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

DERIVATION OF URANIUM RESIDUAL RADIOACTIVE MATERIAL GUIDELINES FOR THE THREE ST. LOUIS FUSRAP SITES: ST. LOUIS DOWNTOWN SITE, ST. LOUIS AIRPORT SITE, AND LATTY AVENUE PROPERTIES

by

Cindy Boggs-Mayes and Charley Yu
Energy and Environmental Systems Division

January 1989

work supported by

U.S. DEPARTMENT OF ENERGY
Oak Ridge Operations
Technical Services Division
Oak Ridge, Tennessee

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February 6, 1989

Jerry Wing
U.S. Department of Energy
Oak Ridge Operations Office
Federal Building
200 Administration Road
P.O. Box 2001
Oak Ridge, TN 37831-8723

Dear Jerry:

Attached are 6 copies of the final report "Derivation of Uranium Residual Radioactive Material Guidelines for the Three St. Louis FUSRAP Sites: St. Louis Downtown Site, St. Louis Airport Site and Latty Avenue Properties" dated January 1989.

Sincerely,

Cindy Boggs

Cindy Boggs
Energy and Environmental Systems Division

Attachment
CB:lmg

cc: B.L. Beck, BNI
S. Liedle, BNI
J. Williams, BNI

A. Dvorak
J. Irving
J. Peterson
C. Yu
Y. Yuan

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SUMMARY

Residual radioactive material guidelines for uranium were derived for three contaminated sites in the St. Louis, Missouri, area: the St. Louis Downtown Site, the St. Louis Airport Site, and the Latty Avenue Properties. These sites have been identified for remedial action under the Formerly Utilized Sites Remedial Action Program of the U.S. Department of Energy (DOE). The derivation of the total uranium guidelines was based on the requirement that the 50-year committed effective dose equivalent for a hypothetical individual who lives or works in the immediate vicinity of these sites should not exceed a dose of 100 mrem/yr following decontamination. The DOE residual radioactive material guideline computer code, RESRAD, which implements the methodology described in the DOE manual for implementing residual radioactive material guidelines, was used in this evaluation. Three potential scenarios were considered for the sites, one assuming industrial use and two assuming residential use. The scenarios also vary with regard to time spent at the sites, sources of water used, and sources of food consumed. Potential radiation doses from seven exposure pathways were analyzed. The results indicate that the basic dose limit of 100 mrem/yr will not be exceeded for uranium at these sites in 1,000 years, provided that the soil concentrations of uranium do not exceed the following for all three St. Louis sites (in pCi/g): Scenario A, 1,800; Scenario B, 430; and Scenario C, 430. These uranium guidelines apply to the total activity concentration of uranium isotopes (i.e., uranium-238, uranium-234, and uranium-235 present in their natural activity concentration of 1:1:0.046). Therefore, if uranium-238 is measured as the indicator radionuclide, the respective limits are as follows for all three St. Louis sites (in pCi/g): Scenario A, 880; Scenario B, 210; and Scenario C, 210.

1 INTRODUCTION AND BRIEF HISTORY

The Formerly Utilized Sites Remedial Action Program (FUSRAP) was established in 1974 by the U.S. Atomic Energy Commission (AEC), a predecessor of the U.S. Department of Energy (DOE). The primary objective of FUSRAP is to identify and decontaminate sites where radioactive material was handled or processed under past government nuclear programs.

As part of its responsibility for identification and cleanup of radioactive materials under the Atomic Energy Act and Public Law 98-50, the DOE proposes to perform remedial action at three FUSRAP sites in the St. Louis, Missouri, area. These sites — which are located in close proximity to each other in St. Louis County — are the St. Louis Downtown Site, the St. Louis Airport Site, and the Latty Avenue Properties (Figure 1). The proposed remedial action will include decontamination of properties and buildings according to applicable guidelines (Appendix A) and long-term management of the wastes at an appropriate disposal site. To the maximum extent practicable, these actions will be permanent solutions to protect public health and the environment.

1.1 ST. LOUIS DOWNTOWN SITE

The 18.2-ha (45-acre) St. Louis Downtown Site is located on Destrehan and Broadway Streets in downtown St. Louis (Figure 2). It is currently owned by Mallinckrodt Chemical Works and contains more than 20 buildings and other facilities involved in the manufacture of chemical products (Bechtel Natl. 1986b). In 1942, the U.S. Army Corps of Engineers, Manhattan Engineer District (MED) — a predecessor of the AEC — requested the Destrehan Street Refinery and Metal Plant (later the Mallinckrodt Chemical Works) to initiate activities for the production of uranium dioxide and trioxide (UO_2 and UO_3). Subsequently, plant operations involved the processing of uranium ores, refinement of uranium concentrates, recovery of uranium, extraction and concentration of thorium from pitchblende raffinate, and experimental processing of very-low-enrichment uranium tetrafluoride (UF_4).

During the uranium-processing period, certain buildings on-site were constructed for and owned by the MED/AEC. The remainder of the approximately 60 buildings involved with the program were owned by Mallinckrodt, and some were leased to the MED/AEC.

Based on survey results, the Downtown Site is primarily contaminated with natural uranium and its associated decay products. This waste consists primarily of contaminated soil and building materials. A single water sample taken from an old waste pit during the 1977 survey had a uranium-238 concentration of 59,000 pCi/L (Oak Ridge Natl. Lab. 1981). Surface soil samples taken in areas of suspected contamination during a later survey contained uranium-238 at concentrations up to 8,100 pCi/g and thorium-230 at concentrations up to 14,000 pCi/g; subsurface samples contained uranium-238 at concentrations up to 33,000 pCi/g and thorium-230 at concentrations up to 6,600 pCi/g (Avel 1988). Further radiological characterization is planned for the site in fiscal year 1989. The amount of radioactive material generated by cleanup of the

