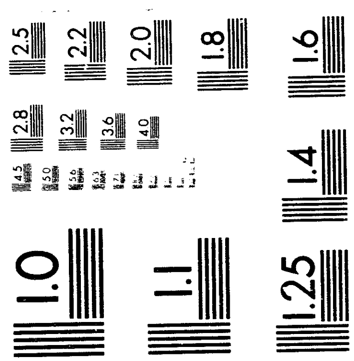
2.5
2.2
2.0
1.8
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2.8
3.2
3.6
4.0
1.4
1.0
1.1
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ANL/EAD/TM-9

Derivation of Uranium Residual Radioactive Material Guidelines for the Former Alba Craft Laboratory Site, Oxford, Ohio

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MASTER

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NOTATION

The following is a list of the acronyms, initialisms, and abbreviations (including units of measure) used in this document. Some acronyms used in tables or equations only are defined in the respective tables or equations.

ACRONYMS, INITIALISMS, AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
ALARA	as low as reasonably achievable
DOE	U.S. Department of Energy
FUSRAP	Formerly Utilized Sites Remedial Action Program
MED	Manhattan Engineer District
NLO	National Lead of Ohio
ORNL	Oak Ridge National Laboratory
RESRAD	*res*idual *rad*ioactive material guideline computer code

UNITS OF MEASURE

cm	centimeter(s)
cm^3	cubic centimeter(s)
d	day(s)
g	gram(s)
h	hour(s)
kg	kilogram(s)
L	liter(s)
m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
mrem	millirem(s)
pCi	picocurie(s)
s	second(s)
yr	year(s)

DERIVATION OF URANIUM RESIDUAL RADIOACTIVE MATERIAL GUIDELINES FOR THE FORMER ALBA CRAFT LABORATORY SITE, OXFORD, OHIO

by

M. Nimmagadda, E. Faillace, and C. Yu

SUMMARY

Residual radioactive material guidelines for uranium were derived for the former Alba Craft Laboratory site in Oxford, Ohio. This site has been identified for remedial action under the Formerly Utilized Sites Remedial Action Program (FUSRAP) of the U.S. Department of Energy (DOE). Single nuclide and total uranium guidelines were derived on the basis of the requirement that the 50-year committed effective dose equivalent to a hypothetical individual who lives or works in the immediate vicinity of the former Alba Craft Laboratory site should not exceed a dose of 30 mrem/yr following remedial action for the current use and likely future use scenarios or a dose of 100 mrem/yr for less likely future use scenarios (Yu et al. 1993). 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 are considered in which it is assumed that, for a period of 1,000 years following remedial action, the site will be used without radiological restrictions. The three scenarios vary with regard to the type of site use, time spent at the site, and sources of food consumed. The results of the evaluation indicate that the basic dose constraint of 30 mrem/yr will not be exceeded for uranium (including uranium-234, uranium-235, and uranium-238) within 1,000 years, provided that the soil concentration of total combined uranium (uranium-234, uranium-235, and uranium-238) at the former Alba Craft Laboratory site does not exceed the following levels: 770 pCi/g for Scenario A (industrial worker: current use scenario) and 280 pCi/g for Scenario B (resident: municipal water supply, a likely future use scenario). The basic dose limit of 100 mrem/yr will not be exceeded at the site if the total uranium concentration does not exceed the level of 310 pCi/g for Scenario C (resident: on-site well water, a plausible but unlikely future use scenario).

The uranium guidelines derived in this analysis apply to the total activity concentration of uranium isotopes, i.e., uranium-238, uranium-234, and uranium-235 present in their natural activity concentration ratio of 1:1:0.046. Consequently, if uranium-238 were measured as the indicator radionuclide, the respective limits for Scenarios A, B, and C would be 380, 140, and 150 pCi/g, respectively. These guidelines were calculated on the basis of a dose of 30 mrem/yr for Scenarios A and B and a dose of 100 mrem/yr for Scenario C (Yu et al. 1993). In setting the actual uranium guidelines for the former Alba Craft Laboratory site,

DOE will apply the as low as reasonably achievable (ALARA) policy to the decision-making process, along with other factors such as whether a particular scenario is reasonable and appropriate.

1 INTRODUCTION AND BRIEF HISTORY

The former Alba Craft Laboratory, Incorporated, is located in Oxford, Ohio (Figure 1). The site has been designated by the U.S. Department of Energy (DOE) as a candidate for remedial action under its Formerly Utilized Sites Remedial Action Program (FUSRAP). This designation was made after a preliminary inspection by Oak Ridge National Laboratory (ORNL) in June 1992 indicated that uranium contamination is present both inside and outside the Alba Craft building. FUSRAP was established in 1974 by the U.S. Atomic Energy Commission (AEC), a predecessor of DOE. The mandate of the program is to identify, evaluate, and, if necessary, decontaminate sites previously used by the AEC or its predecessor, the Manhattan Engineer District (MED).

Remedial action activities at the former Alba Craft Laboratory site will follow the guidelines established in DOE Order 5400.5 (DOE 1990). The DOE residual radioactive material computer code, RESRAD (Yu et al. 1993), is used to derive residual radionuclide guidelines on a site-specific basis. This report presents the uranium guidelines derived for the former Alba Craft Laboratory site on the basis of a dose constraint of 30 mrem/yr for the current use and likely future use scenarios and a dose limit of 100 mrem/yr for less likely but plausible future use scenarios (Yu et al. 1993). The dose constraint of 30 mrem/yr is not currently required under DOE Order 5400.5. However, DOE is proposing to reduce the existing limit of 100 mrem/yr on the basis of recommendations from the International Commission on Radiological Protection (1991).

