FINAL

FEASIBILITY STUDY FOR THE MADISON SITE

MADISON, ILLINOIS

JANUARY 2000

U.S. Army Corps of Engineers
St. Louis District Office
Formerly Utilized Sites Remedial Action Program

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AEA	Atomic Energy Act
AEC	Atomic Energy Commission
ALARA	as low as reasonably achievable
ARAR	Applicable or Relevant and Appropriate Requirements
Bq	Becquerel
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
$DCGL_W$	Derived Concentration Guideline Level
DOE	Department of Energy
dpm	disintegration per minute
EPA	U.S. Environmental Protection Agency
FS	Feasibility Study
FUSRAP	Formerly Used Sites Remedial Action Program
HEAST	Health Effects Assessment Summary Tables
IDNS	Illinois Department of Nuclear Safety
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MED	Manhattan Engineer District
mrem	millirem
NRC	U.S. Nuclear Regulatory Commission
O&M	operation and maintenance
ORNL	Oak Ridge National Laboratory
pCi	picoCurie
RI	Remedial Investigation
ROD	Record of Decision
sf	square feet
Sv	Sievert
TEDE	total effective dose equivalent
USACE	United States Army Corps of Engineers
μR	microRoentgen

EXECUTIVE SUMMARY

The Madison site (former Dow Chemical Company facility) located at College and Weaver Streets in Madison, Illinois contains a press that was used to perform extrusions of uranium metal and straightening of extruded uranium rods for the U.S. Atomic Energy Commission (AEC) during the late 1950s and early 1960s. Public Law 106-60 grants authority for United States Army Corps of Engineers (USACE) to conduct response actions at this site under the Formerly Utilized Site Remedial Action Program (FUSRAP) subject to the requirements of the Comprehensive Environmental Response, Compensation, and Liabilities Act (CERCLA) and the National Contingency Plan (NCP).

This Feasibility Study (FS) was performed to address the release of uranium inside of Buildings 6 and 4 of the site due to past operations by Dow Chemical Company (Dow) and Mallinckrodt Chemical Works (Mallinckinrodt) in support of programs of the AEC. Other hazardous substances or pollutants or contaminants that may be present or any other part of this site are not eligible for FUSRAP and are not addressed by this FS. This FS specifically addresses unacceptable risk from exposure to uranium including exposures the event institutional controls are lost.

SITE DESCRIPTION

The Madison site consists of a large, multi-sectional complex of 10 interconnecting buildings with a total under roof area of about 130,000 square meters (m^2) [1.4 million square feet, (ft^2)]. Work for the AEC was conducted in Building 6, which is about 83 meters (m) (275 feet) wide and 303 m (1,000 feet) long. The main bay ceiling is approximately 14 m (46 feet) high, 18 m (60 feet) at the highest point along the building centerline. The structure consists of steel columns, beams, and vertical and horizontal cross members. Walls are concrete block with brick veneer. Floors are concrete. The floor surfaces are rough and pitted, and much of the floor in the vicinity of the extrusion press for uranium metal is covered with a thin layer of oily dirt and fine metal debris. Contamination from the uranium extrusion activities has been detected in dust on overhead beams in the general vicinity of the extrusion press.

HISTORY

During the late 1950s and early 1960s, the Dow Metal Products Division of Dow Chemical Company performed work at the Madison site for the AEC. The work was performed under subcontract to Mallinckrodt. Work for the AEC was limited to extrusions of uranium metal and straightening of extruded uranium rods. All work took place in Building 6. Records suggest that the total quantity of uranium involved in the operations was small, and that Mallinckrodt retained accountability for the uranium throughout the operations (ORNL, 1990). After AEC operations were shut down, Mallinckrodt removed unused uranium material and cleaned up the facility, although records detailing the operations or the effectiveness of the cleanup have not been located.

Separate, licensed processes being conducted by the current facility owners involve Thorium-232. This thorium is not related to the AEC uranium contamination and is not significantly collocated with the AEC uranium contamination as shown in the data from the remedial investigation. The USACE is authorized only to address uranium contamination resulting from the AEC operations.

NATURE AND EXTENT OF CONTAMINATION

Two characterization efforts have been conducted at the Madison Site. Oak Ridge National Laboratory (ORNL), under contract with the Department of Energy (DOE), performed a preliminary radiological survey of the facility in March 1989. The second radiological survey was performed by the USACE in the summer and fall of 1998. A summary of the results of these investigations follows. More information is provided in the referenced reports and a more detailed summary is also available in Section 2.3.

1989 ORNL Survey

ORNL conducted a survey in 1989 to establish the radiological status of the facility. ORNL concluded that most of Building 6 was free of residual radioactive material attributable to former AEC- or DOE-sponsored activities. Above-background levels of uranium were identified in dust on overhead surfaces above the general vicinity of the extrusion press. The maximum concentration measured was 310 picoCuries/gram (pCi/g) of uranium-238 (U-238). This is equivalent to a total uranium concentration of approximately 635 pCi/g. The ORNL report contained recommendations for further investigations to better define the extent of uranium contamination in Building 6 and the adjacent Building 4. As a result of the survey findings, the site was designated to be addressed by FUSRAP. (Note that in October of 1997, the responsibility for FUSRAP was transferred from DOE to the USACE by Congressional action).

1998 USACE Survey

The purpose of the USACE survey and sampling effort was to 1) characterize the current radiological conditions of the Madison site attributable to AEC operations; and 2) perform final status survey activities on areas of the site determined by the ORNL survey to be unaffected by previous AEC operations. Final status surveys were compared to State of Illinois guidelines for unrestricted release. Activities included:

- surface beta scans
- surface gamma scans
- measurements of total beta surface activity
- measurements of removable alpha and beta activity
- measurement of gamma exposure rates at 1 m above the surface
- sampling surface dust from overhead surfaces
- sampling residues from the floor and floor penetrations, and
- sampling soil (for the final status survey effort only).

These activities confirmed that AEC-related contamination at the Madison site is in the form of dust adhering to the overhead surfaces in the vicinity of the extrusion press. The contamination pattern observed was similar to that observed in the 1989 ORNL survey. However, the total uranium concentrations that were detected were approximately 40 to 50% lower than those detected during the ORNL survey. The contamination is still present on the overhead beams even though the activities that deposited this contamination were discontinued over 30 years ago. The contamination is also confined within the structure. No airborne uranium was detected during sampling activities, and no contamination was detected on the equipment and floor surfaces directly beneath the contaminated beams. This provides evidence that the contamination is not migrating.

The affected surfaces total approximately 2300 m^2 (25,000 ft^2) in area. The radionuclide analysis showed the contaminants are a natural uranium isotopic mixture (approximately 50.6% U-234, 2.3% U-235, and 47.1% U-238 by activity). The affected surfaces are horizontal surfaces above the extrusion press, including beams, cross members, and window ledges. Survey records identify the dust on overhead surfaces as ranging from "dry to oily layers", except above the extrusion press where the dust was a "hard cake type material." Dust thickness was reported to range from 0.64 to 0.95 centimeters (cm) (0.25 to 0.37 inches).

Details regarding the number of measurements taken, the locations, and the individual results can be found in the *Remedial Investigation Report for the Madison Site*. (USACE 2000a)

SUMMARY OF SITE RISKS

Risk and dose assessments were performed for the conditions at the site. Spectrulite Consortium, Inc. currently operates the site. The results of these assessments are contained in Appendix B of the *Remedial Investigation Report for the Madison Site* (USACE, 2000a). Existing Illinois and Nuclear Regulatory Commission (NRC) regulations impose obligations on license holders to limit radiation exposures to workers, invitees, and members of the public from any source of radiation other than natural background. There are also OSHA standards that impose worker protection requirements regarding radiation exposure at this facility. However, if the institutional controls should be lost or fail, then unacceptable doses could result. Exposure scenarios assumed that no actions are taken to reduce, contain, or remove the contamination in the building, and no worker controls are implemented to reduce exposure to the contaminated dusts.

Two types of workers were evaluated for the dose and risk assessment: a site worker on the floor level, and a utility worker who works in closer proximity to the contaminated overhead surfaces. The site worker on the floor level is exposed daily for 8 hours, 250 days per year for 25 years. The utility worker performs work such as pulling cables and changing light bulbs, for an estimated 20 hours per year for 25 years.

Table 1 summarizes the risks and annual total effective dose equivalent (TEDE) for each worker potentially exposed during operations at the Madison site. The risk assessment concludes that the uranium present in the dust on overhead structures, in the vicinity of the extrusion press, does not pose an unacceptable potential risk to workers on the floor level. However, an unacceptable potential risk is calculated for the utility worker who is in close contact with contaminated surfaces.

Table 1. Summary of Excess Lifetime Cancer Risk and Total Effective Dose Equivalent

Evaluation Factor	Comparison Criteria	Scenario	
		Facility Worker	**Utility Worker***
Excess Lifetime Cancer Risk	CERCLA risk range (10^{-4} to 10^{-6})	2.2×10^{-5}	5.3×10^{-4} ($9.5 \times 10^{-5} – 2.0 \times 10^{-3}$)
TEDE	25 millirem/year (mrem/yr)	9 mrem/yr	210 mrem/yr (39 – 790 mrem/yr)

* The risk and TEDE to the utility worker are driven primarily by the assumed dust resuspension factor. A range of values was modeled. The resuspension factor may vary by 6 orders of magnitude depending on the conditions. The value of 5.0 E-5 is the value cited by the International Atomic Energy Agency for operating nuclear facilities. The range of values provided is the proposed range in NRC 1998. The average value is reported first, followed by the range of potential values depending on the dust resuspension factor chosen in the risk model.

The dose to the construction worker during building demolition or dismantlement was also evaluated to determine whether a future risk exists when the site is closed. The dose experienced by the construction worker demolishing the building was estimated at less than 1 mrem, assuming normal construction practices such as use of dust suppression techniques. The dose absorbed if the building were dismantled with existing contamination levels, assuming no controls, could be as high as 40 mrem.

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Identifying ARARs involves determining whether a requirement is applicable, and if it is not applicable, then whether a requirement is relevant and appropriate. Individual ARARs for each site must be identified on a site-specific basis. Factors, which assist in identifying ARARs, include the physical circumstances of the site, contaminants present, and characteristics of the remedial action.

Applicable requirements are those standards of control and other substantive environmental protection requirements, criteria or limitations promulgated under federal or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. The p The Chemical-specific ARAR for the Madison site is discussed below.

Relevant and appropriate requirements are those standards of control, and other substantive requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well-suited to the particular site. ARARs provide standards for the degree of remediation of the hazardous substances, pollutants or contaminants that will remain at the completion of the remedial action.

10 CFR 20, Subpart E

The U.S. Nuclear Regulatory Commission's (NRC) rule on radiological criteria for license termination establishes dose criteria that apply when a licensee terminates its license. Although this rule is not applicable, because the uranium processing at the site was not performed under an NRC license, it is considered relevant and appropriate since the activities conducted at the site and the resulting contamination are similar to those requiring an NRC license. The pertinent sections of this ARAR are discussed below:

§ 20.1402 Radiological criteria for Unrestricted Use

A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a TEDE to an average member of the critical group that does not exceed 25 mrem [0.25 milliSievert (mSv)] per year, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA). Determination of the levels that are ALARA must take into account consideration of any detriments, such as deaths from transportation accidents, expected to potentially result from decontamination and waste disposal.

§ 20.1403 Criteria for License Termination Under Restricted Conditions

A site will be considered acceptable for license termination under restricted conditions if:

a) The licensee can demonstrate that further reductions in residual radioactivity necessary to comply with the provisions of § 20.1402 would result in net public or environmental harm or were not being made because the residual levels associated with restricted conditions are ALARA must take into account consideration of any detriments, such as traffic accidents, expected to potentially result from decontamination and waste disposal;

b) The licensee has made provisions for legally enforceable institutional controls that provide reasonable assurance that the TEDE from residual radioactivity distinguishable from background to the average member of the critical group will not exceed 25 mrem (0.25 mSv) per year;

c) The licensee has provided sufficient financial assurance to enable an independent third party, including a governmental custodian of a site, to assume and carry out responsibilities for any necessary control and maintenance of the site. Acceptable financial assurance mechanisms are-

    1. Funds placed into account segregated from the licensee's assets and outside the licensee's administrative control as described in § 30.35(f)(1) of this chapter;

2. Surety method, insurance, or other guarantee method as described in § 30.35(f)(2) of this chapter;
3. A statement of intent in the case of Federal, State, or local Government licensees, as described in § 30.35(f)(4) of this chapter; or
4. When a governmental entity is assuming custody and ownership of a site, an arrangement that is deemed acceptable by such governmental entity.

e) Residual radioactivity at the site has been reduced so that if the institutional controls were no longer in effect, there is reasonable assurance that the TEDE from residual radioactivity distinguishable from background to the average member of the critical group is as low as reasonably achievable and would not exceed either-

1 100 mrem (1 mSv) per year; or
2 500 mrem (5 mSv) per year provided the licensee-

i. demonstrates that further reductions in residual radioactivity necessary to comply with the 100 mrem/y (1 mSv) value of paragraph (e)(1) of this section are not technically achievable, would be prohibitively expensive, or would result in net public or environmental harm;
ii. make provisions for durable institutional controls;
iii. provides sufficient financial assurance to enable a responsible government entity or independent third party, including a governmental custodian of a site, both to carry out periodic rechecks of the site no less frequently than every 5 years to assure that the institutional controls remain in place as necessary to meet the criteria of § 20.1403(b) and to assume and carry out responsibilities for any necessary control and maintenance of those controls. Acceptable financial assurance mechanisms are those in paragraph (c) of this section.

This regulation provides a dose limitation from all possible pathways of exposure and is applied by developing a Derived Concentration Guideline Level (DCGL) to limit doses to meet the criteria.

REMEDIAL ACTION OBJECTIVES

The objective of remedial action at the Madison site is to eliminate, reduce, or control the unacceptable exposure to uranium in dust in Buildings 6 and 4 by complying with the ARAR. In areas of the plant where it is necessary to undertake remedial action to accomplish this objective, the USACE expects the remedial action will achieve the removable and total disintegrations per minute (dpm)/100 cm^2 levels which are only a small fraction of the ARAR. The final status surveys will document compliance with the ARAR. The DCGL is 6,000 dpm/100 cm^2 for surficial contamination and 20 pCi/g for volumetric contamination based on the exposure scenario described in Appendix A.

SUMMARY OF FEASIBILITY STUDY ALTERNATIVES

The *Feasibility Study for the Madison Site* was prepared to develop and evaluate several remediation options for the site based on the results of the Remedial Investigation. (USACE 2000) Four remediation alternatives were developed in the FS and evaluated using the nine criteria outlined in the National Contingency Plan (NCP). Per EPA's feasibility study guidance, the cost estimates assume a 30-year performance period for ongoing actions such as monitoring and maintenance. (EPA 1988) The four remediation alternatives developed for the site are discussed in the following paragraphs.

Alternative 1: No Action

The no action alternative is required by CERCLA to provide a baseline for comparison against the other alternatives. No remedial actions would be undertaken by USACE to reduce, contain, or remove site contamination. The site is assumed to operate in compliance with the existing NRC, Illinois, and OSHA regulations that limits occupational and public exposure.

Alternative 2: Institutional Controls

Institutional controls are intended to protect against human exposure to contaminated material by preventing or minimizing opportunities for exposure. The facility is assumed to operate in compliance with the existing, NRC, Illinois, and OSHA regulations, which impose limitations on occupational and public exposure. This alternative would include:

- Continued use as an industrial facility,
- Work instructions and work permits that identify the contamination and measures to preclude or reduce exposure when employees, contractors or others, such as utility workers, are required to perform activities in the vicinity of the contaminated surfaces,
- Land use restrictions,
- Airborne particulate sampling and analysis for the isotopes of concern,
- Use of breathing zone monitors, if required, based on the results of airborne particulate sampling and analysis,
- Maintenance of signs and fences, and
- Periodic inspections by the government to enforce any such restrictions.

This alternative assumes continued use of the site as an industrial facility. Periodic monitoring and 5-year reviews would be used to control the amount and duration of potential exposures. By taking actions to comply with NRC, Illinois, and OSHA standards, the facility owner precludes or reduces exposures in areas in which contaminated surfaces may be encountered. It also includes compliance with the controls by current and future building owners.

Alternative 3: Containment

The containment alternative would seek to reduce human exposure to contamination on the horizontal surfaces by preventing the dust from becoming mobilized. This would be accomplished by the application of a sprayed coating that would adhere to the beams and immobilize the dust by trapping it beneath the coating. When use of the building is discontinued in the future, radiological controls would be provided for decontamination prior to demolition of the building or disposal of the rubble following building decontamination. Five-year reviews, as required by CERCLA, would be conducted to assure that the containment mechanism remains intact and control the amount and duration of potential exposures.

Alternative 4: Decontamination of Accessible Surfaces and Release of Building

Under this alternative, radiological contamination on accessible surfaces (horizontal ledges such as window sills, electrical and water conduits, beams at the 7.6 and 11 m (25 and 36 ft) levels, and beams in the high bay that are accessible from windows on the roof would be removed using appropriate decontamination technologies to a level sufficient to meet or exceed the ARAR. Difficult to access areas are defined as those surfaces that can not be accessed from either the high-bay crane or through windows. This includes the high bay areas above the 36 ft levels and some other areas such as around live power lines. No effort would be made to remove contamination in the difficult to areas because of difficulty to access these areas and that the potential exposures in these areas do not pose an unacceptable risk.

The technologies that may be employed include vacuuming, scraping, scrubbing, etc. Contamination can be removed using either aggressive (needle guns, scabblers, chipping hammers, etc.) or non-aggressive (absorbent cloth, nuclear grade vacuum cleaners, paint remover, etc.) techniques. The decontamination work would take place when the building could be made available by the current owner. This typically occurs in July during the week-long annual plant shutdown. This would prevent potential employee exposure to dust mobilized by the decontamination activities and minimize disruption of plant operations.

For the purposes of analysis and cost estimating this alternative is assumed to proceed as follows.

First, the accessible overhead structures and ledges in the building would be vacuumed to remove contaminated dust. If the treated area still exceeded standards following vacuuming, then the surface would be scrubbed or scraped to loosen crusted contaminated materials, followed by vacuuming the area again. The procedure would be repeated using increasingly aggressive decontamination techniques until the surfaces meet the ARAR for the accessible areas.

Following decontamination of the overhead structures, the equipment and floor areas beneath the decontamination activities, and the areas identified in the Remedial Investigation as containing elevated concentrations of uranium, would be surveyed to ensure these areas meet the ARAR. If found to exceed the standards, the floor would be decontaminated using methods similar to the overhead areas.

Waste generated by the decontamination activities would be disposed in a licensed or permitted disposal facility. Waste packaging would be performed in accordance with all applicable federal, state and local laws and regulations. Shipping containers would meet

Department of Transportation requirements. Paint removed from the building surfaces would be sampled for Resource Conservation and Recovery Act (40 CFR 261) hazardous waste characteristics and would be stored, handled, and disposed in accordance with all applicable regulations. Final status surveys would be conducted to assure compliance with the ARAR.

No five-year review would be required because the potential for unacceptable exposures would be eliminated by the removal action.

ALTERNATIVE COMPARISON

The advantages and disadvantages of each of the alternatives were compared using the nine evaluation criteria established in Section 300.430(d)(9)(iii) of the National Contingency Plan (NCP). Some of these comparisons are summarized below.

Threshold Criteria

Except for Alternative 1 (No Action) all of the alternatives are protective of human health and the environment. Alternative 1 is not considered protective because risks above the CERCLA risk range are possible. Long-term risk reductions obtained by Alternative 4 (Decontamination) and Alternative 3 (Containment) are offset by increased short-term risks to the remediation worker conducting the decontamination or containment activities. These alternatives would effectively control potential exposure without incurring additional short-term risks to the remedial action worker, Alternative 2 (Institutional Controls) ranks high in overall protection of human health and the environment as long as the institutional controls remain effective.

Only Alternative 4 (Decontamination), complies with the ARAR for unrestricted release of a facility. Contamination at levels above the cleanup levels specified by the ARAR for unrestricted release of a facility would remain in place under Alternatives 1 through 3. Alternative 2 (Institutional Controls) and Alternative 3 (Containment) would not result in the release of the facility for unrestricted use; both alternatives would require use restrictions to ensure protectiveness. The transportation and off-site disposal of the waste causes a slight increase in risks due to transportation and disposal.

Primary Balancing Criteria

Alternative 1 (No Action) and Alternative 2 (Institutional Controls) do not involve intrusive remedial activities that would result in community or worker exposure to the contamination. Alternative 3 (Containment) and Alternative 4 (Decontamination) involve little to no risk to the community, but remedial action workers would be subject to increased risks during the performance of the work.