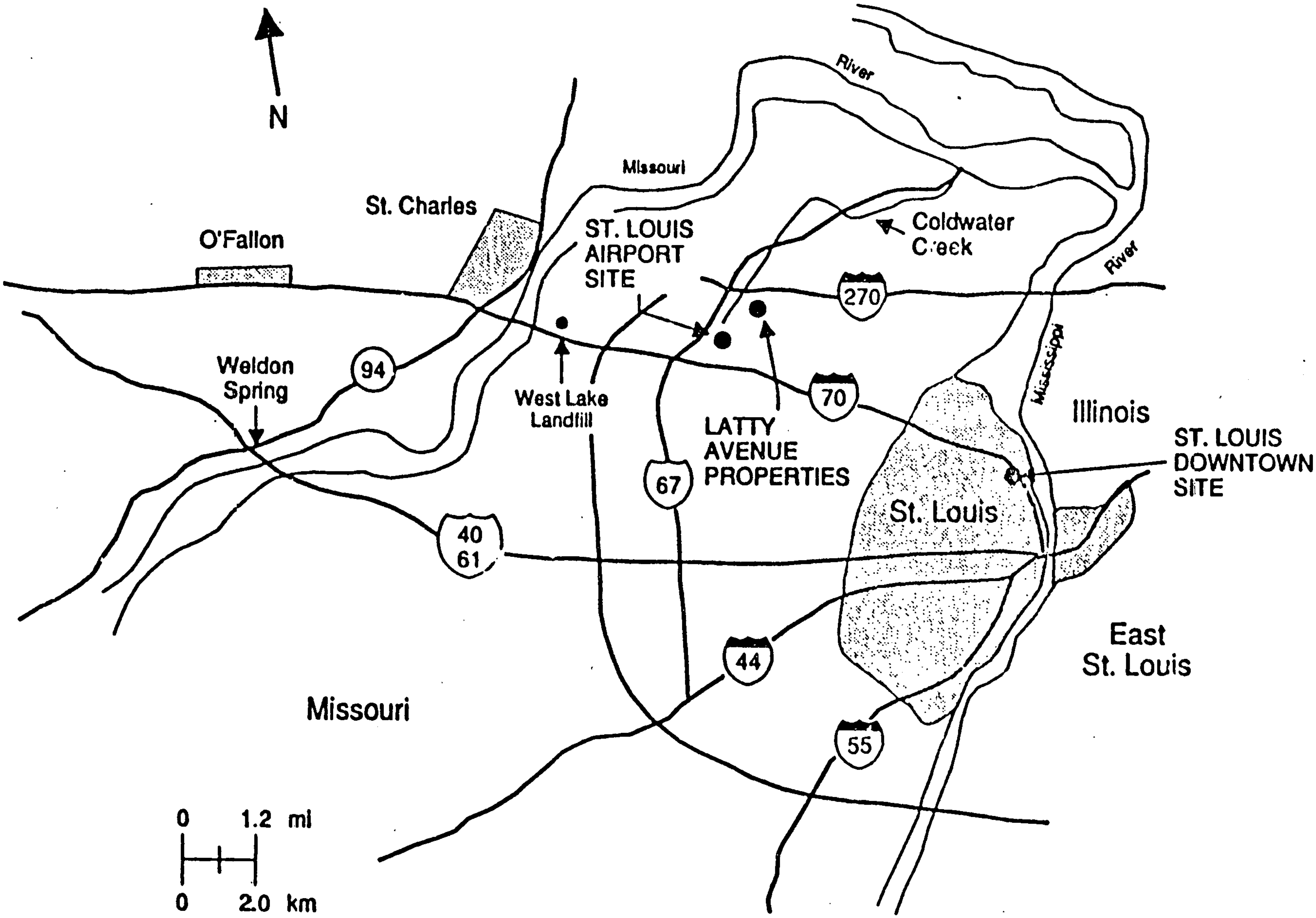

FIGURE 1 Location of the Three St. Louis FUSRAP Sites (Source: Modified from U.S. Dept. Energy 1981)

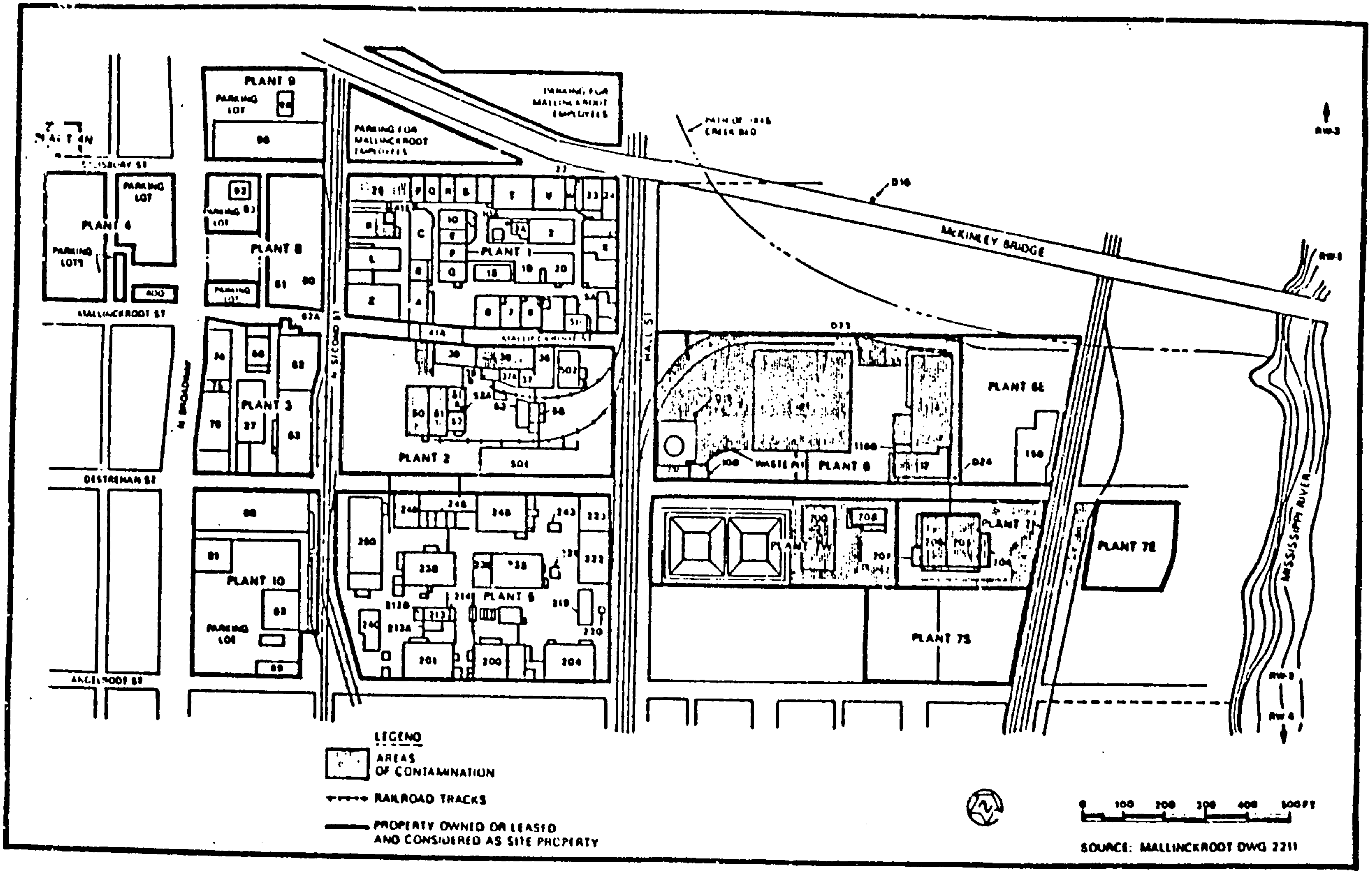

FIGURE 2 Layout of the St. Louis Downtown Site (Source: Bechtel Natl. 1986a)

St. Louis Downtown Site is currently estimated to be 93,200 m^3 (124,000 yd^3) (Liedle 1988). Current plans for remedial action involve decontamination of the site and transportation of all contaminated materials to a permanent disposal site.