1.1 SITE DESCRIPTION AND SETTING

The Alba Craft Laboratory site is occupied by a building that consists of three separate structures that have been joined to appear as one building. At the time of the ORNL radiological survey, the building was being used to support three independent businesses. The east wing contained a chemistry laboratory and supporting offices, the west wing was used to produce custom-embroidered products such as shirts and caps, and the north wing was leased to a contractor to store packaged foods (Murray et al. 1993). The building is surrounded on the east, north, and south sides by residential homes and apartments (Figure 2).

The town of Oxford is located in Butler County, Ohio. Hydrogeologic information for this area was obtained from Smith (1982). This information was used to characterize the contaminated zone, unsaturated zone, and saturated zone for the purpose of modeling contaminant transport in groundwater beneath the former Alba Craft Laboratory site because no boreholes have been drilled at the site. The topsoils and subsoils in the area typically extend to a depth of 2.4 m followed by layers of clay, sandy soil, sand and gravel, and blue clay. Interbedded limestones and shales of the Cincinnatian Series are present below a depth of 10 m and can extend to depths greater than 400 m. These limestones and shales form an effective aquitard, and wells in the area tap the groundwater in the sand and gravel layers

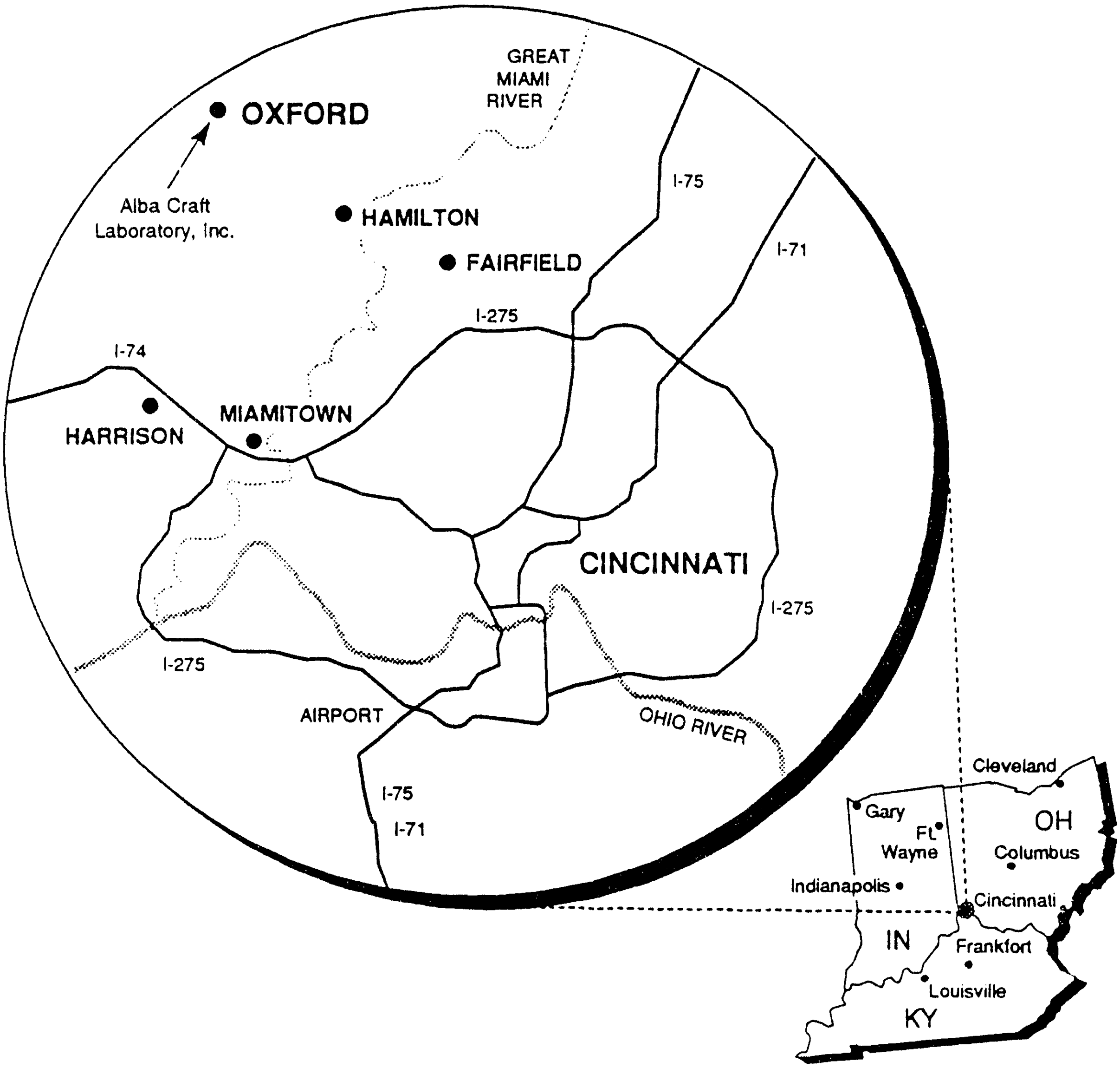

FIGURE 1 Location of the Former Alba Craft Laboratory Site, Oxford, Ohio (Source: Adapted from Murray et al. 1993)

located approximately 6 to 8 m below the surface (Smith 1982). The mean annual precipitation is about 103 cm. The average annual runoff is about 21% of the average precipitation, and evapotranspiration is approximately 57% of the average precipitation (Smith 1982).

1.2 SITE HISTORY

Alba Craft Laboratory, Incorporated, was a subcontractor to National Lead of Ohio (NLO) from approximately October 1952 to February 1957. Alba Craft provided a variety of machine shop services on normal uranium metal for NLO, a primary contractor for the AEC.

