DATE: May 11, 2006

FROM: ROBIN TOPOLSKI, ACTING DIRECTOR
OFFICE OF INFORMATION RESOURCES, MA-44

TO: DIRECTIVES POINTS OF CONTACT

SUBJECT: DRAFT DOE G 441.1-XY, *Guidance for Radiological Control and Release of Game for Human Consumption*

This is to notify you that the subject draft Guide has been posted in the "Draft" section of the DOE Directives portal for simultaneous use and coordination. The draft Guide was developed to support implementation of DOE 5400.5 requirements for protecting the public from radiation. The Guide provides screening concentration guidelines of radionuclides in meat from game animals obtained on DOE sites and released for possible human consumption. The screening values and associated guidance are for use in determining whether potential doses to humans resulting from consumption of game animals provide a significant contribution towards or exceeds DOE 5400.5 public dose limits.

Guides are not requirements documents and are not to be construed as requirements in any audit or appraisal for compliance with the parent Policy, Order, Notice, or Manual. Since Guides do not contain requirements, their content is at the discretion of the author. Therefore, comments on Guides should not be designated "major" or "suggested"; they should simply be labeled as "comments."

Guides are reviewed through the Directives System, but are not coordinated using RevCom. Instead they are posted on the directives portal at:
http://www.directives.doe.gov/directives/draft.html

Comments on the Guide are due June 23, 2006.

The following procedures should be followed for the submission of comments:

Directives Points of Contact at Headquarters Elements: Submit one set of consolidated comments to the originator of the Guide: Emile Boulos, EH-41, Room 3G-089, Forrestal, facsimile: 202-586-0955; or INTERNET address: emile.boulos@eh.doe.gov.

Send an additional copy of comments to LaVerne Fuller, ME-43, Room 4B-172, Forrestal, facsimile: 202-586-1972, or to: laverne.fuller@hq.doe.gov.

Directives Points of Contact at Field Elements: will submit consolidated comments to their appropriate Lead Program Secretarial Office. If appropriate, the package submitted by Field Elements may contain comments provided by contractors.

Contractors will submit comments directly to their appropriate Field Elements.

Questions concerning the content of the Guide should be directed to Emile Boulos at (202) 586-1306. Questions on the directives system should be directed to LaVerne Fuller at (202) 586-1996.

Attachment

NOT MEASUREMENT SENSITIVE

DOE G 441.1-XY
XX-XX-06

GUIDANCE FOR RADIOLOGICAL CONTROL AND RELEASE OF GAME FOR HUMAN CONSUMPTION

[This Guide describes suggested nonmandatory approaches for meeting requirements. Guides are not requirements documents and are not construed as requirements in any audit or appraisal for compliance with the parent Policy, Order, Notice, or Manual.]

U.S. Department of Energy
Washington, D.C. 20585

AVAILABLE ONLINE AT:
www.directives.doe.gov

INITIATED BY:
Office of Environment, Safety and Health

FOREWORD

This Department of Energy (DOE) Guide was prepared by the Office of Air, Water, and Radiation Protection Policy and Guidance, Office of Environment, Safety, and Health, for use by DOE sites where hunting of game is permitted.

The Guide provides radionuclide screening concentration guidelines (SCG)for meat from game obtained on DOE sites and released for possible human consumption. The guidelines are for use in determining whether potential doses to humans resulting from consumption of game provide a significant contribution towards or exceed DOE 5400.5 public dose limits.

Comments or questions regarding this Guide should be directed to:
Office of Air, Water, and Radiation Protection Policy and Guidance, 202-586-8505

This Guide will be available on the DOE directives home page at:
http://www.directives.doe.gov.

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I. INTRODUCTION

Hunting of indigenous game (e.g., deer) is permitted at or around several Department of Energy (DOE) sites. The practice of allowing hunting of deer and other game is part of an ecosystem approach[1] to local wildlife management and conservation efforts, to restore and sustain the health, productivity, and biological diversity of a well balanced ecosystem.

Order DOE 5400.5, Radiation Protection of the Public & the Environment, establishes standards and requirements for DOE operations to protect public and environment from undue risk of radiation. The objective of the Order is to ensure that doses to the public resulting from DOE controlled activities are maintained as low as reasonably achievable (ALARA) and that DOE facilities monitor releases and assess potential doses from these releases. Potential doses resulting from human consumption of game that might have ingested or been in contact with radioactive materials at DOE sites could be a contributing pathway. This pathway should be considered in ensuring compliance with DOE public dose limits and ALARA process requirements.

Although Order requirements are applicable to the hunting pathway, it contains no specific requirements for monitoring or evaluating doses from hunting. For DOE sites where the pathway exists, as with other sources of exposure, DOE line management is responsible for ensuring the pathway is appropriately evaluated and compliance is achieved. The approach and level of effort should be commensurate with the importance of the pathway, and sites and facilities are responsible for documenting and implementing an approach.

Alternative approaches may entail a **process or site-wide knowledge approach** [knowledge of radionuclides and their concentration levels in the environment (air, water, soil, and plants) may be used to assess potential doses to hunters resulting from consumption of game in this area based on modeled uptake]; **selective or statistical sampling approach** (data radionuclide concentrations in game from around the site are used to estimate average and bounding potential doses to hunters); or **a direct measurement approach** (radionuclide concentrations in tissue of game actually taken by hunters are measured or estimated based on radiological measurement and modeled or compared to predetermined screen criteria to ensure DOE dose limits and constraints are met).

The choice of approach depends on the degree of confidence needed to report valid and reliable data. The approach should provide reasonable assurance that the dose attributable to consumption of game meets DOE requirements for protection of the public from radiation is necessary.

To assist facilities and sites in implementing their public radiation protection programs, this Guide describes an approach where game taken by hunters is monitored and the results are

[1] The ecosystem approach is a method for sustaining or restoring ecological systems and their functions and values. It is goal driven and based on a collaboratively developed vision of desired future conditions that integrates ecological, economic, and social factors. It is applied within a geographic framework defined primarily by ecological boundaries. [Federal Highway Administration(FHWA memorandum of Understanding, 12/15/95]; http://www.fhwa.dot.gov/legsregs/legislat.html

compared to calculated radionuclide screening concentration guidelines (SCG). These guidelines can be used to control the release of game to assure that the action in combination with other DOE activities will not exceed the DOE primary dose limit. In addition, the methodology in the Annual Site Environmental Reports (ASERS) provides a basis for assessing and documenting potential doses associated with this pathway per requirements in DOE O 231.1A.

Rationale for the Recommended Approach

The approach discussed in this document is one of direct measurement. It requires measurement of radioactivity levels or radionuclide content of game taken on DOE lands. It presumes that individuals hunting on DOE land should have permission; therefore, their access and egress to and from the site are controlled. They can be required to bring to check stations for tagging and monitoring any game taken on the reservation. Although measurements can be used to calculate estimated doses, in general the use of screening criteria based on a dose constraint will simplify the process. If the measurement indicates the screening criteria are met, the animal may be released.