1.2 ST. LOUIS AIRPORT SITE

The St. Louis Airport Site is located directly north of Lambert-St. Louis International Airport; it is currently owned by the city of St. Louis and controlled by the St. Louis Airport Authority. The layout of the site, which covers 8.7 ha (21.7 acres), is shown in Figure 3. In 1946, the MED used the site primarily for the storage of radioactive residues. The stored wastes included Belgian Congo pitchblende raffinate residues, radium-bearing residues, Colorado raffinate residues, and leached and unleached barium sulfate cake (U.S. Dept. Energy 1981). Responsibility for operation of the site was maintained by the MED, and subsequently by the AEC, until it was transferred to Mallinckrodt Chemical Works in 1953 (Argonne Natl. Lab. 1983).

The Airport Site is contaminated with natural uranium and its associated daughter products. Soil contamination levels at the site range from background to 900 pCi/g uranium-238 (U.S. Dept. Energy 1985). Since 1983, the site has been under consideration for development as a permanent disposal site. Proposed remedial activities at the site would involve consolidation of waste materials from the St. Louis Downtown Site and the Latty Avenue Properties as well as those from the Airport Site.

1.3 LATTY AVENUE PROPERTIES

The Latty Avenue Properties are located in the city of Hazelwood and consist of the property at 9200 Latty Avenue -- which includes the commercially developed Futura Coatings property and the undeveloped Hazelwood Interim Storage Site property — and vicinity properties adjacent to Latty Avenue and its extension (Figure 4). The 4.4-ha (11-acre) property at 9200 Latty Avenue is separated by a chain link fence into (1) the western Futura Coatings section (2.2 ha [5.5 acres]), which contains three building complexes, and (2) the eastern Hazelwood Interim Storage Site section (2.2 ha [5.5 acres]), which contains a vehicle decontamination facility and two surface storage piles of radioactive materials (Carter and McConnel 1987). The property at 9200 Latty Avenue is currently owned by Jarboe Realty and Investment Company and is leased to Futura Coatings, Inc., and DOE. Much of the Futura property is paved for parking and for delivery vehicle access to the building complexes.

Uranium-processing activities occurred at the St. Louis Downtown Site from 1942 through 1957 and generated ore residues and process wastes that were subsequently stored at the St. Louis Airport Site. In 1966, the Continental Mining and Milling Company of Chicago, Illinois, purchased these ore residues and process wastes from the AEC and transported them from the Airport Site to the Hazelwood Interim Storage Site at the Latty Avenue Properties. In January 1967, the Commercial Discount Corporation of Chicago assumed control of these materials and, by November 1970, most of the materials had been transported to other facilities. In 1973, the remaining Colorado raffinate material was shipped to Canon City, Colorado, without drying, and the leached

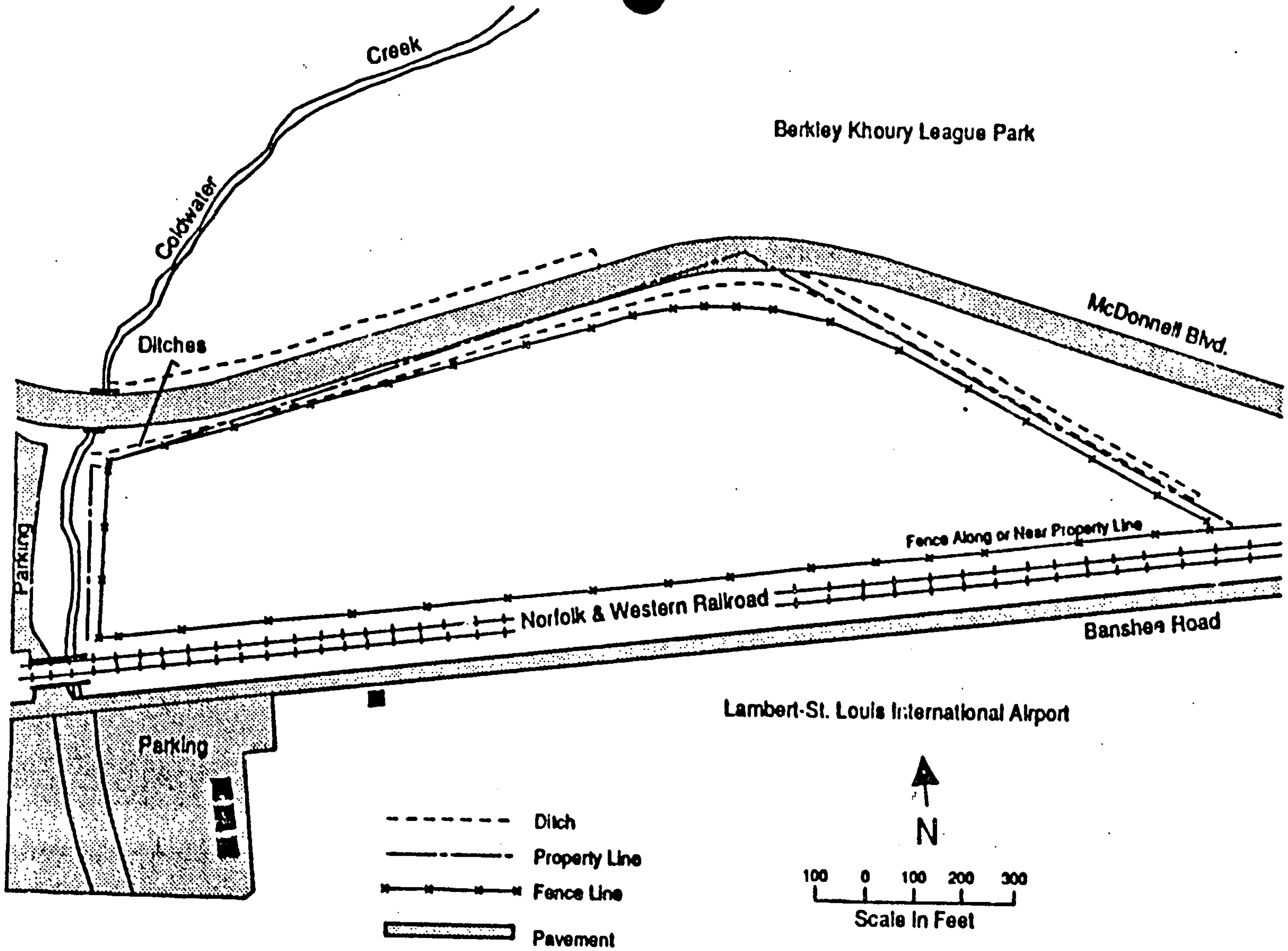

FIGURE 3 Layout of the St. Louis Airport Site (Source: Modified from U.S. Department of Energy 1982)

