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September 1, 2010

Mr. Ron Burrows, Project Manager
Uranium Recovery Licensing Branch
Decommissioning and Uranium Recovery Licensing Directorate
Division of Waste Management and Environmental Protection
Office of Federal and State Materials and Environmental Management Programs
U.S. Nuclear Regulatory Commission
Mail Stop T8-F5
Washington D.C. 20555-0001

RE: Revised Appendix N and O of the Environmental Report for the Three Crow Expansion Areas License Amendment, Docket No. 40-8943, License No. SUA-1534

Dear Mr. Burrows:

On August 3, 2010 Crow Butte Resources, Inc. submitted a request for an amendment to Source Materials License SUA-1534 for the development of additional uranium in-situ leach mining resources at the Three Crow Expansion Area. A number of pages in the Class III Cultural Resources Inventory contained in Appendix O of the Environmental Report were incorrectly labeled as privileged information. To correct that error, and to eliminate any confusion as to which pages are and are not privileged, please replace Appendix N and O of the August 3, 2010 submission with the attached documents. Appendix N has also been included in this revision because it was grouped with Appendix O when entered originally into the electronic system.

I have included five copies of the revised appendices so that each of the applications in NRC possession may be updated. Once the updates are accomplished, the entire license application will be suitable for public viewing.

If you or your staff has any questions regarding the CBR application please contact John Schmuck at (307) 316-7587.

Thomas P. Young
Vice President, Operations

Attachments: As Stated

Cc: Jim Stokey w/o attachment
John P. Schmuck w/o attachment
CR file w/ attachment
Larry Teahon w/ attachment

Wellfield Decommissioning Plan

for

Crow Butte Uranium Project

NRC Source Material License SUA-1534

Docket No. 40-8943

June 2004

Prepared for:

Crow Butte Resources, Inc.

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1.0 Introduction

Crow Butte Resources, Inc. (CBR) is required by the Nuclear Regulatory Commission (NRC) and the Nebraska Department of Environmental Quality (NDEQ) to decommission areas within the site boundary following completion of active mining. Part of this decommissioning involves the reclamation of a mine unit following successful completion of groundwater restoration activities. Reclamation involves proper plugging and abandonment of all wells within the mine unit boundary, removal of surface and subsurface structures, utilities, and pipelines, and removal of surface and subsurface radiological contamination.

The NDEQ has authority for groundwater protection including the proper plugging and abandonment of wells. Proper plugging and abandonment of the mining and monitor wells at Crow Butte is regulated under NDEQ Rules and Regulations, Title 122, *Rules and Regulations for Underground Injection and Mineral Production Wells* and CBR's Class III Underground Injection Control (UIC) Permit.

The NRC regulates the decommissioning of facilities and surface and subsurface soils for the cleanup of radiological contamination. Consideration of other hazardous materials is also required. The requirements for surface and subsurface reclamation are contained in 10 CFR Part 40 Appendix A. CBR's Source Materials License SUA-1534 further specifies actions that must be taken for release of facilities and decommissioning planning.

The purpose of this report is to provide instructions for wellfield reclamation that will ensure that CBR complies with the regulatory requirements of NRC.

On April 12, 1999, the U.S. Nuclear Regulatory Commission (NRC) issued a Final Rule (64 FR 17506) that requires the use of the existing soil Ra-226 standard to derive a dose criterion for the cleanup of byproduct material. The amendment to Criterion 6(6) of 10 CFR Part 40, Appendix A was effective on June 11, 1999. This "benchmark approach" requires that NRC licensees model the site-specific dose from the existing Ra-226 standard and then use that dose to determine the allowable quantity of other radionuclides that would result in a similar dose to the average member of the critical group. These determinations must then be submitted to NRC with the site reclamation plan or included in license applications. This report documents this approach for the Crow Butte Resources Project as well as incorporates other guidance included in NUREG-1569, Standard Review Plan for In Situ Leach Uranium Extraction License Applications (for citation, see NRC, 2003a in Section 9 of this document).

2.0 Crow Butte Project

The Crow Butte Project is permitted for portions of Sections 11, 12, 13, and 24 of Township 31 North, Range 52 West and Sections 18, 19, 20, 29, and 30 of Township 31 North, Range 51 West, Dawes County, Nebraska. The plant site is situated approximately 4.0 miles southeast of the City of Crawford. Figure 2-1 shows the general location of the facility and Figure 2-2 shows the Project Site.

The original development of what is now the Crow Butte Project was done by Wyoming Fuel Corporation, who constructed a Research and Development Facility in 1986. The project was subsequently acquired and operated by Ferret Exploration Company of Nebraska until May 1994, when the name was changed to Crow Butte Resources. This change was only a name change and not an ownership change.

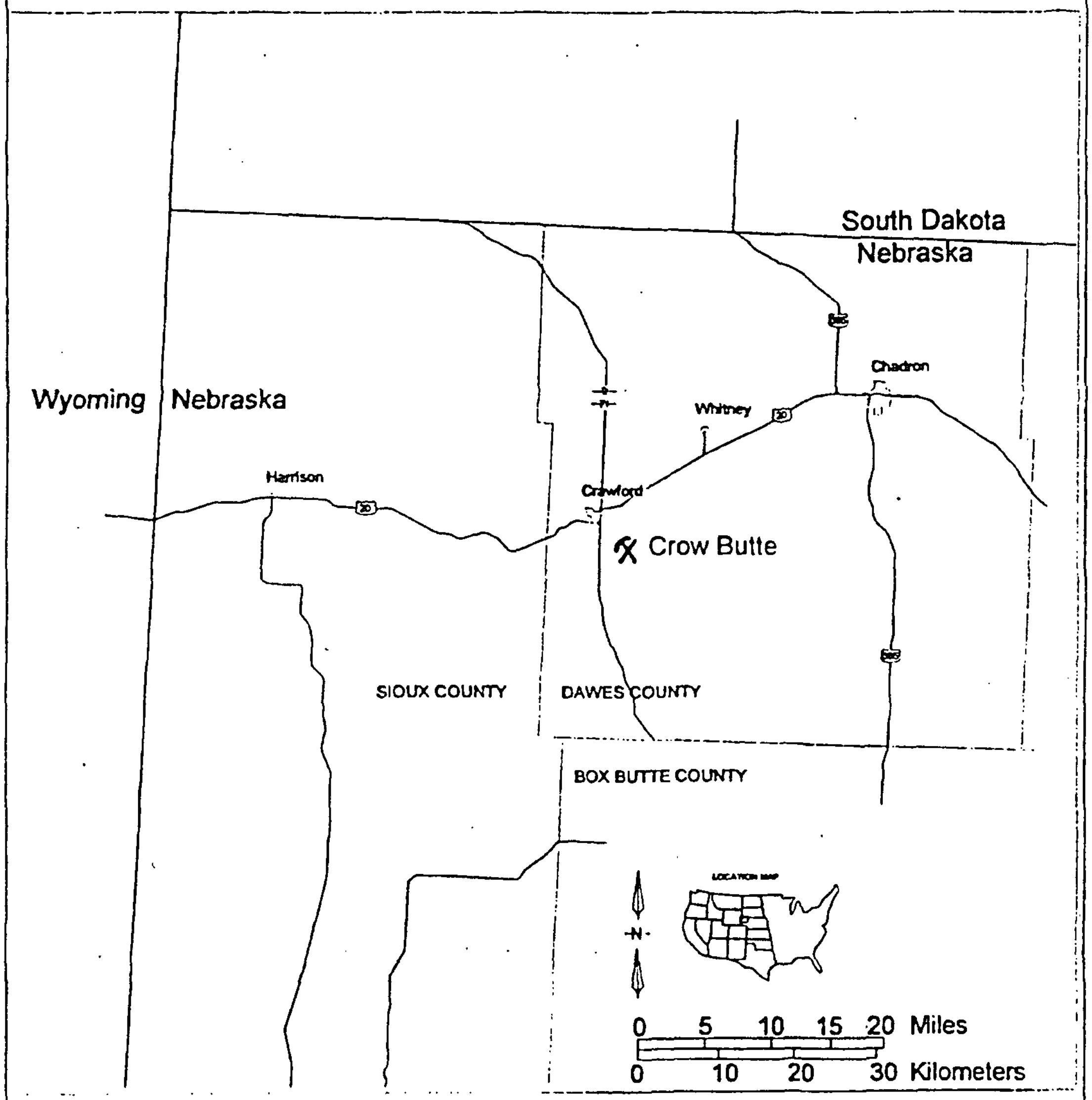
The Research and Development Facility was located in N/2 SE/4 of Section 19, T 31 N, R 51 W. Operations at this facility were initiated in July 1986, and mining took place in two wellfields (WF-1 and WF-2). Mining in WF-2 was completed in 1987 and restoration of that wellfield has been completed. WF-1 was incorporated into Mine Unit One of Commercial Operations.

The production wellfield is located within the permit area as shown in Figure 2-2. The process plant is located in Section 19, Township 31 North, Range 51 West, Dawes County, Nebraska. The permit area is approximately 2,800 acres and the surface area affected over the estimated life of the project is approximately 500 acres.

2.1 Solution Mining Method and Recovery Process

Uranium is recovered by in-situ leaching from the Basal Chadron Sandstone at a depth that varies from 400 feet to 800 feet over the permit area. The overall width of the mineralized area varies from 1000 feet to 5000 feet. The ore body ranges in grade from less than 0.05 to greater than 0.5% U_3O_8, with an average grade estimated at 0.26% equivalent U_3O_8 and 0.31% chemical U_3O_8.