The long-term effectiveness of the alternatives varies. Alternative 1 (No Action) would not be effective in the long-term because contamination would remain in place. Alternatives 2 and 3 require continued institutional controls to restrict future exposures to the contamination.

These controls would include the use of five-year reviews. Alternative 4 (Decontamination) is most effective over the long-term, because contamination would be removed and the facility could be released from the associated restrictions.

Alternatives do not use treatment to reduce the toxicity, mobility, or volume of contaminants at the site. Mobility is reduced through containment in Alternative 3. No effective treatment to reduce toxicity, mobility, or volume was identified. As radioactivity can't be destroyed, toxicity cannot be significantly affected. The uranium is expected to exist as a very stable oxide, thus mobility of the current chemical form is minimized. Solidification agents will increase the volume in exchange for a reduction in mobility. Extraction of the uranium is not practical for the small volume of waste that will be generated.

All of the alternatives are technically feasible to implement. Alternatives 3 and 4 would be the most difficult to implement. This is because containment and decontamination activities would require work in the high bay areas of the building (in close proximity to the contamination). These areas present access limitations due to the facility construction. Additionally, Alternatives 3 and 4 would require coordination with existing facility work activities to limit potential exposures to the employees during remedial action activities.

The cost of each of the alternatives is provided in Table 2. Alternative 1 (No Action) incurs no additional costs, but also provides no additional protection and fails to meet the threshold criteria as required by CERCLA. Alternative 4 (Decontamination) is the most cost-effective of the action alternatives at $250,000.

Modifying Criteria

State and community acceptance will be evaluated following review of comments on the FS/PP received during the public comment period.

Table 2. Cost Comparison

Alternative	Cost*
Alternative 1: No Action	0
Alternative 2: Institutional Controls	$60,000
Alternative 3: Containment	$450,000
Alternative 4: Decontamination	$250,000

* 30 year cost in 1999$ and zero discounting

1 INTRODUCTION

This Feasibility Study (FS) was performed to identify and evaluate remedial alternatives for the Madison site located at College and Weaver Streets in Madison, Illinois. The site, which is currently operated by Spectrulite Consortium, Inc., is being addressed by the United States Army Corps of Engineers (USACE) under the Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP was established in 1974 to identify, investigate, and remediate or control sites with residual radioactivity resulting from activities of the Manhattan Engineer District (MED) or early operations of the Atomic Energy Commission (AEC). In 1997, FUSRAP was transferred by U.S. Congressional action from the Department of Energy (DOE) to the USACE. Public Law 106-60, the 1998 Energy and Water Appreciation Act authorizes USACE to conduct environmental restoration work under FUSRAP as the lead agency, subject to the requirements of CERCLA and the NCP.

1.1 PURPOSE AND ORGANIZATION OF THE REPORT

The purpose of this FS is to evaluate alternatives for remediation of AEC-related contamination at the Madison Site. The USACE will follow the Remedial Investigation / Feasibility Study (RI/FS) process developed by the U.S. Environmental Protection Agency (EPA) for environmental compliance subject to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (NCP). The remedial action selected will comply with all applicable or relevant and appropriate federal and state regulatory requirements (ARARs).

This FS is organized in accordance with guidance from EPA for remedial actions under CERCLA (EPA 1988). Section 1 includes the introduction, purpose, and organization of the report, as well as background information. Section 2 defines remedial action objectives and identifies technologies that can achieve the remedial action objectives. Section 3 develops these technologies into alternatives for remediating the site. Section 4 evaluates the alternatives against the nine CERCLA evaluation criteria. Section 5 compares each alternative against the others for each criterion.

1.2 BACKGROUND INFORMATION

1.2.1 Site Description and History

The Madison site consists of a large, multi-sectional complex of 10 interconnecting buildings with a total under-roof area of about 130,000 square meters (m^2) [1.4 million square feet (ft^2)]. Building 6 is about 83 meters (m) [275 feet (ft)] wide and 303 m (1,000 ft) long. The main bay ceiling is approximately 14 m (46 ft) high, 18 m (60 ft) at the highest point along the building centerline. The building structure consists of steel columns on approximately 7.6 m (25 ft) centers, connected by large horizontal beams and multiple smaller vertical and horizontal cross members. Walls are concrete block with brick veneer. Floors are concrete; floor surfaces are rough, and pitted, and much of the floor in the vicinity of the extrusion press for uranium metal is covered with a thin layer of oily dirt and fine metal debris.

The Madison Site located in Madison, Illinois, (Figure 1-1) was used to perform extrusions of uranium metal and straightening of extruded uranium rods for the AEC during the late 1950s and early 1960s. This work was conducted by the Dow Metal Products Division of Dow Chemical Company (DOW) under subcontract to the Uranium Division of the Mallinckrodt Chemical Works (Mallinckrodt). The work was conducted in Building 6, a large multi-story metal building with a concrete floor shown in Figure 1-2 and 1-3. The adjoining Building 4 was used for material transfers.

On March 15, 1957, Mallinckrodt Chemical Works entered into a subcontract with Dow's Madison Division Office in Madison, Illinois (Subcontract No. 25034-M). This subcontract, issued under Mallinckrodt's primary contract W-14-108-eng-8, was for Dow to perform "certain research and development work in gamma phase extrusion of uranium metal". This work was performed at Dow's Madison, Illinois plant. The objective of this research was to determine factors in the extrusion of uranium metal that would affect the final selection and purchase of tools and auxiliary supplies for use with an extrusion press that was planned to be located at another AEC production facility. Dow performed this work on a "work cycle" basis. The research investigated the properties of various die metals, the contour of the die cavity, the nature of the lubricant to apply to the uranium metal, the composition of the "follower block" (the material placed between the uranium metal and the ram press), and the speed at which the metal could be extruded.

Records suggest that the total quantity of uranium involved in these operations was small, and indicate that Mallinckrodt retained accountability for the uranium throughout the operations. Mallinckrodt was also responsible for removing unused uranium material and cleanup of facilities following operations. However, records detailing the operations or the effectiveness of the cleanup have not been located.

Under the terms of the subcontract Mallinckrodt designed (for approval by Dow) dust arresting and other protective equipment. Mallinckrodt was also responsible for arranging for the Health and Safety Laboratory of the AEC to perform periodic surveys of breathing zone air quality. Mallinckrodt also retained responsibility for the accountability of the uranium metal during the work cycle.

In the Designation Summary for the Former Dow Chemical Company Site in Madison, Illinois, the Department of Energy indicated that Dow also supplied materials (chemicals, induction equipment, and magnesium metal products) and services under purchase orders issued by Mallinckrodt. In March 1960, the Uranium Division of the Mallinckrodt Chemical Works issued a purchase order for Dow to straighten Mallinckrodt-supplied uranium rods. Two rod straightening campaigns were identified in the purchase order. One was to be completed in December 21, 1959, the second on January 25, 1960. Each campaign also included a cost for the cleanup of the area after each campaign. The actual periods of performance for this work and the actual quantity of uranium that was processed are unknown. However, the total value of the

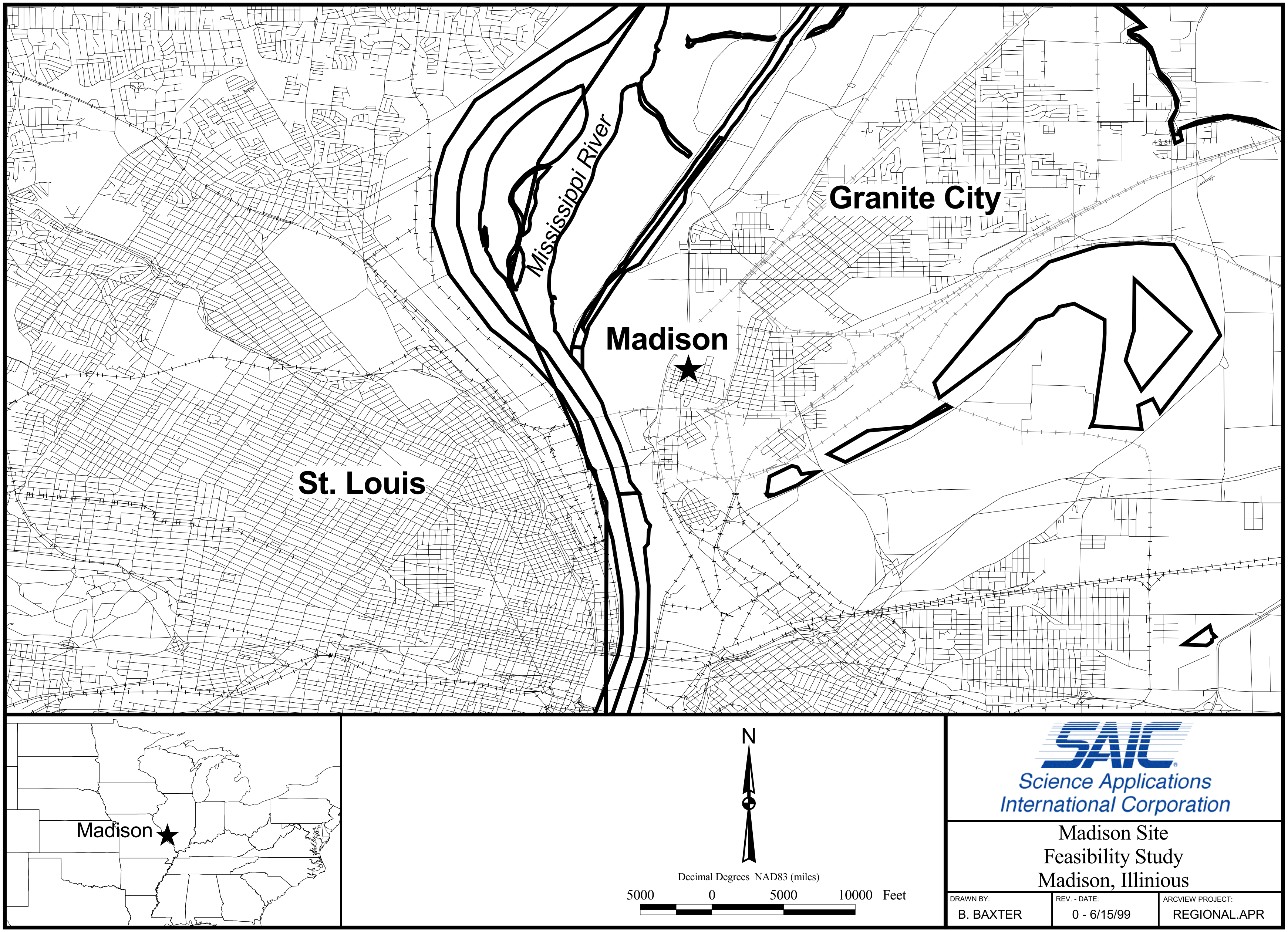

Figure 1-1. Location of Madison Spectrulite Consortium

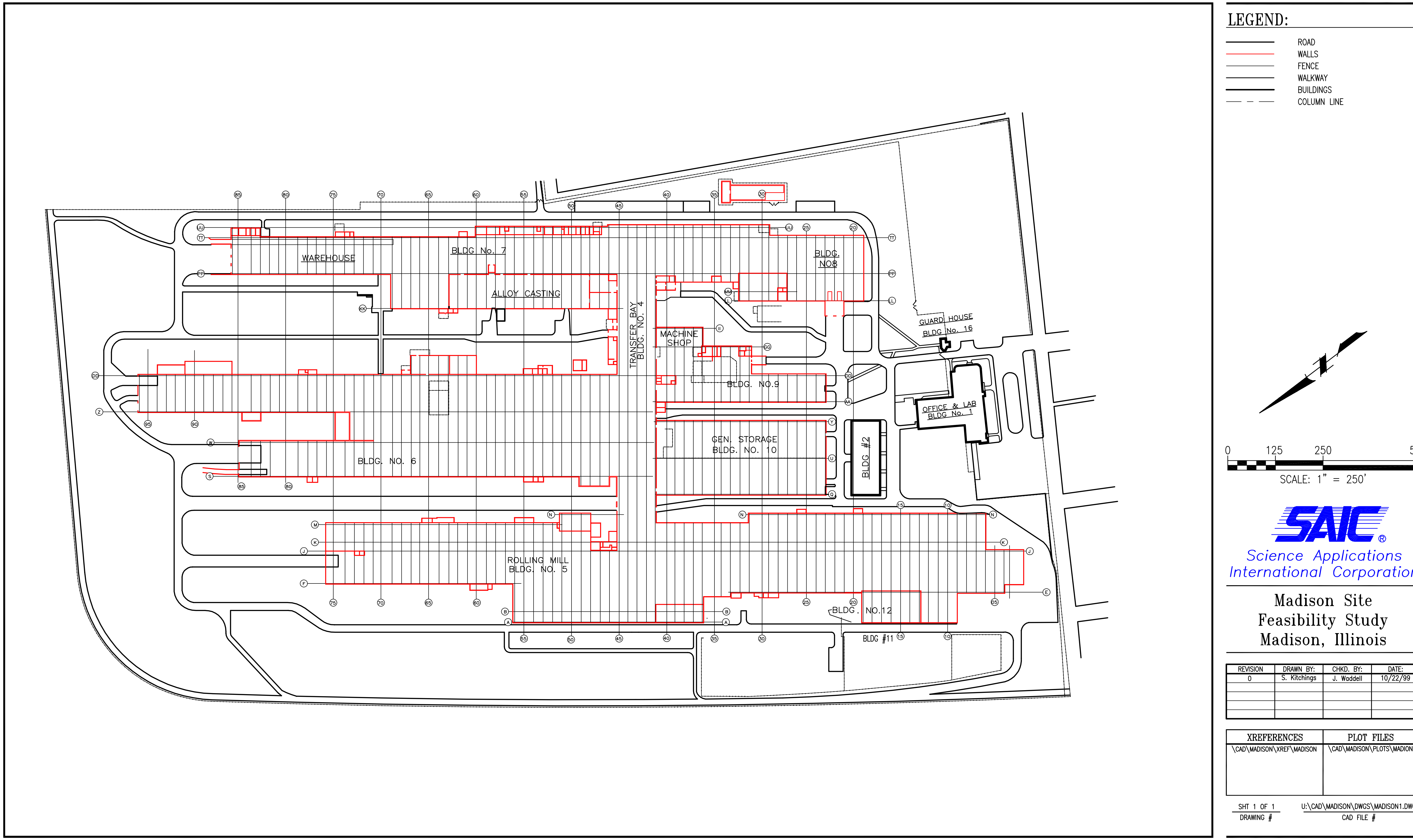

Figure 1-2. Buildings at the Madison Site

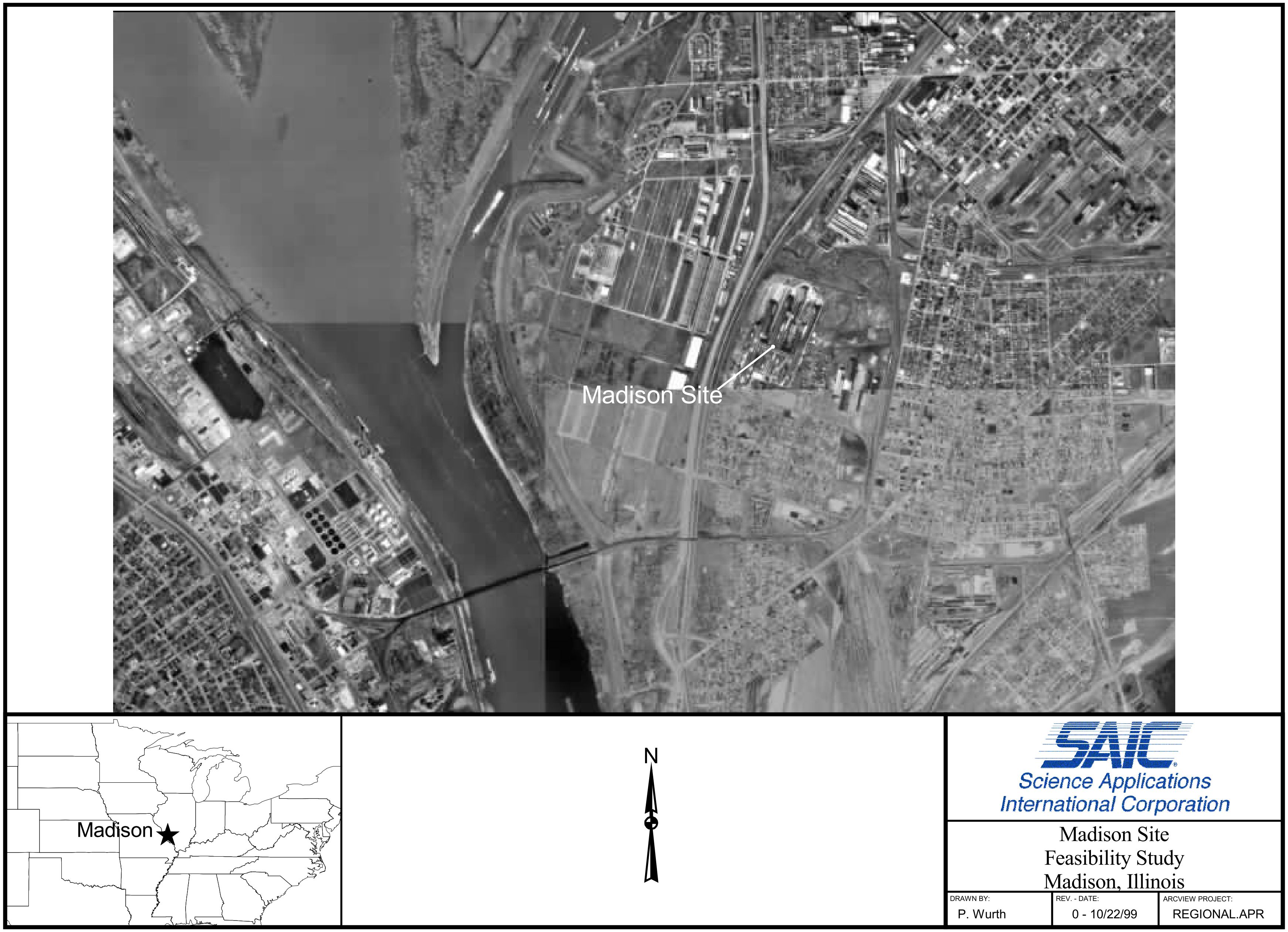

Figure 1-3. Aerial Photograph of the Area Around the Madison Site

purchase order and the unit cost identified with the "lot size" indicate that the quantity of metal involved was most likely small.

DOE indicated that no other operation or period of involvement (for the MED-AEC) with the processing or handling of radioactive material at the Madison Site has been discovered.

Records located in the Nuclear Regulatory Commission (NRC) Public Document Room indicate that Dow applied for an AEC license on December 12, 1956. Dow was granted an AEC license (number C-2782), effective January 1, 1958, to receive and possess thorium metal and thorium compounds, without limitation as to quantity. The thorium, under the terms of the license, was for use in the preparation of magnesium alloys at the Dow plants in Midland, Michigan; Bay City, Michigan; Madison, Illinois; and Freeport, Texas. In 1962 Dow applied for and was granted another AEC license (number STB-527). Although a records search revealed licensing of magnesium-thorium alloys by Dow, ConAl and Spectrulite, the records search revealed no license for uranium processes at the Madison facility.

Dow Chemical Corporation leased the Madison facility to Phelps Dodge Aluminum Corporation in 1969. Consolidated Aluminum Corporation assumed the lease in 1973 and exercised an option to buy the plant in 1973. Consolidated Aluminum Corporation applied for and received a license (number STB-1097) from the NRC in August 1982. Consolidated Aluminum Corporation processed magnesium thorium alloys at the Madison site.

Consolidated Aluminum Corporation sold the Madison plant to Barnes Acquisition, Inc. [which appears to have been a subsidiary of the Spectrulite Consortium, Inc. (Spectrulite)] in September 1986. In August 1986, W. A. Barnes requested that the NRC license that Consolidated had "relating to the manufacturing of magnesium thorium alloys and the storage of same be transferred to the surviving company".

Apparently, NRC denied this request and Spectrulite applied for and was granted an NRC license (number STB-1488) in October 1986. The Spectrulite license was for the manufacture of magnesium-based thorium alloys and listed the byproduct, source, and/or special nuclear material covered under the license as thorium (solid metal), thorium (Mg-Th hardener), and thorium (magnesium sludge).