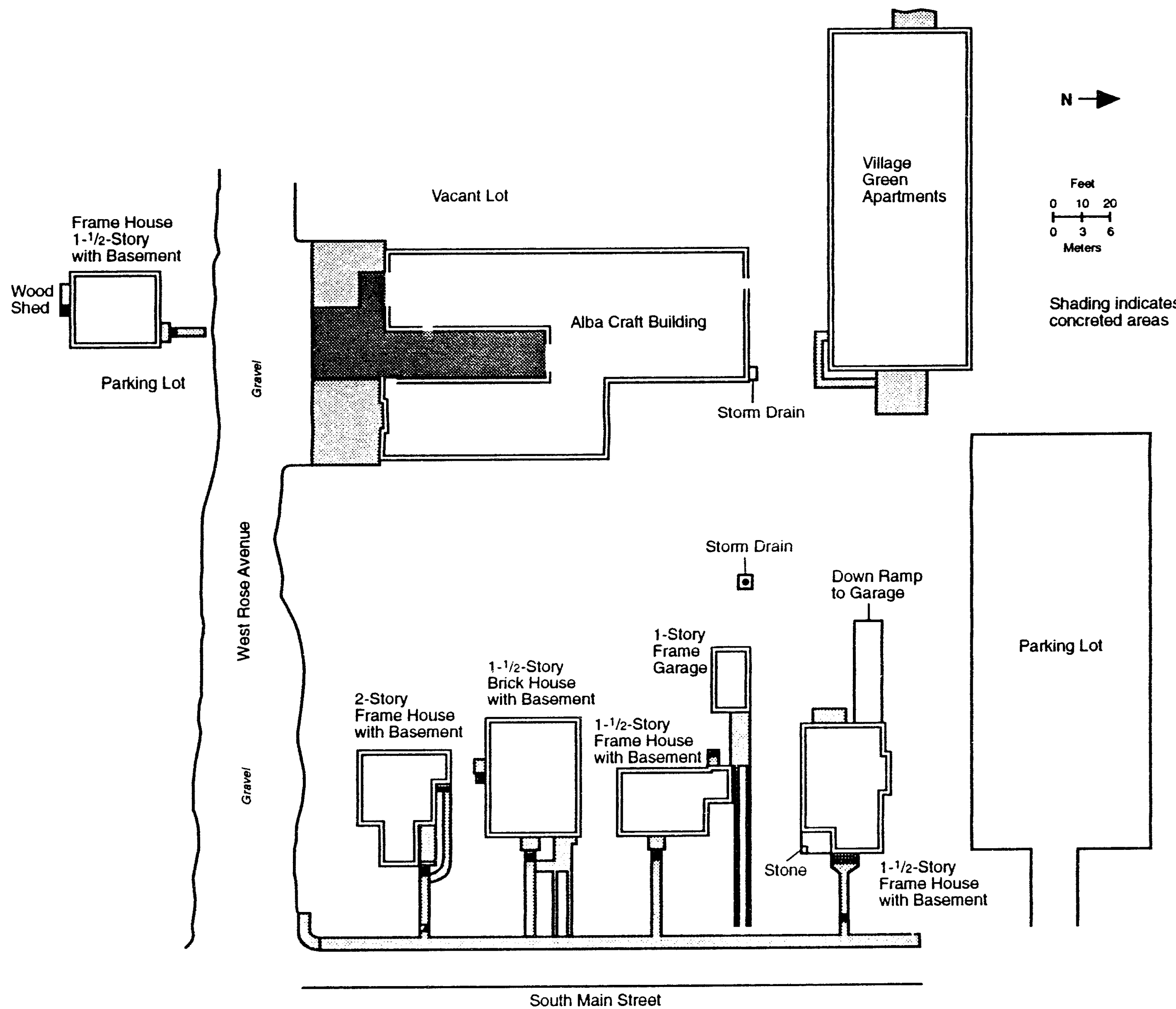

FIGURE 2 Map of the Former Alba Craft Laboratory Site (Source: Adapted from Murray et al. 1993)

Early work included general machining and developmental machining of threaded slugs for the Savannah River Site in Aiken, South Carolina. Final operations were on a large production scale and consisted of hollow drilling and turning slugs for reactors at the Savannah River Site and the Hanford Site in Richland, Washington. In 1954, the Alba Craft facilities were also used by NLO, which supplied its own operators and material for machining. The total quantity of uranium machined by Alba Craft is estimated at several hundred tons; the quantity machined by NLO during 1954 is unknown.

As a result of the activities performed at the site, equipment, buildings, and land at some of the adjacent vicinity properties became contaminated with low levels of radioactive material. At contract termination, sites used by contractors were decontaminated in accordance with the standards and survey methods in use at that time. Since the original assessments, more stringent radiological criteria and guidelines have been implemented for the release of such sites for unrestricted use.

The current owner bought and renovated the building and began using it to support various business enterprises. The east wing has been remodeled with stud walls, a drop ceiling, and carpet. Little remodeling was performed on the west and north wings. The outside area between the east and west wings has been newly concreted and is used to provide access for deliveries (darker shaded area in Figure 2).

Previous investigations were conducted to determine the extent of on-site radioactive contamination. As a follow-up to these investigations and as a precaution to ensure that residual radioactive material exceeding current DOE guidelines did not migrate off-site, DOE requested a radiological survey of the former laboratory and vicinity properties. A preliminary inspection in June 1992 indicated the presence of uranium contamination both inside and outside the former Alba Craft building.