Figure 2-1 CBR General Location



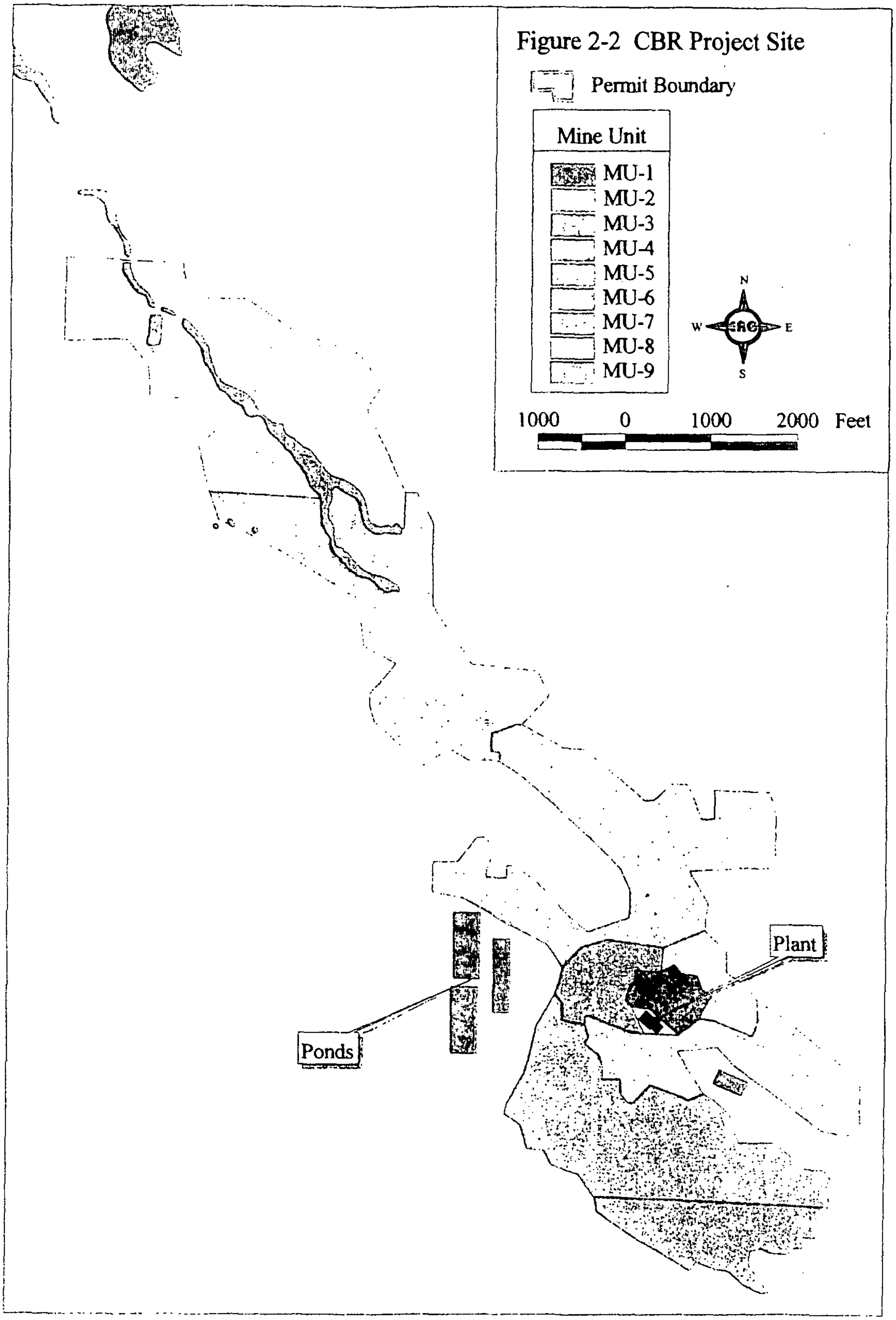


Figure 2-2 CBR Project Site
Permit Boundary
Mine Unit
MU-1
MU-2
MU-3
MU-4
MU-5
MU-6
MU-7
MU-8
MU-9
N
W
E
S
1000 0 1000 2000 Feet
Plant
Ponds

C01

The in-situ leaching process consists of an oxidation step and a dissolution step. Gaseous oxygen or hydrogen peroxide is used to oxidize the uranium, and bicarbonate is used for dissolution. The uranium bearing solution that results from the leaching of uranium underground is recovered from the wellfield and the uranium extracted in the process plant. The plant process uses the following steps:

- Loading of uranium complexes onto ion exchange resin;
- Reconstitution of the solution by the addition of bicarbonate and oxygen;
- Elution of the uranium complexes from the resin;
- Drying and packaging of the uranium.

Sufficient reserves have been estimated to allow mining operations to continue for 10 to 25 years. Status of the current mine unit operations is shown in Table 2-1.

Table 2-1 Mine Unit Status

Mine Unit	Production Initiated	Current Status
Mine Unit 1	April 1991	GroundwaterRestoration Complete
Mine Unit 2	March 1992	Under Restoration
Mine Unit 3	January 1993	Under Restoration
Mine Unit 4	March 1994	Under Restoration
Mine Unit 5	January 1996	Production
Mine Unit 6	March 1998	Production
Mine Unit 7	July 1999	Production
Mine Unit 8	July 2002	Production
Mine Unit 9	October 2003	Production

2.2 Groundwater Restoration

Restoration activities are performed concurrently with mining activities. The restoration process used to successfully restore the R & D Wellfield and Mine Unit No. 1 will be continued. The method consists of four basic activities:

- **Groundwater transfer-** groundwater is transferred between the mining unit commencing restoration and a mine unit commencing production or another water source.

- **Groundwater sweep-** water is pumped from the wellfield which results in an influx of baseline quality water from the wellfield perimeter.

- **Groundwater treatment-** water from injection wells is pumped to the restoration plant where ion exchange, reverse osmosis, filtration or other treatment methods take place.

- **Wellfield recirculation-** water is recirculated by pumping from the production wells and reinjecting the recovered solution. This will act to homogenize the quality of the aquifer.

Following these restoration phases, a groundwater stabilization monitoring program is initiated. Once the restoration values are reached and maintained, restoration is deemed complete. Groundwater restoration activities are conducted under plans submitted to and approved by the NRC and the NDEQ.

2.3 Radioactive Effluents

The only radioactive airborne effluent at the Crow Butte Project is Rn-222 gas. As yellowcake drying and packaging is carried out using a vacuum dryer, there are no airborne effluents from that system.

The Rn-222 is contained in the pregnant lixiviant that comes from the wellfield to the process plant. The majority of this radon is released in the ion exchange columns and process tanks. These vessels are covered and vented to a manifold, which are in turn exhausted to atmosphere outside the building through stacks. The manifolds are equipped with an exhausting fan.

2.4 Liquid and Solid Waste Generation

There are three sources of wastewater and three wastewater disposal options for the Crow Butte Project. The specific method utilized depends upon the volume and characterization of the waste stream.

The operation of the process facility results in three sources of water that are collected on the site. They include the following:

- **Water generated during well development** - This water is recovered groundwater that has not been exposed to any mining process or chemicals. The water is discharged directly to one of the solar evaporation ponds where silt, fines and other suspended matter collected during well development settles out. This water may be land applied.

- **Liquid process waste** - The operation of the process plant results in two primary sources of liquid waste, an eluant bleed and a production bleed. This water is also routed to the evaporation ponds or injected into the deep well.

- **Aquifer restoration** - Following mining operations, restoration of the affected aquifer commences which results in the production of wastewater. The restoration waste is primarily brine from the reverse osmosis unit, which is sent to the waste disposal system. The permeate is either reinjected into the wellfield or sent to the waste disposal system.

Domestic liquid waste is disposed of in an approved septic system.

Solid wastes generated at the site consist of spent resin, resin fines, empty reagent containers, miscellaneous pipe and fittings, and domestic waste. These wastes are classified as contaminated or non-contaminated waste according to their survey results. Contaminated wastes that cannot be decontaminated are stored until they can be shipped to a licensed waste disposal site or licensed mill tailings facility. Non-contaminated solid waste is collected on the site on a regular basis and disposed of in a sanitary landfill.

2.5 Spills

CBR's NRC License requires that all spills of source or 11e.(2) byproduct material and all spills of process chemicals be documented. Radioactive material releases that meet the reporting criteria in 10 CFR 20, Subpart M and 10 CFR §40.60 must be reported to the NRC Operations Center. The license also requires that CBR notify the NRC Project Manager by telephone or electronic mail within 48 hours of any significant spill that may have a radiological impact on the environment and that is reportable to other State or Federal agencies.

The major source of radioactive material releases in the wellfields are broken pipelines that contain injection or production fluid. The potential impact of a radioactive materials release is influenced by several factors such as magnitude of the release, the concentration of radionuclides in the release, and the location of the release. The majority of spills originate in the injection circuit which is under high pressure. A sample of injection water was taken on April 15, 2004 and submitted to a vendor laboratory for analysis. The results are shown in Table 2-2 below.

Table 2-2 Radionuclide Concentrations in Injection Water Sample

Radionuclide	Concentration (pCi/L)	Reporting Limit (pCi/L)
Uranium	4.7	0.2
Ra-226	1140	0.2
Th-230	ND *	0.2
Pb-210	49	2.7

ND – nondetectable at the reporting limit of 0.2 pCi/L

The levels in the production fluid are expected to be similar to the injection water other than the uranium concentrations are much higher, averaging approximately 30,000 pCi/L.

The spill response procedure requires immediate response once a spill has been discovered. A sample of any water that has pooled is taken to verify that it is a process solution. Any water that has pooled is retrieved with a vacuum trailer and placed in the evaporation ponds. The volume of recovered water is recorded.

After all standing water is removed, a measurement of the extent of the release is made and a detailed diagram drawn. Saturation depth measurements are made at several locations to allow determination of an average depth of saturation. A worksheet is prepared showing the exact location of the release, the affected area, the quantity of material released, a description of how the release occurred and how it was discovered.

A data base is maintained that includes the following:

- Release date
- Release location
- Name of individual entering data
- Release area (in square feet)
- Release depth (in inches)
- Injection or Production solution

The following additional information is not required, but is recorded if known:

- Release volume (if estimated from operating data)
- Release volume recovered (if any)
- Solution uranium activity (if known from samples of release)
- Solution Ra-226 activity (if known from samples of release)

A gamma survey is performed and documented. If the results of the gamma survey indicate levels in excess of 20 μR/hr above background, soil sampling may be performed to determine the soil Ra-226 and U-nat concentrations (at the discretion of the RSO).

In release areas adjacent to active wellheads, high background gamma levels from contaminated piping may prevent accurate gamma survey results. Normally these areas are not cleaned up after each release due to the on-going potential for contamination from subsequent releases and the presence of buried utility lines. For these release areas, no soil samples are taken but the release reports are maintained in the Decommissioning File as required by 10 CFR 40.36.

If soil sampling indicates that the Ra-226 concentration exceeds the criteria for final site cleanup standards, the RSO will determine the appropriate corrective actions. Any soil that requires cleanup is treated as byproduct material and handled and disposed of properly.

Following completion of radiological surveys and release reports, the RSO ensures that the following information has been gathered and recorded in the decommissioning file:

- Date
- Release volume
- Total activity of each radionuclide released
- Corrective actions

- Results of remediation surveys
- Map showing release location and impacted area

Records of releases are maintained until NRC license termination. The RSO is responsible for maintaining the release records.

For the four calendar years beginning in the year 2000, 104 spills were reported, releasing an estimated 90,657 gallons of water.