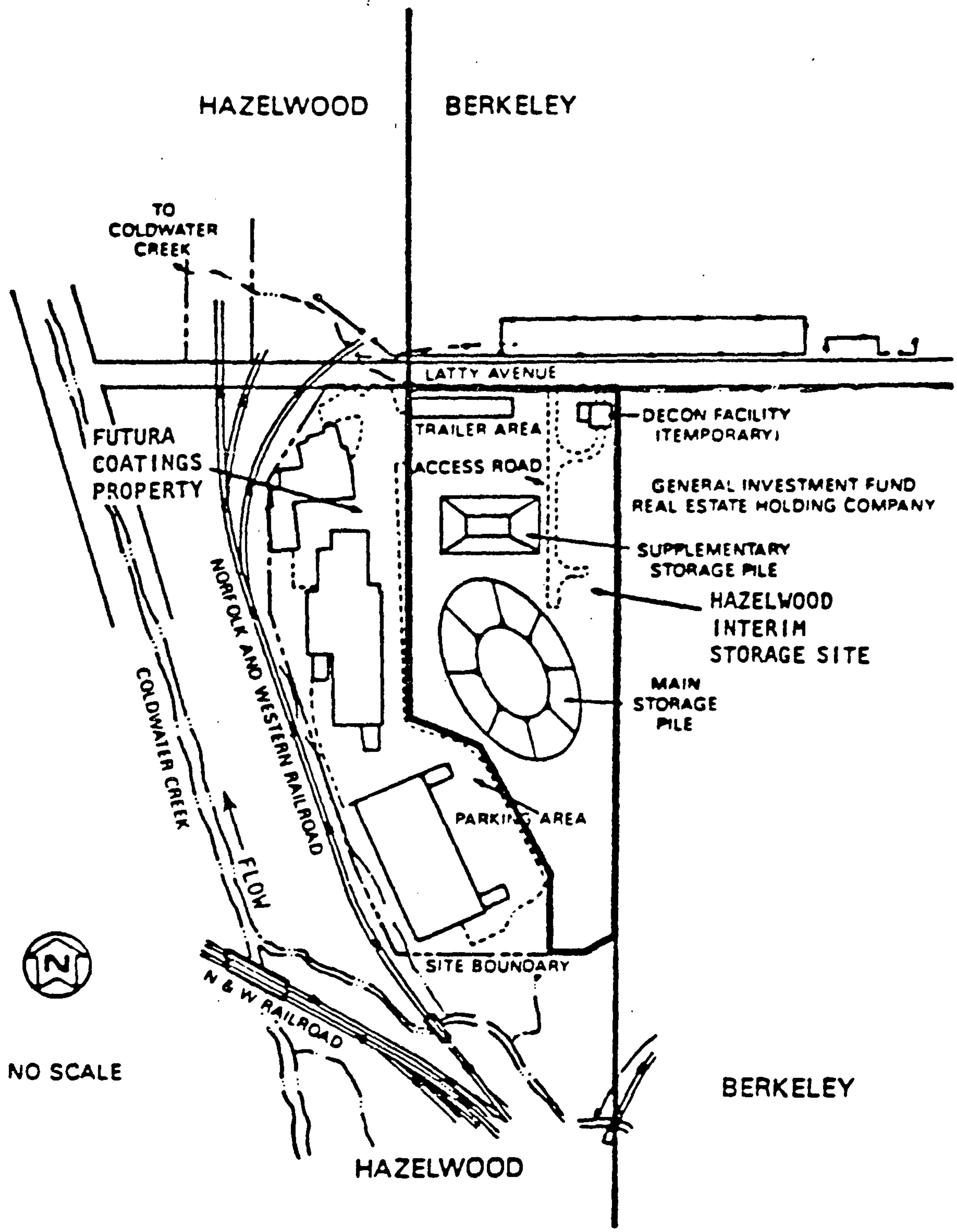

FIGURE 4 Layout of the Latty Avenue Site (Source: Modified from Noey et al. 1987)

barium sulfate cake was moved to the West Lake Landfill in St. Louis County, along with 30 to 46 cm (12 to 18 in.) of topsoil (Leggett et al. 1977; Ford, Bacon & Davis Utah 1978).

In 1976 and 1977, radiological investigations and decontamination activities were performed at the site (Leggett et al. 1977; Bechtel Natl. 1986b). Decontamination activities included demolition of one building, removal of flooring from two other buildings, and excavation of 0.5 m (1.6 ft) of surface soil from the Futura property. The radioactive material resulting from the Futura cleanup activities (about 10,000 m^3 [13,000 yd^3]) was placed on the Hazelwood Interim Storage Site where it remains to date (Cole et al. 1981a, 1981b; Bechtel Natl. 1986a; Noey et al. 1987).

Subsequent remedial activities undertaken during 1984 and 1985 resulted in an additional 11,076 m^3 (14,100 yd^3) of contaminated material. This material was also placed on the storage pile at the Hazelwood Interim Storage Site. In 1986, a radiological survey was performed to define the locations and boundaries of the contamination and to provide the data required to estimate the volume of contaminated material on the site (Noey et al. 1987). Measurements during this survey indicate that the contamination extends to a depth of 1.8 m (6 ft) below the ground surface at one location, with an average depth of 0.9 m (3 ft) at the Hazelwood site. Results of soil samples taken in the suspected areas of contamination contained uranium-238 concentrations at up to 800 pCi/g.

Cleanup of the Latty Avenue Properties (including the Hazelwood Interim Storage Site, the Futura Coatings property, and the vicinity properties) will generate an estimated 90,000 to 158,900 m^3 (119,600 to 211,000 yd^3) of contaminated materials.

1.4 DERIVATION OF CLEANUP GUIDELINES

Activities under way at the three FUSRAP St. Louis sites include reviewing radiological and chemical data and preparing for characterization at the Downtown Site, continuing radiological characterization activities at the Airport Site, and collecting samples to determine boundaries of radioactive contamination at the Latty Avenue vicinity properties. The purpose of this report is to derive the residual radioactive material guidelines for uranium (i.e., uranium-234, uranium-235, or uranium-238) that are applicable to remedial action at the St. Louis sites, i.e., the residual concentration of uranium in a homogeneously contaminated area that must not be exceeded if the sites are to be certified in compliance with guidelines. 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 guidelines for the St. Louis sites is based on a dose limit of 100 mrem/yr (Appendix A), assuming that uranium 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 for each of the three St. Louis sites. All scenarios assume that the contaminated areas will be certified in compliance with guidelines following decontamination. Potential doses are estimated for hypothetical uses of the site up to 1,000 years after cleanup.

Scenario A assumes industrial use of the site. A hypothetical person is assumed to work in the area of the site 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 worker's drinking water is taken from an adjacent 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.

Unlike Scenario A, Scenarios B and C assume a nonindustrial use of the site. In Scenarios B and C, a hypothetical person takes up residence in the immediate vicinity of the site, 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 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. Shallow well scenarios were not considered because of the poor quality of such water. 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 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 doses to the hypothetical future resident or worker for the three scenarios were calculated using the RESRAD computer code, based on the following specific assumptions:

- Scenario A

  - The worker spends 2,000 hours per year on-site (25% indoors and 75% outdoors).

- The walls, floor, and foundation of the industrial building reduce external exposure by 30%; the indoor dust level is 40% of the outdoor dust level (U.S. Dept. Energy 1988).

- The worker does not consume any meat, milk, fish, or vegetables from the site.

- An adjacent deep well provides 50% of the drinking water consumed by the worker.

