APPENDIX C

SITE-SPECIFIC CLEANUP CRITERIA FOR THE FUSRAP MAYWOOD SUPERFUND SITE QUALITATIVE ASSESSMENT OF REMEDIATION WORKER RISK

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115499

Department of Energy

Oak Ridge Operations
P.O. Box 2001
Oak Ridge, Tennessee 37831—

April 13, 1994

Mr. William J. Muszynski, P.E.
Deputy Regional Administrator
U. S. Environmental Protection Agency,
Region II
Jacob K. Javits Federal Building
26 Federal Plaza
New York, New York 10278-0012

Dear Mr. Muszynski:

MAYWOOD SITE - DOE ACCEPTANCE OF EPA'S PROPOSED CLEANUP LEVELS

This letter is response to your letter dated March 23, 1994, which transmits EPA's position on the cleanup levels for radiological contamination at the Maywood site. I am pleased to inform you that DOE is in agreement with the position set forth in your letter and accepts the proposed cleanup criteria.

I would like to take this opportunity to recognize the efforts of our staffs and commend them for their cooperation with one another and their commitment to resolve this complicated issue.

If you have any questions, please do not hesitate to call me at (615) 576-4444.

Sincerely,

Joe La Grone

Joe La Grone
Manager

cc: T. P. Grumbly, EORS, EM-1
R. J. Guimond, FORS, EM-1

Mr. William J. Muszynski, P.E.
Deputy Regional Administrator
U. S. Environmental Protection Agency,
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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION II
JACOB K. JAVITS FEDERAL BUILDING
NEW YORK, NEW YORK 10278-0012

28 MAR 1994

Mr. Joe La Grone
Manager, Oak Ridge Operations Office
U.S. Department of Energy
P.O. Box 2001
Oak Ridge, Tennessee 37831-8501

Re: EPA Region 2's Position on the Dispute Regarding Cleanup Levels for Radionuclide Contamination at the Maywood Chemical Company Superfund Site, Maywood, NJ

Dear Mr. La Grone:

You and I, as members of the Senior Executive Committee (SEC), have conferred in an attempt to resolve the dispute regarding cleanup levels for radionuclide contamination in soil at the Maywood Chemical Company Superfund Site. Although we were not able to resolve the dispute within the timeframe allocated to us in the Federal Facility Agreement (FFA) between the Department of Energy (DOE) and the Environmental Protection Agency (EPA), I directed my staff to continue working with DOE in performing site-specific risk analyses prior to formulating my final position on the dispute. The purpose of this letter is to notify you, as the DOE representative on the SEC, of my position on the dispute regarding radionuclide cleanup levels for soil at the Maywood Site, pursuant to Chapter XV (Resolution of Disputes) of the FFA. Based on recent discussions between George Pavlou of my staff and Les Price of yours, I understand that this position, as presented in the attachment, is acceptable to DOE, and will be incorporated into the revised Proposed Plan for the Maywood site.

In accordance with Chapter XV of the FFA, DOE may, within 21 days of my issuance of this position, issue a written notice elevating the dispute to the Administrator of EPA for resolution. In the event that DOE elects not to elevate the dispute within the 21 day period, DOE will be deemed to have agreed with EPA Region 2's position with respect to the dispute as presented herein. As noted above, it is my understanding that EPA's position is acceptable to DOE, and that DOE will not elevate the dispute to the Administrator.

I commend our respective staffs for their efforts in resolving this dispute and look forward to finalizing the Proposed Plan without further undue delay. If you have any questions on the above matters, please do not hesitate to call me at (212) 264-2525.

Sincerely,

William J. Muszynski

William J. Muszynski, P.E.
Acting Regional Administrator

Attachment

cc: R. Shinn, Jr., Commissioner, DEPE
S. Cange, DOE-OR
J. Wagoner, DOE-HQ
L. Miller, DEPE

EPA Region 2's Position on Cleanup Levels at Maywood

EPA Region 2's position on cleanup levels at the Maywood Site must be put into the context of the actions which DOE outlined in its draft final Proposed Plan for the Maywood Site (April, 1993): DOE selected Alternative 6 - *Phased Action and Offsite Disposal* - as the proposed remedy. This alternative consisted of two "phases" of activities. In Phase I, the pile of approximately 35,000 cubic yards of contaminated dirt and debris at the Maywood Interim Storage Site (MISS) would be removed and sent to a commercial disposal facility. Phase I also included the complete excavation of the residential properties, including the unremediated portion of the Ballod property. Phase II would include the treatment of the remaining accessible contamination at the Maywood Site (the commercial and government properties which include Stepan Company, the Sears property, and the DOE owned MISS). The "clean stream" from the treatment process would be backfilled on the MISS and portions of the Stepan and Sears properties (over which would be placed a foot of clean cover), and the concentrated residuals would be disposed of at an off-site commercial disposal facility. DOE has also expressed an interest to treat the soil in the MISS pile if, during its removal, treatment becomes viable and cost effective. EPA Region 2 agrees with these proposed actions, but not the cleanup levels associated with them. Below is my position, which, if acceptable to DOE, should be incorporated into a final Proposed Plan.

Phase I (Cleanup of the MISS and Residential Properties):

The preferred alternative for the Maywood site is a phased action, in which soil contaminated above a specified criterion would be excavated, and the disposition of the excavated materials will differ for different phases of the project. During Phase I, contaminated soil from the residential properties, the unremediated portion of the Ballod property and the Maywood Interim Storage Site (MISS) waste pile will be excavated and shipped off-site for commercial disposal in accordance with applicable regulations. As proposed by DOE, if during removal of the MISS pile, treatment becomes viable and cost effective, treatment of the MISS pile may be instituted. Excavated areas on residential properties will be backfilled with clean fill material. Surface and subsurface soil at residential properties and the unremediated portion of the Ballod property will be remediated to 5 pCi/g above background.

Phase II (Cleanup of the Commercial/Government Properties):

Phase II will immediately follow Phase I. During Phase II remediation activities, subsurface soil on commercial/government properties will be excavated and removed to a level of 15 pCi/g above background with an "as low as reasonably achievable" (ALARA) goal of 5 pCi/g above background. On the basis of a site-specific risk analysis, these levels are deemed protective for currently zoned commercial/industrial properties. Most excavated areas will be backfilled with clean fill material. Any property that is subject to backfilling of treated material during Phase II (the MISS, and possibly portions of the Stepan and Sears property) will be covered by at least 30 cm of clean fill "to grade." Treated residuals will be at a concentration no greater than 15 pCi/g above background. Consistent with ALARA, if the soil treatment technology, at the time of its implementation, proves capable of treating soils to lower residual concentrations in a cost-effective manner, then DOE shall adopt a lower concentration limit for replacement of treated soils.

DOE will institute ALARA during its field excavation and removal program at commercial/government properties. For the proposed actions, an ALARA goal of 5 pCi/g for Ra-226 and Ra-228, combined, above background, will be instituted for subsurface soils. The design plan for site remediation will include a cleanup confirmation program developed to achieve both the specified cleanup criterion (15 pCi/g) and subsurface ALARA goal (5 pCi/g). At the 26 residential properties previously remediated at the Maywood site, post-remediation verification data show that, although DOE utilized a 15 pCi/g cleanup criterion, measured concentrations of thorium-232 following remediation were below 5 pCi/g above background in over 95% of samples, and radium-226 and uranium concentrations were generally at or near background levels. Subsurface cleanup is therefore expected to attain the subsurface ALARA goal in most cases, consistent with previous removal actions. At those commercial/government properties subject to backfilling of treated residuals, subsurface soil concentrations are expected to range between 5 pCi/g and 15 pCi/g above background; how far below 15 pCi/g is dependent upon the capabilities of the soil treatment technology.

Pursuant to CERCLA §121(c) and the Federal Facility Agreement, following successful remediation, the Maywood site will be subject to 5-year reviews to assure that human health and the environment remain protected by the remedial action being implemented. In addition, DOE will remediate, as may be necessary, any areas of the site which have not been remediated due to their inaccessibility, at such time as those areas become accessible for remediation through demolition, relocation, renovation, excavation or otherwise. Also, DOE and EPA, will request that the Borough of Maywood and the townships of Rochelle Park and Lodi during and after the proposed action inform DOE and EPA of any land use or zoning changes affecting any portion of the commercial/government areas of the site and of any permit, building, construction, excavation or demolition activity that might affect unremediated portions of the site (or involve offsite removal of remediated backfill material).

United States Government 1 3 ' 3 3 5 ~~115663~~ Department of Energ

memorandum

DATE: APR 2 5 1994

REPLY TO ATTN OF: EM-421 (W. A. Williams, 903-8149)

SUBJECT: Uranium Guideline for the Maywood, New Jersey Site

TO: L. Price, OR

This is in response to the request for approval of the uranium guideline for the Maywood Site of the Formerly Utilized Sites Remedial Action Program (FUSRAP), pursuant to Department of Energy (DOE) Order 5400.5. The Site, located in northern New Jersey, was used by a private party for the production of thorium and rare earths from ores. In addition, tailings from the thorium production were carried to off-site locations in Maywood, Lodi, and Rochelle Park, New Jersey. Your staff requested approval of a residual uranium guideline of 100 picoCuries per gram of total uranium, based on a supporting analysis by Argonne National Laboratory (ANL). Further, your staff estimated that the waste volume from remedial action would not be affected by the choice of the guideline because of the co-location of uranium and thorium in the soils to be remediated. Under these conditions, cleanup of the thorium to its authorized guideline (5 picoCuries/gram (pCi/g) for surface soil and up to 15 pCi/g for subsurface soil) will result in a simultaneous cleanup of uranium to levels far below the requested guideline.

Basic Dose Requirement:

The Maywood Site is located in northern New Jersey, and the present land use is industrial. Vicinity properties are used for residential, commercial, governmental, and industrial purposes. Although some vicinity properties have been cleaned up, others have not. For the remediation of the site, it is necessary to determine (using site specific data) the level of uranium that would lead to an exposure of 100 millirem per year for all plausible land uses. A draft analysis was performed by ANL and was submitted with the request.

The ANL analysis calculated a maximum residual concentration of total uranium in soil of 1,400 picoCuries per gram (pCi/g) to 13,000 pCi/g, depending on future land use. These concentrations are equivalent to 100 millirem per year for various land uses. The recommended 100 pCi/g is equivalent to 1.6 millirem per year for an industrial worker (Scenario A in the ANL Report). For recreational use, the exposure is less than 1 millirem per year (Scenario B). For subsistence farming use, the recommended guideline is 7 millirem per year, assuming the use of an on-site water well (Scenario C), and 6 millirem per year, assuming that off-site water is used for drinking, livestock, and irrigation purposes (Scenario D).

Based on the ANL analysis, the recommended value of 100 pCi/g of total uranium is within DOE's dose guideline of 100 millirem per year, which must be met under all worst case, plausible scenarios, including the assumed residential and agricultural use.

As Low As Reasonably Achievable (ALARA) Analysis:

In addition to meeting the basic radiation protection guideline, any cleanup guideline must be analyzed to keep exposures ALARA. In the application of ALARA, practical considerations, costs, and benefits are also taken into account. For practical considerations, it is likely that the contaminated areas will be cleaned up to a level below whatever guideline is established. This is likely for three reasons. First, in order to remove all material above the guideline, some soil contaminated below the guideline will be removed. This will have the practical effect of lowering the guideline as it is applied during cleanup operations. Second, during cleanup operations, it is difficult to precisely delineate the point at which contamination above the guideline ends. As a result, remedial personnel will remove all suspect materials to avoid repeated cleanup operations on the same property. Finally, the uranium is co-located with thorium, and the removal of thorium to meet the applicable guideline will remove uranium at the same time. For these reasons, it is likely that cleanup for uranium will be accomplished at some level lower than the approved cleanup guideline.

A final practical consideration is the use of clean fill material to replace excavated materials. This will cause a shielding and covering effect on the remaining soils, reducing gamma ray, dust, and radon exposures. If the site were to be used for residential or agricultural use in the future, the clean fill would also reduce the projected doses by diluting the residual contamination. The ANL analysis does not assume that there is any clean fill or cover placed over the site after cleanup. For this reason, the doses calculated in the ANL report are clearly a worst case scenario. In the actual application of a cleanup guideline, it is very likely that a cleanup level substantially below the established guideline will be achieved.

Selection of a uranium guideline significantly below 100 pCi/g would, as the request stated, negatively impact the project by reducing the utility of field measurements for confirming the cleanup of uranium. Although other measurement techniques could be used, the cost is much higher, and there is no potential benefit since the uranium is co-located with thorium-232, and remediation of thorium contaminated soils will result in residual uranium concentrations much lower than those under consideration.

Summary and Approval:

Based on the above considerations, a guideline of 100 pCi/g for total uranium above background levels is approved for use in the cleanup of the Maywood Site, pursuant to DOE Order 5400.5, Chapter IV, Section 5a. This guideline should be implemented in conjunction with the authorized guidelines for radium and thorium using the "sum-of-the-fractions" method.

In addition, please direct ANL to finalize the dose report for publication.

We also recommend that your staff discuss the site characterization data and the approved guidelines with the State and Environmental Protection Agency staff at an appropriate time.

for Albert J. Johnson
James W. Wagoner II
Director
Division of Off-Site Programs
Office of Eastern Area Programs
Office of Environmental Restoration

cc:
S. Cange, OR
C. Yu, ANL
D. Dunning, ANL
R. Rodriguez, ORNL

134526 ~~117690~~

Argonne National Laboratory
9700 South Cass Avenue, Argonne, Illinois 60439

DERIVATION OF URANIUM RESIDUAL RADIOACTIVE MATERIAL GUIDELINES FOR THE MAYWOOD SITE

by

D.E. Dunning
Environmental Assessment Division

May 1994

work sponsored by

U.S. Department of Energy
Oak Ridge Operations Office
Formerly Utilized Sites Remedial Action Program
Oak Ridge, Tennessee

CONTENTS

FIGURES

TABLES

TABLES (Cont.)