This approach provides a high level of confidence that the hunting pathway doses comply with DOE requirements. It can be implemented in the field and is similar to the process used at most sites permitting hunting on DOE lands. In addition, because it requires each hunter to check in their game, the approach readily permits DOE to confirm that hunters have not strayed out of the permitted hunting areas into areas that pose risk of direct contamination.

Application of this approach should address and document the following:

1. A methodology for calculating the SCG for game taken during hunts on DOE lands.

2. A methodology for establishing potential doses to hunters including:

   - Dose limit and constraint applied;
   - Formulas for calculating the SCG;
   - Estimation of the annual human intake of game;
   - Calculation of SCG using other methodology;

3. Environmental monitoring and dose assessment approaches for determining the contribution of game consumption to human dose; and

4. Selected references from several Federal agencies, academia, and Web sites of DOE National Labs and facilities.

Selecting a dose constraint: The DOE 5400.5 primary dose limit from DOE facilities for a member of the public is 100 mrem effective dose equivalent (EDE)[2] in one year. This dose limit applies to the radiation dose from all sources and pathways except natural background radiation and dose received from medical applications. It should not be used exclusively for setting allowable radionuclide levels from consumption of game.

To ensure multiple sources will not result in doses exceeding the DOE primary dose limit of 100 mrem/year, DOE recommends potential doses from a single pathway be constrained so as not to exceed 10 to 30% of the primary public dose limit of 100 mrem per year.[3] This recommendation is consistent with established radiation protection practices and policies articulated by the National Council on Radiation Protection (NCRP), the International Council on Radiation Protection (ICRP), and the International Atomic Energy Agency (IAEA) as well as proposed Federal Guidance for Radiation Protection. These guidance documents recommend the projected dose attributable to any single source, practice, or activity should be some fraction less than the applicable overall primary dose limit.

Depending on the particular source of concern DOE, EPA, NRC and others have typically established single source or pathway constraints or limits (e.g., 10 CFR Part 20, liquid discharge limits) from less than 10 to 50 percent of the primary dose limit for protection of the public (100 mrem/year) from any particular source. In this Guide DOE used a dose constraint of 30 mrem per year for developing screening criteria. The rationale and considerations for selection of other dose restraints are discussed in Section II.

II. A METHODOLOGY FOR CALCULATING SCREENING CONCENTRATION GUIDELINES (SCG) FOR RELEASE OF GAME FOR POSSIBLE HUMAN CONSUMPTION

This section lists possible SCG for release of game for human consumption (see Table II-1, below). The methodology used to develop Table II-1. values is explained in the next chapter. Screening criteria in this Guide are based on a 30 mrem per year dose constraint, a value consistent with national and international guidance and past practices. DOE believes it provides reasonable assurance that this pathway will not cause the all sources/all pathways public dose limit to be exceeded when using a direct measurement approach. Furthermore, the screening concentrations are sufficiently conservative that for most individuals consuming meat from game, doses will amount to much less than the constraint. It is also noted that records from DOE sites indicate few if any animals taken on these sites will contain residual radioactive material at these levels – most are well below constraints (Section IV). Another important criterion is that the concentration guideline or other measurable quantity be readily implemented in the field. It should be determined if the subject game can be taken by the hunter during the hunt, not days or weeks later.

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[2] EDE is the sum of the products of the dose equivalent received by specified tissues of the body and a tissue-specific weighting factor. This is a risk-equivalent value and can be used to estimate the health-effects risk of the exposed individual. The tissue-specific weighting factor represents the fraction of the total health risk resulting from uniform whole-body irradiation that would be contributed by that particular tissue. The EDE includes the committed effective dose equivalent (CEDE) from internal deposition of radionuclides and the EDE due to penetrating radiation from external sources. EDE is expressed in units of rem (or sievert). (DOE 5400.5)

[3] DOE G 435.1-1

Site-specific values may also be developed using the methods and assumptions described in this Guide. Derivation of equations to calculate the radionuclide SCG and guidance for calculating concentration limits for other radionuclides not listed in this Guide are described in Section III.

If local or regional data on the intake of meat from game is used for estimating doses rather than the data in this document, the methods of collection should be documented and approved by the appropriate DOE field organizations. The use of alternative guidelines should be reported in the Annual Site Environmental Report (ASER) together with the data on radionuclide concentrations and estimated radiation dose.

Use of other constraints: Site-specific screening criteria may be established using lower dose constraints and the procedures discussed in this guidance, but if constraints used with this methodology are higher than the 30 mrem per year value, their use should be justified and documented to explain how such values provide reasonable assurance that the potential doses from this pathway and others will not cause the all sources/all pathways limit to be exceeded. In any case, in addition to reporting game releases and associated radiological control procedures in the site's annual report, DOE sites permitting hunting should make information on DOE control procedures, constraints, and screening criteria available to the public, especially to those permitted to hunt game on DOE sites.

It is noted that the 30 mrem per year dose constraint was selected and is reasonable for the direct measurement approach discussed in this guidance. However, if another method is employed (e.g., statistical sampling or site-wide knowledge approaches), comparison to the 30 mrem per year constraint may not be a sufficient test to ensure compliance with DOE 5400.5. For example, incomplete characterization of a site's radiological condition, uncertainty in the movement of game, and other factors increase uncertainty in dose estimates where the actual game taken are not monitored; hence, to achieve the same level of confidence as the direct measurement approach, an increased margin of safety may be needed.

TableII-1.
Radionuclide Screening Concentration Guidelines that Give a 30 mrem/yearCEDE[4] for a Meat Intake of 100 kg/year

Nuclide	Ingestion Dose Factor (mrem/pCi intake)	Radionuclide Screening Concentrations Guidelines (pCi/g)
Tritium (H-3)	6.4e-08	4.7e+03
Beryllium-7	1.3e-07	2.3e+03
Carbon-14	2.1e-06	1.4e+02
Sodium-22	1.1e-05	2.7e+01
Sodium-24	1.4e-06	2.1e+02
Phosphorus-32	8.8e-06	3.4e+01
Sulfur-35	4.5e-07	6.7e+02
Chlorine-36	3.0e-06	1.0e+02
Chromium-51	1.5e-07	2.0+03
Manganese-54	2.8e-06	1.1e+02
Iron-55	6.1-07	4.9e+02
Iron-59	6.7e-06	4.5e+01
Nickel-63	5.8e-07	5.2e+02
Copper-64	4.7e-07	6.4e+02
Strontium-89	9.3e-06	3.2+01
Strontium-90	1.2e-05	2.5e+01
Zirconium-95	3.8e-06	7.9e+01
Niobium-95	2.6e-06	1.2e+02
Technetium-99	1.5e-06	2.0e+02
Technetium-99^m	6.2e-08	4.8e+03
Ruthenium-103	3.1e-06	9.8e+01
Ruthenium-106	2.7e-05	1.1e+01
Antimony-125	2.8e-06	1.1e+02
Tellurium-132	9.4e-06	3.2e+01
Iodine-129	2.7e-04	1.1e+00
Cobalt-60	1.0e-05	3.0e+01
Cobalt-58	3.6e+00	8.4e+01