- After remedial action, no cover material is placed above the decontaminated area.

- Scenario B

  - The resident spends 50% of his/her time indoors in the decontaminated area, 25% outdoors in the decontaminated area, and 25% away from the decontaminated area.

  - The walls, floor, and foundation of the house 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 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.

  - Vegetables are irrigated by, and livestock are provided with, water drawn from a deep well located adjacent to the decontaminated area.

  - The resident consumes no fish from the site.

  - An adjacent deep well provides 100% of the drinking water consumed by the resident.
  - After remedial action, no cover material is placed above the decontaminated area.

- Scenario C

  - The resident spends 50% of his/her time indoors in the decontaminated area, 25% outdoors in the decontaminated area, and 25% away from the decontaminated area.

- The walls, floor, and foundation of the house 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 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.

- Vegetables are irrigated by, and livestock are provided with, water drawn from a pond located adjacent to the decontaminated area.

- An adjacent pond provides 50% of the fish consumed by the resident.

- An adjacent pond provides 100% of the drinking water consumed by the resident.

- After remedial action, no cover material is placed above the decontaminated area.

All pathways considered for Scenarios A, B, and C are summarized in Table 1. All three scenarios were used for each of the three St. Louis sites.

TABLE 1 Summary of Exposure Pathways at the St. Louis Sites

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

[a]Source 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.

3 DOSE/SOURCE CONCENTRATION RATIOS

The dose/source concentration ratio $DSR_{ip}(t)$ for uranium 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 Appendix B. The calculated maximum dose/source concentration ratios for all pathways are presented in Tables 2 through 10. The calculated maximum dose/source concentration ratios are the same for each scenario for all three sites within 1,000 years. These maximum ratios would occur at time 0 (immediately after decontamination) in all three scenarios at all three sites.

The maximum dose/source concentration ratios for Scenario A would occur at time 0 and would be the same for all three sites. In Scenario A (industrial use of the site), only the inhalation and external exposure pathways would contribute to dose to the the hypothetical individual at time 0. The water ingestion pathway would not contribute because it would take at least 1,000 years for the contaminants to reach the deep groundwater table.

In Scenario B (residential use with water from a deep well), the maximum dose/source concentration ratios would also occur at time 0 at all three sites. The two primary pathways contributing to the dose to the hypothetical individual would be inhalation and ingestion of plant foods. Three other pathways -- external radiation, ingestion of meat, and ingestion of milk -- would contribute about 10% of the dose. As in Scenario A, the water ingestion pathway would not contribute to the dose in Scenario B because the contaminants would not reach the deep groundwater table within 1,000 years.

In Scenario C (residential use with water from a pond), the maximum dose/source concentration ratios would also occur at time 0 at all three sites. As in Scenario B, the two primary pathways, inhalation and ingestion of plant foods, would contribute almost 90% of the dose to a hypothetical individual in Scenario C for all three sites. At the Downtown Site, the contaminants would not reach the groundwater table and the pond within 1,000 years. However, the contaminants would initially reach the pond within the first year at the Airport Site and within 300 years at the Latty Avenue Properties. Although the largest dose/source concentration ratios for the ingestion of pond water would occur at about 500 years for both the Airport Site and the Latty Avenue Properties, these values are still less than the dose/source concentration ratios occurring at time 0 for the inhalation and ingestion of plant foods pathways.

The summation of $DSR_{ip}(t)$ for all pathways p is the $DSR_i(t)$ for the i^{th} isotope, i.e.,

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

TABLE 2 Maximum Dose/Source Concentration Ratios for Scenario A at the St. Louis Downtown Site

Pathway	Maximum Dose/Source Concentration Ratio,[a] (mrem/yr)/(pCi/g)		
	Uranium-234	Uranium-235	Uranium-238
1, External exposure	2.4×10^{-4}	1.8×10^{-1}	2.5×10^{-2}
2, Inhalation	4.1×10^{-2}	3.8×10^{-2}	3.7×10^{-2}
3, Ingestion of plant foods	NC[b]	NC	NC
4, Ingestion of meat	NC	NC	NC
5, Ingestion of milk	NC	NC	NC
6, Ingestion of fish	NC	NC	NC
7, Ingestion of water	Negl.[b]	Negl.	Negl.

[a]The maximum dose/source concentration ratio would occur at time 0. All values reported to two significant figures.

[b]NC = pathway not considered; negl. = contribution $<1 \times 10^{-10}$.

TABLE 3 Maximum Dose/Source Concentration Ratios for Scenario B at the St. Louis Downtown Site

Pathway	Maximum Dose/Source Concentration Ratio,[a] (mrem/yr)/(pCi/g)		
	Uranium-234	Uranium-235	Uranium-238
1, External exposure	6.8×10^{-4}	5.1×10^{-1}	7.2×10^{-2}
2, Inhalation	1.1×10^{-1}	1.0×10^{-1}	9.7×10^{-2}
3, Ingestion of plant foods	6.2×10^{-2}	5.8×10^{-2}	5.6×10^{-2}
4, Ingestion of meat	1.5×10^{-2}	1.4×10^{-2}	1.4×10^{-2}
5, Ingestion of milk	2.2×10^{-3}	2.0×10^{-3}	2.0×10^{-3}
6, Ingestion of fish	NC[b]	NC	NC
7, Ingestion of water	Negl.[b]	Negl.	Negl.

[a]The maximum dose/source concentration ratio would occur at time 0. All values reported to two significant figures.

[b]NC = pathway not considered; negl. = contribution $<1 \times 10^{-10}$.

TABLE 4 Maximum Dose/Source Concentration Ratios for Scenario C at the St. Louis Downtown Site

Pathway	Maximum Dose/Source Concentration Ratio,[a] (mrem/yr)/(pCi/g)		
	Uranium-234	Uranium-235	Uranium-238
1, External exposure	6.8×10^{-4}	5.1×10^{-1}	7.2×10^{-2}
2, Inhalation	1.1×10^{-1}	1.0×10^{-1}	9.7×10^{-2}
3, Ingestion of plant foods	6.2×10^{-2}	5.8×10^{-2}	5.6×10^{-2}
4, Ingestion of meat	1.5×10^{-2}	1.4×10^{-2}	1.4×10^{-2}
5, Ingestion of milk	2.2×10^{-3}	2.0×10^{-3}	2.0×10^{-3}
6, Ingestion of fish	Negl.[b]	Negl.	Negl.
7, Ingestion of water	Negl.	Negl.	Negl.

[a]The maximum dose/source concentration ratio would occur at time 0. All values reported to two significant figures.

[b]Negl. = contribution $<1 \times 10^{-10}$.

TABLE 5 Maximum Dose/Source Concentration Ratios for Scenario A at the St. Louis Airport Site

Pathway	Maximum Dose/Source Concentration Ratio,[a] (mrem/yr)/(pCi/g)		
	Uranium-234	Uranium-235	Uranium-238
1, External exposure	2.4×10^{-4}	1.8×10^{-1}	2.5×10^{-2}
2, Inhalation	4.2×10^{-2}	3.9×10^{-2}	3.7×10^{-2}
3, Ingestion of plant foods	NC[b]	NC	NC
4, Ingestion of meat	NC	NC	NC
5, Ingestion of milk	NC	NC	NC
6, Ingestion of fish	NC	NC	NC
7, Ingestion of water	Negl.[b]	Negl.	Negl.