DERIVATION OF URANIUM RESIDUAL RADIOACTIVE MATERIAL GUIDELINES FOR THE MAYWOOD SITE

by D.E. Dunning

SUMMARY

Residual radioactive material guidelines for uranium were derived for the Maywood site located in the Boroughs of Maywood and Lodi and the Township of Rochelle Park, New Jersey. The Maywood site became contaminated as a result of thorium-processing operations conducted at the former Maywood Chemical Works (MCW) facility from the early 1900s through 1959. Properties within the Maywood site include the Maywood Interim Storage Site (MISS); the Stepan Company (formerly MCW) property; and numerous residential, commercial, federal, state, and municipal properties that became contaminated as a result of the former thorium-processing operations. Several vicinity properties have been remediated by previous removal actions. The U.S. Department of Energy (DOE) is responsible for cleanup activities at the Maywood site under its Formerly Utilized Sites Remedial Action Program (FUSRAP), as defined in the Federal Facilities Agreement (FFA) between DOE and the U.S. Environmental Protection Agency (EPA) for the site. Remedial actions at the Maywood site are being conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended. In addition, DOE has chosen to integrate the values of the National Environmental Policy Act (NEPA). The DOE is currently preparing a comprehensive remedial investigation/feasibility study-environmental impact statement (RI/FS-EIS) for remedial action at the Maywood site.

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 Maywood site should not exceed 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. Four potential scenarios were considered for the site; the scenarios vary with regard to time spent at the site, sources of water used, and sources of food consumed. The results of the evaluation indicate that the basic dose limit of 100 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 combined uranium (uranium-234, uranium-235, and uranium-238) at the Maywood site does not exceed the following levels: 3,800 pCi/g for Scenario A (industrial worker); 8,300 pCi/g for Scenario B (recreationist); 1,400 pCi/g for Scenario C (resident using a water source not affected by site conditions as the only water source); and 910 pCi/g for Scenario D (resident farmer using well water as the only water source). The uranium guidelines derived in this report apply to the combined activity concentration of uranium-234, uranium-235, and uranium-238, and were calculated on the basis of a dose limit of 100 mrem/yr. In setting the final uranium guidelines for the Maywood 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 and whether the contamination is isolated and localized.

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 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), or otherwise designated for FUSRAP responsibility.

The Maywood site is located in Bergen County, New Jersey. The U.S. Congress assigned DOE the responsibility of cleaning up the contamination at the Maywood site that resulted from past thorium-processing operations at the Maywood Chemical Works (MCW) from the early 1900s through 1959. Remedial actions at the Maywood site are being conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA). In addition, DOE has chosen to integrate the values of the National Environmental Policy Act (NEPA), which ensure that the environmental consequences of a proposed action are considered as part of the decision-making process for that action. The DOE is currently preparing a comprehensive remedial investigation/feasibility study-environmental impact statement (RI/FS-EIS) for remedial action at the Maywood site. This report presents guidelines for residual uranium concentrations in soils at the Maywood site. The guidelines were derived with the RESRAD computer code (Gilbert et al. 1989; Yu et al. 1993) on the basis of a dose limit of 100 mrem/yr.

1.1 SITE DESCRIPTION AND SETTING

The Maywood site is composed of properties in the Boroughs of Maywood and Lodi and the Township of Rochelle Park, New Jersey. The three municipalities adjoin each other and are located in a highly developed area of northeastern New Jersey, approximately 20 km (12 mi) north-northwest of New York City and 21 km (13 mi) northeast of Newark, New Jersey (Figure 1). The Maywood site became contaminated, at least in part, as a result of thorium processing and disposal activities that took place during the operation of the former MCW facility from the early 1900s through 1959. The Maywood site consists of the Maywood Interim Storage Site (MISS); the Stepan Company property (formerly the MCW); and numerous residential, commercial, federal, state, and municipal properties in Maywood, Rochelle Park, and Lodi, New Jersey. These properties became radioactively contaminated as a result of thorium-processing operations at the MCW. The site is listed on the National Priorities List (NPL) as the Maywood Chemical Company.

The U.S. Congress has assigned DOE the responsibility of cleaning up contamination at the site that resulted from thorium-processing operations by the former MCW. The U.S. Environmental Protection Agency (EPA) oversees the Maywood site cleanup. Each agency's responsibilities are described in a Federal Facilities Agreement (FFA) negotiated by

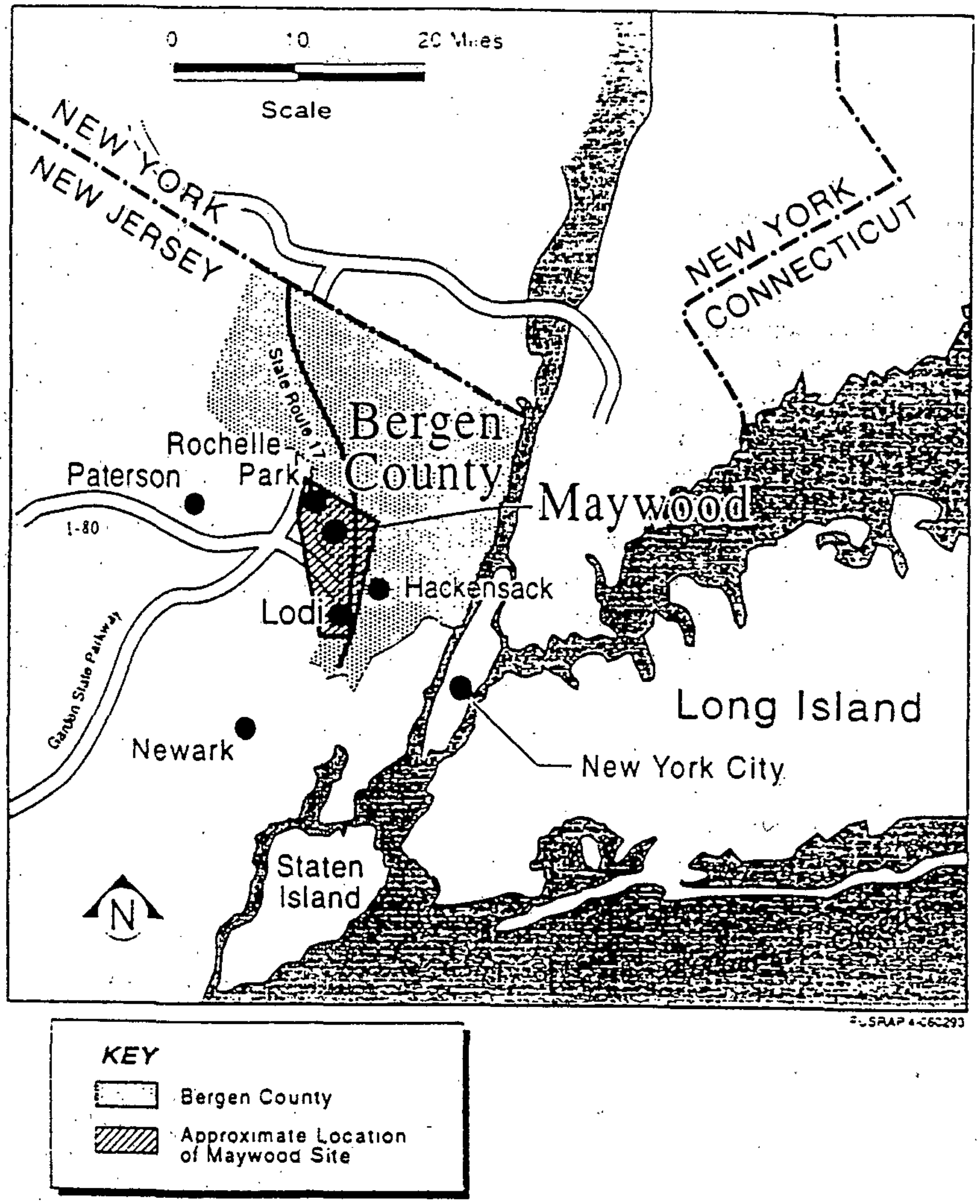

FIGURE 1 Location of the Maywood Site

DOE and EPA Region II. The DOE is primarily responsible for addressing radioactive contamination and the contaminants that meet the definition of FUSRAP waste as set forth in the FFA. A separate RI/FS is being conducted by the Stepan Company, owner of the former MCW property, and focuses on chemical contamination at the site under an administrative order of consent (1987) and an administrative order (1991). Although DOE and Stepan Company RI/FS activities are being conducted independently, EPA oversight over both actions, in consultation with the parties, will ensure that sufficient coordination occurs between the parties to fully address the Maywood site.

For the purpose of developing and evaluating remedial action alternatives, the Maywood site has been divided into multiple operable units (OUs) on the basis of land use and environmental media of concern. The location of the properties composing these OUs is shown in Figure 2. Each OU is briefly described below.

The MISS is a 4.7-ha (11.7-acre) property owned by DOE and located in the Borough of Maywood and the Township of Rochelle Park. The MISS property was previously part of a 12-ha (30-acre) property owned by the Stepan Company and formerly part of the MCW; DOE acquired the property from the Stepan Company in 1985. The property contains an interim waste storage pile, two buildings (Building 76 and a pumphouse), two partially buried structures, temporary office trailers, a reservoir, and two rail spurs. The property is bordered on the west by State Route 17; on the north by a New York, Susquehanna, and Western Railroad line; and on the south and east by commercial and industrial properties. Residential properties are located north of the railroad line and within 274 m (300 yd) to the north of the MISS property boundary. The interim storage pile at the MISS occupies approximately 0.8 ha (2 acres) and contains about 27,000 m^3 (35,000 yd^3) of contaminated soils and materials from previous removal actions conducted on vicinity properties at the Maywood site. A building at the MISS (Building 76) houses containerized solid waste from previous removal actions and site investigations. Former waste retention ponds are also located at the MISS. The property is enclosed by a chain-link fence, and access is restricted within the fenced area. Major features of the MISS property are indicated in Figure 3.

The Stepan Company, a pharmaceutical manufacturer, is located at 100 West Hunter Avenue in the Borough of Maywood, adjacent to the MISS. The property covers 7.4 ha (18 acres), approximately two-thirds of which contains buildings, some in or near locations where the MCW thorium-processing operations occurred. Burial pits containing thorium-processing and other wastes are located on the site (see Figure 3). The property (excluding the main office and parking area) is enclosed by a chain-link fence, and access is restricted within the fenced area.

Residential vicinity properties in the Boroughs of Maywood and Lodi and the Township of Rochelle Park contain radioactive contamination from thorium-processing operations. These properties were identified by DOE through surveys performed by Oak Ridge National Laboratory (ORNL). Nine residential properties in Rochelle Park on Grove Avenue and Park Way and eight residential properties in Maywood on Davison Avenue and Latham Street were completely decontaminated by DOE between 1984 and 1986 and independently verified for use without restriction. Eight residential properties in Lodi have also been decontaminated and have been independently verified as clean; one additional property in Lodi was partially remediated during previous removal actions. Of the remaining 32 contaminated residential properties to be addressed by DOE, 30 are located in Lodi and two are located in Maywood.

Commercial/government vicinity properties include 27 properties located in Maywood, Rochelle Park, and Lodi. Twenty commercial vicinity properties are part of the Maywood site. State and federally owned properties include right-of-ways for Interstate 80, a State

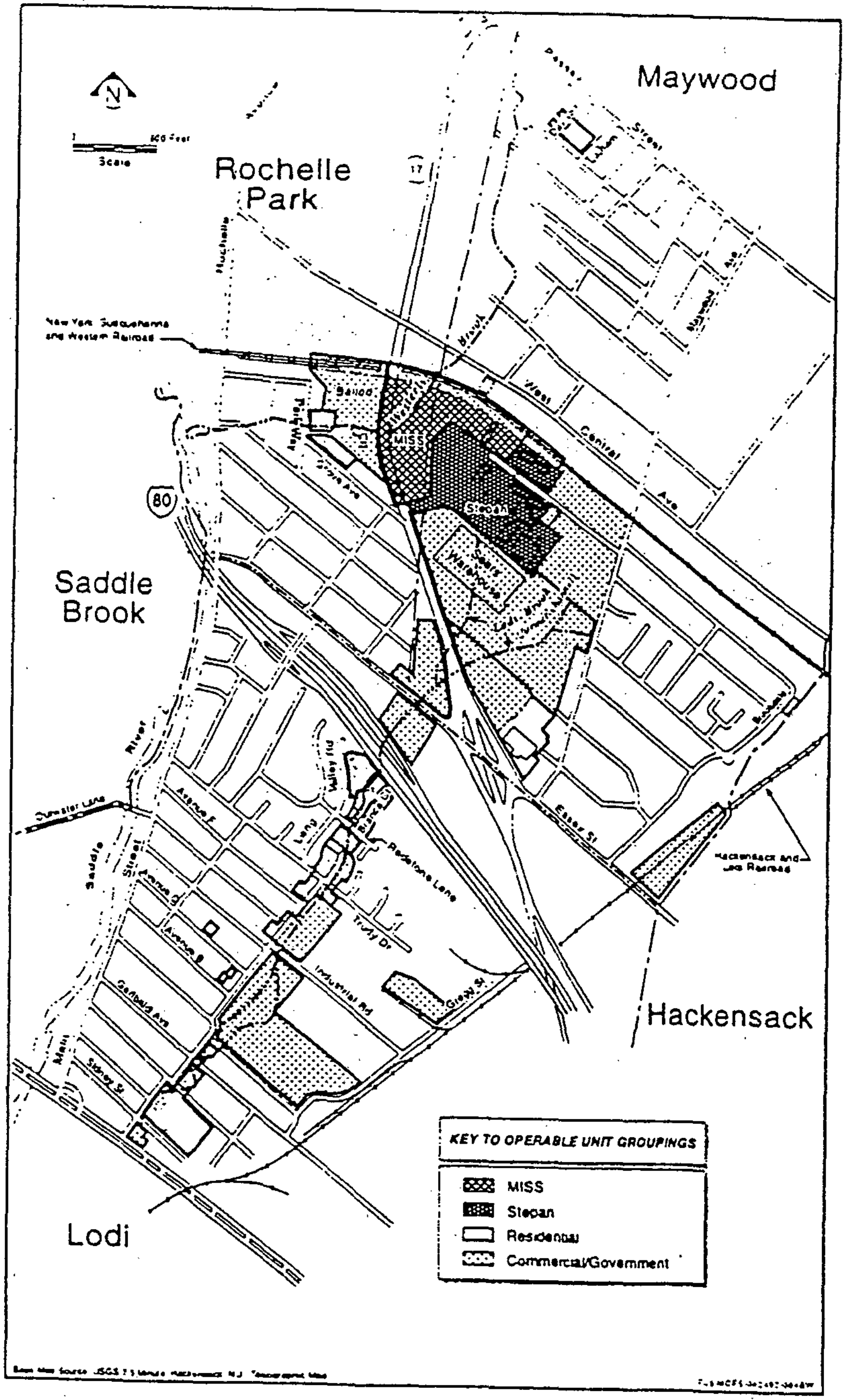

FIGURE 2 Map of the Maywood Site Showing the Locations of the Maywood Interim Storage Site and Vicinity Properties