Nuclide	Ingestion Dose Factor (mrem/pCi intake)	Radionuclide Screening Concentrations Guidelines (pCi/g)
Iodine-131	5.3e-05	5.7e+00
Cesium-134	7.3e-05	4.1e+00
Cesium-137	5.0e-05	6.0e+00
Barium-140	9.5e-06	3.2e+01
Lanthanum-140	8.4e-06	3.6e+01
Cerium-144	2.1e-05	1.4e+01
Neodymium-147	4.4e-06	6.8e+01
Promethium-147	1.0e-06	3.0e+02
Europium-154	9.5e-06	3.2e+01
Lead-210	5.4e-03	5.6e-02
Polonium-210	1.9e-03	1.6e-01
Radium-226	1.3e-03	2.3e-01
Radium-228	1.4e-03	2.1e-01
Thorium-230	5.5e-04	5.5e-01
Thorium-232	2.7e-03	1.1e-01
Uranium-232	1.3e-03	2.3e-01
Uranium-234	2.6e-05	1.2e+01
Uranium-235	2.7e-04	1.1e+00
Uranium-238	2.5e-04	1.2e+00
Plutonium-238	3.2e-03	9.4e-02
Plutonium-239	3.5e-03	8.6e-02
Plutonium-240	3.5e-03	8.6e-02
Plutonium-241	6.8e-05	4.4e+00
Plutonium-242	3.4e-03	8.8e-02
Americium-241	3.6e-03	8.3e-02
Zinc-65	1.4e-05	2.1e+01

[4] Committed effective dose equivalent (CEDE): is the sum of the committed dose equivalents to various tissues in the body, each multiplied by the appropriate weighting factor. CEDE is expressed in units of rem (or sievert), DOE 5400.5.

Example for Calculation of Radionuclide SCG

The following example shows how the Radionuclide SCG are calculated using an annual dose constraint of 30 mrem (see Section 3.1) and an annual consumption of 100 kg (see Section 3.3). This method can be used to calculate Radionuclide SCG for radionuclides not included in Table II-1 by substituting the appropriate ingestion dose conversion factor from Federal Guidance Report No. 11 (FGR No. 11)[5]. If other dose conversion factors documents (e.g., FGR NO. 13, or other ICRP 60 based factor) are used, they should be documented and approved by DOE.

Cobalt (Co-60):

Exposure-to-Dose Conversion Factors for Ingestion

- **The ingestion dose conversion factor for Co-60** expressed in Sv/Bq is

  2.77×10^{-9} Sv/Bq

- Multiply by 3.7×10^{9}, to convert from Sv/Bq to mrem/µCi

  $2.77 \times 10^{-9} \times 3.7 \times 10^{9} = 1.0e + 01$ mrem/µCi

- Multiply by 10^{-6} to convert from µCi to pCi

  $1.0e + 01$mrem / µCi $\times 10^{-6} = 1.0e\text{-}05$ mrem/pCi

- Co-60 SCG

$$\frac{\text{30 mrem/year CEDE}}{\text{Conversion Ingestion Factor mrem/pCi x Intake of meat (g)}} = \text{pCi/g}$$

$$\frac{\text{30 mrem}}{\text{1.0e-05 mrem/pCi x 1.0e+05g}} = \text{30.0pCi/g}$$

- **Co-60- SCG = 3.0e + 01 pCi/g**

Implementation Considerations and Lessons Learned from DOE Site Monitoring Programs

Monitoring data from DOE Annual Site Environmental Reports indicates the primary radionuclides typically detected in the edible portions of game include alpha, beta, and gamma-emitting radionuclides such as plutonium-239, strontium-90, -137, and tritium (H-3). Gamma

[5] Source information for the EDE conversion factors in Table II-1. is U.S. Environmental Protection Agency (EPA), Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion (Table 2.2); Federal Guidance Report (FGR) No. 11. EPA 520/1-88-020, September 1988. The most restrictive ingestion dose conversion factors (those with the highest f_1 factors) from FGR No. 11 were used in developing the guidelines, resulting in the highest dose.

emitters may be detected using field gamma spectrometers (e.g., cesium would be expected to concentrate in the muscle tissue and thus be amenable to this technique). If the analysis results of samples of game killed in accidents or hunted by licensed hunters according to State permits confirm the presence of any radionuclide above the screening criteria or dose constraint, game should not be released for human consumption. Dose could also be received from external tissues (fur, skin, GI tract) that may include radionuclides that are not likely to be consumed by humans and would likely be an insignificant fraction of the dose from ingestion. Therefore, doses and guidance for these media were not calculated.

III. A METHODOLOGY FOR ESTABLISHING POTENTIAL DOSES TO HUNTERS

This section provides information on the dose limit and constraint applied for setting allowable radionuclide levels from consumption of game; derivation of formulas for calculation of radionuclide SCG; and methods for estimating annual intake of meat from game.

3.1. DOSE LIMIT AND CONSTRAINT APPLIED

The dose limit to a member of the public from DOE facilities is 100 mrem/year total effective dose equivalent (DOE 5400.5) and applies to doses received from all pathways and all sources. For the purposes of application in this Guide an administratively limited dose constraint of 30 mrem in a year was selected. The Department's ALARA policy limits doses in released game to as far below 30 mrem/yr as is practicable.

3.2. FORMULAS FOR CALCULATING SCG

The intake of radionuclide i as a consequence of the consumption of game is a function of the amount of game consumed and the concentration of radionuclide(i) in the edible portion of the game. This can be represented by the following equation:

(1)

$$I_{i,j} = M_j \times C_{i,j}$$

$I_{i,j}$ = annual intake of radionuclide i via food source j (μCi)

M_j = annual intake of food source j (kg)

$C_{i,j}$= concentration of radionuclide i in food source j (μCi / kg).