Even though the State of Illinois became an agreement state in the early 1980s, the NRC continued to manage licenses associated with the Madison Site instead of referring either Consolidated Aluminum or Spectrulite to the State of Illinois. The NRC managed license STB-1097 for Consolidated Aluminum until it was terminated February 20, 1992 in Amendment 6. Consolidated Aluminum submitted a Decommissioning Plan for a magnesium – thorium sludge storage area on May 18, 1983. The NRC responded to Consolidated Aluminum on February 17, 1984 with requests for more information for the Decommissioning Plan. Also, NRC issued Amendments 4, 5 and 6 to STB-1097 in July 1985 and October 3, 1986. In addition, the NRC issued Materials License STB-1488 to Spectralite on October 3, 1986. This license was for the operating area only since the magnesium-thorium sludge storage area was retained by Consolidated Aluminum.

1.2.2 Nature and Extent of Contamination

Two characterization efforts have been conducted at the Madison Site. Oak Ridge National Laboratory (ORNL), under contract with DOE, performed a preliminary radiological survey of the site in March 1989 (ORNL 1990). The second radiological survey was performed by the USACE, in the summer and fall of 1998.

1.2.2.1 1989 ORNL Survey

The March 1989 survey performed by ORNL was conducted to establish the radiological status of the facility. The ORNL survey concluded that most of Building 6 was free of residual radioactive material attributable to former AEC- or DOE-sponsored activities (ORNL 1990). Above-background levels of uranium were identified in dust on overhead surfaces above the general vicinity of the extrusion press. The maximum concentration of uranium-238 (U-238) measured in this dust was 310 picocuries per gram (pCi/g). Based on the abundance of uranium isotopes present in natural uranium, this quantity of U-238 is equivalent to a total uranium concentration of approximately 635 pCi/g. The ORNL report also concluded that the uranium dust on the overhead surfaces corresponded to a total surface contamination level in excess of the DOE limit for unrestricted release [i.e., 5,000 disintegrations per minute per 100 square centimeters (dpm/100cm^2)] applicable at the time of their report. In addition to the residual uranium contamination on the overhead surfaces, the survey also identified the presence of smaller amounts of thorium-232 (Th-232) in the facility. This thorium is from separate, licensed processes being conducted by the facility owners and is not of AEC origin. The ORNL report recommended further investigations to better define the extent of uranium contamination in Building 6 and the adjacent Building 4. As a result of these survey findings, the facility was designated for inclusion in FUSRAP.

1.2.2.2 1998 USACE Survey

The USACE radiological survey and sampling effort was conducted during the periods of June 29 through July 3, 1998 and November 10 through 11, 1998. The survey was conducted in accordance with the Radiological Survey Work Plan (USACE 1998a) and Radiological Survey Work Plan-Addendum (USACE 1998b). Guidance provided in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (DOD 1997) and draft NUREG/CR-5849, "Manual for Conducting Radiological Surveys in Support of License Termination" (NRC 1992) was followed in the design, implementation, and data interpretation of the survey.

The purpose of the USACE survey and sampling effort was to 1) evaluate the current radiological conditions of the Madison Site attributable to AEC operations (scoping/ characterization activities); 2) determine the radiological conditions of those areas of the facility determined by the ORNL survey not to be affected by previous AEC operations and 3) compare the levels to various radiological criteria. Field survey activities associated with the scoping/characterization and final status survey efforts consisted of the following:

- surface beta scans,
- surface gamma scans,

- measurements of total beta surface activity,
- measurements of removable alpha and beta activity,
- measurement of gamma exposure rates at 1 m above the surface,
- sampling surface dust from overhead surfaces,
- sampling residues from the floor and floor penetrations, and
- sampling soil (for the final status survey effort only).

Field survey and sampling activities for the scoping/characterization survey were limited to Buildings 6 and 4 and reference areas. The scoping/characterization survey addressed interior structure surfaces in the vicinity of the extrusion press, interior surfaces of Buildings 4 and 6, the exterior Building 6 roof, ground areas immediately outside doors of Buildings 6 and 4 , surfaces of the extrusion press and adjacent equipment, and floor penetrations in the immediate vicinity of the extrusion press.

Field survey and sampling activities for the final status survey addressed the interior structure surfaces other than those in the vicinity of the extrusion press, equipment surface, floor pits and penetrations, exterior roofs, and entrances/exits of Buildings 6 and 4 . For the purposes of guiding the nature and degree of the final status survey the site was divided into Class 1, 2 and 3 areas in accordance with MARSSIM. Class 1 areas have a potential for contamination that exceeds standards; Class 2 areas have a potential for contamination, but it is unlikely that the contamination level exceeds the average Derived Concentration Guideline Level ($DCGL_w$); and Class 3 areas are not expected to contain residual activity significantly in excess of background. The classifications established for this survey are shown in Table 1-1.

Table 1-1. Area Classification for the Madison Site Survey

Area	Surface	Class	Comments
From Building 6, Support Column 57 extending 50 ft into Building 4.	Surfaces above 8 m (25 ft)	N/A	A classification of contamination potential is not applicable for the characterization survey
Building 6, between support column 45 and 54	Surfaces below 8 m (25 ft)	2	Includes floors, equipment, and wall below 25 ft. Some slight potential for contamination based on previous surveys and process knowledge.
Remaining areas of Buildings 6 and 4	All surfaces	3	No contamination expected based on previous surveys and process knowledge.

The ORNL survey identified contamination exceeding the State of Illinois guidelines on overhead surfaces of Building 6, between vertical columns 45 and 54. Since the measured concentrations in this area exceed guidance, a characterization survey was considered appropriate in lieu of a final status survey for the overhead horizontal beam surfaces. This survey encompassed the area from support column 57 of Building 6 and extending 15 m (50 ft) into Building 4. Figure 1-4 illustrates the area of the characterization survey.

The Class 2 area was divided into three survey units extending from column 45 to column 54. Floor, wall, and equipment surfaces in the remainder of Building 6 and 4 were considered Class 3 and surveyed as a single survey unit. The outside areas in the vicinity of the doors and exterior roof surfaces of Buildings 6 and 4 were also treated as Class 3 survey units.

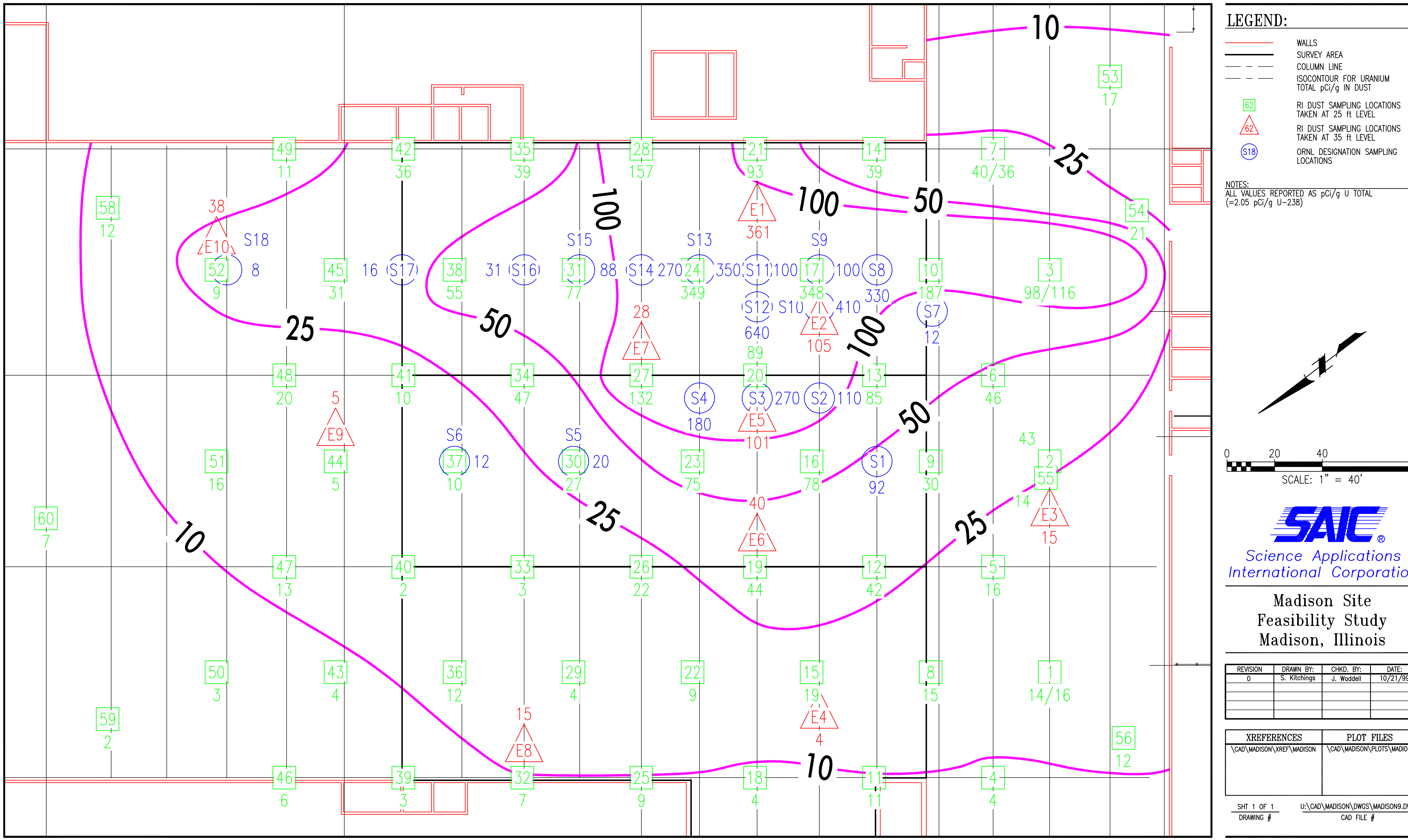

Figure 1-4. Results from Dust Sampling of Major Overhead Beams in Building 6 and 4

Background (Reference Area) Determinations

Ten reference level measurements of gross beta activity and dose equivalent rate were performed in Buildings 9 and 10 over similar surfaces and 12 reference level measurements of exposure rate were performed at exits similar in nature. Ten soil background samples were obtained from soil areas away from doors to Buildings 6 and 4. The results of the reference value determinations are summarized in Table 1-2 and discussed in detail in the RI report.

Table 1-2. Summary of Reference Levels

Measurement Type	Range of Values
Beta Surface Activity	291-650 dpm/100 cm^2
Dose Equivalent Rate	2-4 µrem/h
Exposure Rate (Exits)	6.7-12.2 µR/h
Uranium in Soil	0.9-2.7 pCi/g

Overhead Surface Surveys

Dust samples were obtained from 52 systematic locations on the main horizontal overhead beams (25-ft level) of Buildings 4 and 6 in the vicinity of the extrusion press; from 10 locations from the second level horizontal support beams (36-ft level) in the general area; and from 10 additional locations from the main horizontal beams in other areas of Buildings 4 and 6. Total beta surface activity measurements were performed before and after sampling. Surface scans for beta activity identified generally elevated direct radiation levels throughout the area above the extrusion press. Direct measurements before sampling were typically above background. However, the surfaces after sampling were well within the State of Illinois guidelines. These results indicate that the source of the elevated levels is the dust and residue on the beams. Additionally, the contamination is removable (i.e., decontamination is possible). Dust samples collected from the 8-m (25-ft) level surfaces in the vicinity of the extrusion press contained total uranium concentrations ranging from 2.3 to 348.7 pCi/g. Dust samples from the 11-m (36-ft) level contained total uranium concentrations ranging from 3.5 to 360.8 pCi/g. Uranium concentrations in dust were highest directly above the extrusion press. The contamination pattern was similar to that observed in the 1989 ORNL survey. However, total uranium concentrations observed in the 1998 survey were approximately 40 to 50% lower than those observed during the ORNL survey.

Surface Scans

Gamma and beta scans were performed over 100% of the accessible surfaces in the area beneath the potentially affected overhead structure surfaces (Survey Units 1, 2, and 3) and 5 to 10% in other areas of Building 4 and 6. Gamma scans were also performed at entrances/exits to Buildings 4 and 6. The results of beta and gamma surface scans of Class 2 and 3 building surfaces and equipment are summarized in Table 1-3. Class 2 survey units 2 and 3, and one of the exits (Exit 1) had areas identified with elevated direct radiation levels ranging from 1 to 2 times background. Beta scan data were normalized to adjust for effective area and response of different detectors used for this aspect of the survey. Based on this normalization, several locations exhibited beta activity in excess of 1,000 dpm/100 cm^2.

Table 1-3. Summary of Surface Scan Results

Class	Unit No.	Surface	No. of Blocks or Locations	Elevated Radiation
2	1	Floor	0	N/A
2	2	Floor	2 Blocks (Y-50, Z-49)	Beta
2	3	Floor	4 Blocks (V-45, W-47, W-48, and W-51)	Beta
2	3	Walls	3 Blocks (S-46, S-47, S-49)	Beta
3[1]	N/A	Floor and Equipment	1 (floor and equipment in block K-44)	Beta and Gamma
3	N/A	Areas near Exits	1 location	Gamma

[1] Three sections in the Class 3 area had elevated direct gamma radiation levels attributed to radioactive material processing by Spectrulite Consortium, Inc. This processing is not related to the AEC contamination addressed by this FS.

Surface Activity Measurements

Ten measurements each on floors, lower walls, and equipment surfaces were taken at uniformly spaced locations throughout each survey unit. All of the measurements for removable alpha and beta activity were less than the detection sensitivity of the measurement procedures used (see Table 1-4). Removable activity refers to activity that can be readily removed by wiping, causal contact, etc. Total activity includes both removable activity and activity that is fixed in place and cannot be readily removed by contact or wiping. Four of the total beta activity measurements were greater than 1000 dpm/100cm^2. Total beta activity at these four locations ranged from 1,031 dpm/100 cm^2 to 1,601 dpm/100 cm^2.

Table 1-4. Summary of Surface Activity Measurements

Class	Unit No.	Surface	Range of Removable Alpha Activity[1] (dpm/100 cm^2)	Range of Total Beta Activity[2] (dpm/100 cm^2)	Number of Measurements Greater than the $DCGL_w$
2	1	Equipment	-0.9 to 8.5	-73 to 357	0
2	1	Floor	-0.9 to 2.2	93-998	0
2	1	Walls	-0.9 to 2.2	302-550	0
2	2	Equipment	-0.9 to 2.2	-3 to 412	0
2	2	Floor	-0.9 to 2.2	204 to 641	0
2	3	Equipment	-0.9 to 2.2	-7 to 492	0
2	3	Floor	-0.9 to 2.2	392 to 806	0
2	3	Walls	-0.9 to 2.2	316 to 1130	3
3	N/A	Floor	-0.9 to 2.2	25 to 622	0
3	N/A	Roof	N/A	-53 to 1601	1
Floor Reference Level				**291 to 650**	
$DCGL_w$			33	**1000**	

[1] The detection sensitivities for removable alpha is 15 dpm/100cm^2.
[2] The detection sensitivity for total beta activity is approximately 300 dpm/100 cm^2.

Follow-up measurements on the outside of the walls at grid blocks S-46, S-47, and S-48 indicated a beta activity range of 1,039 to 1,432 dpm/100 cm^2. Based on this finding, it is concluded that the three wall measurements above 1,000 dpm/100 cm^2 are due to natural content of the wall construction material. The source of the elevated measurement on the roof is likely associated with naturally occurring material in the recently applied roofing material in this location. The data set for the roof included one direct measurement result of 1,601 dpm/100 cm^2. This value is above the average $DCGL_W$ of 1,000 dpm/100 cm^2, but is less than the maximum allowable level of 5,000 dpm/100 cm^2. The average for the roof measurements is approximately 500 dpm/100 cm^2 – also well below the average $DCGL_W$ of 1,000 dpm/100 cm^2. Reference area measurements were not performed for roof surfaces, and, therefore, these data cannot be tested using the Wilcoxan Rank Sum (WRS) test.

Soil Sampling

Soil samples were collected to a depth of 15 cm at 10 doorway locations. These samples were analyzed by alpha spectroscopy for isotopic uranium and high-resolution gamma spectrometry for potassium-40 and members of the natural uranium, thorium, and actinium decay series.

Total uranium concentrations in the soil samples ranged from 0.8 pCi/g to 3.8 pCi/g. A soil sample collected near Door 1, which had an elevated gamma level of 32 μR/h, contained 1.6 pCi/g total uranium and 3.0 pCi/g Th-232. These concentrations of radionuclides are insufficient to account for the elevated direct gamma radiation level of 32 μR/h measured at this location.

The source of the elevated gamma radiation outside exit Door 1 was investigated further in July of 1999. Th-232 was identified as the primary radionuclide resulting in conclusion that no FUSRAP remediation is required.

Miscellaneous Sampling and Measurements

Samples of residues were collected from pits and trenches in the Class 2 survey units 1, 2, and 3 beneath potentially affected overhead structures. Scrapings of floor residue were obtained from these same areas. These sampling locations included locations of elevated beta scanning response. There is some evidence of slightly elevated uranium concentrations in some of the floor scraping samples.

Five samples and 10 floor scraping samples were collected. The samples were collected from a large subsurface utility trench that runs from columns 47 to 59, north-south; and from Z to DD, east-west. The uranium concentrations in the samples are within the range observed in the reference area samples indicating that the material in the trench is not contaminated.

Dose Equivalent Rate Measurements

Dose rate measurements were performed at 1 m (3.3 ft) above the floor surface at 10 locations in each Class 2 survey unit and at 17 locations in the Class 3 area. Seven of the Class 3 measurements were near the entrances/exits to Buildings 6 and 4. The results of the dose equivalent measurements are summarized in Table 1-5. In general, the dose equivalent rates are within the range of values observed in the reference area with the exception of one measurement of 6 μrem/h taken in the Class 2 Survey.

Table 1-5. Summary of Dose Equivalent Measurement Results

Survey Class	Location	Dose Equivalent Rate (μrem/h)
2	Floor	2 to 6
3	Floor	2 to 4
Reference Area	Various	2 to 4

Exposure Rate Measurements

Exposure rate measurements were performed at 1 m (3.3 ft) above the surface at each of the 23 exits from Buildings 6 and 4. The results of these exposure rate measurements are summarized in Table 1-6. The exposure rate measurements are within the range of values observed in the reference area with the exception of the measurement of 18.2 μR/h taken from exit Door 1.

Table 1-6. Summary of Exposure Rate Measurement Results

Survey Class	Location	Exposure Rate (μR/h)
3	Exits	6.1 to 18.2
Reference Area	Various	12.2

1.2.3 Contaminant Fate and Transport

The contamination at the Madison Site is in the form of uranium-contaminated dust adhering to the overhead surfaces in the vicinity of the extrusion press. The activities that deposited this contamination were discontinued over 30 years ago. From the fact that the contamination is still present, one can infer that mobility is very limited. To the extent that contaminated dust is becoming dispersed in the surrounding air, it may be released to the environment outside of the facility through the ventilation system. However, no airborne uranium was detected during the sampling activities. If the dust were being dislodged from the overhead structures, contamination should be detectable on the equipment and floor surfaces. The fact that no contamination was found on the surfaces beneath the overhead structured during the RI is strong evidence that migration of the contamination is very limited.

1.2.4 Summary of Site Risks

1.2.4.1 Introduction

Risk and dose assessments were performed for the conditions at the Madison Site. The results of these assessments are contained in Appendix B of the Remedial Investigation Report for the Madison Site (USACE 2000). Existing Illinois and NRC regulations impose obligations on license holders to limit radiation exposures to workers, invitees, and members of the public from any source of radiation other than natural background. There are also OSHA standards that impose worker protection requirements regarding radiation exposure at this facility. However, if the institutional controls should be lost or fail, then doses above the ARAR could result. Exposure scenarios assumed that no actions are taken to reduce, contain, or remove the contamination in the building, and no worker controls are implemented to reduce exposure to the contaminated dusts.

Two types of workers were evaluated for the dose and risk assessment: a site worker on the floor level; and a utility worker in closer proximity to the contaminated overhead surfaces, performing work such as pulling cables and changing light bulbs.

1.2.4.2 Exposure Setting

As identified in the RI Report for the Madison Site, the only residual uranium activity from AEC operations is in the dust that has accumulated on overhead horizontal surfaces above the extrusion press (structure-support beams, cross members, and window ledges). The radionuclide analysis results showed the contaminants to be a natural uranium isotopic mixture (approximately 50.6% U-234, 2.3% U-235, and 47.1% U-238 by activity).

- At approximately 7.6 m (25 ft) above floor level, affected horizontal support beams and cross members covering 14 sections in the vicinity of the extrusion press, were measured. The average uranium concentration from 52 samples was determined to be 48.6 ± 70.4 (1 standard deviation) pCi/g.

- At approximately 11 m (36 ft) above floor level, affected support beams and cross members were measured and the average uranium concentration from 10 samples was determined to be 70.9 ± 108.1 (1 standard deviation) pCi/g.