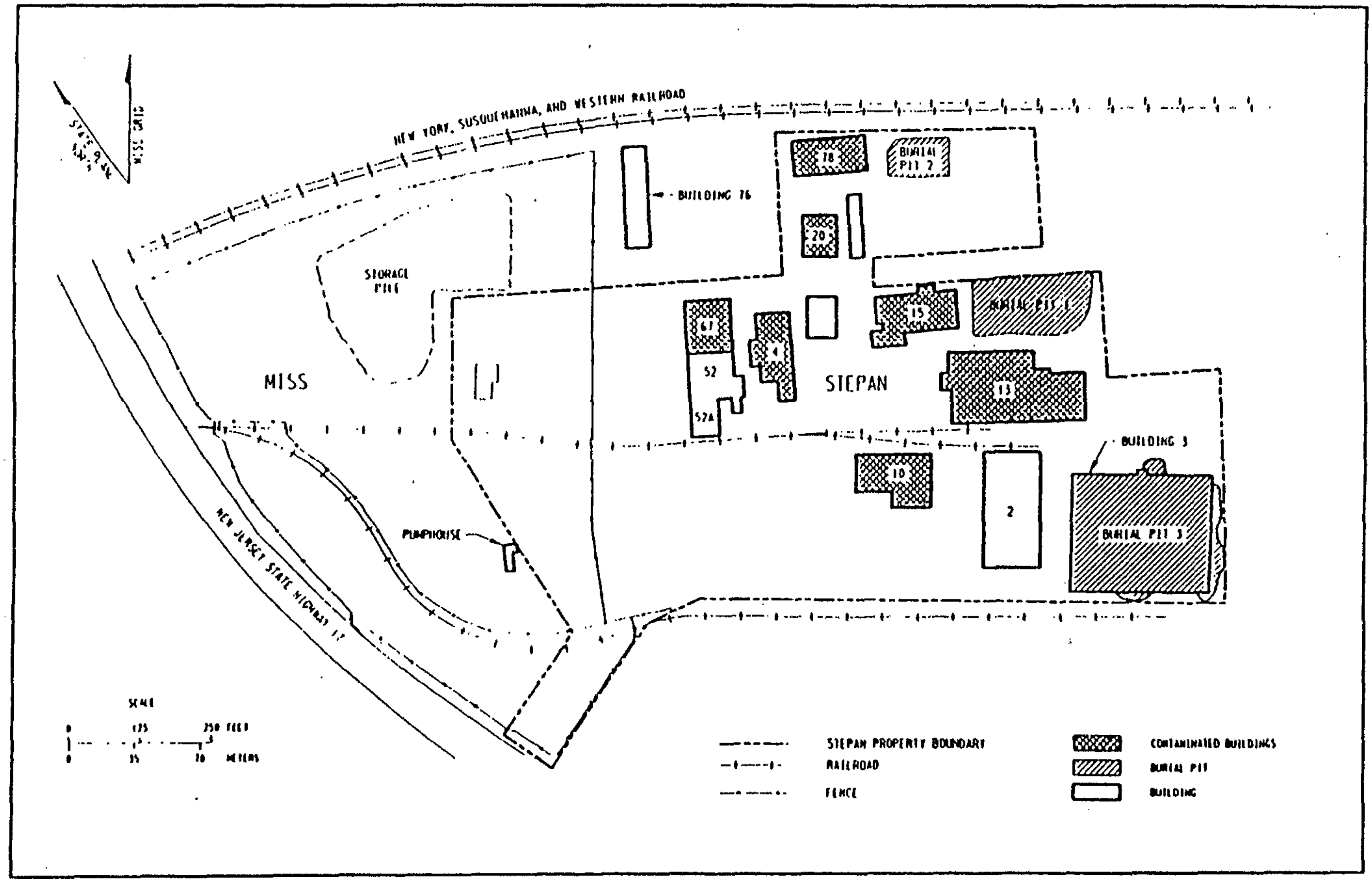

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FIGURE 3 Site Map of the Maywood Interim Storage Site and Adjacent Stepan Company Property

Route 17 embankment, and the New Jersey Vehicle Inspection Station. Four municipal properties (three parks and a fire station), residential streets suspected to have contaminated soils below the surface, and contaminated sediments from Lodi Brook are also included in this OU. The majority of these properties were contaminated through the same processes as the residential properties — transport of contaminated sediments along former stream channels or use of contaminated material as fill and mulch. Three of these properties (Ballod, Sears, and State Route 17) were once part of the former MCW property and were used, at least in part, for waste disposal. A portion of one property (Ballod) was remediated during a previous removal action.

Contaminated buildings and structures are located on the MISS and Stepan properties only. As indicated in Figure 3, radiologically contaminated buildings include the pumphouse at the MISS and the guardhouse and Buildings 4, 10, 13, 15, 20, 67, and 78 on the Stepan property. The radiological contamination is generally localized in discrete areas within buildings and is fixed in place on building floors and surfaces and not readily transferable (i.e., removable by incidental contact). The pumphouse is no longer in use; however, the contaminated buildings at Stepan are part of an active industrial complex. The contaminated buildings are all old buildings that existed during the time that the MCW was processing thorium. No buildings on vicinity properties were found to be contaminated other than one residence in Lodi that contained contaminated building materials from the MCW; the contaminated portion of the structure has been removed and reconstructed.

The regional climate at the Maywood site is humid, with a normal annual precipitation of about 107 cm (42.3 in.). Mean monthly temperatures range from 0.4°C (31°F) in January to 24.9°C (76.8°F) in July. The prevailing winds are from the northwest during October through April and from the southwest during the remainder of the year.

The Maywood site lies within the Saddle River drainage basin. A small portion of the site is located within the 100-year floodplain of the Saddle River. Westerly Brook flows under the MISS property and State Route 17 through a concrete culvert and eventually discharges into the Saddle River approximately 0.8 km (0.5 mi) to the west. Another perennial stream on the Maywood site, Lodi Brook, originates as two branches on the Sears property; most of the original stream channel has been replaced by a subsurface storm drain system, but the former channel correlates with the distribution of contaminated materials in the Borough of Lodi. Lodi Brook empties into the Saddle River downstream of Westerly Brook's confluence with the river. Depth-to-groundwater is shallow and ranges from approximately 1 to 4.6 m (3 to 15 ft) below ground surface.

1.2 SITE HISTORY

The MCW was constructed in 1895. In 1916, the plant began extracting thorium and rare earths from monazite sands for use in manufacturing industrial products such as mantles for gas lanterns. The plant also produced a variety of other materials, including lithium compounds, detergents, alkaloids, and oils. The plant stopped accepting monazite sands for extraction in 1956 but processed stockpiled materials until 1959. On the basis of available historical information and knowledge of the chemical processes involved, the chemicals identified as having been used in the thorium extraction process include sulfuric acid, nitric acid, ammonium hydroxide, and ammonium oxalate. Oxalic acid was also used at the site in the production of higher-grade thorium.

The waste was generated from the extraction process in slurry form. Until 1932, the slurry was pumped to two earthen-diked areas west of the plant. At that time, the disposal areas were affected by the construction of State Route 17, which separated the diked areas from the plant and partially buried them. Waste retention ponds also existed throughout the area of the MCW that is now the MISS.

Some of the process wastes were removed for use as mulch and fill on nearby properties, thereby contaminating those properties with radioactive materials. Although the fill consisted primarily of tea and coca leaves from other MCW processes, these materials were apparently contaminated with the thorium-processing wastes. Additional wastes migrated off the property via natural drainage associated with the former Lodi Brook. Most of the open stream channel in Lodi has been replaced by a subsurface storm drain system.

The MCW received a radioactive materials license from the AEC in 1954. The MCW sold the site to the Stepan Company in 1959, which received a license from the AEC in 1961. Although the Stepan Company never processed radioactive materials, the company agreed to take certain corrective measures in the former disposal area on the west side of State Route 17 (now known as the Ballod property). The Stepan Company began to clean up residual thorium-processing wastes in 1963. From 1966 through 1968, Stepan removed residues and tailings from the Ballod property and reburied them on the Stepan property in three burial pits (Figure 3). After these actions were completed, the AEC certified the portion of the property west of State Route 17 for use without radiological restrictions in 1968.

Radioactive contamination, however, was discovered in the northeast corner of the property in 1980 after a private citizen reported radioactive contamination near State Route 17 to the New Jersey Department of Environmental Protection (NJDEP). A survey of the area (State Route 17, Ballod property, and Stepan property) conducted by the NJDEP identified the contaminants as thorium-232 and radium-226. The U.S. Nuclear Regulatory Commission (NRC) was notified of the results and undertook additional surveys from November 1980 to January 1981; these surveys confirmed high concentrations of thorium-232 in soil samples collected from both the Stepan and Ballod properties. Accordingly, the NRC requested a comprehensive survey of the area.

In January 1981, the EG&G Energy Measurements Group conducted an aerial radiological survey of the Stepan property and surrounding properties. The survey, which covered a 10-km^2 (3.9-mi^2) area, indicated contamination not only on the Stepan and Ballod properties but also in areas to the north and south of the Ballod property. During February 1981, ORNL performed a separate radiological ground survey of the Ballod property, the results of which eventually led to its designation for remedial action under FUSRAP. In June 1981, an additional radiological survey of the Stepan and Ballod properties commissioned by the Stepan Company produced similar findings.

By enacting a provision of the Energy and Water Development Appropriations Act of 1984, Congress authorized DOE to undertake a decontamination research and development project at the Maywood site. Accordingly, the site was assigned to FUSRAP, and DOE negotiated access to a 4.7-ha (11.7-acre) portion of the Stepan Company property for use as an interim storage facility for contaminated materials that were to be removed from vicinity properties. This area is now known as the MISS. In September 1985, ownership of the MISS was transferred to DOE.

In late 1983, DOE initiated a program of surveys of properties in the vicinity of the former MCW plant. From 1984 to 1986, DOE conducted removal actions on 25 properties and placed the waste in temporary storage on the MISS. The interim waste storage pile contains about 27,000 m^3 (35,000 yd^3) of contaminated soil and debris removed from these vicinity properties; the interim storage pile occupies approximately 0.8 ha (2 acres) with an average height of 5.5 m (18 ft). The DOE has maintained a comprehensive environmental monitoring program at the MISS since 1984.

A time-critical removal action was conducted in July 1991 to decontaminate a residential property at 90 Avenue C in Lodi, in response to radiological surveys that identified interior gamma exposure rates above DOE guidelines within a portion of the building. The original owner of the residence was an employee of the MCW, who apparently used discarded building and fill materials from the MCW to construct an addition to the house. Contaminated soil and building materials generated during this removal action were packaged in appropriate containers and placed in Building 76 at the MISS for interim storage.

Eighty-five properties, including the Stepan property and the MISS, have (or have had) residual contamination resulting from MCW thorium-processing activities and are included as a part of the Maywood site. The properties include 56 residential properties (25 of which have been previously remediated and 1 partially remediated), 3 properties owned by the state or federal government, 4 municipal properties, and 20 commercial properties (1 of which has been partially remediated). Vicinity properties are believed to have been contaminated by the use of the waste materials as mulch and fill or through sediment transport via Lodi Brook.

The Maywood site was placed on the National Priorities List (NPL) by the EPA on September 8, 1983. All remedial actions at the site conducted by DOE are being coordinated with EPA Region II under CERCLA. The limits of DOE's responsibilities for the Maywood site are defined under a negotiated FFA between DOE and EPA Region II that became effective April 22, 1991.

Implementation of comprehensive remedial actions will be preceded by completion of the RI/FS-EIS process for the site (Argonne National Laboratory/Bechtel National, Inc. [ANL/BNI] 1992). It is DOE's policy (DOE 1989) to integrate the values of NEPA with the procedural and documentation requirements of CERCLA at sites for which it has responsibility. The combined RI/FS-EIS process will conclude in the issuance of a record of decision (ROD) that will identify the selected remedy for the Maywood site.

1.3 DERIVATION OF CLEANUP GUIDELINES

Because no generic cleanup guidelines for uranium applicable to remedial actions at FUSRAP sites are available, uranium guidelines are derived on a site-specific basis. The purpose of this report is to present the derivation of the residual radioactive material guidelines for uranium (i.e., uranium-234, uranium-235, and uranium-238) that are applicable to remedial action at the Maywood site; that is, 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. On the assumption that the uranium is the only radionuclide present at an above-background concentration, the derivation of site-specific uranium guidelines for the Maywood site was based on the dose limit of 100 mrem/yr (DOE 1990). The RESRAD computer code, which implements the methodology described in the DOE manual for implementing residual radioactive material guidelines (Gilbert et al. 1989; Yu et al. 1993), was used to derive these guidelines. The DOE will establish the final uranium guidelines for the Maywood site by applying the as low as reasonably achievable (ALARA) policy to the derived guidelines presented in this report, along with other factors, such as whether a particular scenario is reasonable and appropriate and whether the contamination is isolated and localized.

2 SCENARIO DEFINITIONS

Current land use at properties composing the Maywood site ranges from residential to commercial/industrial to recreational. Four potential exposure scenarios were considered in deriving site-specific uranium guidelines, including each of these land use categories. In all scenarios it is assumed that, at some time within 1,000 years, the site will be released for use without radiological restrictions following decontamination.

Scenario A assumes industrial use of the site; this is considered the most likely future scenario at the MISS, the Stepan Company property, and numerous commercial/industrial properties within the Maywood site. A hypothetical employee is assumed to work in the area of the site for 8 hours per day (7 hours indoors and 1 hour outdoors), 5 days per week, 50 weeks per year. The industrial worker does not ingest drinking water, plant foods, or fish from the decontaminated area, or ingest meat or milk from livestock raised in the decontaminated area.

Scenario B assumes recreational use of the site; for example, it is assumed that, at some time in the future, the site will be used as a public park; this is considered the expected scenario for the three municipal parks included within the Maywood site. A hypothetical person is assumed to spend 15 hours per week, 50 weeks per year in the decontaminated area of the park. The recreational user does not ingest drinking water, plant foods, or fish from the decontaminated area, or ingest meat or milk from livestock raised in the decontaminated area.

Scenario C assumes residential use of the site; the Maywood site includes numerous residential properties, and continued residential land use is expected. All water used by the resident is assumed to come from a distant source not affected by site conditions (e.g., a municipal water supply); the site is currently served by a municipal water supply, and there is no known use of groundwater at the site as a drinking water source. The resident ingests produce grown in a garden in the decontaminated area but does not ingest meat or milk from livestock raised in the decontaminated area nor fish grown in the decontaminated area.