In July and September 1992, a radiological survey was conducted at the former Alba Craft Laboratory building and vicinity properties. The results indicated that uranium contamination from former AEC-related activities still exists in and around the building in quantities exceeding current DOE guidelines (Murray et al. 1993). The contamination around the building extends onto some of the residential properties now located on the former Alba Craft site (Figure 2).

1.3 DERIVATION OF CLEANUP GUIDELINES

Although most DOE cleanup guidelines applicable to remedial actions at FUSRAP sites are generic in nature (DOE 1990), guidelines for uranium are derived on a site-specific basis. The purpose of this analysis was to derive the residual radioactive material guidelines for uranium (i.e., uranium-234, uranium-235, uranium-238, and total uranium) that are applicable to remedial action at the former Alba Craft Laboratory site. The derived guidelines represent the residual concentration of uranium in a homogeneously contaminated area that must not be exceeded if the site is to be released for use without radiological restrictions. The total uranium guideline is derived by assuming that uranium-238, uranium-234, and uranium-235 are present in their natural activity concentration ratio of 1:1:0.046.

Site-specific uranium guidelines for the former Alba Craft Laboratory site were derived on the basis of a dose constraint of 30 mrem/yr for the current use and likely future use scenarios and a dose limit of 100 mrem/yr for less likely but plausible future use scenarios (Yu et al. 1993); it was assumed that uranium is the only radionuclide present at an above-background concentration. The RESRAD computer code, version 5.03, was used to derive these guidelines. The RESRAD code is used to implement the methodology described in the DOE manual for implementing residual radioactive material guidelines (Yu et al. 1993).

2 SCENARIO DEFINITIONS

Three potential exposure scenarios were considered for the former Alba Craft Laboratory site. In these scenarios it was assumed that, at some time within 1,000 years, the site will be released for use without radiological restrictions following remedial action. All pathways considered for Scenarios A, B, and C are summarized in Table 1.

Scenario A (the current use scenario) assumes continued industrial use of the site. Under this scenario, a hypothetical individual 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, 50 weeks per year. Therefore, in one year the industrial worker is assumed to spend 17% of the time working outdoors at the site; 6% of the time working indoors at the site; and 77% of the time away from the site. It is also assumed that the worker does not ingest water, plant foods, or fish obtained from the decontaminated area or meat or milk from livestock raised in the decontaminated area.

Scenario B (a likely future use scenario) assumes residential use of the site. It is assumed that, at some time in the future, the industrial activities at the site will be discontinued and that the whole site will be transformed into a residential area. Under this scenario, in one year a hypothetical resident is assumed to spend 50% of the time indoors in the decontaminated area; 25% of the time outdoors in the decontaminated area; and 25% of the time away from the site. The resident is assumed to ingest plant foods grown in the garden. All water used by the resident for drinking, household purposes, and irrigation is

TABLE 1 Summary of Pathways for Scenarios A, B, and C at the Former Alba Craft Laboratory Site

Pathway	Scenario A[a]	Scenario B[b]	Scenario C[c]
External exposure	Yes	Yes	Yes
Inhalation	Yes	Yes	Yes
Radon	Yes	Yes	Yes
Ingestion of plant foods	No	Yes	Yes
Ingestion of meat	No	No	Yes
Ingestion of milk	No	No	Yes
Ingestion of fish	No	No	Yes
Ingestion of soil	Yes	Yes	Yes
Ingestion of water	No	No	Yes

[a] Industrial worker.

[b] Resident: water used for drinking, household purposes, and irrigation is assumed to be from uncontaminated municipal sources.

[c] Resident: water used for drinking, household purposes, livestock watering, and irrigation is assumed to be from an on-site well.

from municipal sources that are not radioactively contaminated. For this scenario, it is assumed that no livestock is raised for the production of meat and milk and that no pond is present on-site to provide fish and other aquatic food.

Scenario C (a plausible but unlikely future use scenario) is similar to Scenario B, in which the resident is assumed to ingest plant foods grown in the garden. However, under Scenario C, the resident is assumed to also ingest meat and milk from livestock fed with forage grown on-site and to catch and consume fish and other aquatic organisms from an on-site pond. For this scenario, the groundwater drawn from a well located on-site is the only water source for drinking, household purposes, livestock watering, and irrigation.

The RESRAD computer code (Yu et al. 1993) was used to calculate the potential radiation doses for the hypothetical future industrial worker and resident on the basis of the following assumptions:

- During one year, the industrial worker (Scenario A) spends 1,500 hours (17%) outdoors at the site, 500 hours (6%) indoors at the site, and 6,760 hours (77%) away from the decontaminated area. During one year, the resident (Scenarios B and C) spends 4,380 hours (50%) indoors, 2,190 hours (25%) outdoors in the decontaminated area, and 2,190 hours (25%) away from the site.

- The walls, floor, and foundation of the house or office building reduce external exposure by 30%; the indoor dust level is 40% of the outdoor dust level (Yu et al. 1993).

- The depth of the house or building foundation is 1 m below ground surface, with an effective radon diffusion coefficient of 2×10^{-8} m^2/s.

- The size of the decontaminated area is sufficiently large that 10% and 50% of the plant food diet consumed by the resident for Scenarios B and C, respectively, is grown in a garden in the decontaminated area. The industrial worker does not consume these plant foods.

- The size of the decontaminated area is large enough to produce 15% of the forage used to feed livestock for meat and milk consumed by the resident in Scenario C. The industrial worker and the resident in Scenario B do not consume these animal products.

- For Scenario C, 50% of the fish and other aquatic food consumed by the resident is obtained from an on-site pond.

- The current supply of water for the industrial building and the nearby residential areas is from uncontaminated municipal sources. However, for the plausible but unlikely scenario (Scenario C), the source of water for drinking, household purposes, livestock watering, and irrigation purposes is assumed to be from an on-site well.