- Affected surfaces in high bay areas between 13.7 m (45 ft) to 18.3 m (60 ft) above the floor were difficult to access. No data could be obtained on uranium concentrations at this level.

Survey records identify the dust on overhead surfaces as ranging from “dry to oily layers,” except above the extrusion press where the dust was a “hard cake type material.” Dust thickness is reported to range from 0.64 to 0.95 cm (0.25 to 0.37 inches) with an average thickness of 0.8 cm (0.3 in). A density of 1.5 g/cm^3 (7.8 lb/ft^3) was assumed.

1.2.4.3 Worker Exposure Assumptions

The industrial/facility worker is on site at the floor level working 8 hours per day, 250 days per year for 25 years. This individual is exposed through inhalation to dusts that become dislodged from the overhead surfaces by utility workers and effectively disperse into the air volume below.

The industrial/utility worker is modeled as a person in closer proximity to the contaminated surfaces. The individual could be pulling cables, changing light bulbs, or performing other limited work in these overhead areas. This individual is exposed through inhalation to dusts that become disturbed and resuspended during work, and through ingestion due to direct contact with the surface contamination. Exposure is assumed to be limited to 20 hours per year for 25 years.

Parameters, assumptions, and calculations are documented in Appendix B of the Remedial Investigation Report for the Madison Site (USACE 1999).

1.2.4.4 Summary of Risk and Dose Estimate Results

Table 1-7 summarizes the risks and annual total effective dose equivalent (TEDE) for each worker potentially exposed during operations at the Madison site. The baseline assessment concludes that the uranium present in the dust on overhead structures of Buildings 6 and 4 in the vicinity of the extrusion press, does not pose an unacceptable potential risk to facility workers on the floor level. However, an unacceptable potential risk is calculated for the utility worker who is in close contact with contaminated surfaces. Uranium is also a kidney toxicant by the ingestion pathway. However, the hazard index for the utility worker was computed to be 0.02 (Appendix A). A hazard index less than 1 indicates no adverse noncarcinogenic effects are expected from this level of exposure. Ingestion is not a pathway for the facility worker; therefore, there is no noncarcinogenic risk.

Table 1-7. Summary of Excess Lifetime Cancer Risk and Total Effective Dose Equivalent (TEDE) – Baseline Risk Assessment

	Comparison Criteria	Scenario	
		Facility Worker	**Utility Worker***
Excess Lifetime Cancer Risk	CERCLA: $10^{-4} – 10^{-6}$	2.2×10^{-5}	5.3×10^{-4} ($9.5 \times 10^{-5} – 2.0 \times 10^{-3}$)
TEDE, (mrem/yr)	25 mrem/yr	9	210 (39 – 790)

* (NRC 1998) The resuspension factor may vary by 6 orders of magnitude depending on the conditions. The value of 5.0 E-5 is the value cited by the International Atomic Energy Agency for operating nuclear facilities. The range of values provided is the proposed range in NRC 1998.

The dose to the construction worker during building demolition or dismantlement was also evaluated to determine whether a potential future risk exists when the facility is closed. The dose experienced by the construction worker demolishing the building was estimated at less than 1 mrem, assuming normal construction practices such as use of dust suppression techniques. The dose absorbed if the building were dismantled with existing contamination levels, assuming no controls, could be as high as 40 mrem.

2 IDENTIFICATION OF REMEDIAL ACTION TECHNOLOGIES

2.1 INTRODUCTION

Remedial action objectives are developed in this section based on ARARs and protection of human health and the environment. Following the establishment of remedial action objectives, general response actions are described and technologies that are capable of achieving the remedial action objectives are identified.

2.2 ARARS AND REMEDIAL ACTION OBJECTIVES

The overall objective of remedial action at the Madison Site is to eliminate, reduce, or control the unacceptable exposure to uranium in dust in Buildings 6 and 4 consistent with the ARARs. As stated previously, the USACE is proceeding under the authority of Public Law 106-60 to conduct the response action at this site under FUSRAP, and subject to, but not under, the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), 42 USC 9601 et. seq., and its implementing regulations, the National Contingency Plan (NCP). Under CERCLA Section 121(d), a remedial action "shall attain a degree of cleanup of hazardous substances, pollutants, and contaminants released into the environment and of control of further release at a minimum which assures protection of human health and the environment." CERCLA Section 121(d) also requires that "the remedial action selected…shall require, at the completion of the remedial action, a level or standard of control for [a] hazardous substance or pollutant or contaminant which at least attains such legally applicable or relevant and appropriate standard, requirement, criteria, or limitation [ARAR]."

Two criteria, overall protection of human health and the environment, and compliance with ARARs, are specified by EPA in the NCP, at 40 CFR 300.430(e)(9)(iii)(A) and (B) as the two threshold criteria for evaluating remedial action alternatives. ARARs are deemed to be protective except when multiple contaminants exist.

2.2.1 ARARS

Identifying ARARs involves determining whether a requirement is applicable and, if it is not applicable, then whether a requirement is relevant and appropriate. Individual ARARs for each site must be identified on a site-specific basis. Factors that assist in identifying ARARs include the physical circumstances of the site, contaminants present, and characteristics of the remedial action.

Applicable requirements are those standards of control and other substantive environmental protection requirements, criteria or limitations promulgated under federal or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site.

Relevant and appropriate requirements are those standards of control, and other substantive requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well-suited to the particular site.

10 CFR 20, Subpart E: The Relevant and Appropriate Requirement

The U.S. Nuclear Regulatory Commission's (NRC's) rule on radiological criteria for license termination at 10 CFR Subpart E establishes dose criteria that apply when a licensee terminates its license. It provides a regulatory basis for determining the extent to which lands and structures must be remediated before decommissioning can be complete and a license terminated. Applying these criteria, a site can be released for unrestricted use if the residual radioactivity would result in a dose of less than 25 mrem to the average member of the critical group and the residual radioactivity has been reduced to as low as reasonably achievable (ALARA) levels. The promulgation of this rule supercedes NRC Regulatory Guide 1.86, *Termination of Operating Licenses for Nuclear Reactors*. Although this rule is not applicable because the uranium processing at the site was not performed under an NRC-license, it is considered to be relevant and appropriate because the activities conducted at the site and the resulting contamination are similar to those requiring an NRC license.

The State of Illinois was granted "Agreement State" status by the NRC in the early 1980s pursuant to Section 274 (b) of the Atomic Energy Act. The State of Illinois subsequently promulgated regulations with standards for protection against radiation, 32 Ill. Adm. Code 340 et seq. pursuant to the Illinois Radiation Protection Act of 1990, 420 ILCS 40/16. This state regulation established standards for protection against radiation resulting from activities conducted pursuant to Agreement State licenses and product registrations issued by the Illinois Department of Nuclear Safety. These actions occurred a number of years after uranium processing was conducted at Madison, and this site was never licensed by the State of Illinois for uranium. The policy of the NRC, promulgated under the authority of Section 274 (j)(1) of the Atomic Energy Act, requires that State standards for release limits be essentially identical to those of the Commission unless Federal statutes provide the State authority to adopt different standards. A deadline of three years from the promulgation of the NRC radiological criteria, which became effective on July 21, 1997, was established. Thus Illinois, which has not revised its standards to make them essentially identical to those of the Commission, should be in the process of doing so, with a final deadline of July 21, 2000. This response action will be performed at approximately the same time that the State standards are required to be changed and therefore, while the State standards may be considered relevant, they are not considered to be appropriate for this response action.

The pertinent sections of the ARAR, 10 CFR 20 Subpart E, are as follows:

§ 20.1402 Radiological criteria for Unrestricted Use

A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a TEDE to an average member of the critical group that doses not exceed 25 mrem [0.25 millisievert (mSv)] per year, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA). Determination of the levels that are ALARA must take into account consideration of any detriments, such as deaths from transportation accidents, expected to potentially result from decontamination and waste disposal.

§ 20.1403 Criteria for License Termination Under Restricted Conditions

A site will be considered acceptable for license termination under restricted conditions if:

a) The licensee can demonstrate that further reductions in residual radioactivity necessary to comply with the provisions of § 20.1402 would result in net public or environmental harm or were not being made because the residual levels associated with restricted conditions are ALARA must take into account consideration of any detriments, such as traffic accidents, expected to potentially result from decontamination and waste disposal;

b) The licensee has made provisions for legally enforceable institutional controls that provide reasonable assurance that the TEDE from residual radioactivity distinguishable from background to the average member of the critical group will not exceed 25 mrem (0.25 mSv) per year;

c) The licensee has provided sufficient financial assurance to enable an independent third party, including a governmental custodian of a site, to assume and carry out responsibilities for any necessary control and maintenance of the site. Acceptable financial assurance mechanisms are-

1. Funds placed into account segregated from the licensee's assets and outside the licensee's administrative control as described in § 30.35(f)(1) of this chapter;
2. Surety method, insurance, or other guarantee method as described in § 30.35(f)(2) of this chapter;
3. A statement of intent in the case of Federal, State, or local Government licensees, as described in § 30.35(f)(4) of this chapter; or
4. When a governmental entity is assuming custody and ownership of a site, an arrangement that is deemed acceptable by such governmental entity.

d) Residual radioactivity at the site has been reduced so that if the institutional controls were no longer in effect, there is reasonable assurance that the TEDE from residual radioactivity distinguishable from background to the average member of the critical group is as low as reasonably achievable and would not exceed either-

1. 100 mrem (1 mSv) per year; or

2. 500 mrem (5 mSv) per year provided the licensee-

    i. demonstrates that further reductions in residual radioactivity necessary to comply with the 100 mrem/y (1 mSv) value of paragraph (e)(1) of this section are not technically achievable, would be prohibitively expensive, or would result in net public or environmental harm;
    ii. make provisions for durable institutional controls;
    iii. provides sufficient financial assurance to enable a responsible government entity or independent third party, including a governmental custodian of a site, both to carry out periodic rechecks of the site no less frequently than every 5 years to assure that the institutional controls remain in place as necessary to meet the criteria of § 20.1403(b) and to assume and carry out responsibilities for any necessary control and maintenance of those controls. Acceptable financial assurance mechanisms are those in paragraph (c) of this section.

This regulation provides a dose limitation from all possible pathways of exposure and is applied by developing a DCGL to limit doses to meet the criteria.

2.2.2 Remedial Action Objectives

The objective of remedial action at the Madison site is to eliminate, reduce, or control the unacceptable exposure to uranium in dust in Buildings 6 and 4 by complying with the ARAR. Unacceptable exposures are limited to overhead surfaces at the 25 and 36 foot elevations in areas above the extrusion press. Exposure pathways of concern include external gamma radiation, inhalation of dust, and incidental ingestion of dust. The DCGL derived dose based on 25 mrem per year would be 6,000 dpm/100 cm^2 for surficial contamination and 20 pCi/g for volumetric contamination based on the exposure scenario described in detail in Appendix A.

2.3 GENERAL RESPONSE ACTIONS

General response actions that could be implemented to achieve the remedial action objectives described in Section 1.2.2 reflect the current understanding of contaminants and environmental conditions at the Madison Site. These general response actions include No Action, Institutional Controls, Containment, and Building Decontamination. The medium of interest at the Madison Site is the dust deposited on the overhead structures. The total area impacted by the dust is shown in Figure 1-4.

2.4 IDENTIFICATION OF TECHNOLOGY TYPES AND PROCESS OPTIONS

2.4.1 No Action

No Action means that no new action would be taken. Precautions currently in place to protect workers against exposure to contaminated surfaces would continue. The No Action Alternative is required by CERCLA to provide a baseline for comparison to other alternatives.

Under this alternative, the site is assumed to operate in compliance with the existing, NRC, Illinois, and OSHA regulationsthat impose limitations on occupational and public exposure.

2.4.2 Institutional Controls

The primary goal of institutional controls is to prevent access to contaminated areas. Where active response measures are determined not to be practical, the NCP allows the use of institutional controls to supplement engineering controls for short and long-term management of hazardous substances. Process options included under institutional controls include environmental monitoring, land use restrictions, work restrictions, resource restrictions, well-drilling prohibitions, maintenance of signs and fences, building permits, well use advisories, deed notices, deed restrictions, and periodic reviews. For the Madison Site, the relevant institutional controls are those that are specific to preventing workers from receiving an unacceptable exposure to the dust deposited on the overhead structures. These would include work restrictions, airborne particulate sampling, and posting signs in the contaminated areas. The facility is assumed to operate in compliance with the existing NRC, Illinois, and OSHA regulations that impose limitations on occupational and public exposure to radiation.

2.4.3 Containment

Containment technologies can effectively reduce mobility and exposure, but do not reduce contaminant volume or toxicity. For the Madison Site, containment technology is represented by surface sealants that would fix the contamination to the overhead structures.

2.4.4 Decontamination

Decontamination technologies remove contamination from the surfaces and recover the dust for disposal. Decontamination technologies include vacuuming, scraping, scrubbing, sand blasting, needle guns, scabblers, chipping hammers, and chemical dissolution.

3 DEVELOPMENT OF ALTERNATIVES

Technologies identified in Section 2 are assembled into remedial alternatives in this section. A remedial alternative has been developed to represent each of the general response actions. The overhead areas where the uranium contamination was found during the remedial investigation are shown in Figure 3-1.

3.1 ALTERNATIVE 1: NO ACTION

The No Action Alternative is required by CERCLA to provide a baseline for comparison against the other alternatives. No remedial actions would be undertaken to reduce, contain, or remove contamination in the building. Under this alternative, the site is assumed to operate in compliance with the existing, NRC, Illinois, and OSHA regulations that impose limitations on occupational and public exposure.

3.2 ALTERNATIVE 2: INSTITUTIONAL CONTROLS

Institutional controls are intended to protect against human exposure to contaminated materials by preventing or minimizing opportunities for exposure. Under this alternative, the site is assumed to operate in compliance with the existing, NRC, Illinois, and OSHA regulations, which impose limitations on occupational and public exposure. This alternative would include the following:

- Continued use as an industrial facility.
- Issue work instructions or work permits that identify the contamination and measures to preclude or reduce exposure when employees, contractors, or others, such as, utility workers, are required to perform activities in the vicinity of the contaminated beams.
- Airborne particulate sampling and analysis for the radioactive isotopes of concern.
- Monitor breathing zones if airborne particulates are found to contain radioactive elements.
- Maintain signs and fencing.
- Periodic inspections by the government to enforce any such restrictions.

The continued use of the site as an industrial facility with periodic monitoring and reviews would control the amount and duration of potential exposures. As part of their compliance with NRC, Illinois, and OSHA standards, the facility owners will preclude or reduce exposures in areas in which contaminated surfaces may be encountered. The alternative includes compliance with the controls by current and future building owners.

3.3 ALTERNATIVE 3: CONTAINMENT

The Containment Alternative would seek to reduce human exposure to contamination on surfaces by preventing the dust from becoming mobilized. This would be a sprayed coating that would adhere to the beams and immobilize the dust by trapping it beneath the coating. When use

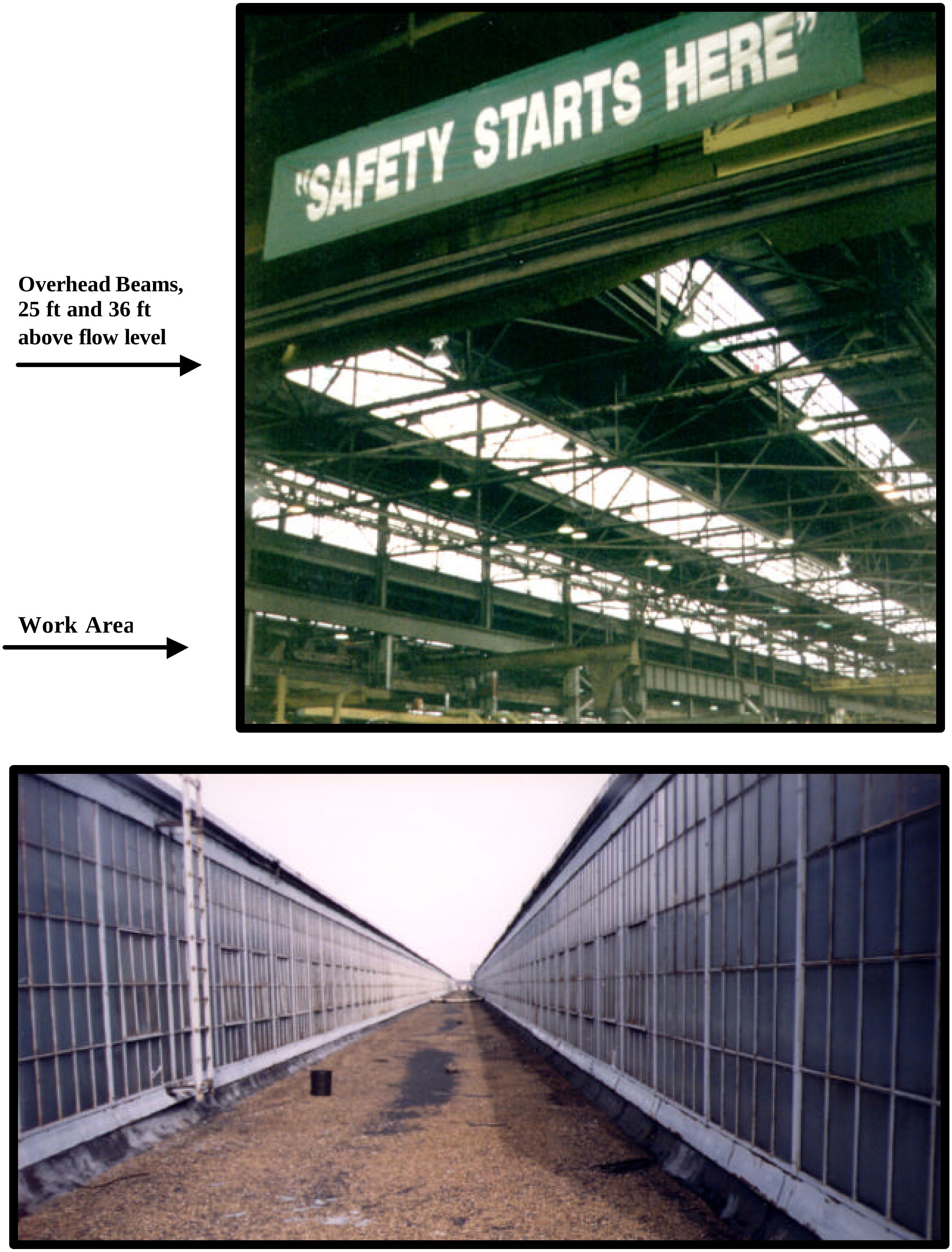

Figure 3-1. Overhead Beam Area Shown from Below and from Roof Above

of the building is discontinued in the future, radiological controls would be provided for decontamination prior to demolition of the building or disposal of the rubble following building demolition.

3.4 ALTERNATIVE 4: DECONTAMINATION OF OVERHEAD SURFACES AND RELEASE OF BUILDING

In developing this alternative, an ALARA analysis was performed to determine whether the high bay areas should be included in the decontamination alternative. The 25 ft and 36 ft levels are occasionally occupied by utility workers because of the electrical and water utilities in those areas. There is no reason for anyone to be in the high bay areas. The high bay was not designed to accommodate occupancy, and there are no utilities or other structures in the high bay that require maintenance, except the windows, which may be reached from the roof. The two decontamination alternatives considered, therefore, are decontamination of accessible surfaces and decontamination of all surfaces.

3.4.1 Decontamination of Accessible Overhead Surfaces

Under this alternative, radiological contamination on accessible surfaces (e.g., horizontal ledges such as window sills, electrical and water conduits, beams at the 7.6 and 11 m (25 and 36 ft) levels, and beams in the high bay that are accessible from windows on the roof) would be removed using appropriate decontamination technologies to a level sufficient to meet or exceed the contaminant-specific ARAR. Difficult to access areas are defined as those surfaces that can not be accessed by personnel from either the high-bay crane or through windows. Contamination would not be removed from these areas because the potential risk and exposure in these areas are essentially indistinguishable from background, and therefore these areas comply with the ARAR both for current and future workers.

The technologies that may be employed include vacuuming, scraping, scrubbing, etc. Contamination can be removed using either aggressive (needle guns, scabblers, chipping hammers, etc.) or non-aggressive (absorbent cloth, nuclear grade vacuum cleaners, paint remover, etc.) techniques. The decontamination work would take place when the current owner could make the building available. This typically occurs during the annual plant shutdown in July. This would prevent potential employee exposure to dust mobilized by the decontamination activities, and minimize disruption of plant operations.

For the purposes of analysis and cost estimating, this alternative is assumed to proceed as follows.