Scenario D assumes the presence of a resident farmer at the site who drinks water obtained from a well located at the downgradient edge of the decontaminated area, ingests produce grown in a garden in the decontaminated area, ingests meat and milk from livestock raised in the decontaminated area, and ingests fish taken from a pond that is assumed to be constructed adjacent to and downgradient of the decontaminated area. All water used for drinking, irrigation, and livestock is assumed to be drawn from the on-site well. There is no current agricultural activity at the site, and production of livestock or construction of a fishing pond in the decontaminated area are considered extremely unlikely.

Potential radiation doses resulting from nine exposure pathways were analyzed: (1) direct exposure to external radiation from the decontaminated soil material; (2) internal radiation from inhalation of contaminated dust; (3) internal radiation from inhalation of emanating radon-222; (4) internal radiation from incidental ingestion of soil; (5) internal radiation from ingestion of plant foods grown in the decontaminated area and irrigated with water drawn from a well located at the downgradient edge of the decontaminated area; (6) internal radiation from ingestion of meat from livestock fed with fodder grown in the decontaminated area and irrigated with water drawn from the on-site well; (7) internal radiation from ingestion of milk from livestock fed with fodder grown in the decontaminated area and irrigated with water drawn from the on-site well; (8) internal radiation from ingestion of fish from a pond downgradient from the decontaminated area; and (9) internal radiation from drinking water drawn from the on-site well.

The RESRAD computer code, version 5.01 (Yu et al. 1993), was used to calculate the potential radiation doses to each of the hypothetical future receptors on the basis of the following assumptions:

- The resident spends 5,900 hours per year on-site in the decontaminated area (16.5 hours/day indoors and 0.5 hour/day outdoors for 350 days/year). The industrial worker spends 2,000 hours per year on-site (7 hours/day indoors and 1 hour/day outdoors for 250 days/year). The recreationist spends 750 hours per year on-site, all outdoors. The resident farmer spends 4,380 hours per year indoors, 2,190 hours outdoors in the decontaminated area, and 2,190 hours away from the site. Exposure times for the resident and employee were selected for consistency with the baseline risk assessment for the site (DOE 1993).

- For all scenarios, the contaminated zone is taken to be the MISS property.

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

- The walls, floor, and foundation of the house or commercial building reduce external exposure by 20%, and the indoor dust level is 40% of the outdoor dust level.

- The depth of the house or building foundation is 1 m (3 ft) below ground surface, with an effective radon diffusion coefficient of 2×10^{-8} m^2/s.

- Under Scenario D, a well located at the downgradient edge of the decontaminated area is assumed to provide 100% of the drinking water consumed by the resident farmer and is also used for irrigating vegetables in the on-site garden and fodder for livestock. Under Scenarios A, B, and C, all water is assumed to come from a distant source unaffected by site conditions.

- Under Scenarios C and D, the resident or resident farmer is assumed to consume produce grown in a garden in the decontaminated area. The industrial worker and recreationist do not consume produce from an on-site garden.

- Under Scenario D, the resident farmer is assumed to obtain meat and milk from livestock raised (i.e., foraged) in the decontaminated area. The industrial worker, recreationist, and resident do not consume meat or milk from livestock raised in the decontaminated area.

- An adjacent pond is assumed to provide 50% of the aquatic food (fish) consumed by the resident farmer (Scenario D). The industrial worker, recreationist, and resident do not consume fish from the decontaminated area.

- Hydrogeologic properties of the Maywood site were taken from the remedial investigation report (DOE 1992b), baseline risk assessment (DOE 1993), and FS-EIS (DOE 1994) for the site.

Most exposure parameter values were selected for consistency with values used in the baseline risk assessment (DOE 1993) and FS-EIS (DOE 1994); however, some additional exposure pathways that were determined in the baseline risk assessment to be implausible and/or inappropriate for the Maywood site (e.g., ingestion of meat and milk from livestock raised on-site) are considered here for completeness. Table 1 provides a summary of the exposure pathways considered for Scenarios A, B, C, and D. RESRAD input parameter values used in the analysis are tabulated in the Appendix.

TABLE 1 Summary of Pathways for Scenarios A, B, C, and D at the Maywood Site[a]

Pathway	Scenario A	Scenario B	Scenario C	Scenario D
External exposure	Yes	Yes	Yes	Yes
Particulate inhalation	Yes	Yes	Yes	Yes
Radon inhalation	Yes	Yes	Yes	Yes
Ingestion of soil	Yes	Yes	Yes	Yes
Ingestion of produce	No	No	Yes	Yes
Ingestion of meat from on-site livestock	No	No	No	Yes
Ingestion of milk from on-site livestock	No	No	No	Yes
Ingestion of fish from an on-site pond	No	No	No	Yes
Ingestion of water from an on-site well[b]	No	No	No	Yes

[a] Scenario A, industrial worker; Scenario B, recreationist; Scenario C, resident using a distant water source unaffected by site conditions; Scenario D, resident farmer using an on-site well as the only water source.

[b] Source of water used: 100% well water for drinking, irrigation, and livestock for Scenario D; 100% distant source for all purposes for Scenarios A, B, and C.

3 DOSE/SOURCE CONCENTRATION RATIOS

The RESRAD computer code, version 5.01 (Yu et al. 1993), was used to calculate the dose/source ratio $DSR_{ip}(t)$ for uranium isotope i and pathway p at time t after decontamination. 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 through 5 for Scenarios A, B, C, and D, respectively. For Scenarios A, B, and C, the maximum dose/source concentration ratios are predicted to occur at time zero (immediately after decontamination). For Scenario D, the maximum dose/source concentration ratio for uranium isotopes is estimated to occur approximately 1,000 years following decontamination. The primary exposure pathway for Scenarios A and B is predicted to be inhalation of resuspended particulates for uranium-234 and external exposure for uranium-235 and uranium-238. For Scenario C, the primary pathway is predicted to be ingestion of produce from an on-site garden for uranium-234 and external exposure for uranium-235 and uranium-238. For Scenario D, the primary pathway is predicted to be ingestion of groundwater for uranium-234 and uranium-238 and external exposure for uranium-235.

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

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

The total dose/source concentration ratio for total uranium (enriched, depleted, or normal) can be calculated as

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

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 uranium isotopes and total uranium are provided in Table 6. These ratios were used to determine the allowable residual radioactivity for uranium at the Maywood 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 more strongly influence the results in each case. For Scenarios A, B, and C, the particulate inhalation, external exposure, and produce ingestion (Scenario C only) pathways contribute most of the dose, so uncertainty in parameters affecting these pathways (e.g., occupancy factors, thickness of the contaminated zone, shielding provided by buildings and site features, mass

TABLE 2 Maximum Dose/Source Concentration Ratios for Scenario A (industrial worker) at the Maywood Site

Pathway	Maximum Dose/Source Concentration Ratio (mrem/yr)/(pCi/g)[a]		
	Uranium-234	Uranium-235	Uranium-238
External exposure	2.6×10^{-4}	1.7×10^{-1}	2.5×10^{-2}
Particulate inhalation	9.3×10^{-3}	8.6×10^{-3}	8.6×10^{-3}
Radon inhalation	0	0	0
Ingestion of soil	3.6×10^{-4}	3.4×10^{-4}	3.4×10^{-4}
Ingestion of produce from on-site garden	0	0	0
Ingestion of meat from on-site livestock	0	0	0
Ingestion of milk from on-site livestock	0	0	0
Ingestion of fish from on-site pond	0	0	0
Ingestion of water from on-site well	0	0	0

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

TABLE 3 Maximum Dose/Source Concentration Ratios for Scenario B (recreationist) at the Maywood Site

Pathway	Maximum Dose/Source Concentration Ratio (mrem/yr)/(pCi/g)[a]		
	Uranium-234	Uranium-235	Uranium-238
External exposure	1.2×10^{-4}	7.8×10^{-2}	1.1×10^{-2}
Particulate inhalation	4.1×10^{-3}	3.7×10^{-3}	3.7×10^{-3}
Radon inhalation	0	0	0
Ingestion of soil	7.8×10^{-4}	7.5×10^{-4}	7.5×10^{-4}
Ingestion of produce from on-site garden	0	0	0
Ingestion of meat from on-site livestock	0	0	0
Ingestion of milk from on-site livestock	0	0	0
Ingestion of fish from on-site pond	0	0	0
Ingestion of water from on-site well	0	0	0

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

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TABLE 4 Maximum Dose/Source Concentration Ratios for Scenario C (resident) at the Maywood Site

Pathway	Maximum Dose/Source Concentration Ratio (mrem/yr)/(pCi/g)[a]		
	Uranium-234	Uranium-235	Uranium-238
External exposure	7.4×10^{-4}	4.9×10^{-1}	7.0×10^{-2}
Particulate inhalation	7.9×10^{-3}	7.3×10^{-3}	7.3×10^{-3}
Radon inhalation	0	0	0
Ingestion of soil	2.5×10^{-3}	2.5×10^{-3}	2.5×10^{-3}
Ingestion of produce from on-site garden	1.8×10^{-2}	1.8×10^{-2}	1.8×10^{-2}
Ingestion of meat from on-site livestock	0	0	0
Ingestion of milk from on-site livestock	0	0	0
Ingestion of fish from on-site pond	0	0	0
Ingestion of water from on-site well	0	0	0

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

TABLE 5 Maximum Dose/Source Concentration Ratios for Scenario D (resident farmer) at the Maywood Site

Pathway	Maximum Dose/Source Concentration Ratio (mrem/yr)/(pCi/g)[a]		
	Uranium-234	Uranium-235	Uranium-238
External exposure	1.3×10^{-2}	3.3×10^{-1}	4.3×10^{-2}
Particulate inhalation	6.6×10^{-3}	1.7×10^{-2}	6.0×10^{-3}
Radon inhalation	1.8×10^{-3}	0	1.6×10^{-6}
Ingestion of soil	2.2×10^{-3}	7.9×10^{-3}	2.0×10^{-3}
Ingestion of produce from on-site garden	1.4×10^{-2}	6.9×10^{-2}	9.9×10^{-3}
Ingestion of meat from on-site livestock	2.9×10^{-3}	6.2×10^{-2}	2.1×10^{-3}
Ingestion of milk from on-site livestock	6.2×10^{-3}	5.7×10^{-3}	5.4×10^{-3}
Ingestion of fish from on-site pond	1.5×10^{-3}	1.5×10^{-3}	1.5×10^{-3}
Ingestion of water from on-site well	4.6×10^{-2}	4.7×10^{-2}	4.5×10^{-2}

[a] Maximum dose/source concentration ratios are predicted to occur approximately 1,000 years following decontamination (based on total uranium); all values are reported to two significant figures.

TABLE 6 Total Dose/Source Concentration Ratios for Uranium at the Maywood Site

Radionuclide	Total Dose/Source Concentration Ratio (mrem/yr)/(pCi/g)[a]			
	Scenario A	Scenario B	Scenario C	Scenario D
Uranium-234	9.9×10^{-3}	5.0×10^{-3}	2.9×10^{-2}	9.4×10^{-2}
Uranium-235	1.8×10^{-1}	8.3×10^{-2}	5.2×10^{-1}	5.2×10^{-1}
Uranium-238	3.4×10^{-2}	1.6×10^{-2}	9.7×10^{-2}	1.1×10^{-1}
Total uranium	2.6×10^{-2}	1.2×10^{-2}	7.3×10^{-2}	1.1×10^{-1}

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

loading of contaminated airborne particulates, inhalation rate, and produce ingestion rate) have the greatest impact on model predictions, and parameters related to other pathways have relatively little impact. Because the maximum dose occurs at time zero for these scenarios, uncertainties in parameters related to the leaching of radionuclides from the contaminated zone do not affect the results. However, the opposite is true for Scenario D, in which a large fraction of the total dose is contributed by the drinking water pathway; in this case, the predicted dose is very sensitive to uncertainties in soil properties, meteorological parameters, distribution coefficients, water consumption rates, thickness of the contaminated zone, and other parameters related to the leaching and transport of radionuclides.

For the purposes of this analysis, site-specific parameter values, primarily from the RI/FS-EIS documentation for the Maywood site, have been used when available. RESRAD default values have been used when no site-specific data were available. These default values are based on national average or reasonable maximum values. The contaminated zone thickness of 2 m used to derive the dose/source concentration ratios is based on the assumption that the soil is uniformly contaminated to that depth; in reality, following decontamination of the site, the residual contamination would occur in localized areas and primarily in the near-surface soil and would not be dispersed uniformly throughout the site to this depth. Therefore, the calculated dose/source ratios are conservative. Furthermore, some of the exposure pathways evaluated in this analysis have been included for purposes of completeness, but are considered very unlikely. For example, the production of meat and milk from livestock raised on-site is considered very unlikely given the location and physical characteristics of the site. Similarly, development of a fishing pond at the site is not likely, given the physical and hydrogeologic characteristics of the site, surrounding land use, and the availability of other fishing resources in the area.

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 the DOE radiation dose limit of 100 mrem/yr effective dose equivalent to a member of the public (DOE 1990, 1992a), the residual radioactive material guideline, G, for uranium at the Maywood site can be calculated as

$$G = DL \; / \; DSR \; ,$$

where DL is the applicable radiation dose limit (100 mrem/yr) and DSR is the total dose/source concentration ratio listed in Table 6. The calculated residual radioactive material guidelines for individual uranium isotopes (uranium-234, uranium-235, and uranium-238) and total uranium are presented in Table 7.

In the calculation of the total uranium guidelines, 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 3,800 pCi/g for Scenario A, 8,300 pCi/g for Scenario B, 1,400 pCi/g for Scenario C, and 910 pCi/g for Scenario D. 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 are 1,900 pCi/g, 4,100 pCi/g, 680 pCi/g, and 440 pCi/g for Scenarios A, B, C, and D, respectively.

In implementing the derived radionuclide guidelines for decontamination of a site, the law of the 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 (120 yd^2) and a depth of 15 cm (6 in.) and divided by its guideline, G_i , should not be greater than unity:

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

The derived guidelines are for a large, homogeneously contaminated area. For an isolated, small area of contamination (i.e., a hot spot), the allowable concentration that can remain on-site may be higher than the homogeneous guideline, depending on the size of the area of contamination and in accordance with Table 8.