2.6 Natural Background Radionuclides in Soil

USNRC Regulatory Guide 4.14, Section 1.1.4 specifies that one set of pre-operational surface soil samples should be collected to a depth of five centimeters at 300-meter intervals in each of the eight compass directions out to a distance of 1500 meters from the center of the milling area, and at each of the air particulate sampling locations. This requirement results in the collection of a minimum of 41 surface soil samples. All pre-operational soil samples are to be analyzed for Ra-226. In addition, all soil samples collected from the air particulate sampling locations, plus ten percent of all other soil samples, are to be analyzed for U-nat, Th-230, and Pb-210. The pre-operational data are intended to be compared with data collected during plant operations. The pre-operations data requirements for the Crow Butte Facility were adjusted somewhat to be appropriate for the potential releases from this ISL facility.

MARSSIM (NRC, 2000) recommends that background soil samples be collected to a depth of 15 centimeters (6 inches). The greater depth recommended by MARSSIM is based on the pathway models which consider plow mixing and crop growth to be over a 0 to 15 cm depth. Additionally, NUREG-1569 specifies in Section 2.9.3 that background soil samples must be collected from both 5-cm depth in conformance with Regulatory Guide 4.14 for operations purposes, and 15 cm for decommissioning purposes. Therefore, additional background samples were collected using MARSSIM guidance.

2.6.1 Pre-Operational Data

In July, 1982, 50 surface (to a depth of 5 centimeters) soil samples were collected in and around the permit area and from the air particulate sampling stations. All 50 samples were analyzed for U-nat and Ra-226. The uranium concentrations ranged from 0.36 to 6.7 pCi/g, and averaged 1.6 ± 1.1 pCi/g (1 standard deviation). It was noted at the time that the sample with the highest uranium concentration, 6.7 pCi/g, was collected from a compacted dirt driveway of a local motel. This datum should probably be considered unrepresentative and discarded. The Ra-226 concentrations ranged from 0.1 to 2.0 pCi/g, and averaged 1.1 ± 0.3 pCi/g. These data were considered typical of background concentrations expected for the area.

2.6.2 Gamma Surveys and Soil Sample Results in Reference Areas

Background studies were conducted by ERG personnel from May 10-14, 2004. Four reference areas were selected which were considered to be non-impacted from site operations and representative of the site physically, chemically, geologically, radiologically, and biologically. The four reference areas include areas near the northern and southern boundaries of the current permitted area as shown in Figure 2-3.

A gamma scanning survey was first conducted over each reference area using transect lines spaced at two-meter intervals and a walking speed of about one meter per second. A Ludlum Model 44-10 2-inch by 2-inch NaI detector was coupled to a Ludlum Model 2221 ratemeter/scaler. Gamma-ray count rates were recorded at one-second intervals. The gamma survey data maps for Areas 1 and 4 are shown in Figures 2-4 and 2-5. A histogram of the gamma-ray survey data for the four reference areas is presented in Figure 2-6. These figures demonstrate that the gamma-ray levels are fairly uniform across the surface of the four reference areas. Table 2-3 summarizes the gamma scanning survey data in tabular form. The number of gamma-ray survey points for the four reference areas ranged from 265 to 423. The average count rate ranged from 13,977 cpm to 14,503 cpm. The standard deviation of the count rate data ranged from 774 to 832.

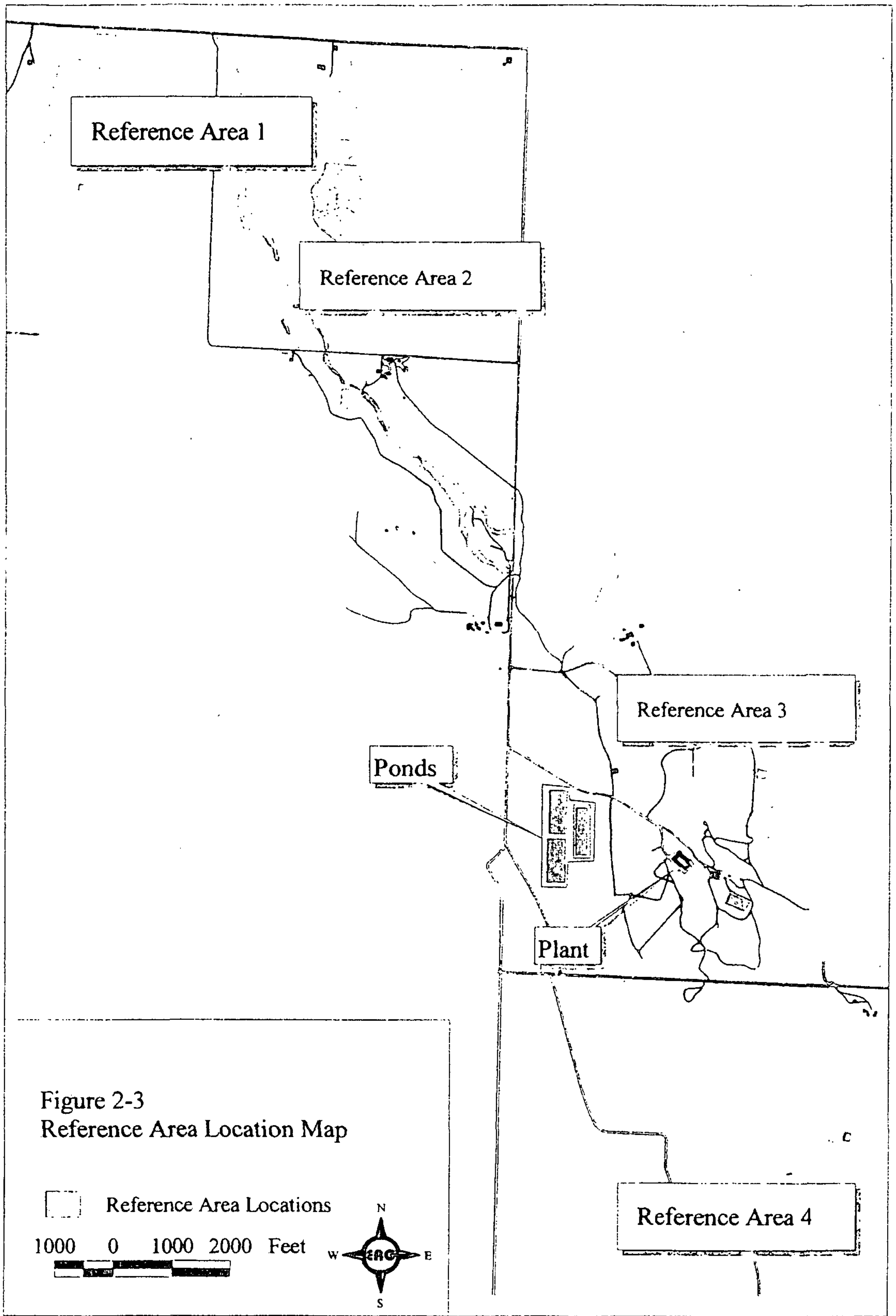


Figure 2-3
Reference Area Location Map

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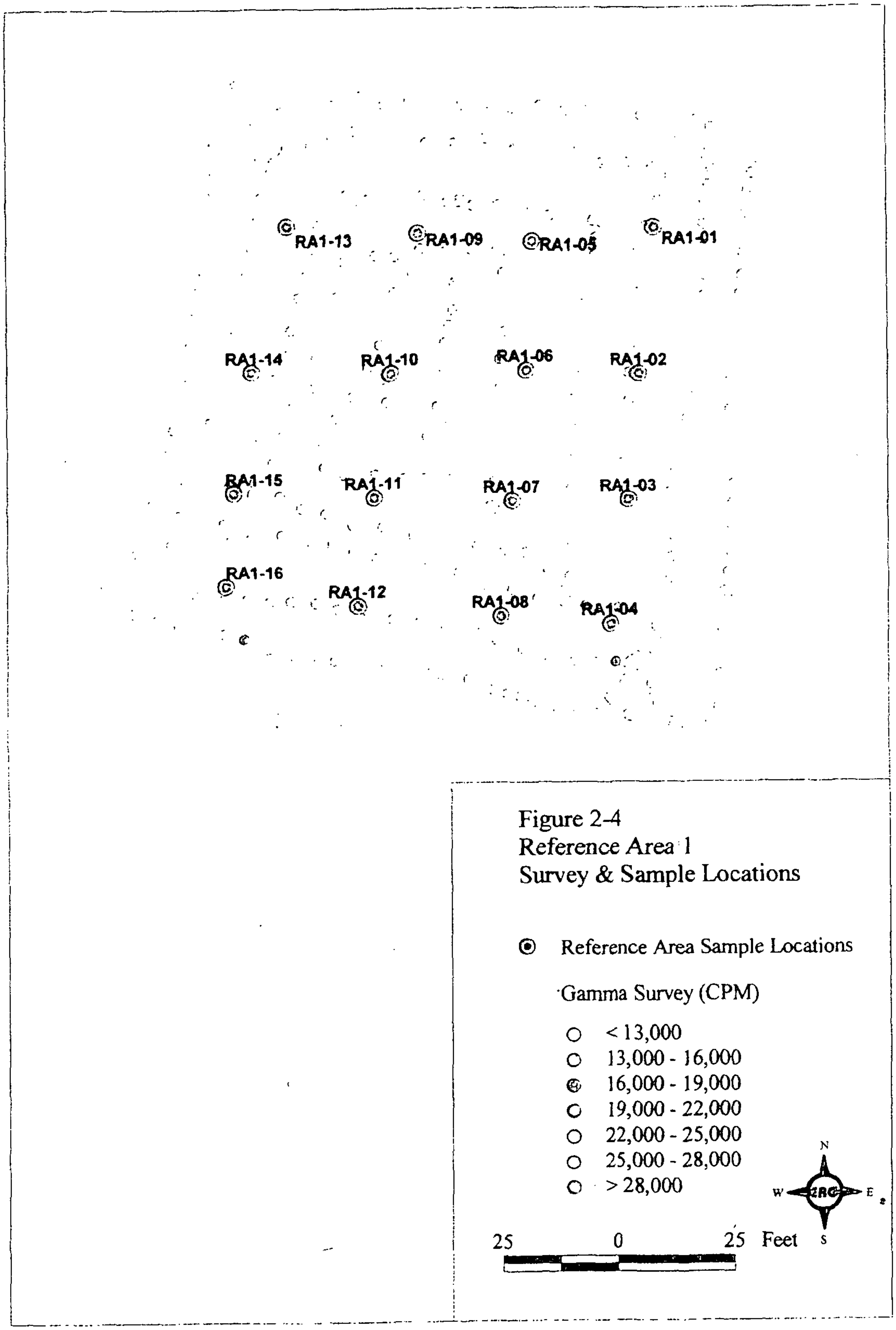