First, the accessible overhead structures and ledges in the building would be vacuumed to remove contaminated dust. If the treated area still exceeded the ARAR following vacuuming, then the surface would be scrubbed or scraped to loosen crusted contaminated materials, followed by vacuuming the area again. The procedure would be repeated using increasingly aggressive decontamination techniques until the surfaces meet the contaminant-specific ARAR.

Following decontamination of the overhead structures, the equipment and floor areas beneath the decontamination activities and the areas identified in the RI (USACE 1999) as containing isolated locations slightly above the guideline level would be surveyed to ensure these areas meet the ARAR. If found to exceed the ARAR, the floor would be decontaminated using methods similar to the overhead areas, and subjected to final status surveys.

Waste generated by the decontamination activities would be disposed in an appropriately licensed or permitted disposal facility. Waste packaging would be performed in accordance with all applicable federal, state, and local laws and regulations. Shipping containers would meet Department of Transportation requirements. Paint removed from the building surfaces would be sampled for Resource Conservation and Recovery Act (40 CFR 261) hazardous waste characteristics and would be stored, handled, and disposed in accordance with all applicable regulations. A final status survey would be conducted to ensure compliance with the ARAR.

No five-year reviews are required because the potential for unacceptable exposures would be eliminated by the removal action.

3.4.2 Decontamination of Difficult to Access Areas

The difficult to access areas do not contribute to dose exceeding 25 mrem/yr. However, because contamination can be found in these areas an evaluation was conducted to evaluate if the decontamination of these areas would be required in accordance with the as low as reasonably achievable (ALARA) provision of the ARAR.

An analysis was performed consistent with NRC Draft Regulatory Guide DG-4006 to compare the cost effectiveness of remediating only the accessible areas with remediating the high bay areas as well. It is not anticipated that anyone would be exposed to the contamination in the high bay area as there is no access to the high bay and there are no job functions requiring access. A facility worker (and not the utility worker) was chosen as the critical group because the high bay does not contain utility lines, control panels, etc. Because there is no reason for the utility worker (or anyone else) to come into direct contact with high bay contaminants, a facility worker is considered to be a more realistic receptor. The facility worker is exposed as materials in the high bay settle to the ground where a worker may be exposed. The levels of contamination measured on the beams were assumed to exist in the difficult to access areas.

$$B_{AD} = \$2000 \times PW(AD_{collective})$$

B_{AD} = Benefit from averted dose for a remediation action (dollars);
\$2000 = Value of a person-rem averted; and
$PW(AD_{collective})$ = Present worth of future collective averted dose.

$$PW(AD_{collective}) = P_D \; x \; A \; x \; 0.025 \; x \; F \; x \; \frac{CONC}{DCGL} \; x \; \frac{1 - e^{-(r+\lambda)N}}{r+\lambda}$$

P_D	=	Population density for the critical group scenario;
A	=	Area being evaluated (m^2); The terms P_D and A are used to estimate the number of people exposed. For this assessment and based on interviews at the site, it is assumed that $P_D \times A = 10$ when considering facility workers.
0.025	=	Annual dose to an average member of the critical group from residual radioactivity at the DCGL concentration (rem/yr);
F	=	Fraction of the residual radioactivity removed by the remediation action (calculated below);
CONC	=	Average concentration of residual radioactivity in the area being evaluated (calculated below in pCi/g or dpm/100 cm^2);
DCGL	=	Derived concentration guideline equivalent to the average concentration of residual radioactivity that would give a dose of 25 mrem/yr to the average member of the critical group (calculated below in pCi/g or dpm/100 cm^2);
r	=	Monetary discount rate (0.07/yr from DG-4006 Table 3);
λ	=	Radiological decay constant equivalent to the natural log of 2 divided by the radiological half-life, or $0.693/t_{½}$ (yr^{-1}). (For uranium isotopes, $\lambda << r$ so that $\lambda + r \approx r$. Therefore, the λ term is dropped.); and
N	=	Number of years over which the collective dose will be calculated (25 years assuming a reasonable yet conservative building lifetime).

Following remediation by decontamination of accessible areas, the dose was calculated to be 4.5 mrem per year when the contamination is at 1,000 dpm/100 cm^2. The average concentration at the 36 ft level was 1,118 dpm/100 cm^2 and was assumed to exist in the difficult to access areas.

The fraction of residual radioactivity removed by the remedial action (F) is assumed to be relatively high given that the contaminants were deposited in the overheads as settling dust. There is little reason to believe that over the years the contaminants have become embedded in the volume of metal beams, etc. Therefore, a conservative value of 0.9 is adopted for F, assuming that 90 percent of the contamination is removed during the remediation process.

Given that $P_D \times A$ = the number of workers on the facility floor under the contaminated area, a value of 10 persons was used with F = 0.90, CONC = 1,118 dpm/100 cm^2, and DCGL = 6,000 dpm/100 cm^2. $PW(AD_{collective})$ is estimated as follows:

$$PW(AD_{collective}) = 10 \; x \; 0.025 \; x \; 0.90 \; x \; \frac{1118}{6{,}000} \; x \; \frac{1 - e^{-(0.07)25}}{0.07} = 0.49$$

Having calculated $PW(AD_{collective})$ for the high bay, the benefit from averted dose is calculated as follows:

$$B_{AD} = 0.49 \times \$2{,}000 = \$980$$

It is not anticipated that anyone would be exposed to the contamination in the high bay given access limitations and given the absence of job functions requiring access. The benefit from the averted dose is calculated to be less that $1000 while the cost to remediate the high bay is estimated to be $250,000, essentially doubling the remediation cost at the Madison site. Nuclear Regulatory Commission Draft Guide DG-4006 recommends that if the cost of a proposed remedial action exceeds the value of the benefit and the residual dose is below 25 mrem/yr, the remedial action is not ALARA. Remediation of the high bay and difficult to access areas is not recommended and is not included in the decontamination alternative.

4 ANALYSIS OF ALTERNATIVES

The alternatives described in the preceding section are evaluated in detail in this section. The detailed analysis of alternatives includes a detailed description of each alternative followed by a detailed evaluation using the nine criteria outlined in CERCLA. The detailed analysis of alternatives is followed by a comparative analysis in which the alternatives are directly compared against one another with respect to each criterion.

Following are the nine evaluation criteria required by CERCLA.

- Threshold Criteria
  - Overall Protection of Human Health and the Environment
  - Compliance with ARARs

- Balancing Criteria
  - Short-term Effectiveness
  - Long-term Effectiveness and Permanence
  - Reduction of Volume, Toxicity, and Mobility Through Treatment
  - Implementability
  - Cost

- Modifying Criteria
  - State Acceptance
  - Community Acceptance

The selected alternative must satisfy the threshold criteria. That is, alternatives that are not protective of human health and the environment or do not comply with ARARs must be rejected.

4.1 DESCRIPTION OF THE NINE CRITERIA

4.1.1 Overall Protection of Human Health and the Environment

The evaluation of the overall protection of human health and the environment for each alternative assesses whether the alternative can adequately protect human health and the environment, in both the short- and long-term, from unacceptable risks posed by contaminants at the site. Overall protection of human health and the environment draws on other factors assessed under the evaluation criteria. The criteria specifically considered are short-term effectiveness, long-term effectiveness and permanence, and compliance with ARARs. For each alternative, the evaluation should include the following:

- how the source of contamination is to be reduced or controlled and
- how the site-related risks are to be reduced and whether target levels are attained.

4.1.2 Compliance with ARARs

Each alternative is assessed for its compliance with ARARs under federal environmental laws and state environmental or facility siting laws.

4.1.3 Short-Term Effectiveness

The short-term effectiveness of an alternative is evaluated relative to its effect on human health and the environment during implementation of the interim action. The short-term effectiveness assessment is based on four key factors:

- Short-term risks that might be posed to the community during implementation of an alternative.
- Potential for impacts on workers during construction and the effectiveness and reliability of protective measures.
- Potential environmental impacts of the action and the effectiveness and reliability of mitigative measures during implementation.
- Time until objectives are achieved.

4.1.4 Long-Term Effectiveness and Permanence

Evaluation of an alternative relative to its long-term effectiveness and permanence is made considering the risks remaining at the site after the response objectives have been met. The assessment of long-term effectiveness is made considering the following four factors:

- The magnitude of the residual risk to human and environmental receptors remaining from untreated waste or treatment residues remaining at the conclusion of the remedial activities. The characteristics of the waste to be considered should include volume, toxicity, mobility, and its propensity to bioaccumulate.
- An assessment of the type, degree, and adequacy of long-term management [including engineering controls, monitoring, and operation and maintenance (O&M)] required for untreated waste or treatment residues remaining at the site.
- An assessment of the long-term reliability of engineering and institutional controls to provide continued protection from untreated waste or treatment residues.
- The potential need for replacement of the action and the continuing need for repairs to maintain the performance of the remedy.

4.1.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

This evaluation criterion addresses the degree to which actions employ treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of the hazardous substances. The ability of an alternative to reduce toxicity, mobility, or volume is not considered under this criterion unless the alternative accomplishes the reduction through treatment. The following specific factors are considered:

- The treatment process.
- The amount of hazardous materials that would be treated.
- The degree of reduction in toxicity, mobility, or volume, including how the principal threat is addressed through treatment.
- The degree to which the treatment is irreversible.
- The type and quantity of treatment residuals that would remain following treatment.

4.1.6 Implementability

Implementability refers to the ease or difficulty of deploying the alternatives. Specific factors used in assessing implementability include the following:

- Technical feasibility, including technical difficulties and unknowns associated with the construction and operation of a technology, the reliability of the technology, ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy.
- Administrative feasibility, including activities needed to coordinate with other offices and agencies and the ability and time required to obtain any necessary approvals and permits from other agencies (for offsite actions).
- Availability of services and materials, including the availability of adequate offsite treatment, storage capacity, and disposal capacity and services; the availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources; the availability of services and materials; and availability of prospective technologies.

4.1.7 Cost

The cost of an alternative reflects the capital and O&M requirements for each alternative and provides an estimate of the dollar cost of each alternative. The costs estimated in this report are based on quotes from suppliers, generic unit costs, vendor information, cost-estimating guides, prior experience, and other information. The cost estimates are developed for FY99 dollars, with no escalation or discount factors. The cost estimates have been prepared for guidance in project evaluation and implementation. They are believed to be accurate within a range between –30 and +50 percent of actual costs in accordance with EPA guidance. The actual costs for these actions could be higher than estimated because of unexpected site conditions and the potential for delays in taking the action. Correspondingly, costs could be lower if construction or disposal efficiencies are achieved. The assumptions and uncertainties that affect the cost estimates are presented in Appendix B.

4.1.8 State and Community Acceptance

The state and community acceptance criteria are modifying criteria. They are not addressed in this document but, as specified by CERCLA guidance, will be addressed after the public comment period on the Proposed Plan. The preferred alternative should be acceptable to state and support agencies. Also, the concerns of the community should be considered in presenting alternatives that would be acceptable to the community. These two criteria will be evaluated following the public comment period and will be addressed in the Record of Decision (ROD).

4.2 ALTERNATIVE 1 – NO ACTION

Under this alternative, no remedial actions would be undertaken to reduce, contain, or remove contamination in the building. The facility is assumed to operate in compliance with the existing, NRC, Illinois, and OSHA regulations, which impose limitations on occupational and public exposure. The facility would continue its current operations and access controls would be maintained. This alternative does not comply with the ARAR based on exposure to utility workers in accessible overhead areas.

4.2.1 Overall Protection of Human Health and the Environment

The risk analysis indicates there are currently no unacceptable risks to the typical employee from the material on the overhead structures in the building. The annual dose to the typical facility worker is estimated to be 9 mrem, which equates to an incremental lifetime excess cancer risk of approximately 2.2×10^{-5}. A dose was also estimated for a maximally exposed worker, a worker making repairs in the overhead utilities. Using conservative assumptions regarding the amount of radioactive dust in this worker's breathing zone, the dose to this worker has been estimated to exceed the 25 mrem/yr ARAR assuming the receptor spends 20 hours per year working on the overhead utilities. Details of the calculations may be found in Appendix A. Thus, the No Action Alternative may not provide adequate long-term protection if the site is released without any controls in place.

4.2.2 Compliance with ARARs

The No Action Alternative leaves material that could potentially result in exposures in excess of the 25 mrem/yr standard and the 100 mrem/yr standard for dose if institutional controls should be lost (10 CFR 20 Subpart E).

4.2.3 Short-term Effectiveness

Because no remedial actions would be performed, there would be no short-term risks to remedial workers or the community associated with implementation of this alternative.

4.2.4 Long-term Effectiveness and Permanence

Release of radioactive dust is possible in the long-term. No reduction in toxicity, mobility, or volume of the contaminants would be realized as a result of implementing this alternative.

The reliability of engineering or institutional controls and the potential need for replacement or repairs are not applicable to this alternative because there are no controls imposed.

4.2.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

No treatment technologies would be implemented in the No Action Alternative. Therefore, there would be no reduction of toxicity, mobility, or volume through treatment.

4.2.6 Implementability

The No Action Alternative would be easy to implement from the technical feasibility and availability of services and materials perspectives.

4.2.7 Cost

No additional costs would be incurred because no remedial actions are implemented.

4.3 ALTERNATIVE 2 – INSTITUTIONAL CONTROLS

Institutional controls would include the following measures:

- Issuing work instructions or work permits that would identify the contamination and mandate measures to preclude or minimize exposure when workers jobs require activities in the vicinity of the contaminated surfaces.
- Airborne particulate sampling and analysis for the radionuclides of concern.
- Breathing zone monitors if uranium is detected in the airborne particulates.
- Maintaining signs and fencing.
- Land use restrictions.
- Periodic inspections by the government to ensure institutional controls are being enforced (five-year reviews).

4.3.1 Overall Protection of Human Health and the Environment

Institutional controls are effective in the short-term because the activities required to implement institutional controls are non-intrusive and would, therefore, not mobilize the materials on the overhead structures. The facility is assumed to operate in compliance with the existing, NRC, Illinois, and OSHA regulations, which impose limitations on occupational and public exposure. No additional risk to the workers, community, or environment would be realized as a result of implementation of this alternative. In the long-term, exposure would be reduced as a result of implementing access restrictions.

4.3.2 Compliance with ARARs

Institutional controls would reduce exposures below the 25 mrem limit for the utility worker as long as they remain effective. However, if institutional controls should be lost exposures greater than 100 mrem/yr could result for utility workers in Building 6 and 4 overhead areas.

4.3.3 Short-Term Effectiveness

No additional risks would be experienced by workers or the community during implementation of this alternative. No additional impacts to the environment would be expected from implementation of this alternative. The alternative could be implemented in approximately three weeks, including establishing work instruction procedures, acquiring and posting signs, and planning and initiating a particulate sampling program.

4.3.4 Long-Term Effectiveness

The contaminant toxicity would not be changed by implementing institutional controls. However, the opportunities for exposure would be curtailed by the controls and, thus, the potential risk would be reduced. The imposed controls on access would be adequate to minimize exposure to the contaminated surfaces and would continue to be protective in the future provided the controls are maintained. The air particulate samplers would require some maintenance, such as calibration of the flow meters and replacement of the pumps on a cycle of 1 to 3 years.

4.3.5 Reduction of Toxicity, Mobility or Volume Through Treatment

No treatment technologies would be implemented for this alternative.

4.3.6 Implementability

Institutional controls are readily implementable. No technical difficulties are anticipated in establishing safe work practices, a particulate sampling program, or posting warning signs. Services and materials to implement the institutional controls are readily available.

4.3.7 Cost

Institutional controls are estimated to cost about $60,000 to maintain over a 30 year period.

4.4 ALTERNATIVE 3 – CONTAINMENT

Containment would remove the inhalation and ingestion pathways by fixing the dust to the surfaces at the 8 and 11 m (25 and 36 ft) heights and at the accessible areas at greater heights with a sprayed coating. When use of the building is discontinued in the future, radiological controls are not required prior to demolishing the building or for disposal of the rubble following demolition to comply with the ARAR.

4.4.1 Overall Protection of Human Health and the Environment

Containment would control the source of contamination by fixing it to a surface to prevent migration and intercept the major pathways to workers by eliminating removable contamination. Site risks would be reduced by eliminating the airborne dust pathway. In the long-term, containment would be protective because it would effectively prevent migration of contamination. This alternative would comply with the ARAR.

4.4.2 Compliance with ARARs

Alternative 3 would further reduce exposures. However, the 10 CFR 20 exposure criterion could be slightly exceeded by the utility worker. Because of the conservative assumptions used in the assessment, it is unlikely that doses exceeding 25 mrem would actually be realized.

4.4.3 Short-Term Effectiveness

Containment would pose little or no risk to the community as the action would take place entirely inside the facility.

Remedial worker exposure to ionizing radiation will be kept well below occupational exposure standards by implementation of a USACE required Site Safety and Health Plan (SSHP).

The time required to implement this alternative is dictated by the scheduled shutdown. It is assumed that a total of three weeks is required to perform the remedial work.

4.4.4 Long-Term Effectiveness and Permanence

Containment would be effective in the long-term because it would ensure that the radioactive materials currently on the horizontal surfaces could not migrate following completion of the remedial activities. Containment would have no impact on the toxicity or volume of the waste, but would reduce its mobility.

The overhead areas would need to be inspected periodically to ensure that the coating does not deteriorate over time. If the coating were to show signs of deterioration such as cracking and peeling, the coating may need to be reapplied. With such maintenance, the remedial action should remain effective.

4.4.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

No treatment technologies are used in this alternative. This alternative uses containment to minimize mobility.

4.4.6 Implementability

The technology is readily implementable and has been used in similar circumstances to contain radiological contaminants and prevent migration. There are no technical impediments to Alternative 3.

There are no administrative impediments to Alternative 3.

Services and materials required to implement this alternative are readily available from the commercial decontamination industry. No radiological disposal capacity is expected to be required as the workers would not directly contact the contaminated surfaces during remedial activities. Therefore, the protective clothing should not become contaminated and require disposal as radiological waste. Protective clothing and equipment may require disposal as hazardous waste, however, depending upon the characteristics of the spray coating. There is adequate hazardous waste storage and disposal capacity available to accept the type and volume of hazardous wastes that could be generated as a result of this action.

4.4.7 Cost

Fixing the dust in place is the most expensive alternative. The estimated cost is approximately $450,000.

4.5 ALTERNATIVE 4 – DECONTAMINATION OF OVERHEAD SURFACES AND RELEASE OF BUILDING

This alternative would achieve the remedial action objectives by removing the contamination from the 8 and 11 m (25 and 36 ft) heights and from the accessible areas at greater heights. As workers are not sent to levels inside the building above the 11 m (36 ft) level (as no utilities are located above this level) no credible exposure exists in this area.

4.5.1 Overall Protection of Human Health and the Environment

Decontamination of the building is protective of human health and the environment. The source of the contamination would be reduced by decontaminating the accessible surfaces and the risk to employees would be reduced as well. The contaminants would be removed and disposed in an appropriate licensed or permitted disposal facility. Decontamination would be effective in the long-term as well as the short-term. This alternative would fully comply with the ARAR. Further decontamination of difficult to access areas is likely to more than double the cost of remediation and result in a benefit due to dose avoidance of less than $1000.

4.5.2 Compliance with ARARs

Decontamination would reduce exposures and remove uranium from generally accessible areas (e.g., at 8 and 11 m (25 and 36 ft) heights) to levels at or below the ARAR. The removal would reduce potential future doses below the 25 mrem/yr level and would be as low as reasonably achievable. Remediation of inaccessible areas would greatly increase the cost with very little effect on worker exposure. Lack of remediation of inaccessible areas would be fully complaint with the ALARA provisions of 10 CFR 20 Subpart E, given the cost, minimal dose remediation, and risk of falls and high voltage accidents.

4.5.3 Short-Term Effectiveness

No short-term risks to the community or to employees would result from this action because the work would take place entirely inside the facility during the period that the plant is shut down and few employees would be at the site.

Remedial worker exposure to ionizing radiation will be kept well below occupational exposure standards by implementation of a USACE required Site Safety and Health Plan (SSHP). Remediation workers will be exposed to risk due to safety hazards from working at heights and electrical hazards, as well as the exposure to the contamination.

No adverse environmental impacts are expected to occur as a result of implementing this alternative, as all remedial activities would be confined to the inside of the building.

Implementation is expected to require three weeks including one week (five days) for mobilization, nine days working inside the plant during its annual shutdown, and one week for demobilization.

There would be a slight risk to the public from the transportation and off-site disposal of the small amount of waste that would be generated. The volume of waste is small (10 to 20 cubic yards) and the facility is located near major transportation routes.

4.5.4 Long-Term Effectiveness and Permanence

Decontamination would be effective and permanent in the long-term at reducing the amount of AEC-related material present in the building. Residual risk from the contaminants would be eliminated by this action.