TABLE 7 Residual Radioactive Material Guidelines for Uranium at the Maywood Site

Radionuclide	Guideline (pCi/g)[a]			
	Scenario A	Scenario B	Scenario C	Scenario D
Uranium-234	1.0×10^4	2.0×10^4	3.4×10^3	1.1×10^3
Uranium-235	5.5×10^2	1.2×10^3	1.9×10^2	1.8×10^2
Uranium-238	3.0×10^3	6.4×10^3	1.0×10^3	8.8×10^2
Total uranium	3.8×10^3	8.3×10^3	1.4×10^3	9.1×10^2

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

TABLE 8 Ranges for Hot Spot Multiplication Factors

Range	Factor (multiple of authorized limit)
< 1 m^2	10[a]
1 - <3 m^2	6
3 - <10 m^2	3
10 - 25 m^2	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: Gilbert et al. (1989).

5 REFERENCES

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APPENDIX:

PARAMETERS USED IN THE ANALYSIS OF THE MAYWOOD SITE

The parametric values used in the RESRAD code for the analysis of the Maywood site are listed in Table A.1. Some parameters are specific to the Maywood site; other values are generic.

TABLE A.1 Parameters Used in the RESRAD Code for the Analysis of the Maywood Site

Parameter	Unit	Value			
		Scenario A	Scenario B	Scenario C	Scenario D
Area of contaminated zone[a,b]	m^2	47,000	47,000	47,000	47,000
Thickness of contaminated zone[b]	m	2	2	2	2
Length parallel to aquifer flow[b]	m	220	220	220	220
Cover depth[b]	m	0	0	0	0
Density of contaminated zone[b]	g/cm^3	1.6	1.6	1.6	1.6
Contaminated zone erosion rate[b]	m/yr	0.0006	0.0006	0.0006	0.0006
Contaminated zone total porosity[a]	-[c]	0.45	0.45	0.45	0.45
Contaminated zone effective porosity[a]	-[c]	0.26	0.26	0.26	0.26
Contaminated zone hydraulic conductivity[a]	m/yr	1.23	1.23	1.23	1.23
Contaminated zone b parameter[a]	-[c]	5.3	5.3	5.3	5.3
Evapotranspiration coefficient[a]	-[c]	0.46	0.46	0.46	0.46
Precipitation[a]	m/yr	1.07	1.07	1.07	1.07
Irrigation[b]	m/yr	0.2	0.2	0.2	0.2
Irrigation mode[b]	-[c]	not used	not used	not used	overhead
Runoff coefficient[a]	-[c]	0.25	0.25	0.25	0.25
Watershed area for pond[a]	m^2	not used	not used	not used	55,750
Density of saturated zone[b]	g/cm^3	1.6	1.6	1.6	1.6
Saturated zone total porosity[a]	-[c]	0.45	0.45	0.45	0.45
Saturated zone effective porosity[a]	-[c]	0.26	0.26	0.26	0.26
Saturated zone hydraulic conductivity[a]	m/yr	123	123	123	123
Saturated zone hydraulic gradient[a]	-[c]	0.01	0.01	0.01	0.01
Saturated zone b parameter[a]	-[c]	5.3	5.3	5.3	5.3
Water table drop rate[b]	m/yr	0.0006	0.0006	0.0006	0.0006
Well pump intake depth[b] (below water table)	m	not used	not used	not used	10
Model: nondispersion (ND) or mass-balance (MB)[b]	-[c]	not used	not used	not used	ND
Well pumping rate[b]	m^3/yr	not used	not used	not used	250
Number of unsaturated zone strata[b]	-[c]	1	1	1	1
Unsaturated zone 1 thickness[a]	m	1	1	1	1
Unsaturated zone 1 soil density[a]	g/cm^3	1.6	1.6	1.6	1.6
Unsaturated zone 1 total porosity[a]	-[c]	0.45	0.45	0.45	0.45
Unsaturated zone 1 effective porosity[a]	-[c]	0.26	0.26	0.26	0.26

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TABLE A.1 (Cont.)

Parameter	Unit	Value: Scenario A	Scenario B	Scenario C	Scenario D
Unsaturated zone 1 soil b parameter[a]	-[c]	5.3	5.3	5.3	5.3
Unsaturated zone 1 hydraulic conductivity[a]	m/yr	1.23	1.23	1.23	1.23
Distribution coefficient (all zones)					
Uranium-238[d]	cm^3/g	250	250	250	250
Uranium-235[d]	cm^3/g	250	250	250	250
Uranium-234[d]	cm^3/g	250	250	250	250
Protactinium-231[d,e]	cm^3/g	2500	2500	2500	2500
Thorium-230[d,e]	cm^3/g	60,000	60,000	60,000	60,000
Actinium-227[d,e]	cm^3/g	1500	1500	1500	1500
Radium-226[d,e]	cm^3/g	450	450	450	450
Lead-210[d,e]	cm^3/g	900	900	900	900
Inhalation rate[f]	m^3/yr	21,900	12,264	7300	7300
Mass loading for inhalation[f,g]	g/m^3	0.00003	0.00003	0.00003	0.00003
Indoor occupancy time fraction[f]	-[c]	0.20	0	0.65	0.65
Outdoor occupancy time fraction[f]	-[c]	0.03	0.086	0.02	0.02
Shielding factor from external radiation afforded by indoor occupancy[b]	-[c]	0.8	not used	0.8	0.8
Fraction of outdoor dust present indoors[b]	-[c]	0.4	not used	0.4	0.4
Shape factor, external gamma[b]	-[c]	1	1	1	1
Dilution length for airborne dust inhalation[b]	m	3	3	3	3
Soil ingestion rate[f]	g/yr	12.5	35	35	35
Homegrown fruit, vegetable, and grain consumption[f]	kg/yr	not used	not used	24	24
Homegrown leafy vegetable consumption[f]	kg/yr	not used	not used	4	4
Milk consumption from livestock[b]	L/yr	not used	not used	not used	92
Meat consumption from livestock[b]	kg/yr	not used	not used	not used	63
Fish consumption[b]	kg/yr	not used	not used	not used	5.4
Other seafood consumption[b]	kg/yr	not used	not used	not used	not used
Drinking water intake[f]	L/yr	not used	not used	not used	700
Fraction of drinking water from on-site well[b]	-[c]	not used	not used	not used	1
Fraction of aquatic food from on-site pond[b]	-[c]	not used	not used	not used	0.5
Livestock fodder intake for meat[b]	kg/d	not used	not used	not used	68
Livestock fodder intake for milk[b]	kg/d	not used	not used	not used	55
Livestock water intake for meat[b]	L/d	not used	not used	not used	50
Livestock water intake for milk[b]	L/d	not used	not used	not used	160
Mass loading for foliar deposition[b]	g/m^3	not used	not used	0.0001	0.0001
Depth of soil mixing layer[b]	m	0.15	0.15	0.15	0.15
Depth of roots[b]	m	not used	not used	0.9	0.9
Contaminated fraction					
Drinking water[b]	-[c]	not used	not used	0	1
Household water[b]	-[c]	not used	not used	0	1
Livestock water[b]	-[c]	not used	not used	not used	1
Irrigation water[b]	-[c]	not used	not used	not used	1
Produce[b]	-[c]	not used	not used	not used	1
Meat[b]	-[c]	not used	not used	not used	-1
Milk[b]	-[c]	not used	not used	not used	-1

TABLE A.1 (Cont.)

Parameter	Unit	Value: Scenario A	Scenario B	Scenario C	Scenario D
Groundwater fractional usage (balance from surface water)					
Drinking water[b]	-[c]	not used	not used	not used	1
Household water[b]	-[c]	not used	not used	not used	1
Livestock water[b]	-[c]	not used	not used	not used	1
Irrigation[b]	-[c]	not used	not used	not used	1
Total porosity of the house or building[b]	-[c]	0.1	not used	0.1	0.1
Volumetric water content of cover material[b]	-[c]	not used	not used	not used	not used
Volumetric water content of the foundation[b]	-[c]	0.05	not used	0.05	0.05
Diffusion coefficient for radon gas	m^2/s				
in cover material		not used	not used	not used	not used
in foundation material[b,f]		2.0×10^{-8}	not used	2.0×10^{-8}	2.0×10^{-8}
in contaminated zone material[b,f]		2.0×10^{-6}	2.0×10^{-6}	2.0×10^{-6}	2.0×10^{-6}
Emanating power of radon gas[b,f]	-[c]	0.2	0.2	0.2	0.2
Radon vertical dimension of mixing[b]	m	2.0	2.0	2.0	2.0
Average annual wind speed[a]	m/s	5.3	5.3	5.3	5.3
Average building air exchange rate[b,f]	hr^{-1}	1.0	not used	1.0	1.0
Height of the building (room)[b]	m	2.5	not used	2.5	2.5
Bulk density of building foundation[b]	g/cm^3	2.4	not used	2.4	2.4
Thickness of building foundation[b]	m	0.15	not used	0.15	0.15
Building depth below ground surface[b]	m	1.0	not used	1.0	1.0

[a] Values based on site specifications as documented by DOE (1992, 1993a, and 1994).

[b] Values based on scenario assumptions or default parameter value.

[c] Parameter is dimensionless.

[d] Distribution coefficient values for uranium are based on laboratory analyses of site-specific soil samples from the Wayne site (DOE 1993b); values for radioactive decay products are based on published values for similar soil types (Baes et al. 1984; Sheppard and Thibault 1990).

[e] Radionuclide is a decay product.

[f] Values based on scenario assumptions specified by DOE (1993a).

[g] Mass loading for inhalation assumes that the total mass loading of airborne particulates is 200 $\mu g/m^3$, that 50% of the airborne particulates originated from soil or soil-like material, and that 30% of the airborne particulates are of respirable size (DOE 1993a).

APPENDIX REFERENCES

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Qualitative Assessment of Remediation Worker Risk

Remediation workers will be exposed to site contaminants while implementing Alternative 3 or 4. This exposure will be controlled according through the use of site controls (e.g., dust suppression, access restrictions, protective clothing), internal radiation monitoring, if appropriate (i.e., bioassay samples), and external radiation monitoring (i.e., personal dosimeters). Construction activities will comply with a USACE-approved health and safety plan and will comply with appropriate federal regulations (e.g., 10 CFR 20 limits for radiation workers and OSHA regulations for general construction activities). Because exposure to a remediation worker will be closely monitored and controlled, it is exceedingly difficult to predict exposures based on current site conditions alone. That is, a default residential scenario may be defined and exposure estimates to a resident are usually considered conservative but reasonably accurate. The exposure to a remediation worker is highly unpredictable given the use of remote handling and heavy equipment such as backhoes, access restriction and personal protective clothing, general health and safety practices, and ALARA (as low as reasonably achievable). For these reasons, the exposure to a remediation worker is only considered qualitatively. It is, therefore, assumed that a remediation worker's exposure will be controlled to within the appropriate limits and will be ALARA.

EXPOSURE TO THE GENERAL PUBLIC DURING REMEDIAL ACTION

Potential health impacts of remedial action at the FUSRAP Maywood Superfund Site were assessed by estimating the radiological risks to the general public that could result from exposure to FUSRAP Maywood Superfund Site releases. Such releases could occur during the excavation, treatment, transportation, and disposal activities associated with implementing any one of the action alternatives for the FUSRAP Maywood Superfund Site cleanup.

The scope of this assessment is limited to impacts resulting from remedial action activities. Other components of the risk assessment process are presented in the Baseline Risk Assessment (BRA) (DOE 1993). Assessment of health impacts to the general public during the remediation action period was conducted in accordance with EPA methodology provided in the *Risk Assessment Guidance for Superfund, Part C - Risk Evaluation of Remedial Alternatives* (EPA 1991). Risks associated with no action at the FUSRAP Maywood Superfund Site were estimated in accordance with EPA methodology for conducting baseline risk assessments. The methodologies used for the exposure assessment, toxicity assessment, and risk characterization are described in detail in the BRA.

From the analysis of preliminary alternatives in Section 4, four final remedial action alternatives were identified for detailed evaluation. Alternative 1, the no-action alternative, was evaluated for the purpose of comparison with the action alternatives. The potential impacts to human health and the environment associated with Alternative 1 are presented in the BRA. Alternative 2, which maintains status quo at the FUSRAP Maywood Superfund Site (monitoring and institutional controls), would not result in additional exposures over Alternative 1. The impacts associated with the two excavation alternatives, Alternatives 3 and 4, are discussed below.

POTENTIAL RECEPTORS AND EXPOSURE SCENARIOS

Table C-1 summarizes the alternatives presenting a remedial action exposure scenario to the general public considered in this assessment. The general public could potentially be exposed to radioactive COCs from the FUSRAP Maywood Superfund Site via airborne dust and gaseous emissions generated during the remediation effort and following remediation for action alternatives where impacted material remains encapsulated at the FUSRAP Maywood Superfund Site. Potential receptors include nearby residents and individuals working at commercial facilities near the FUSRAP Maywood Superfund Site.

Table C-1. Alternatives Evaluated for General Public Exposure

Alternative	General Public During Remediation
1	NP
2	NP
3	Evaluated
4	Evaluated

NP = no pathway

Although other potential receptors could be identified for the general public (e.g., individuals driving by the FUSRAP Maywood Superfund Site, or visitors to the FUSRAP Maywood Superfund Site), risks to these receptors were not evaluated because their exposures would be substantially less than those estimated for the specific receptors identified in this analysis. In addition to assessing the potential health risks to individual receptors, the potential collective health risks associated with exposures to airborne radioactive COCs were assessed for the population within an 80-km (50-mi.) radius of the FUSRAP Maywood Superfund Site.

EXPOSURE PATHWAYS

The principal source of possible exposures at Maywood is radiologically contaminated soil. Remedial action activities such as excavation and loading for disposal could provide a mechanism for COC release. Fugitive dust would be generated during waste excavation, loading, treatment, unloading, and waste placement activities. Surface water and sediment transport would be subject to engineering controls and would not be expected to contribute to COC migration.

The principal COC release mechanisms and transport media associated with such activities are:

- Emission of gamma radiation from radioactively impacted material to the atmosphere,
- Resuspension of radioactively impacted particulate material to the atmosphere through erosion of soil or agitation of soil during remediation,
- Emission of radon gas from radium impacted soil to the atmosphere, and

The potential routes of human exposure to FUSRAP Maywood Superfund Site COCs presented in this assessment are:

- Inhalation of radon and its short-lived decay products,
- External gamma irradiation,
- Inhalation of radioactively impacted airborne dust,
- Incidental ingestion of radioactively impacted soil, and
- Groundwater ingestion.