If $F_{i,\,ing}$ is the ingestion dose factor for radionuclide i (mrem/uCi), then the calculated $H_{i,j}$ (the CEDE from ingestion (mrem) resulting from an intake of $I_{i,\,j}$ micro curies) is:

(2)

$$H_{i,\,j} = F_{i,\,ing} \times I_{i,\,j} = F_{i,\,ing} \times M_j \times C_{i,\,j}$$

When Equation (1) is substituted for $I_{i,\,j}$. If the total dose from all radionuclides via consumption of game $\Sigma_i H_{i,\,j}$ to be consumed is to be less than a specified fraction (f_j) of the dose limit for members of the public, L_{public}, then:

(3)

$$\sum_i H_{i,j} < f_j \times L_{public}$$

This means that the sum of the radionuclides ingested should meet the criterion:

(4)

$$\sum_i F_{i,ing} \times M_j \times C_{i,j} < fj \times L_{public}$$

If both sides are divided by $f_j \times L_{public}$, then the criterion for release becomes:

(5)

$$\sum_i \frac{F_{i,ing} \times M_j \times C_{i,j}}{fj \times L_{public}} < 1$$

Rearranging the factors in the above equation, the equation becomes:

(6)

$$\sum_i \underline{M_j} \times \underline{F_{i,ing}} \times \underline{C_{i,j}} < fj \times L_{public}$$

The ratio M_j/f_j is dependent on the intake of food source, j, and the fraction, f_j, of the annual public dose limit allocated to this food source. Because this ratio is independent of the radionuclide, it may be moved outside the summation sign. The product $C_{i,j} \times F_{i,ing}$ represents the committed dose from radionuclide i, per unit mass of game and $C_{i,j}$ represents the measured concentration of radionuclide i, in food source j. For the intake of several food sources, the sum of all radionuclides and food sources should be less than one:

(7)

$$L_{public}^{-1} \sum_j \frac{M_j}{f_j} \sum_i C_{i,j} \times F_{i,ing} < 1$$

For any single radionuclide i, and food source j , the limiting radionuclide concentration can be obtained by rearranging equation (7) to:

(8)

$$C_{i,j} < \frac{{}^{6}f_j \times L_{public}}{F_{i,ing} \times M_j}$$

The limiting radionuclide concentration is directly proportional to the fraction of the public dose limit allocated to the food source j and inversely proportional to the quantity of that food source consumed annually (M_j) and the committed dose factor for the radionuclide of interest. Equation (8) is used to calculate the concentration limits in (Table A, section III), using the ingestion dose factors from FGR No. 11[7].

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[6] $fj \times L_{public}$, is set for 30mrem/year (section 3.1 of this Guide).

[7] U.S. Environmental Protection Agency (EPA), Limiting values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion (Table 2.2); Federal Guidance Report (FGR) No. 11. EPA 520/1-88-020, September 1988.

3.3. ESTIMATION OF ANNUAL INTAKE OF GAME FOR APPLICATION IN THE DOSE ESTIMATION METHODOLOGY

A major difficulty in estimating the potential radiation dose from game food products is deciding upon the appropriate approach for estimating the annual intake of meat from game. Because the amount of meat that will be consumed cannot be known for each hunter, two possible factors were analyzed:

1. The hunter obtains his minimum daily protein requirement from the consumption of game; and

2. The intake of meat from game is equal to the average daily intake of red meat in the United States.

These factors should produce upper bound intakes that are not likely to be exceeded by an occasional hunter. Based upon the assumption that the game meat provides the minimum daily dietary requirement of protein (.056 kg), the annual meat intake would be 102 kg for a subsistence hunter, (Table III-1). The U.S. average annual intake of red meat is estimated to be 52 kg (Table III-3). The assumed annual meat intake estimate of 102 kg is conservative for non-subsistence hunters because it is unlikely that all of an individual's meat intake would be from game harvested near or on a DOE site.[8]

The following tables provide tabulated estimates of intake for human consumption of specific game (Table III-1) and birds (Table III-2); and examples of U.S. Average Intake of Meat per year (Table III-3). The recommended daily allowance for the intake of protein by an adult male is (0.056 kg).

The annual protein intake = (365 days/year) x (0.056 kg/day) = 20.4 kg/year protein.

If (f) is the fraction of the edible body mass of the animal that is protein, then the annual amount of game consumed (I) by a person deriving all of their protein intake from wild game is:

(1)

$$I\ (\text{kg/year}) = \frac{20.4}{f}$$

The annual intake of meat given by this relationship is the primary quantity of interest for estimating the maximum allowable radionuclide concentration in game taken from DOE sites for consumption as food. The results of these calculations for common game and domestic food animals are shown in Table III-2. Table III-3 contains similar data for game birds. Because of similar protein content, this value does not exhibit a large variation. A default maximum value of 100 kg/year for meat consumption can be assumed for the hypothetical maximum individual's intake.

[8] The assumptions recommended here are generally acceptable for establishing criteria to control or release game and for estimating maximum exposed individual (MEI). However, these intake estimates should not be used for estimating the radiation dose to a specific individual.

It is also possible to calculate the number of individual animals that would be required to provide the recommended daily protein intake. If (s) is the fraction of edible meat in the entire animal and (w) is the animal's body weight, then the number of animals (n) to provide an annual intake (I) kg /year of edible meat is:

(2)

$$n = \frac{I}{s \times w} = \frac{20.4}{f \times s \times w}$$

Table III-1.[9]

Calculated Game (Large, Small & Domestic) Intake to Supply 100 % of Protein to the Human Diet

Game Animal	Fraction of Protein in Meat (f)	Annual Intake of Meat (I)	Edible Fraction of Body Weight (s)	Average Body Weight (kg) (w)	Number of Animals Equivalent to Intake (n) n = 20.4/f×s×w
Large Game					
Elk	(0.20)*	102	(0.8)**	360	0.3
Mule Deer	(0.20)*	102	(0.8)**	100	1.3
Whitetail Deer					
(north)	0.20	102	(0.8)**	72	1.8
(southwest)				45	3.0
Small Game					
Raccoon	(0.2)***	102	(0.60)***	9	19
Opossum	(0.2)***	102	(0.60)***	4	43
Woodchuck/	(0.2)***	102	(0.60)***	2	85
Rockchuck	(0.2)***	102	(0.60)***	5	34
Squirrel,					
(gray)	(0.2)***	102	(0.60)***	0.5	340
(fox)	(0.2)***	102	(0.60)***	0.9	190
Rabbit,					
(cottontail)	0.21	100	0.60	1.4	120
(Brush)	(0.2)***	102	(0.60)***	1.1	155
Hare	0.21	100	(0.60)***	1.6	100
Domestic Animals					
Cattle					
(beef)	0.23	89	0.82	200	0.46
(veal)	0.28	73	0.80		
Sheep					
(lamb)	0.24	85	0.82	50	0.46
(mutton)	0.18	114	(0.82)	80	
Pig					
(ham)	0.23	89	0.85	110	0.32
(pork)	0.18	114	0.79		
Chicken	0.20	102	0.52	2	98.

* reported percentage refuse ** based on reindeer *** based on cottontail rabbit

[9] Data summarized from: Dalrymple, Byron W. (1986); Federation of American Societies for Experimental Biology. (1974); and Watt, Bernice K.; and Merrill, Annabel L. (1963).