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

- No erosion of the contaminated material occurs.

- The thickness of the contaminated zone is based on conservative average values from ORNL measurements (Murray et al. 1993). The area surrounding the former Alba Craft Laboratory site (3,000 m^2) is assumed to be homogeneously contaminated to an average depth of 0.5 m.

3 DOSE/SOURCE CONCENTRATION RATIOS

The RESRAD computer code, version 5.03 (Yu et al. 1993), was used to calculate the dose/source concentration ratio $DSR_{ip}(t)$ for uranium isotope i and pathway p at time t after remedial action. The time frame considered in this analysis was 1,000 years. Radioactive decay and ingrowth were considered in deriving the dose/source concentration ratios. The various parameters used in the RESRAD code for this analysis are listed in the Appendix. The calculated maximum dose/source concentration ratios for all pathways are presented in Tables 2, 3, and 4 for Scenarios A, B, and C, respectively. For Scenarios A and B, the maximum dose/source concentration ratios would occur at time zero (immediately after remedial action); for Scenario C, the maximum dose/source concentration ratio would occur 275 years following remedial action. The primary pathways for Scenarios A and B are inhalation and external exposure; for Scenario C, the dominant pathway is ingestion of water.

The summation of $DSR_{ip}(t)$ for all pathways p is the $DSR_i(t)$ for the ith isotope; that is,

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

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

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

where W_i is the existing activity concentration fraction at the site for uranium-234, uranium-235, and uranium-238.

For this analysis, W_i is assumed to represent the natural activity concentration ratios 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 provided in Table 5. These ratios were used to determine the allowable residual radioactivity for uranium at the former Alba Craft Laboratory site.

Uncertainty in the derivation of dose/source concentration ratios arises from the distribution of possible input parameter values as well as uncertainty in the conceptual model used to represent the site. Depending on the scenario, different parameters affect the results in each case. For Scenarios A and B, the inhalation and external exposure pathways contribute almost equally to most of the dose. Therefore, uncertainty in parameters affecting these pathways, such as the thickness of the contaminated zone and mass loading of dust in the air, will affect the results more than parameters affecting other pathways. In addition, doses will depend strongly on the choice of occupancy factors selected for these two scenarios. Because the maximum dose occurs at time zero, uncertainties in parameters that affect the leaching of radionuclides from the contaminated zone do not affect the results. However, the

TABLE 2 Maximum Dose/Source Concentration Ratios for Scenario A (Industrial Worker) at the Former Alba Craft Laboratory Site

Pathway	Maximum Dose/Source Concentration Ratio[a] (mrem/yr)/(pCi/g)		
	Uranium-234	Uranium-235	Uranium-238
External exposure	3.0×10^{-4}	1.9×10^{-1}	2.8×10^{-2}
Inhalation	2.0×10^{-2}	1.9×10^{-2}	1.9×10^{-2}
Radon	0	0	0
Ingestion of soil	1.8×10^{-3}	1.8×10^{-3}	1.8×10^{-3}

[a] Maximum dose/source concentration ratios would occur at time zero (immediately following remedial action); all values are reported to two significant figures.

TABLE 3 Maximum Dose/Source Concentration Ratios for Scenario B (Resident: Municipal Water Supply) at the Former Alba Craft Laboratory Site

Pathway	Maximum Dose/Source Concentration Ratio[a] (mrem/yr)/(pCi/g)		
	Uranium-234	Uranium-235	Uranium-238
External exposure	8.5×10^{-4}	5.5×10^{-1}	7.8×10^{-2}
Inhalation	4.7×10^{-2}	4.3×10^{-2}	4.3×10^{-2}
Radon	0	0	0
Ingestion of plant foods	6.3×10^{-3}	6.1×10^{-3}	6.1×10^{-3}
Ingestion of soil	4.3×10^{-3}	4.1×10^{-3}	4.1×10^{-3}

[a] Maximum dose/source concentration ratios would occur at time zero (immediately following remedial action); all values are reported to two significant figures.

TABLE 4 Maximum Dose/Source Concentration Ratios for Scenario C (Resident: On-Site Well Water) at the Former Alba Craft Laboratory Site

Pathway	Maximum Dose/Source Concentration Ratio[a] (mrem/yr)/(pCi/g)		
	Uranium-234	Uranium-235	Uranium-238
External exposure	3.2×10^{-4}	2.3×10^{-2}	3.2×10^{-3}
Inhalation	2.0×10^{-3}	2.2×10^{-3}	1.8×10^{-3}
Radon	9.5×10^{-6}	0	1.9×10^{-9}
Ingestion of plant foods	2.4×10^{-2}	4.1×10^{-2}	2.3×10^{-2}
Ingestion of meat	3.4×10^{-4}	1.6×10^{-3}	3.3×10^{-4}
Ingestion of milk	1.3×10^{-3}	1.3×10^{-3}	1.2×10^{-3}
Ingestion of fish	8.2×10^{-4}	4.6×10^{-3}	7.9×10^{-4}
Ingestion of soil	1.9×10^{-4}	2.5×10^{-4}	1.7×10^{-4}
Ingestion of water	2.9×10^{-1}	5.0×10^{-1}	2.8×10^{-1}

[a] Maximum dose/source concentration ratios would occur at 275 years following remedial action; all values are reported to two significant figures.