EXPOSURE POINT CONCENTRATIONS

Soil

Exposure point concentrations of radioactive COCs were estimated for each alternative. Because the different remedial action alternatives at the FUSRAP Maywood Superfund Site involve the handling of material from several distinct source areas that are impacted with varying concentrations of different COCs, and the workers are assumed to be relatively mobile, COC concentrations were developed which are representative of the FUSRAP Maywood Superfund

Site as a whole. The data from all boreholes and soil samplings (both surface and subsurface) from the individual areas site-wide were aggregated for Alternatives 3 and 4 and overall FUSRAP Maywood Superfund Site exposure point concentrations for radionuclides were obtained. The upper confidence limit on the mean (i.e., UCL_{95}) was calculated based on log-normally distributed statistics and was used as the reasonable maximum exposure (RME) point concentration. The RME is reported in this assessment as a reasonable estimate of the maximum exposure likely to be received to estimate all risk exposures. The concentrations of radioactive COCs for the areas undergoing remediation in each of the alternatives are presented in Table C-2.

Table C-2. Radionuclide Concentrations (pCi/g) in FUSRAP Maywood Superfund Site Soils

Alternative[a]	Th-232 + D[b]			Ra-226 + D		U-238 + D			U-235 + D[c]		
	Th-232	Ra-228	Th-228	Ra-226	Pb-210	U-238	U-234	Th-230	U-235	Pa-231	Ac-227
3 and 4	**4.0**	4.0	4.0	0.91	0.91	4.0	4.0	4.0	0.2	0.2	0.2

Shaded area indicates measured concentrations.

[a] All the soil that is remediated under an alternative is aggregated as a homogeneous unit. The values are calculated RME concentrations.

[b] + D denotes secular equilibrium was assumed to derive concentrations for associated decay products (non-shaded areas)

[c] U-235 + D concentrations are 5% of U-238 value.

The soil data presented in the RI Report (BNI 1992) and historical data from the FUSRAP Maywood Superfund Site were used in this assessment. Soil samples were analyzed for U-238, Ra-226, and Th-232. The decay progeny associated with these nuclides are assumed to be in secular equilibrium. Alternatives involve either complete or substantial excavation of the impacted material. The exposure point concentrations for these alternatives were developed by aggregating all soil data for the FUSRAP Maywood Superfund Site. The data set includes between 4,848 and 5,020 individual samples, depending on the analyte.

Air

Airborne COCs concentrations of radionuclides other than radon were estimated from the concentrations in soil being remediated. Separate methods were used to estimate onsite concentrations and fugitive emissions offsite. The methods are discussed below.

Onsite

Onsite receptors will be exposed to airborne COCs resuspended from the soil. A mass loading value of 6×10^{-4} g/m^3 was assumed to represent the concentration of dust in air at the FUSRAP Maywood Superfund Site (Yu et al. 1993). All of the dust was assumed to originate from impacted soil. The respirable portion of the total particulate concentration was assumed to be 30% (Paustenbach 1989).

The COC concentration in onsite air (pCi/m^3) potentially available for inhalation was estimated for each radiological COC as follows:

$$C_{air,i} = C_{soil,i} \times Dust_{air} \times 0.3 \times 0.1$$

where:

$C_{soil,i}$	=	soil concentration of radionuclide i (pCi/g),
$Dust_{air}$	=	mass loading of dust in air (6×10^{-4} g/m^3),
0.3	=	30% of the dust is of respirable size, and
0.1	=	concentration reduction by respiratory protection.

Offsite

Particulate concentrations at the exposure points beyond the FUSRAP Maywood Superfund Site perimeter were estimated by determining the concentration of each radionuclide released from the FUSRAP Maywood Superfund Site. The airborne release rate from the FUSRAP Maywood Superfund Site was based on EPA-derived (EPA 1985) emission factors for construction activities. The alternatives (2 through 4) involve various combinations of dust generating operations such as loading and unloading radioactive soil (batch drops), wind erosion of exposed materials, and movement of equipment across impacted areas. All volume, project duration and other applicable data were taken from the 1997 Maywood detailed cost analysis. To simplify modeling and to provide conservative dose estimates, it is assumed that the same fugitive emissions are released by Alternatives 3 and 4.

The following equation was used to estimate the COC release rate during material loading and unloading:

$$Ci/y = C_R \times 1 \times 10^{-12} \times F_{3or10} \times M_{3or10,alt,T\,or\,UT} \times 1{,}000 / YTI$$

where:

C_R	=	radionuclide concentration in soil (pCi/g),
1×10^{-12}	=	conversion from pCi to Ci (Ci/pCi),
F_{3or10}	=	emission factor for a 3 yd^3 drop or a 10 yd^3 batch drop (kilogram/megagram or kg/Mg)
$M_{5or10,alt,TorUT}$	=	total soil mass from 3 or 10 yd^3 batch drops during a specified alternative with treated or untreated soil (Mg),
1,000	=	conversion from grams to kilograms (g/kg), and
YTI	=	years to implement or alternative duration is 6.0 for Alternatives 2, 3, and 4 and 7.0 for Alternative 5.

A 90 percent dust control efficiency is applied to treated soil due to a combination of chemical and water treatment. A 50 percent dust control efficiency is applied to untreated soil from water spraying (EPA 1985).

Fugitive emissions from vehicular traffic (during excavation) was estimated using the following equation:

$$Ci/y = C_R \times 1 \times 10^{-12} \times F_V \times M_{V,alt} \times 1{,}000 / YTI$$

where:

C_R	=	radionuclide concentration in soil (pCi/g),
1×10^{-12}	=	conversion from pCi to Ci (Ci/pCi),
F_v	=	emission factor for a dust mass released per vehicular kilometer traveled (kg/VKT)
$M_{v,alt}$	=	total VKT during a specified alternative (km),

1,000	=	conversion from grams to kilograms (g/kg), and
YTI	=	years to implement or alternative duration (years).

Vehicle miles were estimated assuming that a ten-wheel, 10 yd^3 truck was used to transport the impacted material. The release fraction was developed using methodology from EPA 1985, where the truck was assumed to weigh 25 tons empty, averaging 2 mph over 100 meters per trip (one-way) between the excavation face and the loadout or treatment facility. A 50% dust control efficiency over general construction conditions was also assumed.

Fugitive emissions from wind erosion (during excavation) was calculated using the following equation:

$$Ci/y = C_R \times 1 \times 10^{-12} \times F_W \times M_{W,alt} \times 1{,}000 \,/\, YTI$$

where:

C_R	=	radionuclide concentration in soil (pCi/g),
1×10^{-12}	=	conversion from pCi to Ci (Ci/pCi),
F_w	=	emission factor for a dust mass released per unit surface area per day (kg/hectare/day)
$M_{w,alt}$	=	surface area times the number of days the material is exposed for each alternative (hectare days),
1,000	=	conversion from grams to kilograms (g/kg), and
YTI	=	years to implement or alternative duration (years).

The surface area was determined by assuming one week's worth of excavated material would be exposed year round (approximately 0.1 hectare for all alternatives). A 40-week work year is assumed.

The alternative-specific parameters and the resultant estimates of airborne dust emissions for the cleanup period are presented in Table C-3. Only estimates for fugitive dust originating from impacted areas were used in this assessment; estimates of dust generated by the movement of construction equipment on unimpacted areas were not included.

The fugitive dust emissions were used to estimate potential inhalation exposures for offsite receptors. The radionuclide emission rates for the various alternatives are presented in Table C-4. The predicted emissions are for the complete implementation of the given alternative. Since the excavation/treatment phases of all alternatives exceed one work year, the calculated total emissions were divided by the total number of years to complete action, representing the annual emission rate. Changes in the implementation time would change the annual fugitive dust release rate, and hence the annual dose to the maximum exposed individual, but not the cumulative collective population dose.

ESTIMATED DOSES AND INTAKES OF COCs

Estimates of exposure are based on the COC concentrations at the exposure points and scenario specific assumptions and intake parameters.

For radioactive COCs the exposure is expressed in terms of the effective dose equivalent for all exposure pathways.

Table C-3. Estimated Airborne Fugitive Dust Releases

		Fugitive Emissions (kg/yr)				
Alternative	Years to Implement	Vehicular Traffic	Pre-Treatment[a]	Post-Treatment[b]	Wind Blown	Total[c]
3 Excavation of Accessible Soils	≈ 6.0	567	122	5.9	525	1,220
4 Excavation of Accessible Soils with Treatment	≈ 6.0	567	122	5.9	525	1,220

[a] With 50% dust control efficiency.
[b] With 90% dust control efficiency.
[c] Total emissions for remediation, annual emissions are assumed to be reduced by dividing the total emissions by the implementation time.
N/A = not applicable

Table C-4. Radionuclide Emissions (Ci/yr) for CAP88 Analysis

Alternative	Th-232 + D			Ra-226 + D[a]		U-238 + D			U-235 + D[b]		
	Th-232	Ra-228	Th-228	Ra-226	Pb-210	U-238	U-234	Th-230	U-235	Pa-231	Ac-227
3 and 4	4.88E-06	4.88E-06	4.88E-06	1.11E-06	1.11E-96	4.88E-06	4.88E-06	4.88E-06	2.24E-07	2.24E-07	2.24E-07

Shaded area indicates measured concentrations
[a] + D denotes secular equilibrium was assumed to derive concentrations for associated decay products (non-shaded areas)
[b] U-235 + D concentrations are 5% of U-238 value

General Public

The general public could be exposed both to COCs released during the remediation period and to materials remaining onsite after remediation. Fugitive dust emissions are the principal release mechanism during remediation. After remediation, members of the general public who reoccupy the FUSRAP Maywood Superfund Site could be exposed to residual COCs.

The CAP-88PC computer code (Parks 1991) was used to estimate both collective population, and maximally exposed individual, dose and risk. CAP-88PC is intended for use in estimating radiation dose equivalents and risks from radionuclides emitted into the air. The code consists of computer models, databases, and associated utility programs developed by the EPA for assessing compliance of radionuclide releases with limits established under the Clean Air Act. CAP-88PC considers exposures to emitted radionuclides from inhalation of and immersion in impacted air; ingestion of meat, milk, and vegetables; and direct exposure to impacted land surfaces. The analysis was performed using the urban setting default parameters for ingestion quantities and other exposure sources. Radiation dose equivalents to the maximally exposed individual and to regional populations within 80 km (50 mi) of the emission source were calculated. Doses for the maximally exposed individual are estimated for the location of highest risk. The collective population dose is found by summing, for all sector segments, the intake and exposure rates multiplied by the appropriate dose conversion factor. Collective population dose is reported in person-rem/year.

CAP-88PC uses a modified Gaussian plume equation to calculate radionuclide-specific average ground level air concentrations at selected locations. Radon exposures were not modeled because actual radon measurements at the FUSRAP Maywood Superfund Site indicate that radon flux is minimal and would not significantly contribute to the dose and risk estimates.

Radiological exposures were calculated for an individual receptor with pathway-specific equations and receptor-specific intake parameters. For each pathway, the exposure point concentration was multiplied by the quantity of the intake and the appropriate dose conversion factor, which gives the dose (in mrem) for a unit intake of a radionuclide. In addition to inhalation, airborne COCs released during the cleanup period could settle on the ground, resulting in three additional pathways: direct external gamma irradiation, incidental ingestion of soil and ingestion of food. Although these three potential exposure pathways are not expected to be significant, the radiation doses from these pathways were included for completeness.

The estimated dose to the hypothetical maximally exposed member of the general public at 50 m (160 ft) from the FUSRAP Maywood Superfund Site is 0.049 mrem/yr for Alternatives 3 and 4. As shown on Table C-5, the estimated dose is even smaller for the other alternatives. The results of this analysis indicate that no individual would receive a dose from the combined exposure pathways that could be associated with FUSRAP Maywood Superfund Site activities in excess of 15 mrem/year.

Table C-5. Maximum Individual and Collective Population Dose and Risk Summary

Alternative	Maximum Individual[(a)]			Population Collective Dose[(a)]	
	Dose Rate (mrem/yr)	Total Dose[b] (mrem)	Risk[c]	Dose Rate (mrem/yr)	Total Dose[b] (mrem)
Alternatives 3 and 4	0.049	0.29	1.7×10^{-7}	0.25	1.5

[a] To offsite member of the public from fugitive emissions.

[b] Total dose = (Dose Rate) × (Alternative Duration) where Alternative Duration is 6.0 years for Alternatives 2, 3, and 4, and 7.0 years for Alternative 5.

[c] Risk = (Total Dose) × (6×10^{-7}) where 6×10^{-7} is the risk of excess cancers per mrem.

Radiological risks to the public were estimated using a dose to risk conversion factor. The maximum individual dose for each alternative (Table C-5) was multiplied by 6×10^{-7} excess cancers per mrem to estimate the annual risk from remediation. The annual risk was multiplied by the implementation time (in years) to estimate the total excess cancer risk from each alternative.

Offsite population doses from radioactive COCs were calculated for all persons residing within a 80 km (50 mi.) radius of the FUSRAP Maywood Superfund Site (Table C-5). The population distribution assumed for the CAP-88 calculations was derived using 1990 census data (von Buelow 1994). The maximum estimated collective dose to the population residing within this area during the remedial action period is 1.5 person-rem.

HEALTH RISK EVALUATION FROM EXPOSURE TO COCs

Radiological risks were determined using a dose to risk conversion factor of 6×10^{-7}, integrating the annual doses over the implementation time. The health risk evaluated is the induction of cancer related to exposure to low levels of ionizing radiation. The lifetime individual risks to members of the general public from radiation exposure during remedial action activities would be low, i.e., much less than 1×10^{-6} for all receptors. It is unlikely that any cancer induction in offsite individuals would result from FUSRAP Maywood Superfund Site cleanup.

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SECTION 5 TO APPENDIX C

ASSESSMENT OF REMEDIAL ALTERNATIVE PROTECTIVENESS

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1 INTRODUCTION

The U.S. Army Corps of Engineers (USACE) is addressing this site under its Formerly Utilized Sites Remedial Action Program (FUSRAP) and has prepared a Feasibility Study (FS) to which this document is attached as a section 5 of appendix (C). Potential human health impacts due to remedial action at the FUSRAP Maywood Superfund Site (the "Site") were assessed by estimating the risks to workers and the general public that could result from exposure to radiological contaminants on, or released from, the site. Potential exposures include exposure to potentially contaminated dust during remediation, exposure of workers preparing the site for release, contaminants in fugitive emissions released during excavation activities, and exposure of future occupants after the site is released. Potential impacts for the remedial action alternatives were evaluated to estimate the increased likelihood of cancer induction as a result of exposure to site contaminants. The approach used for the human health evaluation is based on the Environmental Protection Agency (EPA) guidance in *Risk Assessment for Superfund Volume I, Human Health Evaluation Manual (Part A)* (RAGS Part A) (EPA 1989). Assessment of health impacts to workers and the general public during the remediation action period was conducted in accordance with EPA methodology provided in the *Risk Assessment Guidance for Superfund, Part C - Risk Evaluation of Remedial Alternatives* (EPA 1991).