No further active management of the contaminated materials would be necessary following this remedial action because all the accessible contaminated areas would have been decontaminated. Doses and risks when the facility is dismantled or demolished would be below the 25 mrem/yr ARAR and within the CERCLA risk range.

The long-term reliability of this alternative is high because most of the contaminated material would be removed from the site and placed in an appropriately licensed or permitted disposal facility.

4.5.5 Reduction of Toxicity, Mobility, or Volume Through Treatment

No treatment technologies would be used in this alternative. Therefore, there would be no reduction in the contaminant toxicity, mobility, or volume as a result of treatment.

4.5.6 Implementability

Decontamination technology is well established and reliable. The difficulty of implementing this alternative is increased by the height at which the contamination is present, by the brief time frame in which the work must take place due to the operational schedule of the plant, and by the high ambient temperatures expected at the time the work would be performed. However, all of these difficulties could be overcome by good planning and safe work practices.

Administrative feasibility should not present any barriers to implementing this alternative. Coordination among USACE, the building owner, and the regulatory agencies would be necessary, but this should not present any difficult obstacles to implementation.

Services and materials are readily available for this type of work from a number of construction contractors. No difficulty in obtaining multiple competitive bids is anticipated.

4.5.7 Cost

The estimated cost for decontamination of the accessible areas is approximately $250,000.

5 COMPARATIVE ANALYSIS OF ALTERNATIVES

5.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

Except for Alternative 1 (No Action), all of the alternatives are protective of human health and the environment. For Alternative 3 (Containment) and Alternative 4 (Decontamination), the short-term risks to the workers involved in the remediation would be slightly higher due to the risks associated with containment and decontamination activities. Alternative 1 (No Action) is not protective of human health and the environment in the long-term because the source of contamination is not reduced or controlled. Alternative 2 (Institutional Controls) and Alternative 3 (Containment) are expected to decrease risk and exposure, but do not remove contamination. Alternative 4 (Decontamination) is protective of human health and the environment in the long-term as the contaminated materials are contained and removed. A slight increase in transportation and disposal risk would result for Alternative 4 (Decontamination).

5.2 COMPLIANCE WITH ARARS

Alternative 1 (No Action) does not comply with the ARAR because doses may be received by utility workers that exceed the 25 mrem/year allowed by 10 CFR Part 20. Alternative 2 (Institutional Controls) could be made to comply with the 25 mrem/yr standard in 10 CFR Part 20 by the imposition of more stringent work restrictions. However, if institutional controls were lost, doses could exceed the 100 mrem/yr standard in 10 CFR Part 20 Subpart E. Alternative 3 (Containment) could be made to comply with the ARAR by imposing minimal institutional controls in addition to the coating. Alternative 4 (Decontamination) would comply with the ARAR.

5.3 SHORT-TERM EFFECTIVENESS

Alternative 1(No Action) and Alternative 2 (Institutional Controls) do not involve intrusive remeiation work and, therefore, would pose little to no risk to the community or workers. Alternative 3 (Containment) and Alterative 4 (Decontamination) would pose little to no risk to the community, however, the remedial workers would be subjected to increased risks during the performance of work.

No time period is associated with implementation of Alternative 1 (No Action). The time period for implementation is three weeks for Alternatives 3 and 4. The remedial action schedule for Alternative 3 (Containment) and Alternative 4 (Decontamination) is driven by the need to complete the action during the plant shutdown so as not to impact operations or pose potential risk to employees.

5.4 LONG-TERM EFFECTIVENESS

Alternative 1 (No Action) would not be effective in the long-term as the contaminated materials would remain and would not be controlled. Alternative 2 (Institutional Controls) and Alternative 3 (Containment) are expected to decrease the dose and risk. Alternative 4 (Decontamination) would be effective in the long-term. Alternative 4 (Decontamination) would be the most effective in the long-term as the contamination would be removed and the structure would be released by the USACE.

5.5 REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THOUGH TREATMENT

No effective treatment to reduce toxicity, mobility, or volume was identified as radioactivity can't be destroyed and toxicity cannot be significantly effected. The uranium is expected to exist as a very stable oxide, thus mobility of the current chemical form is minimized. Solidification agents would increase the volume in exchange for a reduction in mobility. Extraction of the uranium is not practical for the small volume of waste that will be generated.

5.6 IMPLEMENTABILITY

All alternatives are technically feasible to implement. Alternative 3 (Containment) and Alternative 4 (Decontamination) would require working around equipment and obstacles in the buildings. Services and materials are readily available to implement all alternatives.

5.7 COST

No action has no additional cost but also provides no additional protection. Institutional controls costs are very low, but this alternative doses not meet the 100 mrem/yr standard if institutional controls are lost. the cost for decontamination is significantly lower than the cost for contaminant. The 30-year cost, in 1999 dollars and zero discounting, is shown below for each alternative.

Action	Cost
Alternative 1 – No Action	0
Alternative 2 – Institutional Controls	$60,000
Alternative 3 – Containment	$450,000
Alternative 4 – Decontamination	$250,000

5.8 STATE AND COMMUNITY ACCEPTANCE

The state and community acceptance criteria will be evaluated following comments on the FS/PP received during the public comment period.

6 REFERENCES

DOE (U.S. Department of Energy) 1997. *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*, NUREG-1575, EPA 402-R-97-016, DOD, DOE, EPA, and NRC, December.

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EPA 1999. *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and other Remedy Selection Decision Documents.*

NRC (U.S. Nuclear Regulatory Commission) 1992. *Manual for Conducting Radiological Surveys in Support of License Termination*, NUREG/CR-5849 (draft), Nuclear Regulatory Commission, June 1992.

ORNL (Oak Ridge National Laboratory) 1990. *Preliminary Results of the Radiological Survey at the Former Dow Chemical Company Site, Madison, Illinois*, ORNL/TM-11552, Oak Ridge, Tennessee, December.

USACE (U.S. Army Corps of Engineers) 1998a. *Radiological Survey Work Plan, Spectrulite Consortium, Inc., Facility, Madison, Illinois*, St. Louis, Missouri, June.

USACE 1998b. *Radiological Survey Work Plan-Addendum, Spectrulite Consortium, Inc., Facility, Madison, Illinois*, U.S. Army Corps of Engineers, November.

USACE 2000. *Remedial Investigation Report for the Madison Site, Madison Illinois*, St. Louis, Missouri, June.

APPENDIX A

EVALUATION OF RISKS

A.1 INTRODUCTION

Background

The U.S. Army Corps of Engineers (USACE) is currently working to remediate sites that contain residual radioactive material as a result of former operations performed under contract with the United States government. Remedial actions are being performed under the Formerly Utilized Sites Remedial Action Program (FUSRAP). During the late 1950s and early 1960s, Mallinckrodt Chemical Works contracted with the former Dow Chemical Company facility (currently Spectrulite Consortium, Inc.), in Madison, Illinois, to perform extrusions of uranium metal and straightening of extruded uranium rods for the U.S. Atomic Energy Commission (AEC).

Two evaluations of the Madison site have been performed. A preliminary radiological survey was conducted in 1989 by Oak Ridge National Laboratory (ORNL), under contract to the U.S. Department of Energy (DOE). That survey identified low concentrations of uranium in dust on overhead structures above the general vicinity of the extrusion press, and ORNL concluded that this residual radioactive material did not pose a potential for significant radiation exposure to current building occupants (ORNL 1990). The ORNL report recommended further investigations to better define the extent of uranium contamination (ORNL 1990). The second survey effort was conducted by the USACE in 1998. Results of the USACE survey are documented in the Remedial Investigation (RI) Report for the Madison site (USACE 1998). The concentration and extent of uranium contamination in dust on overhead structures near the extrusion press in Building 6 were quantified.

The Madison site will be remediated, as appropriate, subject to U.S. Environmental Protection Agency (EPA) Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (NCP). As part of the CERCLA process, applicable or relevant and appropriate requirements (ARARs) are selected. Although not applicable, the Nuclear Regulatory Commission's (NRC's) 10 CFR 20 is relevant and appropriate for the Madison site. Subpart E of 10 Code of Federal Regulations (CFR) Part 20 specifically addresses radiological criteria for site release limiting radiological doses to be less than 25 mrem/yr to a member of the critical group. The dose must also be as low as reasonably achievable (ALARA), and less than 100 mrem/yr is institutional controls are lost.

This assessment, therefore, evaluates radiological dose and radiological risk.

NRC Guidance for unrestricted release of equipment and facilities was previously defined in NRC Regulatory Guide 1.86. This guide is currently being replaced by site specific derived concentration criteria.

A.2 SCOPE AND PURPOSE

The purpose of this risk evaluation is to determine the carcinogenic risk and total effective dose equivalent (TEDE) for individuals who might be exposed to the residual AEC-related contamination at the Madison site. The remedial action alternatives include: (1) No Action, (2) Institutional Controls (with no removal), (3) Containment, and (4) Decontamination.

Assessments are performed for five groups of individuals: the industrial/site worker who works on the floor level of the Madison Site, the industrial/utility worker who works in overhead areas; the industrial or safety worker who performs air sampling in overhead areas; the remediation worker; and individuals exposed as a result of building demolition or dismantlement.

The general approach for the dose and risk evaluation follows guidelines established by EPA for conducting Baseline Risk Assessments [*Risk Assessment Guidance for Superfund, (RAGS) Volume 1 Human Health Evaluation Manual, Part A*] (EPA 1989). It also incorporates generic modeling analysis guidance from the NRC contained in NUREG/CR-5512, Volume 3 and associated NRC letter reports. Residual risks were calculated in accordance with EPA CERCLA guidance using cancer risk slope factors from EPA Health Effects Assessment Summary Tables (HEAST). The TEDEs were calculated using exposure-to-dose conversion factors from Federal Guidance Report 11, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion* (EPA 1988).

A.3 EXPOSURE SETTING

As identified in the Madison RI Report, the only significant levels of residual uranium from AEC operations are in the dust accumulated on overhead horizontal surfaces above the extrusion press, including structure-support beams, cross members, and window ledges. The affected surfaces were broken down into three categories of surface that total approximately 2,300 m^2 (25,000 ft^2) in area.

- At approximately 7.6 m (25 ft) above floor level, affected horizontal support beams and cross members covering 14 sections in the vicinity of the press, were determined to cover an area of 743 m^2 (8,000 ft^2). The average uranium concentration from 52 samples was determined to be 48.6 ± 70.4 (1 standard deviation) pCi/g.

- At approximately 11 m (36 ft) above floor level, affected support beams and cross members were determined to cover an area of 496 m^2 (5,339 ft^2). The average uranium concentration from 10 samples was determined to be 70.9 ± 108.1 (1 standard deviation) pCi/g.

- Affected surfaces in high bay areas between 13.7 m (45 ft) to 18.3 m (60 ft) above the floor were determined to have a combined surface area of 1,057 m^2 (11,378 ft^2). For safety concerns, no data were collected from the 13.7-m (45-ft) or higher levels.

To be conservative it is assumed that the average concentration in all areas is 70.9 pCi/g. Therefore, the dose and risk estimates presented likely overestimate the exposure to potential receptors.

Survey records identify the dust on overhead surfaces as ranging from “dry to oily layers” except above the extrusion press where the dust was a “hard cake type material.” Dust thickness is reported to range from 0.64 to 0.95 cm (0.25 to 0.37 inches) with an average thickness of 0.8 cm (0.3 in). A density of 1.5 g/cm^3 (7.8 lb/ft^3) was assumed. The radionuclide analysis results showed the contaminants to be a natural uranium isotopic mixture (approximately 50.6% U-234, 2.3% U-235, and 47.1% U-238 by activity). (USACE 2000)

A.4 EXPOSED INDIVIDUALS – WORKER SCENARIOS

Groups of individuals assumed to be exposed for the various remedial action alternatives include (1) an industrial/site worker, (2) an industrial/utility worker, (3) an industrial/safety worker, (4) a remediation worker, and (5) individuals exposed as a result of building demolition and subsequent recycle of contaminated beams. A basic description of each potential receptor is presented below. Specific receptor characteristics and exposure conditions used in dose and risk calculations are presented in future sections.

The industrial/site worker is modeled as on site at the floor level working 8 hours per day, 250 days per year for 25 years. This individual is modeled as a person exposed through inhalation to dusts that becomes dislodged from the overhead surfaces and effectively falls into the air volume below.

The industrial/utility worker is modeled as a person in closer proximity to the contaminated surfaces than the industrial/facility worker. This individual may be pulling cables, changing light bulbs, or performing other limited work in these overhead areas. This scenario evaluates an individual that is exposed through inhalation of dusts that become disturbed and resuspended during work, and through contaminant ingestion due to the worker's contact with the surface contamination. Exposure is assumed to be limited to 20 hours per year for 25 years.

The industrial/safety worker is a worker who would be responsible for institutional controls such as air sampling in overhead areas. Exposure for this worker is conservatively estimated at 8 hours per year.

The remediation worker is a worker who has been trained in contamination control practices who is implementing the applicable remedial action alternative of either containment or decontamination.

Persons exposed as a result of building demolition include the construction worker who either demolishes or dismantles the building and the worker in the scrap yard where the overhead structures are sent for recycling.

A.5 RISK/DOSE EVALUATION – NO ACTION ALTERNATIVE

A baseline risk and dose assessment was performed and documented in Appendix B of the Madison Remedial Investigation Report (USACE 2000). This scenario assumed that no remedial actions were taken to reduce, contain, or remove the contamination in the building, and no worker controls are implemented to reduce exposure. Inhalation was assumed to account for greater than 99% of the TEDE. This assumption was based on RESRAD-BUILD computer code runs using default parameters, decontamination and decommissioning computer code runs with default parameters for the building occupancy scenario, and published studies (none of these are included in the assessment but form the basis for the dose and risk calculations). Parameters, assumptions, calculations, and results from this baseline assessment can be found in Appendix B to the Remedial Investigation Report (USACE 2000). An ingestion pathway is included for the industrial/utility worker assessment due to contact with the contaminated surfaces. The increased stress due to heat and elevation might cause a worker to touch his face more frequently.

A.5.1 Parameters and Assumptions for the No Action (Baseline) Alternative

Exposure parameters for the industrial/site worker are listed in Table A-1. Exposure parameters for the industrial/utility worker are listed in Table A-2.

Table A-1. Industrial/Site Worker Exposure Parameters – No Action

Exposure Parameter	Value	Source/Comments
Inhalation rate (m^3/day)	10	The 1997 Exposure Factors Handbook lists the mean hourly rate for adults as 1.0 m^3/hour for light activities and 1.6 m^3/hr for moderate activities. A mix of activities was used to represent the facility worker's activities for as 8 hour shift spent mostly in the contaminated zone. The value used was 10 m^3/day or 1.25 m^3/hr.
Exposure frequency (days/yr)	250	EPA (1991) Working 5 days per week for 50 weeks per year.
Exposure duration (yrs)	25	EPA (1991) Exposure duration for commercial/industrial use.
Inhalation class	Y	Chemical form inhalation class refers to the clearance half time from the pulmonary region of the lungs. Class Y is the most conservative uranium class.

Table A-2. Industrial/Utility Worker Exposure Parameters - No Action

Exposure Parameter	Value	Source/Comments
Risk coefficients, inhalation slope factors (risk/pCi)	U-234 = 1.4 E-8 U-235 = 1.3 E-8 U-238 = 1.24 E-8	EPA (1995) tabulated values. An average value of 1.3 E-8 will be used for the natural uranium isotopic mixture at the Spectrulite facility.
Exposure-to-dose conversion factor for inhalation (Sv/Bq)	U-234 = 3.58 E-5 U-235 = 3.32 E-5 U-238 = 3.2 E-5	EPA (1988) values from Table 2.1 for TEDE for class Y uranium isotopes. The dose conversion factor for U-234 will be conservatively used for the dose assessment.
Inhalation rate (m^3/hr)	1.875	The 1997 Exposure Factors Handbook lists the mean hourly rate for adults as 1.0 m^3/hr for light activities, 1.6 m^3/hr for moderate activities, and 3.2 m^3/hr for heavy activities. Activities for utility workers are typically moderate activities, but the value was increased to account for brief periods of heavy activities. The value used was 1.875 m^3/hr.
Exposure frequency (hours/yr)	20	20 hours is an estimate for someone pulling utility cables or changing light bulbs.
Exposure duration (yrs)	25	EPA (1991) Exposure duration for the commercial/industrial use.
Inhalation class	Y	Chemical form inhalation class refers to the clearance half time from the pulmonary region of the lungs. Class Y is the most conservative uranium class.

Table A-2. Industrial/Utility Worker Exposure Parameters - No Action (Cont'd)

Exposure Parameter	Value	Source/Comments
Resuspension factor (m^{-1})	5.0 E-5 Range: 9.1 E-6 to 1.9 E-4	NRC (1998a) The resuspension factor is noted to vary by 6 orders of magnitude depending on the conditions. The value of 5.0 E-5 is the value cited by the International Atomic Energy Agency for operating nuclear facilities. The range of values provided is the proposed range in NRC 1998a.
Transfer rate for ingestion of removable surface contamination (m^2/hr)	1.0 E-4	NRC (1998a) This factor represents a plausible ingestion fraction.
Risk coefficients, inhalation slope factors (risk/pCi)	U-234 = 1.4 E-8 U-235 = 1.3 E-8 U-238 = 1.24 E-8	EPA (1995) tabulated values. An average value of 1.3 E-8 will be used for the natural uranium isotopic mixture at the Spectrulite facility.
Risk coefficients, ingestion slope factors (risk/pCi)	U-234 = 4.4 E-11 U-235 = 4.7 E-11 U-238 = 6.2 E-11	EPA (1995) tabulated values. An average value of 5.0 E-11 will be used as the average for the natural uranium isotopic mixture at the Spectrulite facility.
Exposure-to-dose conversion factor for inhalation (Sv/Bq)	U-234 = 3.58 E-5 U-235 = 3.32 E-5 U-238 = 3.2 E-5	EPA (1988) values from Table 2.1 for TEDE for class Y uranium isotopes. The dose conversion factor for U-234 will be conservatively used for the dose assessment.
Exposure-to-dose conversion factor for ingestion (Sv/Bq)	U-234 =7.66 E-8 U-235 = 7.19 E-8 U-238 = 6.88 E-8	EPA (1988) values from Table 2.2 for TEDE for uranium isotopes. The dose conversion factor for U-234 will be conservatively used for the dose assessment.

Following are other assumptions used for this evaluation:

- Average ventilation rate of 3 air changes /hr.
- Material dispersion is limited to the volume area under the affected beams.
- The total contaminated surface area is 2,300 m^2.
- All the contaminated surfaces are modeled at 40 ft above the floor; this represents an average height for the contaminated beams.
- The volume of the work area beneath the affected beams is 1.09 10E5 m^3 [350 ft (14 column sections) $\times$ 275 ft $\times$ 40 ft]/[35.3ft^3/m^3].
- All surfaces are assumed to be uniformly contaminated with an average uranium concentration of 70.9 pCi/g. A thickness of 0.8 cm and a density of 1.5 g/cm^3 are also assumed.
- All uranium enters the air over a working lifetime of 25 years.

A.5.2 Risk Results for the No Action (Baseline) Alternative

Table A-3 summarizes the results for the No Action (baseline) Alternative. The conclusion of this evaluation is that the uranium present in the dust on overhead structures of Buildings 6 and 4 in the vicinity of the extrusion press does not pose an unacceptable potential risk to workers on the floor level. However, an unacceptable potential risk is calculated for the worker who is in close contact with contaminated surfaces unless work time restrictions or the facility owner implements other controls. In addition, since the surface contamination is readily removable, the regulatory expectation is usually to reduce the contamination to ALARA levels.

Table A-3. Summary of Excess Lifetime Cancer Risk and Total Effective Dose Equivalent – No Action Alternative

	Comparison Criteria	Scenario	
		Site Worker	Utility Worker*
Excess lifetime cancer risk (25 year exposure duration)	CERCLA: 10^{-4}-10^{-6}	2.2E-5	5.3 E-4 (9.5E-5to 2.0E-3)
TEDE, mrem/yr	25 mrem/yr	9	210 (39 to 790)

* Since the risk and TEDE to the utility worker are so dependent on the assumed dust resuspension factor, a range of values is provided in parentheses based on NRC 1998a guidance on the proposed distribution.

