F.3 Justification for Supplemental Limits and Exceptions

Supplemental limits and exceptions must be justified by the field office on a case-by-case basis using site-specific data. Every effort should be made to minimize use of the supplemental limits and exceptions. Examples of specific situations that warrant use of the supplemental standards and exceptions are:

- a. Where remedial action would pose a clear and present risk of injury to workers or members of the general public, notwithstanding reasonable measures to avoid or reduce risk.

- b. Where remedial action -- even after all reasonable mitigative measures have been taken -- would produce environmental harm that is clearly excessive compared to the health benefits to persons living on or near affected sites, now or in the future. A clear excess of environmental harm is harm that is long-term, manifest, and grossly disproportionate to health benefits that may reasonably be anticipated.
- c. Where it is clear that the scenarios or assumptions used to establish the authorized limits do not, under plausible current or future conditions, apply to the property or portion of the site identified and where more appropriate scenarios or assumptions indicate that other limits are applicable or necessary for protection of the public and the environment.
- d. Where the cost of remedial action for contaminated soil is unreasonably high relative to long-term benefits and where the residual radioactive material does not pose a clear present or future risk after taking necessary control measures. The likelihood that buildings will be erected or that people will spend long periods of time at such a site should be considered in evaluating this risk. Remedial action will generally not be necessary where only minor quantities of residual radioactive material are involved or where residual radioactive material occurs in an inaccessible location at which site-specific factors limit their hazard and from which they are costly or difficult to remove. Examples include residual radioactive material under hard-surface public roads and sidewalks, around public sewer lines, or in fence-post foundations. A site-specific analysis must be provided to establish that it would not cause an individual to receive a radiation dose in excess of the basic dose limits stated in Section B, and a statement specifying the level of residual radioactive material must be included in the appropriate state and local records.
- e. Where there is no feasible remedial action.

G. SOURCES

<u>Limit or Guideline</u>	<u>Source</u>
<u>Basic Dose Limits</u>	
Dosimetry model and dose limits	International Commission on Radiological Protection (1977, 1978)
<u>Generic Guidelines for Residual Radioactivity</u>	
Residual concentrations of radium and thorium in soil	40 CFR Part 192
Airborne radon decay products	40 CFR Part 192
External gamma radiation	40 CFR Part 192
Surface contamination	Adapted from U.S. Nuclear Regulatory Commission (1982)
<u>Control of Radioactive Wastes and Residues</u>	
Interim storage	DOE Order 5480.1A and subsequent guidance
Long-term management	DOE Order 5480.1A and subsequent guidance; 40 CFR Part 192; DOE Order 5820.2

H. REFERENCES

- International Commission on Radiological Protection, 1977. Recommendations of the International Commission on Radiological Protection (Adopted January 17, 1977). ICRP Publication 26. Pergamon Press, Oxford. [As modified by "Statement from the 1978 Stockholm Meeting of the ICRP." Annals of the ICRP, Vol. 2, No. 1, 1978.]
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- U.S. Atomic Energy Commission, 1974. Regulatory Guide 1.86, Termination of Operating Licenses for Nuclear Reactors. June 1974.
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- U.S. Department of Energy, 1987. Supplement to U.S. Department of Energy Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites. A Manual for Implementing Residual Radioactive Material Guidelines. Prepared by Argonne National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, and Pacific Northwest Laboratory for the U.S. Department of Energy. [In press.]
- U.S. Environmental Protection Agency, 1983. Standards for Remedial Actions at Inactive Uranium Processing Sites; Final Rule (40 CFR Part 192). Federal Register 48(3):590-604 (January 5, 1983).
- U.S. Nuclear Regulatory Commission, 1982. Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material. Division of Fuel Cycle and Material Safety, Washington, D.C. July 1982.

APPENDIX B

PARAMETERS USED IN THE NFSS ANALYSIS

The parameter values used in the RESRAD code for the NFSS analysis are listed in Table B.1. All parameter values are reported at up to two significant figures.