Table III-2.[10]
Calculated Game Bird Intake to Supply 100% of Protein to the Human Diet

Bird	Fraction of Protein in Meat (f)	Annual Intake of Meat (I)	Fraction of Body which is Edible (s)	Average Body Weight (w)	Number of Animals Equivalent to Intake n = 20.4/f×s×w
Duck	0.16	128	0.57	1.9	118.
Goose	0.16	128	0.50	5.0	50.
Pheasant	0.16	128	0.66	1.5	130.
Quail	0.17	120	0.67	0.4	450.
Squab	0.19	108	0.37	0.32	900.
Turkey	0.20	102	0.55	3.7	50.

Table III-3.[11]
Examples of U.S. Average Intake of Meat

	Annual Average Intake of Meat					
Type of Meat	**1950-59**	**1960-69**	**1970-79**	**1980-89**	**1990-99**	***2000**
Pounds per capita, boneless-trimmed weight						
Red meats	106.7	122.34	129.5	121.8	112.4	113.5
Beef	52.8	69.2	80.9	71.7	63.2	64.4
Pork	45.4	46.9	45.0	47.7	47.6	47.7
Veal and Lamb	08.5	06.2	03.5	02.4	01.7	01.4
Poultry	20.5	28.70	35.2	46.2	61.9	66.5
Chicken	16.4	22.7	28.4	36.3	47.9	52.9
Turkey	04.1	06.0	06.8	09.9	13.9	13.6
Fish and shellfish	10.9	10.70	12.5	14.2	14.7	15.2
Total meats	**138.10**	**161.70**	**177.20**	**182.20**	**189.0**	**195.20**
*In 2000, Americans consumed an average of 57 pounds more meat than they did annually in the 1950s.						

[10] Data summarized from: Dalrymple, Byron W. (1986); Federation of American Societies for Experimental Biology. (1974); and Watt, Bernice K.; and Merrill, Annabel L. (1963).

[11] Agriculture Fact Book 2001-2002/Chapter 2, Table 2-1 http://www.usda.gov/factbook/chapter2.ht.

3.4. CALCULATION OF SCG FOR RADIONUCLIDES NOT LISTED IN THIS GUIDE

This section describes the derivation of SCG for radionuclides not listed in this Guide; annual meat intake for human consumption of specific game; and site-specific SCG through application of local or regional data and information on game animal intake.

Screening concentration guidelines can be derived for pathways and radionuclides not listed in this Guide by using simple ratios. Values should be based on a radionuclide of an element chemically resembling the radionuclide of interest, preferably an isotope of the radionuclide of interest. If $F_{m,ing}$ is the dose factor for the radionuclide of interest, m, then the limiting concentration for this radionuclide can be estimated from the limiting concentration for radionuclide, n, as follows:

(1)

$$\frac{C_{n,j}}{F_{n,\,ing}} = \frac{C_{m,j}}{F_{m,\,ing}}$$

where

$F_{m,\,ing}$ = the ingestion dose factor for the radionuclide of interest, m
$C_{m,\,j}$ = the limiting concentration of the radionuclide of interest, m
$F_{n,\,ing}$ = the ingestion dose factor for the radionuclide, n
$C_{n,\,j}$ = the limiting concentration of the radionuclide, n

Rearranging equation (1) in order to solve for $C_{m,\,j}$, the equation becomes:

(2)

$$C_{n,j} \times F_{m,ing} = C_{m,j} \times F_{n,}$$

$$C_{m,j} = \frac{F_{m,ing}}{F_{n,\,ing}} \times C_{n,j}$$

Since the concentration is a limiting factor, the equal sign can be replaced by a less than sign to get:

(3)

$$C_{m,\,j} < \frac{F_{m,ing}}{F_{n,ing}} \times C_{n,j}$$

If several radionuclides are present, the sum of the ratios approach can be used to demonstrate compliance as follows:

$$\sum_i \; [\, c_i / C_i \,] \; < \; 1.0$$

where c_i = the measured concentration in meat of radionuclide, i
C_i = the concentration guideline from Table II-1. of this report or alternative site-specific derived guideline. Both c_i and C_i should be expressed in the same units. This means that measured concentration is less than the concentration guideline as it should be.

IV. ENVIRONMENTAL MONITORING AND DOSE ASSESSMENT APPROACHES FOR DETERMINING THE CONTRIBUTION OF GAME CONSUMPTION TO HUMAN DOSE

This section provides examples of the range of radionuclides and their concentrations that have been found in game and provides site-specific examples of environmental monitoring. Section 4.4 summarizes dose assessment results for a number of DOE sites and associated game. These examples were extracted directly from selected 2003 DOE Annual Site Environmental Reports (ASERS).

4.1. BROOKHAVEN NATIONAL LABORATORY (BNL)

In 2003, deer sampling results were consistent with previous years. Deer sampled on the BNL site contain higher concentrations of Cesium (Cs-137) than deer sampled from greater than 1 mile off site. This is most likely the result of deer consuming contaminated soil and grazing on vegetation growing in soil where elevated Cs-137 levels are known to exist. Removal of areas of contaminated soil at BNL began in 2000 and will continue. The New York State Department of Health (NYSDOH) has reviewed the potential public health risk associated with elevated Cs-137 levels in on-site deer and determined that neither hunting restrictions nor formal health advisories are warranted.

BNL consistently updates information on the resident population of white-tailed deer (*Odocoileus virginianus).* As there are no natural predators on site and hunting is not permitted at BNL, there are no significant pressures on the population to migrate beyond their typical home range of approximately 1 square mile. A 1992 study indicated that the population of deer on site exceeded 700, or approximately 85 per square mile (Thomlinson 1993). Normally, a population density of 10 to 30 per square mile is considered an optimum sustainable level for a given area. Significant damage to the ecosystems can occur when there are only 8 deer per square mile. The current estimate, based on surveys conducted late in 2003, is 1,784 deer, or approximately 217 deer per square mile.

The deer surveys are conducted at least twice per year: mid-spring before fawns are born and late summer after all fawns have been born. These surveys track reproductive success and mortality. In 2003, spring surveys indicated a population of 1,202 deer. Late summer surveys estimated 1,784 deer, for an 11 percent increase in the population over the previous year, and a 48 percent increase over the spring population.

The significant increase resulted in higher rates of car/deer accidents in 2003. The spring count of 1,202 deer indicated a winter mortality of approximately 25 percent. The survey methods used require good weather for accurate counts. It is felt that an infrared aerial survey would be more accurate and less dependent on weather conditions.