Uranium is also a kidney toxicant. A hazard index (HI) was calculated to evaluate non-cancer hazard from uranium. An HI is the ratio between an intake that is considered safe (called a reference dose, or RfD) and the expected intake at the site. An HI less than 1 is taken as an indication that no adverse effects are expected. The HI for the uranium dust was calculated as follows:

$$\text{Intake} = \frac{CS \times IR \times CF \times FI \times EF \times ED}{BW \times AT}$$

where

CS = concentration in soil, 70.9 pCi/g = 101.3 mg/kg
IR = ingestion rate, 100 mg/day
CF = conversion factor, 10^{-6} kg/mg
FI = fraction of dust eaten that comes from a contaminated source, 0.5 (half the soil or dust ingested in a day)
EF = exposure frequency, 250 days per year
ED = exposure duration, 25 years
BW = Body weight, 70 kg
AT = averaging time, which for non-carcinoginic toxicants is ED times 365 days/yr.

$$\text{Intake} = \frac{101.3\,\text{mg/kg} \times 100\,\text{mg/day} \times 10^{-6}\,\text{kg/mg} \times 0.5 \times 250\,\text{days/yr} \times 25\,\text{years}}{70\,\text{kg} \times 25\,\text{yrs} \times 365\,\text{days/yr}} = 4.96 \times 10^{-5}$$

HI = Intake/RfD
RfD = 3×10^{-3} (the RfD was taken from IRIS)
HI = 0.017

A.6 RISK/DOSE EVALUATION – INSTITUTIONAL CONTROLS ALTERNATIVE

The Institutional Controls Alternative assumes that exposure can be reduced without removing the contamination by providing control and monitoring of site workers. Work permits would be required for work in the overhead regions. These work permits would require some level of briefing to workers so that care would be taken to minimize resuspension of the particulates. The risk and TEDE estimates will remain as determined for the No Action Alternative evaluation for the industrial/facility worker. The industrial/utility worker exposure scenario will assume that controls and training will be effective in reducing the resuspension factor and the transfer rate for ingestion by a factor of 0.5. The industrial/safety worker who spends 8 hours a year changing air samples is assumed to be exposed under the same conditions as the industrial/utility worker. Therefore, the exposure and risk will be calculated as 40% (8 hrs/20hrs) of the industrial/utility workers exposure and risk.

A.6.1 Parameters and Assumptions for the Institutional Controls Alternative

Parameters for the industrial/utility worker Institutional Controls Alternative scenario are provided in Table A-4.

Table A-4. Industrial/Utility Worker Exposure Parameters – Institutional Controls Alternative

Exposure Parameter	Value	Source/Comments
Inhalation rate (m^3/hr)	1.875	The 1997 Exposure Factors Handbook lists the mean hourly rate for adults as 1.0 m^3/hr for light activities, 1.6 m^3/hr for moderate activities, and 3.2 m^3/hr for heavy activities. Activities for utility workers are considered moderate activities (working at heights of 25-36 feet, use of a ladder to access utilities, etc.) brief periods of heavy activities (cable pulling at heights, walking on beams, working in vicinity of live electrical wires). The value used was 1.875 m^3/hr was used to represent this mix of activities.
Exposure frequency (hours/yr)	20	20 hours is an estimate for someone pulling utility cables or changing light bulbs.
Exposure duration (yrs)	25	EPA (1991) Exposure duration for the commercial/industrial use.
Inhalation class	Y	Chemical form inhalation class refers to the clearance half time from the pulmonary region of the lungs. Class Y is the most conservative uranium class.
Resuspension factor (m^{-1})	2.5 E-5	Factor of 0.5 reduction from the baseline assessment. Reduction is achieved through worker knowledge and control.
Transfer rate for ingestion of removable surface contamination (m^2/hr)	5.0 E-5	Factor of 0.5 reduction from the baseline assessment. Reduction is achieved through worker knowledge and control.
Risk coefficients, inhalation slope factors (risk/pCi)	U-234 = 1.4 E-8 U-235 = 1.3 E-8 U-238 = 1.24 E-8	EPA (1995) tabulated values. An average value of 1.3 E-8 will be used for the natural uranium isotopic mixture at the Spectrulite facility.
Risk coefficients, ingestion slope factors (risk/pCi)	U-234 = 4.4 E-11 U-235 = 4.7 E-11 U-238 = 6.2 E-11	EPA (1995) tabulated values. An average value of 5.0 E-11 will be used for the natural uranium isotopic mixture at the Spectrulite facility.
Exposure-to-dose conversion factor for inhalation (Sv/Bq)	U-234 = 3.58 E-5 U-235 = 3.32 E-5 U-238 = 3.2 E-5	EPA (1988) values from Table 2.1 for TEDE for class Y uranium isotopes. The dose conversion factor for U-234 will be conservatively used for the dose assessment.
Exposure-to-dose conversion factor for ingestion (Sv/Bq)	U-234 =7.66 E-8 U-235 = 7.19 E-8 U-238 = 6.88 E-8	EPA (1988) values from Table 2.2 for TEDE for uranium isotopes. The dose conversion factor for U-234 will be conservatively used for the dose assessment.

Calculations – Industrial/Utility Worker

Surface Activity

The mean surface activity is estimated using the mean concentration of 70.9 pCi/g, the assumed dust thickness of 0.8 cm, and the assumed dust density of 1.5 g/cm^3.

$$(70.9 \text{ pCi/g}) \times (1.5 \text{ g/cm}^3) \times (0.8 \text{ cm}) \times (10^4 \text{ cm}^2/\text{m}^2) = 8.5 \text{ E5 pCi/m}^2$$

Airborne Concentration

The airborne concentration the industrial/utility worker breathes when institutional controls are implemented is calculated using a resuspension factor of 2.5 E-5 m^{-1}.

$(8.5\ E5\ pCi/m^2) \times (2.5\ E\text{-}5\ m^{-1}) = 2.1\ E1\ pCi/m^3$

Calculation of Inhalation and Ingestion Intake of Activity

The total activity the industrial/utility worker is assumed to intake through *inhalation*, over the 20 hours of work per year and the 25-year exposure duration is calculated.

$(2.1\ E1\ pCi/m^3) \times (1.875\ m^3/hr) \times (20\ hours/yr) \times (25\ yrs) = 2.0\ E4\ pCi$ *from inhalation.*

The intake of activity due to ingestion is similarly calculated using the transfer rate for *ingestion*.

$8.5\ E5\ pCi/m^2 \times 5.0\ E\text{-}5\ m^2/hr \times 20\ hours/yr \times 25\ yrs = 2.1\ E4\ pCi$ *from ingestion*.

Calculation of Excess Cancer Risk and TEDE

The radionuclide slope factor provides a lifetime cancer incidence risk per unit inhalation. The excess cancer risk is calculated as follows:

$(2.0\ E4\ pCi) \times (1.3\ E\text{-}8\ risk/pCi) = 2.6\ E\text{-}4$ *lifetime cancer risk from inhalation*.
$(2.1\ E4\ pCi) \times (5.0\ E\text{-}11\ risk/pCi) = 1.1\ E\text{-}6$ *lifetime cancer risk from ingestion*.

The total *lifetime attributable cancer risk is, therefore, 2.6 E-4*, and exceeds the CERCLA risk range of 10^{-4} to 10^{-6}.

Committed Effective Dose Equivalent (CEDE) from inhalation and ingestion is obtained using the exposure-to-dose conversion factors from Federal Guidance Report No. 11 (EPA 1988).

$(2.0\ E4\ pCi) \times (0.037\ Bq/pCi) \times (3.58\ E\text{-}5\ Sv/Bq) \times (1.0\ E5\ mrem/Sv) = 2.6\ E3\ mrem/25\ yrs$
$(2.1\ E4\ pCi) \times (0.037\ Bq/pCi) \times (7.66\ E\text{-}8\ Sv/Bq) \times (1\ E5\ mrem/Sv) = 6.0\ mrem/25\ yrs$

For comparison with the 25 mrem/yr annual TEDE criterion in 10 CFR 20 Subpart E, the above equates to an annual TEDE of 110 mrem/yr, for the industrial/utility worker exceeding the dose criterion. An annual TEDE of 44 mrem/yr is calculated for the industrial/safety worker (i.e., 40% of the 110 mrem/yr).

A.6.2 Risk Results for the Institutional Controls Alternative

Table A-5 summarizes the results for the Institutional Controls Alternative. The results show that the uranium present in the dust on overhead structures of Buildings 6 and 4, in the vicinity of the extrusion press, does not pose an unacceptable potential risk to any of the site workers. The industrial/utility and industrial/safety TEDE results reflect an unacceptable potential dose unless work time restrictions or other controls are implemented by the facility owner.

Table A-5. Summary of Risk and TEDE – Institutional Controls Alternative

	Comparison Criteria	Scenario		
		Site Worker	Utility Worker	Safety Worker
Excess Lifetime Cancer Risk (25 year exposure duration)	CERCLA: $10^{-4} – 10^{-6}$	2.2E-5	2.0E-4	8.0E-5
TEDE, mrem/yr	25 mrem/yr	9	110	44

A.7 RISK/DOSE EVALUATION – CONTAINMENT ALTERNATIVE

The Containment Alternative assumes applying a sprayed coating to the surfaces to immobilize the dust can reduce that exposure by trapping it beneath the coating. This method is sometimes referred to as macroencapsulation. Although specific factors for loose surface contamination reduction were not found in the available literature, this method is described in general terms as being effective in substantially reducing surface exposure to potential leaching (DOE 1994). For this assessment, the fixing is assumed to have 85% effectiveness on average over the 25-year assumed exposure period. This 85% effectiveness is assumed to account for some long-term wear. The No Action Alternative exposure risk and TEDE to the industrial/facility worker and the industrial/utility worker are, therefore, multiplied by a factor of 0.15 to arrive at the exposure from the Containment Alternative. The remedial action worker is assumed to be exposed for nine days during the remedial action. The resuspension of dust during application of the spray coating will be assumed to be reduced to a factor of 1.0E-5 m^{-1} because there will be no contact with the surface and the only mode for resuspension is the increased air flow from the spray. Inhalation is the only exposure pathway.

A.7.1 Parameters and Assumptions for the Containment Alternative

Parameters for the remedial worker are provided in Table A-6. Calculations follow.

Table A-6. Remedial Worker Exposure Parameters – Containment Alternative

Exposure Parameter	Value	Source/Comments
Inhalation Rate (m^3/hr)	1.875	The 1997 Exposure Factors Handbook lists the mean hourly rate for adults as 1.0 m^3/hr for light activities, 1.6 m^3/hr for moderate activities, and 3.2 m^3/hr for heavy activities. Activities for utility workers are considered moderate activities (working at heights of 25-36 feet, use of a ladder to access utilities, etc.) brief periods of heavy activities (cable pulling at heights, walking on beams, working in vicinity of live electrical wires). The value used was 1.875 m^3/hr was used to represent this mix of activities.
Exposure Frequency (hours/yr)	72	72 hours assumes 8 hours per day for 9 days to apply the spray coating to the structures.
Exposure Duration (yrs)	1	
Inhalation Class	Y	Chemical form inhalation class refers to the clearance half time from the pulmonary region of the lungs. Class Y is the most conservative uranium class.

Table A-6. Remedial Worker Exposure Parameters – Containment Alternative (Cont'd)

Exposure Parameter	Value	Source/Comments
Resuspension Factor (m^{-1})	1.0 E-5	Factor assumed based on no contact by worker with the surface, only air currents from the spray will resuspend the material and reduction achieved through worker knowledge and control.
Risk Coefficients, Inhalation Slope Factors (risk/pCi)	U-234 = 1.4 E-8 U-235 = 1.3 E-8 U-238 = 1.24 E-8	EPA (1995) tabulated values. An average value of 1.3 E-8 will be used as the average for the natural uranium isotopic mixture at the Spectrulite facility.
Exposure-to-Dose Conversion Factor for Inhalation (Sv/Bq)	U-234 = 3.58 E-5 U-235 = 3.32 E-5 U-238 = 3.2 E-5	EPA (1988) values from Table 2.1 for TEDE for class Y uranium isotopes. The dose conversion factor for U-234 will be conservatively used for the dose assessment.

Calculations – Remedial Worker – Containment Alternative

Surface Activity

The mean surface activity is estimated using the mean concentration of 70.9 pCi/g, the assumed dust thickness of 0.8 cm and the assumed dust density of 1.5 g/cm^3.

$$(70.9 \text{ pCi/g}) \times (1.5 \text{ g/cm}^3) \times (0.8 \text{ cm}) \times (10^4 \text{ cm}^2/\text{m}^2) = 8.5 \text{ E5 pCi/m}^2$$

Airborne Concentration

The airborne concentration is calculated using the resuspension factor of 1.0 E-5 m^{-1}.

$$(8.5\text{E5 pCi/m}^2) \times (1.0 \text{ E-5 m}^{-1}) = 8.5 \text{ pCi/m}^3$$

Calculation of Inhalation Intake of Activity

The total activity the remedial worker is assumed to intake through *inhalation*, over the 72 hours of work to apply the spray coating is calculated.

$$(8.5 \text{ pCi/m}^3) \times (1.875 \text{ m}^3/\text{hr}) \times (72 \text{ hours/yr}) \times (1 \text{ yrs}) = 1.1 \text{ E3 pCi } \textit{from inhalation.}$$

Calculation of Excess Cancer Risk and TEDE

The radionuclide slope factor provides a lifetime cancer incidence (fatal and nonfatal) risk per unit inhalation. The excess cancer risk is calculated by

$$(1.1 \text{ E3 pCi}) \times (1.3 \text{ E-8 risk/pCi}) = 1.5 \text{ E-5 } \textit{lifetime cancer risk from inhalation}.$$

The total *lifetime attributable cancer risk is, therefore, 1.5 E-5*, and is within the CERCLA risk range of 1 E-4 to 1 E-6.

CEDE from inhalation is obtained using the exposure-to-dose conversion factors from Federal Guidance Report No. 11 (EPA 1988)

$$(1.1 \text{ E3 pCi}) \times (0.037 \text{ Bq/pCi}) \times (3.58 \text{ E-5 Sv/Bq}) \times (1.0 \text{ E5 mrem/Sv}) = 150 \text{ mrem}$$

Since this dose is to an occupationally exposed radiation worker, it is not compared to the license termination criterion.

A.7.2 Risk Results for the Containment Alternative

Table A-7 summarizes the results for the Containment Alternative. The CERCLA risk range criterion is achieved with this alternative but the long-term effectiveness of the spray encapsulation should be evaluated further. The dose to the industrial/utility worker (32 mrem/yr) exceeded the 10 CFR 20 Subpart E limit of 25 mrem/yr. All other doses are acceptable.

Table A-7. Summary of Risk and TEDE – Containment Alternative

	Comparison Criteria	Scenario		
		Site Worker	Utility Worker	Remedial Worker*
Excess lifetime cancer risk (25 year exposure duration)	CERCLA: 10^{-4}-10^{-6}	5.5E-6	8.0E-5	1.5E-5
TEDE, mrem/yr	25 mrem/yr	2.3	32	150

* The remedial worker is an occupationally exposed radiation worker and therefore comparison with license termination criteria is not applicable.

A.8 RISK/DOSE EVALUATION – DECONTAMINATION ALTERNATIVE

The accessible decontaminated areas will be assumed to contain residual activity at 1,000 dpm/100cm^2 total contamination and 33 dpm/100 cm^2 of removable contamination. The additional high bay area is considered inaccessible by the industrial/facility and industrial/utility worker. Therefore, exposure to these surfaces is not considered in this section. Radiological risks from the potential remaining contamination located on inaccessible surfaces will be considered in Section A.9, Building Demolition. The industrial/facility worker and the industrial/ utility worker exposures to airborne contamination are evaluated by applying appropriate parameter adjustments. The risk estimate and the dose estimate are established by adjusting parameters for the industrial/utility worker. The remediation worker is assumed to be exposed for nine days during the remedial action. The resuspension of dust during decontamination will be assumed to be the same as for the remediation worker under the decontamination scenario are identical to the exposure conditions for the containment alternative remediation worker resulting in the same risk and dose. Resuspension of dust after decontamination will be assumed to be 2.0E-5 reflecting the average resuspension factor for the impacted area..

A.8.1 Parameters and Assumptions for the Decontamination Alternative

Parameters are provided in Table A-8 for the industrial/utility worker for the Decontamination Alternative. Calculations follow the table.

Table A-8. Utility/Site Worker Exposure Parameters – Decontamination Alternative

Exposure Parameter	Value	Source/Comments
Inhalation Rate (m^3/hr)	1.875	The 1997 Exposure Factors Handbook lists the mean hourly rate for adults as 1.0 m^3/hr for light activities, 1.6 m^3/hr for moderate activities, and 3.2 m^3/hr for heavy activities. Activities for utility workers are considered moderate activities (working at heights of 25-36 feet, use of a ladder to access utilities, etc.) brief periods of heavy activities (cable pulling at heights, walking on beams, working in vicinity of live electrical wires). The value used was 1.875 m^3/hr was used to represent this mix of activities.
Exposure Frequency (hours/yr)	20	20 hours is an estimate for someone pulling utility cables or changing light bulbs.
Exposure Duration (yrs)	25	EPA (1991) Exposure duration for the commercial/industrial use.
Inhalation Class	Y	Chemical form inhalation class refers to the clearance half time from the pulmonary region of the lungs. Class Y is the most conservative uranium class.
Resuspension Factor (m^{-1})	2.0 E-5	Reduction after decontamination is based on dust being removed from most of the area. The resuspension factor after decontamination is an average value over the impacted area.
Risk Coefficients, Inhalation Slope Factors (risk/pCi)	U-234 = 1.4 E-8 U-235 = 1.3 E-8 U-238 = 1.24 E-8	EPA (1995) tabulated values. An average value of 1.3 E-8 will be used as the average for the natural uranium isotopic mixture at the Spectrulite facility.
Exposure-to-Dose Conversion Factor for Inhalation (Sv/Bq)	U-234 = 3.58 E-5 U-235 = 3.32 E-5 U-238 = 3.2 E-5	EPA (1988) values from Table 2.1 for TEDE for class Y uranium isotopes. The dose conversion factor for U-234 will be conservatively used for the dose assessment.

Calculations – Industrial/Utility Worker – Decontamination Alternative

Surface Activity

The mean surface activity is estimated using a total activity of 1,000 dpm/100cm$^{2.}$

[1,000 dpm/100 cm^2 $\times$ 10^4 cm^2/m^2]/[2.2 dpm/pCi] = 4.5 E4 pCi/m^2

Airborne Concentration

The airborne concentration is calculated using the resuspension factor of 2 E-5 m^{-1}.

(4.5 E4 pCi/m^2) $\times$ (2 E-5 m^{-1}) = 9 E-1 pCi/m^3

Calculation of Inhalation Intake of Activity

The total activity that the utility worker is assumed to intake through *inhalation*, over the 20 hours of work per year and the 25-year exposure duration is calculated.

(9 E-1 pCi/m^3) $\times$ (1.875 m^3/hr) $\times$ (20 hours/yr) $\times$ (25 yrs) = 8.4 E2 pCi *from inhalation.*

Calculation of Excess Cancer Risk and TEDE

The radionuclide slope factor provides a lifetime cancer incidence (fatal and nonfatal) risk per unit inhalation. The excess cancer risk is calculated by

(8.4 E2 pCi) × (1.3 E-8 risk/pCi) = 1E-5 *lifetime cancer risk from inhalation*.

The total *lifetime attributable cancer risk is, therefore,* , and is within the CERCLA risk range of 1 E-4 to 1 E-6.

TEDE from inhalation is obtained using the exposure-to-dose conversion factors from Federal Guidance Report No. 11 (EPA 1988).

(8.4 E2 pCi) × (0.037 Bq/pCi) × (3.58 E-5 Sv/Bq) × (1.0 E5 mrem/Sv) = 111mrem/25 yrs

For comparison with the 25 mrem/yr annual TEDE criterion in 10 CFR 20 subpart E, the above equates to an annual TEDE of 4.5 mrem/yr, which is well below the dose criterion.

A.8.2 Risk Results for the Decontamination Alternative

Table A-9 summarizes the results for the Decontamination Alternative. The CERCLA risk range and 10 CFR 20 dose criterion are achieved for all industrial workers.

Table A-9. Summary of Risk and TEDE – Decontamination Alternative

	Comparison Criteria	Scenario		
		Site Worker	Utility Worker	Remedial Worker
Excess lifetime cancer risk (25 year exposure duration)	CERCLA: 10^{-4}-10^{-6}	1.8E-7	1E-5	1.5E-5
TEDE, mrem/yr	25 mrem/yr	0.077	4.5	150

A.9 BUILDING DEMOLITION

Potential radiological risks to a construction worker during building demolition were evaluated for the No Action Alternative. This evaluation also considered the potential risk from any remaining contamination located on inaccessible surface from the Decontamination Alternative. NUREG 1640 was consulted to model this scenario. The dose factors published there for concrete processing for recycle would be similar to worker exposure during building demolition. The dose factors in NUREG 1640 (NRC 1998b) were developed for crushing scrap concrete. A duration of 5 workdays is assumed for the demolition work out of 250 working days in a year (time fraction of 0.02). The other exposure parameters were chosen to be consistent with other scenarios evaluated in this appendix. These include 70.9 pCi/g total uranium with a composition of 50.6% U-234, 2.3% U-235, and 47.1% U-238. Density is assumed to be 1.5 g/cm^3 and the average thickness on the surface of the concrete is assumed to be 0.8 cm. The 95th percentile dose factors were used in the calculations.