TABLE B.1 Parameters Used in the RESRAD Code for the NFSS Analysis

Parameter	Unit	Value		
		Scenario A	Scenario B	Scenario C
Area of contaminated zone	m ²	37,000	37,000	37,000
Cover depth	m	0	0	0
Thickness of contaminated zone	m	6	6	6
Length parallel to aquifer flow	m	120	120	120
Erosion rate	m/yr	0	0	0
Density of contaminated zone	g/cm ³	1.8	1.8	1.8
Density of saturated zone	g/cm ³	1.7	1.7	1.7
Well pump intake depth	m	4	4	10
Effective saturated zone porosity	-b	0.1	0.1	0.1
Contaminated zone porosity	-b	0.4	0.4	0.4
Evapotranspiration coefficient	-b	0.85	0.85	0.85
Hydraulic conductivity, saturated zone	m/yr	72	72	3.5
Hydraulic gradient at water table	-b	0.0016	0.0016	0.001
Precipitation	m/yr	0.89	0.89	0.89
Irrigation	m/yr	0.2	0.2	0.2
Irrigation mode	-b	0	0	1
Runoff coefficient	-b	0.2	0.2	0.2
Watershed area for nearby pond	m ²	100,000	100,000	100,000
Crossover area (for model selection)	m ²	1,000	1,000	1,000
Distance from surface to water table	m	15	15	6
Individual's use of groundwater	m ³ /yr	150	150	150
Soil density, unsaturated zone	g/cm ³	1.6	1.6	-a
Hydraulic conductivity, unsaturated zone	m/yr	0.14	0.14	-a
Thickness, unsaturated zone	m	9	9	0
Effective porosity, unsaturated zone	-b	0.2	0.2	-a

TABLE B.1 (Cont'd)

Parameter	Unit	Value		
		Scenario A	Scenario B	Scenario C
Distribution coefficient:	cm^3/g			
Contaminated zone				
Cesium-137		2	2	2
Uranium-234		16	16	16
Uranium-235		16	16	16
Uranium-238		16	16	16
Unsaturated zone				
Cesium-137		2	2	-a
Uranium-234		16	16	-a
Uranium-235		16	16	-a
Uranium-238		16	16	-a
Saturated zone				
Cesium-137		2	2	2
Uranium-234		16	16	16
Uranium-235		16	16	16
Uranium-238		16	16	16
Inhalation rate	m^3/yr	8,400	8,400	8,400
Mass loading for inhalation	g/m^3	0.0002	0.0002	0.0002
Occupancy and shielding factor (external gamma)	-b	0.21	0.6	0.6
Occupancy factor (inhalation)	-b	0.19	0.5	0.5
Shape factor (external gamma)	-b	1	1	1
Dilution length for airborne dust	m	3	3	3
Fruits, vegetables, and grain consumption	kg/yr	0	160	160
Leafy vegetable consumption	kg/yr	0	14	14
Milk consumption	L/yr	0	92	92
Meat and poultry consumption	kg/yr	0	63	63
Fish consumption	kg/yr	0	0	5.4
Other seafood consumption	kg/yr	0	0.9	0.9
Drinking water intake	L/yr	410	410	410
Fraction of drinking water from site	-b	0.5	1	1
Fraction of aquatic food from site	-b	0	0.5	0.5
Livestock fodder intake for meat	kg/d	68	68	68
Livestock fodder intake for milk	kg/d	55	55	55
Livestock water intake for meat	L/d	50	50	50
Livestock water intake for milk	L/d	160	160	160

TABLE B.1 (Cont'd)

Parameter	Unit	Value		
		Scenario A	Scenario B	Scenario C
Mass loading for foliar deposition	g/m ³	0.0001	0.0001	0.0001
Depth of soil mixing layer	m	0.15	0.15	0.15
Groundwater fractional usage (balance from surface water)	- ^b			
Drinking water		1	1	0
Livestock water		1	1	0
Irrigation		1	1	0

^aParameter not required for this scenario.

^bParameter is dimensionless.