Four cleanup alternatives are considered as defined below:

Alternative 1 - No Action: Site is released for unrestricted use in its current condition;
Alternative 2 - Monitoring and Institutional Controls: Site is released for unrestricted use in its current condition with continued monitoring of site conditions and institutional controls such as access restrictions to prevent additional exposures beyond current uses of some properties at the Site and to reduce exposures at other properties at the Site;
Alternative 3 – Excavation and Disposal of Accessible and Inaccessible Soils: Site is released after removal and offsite disposal of contaminated accessible and inaccessible soils above the appropriate clean up criteria, with institutional controls for properties which are not remediated to the unrestricted use criterion; and
Alternative 4 – Excavation, Treatment, and Disposal of Accessible Soils; and Excavation and Disposal of Inaccessible Soils: Site is released after removal and offsite disposal of contaminated accessible and inaccessible soils above the appropriate clean up criteria, and, if treatment is proven effective, treated soils are used as backfill on commercial properties, with institutional controls for properties which are not remediated to the unrestricted use criterion. A clean cover of at least 1 foot in thickness is maintained over all areas subject to backfilling with treated materials.

Five exposure scenarios are evaluated including an onsite residential, an offsite residential, an industrial worker, a maintenance worker, and a remediation worker. The offsite residential scenario is used to estimate the risks from release of fugitive emissions during remedial activities for Alternatives 3 and 4. The offsite resident and the remediation worker are evaluated to address the short-term effectiveness (i.e., approximating risks that occur during the implementation of remedial alternatives) of each alternative. The risks to the offsite resident and the remediation worker are discussed in the Qualitative Assessment of Remediation Worker Risk and Exposure To the General Public During Remediation sections of this appendix (See page C-37 and C-38). All other scenarios are considered to evaluate the long-term effectiveness (approximating risks from exposure to onsite residual contamination) of each alternative and are presented below.

The site Baseline Risk Assessment (BRA) (DOE 1993a) evaluated the baseline risk from exposure to contaminants at the Site. Risks from exposure to chemicals are estimated using standard RAGS equations (EPA 1989) and slope factors found in Integrated Risk Information System (IRIS) (EPA 1998) and Health Effects Assessment Summary Tables (HEAST) (EPA 1995). The BRA is summarized in section 2.6 of this document. Since the release of the BRA for public comment, additional site information has been collected. Risks from post remedial action exposure to radionuclides in soil for Alternatives 3 and 4 are estimated using the RESRAD computer code Version 6.0 (which uses the RAGS methodology and HEAST factors, and which was developed by Argonne National Laboratory).

2 SELECTION OF CONTAMINANTS OF POTENTIAL CONCERN (COPCs)

2.1 RADIONUCLIDE SCREENING

The FUSRAP Maywood Superfund Site is being addressed under FUSRAP because is contains elevated concentrations of radionuclides as a result of processing monazite sands and because the Site was assigned by the U.S. Congress to DOE, who then designated the Site for FUSRAP. In 1997-8 the USACE was then identified as the lead agency for FUSRAP implementation. Monazite sands are known to contain elevated concentrations of radionuclides from the three naturally occurring decay series. Radionuclide contaminants of potential concern (COPCs), therefore, include all members of the uranium, thorium, and actinium series. Cancer slope factors are limited to radionuclides with half-lives of six months or longer. Short-lived decay products are included in slope factors for the long-lived radionuclides so that they need not be included explicitly. The list of long-lived radionuclides includes uranium-238 (U-238), U-234, thorium-230 (Th-230) and radium-226 (Ra-226) from the uranium series, Th-232, Ra-228 and Th-228 from the thorium series; and U-235, Pa-231 and Ac-227 from the actinium series. The site database contains mostly data on U-238, Ra-226 and Th-232 and little or no data on remaining radionuclides. However, the intimate relationship between radionuclides in these series can be used to estimate concentrations for the other radionuclides. Therefore, this is not considered to be a data gap.

While concentrations of U-238 and Ra-226 may be estimated by summarizing characterization data, concentrations of U-234 and Th-230 must be estimated using different means. Because U-238 and U-234 are chemically identical, and the uranium was neither depleted or enriched, it can be assumed that these radionuclides are in equilibrium (i.e., are present at the same concentration). Because the thorium extraction process at Maywood would have removed Th-230 as well as Th-232, Th-230 is likely not in equilibrium with other radionuclides in the series.

Radionuclides in the thorium series are assumed to be in " equilibrium" (when a long-lived radionuclide decays into a short-lived daughter, and the activity of the daughter radionuclide approaches that of the parent, reaching equilibrium) because sufficient time has passed since the last extraction operations. In fact, an analysis of site data show Th-232 (the first long-lived radionuclide, with a half-life of 14 billion years) in equilibrium with Th-228 (the last long-lived radionuclide, with a half-life of 1.9 years).

Members of the actinium series are assumed to be present at approximately five % of the U-238 concentration. This is because the uranium was neither enriched nor depleted, thus all uranium including U-235 is assumed to be present in natural abundance. In nature, U-235 is present at 4.6 % of the U-238 concentration. Because there is no evidence that the extraction process affected Pa-231 or Ac-227, they are assumed to be present in equilibrium with (at the same concentration as) U-235. All members of the actinium series are, therefore, assumed to be present at 4.6 % of the U-238 concentration.

The relative radionuclde concentrations are calculated based on the relative magnitude of measured Th-232, Ra-226, and U-238, concentrations in soils at the FUSRAP Maywood Superfund

Site. The concentration of Ra-226 is assumed to be approximately 25percent of the Th-232 concentration, based on a review of site characterization data (the Ra-226:Th-232 concentration ratio ranges from approximately 0.05 to 0.28 for residential properties, and from 0.005 to 0.26 for commercial\industrial properties, with a site-wide average of 0.23), and the composite concentration of Ra-226 and Th-232 is constrained to 15 picocurries/gram (pCi\g) (EPA 1994). Th-230 concentrations are assumed to be equivalent to Ra-226 concentrations in soil (a conservative measure since Th-230 would have been removed in the MCW milling operation). The 5 and 15 pCi/g criteria are not applicable to uranium, for which a site-specific concentration limit is derived; however, a review of the site characterization data indicates that the U-238 concentration measurements in soil are similar to the Th-232 concentrations (the U-238: Th-232 ratio ranges from 0.35 to 1.7 for residential properties and from 0.14 to 3.3 for commercial\industrial properties, with a site-wide average of 1.0), and the concentration of U-238 and progeny is assumed to be equal to the residual Th-232 concentration for evaluation of residual risk (EPA 1994).

2.2 NONRADIONUCLIDE SCREENING

This appendix focuses upon the cancer risk associated with radiological contaminants at the Site. As indicated in the body of the FS, the U.S. Department of Energy's ["DOE", predecessor to USACE for implementation of the FUSRAP)] BRA for the Site also calculated some potentially significant ecological risk associated with some wetlands at the Site. For this reason, Alternative 1 (No Action) is considered unprotective for ecological risk, as well as for human health. Alternatives 3 and 4 are considered protective for ecological risk, as well as for human health, because the sediment contamination in the wetlands is above the human health criterion for soil/sediment, and the contaminated sediments would be removed from the wetland. (Such activity would comply with New Jersey's Freshwater Wetland Mitigation Requirements, which are considered an ARAR in this FS.) Alternative 2, Monitoring and Institutional Controls, is also presumed to be unprotective for ecological risk, since institutional controls would not be effective for reducing nonhuman exposure to contamination. However, the ecological assessment completed by DOE in 1993 is considered a screening level assessment. It is possible that additional data could be collected on the Site, and a more detailed ecological assessment completed, consistent with EPA guidance, and find protective levels of ecological risk. (As more data is collected in order to complete more detailed ecological assessments, uncertainty is often reduced, resulting in lower levels of ecological risk.)

DOE's 1993 BRA also addressed cancer risk from chemical, non-radiological contaminants. Except for groundwater, which is not addressed by this FS as part of this operable unit, no cancer risks for chemicals above the CERCLA protective range were calculated for the Site. While it is true that both the radiological and chemical carcinogens at the Site may both present some human cancer risk, the chemical cancer risk calculated by DOE in the 1993 BRA would not cause Alternatives 2, 3 or 4 to exceed the CERCLA protective range if chemical and radiological cancer risks were added.

Finally, DOE's 1993 BRA also addressed noncancer toxicity related to potential human exposure to chemical contamination at the Site. Again except for groundwater, which is not addressed by this FS as part of this operable unit, no unprotective levels of human noncancer risk were calculated (See section 2.6.2.3 of the Feasibility Study).

3 EXPOSURE ASSESSMENT

3.1 LAND USE

If the Site were released without restrictions or institutional controls after the final remedy has been implemented, there are several potential land uses. Areas surrounding portions of the Site are residential, so one option is that the land is converted into residential parcels. A residential exposure scenario is evaluated under Alternatives 1, 3, and 4. It is conceivable that a commercial/industrial facility could be constructed on portions of the Site after its release. Because the industrial scenario is the current zoned land use, an industrial receptor is considered under Alternatives 1, 2, 3, and 4. Site security measures could continue after the final remedy is implemented. The future land uses which are considered reasonable, therefore, include residential as well as industrial uses.

3.1.1 Identification of Receptors

Table C-1 summarizes the potential receptors and exposure pathways considered in this assessment. Exposure pathways include direct gamma, soil ingestion, soil/dust inhalation, drinking water (although groundwater is not considered part of the operable unit addressed by this FS) and produce consumption (resident only). All receptors are exposed on-site to contaminants in soil, or in the case of the industrial worker, additional exposure to radiological contaminants in building surfaces is also considered. The offsite resident and the remediation worker are considered to evaluate the short-term effectiveness of each alternative. The onsite resident, industrial worker, maintenance worker and recreational receptor are considered to evaluate the long-term effectiveness of each alternative. Exposure to drinking groundwater was included as a conservative measure, however the potential for groundwater contamination is currently being investigated and will be addressed under a separate operable unit.

Onsite Resident

The onsite resident is assumed to live on site for 365 days per year for 30 years. Each day the resident is assumed to spend 16.4 hours indoors and 2.0 hours outdoors onsite. This individual ingests 70 g of soil and breaths 6000 m^3 of air per year. It is also assumed that the resident has a small garden equating to 17.136 kilograms per year of homegrown crops and obtains all drinking water (700 l/yr) from an onsite well. No cover is assumed to be maintained. However, contamination onsite is initially present in the subsurface soils and is assumed to be brought to the surface (with mixing) during construction of the residence. Exposure pathways include external gamma, inhalation, ingestion, drinking water, and produce ingestion.

Industrial Worker

The industrial worker is assumed to be onsite for 6.3 hours per day while indoors and 1.75 hour per day while outdoors. The worker is at the site for 250 days per year for 30 years. It is assumed that the industrial worker ingests 12.5 mg of soil and breaths 12000 m^3 of air per year and obtains 100% of his/her drinking water (700 l/yr) from an onsite well. For Alternatives 1, 2, and 3, no clean cover is assumed to be present, however, contamination onsite is initially present in the subsurface soils and is brought to the surface (with mixing) during facility construction so the industrial worker is exposed to contaminants in soils. A clean 1 ft cover is maintained over treated backfill material for Alternative 4. It is also assumed that the industrial worker has an office or work space in a building built on a portion of the site with residual contamination or treated backfill for Alternative 4. Exposure pathways include external gamma, inhalation, ingestion, and drinking water.

Table C-1. Potential Receptors

Alternative	Exposure Scenarios and Pathways		
	Scenario	**Pathways**	**Assumptions**
1	Residential	Direct gamma, soil ingestion, dust inhalation, drinking water, and produce consumption.	Site released in current condition.
	Industrial	Direct gamma, soil ingestion, dust inhalation, and drinking water	Site released in current condition.
2	Monitoring	Direct gamma, soil ingestion, and dust inhalation.	Cover and institutional controls assumed to preclude exposures greater than the criteria.
3	Residential	Direct gamma, soil ingestion, dust inhalation, drinking water, and produce consumption.	Exposed to residual contaminants in soil after remedial action.
	Industrial	Direct gamma, soil ingestion, dust inhalation, and drinking water	Exposed to residual contaminants in soil after remedial action.
4	Residential	Direct gamma, soil ingestion, dust inhalation, drinking water, and produce consumption.	Exposed to residual contaminants in soil after remedial action.
	Industrial	Direct gamma, soil ingestion, dust inhalation, and drinking water	Exposed to residual contaminants in soil after remedial action potentially including backfill with treated material.

Maintenance Worker

Given the discussion for an industrial worker above, the industrial worker receptor represents a reasonable maximum risk for a maintenance worker that visits the Site routinely and whose activities involves limited soil disturbances, such as lawn mowing.

Treated material may be used as backfill in Alternative 4. It is assumed that a 1ft clean cover will be maintained and any maintenance requiring breaching of the cover will be conducted using methods designed to reduce exposures to radiological contaminants thus risks would be controlled accordingly. The industrial worker receptor represents a maximum risk for a maintenance worker without breaching the cover.

3.1.2 Short-term Effectiveness

The offsite resident and the remediation worker are evaluated to address the short-term effectiveness (i.e., approximating risks that occur during the implementation of remedial alternatives) of each alternative. The risks to the offsite resident and the remediation worker are discussed in the Qualitative Assessment of Remediation Worker Risk and Exposure To the General Public During Remediation sections of this appendix (See page C-37 and C-38).

3.1.3 Long-term Effectiveness

Long-term effectiveness is an evaluation of those risks that occur after the implementation of each alternative. Three potential receptors are considered in this evaluation including an onsite resident, a maintenance worker, and an industrial worker. These potential receptors are considered the most plausible and maximum exposed individuals as defined by the remedial alternative. Each potential receptor is defined below. Tables C-2 and C-3 include site-specific parameters used in RESRAD calculations to complete exposure calculations. Exposure parameters were taken from the 1997 Exposure Factors Handbook Volumes 1, 2, and 3, where available. When acceptable exposure assumptions could not be obtained from the 1997 Exposure Factors Handbook, then values from RESRAD, the State of New Jersey guidance, or other EPA risk assessment guidance were then used.