TABLE 5 Total Dose/Source Concentration Ratios for Uranium at the Former Alba Craft Laboratory Site

Radionuclide	Maximum Dose/Source Concentration Ratio[a] (mrem/yr)/(pCi/g)		
	Scenario A[b]	Scenario B[c]	Scenario C[d]
Uranium-234	2.2×10^{-2}	5.8×10^{-2}	3.2×10^{-1}
Uranium-235	2.1×10^{-1}	6.1×10^{-1}	5.7×10^{-1}
Uranium-238	4.8×10^{-2}	1.3×10^{-1}	3.1×10^{-1}
Total uranium	3.9×10^{-2}	1.1×10^{-1}	3.2×10^{-1}

[a] All values are reported to two significant figures.

[b] Industrial worker (current use scenario).

[c] Resident: water used for drinking, household purposes, and irrigation is assumed to be from uncontaminated municipal sources (likely future use scenario).

[d] Resident: water used for drinking, household purposes, livestock watering, and irrigation is assumed to be from an on-site well (unlikely future use scenario).

opposite is true for Scenario C, in which almost all of the dose is contributed by the drinking water pathway; in this case, the resulting dose will be affected by uncertainties in soil properties, meteorological parameters, distribution coefficients, water consumption rate, and other parameters affecting the leaching and transport of radionuclides. For Scenario C, the dose is almost linearly proportional to the assumed thickness of the contaminated zone as well as the drinking water consumption rate, and the choice of occupancy factors does not significantly affect the results. Laboratory analysis of the uncontaminated soil samples obtained from the site indicated that the distribution coefficient for uranium is on the order of 70,000 cm^3/g (Orlandini 1994). This value is much higher than the conservative values, 50 and 5 cm^3/g, assumed in the analysis.

The RESRAD default values have been used if no site-specific data were available. These default values are based on national average or reasonable maximum values. In addition, the contaminated zone thickness of 0.5 m that was selected to derive the dose/source concentration ratios is based on the assumption that the soil is uniformly contaminated to that depth. In reality, most of the contamination occurs in the top 15 cm of soil and is not dispersed uniformly throughout the site. Therefore, the calculated dose/source ratios are conservative.

4 RESIDUAL RADIOACTIVE MATERIAL GUIDELINES

The residual radioactive material guideline is the concentration of residual radioactive material that can remain in a decontaminated area and still allow use of the area without radiological restrictions. Given a dose limit of H_{EL} for an individual, the residual radioactive material guideline G for uranium at the former Alba Craft Laboratory site can be calculated as

$$G = H_{EL}/DSR ,$$

where DSR is the total dose/source concentration ratio listed in Table 5. The dose limit, H_{EL}, used to derive the residual radioactive material guideline is 30 mrem/yr for the current use and likely future use scenarios and 100 mrem/yr for all other plausible future use scenarios (Yu et al. 1993). The calculated residual radioactive material guidelines for both single radionuclides (uranium-234, uranium-235, and uranium-238) and total uranium are presented in Table 6.

In calculating the total uranium guidelines (reported to two significant figures), it was assumed that the activity concentration ratio of uranium-238, uranium-234, and uranium-235 is 1:1:0.046. The derived guidelines for total uranium are 770, 280, and 310 pCi/g for Scenarios A, B, and C, respectively. If uranium-238 is measured as the

TABLE 6 Residual Radioactive Material Guidelines for the Former Alba Craft Laboratory Site

	Guideline (pCi/g)[a]		
Radionuclide	Scenario A[b]	Scenario B[c]	Scenario C[d]
Uranium-234	1,400	520	310
Uranium-235	140	50	180
Uranium-238	630	230	320
Total uranium	770	280	310

[a] All values are reported to two significant figures.

[b] Industrial worker (current use scenario: dose constraint = 30 mrem/yr).

[c] Resident: water used for drinking, household purposes, and irrigation is assumed to be from uncontaminated municipal sources (likely future use scenario: dose constraint = 30 mrem/yr).

[d] Resident: water used for drinking, household purposes, livestock watering, and irrigation is assumed to be from an on-site well (unlikely but plausible future use scenario: dose limit = 100 mrem/yr).

indicator radionuclide, the uranium-238 limits for total uranium can be calculated by dividing the total uranium guidelines by 2.046. The resulting uranium-238 limits are 380, 140, and 150 pCi/g for Scenarios A, B, and C, respectively.

When implementing the derived radionuclide guidelines for decontamination of a site, the law of sum of fractions applies. That is, the summation of the radionuclide concentrations S_i remaining on-site (averaged over an area of 100 m^2 and a depth of 15 cm) divided by their guidelines G_i should not be greater than unity; that is,

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

The derived guidelines listed in Table 6 are for a large homogeneously contaminated area. For a small, isolated area of contamination — a hot spot — the allowable concentration that can remain on-site may be higher than the homogeneous guideline, depending on the size of the contaminated area and in accordance with the ranges given in Table 7.

TABLE 7 Ranges for Hot Spot Multiplication Factors

Range (m^2)	Factor (multiple of authorized limit)
<1	10[a]
1 - <3	6
3 - <10	3
10 - 25	2

[a] Areas less than 1 m^2 are to be averaged over a 1-m^2 area, and that average shall not exceed 10 times the authorized limit.

Source: Yu et al. (1993).

5 REFERENCES

International Commission on Radiological Protection, 1991, *1990 Recommendations of the International Commission on Radiological Protection*, ICRP Publ. 60, Annals of the ICRP 21(1-3).

Murray, M.E., et al., 1993, *Results of the Radiological Survey at the Former Alba Craft Laboratory Site Properties, Oxford, Ohio (OXO001)*, ORNL/RASA-92/14, prepared by Oak Ridge National Laboratory, Health and Safety Research Division, Oak Ridge, Tenn., for U.S. Department of Energy, Office of Environmental Restoration, March.