Figure 2-4
Reference Area 1
Survey & Sample Locations

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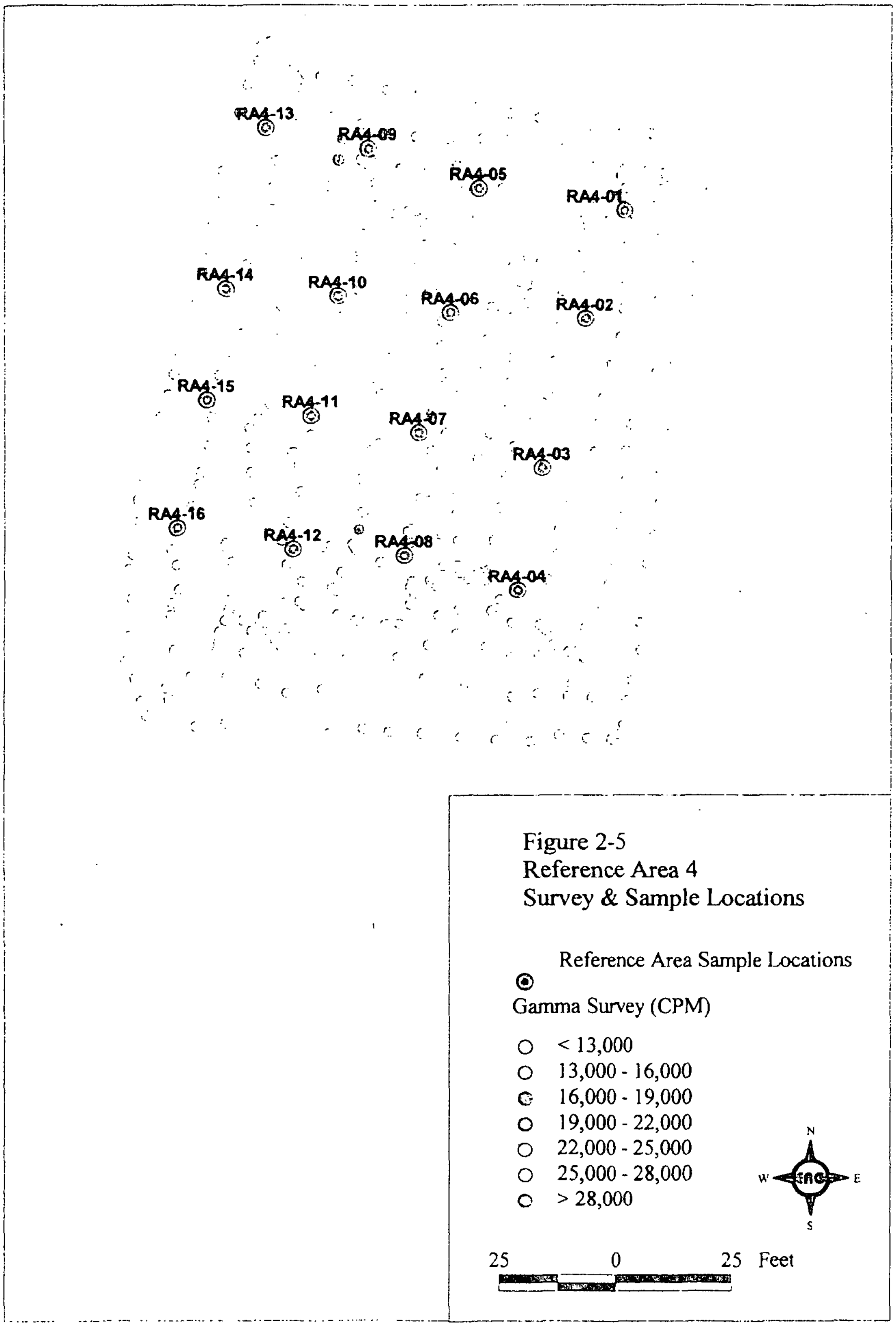

Figure 2-5
Reference Area 4
Survey & Sample Locations

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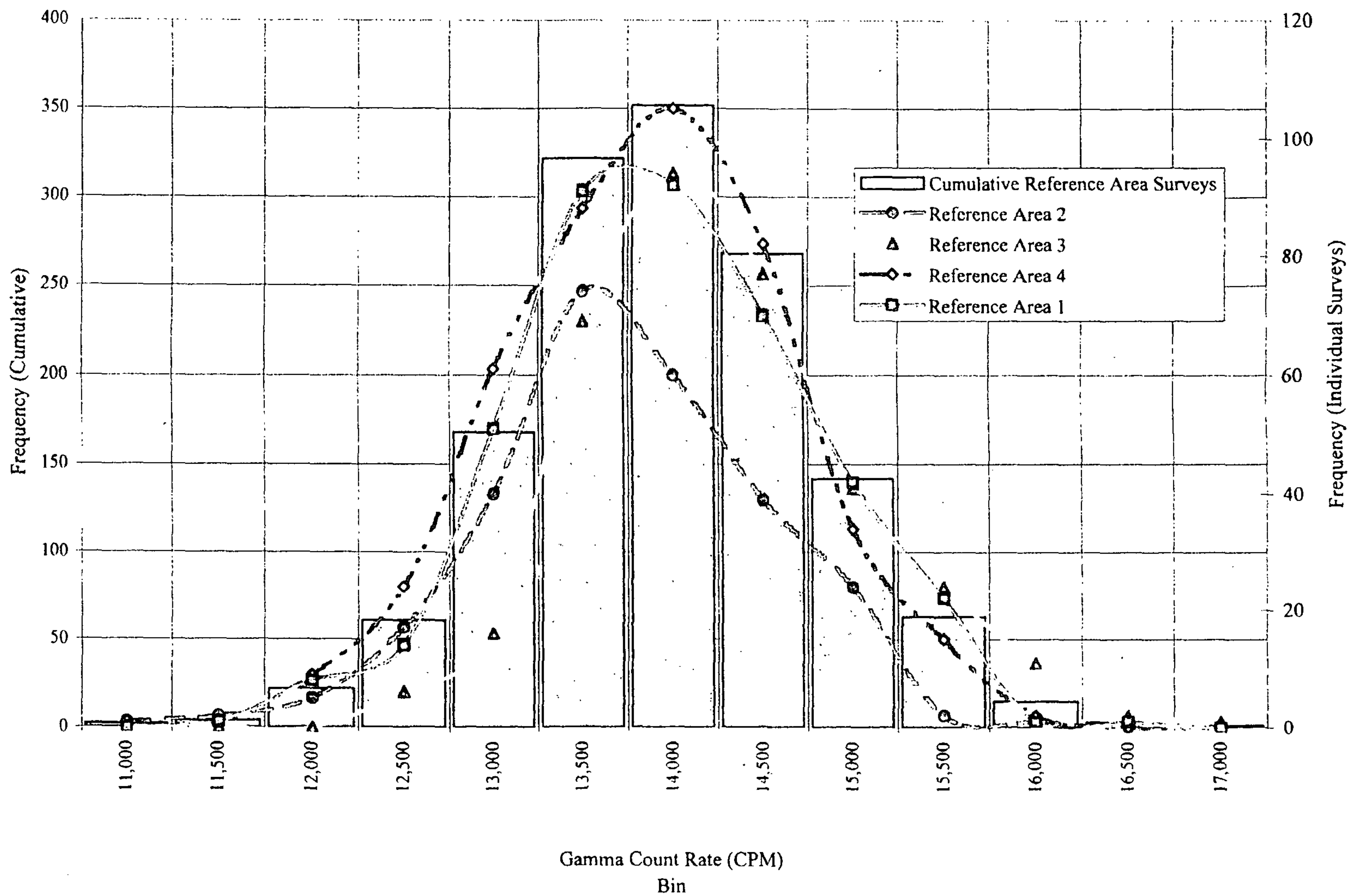

Figure 2-6 Reference Area Survey Data Histogram

Table 2-3 Reference Area Gamma Survey Data Summary

Location	Population Size (n)	Avg. Ratemeter Count Rate (cpm)	Standard Deviation
RA-1	393	14199	803
RA-2	265	13977	775
RA-3	341	14503	744
RA-4	423	14098	832

A casual review of the gamma count rate data leads to the conclusion that the four reference areas appear to have uniform background gamma-ray radiation levels, and therefore uniform concentrations of naturally occurring radionuclides. To assess the accuracy of this conclusion, a more detailed characterization of Reference Area 1 and Reference Area 4 was performed. Sixteen survey points were uniformly spaced across the areas for additional study. These survey points are identified as RA1-1 through RA1-16, and RA4-1 through RA4-16 on Figures 2-4 and 2-5, respectively. At these survey points, a static one-minute gamma-ray count was collected using the same portable instruments as the scanning survey. The difference between the measurements is that the scanning survey data is the estimated cpm from a one second count time, whereas the static measurement is a true one-minute data collection. The exposure rate was also measured at a height of 18 inches above each survey point using a Ludlum Model 19. After gamma-ray and exposure rate data were recorded, a soil sample was collected to a depth of six inches (15 cm) using a 5-point composite sampling method. These soil samples were analyzed by a vendor laboratory for total uranium, Ra-226, and Pb-210. The static gamma-ray count, exposure rate, and laboratory analyses for each survey point is presented in Table 2-4.

Any difference in the mean radionuclide concentration between the survey unit and the reference area will be interpreted as caused by residual radioactivity from site activities. If there is a significant variability in background concentration, or when there is a significant difference in backgrounds between reference areas, then the NRC recommends that a Kruskal-Wallis (K-W) test be conducted to determine whether there are, in fact, significant differences in the mean background between the reference areas. The K-W test is described in NUREG-1505 (NRC, 1997). The test assumes that if the distribution of the measurements in each reference areas are the same, then the average rank for each reference area should also be about the same. A Kruskal-Wallis statistic (K) for each survey unit is calculated, which is a measure of how different the reference areas are from each other. While NUREG-1505 does not recommend a specific value of K_c, the critical value, the NRC staff recommends in DG-4006 (NRC, 1998a) a Type I error rate of an a_{kw}=0.2. From Table 13.3 of NUREG-1505, given that two reference areas are being compared at CBR and an a_{kw} of 0.2, the acceptable K_c is 1.6.

A K-W statistical test was performed on the static one minute gamma-ray data, the Ra-226 soil sample results, and the total uranium soil sample results presented in Table 2-4. In the case of the Ra-226 and total uranium data, several of the analytical results were identical. Abelquist, 2001 (page 134) states "when ranking, if several measurements are tied, they are all assigned the average rank of that group of tied measurements". Also, in the case of total uranium data, several of the analytical results were reported as not detectable at the reporting limit of 0.3 pCi/g. For ranking purposes, the data were ranked as if the concentration reported was 0.3 pCi/g. The K for each measurement type was calculated with the results as follows:

- One minute gamma-ray count rate K = 9.5
- Ra-226 soil data K = 13.1
- Total uranium soil data K = 21.4

In all three statistical tests, the calculated K significantly exceeds the critical value of 1.6. This suggests that the reference areas do have significantly different distributions of gamma-ray count rates and soil concentrations.