In 2003, the Upton Reserve committee began discussing plans for conducting an infrared aerial survey of several Long Island properties, including BNL. Deer overpopulation can affect animal and human health (e.g., animal starvation, Lyme disease from deer ticks, collision injuries—both human and animal), species diversity (songbird species reduction due to selective grazing and

destruction of habitat by deer), and property values (auto damage and browsing damage to ornamental plantings).

In 2003 there were 24 deer-related collisions on site, compared to 20 accidents documented in 2002. This increase in the number of on-site collisions is attributed to increasing populations.

Because the high deer population is a regional problem, BNL is working on the issue with other entities. In addition, BNL environmental biologists would like to see a regional approach to deer management in place before attempting large-scale deer management on site. Approaches are limited, and most are controversial. A regional approach would benefit the community, land managers, and the health of the deer population.

Deer Sampling

Deer in New York State typically are large, with males weighing, on average, about 150 pounds; females typically weigh about 100 pounds. However, deer on Long Island tend to be much smaller, weighing an average of 80 pounds. The available meat on local deer ranges from 20 to 40 pounds per deer. This fact has implications for calculating potential radiation dose to consumers of deer meat containing Cs-137.

In 2003, as in recent years, an off-site deer sampling program was conducted with the New York State Department of Environmental Conservation (NYSDEC) Wildlife Branch and FWS. While most off-site samples are from road-killed deer at and near BNL, NYSDEC provides a few samples that result in data on deer that move beyond BNL boundaries, where they can be legally hunted, and also provides control data on deer living 1 mile or more from BNL. Also, FWS informs BNL staff of deer that have died in or near the Wertheim National Wildlife Refuge and other FWS properties on Long Island. Compared to a few years ago, a larger number of deer samples were collected in 2003. This is due to the larger number of deer/vehicle accidents that occurred on and off site, which corresponds to an increasing deer population

In all, 24 deer were obtained on site and 31 were from off-site locations, ranging from adjacent to BNL along the William Floyd Parkway, to as far away as East Islip, New York. BNL sampling technicians collect the samples and process them for analysis. A sample of meat, liver, and bone is taken from each deer, when possible. The meat and liver are analyzed for Cs-137, and the bone is analyzed for strontium-90 (Sr-90). In addition to the 55 deer samples taken under the routine monitoring program, four deer that entered the Former Waste Management Facility (FWMF) area were sampled to determine uptake of Cs-137 and Sr-90.

Cesium-137 in Deer

It has been previously established (2000 BNL Annual Site Environmental Report) that deer sampled on the BNL site contain higher concentrations of Cs-137 (half-life = 30 years) than deer from greater than 1 mile off site. This is most likely the result of deer consuming contaminated soil and grazing on vegetation growing in soil where elevated Cs-137 levels are known to exist. Cs-137 in soil can be transferred to aboveground plant matter via root uptake, where it then becomes available to browsing animals.

Removal of contaminated soil areas at BNL has occurred under the Laboratory's Environmental Restoration (ER) Program. All major areas of contaminated lawn soils were remediated in 2000. The number of deer taken for sampling has steadily increased since 1996. In 1998, a statistical analysis based on existing data suggested that 40 deer from off site and 25 deer from on site were needed to achieve a statistically sound data set. Since that analysis was completed, BNL has attempted to obtain the required number of deer. The number taken each year has varied, due to the sampling method that depends on vehicle/deer accidents and people reporting dead deer.

The number of deer hit by cars varies widely from year to year, depending on the population of deer present near major roadways .The concentration on site is near the front gate area and the constructed portions of BNL. This distribution is most likely due to the fact that people on their way to work see and report dead deer. Vehicle collisions with deer on site occur primarily early or late in the day, when deer are more active.

In 2003, Cs-137 concentrations in deer meat samples taken at BNL ranged from 0.07 to 5.57 picocuries per gram (pCi/g) wet weight. The "wet weight" concentration is before a sample is dried for analysis, and is the form most likely to be consumed. Dry weight concentrations are typically higher than wet weight values. The maximum 2003 on-site concentration (5.57 pCi/ g wet weight) is slightly higher than the highest level reported in 2002 (4.95 pCi/g wet weight), but much lower than the highest level ever reported (11.74 pCi/g wet weight, in 1996). The arithmetic average concentration in on-site meat samples was 1.06 pCi/g. The average concentration of all off-site meat samples was 1.07 pCi/g wet weight.

Cesium-137 concentrations in off-site deer meat samples were separated into two groups: samples taken within 1 mile of BNL and samples taken farther away (see Table 6-2). Concentrations in meat samples nearby range from 0.07 to 4.23 pCi/g wet weight, with an average of 1.51 pCi/g wet weight; concentrations in meat taken from farther away ranged from nondetectable to 0.32 pCi/g wet weight, with an average of 0.11 pCi/g wet weight. Figure 6-4 compares the average values of Cs-137 concentrations in meat samples collected in 2003 from four different location groupings. Although the figure does not show this, 70 percent of all samples taken both on and off site are below 1 pCi/g wet weight (see Table 6-2). Figure 6-5 presents the five-year trend of onsite and near off-site Cs-137 averages in deer meat. Although there is no statistical difference between the values across the 5 years, there is a statistical difference between values in 2000 (when landscape soils were cleaned up) and values in 2002.

When possible, liver samples are taken concurrently with meat samples. Liver generally accumulates Cs-137 at a lower rate than muscle tissue (meat). In liver samples collected on site in 2003, the range of Cs-137 concentrations was 0.05 to 1.43 pCi/g wet weight, with an average of 0.33 pCi/g wet weight. The off-site Cs-137 concentration in liver ranged from nondetectable to 2.22 pCi/g wet weight, with an average for all off-site liver samples being 0.34 pCi/g wet weight.

The potential radiological dose resulting from deer meat consumption is discussed in Chapter 8. NYSDOH has formally considered the potential public health risk associated with elevated Cs-137 levels in on-site deer and determined that neither hunting restrictions nor formal health advisories are warranted (NYSDOH 1999). Their report can be accessed at: http://www.bnl.gov/esd/wildlife/deer issues.htm.

With respect to the health of the on-site deer based on their exposure to radionuclides, the International Atomic Energy Agency (IAEA) has concluded that chronic dose rates of 100 millirad per day to even the most radiosensitive species in terrestrial ecosystems are unlikely to cause detrimental effects in animal populations (IAEA 1992). A deer containing a uniform distribution of Cs-137 within muscle tissue at the highest levels observed to date (11.74 pCi/g wet weight, reported in 1996) would carry a total body burden (total amount in body) of about 0.2 μCi. Under these conditions, an animal would receive an absorbed dose of approximately 3 millirad per day, which is only 3 percent of the threshold evaluated by the IAEA. The deer observed and sampled on the BNL site appear to have no health effects from the level of Cs-137 found in their tissues, although the general health of the herd is not optimal because of overpopulation.