Orlandini, K.A., 1994, "Distribution Coefficient of Uranium between an Ohio Soil and Rain Water," interoffice memorandum from K.A. Orlandini (Environmental Research Division) to C. Yu (Environmental Assessment Division), Argonne National Laboratory, Argonne, Ill., Jan. 19.

Smith, B.S., 1982, *Occurrence and Quality of Ground Water in the Oxford-Morning Sun Area, Ohio,* Master's thesis, Miami University, Oxford, Ohio.

U.S. Department of Energy, 1990, *Radiation Protection of the Public and Environment*, DOE Order 5400.5, Feb. 8.

Yu, C., et al., 1993, *Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0,* ANL/EAD/LD-2, prepared by Argonne National Laboratory, Argonne, Ill., for U.S. Department of Energy, Office of Environmental Restoration, Sept.

APPENDIX:

SCENARIOS AND PARAMETERS USED FOR THE ANALYSIS OF THE FORMER ALBA CRAFT LABORATORY SITE

The following exposure scenarios were analyzed for the former Alba Craft Laboratory Site in Oxford, Ohio:

- Scenario A: Industrial Use of the Site. A hypothetical person is assumed to work in the area of the site.

- Scenario B: Residential Use of the Site — Municipal Water Supply. A hypothetical resident is assumed to live in the decontaminated area and to use an uncontaminated municipal water supply for drinking, household purposes, and irrigation. The resident is assumed to ingest plant foods grown on-site; however, no livestock is raised for the production of meat and milk, and no pond is present on-site to provide fish and other aquatic food.

- Scenario C: Residential Use of the Site — On-Site Well Water. A hypothetical resident is assumed to live in the decontaminated area and to use water from an on-site well for drinking, household purposes, livestock watering, and irrigation. The resident is assumed to ingest plant foods grown in the garden and meat and milk from livestock fed with forage grown on-site. The resident is assumed to catch and consume fish and other aquatic organisms from an on-site pond.

The parametric values used in the RESRAD code for the analysis of the former Alba Craft Laboratory site are listed in Table A.1. All parametric values are reported at up to three significant figures. Some parameters are specific to the former Alba Craft Laboratory site; other values are generic.

TABLE A.1 Parameters Used in the RESRAD Computer Code for the Analysis of the Former Alba Craft Laboratory Site

		Value		
Parameter	Unit	Scenario A	Scenario B	Scenario C
Area of contaminated zone[a]	m^2	3,000	3,000	3,000
Thickness of contaminated zone[a]	m	0.5	0.5	0.5
Length parallel to aquifer flow[a]	m	Not used	Not used	55
Basic radiation dose limit[a,b]	mrem/yr	30	30	100
Cover depth[a]	m	0	0	0
Contaminated zone:				
Density[b]	g/cm^3	1.5	1.5	1.5
Erosion rate[a]	m/yr	0	0	0
Total porosity[b]	-[c]	0.4	0.4	0.4
Effective porosity[b]	-[c]	0.2	0.2	0.2
Hydraulic conductivity[b]	m/yr	10	10	10
Soil-specific b parameter[b]	-[c]	5.3	5.3	5.3
Evapotranspiration coefficient[a]	-[c]	0.57	0.57	0.57
Precipitation[a]	m/yr	1.03	1.03	1.03
Irrigation[b]	m/yr	0.2	0.2	0.2
Irrigation mode[b]	-[c]	Overhead	Overhead	Overhead
Runoff coefficient[a]	-[c]	0.21	0.21	0.21
Watershed area for nearby pond[a,b]	m^2	Not used	Not used	1,000,000
Saturated zone:				
Density[a,b]	g/cm^3	Not used	Not used	1.5
Total porosity[a]	-[c]	Not used	Not used	0.34
Effective porosity[a]	-[c]	Not used	Not used	0.28
Hydraulic conductivity[a]	m/yr	Not used	Not used	5,000
Hydraulic gradient[a,b]	-[c]	Not used	Not used	0.02
Soil-specific b parameter[a]	-[c]	Not used	Not used	Not used
Water table drop rate[a]	m/yr	Not used	Not used	0
Well pump intake depth (below water table)[a]	m	Not used	Not used	2.1
Model: nondispersion (ND) or mass balance (MB)[b]	-[c]	Not used	Not used	ND
Individual use of groundwater[a]	m^3/yr	Not used	Not used	Not used
Number of unsaturated zone strata[a]	-[c]	Not used	Not used	2
Unsaturated zone 1:				
Thickness[a]	m	Not used	Not used	1.7
Soil density[a,b]	g/cm^3	Not used	Not used	1.5
Total porosity[a,b]	-[c]	Not used	Not used	0.4
Effective porosity[a,b]	-[c]	Not used	Not used	0.2
Soil-specific b parameter[a,b]	-[c]	Not used	Not used	5.3
Hydraulic conductivity[b]	m/yr	Not used	Not used	10
Unsaturated zone 2:				
Thickness[a]	m	Not used	Not used	4
Soil density[a,b]	g/cm^3	Not used	Not used	1.5
Total porosity[a]	-[c]	Not used	Not used	0.42
Effective porosity[a]	-[c]	Not used	Not used	0.06
Soil-specific b parameter[a]	-[c]	Not used	Not used	11.4
Hydraulic conductivity[a]	m/yr	Not used	Not used	40
Distribution coefficient[a,b]:	cm^3/g			
Contaminated zone				
Uranium-234		Not used	Not used	50
Uranium-235		Not used	Not used	50
Uranium-238		Not used	Not used	50
Actinium-227		Not used	Not used	20
Protactinium-231		Not used	Not used	50
Lead-210		Not used	Not used	100
Radium-226		Not used	Not used	70
Thorium-230		Not used	Not used	60,000

TABLE A.1 (Cont.)