While these tests demonstrate that the distribution of all three measurements in Reference Areas 1 and 4 are statistically different, another question to consider is are these differences in backgrounds significant? Guidance presented in Section 2.3.1 of NUREG-

Table 2-4 Reference Area Sample Data

Reference Area 1

Sample ID	1-Minute Integrated Count (cpm)	Exposure Reading (µR/hr)	Pb-210 (pCi/g) *	Ra-226 (pCi/g)	Uranium (pCi/g)	Ra-226 : Uranium Ratio
RA1-01	14317	17	ND	0.8	0.5	1.5
RA1-02	14434	18	ND	0.7	0.5	1.5
RA1-03	14381	17	ND	0.7	0.4	1.7
RA1-04	14373	18	ND	0.6	0.5	1.3
RA1-05	14518	18	ND	0.6	0.5	1.3
RA1-06	14113	17	ND	0.6	0.4	1.5
RA1-07	14543	18	ND	0.6	0.4	1.5
RA1-08	14177	18	ND	0.7	0.5	1.5
RA1-09	14339	18	ND	0.8	0.5	1.7
RA1-10	13967	17	ND	0.6	0.4	1.5
RA1-11	14191	17	ND	0.4	0.4	1.0
RA1-12	14208	16	ND	0.5	0.4	1.2
RA1-13	13842	16	ND	0.6	0.5	1.3
RA1-14	13767	16	ND	0.5	0.4	1.2
RA1-15	13820	17	ND	0.7	0.4	1.7
RA1-16	13496	16	ND	0.8	0.5	1.7
Average	*14155*	*17*		*0.6*	*0.4*	*1.4*
Std. Dev.	*291*	*0.8*		*0.1*	*0.0*	*0.2*

Reference Area 4

Sample ID	1-Minute Integrated Count (cpm)	Exposure Reading (µR/hr)	Pb-210 (pCi/g) *	Ra-226 (pCi/g)	Uranium (pCi/g) **	Ra-226 : Uranium Ratio
RA4-01	13784	17	ND	0.5	0.4	1.2
RA4-02	13778	16	ND	0.6	** *0.3*	1.8
RA4-03	13810	16	ND	0.5	** *0.3*	1.5
RA4-04	13873	16	ND	0.4	0.4	1.0
RA4-05	13808	18	ND	0.7	0.4	1.7
RA4-06	14096	17	ND	0.6	0.3	1.8
RA4-07	13936	17	ND	0.5	** *0.3*	1.5
RA4-08	13732	16	ND	0.4	** *0.3*	1.2
RA4-09	14086	17	ND	0.5	0.3	1.5
RA4-10	13730	16	ND	0.5	0.4	1.2
RA4-11	13843	16	ND	0.4	** *0.3*	1.2
RA4-12	13550	17	ND	0.4	0.3	1.2
RA4-13	14094	16	ND	0.7	0.4	1.7
RA4-14	13781	17	ND	0.5	0.3	1.5
RA4-15	13782	17	ND	0.4	** *0.3*	1.2
RA4-16	13870	16	ND	0.4	0.4	1.0
Average	*13847*	*17*		*0.5*	*0.4*	*1.4*
Std. Dev.	*142*	*0.6*		*0.1*	*0.0*	*0.3*

* *ND - nondetectable at the reporting limit of 0.2 pCi/g*
** *0.3 - nondetectable at the reporting limit of 0.3 pCi/g*

CR/5849 (NRC, 1998b) indicates that if the sum of the mean background and 2 standard deviations of the measurements is less than 10% of the DCGL, variations in background can be considered insignificant. This is the case for the total uranium analyses where the average concentrations and standard deviations for Reference Areas 1 and 4 are 0.5 ± 0.1 pCi/g, and 0.3 ± 0.1 pCi/g respectively and the DCGL is 240 pCi/g. These differences are clearly insignificant. For Ra-226, the average concentrations for Reference Areas 1 and 4 are 0.6 ± 0.1 pCi/g and 0.5 ± 0.1 pCi/g, respectively, and the DCGL is 5 pCi/g. While this comparison is not quite as conclusive, the same argument can be made that the variability in radium background can be neglected for cleanup comparison purposes. A radium background concentration of 0.55 pCi/g is proposed.

3.0 Current Site Conditions

A characterization survey was conducted in May 2004 to provide information needed to develop a final verification plan for contaminated soils. Spill areas within the wellfields and near evaporation ponds were surveyed in an effort to collect data used to develop a gamma count rate to radionuclide soil concentration correlation. This correlation will assist in interpreting the radiological survey data and to develop a gamma-ray action level. Four areas were chosen for survey and soil sampling. Figure 3-1 shows the four areas relative to the overall site. Spill areas involving large quantities of injection well solution were selected. Spills in the proximity of contaminated piping, such as next to the wellheads or trunklines, were not considered since the gamma shine from such features would influence the correlation.

3.1 Gamma Surveys and Soil Sampling

Each area was surveyed using a 2-inch by 2-inch NaI detector (Ludlum Model 44-10), coupled to a Ludlum Model 2221 ratemeter/scaler and a Trimble ProXRS GPS unit. The survey system automatically logged individual gamma count rates with a corresponding coordinate every one second. The GPS system was placed into a backpack and was worn by field personnel while walking at a rate of approximately 2.5 feet per second over the area to be surveyed. The data were managed using ArcView GIS, a geographic information system computer application for managing, displaying, and analyzing data geographically. After review of the survey data maps, the area was further scanned with only the Ludlum Model 2221 and 44-10 to identify locations within a specific range of gamma readings from which to sample. The coordinates of each sample location were recorded using the GPS. A one-minute integrated gamma count was taken using the 2221 and 44-10 at eighteen inches above the sample location. An exposure-rate reading was taken with a Ludlum Model 19 at eighteen inches above the sample location. Lastly, a five point composite surface to 15-cm deep sample was taken. One sample was taken directly beneath the detector and the four other samples were taken at points extending in the compass directions eighteen inches from the center.

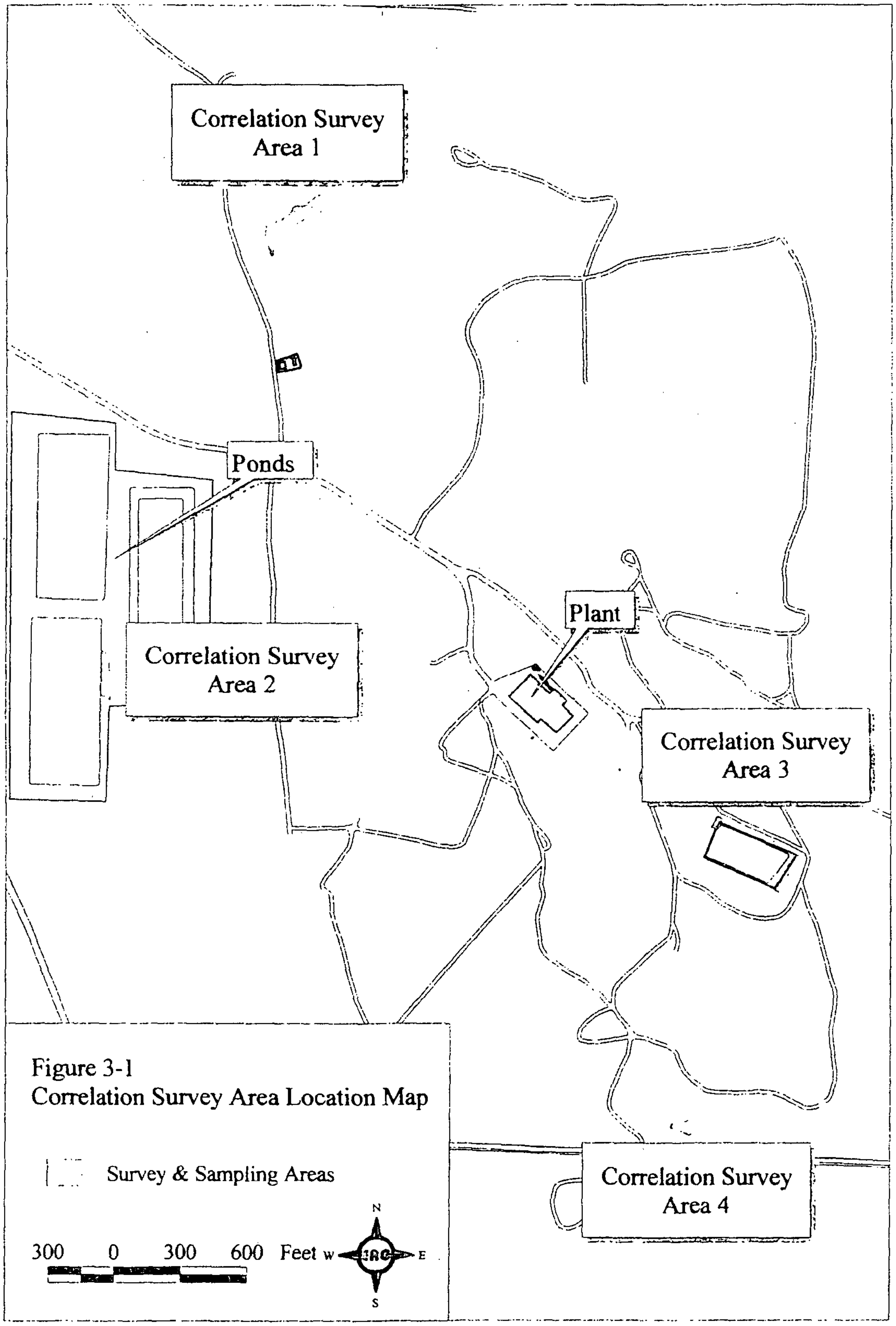

Figure 3-1
Correlation Survey Area Location Map

C06

3.2 Soil Sample Data and Gamma Survey Results

A total of fifteen soil samples were taken from the four correlation survey areas. The results of the one-minute integrated counts, exposure rates, and soil concentrations are shown in Table 3-1. Figures 3-2 through 3-5 show the GPS-radiological survey and correlation sample locations for each of the four areas. Each color dot in the figures represents a recorded count rate within one of the count-rate ranges given in the legends of the figure. Of the few locations that indicate elevated gamma levels, some are near pipes or other gamma-emitting sources. The correlation survey resulted in over 2100 individual gamma records with associated coordinates. The maximum reading observed was 28,272 cpm in Area 4 while the minimum reading was 10,411 cpm in Area 1.