U-234:

- (4.6 μSv/yr/Bq/cm^2) × (3.7E-3 mrem/yr/pCi/cm^2 per μSv/yr/Bq/cm^2) = 0.017 mrem/yr/pCi/cm^2
- (70.9 pCi/g) × (1.5 g/cm^3) × (0.8 cm) × (0.017 mrem/yr/pCi/cm^2) × (0.506) × (0.02 yr) = 0.015 mrem

U-235:

- (4.3 μSv/yr/Bq/cm^2) × (3.7E-3 mrem/yr/pCi/cm^2 per μSv/yr/Bq/cm^2) = 0.016 mrem/yr/pCi/cm^2
- (70.9 pCi/g) × (1.5 g/cm^3) × (0.8 cm) × (0.016 mrem/yr/pCi/cm^2) × (0.023) × (0.02 yr) = 0.00062 mrem

U-235:

- (4.1 μSv/yr/Bq/cm^2) × (3.7E-3 mrem/yr/pCi/cm^2 per μSv/yr/Bq/cm^2) = 0.015 mrem/yr/pCi/cm^2
- (70.9 pCi/g) × (1.5 g/cm^3) × (0.8 cm) × (0.015 mrem/yr/pCi/cm^2) × (0.471) × (0.02 yr) = 0.012 mrem

Total Dose = (0.015 mrem) + (0.00062 mrem) + (0.012 mrem) = 0.03 mrem

The development of the dose factors assumes that water is sprayed on the dust to contain it and that workers near the site typically wear respirators.

If the building were dismantled rather than demolished, the dose to the construction worker would be a fraction of the dose experienced by the remedial worker because the construction worker would spend less time in close contact with the contaminated surfaces. About 25% of the overhead structures are contaminated. Assuming that dismantlement of the entire building requires about the same duration as decontamination, then the upper bound dose to the construction worker dismantling the building at current contamination levels would be 25% of the remedial worker's dose, or 38 mrem.

In addition, the dose that would be incurred as a result of recycling the overhead beams was also considered. NUREG 1640 (NRC 1998b) considered 27 separate scenarios in developing dose factors for contaminated scrap steel recycling. The scenario with the highest dose factor, handling the contaminated scrap metal at the scrap yard, was chosen for use in this analysis to represent the worst case if no action is taken when the building is demolished or dismantled. Activities considered under this scenario include unloading, sorting, cutting, shredding, baling, and loading for shipment. NUREG 1640 set the exposure frequency at 5 hours per day for 250 days per year in the scrap handling scenario. The same site-specific assumptions made for the building demolition were retained for the steel recycling. It is assumed that the 25,000 ft^2 of scrap will require about 2 weeks (10 working days) to process.

U-234

- 66 μSv/yr/Bq/cm^2 × (3.7 × 10^{-3} mrem/yr/pCi/cm^2 per μSv/yr/Bq/cm^2) = 0.24 mrem/yr/pCi/cm^2
- 70.9 pCi/g × 1.5 g/cm^3 × 0.8 cm × 0.24 mrem/yr/pCi/cm^2 × 0.506 × 0.04 yr = 0.49 mrem

U-235

- 62 μSv/yr/Bq/cm^2 $\times$ (3.7 $\times$ 10^{-3} mrem/yr/pCi/cm^2 per μSv/yr/Bq/cm^2) = 0.23 mrem/yr/pCi/cm^2
- 70.9 pCi/g $\times$ 1.5 g/cm^3 $\times$ 0.8 cm $\times$ 0.23 mrem/yr/pCi/cm^2 $\times$ 0.023 $\times$ 0.04 yr = 0.022 mrem

U-238

- 59 μSv/yr/Bq/cm^2 $\times$ (3.7 $\times$ 10^{-3} mrem/yr/pCi/cm^2 per μSv/yr/Bq/cm^2) = 0.21 mrem/yr/pCi/cm^2
- 70.9 pCi/g $\times$ 1.5 g/cm^3 $\times$ 0.8 cm $\times$ 0.21 mrem/yr/pCi/cm^2 $\times$ 0.471 $\times$ 0.04 yr = 0.40 mrem

Total Dose = 0.49 mrem + 0.022 mrem + 0.40 mrem = 0.91 mrem

The incremental lifetime cancer risk from these exposures was estimated by applying a dose to cancer risk factor to the calculated doses (ICRP 1990). EPA does not recommend using this method (EPA 1996). This method tends to overstate risks and, given the uncertainties inherent in the risk calculations, this method is appropriate for this application. The dose to risk factor is 5E-2/Sv (5E-7/mrem). Thus an estimate of the incremental lifetime cancer risk as a result of taking no action and allowing the building to be demolished and disposed:

Building Demolition for No Action
0.03 mrem $\times$ 5E-7/mrem = 1.5E-8

Building Dismantlement for No Action
38 mrem $\times$ 5E-7/mrem = 1.9E-5

Steel Recycle for No Action
0.91 mrem $\times$ 5E-7/mrem = 4.6E-7

It is assumed for the Decontamination Alternative that all accessible areas are reduced to below the TBC guidelines level. It is also assumed that contamination in the inaccessible areas is at the baseline level, i.e., 70.9 pCi/g. The inaccessible area accounts for one-third of the total area, therefore, doses and risks to construction workers performing demolition or dismantlement would be reduced to 0.01 mrem and 12.7 mrem respectively (one-third of the no action levels). The dose to the worker recycling steel would be 0.3 mrem.

A.10 CALCULATION OF DCGL

A DCGL of 6000 dpm/100 cm^2 will be used for for surficial contamination. A DCGL of 20 pCi/g that is equivalent to the 6000 dpm/100 cm^2 will be used for volumetric contamination in areas where surface scanning may not be appropriate to show compliance with the ARAR.

Surface Activity per 1,000 dpm/100cm²

The mean surface activity per 1000 dpm/100cm²

$[1,000 \text{ dpm/100cm}^2 \times 10^4 \text{ cm}^2/\text{m}^2]/[2.2 \text{ dpm/pCi}] = 4.5\text{E}4 \text{ pCi/m}^2$

Airborne concentration per 1000 dpm/100cm²

The airborne concentration is calculated using a resuspension factor of 2E-5 m^{-1}. The resuspension factor represents an average value over the impacted area. This value is reduced from the resuspension factor before decontamination of 5E-5 m^{-1}.

$(4.5\text{E}4 \text{ pCi/m}^2) \times (2\text{E-}5 \text{ m}^{-1}) = 9\text{E-}1 \text{ pCi/m}^3$

Inhalation Intake of Activity per 1000 dpm/100cm²

The total activity that is assumed through inhalation over 20 hours of work per year is calculated.

$(9\text{E-}1 \text{ pCi/m}^2)(1.875 \text{ m}^3/\text{hr})(20 \text{ hr/yr}) = 34 \text{ pCi}$

Calculation of Dose per 1000 dpm/100cm²

Using the exposure-to-dose conversion factors from Federal Guidance Report No. 11 (EPA, 1988).

$(34 \text{ pCi}) \times (0.037 \text{ Bq/pCi}) \times (3.58\text{E-}5 \text{ Sv/Bq}) \times (1\text{E}5 \text{ mrem/Sv}) = 4.5 \text{ mrem}$

Surficial DCGL

The surficial activity corresponding to 25 mrem/yr is calculated.

$(25 \text{ mrem/yr})[(1000 \text{ dpm/100cm}^2)/(4.5 \text{ mrem/yr})] = 6000 \text{ dpm/100cm}^2$

Volumetric DCGL

The volumetric DCGL is calculated using the average density and thickness of the dust described earlier.

$$\left(6000\ dpm/100cm^2\right) / \left[\left(1.5 g/cm^3\right) \times \left(0.8\ cm\right) \times \left(2.2\ dpm/pCi\right) \times \left(\frac{100\ cm^2}{100\ cm^2}\right)\right] = 20\ pCi/gm$$

A.11 SUMMARY AND CONCLUSIONS

Table A-10 summarizes the risks and TEDE estimates for each of the worker categories and each of the alternatives. Only the Decontamination Alternative meets the ARAR. The Containment Alternative meets the CERCLA risk range, but does not meet the 10 CFR 20 Appendix E dose criterion.

Table A-10. Summary of Risk and TEDE

	Comparison Criteria	**No Action Scenario Without Time Restrictions or Other Institutional Controls**		
		Facility Worker	**Utility Worker**	
Excess lifetime cancer risk (25 year exposure duration)	CERCLA: 10^{-4}-10^{-6}	2.2×10^{-5}	**5.3 ´ 10^{-4}**	
TEDE, mrem/yr	25 mrem/yr	9	**210**	
	Comparison Criteria	**Industrial Controls Scenario Without Time Restrictions or Other Institutional Controls**		
		Facility Worker	**Utility Worker**	**Safety Worker**
Excess lifetime cancer risk (25 year exposure duration)	CERCLA: 10^{-4}-10^{-6}	2.2×10^{-5}	2.0×10^{-4}	**8.0 ´ 10^{-5}**
TEDE, mrem/yr	25 mrem/yr	9	**110**	**44**
	Comparison Criteria	**Containment Scenario Without Time Restrictions or Other Institutional Controls**		
		Facility Worker	**Utility Worker**	**Remedial Worker**
Excess lifetime cancer risk (25 year exposure duration)	CERCLA: 10^{-4}-10^{-6}	5.5×10^{-6}	8×10^{-5}	1.5×10^{-5}
TEDE, mrem/yr	25 mrem/yr	2.3	**32**	150*
	Comparison Criteria	**Decontamination Scenario**		
		Facility Worker	**Utility Worker**	**Remedial Worker**
Excess lifetime cancer risk (25 year exposure duration)	CERCLA: 10^{-4}-10^{-6}	1.8×10^{-7}	1E-5	1.5×10^{-5}
TEDE, mrem/yr	25 mrem/yr	0.077	4.5	150*

Bolded values exceed ARAR limits.
* Occupational limits apply.
Risks for demolition and recycle were calculated for the No Action Alternative and were found to be within the CERCLA risk range.

A.11 REFERENCES

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APPENDIX B

BASIS OF COST ESTIMATE

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BASIS OF COST ESTIMATE FOR ALTERNATIVE 2 (INSTITUTIONAL CONTROLS)
Project: Spectrulite Manufacturing Site
Madison, Illinois
1999

INTRODUCTION

Developing cost estimates requires assumptions to be made regarding how the remediation is to be performed and what equipment will be used. These assumptions are made for the sole purpose of estimating cost and should not be interpreted as a detailed plan for implementing an alternative. These assumptions will be refined during the remedial design process.

SCOPE

Institutional controls to protect or prevent human exposure to the contaminated areas are to be installed. The controls include five year reviews and work-time restrictions.

GENERAL ASSUMPTIONS

- Unit costs are based on 1999 pricing.
- Data sources for key parameters are based on best engineering judgment and information from a site walk over.
- Costs obtained from Means for a subcontractor include overhead and profit.
- Productivity adjustments are used in many elements for weather, heat, access, and equipment capability.
- Contract is issued to a contractor with previous experience in performing similar types of remediation and experience working during a factory shut down.

Scheduling Assumptions

- The total duration for the project is 30 years. The duration is based on the anticipated time of plant operation and reflects the period used for cost evaluations under CERCLA.

SPECIFIC ASSUMPTIONS

01. Mobilization and Preparatory Work

Employees have been previously trained for 40-hr OSHA, RAD worker II, and use of a respirator. General employee training to orient personnel with the specific site requirements and plans will be required.

02. Monitoring and Sampling

Air monitoring may be done by the facility operator, but no costs are included for FUSRAP materials.

03. Building #6 Institutional Controls

General description and requirements

The building contains Spectralite's manufacturing process equipment and will be in production during the installation of institutional controls consisting of the following:

- Maintaining institutional controls over a period of 30 years.
- Issuing work permits for personnel to monitor and control their exposure to the contamination at the elevated steel surfaces.
- Restricting future use of the facility in the acquisition by other interest or means.
- Periodic inspections by the government to enforce such restrictions.

20. Site Restoration

Not required.

21. Demobilization

Not required.

BASIS OF COST ESTIMATE FOR ALTERNATIVE 3 (CONTAINMENT)
Project: Spectrulite Manufacturing Site
Madison, Illinois
1999

SCOPE

Containment of elevated accessible interior surfaces.

GENERAL ASSUMPTIONS

- Unit costs are based on 1999 pricing.
- Data sources for key parameters are based on best engineering judgment and information from a site walk over.
- Source for equipment cost and output is Means unless otherwise cited.
- Costs obtained from Means for a subcontractor include overhead, and profit.
- Productivity adjustments are used in many elements for weather, heat, access, and equipment capability.
- Contract being issued to a contractor with previous experience in performing similar types of remediation and experienced with working during a factory shut down.

Scheduling Assumptions

- Work will be performed during the plant shut down in July. The duration is 28 shifts occurring from the end of the first shift on Friday until the beginning of the first shift Monday morning nine days later.
- The total duration for the project is 14 days. The duration is based on 3 days for mobilization, orientation and temporary facility setup, 9 days for remediation and 2 days for demobilization.

SPECIFIC ASSUMPTIONS

01. Mobilization and Preparatory Work

This category includes the mobilization of construction equipment and the installation of temporary personnel change facilities, utilities for equipment operation, and an equipment decontamination area. A construction staging area and temporary access routes will be set up. Also included is the cost for pre-construction plans and submittals. Costs assume that employees have been previously trained for 40-hr OSHA, RAD Worker II, and use of a respirator. General employee training to orient personnel with the specific site requirements and plans will be required.

02. Monitoring and Sampling

Not required.

03. Building #6 Surface Containment

General Description and Requirements

The building contains Spectrulite's manufacturing process equipment. The surfaces are coated with dust approximately 0.6 to 0.8 cm in depth. These contaminated surfaces are to be encapsulated with a polymeric barrier coating system in two applications. A total dry film thickness of approximately 30 mils is to be applied.

The contamination present is in Buildings 6 and 4. The framing is structural, with beams supporting joists to form a gable roof. The building is approximately 60' in height. The exterior walls are enclosed with operable windows. The window ledges and framing will receive the same coating as the structural framing.

Access to the areas of contamination is impeded by floor mounted process equipment and elevated heights of 25' to 60'. Access to these areas will require various methods of hoisting, platforms, and scaffolding. Equipment for access will consist of scissors jack platform, personnel hoist with buckets, rolling scaffold floor mounted, and swinging scaffold suspended from the roof framing above. A 15-ton hydraulic crane to assist with material handling and rigging is included. Work platforms will be designed for human occupancy at elevated heights.

Health and safety issues for workers are exposure to the contaminated dust, heat exposure, and elevated work conditions. To protect the workers from contamination, Level "D" PPE with a potential for use of respirators, if required, will be used. Temperatures at the bottom of the roof during the period of July are anticipated to range from 100 to 125 degrees Fahrenheit. To reasonably reduce these temperatures, vent fans with HEPA filters will be located near the work to draw out as much heat as possible from the work areas. Additional protection for workers from heat stress is the utilization of two crews. One crew will work on the elevated platforms as the other crew is on the floor resting & cooling down. Work areas over 6' in height will require the use of a safety harness.

04. Building #6 and #4 quantities

Listing of quantities:

Truss Bottom Chord	11,000 sf
Joist Bottom Chord	23,000 sf
Window ledges & framing	1,900 sf
Wall framing	900 sf

20. Site Restoration

Not required.

21. Demobilization

This category includes the removal of equipment, facilities, and personnel from the site. The cost of post-remediation submittals is also included.

BASIS OF COST ESTIMATE FOR ALTERNATIVE 4(DECONTAMINATION)
Project: Spectrulite Manufacturing Site
Madison, Illinois
1999

SCOPE

Decontamination of elevated accessible interior surfaces.

GENERAL ASSUMPTIONS

- Costs are based on 1999 pricing.
- Data sources for key parameters are based on best engineering judgment and information from a site walk over.
- Source for equipment cost and output is Means unless otherwise cited.
- Costs obtained from Means for a subcontractor include overhead and profit.
- Productivity adjustments are used in many elements for weather, heat, access, and equipment capability.
- Contract is issued to a contractor with previous experience in performing similar type of remediation and experienced with working during a factory shut down.

Scheduling Assumptions

- Work will be performed during the plant shut down in July. The duration is 28 shifts, occurring from the end of the first shift on Friday until the beginning of the first shift nine days later.
- The total duration for the project is 14 days. The duration is based on 3 days for mobilization, orientation, and temporary facility setup; 9 days for remediation; and 2 days for demobilization.

SPECIFIC ASSUMPTIONS

01. Mobilization and preparatory work

This category includes the mobilization of construction equipment and the installation of temporary personnel change facilities, utilities for equipment operation and equipment decontamination area. A construction staging area and temporary access routes will be setup. Also included is the cost for pre-construction plans and submittals. Costs assume that employees have been previously trained for 40-hr OSHA, RAD Worker II, and use of a respirator. General employee training to orient all personnel with the specific site requirements and plans will be required.

02. Monitoring and Sampling

The surfaces will be analyzed to determine when an area has been remediated to achieve remedial goals. Samples from swipes taken at a frequency of 1 per 1,000 sf will be analyzed for radioactivity. The surfaces will also be scanned with a scanner to indicate the alpha and beta-gamma dpm.

After completion of remediation, the floor and equipment below the elevated remediated areas will be checked for contamination that may have inadvertently fallen from above. A Final Status Survey will be performed for all floor and elevated areas.

03. Building #6 and #4 Remediation

General Description and Requirements

The building is occupied by Spectrulite's manufacturing process equipment. Overhead surfaces are coated with dust approximately 0.6 to 0.8 cm in depth. These surfaces are to be decontaminated with a three-phase process. First the surfaces will be vacuumed to remove any loose particles. Second, surface will be scraped and wire brushed to remove dust adhered to the surfaces. During this operation, continuous vacuuming will be ongoing to minimize dust particles from becoming airborne and settling on the equipment and floor below. Also a visqueen cover will be placed over process equipment with exposed internal areas that could not be readily decontaminated in the event of a spill. The third and final cleaning of the surfaces will be a wipe down with cloths as necessary. Swipe samples to verify an area is clean will be collected. The surfaces will be scanned with a scanner to indicate the alpha and beta-gamma dpm.

The contamination is in Building 6 and 4. The framing is structural framed with beams supporting joist to form gable roof and is approximately 60' in height. The exterior walls are enclosed with operable windows. The window ledges and framing will receive the same process remediation as the structural framing.

Vacuum heads will be attached by hoses to the vacuum equipment. The vacuum equipment will have HEPA filters attached. Vacuum bags and HEPA filters are to be disposed of in the same containers as the dust particles.

Access to the areas of contamination is impeded by floor mounted process equipment and elevated heights of 25' to 60'. Access to these areas will require varying methods of hoisting platforms and scaffolding. Equipment for access will consist of scissors jack platform, personnel hoist with buckets, rolling scaffold floor mounted, and swinging scaffold suspended from the roof framing above. All work platforms will be designed for human occupancy at elevated heights.

Health and Safety issues for workers are exposure to the contaminated dust, heat exposure, and elevated work conditions. To protect the workers from contamination, Level “C” and “D” PPE each with respirators will be used. Temperatures at the bottom of the roof during the period of July are anticipated to range from 100 to 125 degrees Fahrenheit. To reasonably reduce these temperatures, vent fans with HEPA filters will be located near the work to draw out as much heat as possible from the work areas. Additional protection for workers from heat stress is the utilization of two crews. One crew will work on the elevated platforms as the other crew is on the floor resting & cooling down. Work areas over 6' in height will require the use of safety harness.

04. Building #6 and # 4 quantities

Listing of quantities:

Truss Bottom Chord	11,000 sf
Joist Bottom Chord	23,000 sf
Window ledges & framing	1,900 sf
Wall framing	900 sf

.08 Hot spots at floor
63,750 sf [-] Equipment area = 10,500 sf of open floor
Floor area contaminated is 25%   2600 sf

20. Site Restoration

This category includes repainting of any painted surfaces damaged during wire brushing and scraping. The quantity is assumed to be 20% of the total square feet of the remediated steel framing and the sealing of the remediated floor areas.

21. Demobilization

This category includes the removal of equipment, facilities, and personnel from the site. The cost of post-remediation submittals is also included.