Parameter	Unit	Value Scenario A	Scenario B	Scenario C
Distribution coefficient[a,b] (cont.):	cm^3/g			
Unsaturated zone 1				
Uranium-234		Not used	Not used	50
Uranium-235		Not used	Not used	50
Uranium-238		Not used	Not used	50
Actinium-227		Not used	Not used	20
Protactinium-231		Not used	Not used	50
Lead-210		Not used	Not used	100
Radium-226		Not used	Not used	70
Thorium-230		Not used	Not used	60,000
Unsaturated zone 2				
Uranium-234		Not used	Not used	50
Uranium-235		Not used	Not used	50
Uranium-238		Not used	Not used	50
Actinium-227		Not used	Not used	20
Protactinium-231		Not used	Not used	50
Lead-210		Not used	Not used	100
Radium-226		Not used	Not used	70
Thorium-230		Not used	Not used	60,000
Saturated zone				
Uranium-234		Not used	Not used	5
Uranium-235		Not used	Not used	5
Uranium-238		Not used	Not used	5
Actinium-227		Not used	Not used	2
Protactinium-231		Not used	Not used	5
Lead-210		Not used	Not used	10
Radium-226		Not used	Not used	7
Thorium-230		Not used	Not used	6,000
Inhalation rate[b]	m^3/yr	8,400	8,400	8,400
Mass loading for inhalation[a]	g/m^3	0.0001	0.0001	0.0001
Shielding factor, inhalation[b]	-[c]	0.4	0.4	0.4
Shielding factor, external gamma[b]	-[c]	0.7	0.7	0.7
Fraction of time indoors[a,b]	-[c]	0.057	0.5	0.5
Fraction of time outdoors[a,b]	-[c]	0.171	0.25	0.25
Shape factor, external gamma[b]	-[c]	1	1	1
Dilution length for airborne dust, inhalation[b]	m	3	3	3
Food consumption:				
Fruits, vegetables, and grain[a,b]	kg/yr	Not used	160	160
Leafy vegetables[a,b]	kg/yr	Not used	14	14
Milk[a,b]	L/yr	Not used	Not used	92
Meat and poultry[a,b]	kg/yr	Not used	Not used	63
Fish[a]	kg/yr	Not used	Not used	5.4
Other aquatic food[a]	kg/yr	Not used	Not used	0.9
Soil ingestion[a,b]	g/yr	36.5	36.5	36.5
Drinking water intake[a,b]	L/yr	Not used	Not used	510
Contaminated fraction of food and water:	-[c]			
Drinking water[a,b]		Not used	0	1.0
Household water[a,b]		Not used	0	1.0
Livestock water[a,b]		Not used	Not used	1.0
Irrigation water[a,b]		Not used	0	1.0
Aquatic food[a,b]		Not used	Not used	0.5
Plant food[a]		Not used	0.1[a]	0.5[d]
Meat[a]		Not used	Not used	0.15[d]
Milk[a]		Not used	Not used	0.15[d]
Livestock fodder intake for meat[a,b]	kg/d	Not used	Not used	68
Livestock fodder intake for milk[a,b]	kg/d	Not used	Not used	55

TABLE A.1 (Cont.)

Parameter	Unit	Value		
		Scenario A	Scenario B	Scenario C
Livestock water intake for meat[a,b]	L/d	Not used	Not used	50
Livestock water intake for milk[a,b]	L/d	Not used	Not used	160
Livestock soil intake[a,b]	kg/d	Not used	Not used	0.5
Mass loading for foliar deposition[a,b]	g/m^3	Not used	0.0001	0.0001
Depth of soil mixing layer[b]	m	0.15	0.15	0.15
Depth of roots[a,b]	m	Not used	0.9	0.9
Groundwater fractional usage (balance from surface water):	-[c]			
Drinking water[a,b]		Not used	Not used	1.0
Household water[a,b]		Not used	Not used	1.0
Livestock water[a,b]		Not used	Not used	1.0
Irrigation[a,b]		Not used	Not used	1.0
Total porosity of the cover material[a]	-[c]	Not used	Not used	Not used
Total porosity of the house or building foundation[b]	-[c]	0.1	0.1	0.1
Volumetric water content of the cover material[a]	-[c]	Not used	Not used	Not used
Volumetric water content of the foundation[b]	-[c]	0.03	0.03	0.03
Diffusion coefficient for radon gas:	m^2/s			
In cover material[a]		Not used	Not used	Not used
In foundation material[b]		3.0×10^{-7}	3.0×10^{-7}	3.0×10^{-7}
In contaminated zone soil[b]		2.0×10^{-6}	2.0×10^{-6}	2.0×10^{-6}
Emanating power of radon-222[b]	-[c]	0.25	0.25	0.25
Emanating power of radon-220[a]	-[c]	Not used	Not used	Not used
Radon vertical dimension of mixing[b]	m	2.0	2.0	2.0
Average annual wind speed[b]	m/s	2.0	2.0	2.0
Average building air exchange rate[b]	1/h	0.5	0.5	0.5
Height of building (room)[b]	m	2.5	2.5	2.5
Building indoor area factor[b]	-[c]	0	0	0
Bulk density of house or building foundation[b]	g/cm^3	2.4	2.4	2.4
Thickness of house or building foundation[b]	m	0.15	0.15	0.15
Building depth below ground surface[b]	m	1.0	1.0	1.0

[a] Values based on site specifications, scenario assumptions, or Yu et al. (1993).

[b] RESRAD default values.

[c] Parameter is dimensionless.

[d] Calculated with the RESRAD computer code.

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