Strontium-90 in Deer Bone

BNL began testing deer bones (when available) for Sr-90 content in 2000, and continued this analysis in 2003. Sr-90 content ranged from nondetectable to 7.65 pCi/g dry weight in on-site samples, with higher values seen in bone taken during special sampling at the FWMF. Sr-90 in off-site samples ranged from nondetectable to 5.75 pCi/g dry weight in samples taken within 1 mile of BNL, and 1.09 to 2.61 pCi/g dry weight in samples taken from locations greater than a mile from BNL. This overlap in values between all samples suggests that Sr-90 is present in the environment at background levels; this is likely a result of worldwide fallout from nuclear weapons testing.

Sr-90 is present at very low levels in the environment, is readily incorporated into bone tissue, and may concentrate over time. BNL will continue to test for Sr-90 in bone to develop baseline information on this radionuclide and its presence in deer.

Special Sampling of Deer in Formal Waste Management Facility (FWMF)

Cesium-137 in liver ranged from 1.37 to 5.07 pCi/g wet weight. Although it is not known whether these deer had a significant Cs-137 content prior to their entering the facility, the values in both meat and liver suggest that Cs-137 can be incorporated into tissues. A sample of bone was taken from each animal and analyzed for Sr-90. Three of the deer, the two fawns and one doe, contained high levels of this bone-seeking radionuclide, values from 38.6 to 68.9 pCi/g dry weight. The other doe had a Sr-90 value of 5.1 pCi/g, which is in the typical range for deer on Long Island. The higher values in three of the deer may be a result of the doe having consumed dirt containing high levels of Sr-90.

Reference: 2003 Brookhaven National Lab, Site Environmental Report
http://www.bnl.gov/esd/SER.htm

4.2. SAVANNAH RIVER SITE (SRS)

Description of Surveillance Program

Annual hunts open to members of the general public are conducted at SRS to control the site's deer and feral hog populations and to reduce animal-vehicle accidents. Before any animal is released to a hunter, Environmental Monitoring and Analysis Group (EMA) uses portable sodium iodide detectors to perform field analysis for Cesium-137. Media samples (muscle

and/or bone) are collected periodically for laboratory analysis based on a set frequency, on Cesium-137 levels, and/or on exposure limit considerations.

Surveillance Results

A total of 1,128 deer and 106 feral hogs were taken during the 2003 site hunts. As observed during previous hunts, Cesium-137 was the only manmade gamma-emitting radionuclide detected during laboratory analysis. Generally, the Cesium-137 concentrations measured by the field and lab methods were comparable. Field measurements from all animals ranged from 1 pCi/g to 17.1 pCi/g, while lab measurements ranged from 1 pCi/g to 18.2 pCi/g. The average field Cesium-137 concentration was 1.29 pCi/g in deer (with a maximum of 17.1 pCi/g) and 1.18 pCi/g in hogs (with a maximum of 3.1 pCi/g). Strontium levels are determined in some of the animals analyzed for Cesium-137. Typically, muscle and bone samples are collected for analysis from the same animals checked for Cesium-137, and the samples are analyzed for Strontium-89,90. As in previous years, Strontium-89,90 was not quantified in muscle samples. Lab measurements of Strontium-89,90 in bone ranged from a high of 11.6 pCi/g to a low of 2.56 pCi/g.

Reference: 2003 Savannah River Site, Site Environmental Report.

4.3. OAK RIDGE RESERVATION (ORR)

ORR Environmental Monitoring Programs

The year's total harvest was 256 deer. The heaviest doe weighed 114 lb (51.7 kg). Since 1985, 8,519 deer have been harvested; of these only 170 (2.0%) have been retained due to potential radiological contamination. The heaviest buck was 218 lb (98.9 kg) (harvested in 1998), and the average weight is 85.5 lb (38.8) kg). The oldest deer harvested was 12 years old; the average age is 1.9 years. For more information, see the Oak Ridge National Laboratory (ORNL) wildlife Web page: http://www.ornl.gov/sci/rmal/huntinfo.htm.

Results

In the 2003 hunts, 256 deer were harvested. Of the deer harvested, two (0.8%) were retained for exceeding the administrative release limits [1.5 times the background for beta activity in bone (~20 pCi/g) or 5 pCi/g (0.19 Bq/g) of 137Cs in edible tissue]. The two retained deer exceeded the limit for beta-particle activity in bone. The average weight was 76.9 lb (34.9 kg) and the maximum weight of the released deer was 161 lb (73.0 kg). The average Cesium-137 concentration in the released deer was 0.7 pCi/g (0.026 Bq/g), and the maximum Cesium-137 concentration in the released deer was 1.9 pCi/g (0.07 Bq/g). It is assumed that 55% of the field weight is edible meat; therefore, the average deer would yield 51.5 lb (23.4 kg) of meat. Based on the average weight, the total harvest of edible meat (254 released deer) is estimated at 13,081 lb (5,946 kg).

Reference: 2003 Oak Ridge Reservation, Site Environmental Report.
http://www.ornl.gov/Env_Rpt

4.4 EXAMPLES OF ESTIMATED DOSES FROM INGESTION OF GAME HARVESTED AT SELECTED DOE SITES[12]

The examples from DOE ASERS in Sections 4.1 to 4.3 provided information on the range of radionuclides and their concentrations that have been found in game in terms of (pCi/g). These examples did not show the doses to humans as a result of consuming the game for compliance with Order DOE 5400.5.

Table IV-1. provides examples of hypothetical estimated maximum doses resulting from consumption of game reported by DOE sites. Although most sites report only maximum dose, it would be useful to include estimates of average dose to hunters where applicable. The dose should be reported in mrem/year. This information is useful in demonstrating (1) the reported dose does not exceed the recommended DOE 30 mrem/year constraint; (2) whether hunting is permitted on site; (3) whether a site has a game monitoring program; and (4) what species are collected for dose assessment.

Table IV-1.
Examples of Hypothetical Estimated Maximum Doses From Consumption of Game Reported by DOE Sites

DOE SITE	Onsite Hunting Permitted	Harvested Game Assessed	Species Collected	Game Monitoring Program	DOSE Contribution from Consumption of Game to MEI[13] (MREM/YR)
BNL	Y	Y	White-tail deer	Y	.05-2.2
ORR	Y	Y	White-tail deer, boar	Y	0.3-4.0
SRS	Y	Y	White-tail deer	Y	15.6
INEEL	Y	N	Elk, pronghorn, mule deer	Y	Dose primarily from Cs-137 1999-2004, doses range (0.002-0.05)
NTS	Y	Y	pronghorn	Y	.064

[12] Collected from the Calendar Year 2003 ASERS.
[13] MEI (maximum exposed individual): The hypothetical individual whose location and habits tend to maximize his/her potential radiation dose, resulting in a potential dose higher than that received by other individuals in the general population.