[a]The maximum dose/source concentration ratio would occur at time 0. All values reported to two significant figures.

[b]NC = pathway not considered; negl. = contribution $<1 \times 10^{-10}$.

TABLE 6 Maximum Dose/Source Concentration Ratios for Scenario B at the St. Louis Airport Site

Pathway	Maximum Dose/Source Concentration Ratio,[a] (mrem/yr)/(pCi/g)		
	Uranium-234	Uranium-235	Uranium-238
1, External exposure	6.8×10^{-4}	5.1×10^{-1}	7.2×10^{-2}
2, Inhalation	1.1×10^{-1}	1.0×10^{-1}	9.8×10^{-2}
3, Ingestion of plant foods	6.2×10^{-2}	5.8×10^{-2}	5.6×10^{-2}
4, Ingestion of meat	1.5×10^{-2}	1.4×10^{-2}	1.4×10^{-2}
5, Ingestion of milk	2.2×10^{-3}	2.0×10^{-3}	2.0×10^{-3}
6, Ingestion of fish	NC[b]	NC	NC
7, Ingestion of water	Negl.[b]	Negl.	Negl.

[a]The maximum dose/source concentration ratio would occur at time 0. All values reported to two significant figures.

[b]NC = pathway not considered; negl. = contribution $<1 \times 10^{-10}$.

TABLE 7 Maximum Dose/Source Concentration Ratios for Scenario C at the St. Louis Airport Site

Pathway	Maximum Dose/Source Concentration Ratio,[a] (mrem/yr)/(pCi/g)		
	Uranium-234	Uranium-235	Uranium-238
1, External exposure	6.8×10^{-4}	5.1×10^{-1}	7.2×10^{-2}
2, Inhalation	1.1×10^{-1}	1.0×10^{-1}	9.8×10^{-2}
3, Ingestion of plant foods	6.1×10^{-2}	5.8×10^{-2}	5.6×10^{-2}
4, Ingestion of meat	1.5×10^{-2}	1.4×10^{-2}	1.4×10^{-2}
5, Ingestion of milk	2.2×10^{-3}	2.0×10^{-3}	2.0×10^{-3}
6, Ingestion of fish	Negl.[b]	Negl.	Negl.
7, Ingestion of water	Negl.	Negl.	Negl.

[a]The maximum dose/source concentration ratio would occur at time 0. All values reported to two significant figures.

[b]Negl. = contribution $<1 \times 10^{-10}$.

TABLE 8 Maximum Dose/Source Concentration Ratios for Scenario A at the Hazelwood Interim Storage Site on the Latty Avenue Properties

Pathway	Maximum Dose/Source Concentration Ratio,[a] (mrem/yr)/(pCi/g)		
	Uranium-234	Uranium-235	Uranium-238
1, External exposure	2.4×10^{-4}	1.8×10^{-1}	2.5×10^{-2}
2, Inhalation	4.2×10^{-2}	3.9×10^{-2}	3.7×10^{-2}
3, Ingestion of plant foods	NC[b]	NC	NC
4, Ingestion of meat	NC	NC	NC
5, Ingestion of milk	NC	NC	NC
6, Ingestion of fish	NC	NC	NC
7, Ingestion of water	Negl.[b]	Negl.	Negl.

[a]The maximum dose/source concentration ratio would occur at time 0. All values reported to two significant figures.

[b]NC = pathway not considered; negl. = contribution $<1 \times 10^{-10}$.

TABLE 9 Maximum Dose/Source Concentration Ratios for Scenario B at the Hazelwood Interim Storage Site on the Latty Avenue Properties

Pathway	Maximum Dose/Source Concentration Ratio,[a] (mrem/yr)/(pCi/g)		
	Uranium-234	Uranium-235	Uranium-238
1, External exposure	6.8×10^{-4}	5.1×10^{-1}	7.2×10^{-2}
2, Inhalation	1.1×10^{-1}	1.0×10^{-1}	9.8×10^{-2}
3, Ingestion of plant foods	6.1×10^{-2}	5.7×10^{-2}	5.5×10^{-2}
4, Ingestion of meat	1.5×10^{-2}	1.4×10^{-2}	1.4×10^{-2}
5, Ingestion of milk	2.1×10^{-3}	2.0×10^{-3}	2.0×10^{-3}
6, Ingestion of fish	NC[b]	NC	NC
7, Ingestion of water	Negl.[b]	Negl.	Negl.

[a]The maximum dose/source concentration ratio would occur at time 0. All values reported to two significant figures.

[b]NC = pathway not considered; negl. = contribution $<1 \times 10^{-10}$.

TABLE 10 Maximum Dose/Source Concentration Ratios for Scenario C at the Hazelwood Interim Storage Site on the Latty Avenue Properties

Pathway	Maximum Dose/Source Concentration Ratio,[a] (mrem/yr)/(pCi/g)		
	Uranium-234	Uranium-235	Uranium-238
1, External exposure	6.8×10^{-4}	5.1×10^{-1}	7.2×10^{-2}
2, Inhalation	1.1×10^{-1}	1.0×10^{-1}	9.8×10^{-2}
3, Ingestion of plant foods	6.1×10^{-2}	5.7×10^{-2}	5.5×10^{-2}
4, Ingestion of meat	1.5×10^{-2}	1.4×10^{-2}	1.4×10^{-2}
5, Ingestion of milk	2.1×10^{-3}	2.0×10^{-3}	1.9×10^{-3}
6, Ingestion of fish	Negl.[b]	Negl.	Negl.
7, Ingestion of water	Negl.	Negl.	Negl.

[a]The maximum dose/source concentration ratio would occur at time 0. All values reported to two significant figures.

[b]Negl. = contribution $<1 \times 10^{-10}$.

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

$$\mathrm{DSR}(t) = \sum_i W_i \, \mathrm{DSR}_i(t)$$

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 Tables 11 through 13. These ratios were used to determine the allowable residual radioactivity for uranium at the St. Louis sites.

TABLE 11 Total Dose/Source Concentration Ratios for Uranium at the St. Louis Downtown Site

	Total Dose/Source Concentration Ratio,[a] (mrem/yr)/(pCi/g)		
Radionuclide	Scenario A	Scenario B	Scenario C
Uranium-234	0.042	0.19	0.19
Uranium-235	0.22	0.68	0.68
Uranium-238	0.062	0.24	0.24
Total uranium	0.056	0.23	0.23

[a]All values reported to two significant figures.

TABLE 12 Total Dose/Source Concentration Ratios for Uranium at the St. Louis Airport Site

	Total Dose/Source Concentration Ratio,[a] (mrem/yr)/(pCi/g)		
Radionuclide	Scenario A	Scenario B	Scenario C
Uranium-234	0.042	0.19	0.19
Uranium-235	0.22	0.68	0.68
Uranium-238	0.062	0.24	0.24
Total uranium	0.056	0.23	0.23

[a]All values reported to two significant figures.