Four samples were taken from Area 1 where a trunkline had leaked and solution had run down the hillside. At Area 2 three samples were taken from a location between two evaporation ponds currently in use. There were three samples taken at Area 3, next to the pilot plant evaporation pond. At Area 4, five samples were taken in an area where a large trunkline spill had occurred. Several elevated areas were not suitable for correlation studies since the source of gamma rays were from nearby process components or from a spill of a very concentrated material in a small localized area.

The high Ra-226 to U-nat concentration ratios for the data in Table 3-1 suggest that all spills were from injection water with the exception of Area 2, which was not wellfield water line spill related. The contamination in Area 2 is believed to have arisen from spillage while transferring water from one evaporation pond to another.

Table 3-1 Correlation Area Sample Data

Correlation Area	Sample ID	1-Minute Integrated Count (cpm)	Exposure Rate (µR/hr)	Pb-210 (pCi/g)	Ra-226 (pCi/g)	Uranium (pCi/g)	Ra-226:U-nat Ratio	Average Ratio
1	CBR-CS-01	16330	20	ND	3.4	0.9	3.6	3.3
	CBR-CS-02	15911	19	ND	4.6	1.4	3.2	
	CBR-CS-03	13868	17	ND	0.7	0.5	1.3	
	CBR-CS-04	17359	21	ND	4.1	0.8	5.0	
4	CBR-CS-05	35132	40	1.5	53.0	1.6	32.6	26.2
	CBR-CS-06	29930	34	ND	45.0	1.8	25.6	
	CBR-CS-07	21756	27	ND	29.0	1.4	20.4	
	CBR-CS-08	19504	24	ND	10.0	1.2	8.2	
	CBR-CS-09	15712	19	ND	0.8	1.0	0.8	
2	CBR-CS-10	16233	19	ND	0.9	3.1	0.3	0.2
	CBR-CS-11	17070	19	ND	1.2	7.6	0.2	
	CBR-CS-12	17981	20	1.2	1.0	11.3	0.1	
3	CBR-CS-13	21606	25	3.9	10.0	1.5	6.7	5.7
	CBR-CS-14	18462	21	2.7	5.0	1.0	4.9	
	CBR-CS-15	23223	27	4.5	11.0	2.0	5.4	

** ND - nondetectable at the reporting limit of 0.2 pCi/g*

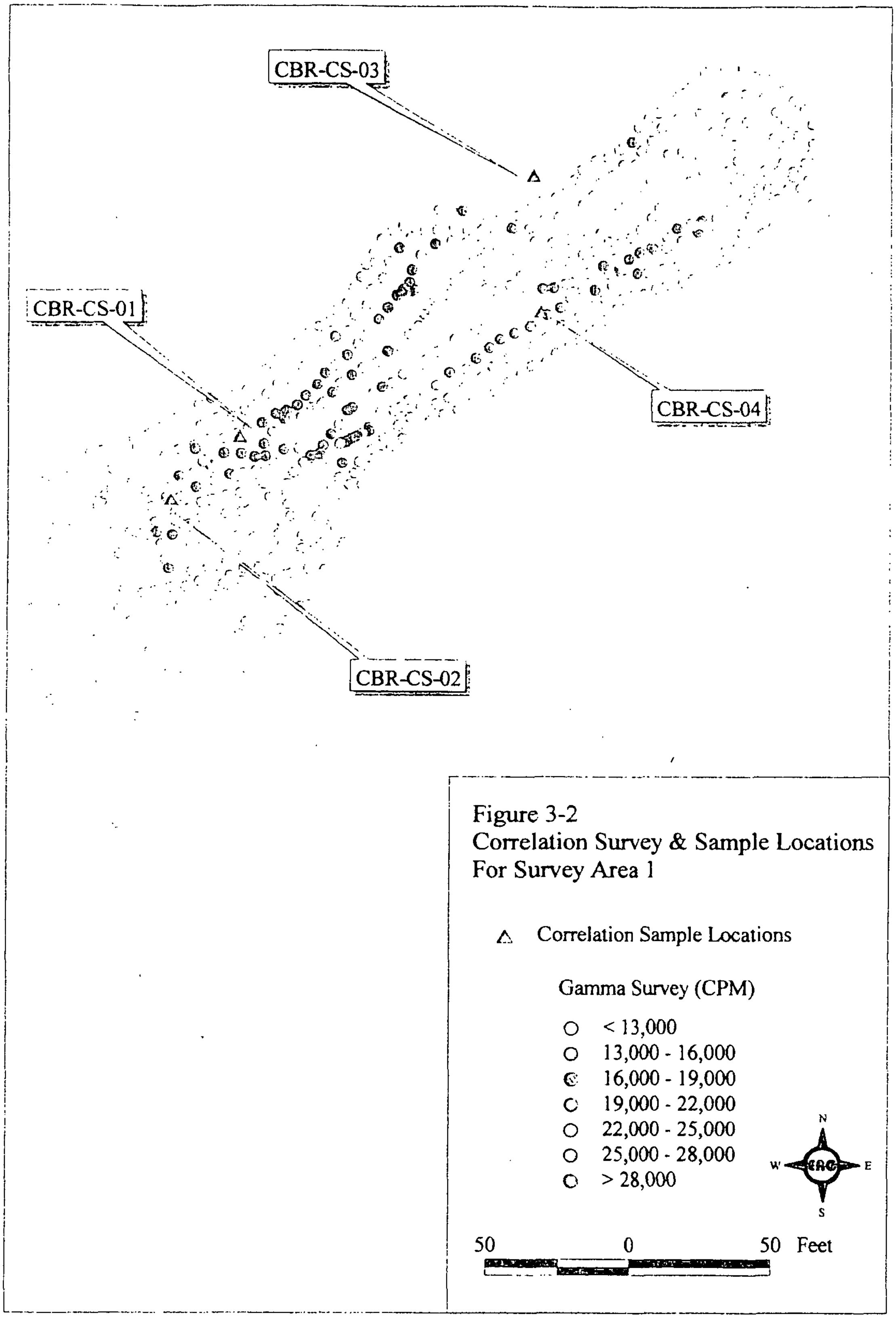

Figure 3-2
Correlation Survey & Sample Locations
For Survey Area 1

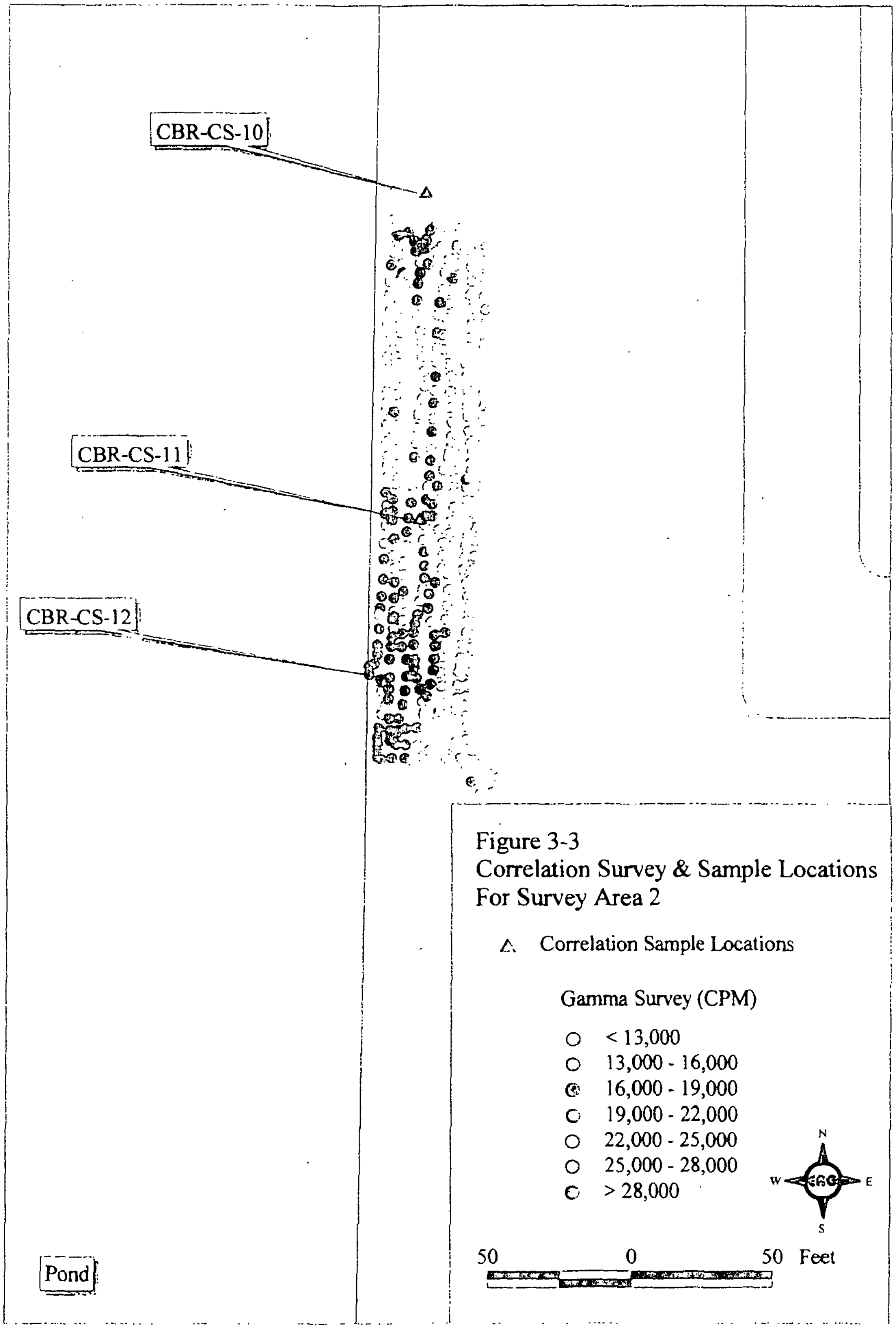

Figure 3-3
Correlation Survey & Sample Locations
For Survey Area 2

△ Correlation Sample Locations

Gamma Survey (CPM)

- < 13,000
- 13,000 - 16,000
- 16,000 - 19,000
- 19,000 - 22,000
- 22,000 - 25,000
- 25,000 - 28,000
- > 28,000