V. REFERENCES

1. U. S. Environmental Protection Agency. Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion and Ingestion. Federal Guidance Report No. 11. EPA-520/1-88-20. September 1988.

2. U.S. Department of Energy (DOE)/ Office of Environment, Safety and Health. Internal Dose Conversion Factors for Calculation of Dose to the Public. Report DOE/EH-0071. July 1988

3. Cornell University, Ithaca, New York. http://www.sheep.cornell.edu/sheep/management/mimeos/_hogueefficiency.pdf

4. Agriculture Factbook 2001-2002/chapter 2, table 2-1.http://www.usda.gov/factbook/chapter2.htm

5. U.S Department of Agriculture. http://www.nass.usda.gov/in/annbul/9798/pg56.htm

6. Economic Research Service (ERS). U.S. Department of Agriculture. World Red Meat and Poultry Consumption. 1975-199 http//usda.mannlib.cornell.edu/data-sets/food/91004

7. C.A. Fontana, N. R. Sunderland, S. C. Black, B. B. Dicey, A. N. Jarvis, D. D. Smith, D. J. Thomé, and A. A. Mullen. Off-Site Environmental Monitoring Report - Radiation Monitoring Around United States Nuclear Test 2 Areas, Calendar Year 1987. EPA/600/4-87/017, DOE/DP/00539-060. May 1988.

8. Federation of American Societies for Experimental Biology. http://www.faseb.org/publications

9. DOE Annual Site Environmental Reports: See Table V-1.

Table V-1.
ASERS Available on the Web
October 2005

** unavailable indicates status as of October 14, 2005*

Site	URL
Ames Laboratory	http://www.ameslab.gov/esha/ESH&A_Documents/reportlist.html Available: 1999-2004
Argonne National Laboratory-East	http://www.anl.gov/Community_and_Environment/Environmental_Reports/ Available: 1972-2004
Ashtabula Environmental Management Project	Unavailable
Battelle Columbus Laboratories	Unavailable
Bettis Atomic Power Laboratory	Unavailable
Brookhaven National Laboratory	http://www.bnl.gov/esd/SER.asp Available: 1997-2004
Energy Technology Engineering Center	Unavailable
Fernald Environmental Management Project	http://www.fernald.gov/Cleanup/Environmental_Monitoring/EnvMon.htm Available: 2003 and 2004
Grand Junction Office	http://www.lm.doe.gov/documents/sites/co/gjo/aser/2004aser.pdf Available: 2004 http://www.lm.doe.gov/documents/sites/co/gjo/aser/2003aser.pdf Available: 2003
Hanford Site	http://hanford-site.pnl.gov/envreport/ Available: 1995-2003
Idaho National Engineering and Environmental Laboratory	http://www.stoller-eser.com/Publications.htm Available: 1995-2003
Knolls Atomic Power Laboratory – Kesselring	Unavailable
Knolls Atomic Power Laboratory - Knolls	Unavailable
Knolls Atomic Power Laboratory - Windsor	Unavailable
Laboratory for Energy-Related Health Research	http://lso.oak.doe.gov/SiteMgr/Env_Rprts/LSO_EnvRptsIndex_WF.html Available: 2001-2003
Lawrence Berkeley National Laboratory	http://www.lbl.gov/ehs/esg/tableforreports/tableforreports.htm Available: 1995-2004
Lawrence Livermore National	http://www.llnl.gov/saer/index.html

Laboratory	Available: 1994-2004
Los Alamos National Laboratory	http://www.airquality.lanl.gov/AirReports.htm Available: 1997-2004
Miamisburg Environmental Management Project	http://www.doe-md.gov/ Available: 2000-2002 (Under Environmental Monitoring)
Moab	http://gj.em.doe.gov/moab/project_docs/pro_docs.htm Available: 2004
Monticello Mill Tailings Site	http://lts1.gjo.doe.gov/documents/mnt/aser2000.pdf Available: 2000 (Last Year)
National Energy Technology Laboratory	http://www.netl.doe.gov/ISO14001/esh-ism/reports.html Available: 1998-2002
National Renewable Energy Laboratory	http://www.eere.doe.gov/golden/Reading_Room.aspx Available: 2003
Naval Petroleum Reserve	http://www.osti.gov/dublincore/gpo/servlets/purl/769371-kubSA6/webviewable/769371.pdf Available: 1999
Naval Reactor Facility	Unavailable
Nevada Test Site	http://www.nv.doe.gov/library/publications/environmental.aspx Available: 1996, 1999-2004
Oak Ridge Reservation	http://www.ornl.gov/Env_Rpt/ Available: 1995-2004
Paducah Gaseous Diffusion Plant	http://www.bechteljacobs.com/pad_reports.shtml Available: 2001-2003
Pantex Plant	http://www.pantex.com/aser/ Available: 1995-2004
Portsmouth Gaseous Diffusion Plant	unavailable
Princeton Plasma Physics Laboratory	http://www.pppl.gov/pub_report/ Available: 1994-2003 (1993-1994 available from DOE Information Bridge)
Sandia National Laboratories, Albuquerque	http://www.sandia.gov/news-center/publications/enviro-reports/index.html Available: 2004
Sandia National Laboratories, Livermore	http://www.ca.sandia.gov/pubs/ Available: 1995 (summary), 1998-1999, 2001 (summary), 2003
Sandia National Laboratories, Tonopah	http://www.sandia.gov/news-center/publications/enviro-reports/index.html Available: 2004
Savannah River Site	http://www.srs.gov/general/pubs/ERsum/index.html Available: 2001-2004
Stanford Linear Accelerator Center	http://www.slac.stanford.edu/esh/aser.html

	Available: 1993-2001
Strategic Petroleum Reserve	http://www.spr.doe.gov/esh/Default.htm Available: 2001-2003
Thomas Jefferson National Accelerator Facility	http://www.jlab.org/div_dept/admin/publications/SER.html Available: 2000-2003
Waste Isolation Pilot Plant	http://www.wipp.ws/library/caolib.htm#Info Available: 2002-2003 (Look for "WIPP Site Environmental Report") http://www.osti.gov/bridge/basicsearch.jsp Available: 1994, 1995, 1998, 2000,2001 (Type in "Waste Isolation Pilot Plant Site Environmental Report")
Weldon Spring Site Remedial Action Project	http://www.lm.doe.gov/land/sites/mo/weldon/weldon.htm Available: 2004 (Select Annual Site Environmental Report) Previous versions (1986-2003) available at: http://lts1.gjo.doe.gov/gjoreclog/lm_search2.cfm?FC_pasSite=WEL&FC_pasSite2=WEL (Type in "Weldon Spring Site Environmental Report" in the Title/Description field and click on the Search button.)
West Valley Demonstration Project	http://www.wv.doe.gov/ASER/ASERIndex.htm Available: 1982-2004