TABLE 13 Total Dose/Source Concentration Ratios for Uranium at the Hazelwood Interim Storage Site on the Latty Avenue Properties

	Total Dose/Source Concentration Ratio,[a] (mrem/yr)/(pCi/g)		
Radionuclide	Scenario A	Scenario B	Scenario C
Uranium-234	0.042	0.19	0.19
Uranium-235	0.22	0.68	0.68
Uranium-238	0.062	0.24	0.24
Total uranium	0.056	0.23	0.23

[a]All values reported to two significant figures.

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 use of that area without restrictions. Using the annual radiation dose limit of 100 mrem/yr (Appendix A), the residual radioactive material guideline, G, for uranium at the St. Louis sites may be calculated as

$$G = 100/DSR$$

where DSR is the total dose/source concentration ratio listed in Tables 11 through 13.

The calculated residual radioactive material guidelines for both single radionuclides (uranium-234, uranium-235, and uranium-238) and total uranium are presented in Tables 14 through 16. The total uranium guidelines (reported to two significant figures) were calculated assuming 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 uranium using total uranium or uranium-238 as the indicator radionuclide are presented in Table 17.

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 m^2 and a depth of 15 cm and divided by its guideline G_i, should not be greater than unity — i.e.,

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

The derived guidelines listed in Tables 14 through 17 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.

TABLE 14 Residual Radioactive Material Guidelines for the St. Louis Downtown Site

	Guideline (pCi/g)[a]		
Radionuclide	Scenario A	Scenario B	Scenario C
Uranium-234	2,400	530	530
Uranium-235	460	150	150
Uranium-238	1,600	420	420
Total uranium	1,800	430	430

[a]All values reported to two significant figures.

TABLE 15 Residual Radioactive Material Guidelines for the St. Louis Airport Site

	Guideline (pCi/g)[a]		
Radionuclide	Scenario A	Scenario B	Scenario C
Uranium-234	2,400	530	530
Uranium-235	460	150	150
Uranium-238	1,600	420	420
Total uranium	1,800	430	430

[a]All values reported to two significant figures.

TABLE 16 Residual Radioactive Material Guidelines for the Hazelwood Interim Storage Site on the Latty Avenue Properties

	Guideline (pCi/g)[a]		
Radionuclide	Scenario A	Scenario B	Scenario C
Uranium-234	2,400	530	530
Uranium-235	460	150	150
Uranium-238	1,600	420	420
Total uranium	1,800	430	430

[a]All values reported to two significant figures.

TABLE 17 Summary of Soil Concentration Guidelines for Uranium at the St. Louis Sites

	Soil Concentration of Uranium (pCi/g) Using Total Uranium as the Indicator[a]		
Site	Scenario A	Scenario B	Scenario C
St. Louis Downtown Site	1,800	430	430
St. Louis Airport Site	1,800	430	430
Latty Avenue Properties	1,800	430	430

	Soil Concentration of Uranium (pCi/g) Using Uranium-238 as the Indicator[a]		
Site	Scenario A	Scenario B	Scenario C
St. Louis Downtown Site	880	210	210
St. Louis Airport Site	880	210	210
Latty Avenue Properties	880	210	210

[a]All values reported to two significant figures.

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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 m^2. 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 m^2 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.

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*A working level (WL) is any combination of short-lived radon decay products in o[illegible] liter of air that will result in the ultimate emission of 1.3 [illegible] V 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 μR/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

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*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 m^2. 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 cm^2.

[f] The amount of removable radioactive material per 100 cm^2 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 cm^2 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

[illegible]20.2, 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 $pCi/m^2/s$ 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

Limit or Guideline	Source
Basic Dose Limits	
Dosimetry model and dose limits	International Commission on Radiological Protection (1977, 1978)
Generic Guidelines for Residual Radioactivity	
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)
Control of Radioactive Wastes and Residues	
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. 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 ANALYSIS OF THE ST. LOUIS SITES

The parameter values used in the RESRAD code for the analysis of the St. Louis sites are listed in Tables B.1, B.2, and B.3. All parameter values are reported at up to two significant figures.

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

		Value		
Parameter	Unit	Scenario A	Scenario B	Scenario C
Area of contaminated zone	m^2	22,000	22,000	22,000
Cover depth	m	0	0	0
Thickness of contaminated zone	m	2.4	2.4	2.4
Length parallel to aquifer flow	m	850	850	850
Erosion rate	m/yr	0	0	0
Density of contaminated zone	g/cm^3	2.0	2.0	2.0
Density of saturated zone	g/cm^3	2.4	2.4	2.4
Well pump intake depth	m	10	10	10
Effective saturated zone porosity	–[a]	0.15	0.15	0.15
Contaminated zone porosity	–[a]	0.4	0.4	0.4
Evapotranspiration coefficient	–[a]	0.89	0.89	0.89
Hydraulic conductivity, saturated zone	m/yr	150	150	150
Hydraulic gradient at water table	–[a]	0.01	0.01	0.01
Precipitation	m/yr	0.94	0.94	0.94
Irrigation	m/yr	0.0	0.2	0.2
Irrigation mode[b]	–[a]	–[c]	0 (overhd)	1 (ditch)
Runoff coefficient	–[a]	0.2	0.2	0.2
Watershed area for nearby pond	m^2	1.0×10^6	1.0×10^6	1.0×10^6
Crossover area (for model selection)	m^2	1,000	1,000	1,000
Distance from surface to water table	m	11.6	11.6	11.6
Individual's use of groundwater	m^3/yr	150	150	150
Soil density, unsaturated zone	g/cm^3	2.1	2.1	2.1
Hydraulic conductivity, unsaturated zone[d]	m/yr	0.105	0.105	0.105

TABLE B.1 (Cont'd)

Parameter	Unit	Value: Scenario A	Scenario B	Scenario C
Thickness, unsaturated zone	m	9.2	9.2	9.2
Effective porosity, unsaturated zone	–[a]	0.15	0.15	0.15
Distribution coefficient	cm^3/g			
Contaminated zone				
Uranium-234		150	150	150
Uranium-235		150	150	150
Uranium-238		150	150	150
Unsaturated zone				
Uranium-234		150	150	150
Uranium-235		150	150	150
Uranium-238		150	150	150
Saturated zone				
Uranium-234		150	150	150
Uranium-235		150	150	150
Uranium-238		150	150	150
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)	–[a]	0.21	0.6	0.6
Occupancy factor (inhalation)	–[a]	0.19	0.5	0.5
Shape factor (external gamma)	–[a]	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	5.4	5.4	5.4
Other aquatic foods consumption	kg/yr	0.0	0.0	0.0
Drinking water intake	L/yr	410	410	410
Fraction of drinking water from site	–[a]	0.5	1.0	1.0
Fraction of aquatic foods from site	–[a]	0	0	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)	–[a]			
Drinking water		1	1	0
Livestock water		1	1	0
Irrigation		1	1	0

[a]Parameter is dimensionless.