Table C-2. RESRAD Input Parameters

Parameter	Units	Value
Breathing Rate	m^3/yr	6000
Soil ingestion rate	g/yr	70
Onsite crop ingestion	g/yr	17,136
Drinking water intake	l/yr	700
Shielding factors	none	0.8 (basement)
Outside shielding factor	none	1
Fraction of time indoors	none	68%
Fraction of time outdoors	none	8%
Exposure duration	yr	30
Contaminated area	m^2	1000
Percolation rate	m/yr	0.54
Soil density	g/cm^3	1.6
Unsaturated zone thickness	m	0.5
Contaminated zone thickness	m	0.3
Length parallel to aquifer flow	m	32
Density of fill	g/cm^3	1.5
Soil erosion rate	m/yr	6E-5
Fraction of drinking water from onsite well	none	1
Commercial/Industrial (If Different from Residential)		
Parameter	**Units**	**Value**
Breathing Rate	m^3/yr	12000
Soil ingestion rate	g/yr	12.5
Crop ingestion	kg/yr	0
Shielding factors	none	0.56 (slab assumed)
Outside shielding factor	none	1
Fraction of time indoors	none	18%
Fraction of time outdoors	none	5%
Exposure duration	yr	30

Table C-3. Site Specific Geotechnical and Other Assumptions.

Parameter	Units	Value
Contaminated zone porosity	-	0.45
Contaminated zone hydraulic conductivity	m/yr	1.23
Saturated zone porosity	-	0.45
Saturated zone effective porosity	-	0.26
Saturated zone hydraulic conductivity	m/yr	123
Hydraulic gradient	-	0.01
Unsaturated zone thickness	m	1-4 (0.5 assumed)
Unsaturated zone porosity	-	0.45
Unsaturated zone effective porosity	-	0.26
Unsaturated zone hydraulic conductivity	m/yr	1.23
Precipitation rate	m/yr	1.07
Run off coefficient	-	0.25
Soil b parameter	-	5.3
Well intake depth	m	10
Soil erosion rate	m/yr	6E-5
Distribution Coefficients (Kd)	cm^3/g	Thorium – 60,000 Radium – 450 Uranium – 250 Lead – 900 Actinium – 1,500 Protactinium – 2,500

3.2 MIGRATION AND EXPOSURE PATHWAYS

Radiologically contaminated soil is the principal source of contamination at the FUSRAP Maywood Superfund Site. Exposure pathways associated with COPCs in soil include direct gamma radiation, soil ingestion, soil inhalation, drinking water, and produce ingestion (resident only).

3.3 EXPOSURE POINT CONCENTRATIONS

There are two potential modes of exposure at the Site including exposure to contaminants in soil and exposure to contaminants in the site building. Development of the exposure concentrations for each mode is provided below.

3.3.1 Soil

Exposure point concentrations of radiological contaminants were estimated for each alternative. The Alternative 1 (No Action) source term (e.g. activity of radiologically contaminated soil) is from the BRA. Because Alternative 2 only requires monitoring and institutional controls, the source term for Alternative 2 is the same as for Alternative 1 for all potential receptors. The Alternative 3 and 4 source terms are developed to estimate residual concentrations in site soil after remedial actions are complete and change based on the expected land use (residential or industrial).

The net (above background) concentrations of radioactive contaminants are given in Table C-4. Analytical data collected near the Site show background values for soil to be approximately 0.7 pCi/g for Ra-226, 1 pCi/g for Th-230, 1 pCi/g for Th-232 and 1 pCi/g for U-238 (USACE 2000). Note that Table C-4 also lists source terms assuming the remedial action leaves soil concentrations for the entire Site at the FS soil criteria (e.g., Ra-226 + Th-232 = 5 pCi/g above background resulting in total uranium = 9 pCi/g). Although residual risk is not always modeled at the concentration limits, given that residual concentrations can be estimated using a database of soil sampling results, the limits are modeled in this assessment as requested by EPA Region II. The actual residuals are expected to be less for Alternatives 3 and 4.

The soil data presented in the Remedial Investigation Report (DOE 1992), and historical data from the Site were used in this assessment. Over a thousand soil samples were analyzed for U-238, Ra-226, and Th-232. Decay progeny associated with these radionuclides are assumed to be in secular equilibrium. The Th-230 concentration is assumed to be equal to the Ra-226 concentration based on an analysis of the Th-230 data set and the fact that Th-230 would have been removed in the process extracting Th-232, thus reducing the Th-230 concentration compared to U-238.

The residual radionuclide concentrations assumed for this analysis are considered to be conservative based on an analysis of post-remediation data at the vicinity properties previously cleaned up by USACE to the proposed criteria. A review of these data indicate that residual concentrations of Th-232 are generally below 2 pCi\g (i.e., in only 10% of the 811 final status soil samples collected; Th-232 was greater than 2 pCi\g above background; with only 4 samples greater than 5 pCi/g), and the data suggests the radium source term considered in this analysis is conservative.

Table C-4. Net Residual Radionuclide Concentrations in Soil (pCi/g)[a]

Alternative	Th-232 +D[b]			Ra-226 +D		Th-230	U-238 +D		U-235 +D[c]		
	Th-232	Ra-228	Th-228	Ra-226	Pb-210	Th-230	U-238	U-234	U-235	Pa-231	Ac-227
1 and 2[f]	47	47	47	5	5	27	27	27	1.3	1.3	1.3
3[d] residential	4	4	4	0.91	0.91	1	4	4	0.18	0.18	0.18
3 and 4 industrial	12	12	12	3	3	3	12	12	0.55	0.55	0.55
4[d] maximum treated backfill (industrial only)	12	12	12	3	3	3	12	12	0.55	0.55	0.55
3 and 4 [e]	2	2	2	.45	.45	1	2	2	0.01	0.01	0.01

Shaded area indicates measured concentrations

[a] Background has been subtracted from listed values. If the net value is less than 0.0, 0.0 is listed. Background is assumed to be 0.7 pCi/g for Ra-226, 1 pCi/g for Th-230, 1 pCi/g for Th-232 and 1 pCi/g for U-238. Relevant decay products are assumed to be in equilibrium with their respective long-lived parent. Background for U-235 and decay products assumed to be 0.05 pCi/g.

[b] +D denotes secular equilibrium was assumed to derive concentrations for associated decay products (non-shaded boxes)

[c] U-235 +D concentrations are 5% of U-238 value

[d] Estimated assuming the final concentration = the target cleanup criteria

[e] Estimated residual concentrations after removing contaminant concentrations above the cleanup criteria

[f] Mean surface concentrations from maximum risk property (7H in BRA) Note: the BRA assumed Th-230 = U-238

The exposure point concentrations for Alternatives 1 and 2 were taken from the BRA property (7H) with the maximum risk calculated in the BRA (the property at 96 Park Way was excluded as previously addressed under a removal action). The exposure point concentrations for Alternative 3 and 4 (without treatment) were derived by applying the site isotopic ratios (see section 2.1) to the dispute resolution criteria. For Alternative 4 with treatment, the residual soil data was derived by applying the site isotopic ratios to the maximum allowable concentration for treated backfill as stated in the dispute resolution. [The EPA and DOE (USACE's predecessor on the FUSRAP) had a dispute regarding soil cleanup levels on this site. This dispute was resolved in 1994, and the dispute resolution is contained in section 1 this appendix (C)]. The residual exposure point concentration was developed through analysis of the final status survey samples from properties addressed in recent removal actions.

3.3.2 Onsite Buildings

Buildings on the former Maywood Chemical Works Property may have been contaminated as a result of site activities. All existing buildings have industrial uses. Exposure to residual contamination in buildings as well as site soils results in a cumulative dose and risk to employees which should be considered. Additional data collection is necessary to adequately address site buildings (as explained in FS sections 2.1.5 and 2.4.6) and this concern.

4 RISK CHARACTERIZATION

4.1 METHODOLOGY

Cancer risk from radionuclides is estimated using the RESRAD code Version 6.0 (Yu et al. 1993). The code uses the RAGS methodology to estimate risks from the uptake of radionuclides and the exposure to external gamma radiation over time. In addition to providing results consistent with the basic RAGS methods, RESRAD supplements RAGS by considering the following:

- Decay and ingrowth of radionuclides over time;
- Physical removal of radionuclides (erosion, leaching, etc.) over time; and
- Radiation shielding from material used as clean cover.

RESRAD uses cancer slope factors tabulated in HEAST and lists risks over time so that an assessor may select the year of maximum exposure.

Risk and dose for Alternative 1 are from the BRA. Estimated risk and dose from Alternative 2 is based on institutional controls being implemented to preclude human exposures to site soils in excess of the FS's soil cleanup criteria.

To estimate risks and dose from Alternatives 3 and 4, the parameter values listed in Table C-2, C-3, and the soil concentrations listed in Table C-4 were entered into the RESRAD model. Other scenario-specific information such as exposure pathways and possible cover depths were entered and the model was executed to provide final risk estimates. Results were obtained for years 0 (current year), 1, 3, 10, 30, 100, 300 and 1000.

4.2 UNCERTAINTIES

Exposure parameters were selected to provide a conservative, yet reasonable, estimate of potential exposure and then risks to each receptor. Site-specific measurements and data were used, as appropriate, to describe site conditions as accurately as possible. Where site-specific data were not available, parameter values were chosen to provide reasonably conservative estimates of risk, or standard default values recommended by the RESRAD code or the Exposure Factors Handbook (EPA 1997) were used.

The accuracy of risk calculations is ultimately limited to the accuracy of the site data and risk models. The data used in the assessment include results from several characterization efforts and include different target analytes, analysis methods, and reporting requirements. The data in this assessment are used assuming the best knowledge of the distribution of contaminants in site soils with the goal of providing conservative, yet reasonable, estimates of risk. As an example: Characterization data indicates the typical depth of contamination is greater than 4 feet (site average of 6.5 feet with maximum of 14 feet) resulting in a post remedial action depth of clean backfill (not a maintained cover) greater than 6 feet. To ensure a conservative estimate, contamination was modeled at a 3 foot depth (accounts for regrading of site). The depth of a slab footing was set at 4 feet and a basement was 7 feet below grade. This meant that in either a slab or basement construction scenario some contaminated material would be mixed with the backfill and brought to the surface during construction. Modeling the contamination at other depths would not change the concentration on the surface as long as it is 4 feet or less for the slab scenario and 7 feet or less for the basement scenario. Characterization data indicates, and the requirements for clean backfill and a cover over treated backfill in excavated areas ensures, minimal post remedial action surface contamination. Modeling the cleanup criteria at the surface would be extremely conservative as it is not representative of site conditions and would result in exposures exceeding the NJAC 7:28-12 criteria.

The models used to calculate risks are accepted by EPA and are assumed to provide a reasonable prediction of site risks. After implementation of the final remedial alternative, additional post remedial action data may be used to improve residual risk estimates.

Lifetime cancer risk estimates are provided for exposure to radiological and are compared to the CERCLA target risk range of 10^{-4} to 10^{-6} (defined here as 3E-4 to 1E-6). Radiological risk slope factors have been developed primarily using data from Japanese atomic bomb survivors. These individuals received large doses of radiation over a short period of time. By contrast, potential receptors in this assessment receive relatively small radiological doses over a long period of time. Although cancerous effects have only been detected at doses several orders of magnitude larger than those estimated at the Site, it is assumed that the slope factors apply to both large and small radiological doses.

4.3 RESULTS

Estimated radiological risks for each alternative and receptor are summarized in the following sections. Results are compared to the CERCLA target risk range of 10^{-4} to 10^{-6} and 15 mrem/yr dose limit. Only Alternative 1 is not protective of human health given the ARAR dose criteria and the CERCLA risk range.

The results of the radiological risk assessment for the FUSRAP Maywood Superfund Site are presented in Table C-5.

Table C-5. Radiological Risk Estimates

Alternative	Receptor Risks (lifetime^{-1}) (a)		
	Residential	**Industrial**	**Transient/Maintenance**
1	2 E-2	4 E-3	b
2	b	3 E-4	b
3 (criteria)	1 E-4	1 E-4	1 E-4
3 (residuals)	5 E-5	b	b
4[c] (treated backfill)	b	5 E-5	5 E-5

(a) All values rounded to one significant digit.
(b) Not evaluated for this alternative.
(c) Same risks for Alternative 3 if treatment not utilized. Treated fill requires minimum of 1 foot cover

The results of the radiological dose assessment for the Site are presented in Table C-6.

Table C-6. Radiological Dose Estimates

Alternative	Receptor Dose (mrem/yr) (a)		
	Residential	**Industrial**	**Transient/Maintenance**
1	859	281	191[d]
2	b	15	b
3 (criteria)	7	6	6
3 (residuals)	3.5	b	b
4[c] (treated back fill)	b	4.5	4.5

(a) All values rounded to significant digit.
(b) Not evaluated for this alternative.
(c) Same dose for Alternative 3 if treatment not utilized. Treated fill requires minimum of 1 foot cover.
(d) Maximum as reported from BRA property 6H. Property 7H not evaluated.

The risks to the future resident were estimated for Alternatives 1, 3, and 4. Radiological risks for Alternatives 1 which assumes no remediation, is estimated to be 2 E-2, which significantly exceeds the upper bound of the CERCLA target cancer risk range. Risks to residents under Alternative 2 were not analyzed since this alternative would preclude residential receptors. The radiological risk for Alternative 3 and 4 (without treatment) is estimated to be 1.2 E-4 if it is assumed that all of the site soils are at the limit (i.e., 5 pCi/g above background for Th-232 + Ra-226) or 5.4 E-5 using residual concentration estimates. Treated backfill would not be utilized on properties that may become residential.

The risks to a future industrial worker were estimated for Alternatives 1, 2, 3, and 4. Radiological risks for Alternatives 1 which assumes no remediation, is estimated to be 4 E-3, which exceeds the upper bound of the target risk range. The BRA estimates risks to current employees exceed the CERCLA risk range on some properties, however, under Alternative 2 these exposures would be controlled to ensure that cancer risks do not exceed the CERCLA cancer risk range nor cause a dose of 15 mrem/year to be exceeded. The radiological risk for Alternative 3 and 4 (without treatment) is estimated to be 1.0 E-4 if it is assumed that all of the site soils are at the limit (i.e., 15 pCi/g above background for Th-232 + Ra-226).

If treatment is proven effective, the use of treated material as backfill on some properties in Alternative 4 would be protective. It is assumed that a 1ft clean cover will be maintained and any maintenance requiring breaching of the cover will be conducted using methods designed to reduce exposures to radiological contaminants thus risks would be controlled accordingly. The radiological risk for Alternative 4 (with treatment) is estimated to be 5.4 E-5 if it is assumed that all of the treated fill is at the criterion(i.e., 15 pCi/g above background for Th-232 + Ra-226) and the cover remains intact. The industrial worker receptor represents a maximum risk for a maintenance worker without breaching the cover.

5 REFERENCES

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