C08

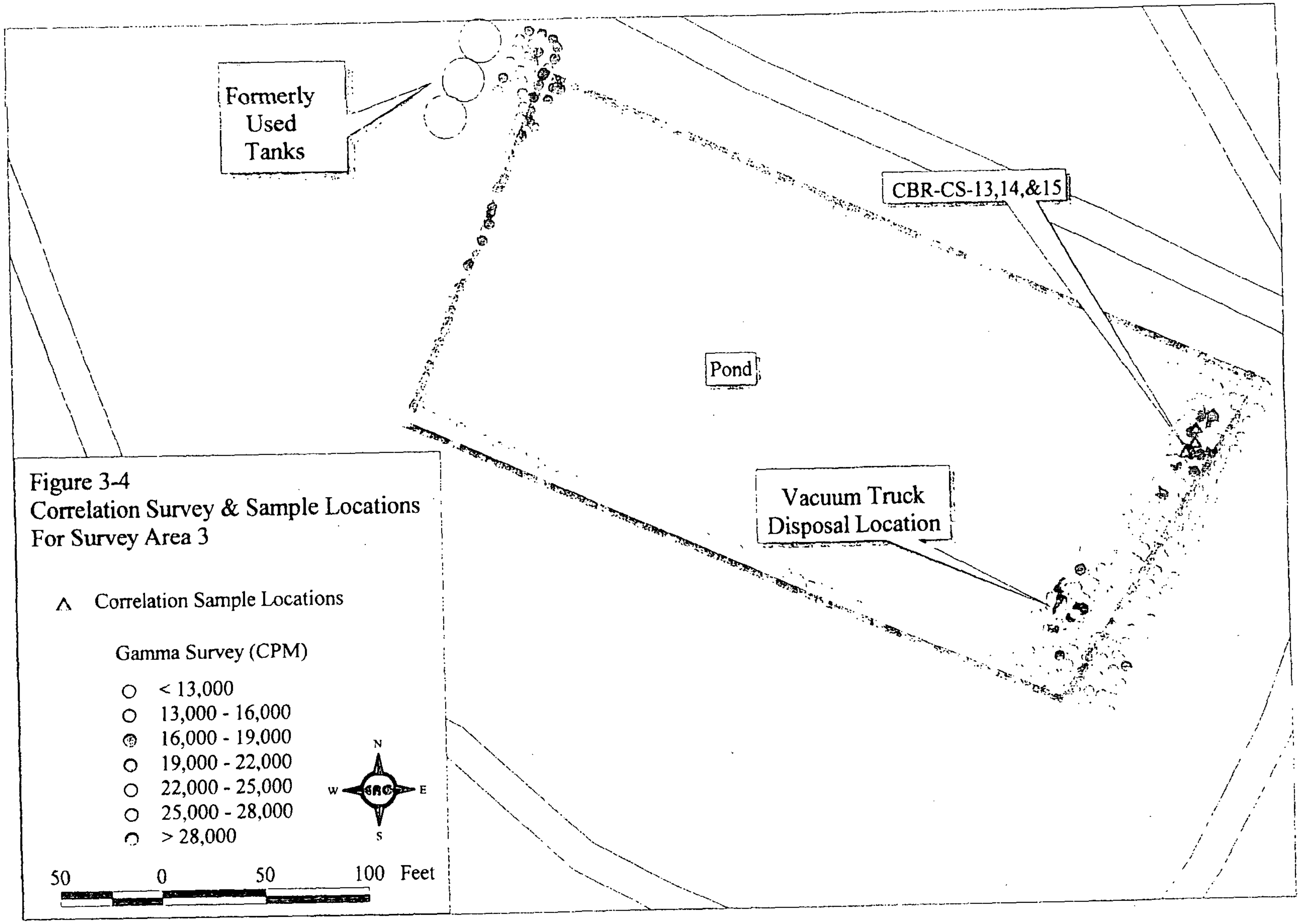

Figure 3-4
Correlation Survey & Sample Locations
For Survey Area 3

C09

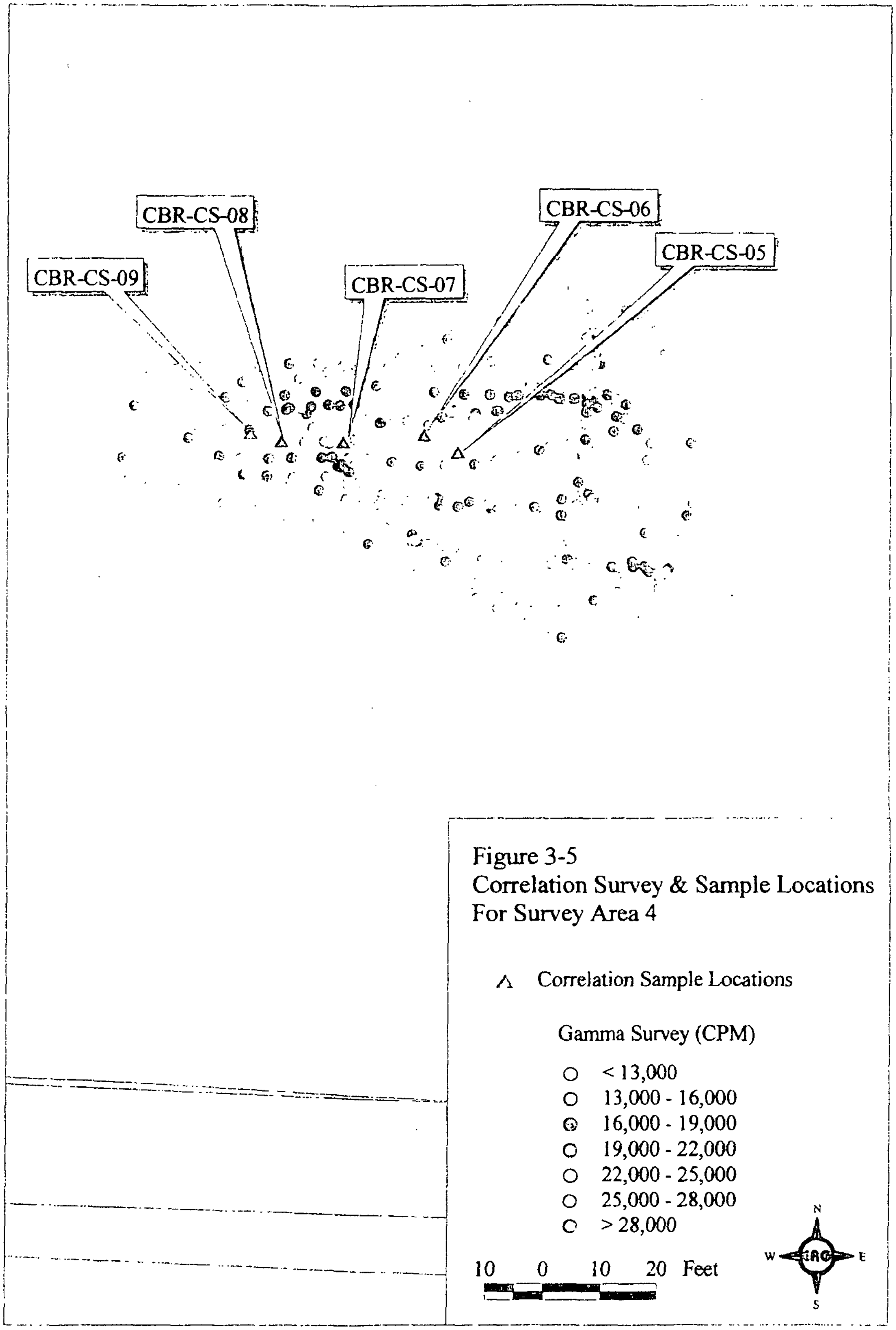

Figure 3-5
Correlation Survey & Sample Locations
For Survey Area 4

C10

4.0 Wellfield Decommissioning

Decommissioning and demolition work will be performed by CBR personnel and outside contractor(s). All workers will receive industrial and radiation safety training according to the Section 7.2 of this plan. As stated in that section, the ESH department will monitor decommissioning activities related to safe work practices and assure compliance with procedures. All personnel have the authority to terminate work when unsafe practices are observed. Section 5.0 lists the disposal options and survey requirements for decommissioned equipment, materials and structures. Contaminated soil and those items that cannot be economically decontaminated below the releasable limits will be disposed of as byproduct material according to Section 5.4.

Wellfield decommissioning includes the removal of surface equipment consisting of feed lines, electrical conduit, well boxes, and wellhead equipment. Wellhead equipment such as valves, meters, or control fixtures will be salvaged when possible. Buried wellfield piping will be removed. Wells will be plugged and abandoned according to the procedure below. Following removal of all equipment and piping, a gamma survey will be performed in potentially contaminated areas to identify and remove contaminated soil above the cleanup criteria. The wellfield area may then be recontoured, if necessary. Additional information regarding each step of the decommissioning is discussed below.

4.1 Well Plugging and Abandonment

Wells no longer useful for continued mining or restoration will be abandoned. This includes injection and recovery wells, monitoring wells, and any other wells used for the collection of hydrologic or water quality data. One known exception may be a well could be transferred to the landowner for personal use.

The objective of the CBR well abandonment program is to seal all wells such that the groundwater supply is protected, and to remove potential physical hazards. All abandoned wells will be plugged and abandoned in accordance with The Plugging and Abandonment Plan approved by the NDEQ and summarized in Section 6.2.3.1 of the CBR license renewal application. This procedure is summarized below.

A hose is lowered to the bottom of the well casing, and an approved abandonment mud is pumped down the hose. After filling the casing, the hose is removed and a cement plug is placed on the top. A hole is dug around the well, and the top three feet of casing are removed. The hole is then backfilled and vegetated.

A well abandonment report will be filed with the appropriate agencies upon completion of the wellfield decommissioning.

4.2 Trunk Lines, Pipes, and Wellfield Equipment

Surface piping used for wellfield activities, such as injection and recovery well lines or trunk lines, will be removed from the wellfields along with the valves, meters, and other related equipment. The underground piping (well lines and trunk lines) will be excavated and removed. Salvageable lines will be held for future use in ongoing mining operations. Non-salvageable lines will either be surveyed for unrestricted release, or disposed of at a licensed disposal facility as radioactive waste.

In some situations, CBR may desire to leave buried pipes in place. If so, studies will be conducted to determine the effectiveness of acid washes or other decontamination methods. The results will be documented and, if successful, used to develop a procedure for submission to the NRC for approval.

Contaminated equipment will be evaluated on a cost-benefit basis to determine if an attempt to decontaminate the item is warranted. Possible decontamination methods include acid wash, sandblasting, and pressurized water spray. During decontamination attempts, the work area will be controlled in accordance with radiological control requirements using procedures from the CBR Health Physics Manual (HPM). If decontamination is not successful, items will be disposed of at a licensed facility. Areas where wash water has been released to the ground will be considered potentially contaminated and monitored in accordance with Section 6 of this plan.

After all surface equipment and piping are removed, and all wells are properly plugged and abandoned, soil monitoring and removal procedures specified in Section 6 of this D&D plan will be applied.

4.3 Wellfield Buildings

Wellfield buildings are small enough to be transported intact and may be reused at another wellfield, transferred to another licensee, or released for unrestricted use if they can be decontaminated to release criteria. These small, industrial structures are not suitable for long-term occupancy by workers or as a residence. Therefore, the release criteria for materials and equipment as specified in Section 5.1 will be applied.