[b]The abbreviation overhd = overhead.

[c]Parameter not required for this scenario.

[d]In estimating the radionuclide transport time through the unsaturated stratum, the unsaturated hydraulic conductivity is assumed to be the same as the infiltration rate.

TABLE B.2 Parameters Used in the RESRAD Code for the Airport Site Analysis

Parameter	Unit	Value: Scenario A	Value: Scenario B	Value: Scenario C
Area of contaminated zone	m^2	87,000	87,000	87,000
Cover depth	m	0	0	0
Thickness of contaminated zone	m	2.1	2.1	2.1
Length parallel to aquifer flow	m	400	400	400
Erosion rate	m/yr	0	0	0
Density of contaminated zone	g/cm^3	2.0	2.0	2.0
Density of saturated zone	g/cm^3	2.0	2.0	2.0
Well pump intake depth	m	2.7	2.7	2.7
Effective saturated zone porosity	–[b]	0.2	0.2	0.2
Contaminated zone porosity	–[b]	0.2	0.2	0.2
Evapotranspiration coefficient	–[b]	0.89	0.89	0.89
Hydraulic conductivity, saturated zone	m/yr	0.34	0.34	0.34
Hydraulic gradient at water table	–[b]	0.0059	0.0059	0.0087
Precipitation	m/yr	0.94	0.94	0.94
Irrigation	m/yr	0.0	0.2	0.2
Irrigation mode[c]	–[b]	–[a]	0 (overhd)	1 (ditch)
Runoff coefficient	–[b]	0.2	0.2	0.2
Watershed area for nearby pond	m^2	3.1×10^7	3.1×10^7	3.1×10^7
Crossover area (for model selection)	m^2	1,000	1,000	1,000
Distance from surface to water table	m	14.7	14.7	2.1
Individual's use of groundwater	m^3/yr	150	150	150
Soil density, unsaturated zone	g/cm^3			
Zone 1		1.5	1.5	–[a]
Zone 2		1.5	1.5	–[a]
Zone 3		1.3	1.3	–[a]
Hydraulic conductivity, unsaturated zone[d]	m/yr			
Zone 1		0.105	0.105	–[a]
Zone 2		0.105	0.105	–[a]
Zone 3		0.105	0.105	–[a]
Thickness, unsaturated zone	m			
Zone 1		2.1	2.1	0
Zone		7.4	7.4	0
Zone		3.1	3.1	0

TABLE B.2 (Cont'd)

Parameter	Unit	Value: Scenario A	Value: Scenario B	Value: Scenario C
Effective porosity, unsaturated zone	–[b]			
Zone 1		0.2	0.2	–[a]
Zone 2		0.2	0.2	–[a]
Zone 3		0.2	0.2	–[a]
Distribution coefficient	cm^3/g			
Contaminated zone				
Uranium-234		9.5	9.5	9.5
Uranium-235		9.5	9.5	9.5
Uranium-238		9.5	9.5	9.5
Unsaturated zone				
Uranium-234		9.5	9.5	–[a]
Uranium-235		9.5	9.5	–[a]
Uranium-238		9.5	9.5	–[a]
Saturated zone				
Uranium-234		9.5	9.5	9.5
Uranium-235		9.5	9.5	9.5
Uranium-238		9.5	9.5	9.5
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	5.4	5.4	5.4
Other aquatic foods consumption	kg/yr	0.0	0.0	0.0
Drinking water intake	L/yr	410	410	410
Fraction of drinking water from site	–[b]	0.5	1	1
Fraction of aquatic foods from site	–[b]	0	0	0.5

TABLE B.3 Parameters Used in the RESRAD Code for the Latty Avenue Analysis

Parameter	Unit	Value		
		Scenario A	Scenario B	Scenario C
Area of contaminated zone	m^2	61,000	61,000	61,000
Cover depth	m	0	0	0
Thickness of contaminated zone	m	0.9	0.9	0.9
Length parallel to aquifer flow	m	200	200	200
Erosion rate	m/yr	0	0	0
Density of contaminated zone	g/cm^3	2.0	2.0	2.0
Density of saturated zone	g/cm^3	2.0	2.0	2.0
Well pump intake depth	m	10	10	10
Effective saturated zone porosity	-[b]	0.2	0.2	0.2
Contaminated zone porosity	-[b]	0.15	0.15	0.15
Evapotranspiration coefficient	-[b]	0.89	0.89	0.89
Hydraulic conductivity, saturated zone	m/yr	315	315	47.3
Hydraulic gradient at water table	-[b]	0.017	0.017	0.017
Precipitation	m/yr	0.94	0.94	0.94
Irrigation	m/yr	0.0	0.2	0.2
Irrigation mode[c]	-[b]	-[a]	0 (overhd)	1 (ditch)
Runoff coefficient	-[b]	0.2	0.2	0.2
Watershed area for nearby pond	m^2	1.0×10^6	1.0×10^6	1.0×10^6
Crossover area (for model selection)	m^2	1,000	1,000	1,000
Distance from surface to water table	m	18.3	18.3	2.1
Individual's use of groundwater	m^3/yr	150	150	150
Soil density, unsaturated zone	g/cm^3	2	2	2
Hydraulic conductivity, unsaturated zoned[d]	m/yr	0.105	0.105	0.105
Thickness, unsaturated zone	m	17.4	17.4	1.2
Effective porosity, unsaturated zone	-[b]	0.2	0.2	0.2
Distribution coefficient	cm^3/g			
Contaminated zone				
Uranium-234		9.5	9.5	9.5
Uranium-235		9.5	9.5	9.5
Uranium-238		9.5	9.5	9.5

TABLE B.3 (Cont'd)

Parameter	Unit	Value Scenario A	Scenario B	Scenario C
Distribution coefficient (cont'd)				
Unsaturated zone				
Uranium-234		9.5	9.5	9.5
Uranium-235		9.5	9.5	9.5
Uranium-238		9.5	9.5	9.5
Saturated zone				
Uranium-234		9.5	9.5	9.5
Uranium-235		9.5	9.5	9.5
Uranium-238		9.5	9.5	9.5
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	5.4	5.4	5.4
Other aquatic foods consumption	kg/yr	0.0	0.0	0.0
Drinking water intake	L/yr	410	410	410
Fraction of drinking water from site	-[b]	0.5	1	1
Fraction of aquatic foods from site	-[b]	0	0	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
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

TABLE B.3 (Cont'd)

Parameter	Unit	Value		
		Scenario A	Scenario B	Scenario C
Groundwater fractional usage (balance from surface water)	-[b]			
Drinking water		1	1	0
Livestock water		1	1	0
Irrigation		1	1	0

[a]Parameter not required for this scenario.

[b]Parameter is dimensionless.

[c]The abbreviation overhd = overhead.

[d]In estimating the radionuclide transport time through the unsaturated stratum, the unsaturated hydraulic conductivity is assumed to be the same as the infiltration rate.

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9808191007	Initial Screening of Alternatives Report for the St. Louis Site See 9810231003	USDOE/SAIC		Vol. 3d	10/92
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