5.0 Disposition Options and Release Surveys

The disposition of potentially contaminated items and materials fall within four broad categories. These categories are the unrestricted release of equipment and pipe, the unrestricted release of wellfield buildings, the transfer of contaminated equipment and buildings to another licensee, and the disposal of contaminated equipment as waste byproduct material.

5.1 Equipment, Pipe and Materials to be Released for Unrestricted Use

Salvageable equipment, pipe and other materials to be released for unrestricted use will be surveyed for alpha radiation contamination in accordance with the NRC guidance document, "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material," dated May 1987.

The monitoring for beta-gamma dose rate is a current license requirement, based on the referenced 1987 NRC guidance document. This requirement has been eliminated in subsequent ANSI standards, including the latest ANSI/HPS N13.12-1999 standard, "Surface and Volume Radioactivity Standards for Clearance." CBR has routinely made these measurements but has never found them limiting. The characterization data indicate that the long-lived radionuclides, uranium, Ra-226, and Pb-210 are the principal radionuclides in the process water and thus are the principal constituents in contaminated areas. Anticipated mixtures of these radionuclides anywhere on the CBR site, including within process equipment, result in alpha and beta emission rates that are approximately the same. When Ra-226 is the predominant constituent, then the alpha emission rate should be approximately twice the beta emission rate. Considering that the background count rate is approximately 10 times higher (per unit area surveyed) for a beta-gamma detector compared to an alpha detector, it is reasonable to expect that the alpha measurement will always be more sensitive and limiting. Therefore, CBR proposes to make only alpha surface contamination measurements during release surveys for unrestricted use.

The CBR release limits for alpha radiation are as follows:

- Removable total of 1,000 dpm/100 cm^2.
- Average total of 5,000 dpm/100 cm^2 over an area no greater than 1 square meter.
- Maximum total of 15,000 dpm/100 cm^2 over an area no greater than 100 cm^2.

Decontamination of surfaces will be done to comply with CBR's ALARA policy to reduce the contamination as far below the limits as practical. Decontamination methods include pressurized spray washing, acid treatment, and sandblasting. Decontamination residues will be properly handled and disposed of as byproduct material. Equipment and materials released for unrestricted use will either be placed in an approved landfill, or salvaged.

5.2 Buildings to be Released for Unrestricted Use

The only buildings to be released or disposed of under this plan are the small wellfield buildings which provide environmental protection to valves, meters, and other equipment. These small industrial structures are not suitable for long-term occupancy by workers or others. Therefore, the applicable release criteria for their unrestricted use are the same criteria specified for equipment above. These structures will be surveyed for alpha contamination and released for unrestricted use or disposed of in a licensed facility.

5.3 Contaminated Equipment, Materials, and Buildings Transferred to Another Licensee

Salvageable contaminated equipment such as valves, meters, and other valuable components, along with small movable structures such as wellfield buildings, may be transferred to another licensed facility. If surface contamination exceeds the limits for unrestricted release, the equipment or structures may be shipped to another licensed facility in accordance with Title 49 of the Code of Federal Regulations (CFR). In most cases the equipment or structures will be shipped as Surface Contaminated Object (SCO-I), DOT regulations 49CFR173.427, UN2913, or as Empty Packages as Excepted Packages, DOT regulations 49CFR173.428, UN 2910.

Equipment and structures will be free of any loose exterior contamination and drained of any process liquids prior to shipment. If necessary, the equipment or structures will be washed to ensure that the exterior contamination is not easily removable. External exposure and contamination surveys will be conducted and documented to ensure that the DOT limits in 49 CFR 173.427 (a) (1), 173.441 and 173.443 are met. Surface contaminated objects (SCO-1) may be transported as an exclusive use shipment in a strong tight container that prevents leakage of the radioactive contents under normal conditions of transport, as specified in 173.427(b) (3).

5.4 Contaminated Equipment, Materials, and Buildings Disposed of as Byproduct Material

Non-salvageable contaminated equipment, materials, dismantled structural sections, and soils will be sent to an NRC licensed facility for disposal. Shipments will be conducted per procedures in the HPM. In most cases the byproduct material will be shipped as Low Specific Activity (LSA-I) material, pursuant to DOT regulations in 49 CFR 173.427, UN2912.

External exposure and contamination surveys will be conducted and documented to ensure that the DOT limits in 49 CFR 173.427 (a) (1), 173.441 and 173.443 are met. Byproduct material will normally be transported as an exclusive use shipment in a strong tight container that prevents leakage of the radioactive contents under normal conditions of transport, as specified in 173.427(b) (3).

6.0 Cleanup of Surface and Subsurface Soils

The cleanup of surface and subsurface soils will be done according to the requirements in 10 CFR Part 40, Appendix A. Appendix A indicates that the Ra-226 concentration in soil should be limited to 5 pCi/g above background for 15-cm thick surface layers, averaged over 100-m^2. Similar layers of subsurface contamination are limited to15 pCi/g.

The NRC amended 10 CFR Part 40 on April 12, 1999 (FR/Vol. 64, No. 69, pp17506-17509) to require uranium recovery licensees to consider radionuclides other than Ra-226 in soil cleanup criteria. The existing soil Ra-226 criterion in 10 CFR Part 40, Appendix A, is used to derive a dose criterion (Benchmark Approach) for the cleanup of byproduct material radionuclides, including Ra-226. The radionuclide-specific criteria are adjusted so that the total dose resulting from the mixture of residual radionuclides will not exceed the Benchmark Dose. The dose from radon is excluded from the benchmark calculation. Other recommended guidance documents that were reviewed include NUREG-1620 (NRC, 2003b) and NUREG-1549.

The only radionuclides other than Ra-226 of concern at the CBR Project are from U-nat, a mixture of U-238, U-234, and U-235. The natural abundance activity percentages for these radionuclides are approximately 0.489, 0.489, and 0.022, respectively.

6.1 Cleanup Limits for Soils

The Benchmark Dose was modeled (see Appendix A) using the RESRAD code. The results show that a concentration of 537 pCi/g for uranium (U-nat) in the top 15-cm layer of soil for the resident farmer scenario is equivalent to the Benchmark Dose derived from a concentration of 5 pCi/g of Ra-226. It can conservatively be assumed, from a radiological exposure perspective, that since the subsurface concentration limit for Ra-226 is 15 pCi/g, the subsurface concentration limit for uranium would be 1600 pCi/g. It will be shown below that the uranium concentration should be limited to 230 pCi/g for all soil depths because of chemical toxicity concerns. A maximum soil contamination limit for uranium of 230 pCi/g in the surface and subsurface 15-cm layers is therefore proposed for CBR.

6.1.1 Radiological Dose Assessment

The NRC requires that when more than one radionuclide is present, the unity rule is applied to the radiological concentrations and corresponding radiological limits. The sum of the fractions of concentrations compared to their corresponding limits should be less than one. CBR interprets this to mean that the concentration of uranium in the surface soil layer will be divided by 537 pCi/g (as opposed to the limit based on chemical toxicity). Similarly, the concentration in a subsurface layer will be divided by 1600 pCi/g to obtain the fraction for the uranium concentration.

ALARA considerations require that an effort be made to reduce contaminants to as low as reasonably achievable levels. The ALARA goals are normally based on a cost-benefit analysis. For the cleanup of gamma-emitting radionuclides, the cost of cleanup becomes excessively high as the soil concentrations become either indistinguishable from background or the gamma emission rate corresponding to a soil concentration becomes indistinguishable from the gamma background count-rate. For uranium, the concentrations corresponding to these two situations are quite different.

Cleanup of uranium mill sites has demonstrated that conservatively derived gamma action levels, along with procedures similar to those in this plan, result in near background Ra-226 concentrations for the site. It is therefore believed that no specific ALARA goal is required for surface Ra-226. The proposed gamma action level (See Section 6.3) has been established at near background levels and is considered adequate to limit the concentration of Ra-226 to 5 pCi/g above background levels. The presence of a mixture of Ra-226 and uranium will tend to drive the cleanup to even lower Ra-226 concentrations.

Establishing an ALARA goal for uranium is more difficult. The calculated dose rates from the direct exposure to uranium and Ra-226 in soils are available from the RESRAD runs in Appendix A. The ratio of the Ra-226 dose rate per pCi/g to the uranium dose rate per pCi/g is 120. In this analysis, it is assumed that the dose rate for direct exposure is proportional to the average photon energy times the emission rate, or:

$$D = k \times E \times R$$

Where:

k = proportionality constant,

D = direct dose rate,

E = average photon energy

R = emission rate.

Writing an equation for pure uranium and one for Ra-226 plus progeny, and dividing results in the following equation:

$$\frac{R_{Ra}}{R_U} = \frac{D_{Ra} \times E_U}{D_U \times E_{Ra}}$$

The average gamma energy from uranium is approximately 100 keV and the average energy from Ra-226 plus progeny is on the order of 400 keV. Substituting $D_{Ra} / D_U = 120$ and $E_U / E_{Ra} = 100 / 400$, then $R_{Ra} / R_U \approx 30$.

For a gross-gamma count rate meter in the field, the count rates are proportional to the emission rate ratios, adjusted for the detection efficiency differences for the two different spectra. Assuming that the difference is small, the ratio of the count rates should be about 30. Therefore if the action level for pure Ra-226 results in cleanup of the site to less than 5 pCi/g, the action level should result in the cleanup of pure uranium to 30 × 5, or 150 pCi/g. When both radionuclides are present, the levels should be somewhat lower. Based on the above argument, CBR proposes an ALARA goal of limiting the U-nat concentration in the top 15-cm layer to 150 pCi/g, averaged over an area of 100 m^2.

Subsurface contamination is expected around some of the well heads, wellfield pipe trenches, and wellfield houses. The difficulty in monitoring for removal is seldom as favorable under these conditions as for contamination on the surface. It is CBR's desire to reduce the subsurface concentrations to a maximum of two-thirds of the proposed limits of 15 pCi/g above background for Ra-226 and 230 pCi/g for U-nat. Therefore ALARA goals for Ra-226 of 10 pCi/g above background and for U-nat of 230 pCi/g are proposed. The subsurface uranium goal has not been reduced below the limit since it has not been demonstrated that these levels can be detected with readily available field instruments. The limits are summarized in Table 6-1.

Table 6-1 Proposed Limits and ALARA Goals for Cleanup of Soils *

Layer Depth	Ra-226 Limit (pCi/g)	Ra-226 Goal (pCi/g)	U-nat Limit** (pCi/g)	U-nat Goal** (pCi/g)
Surface 0-15 cm	5	5	230	150
Subsurface 15 cm layers	15	10	230	230

* *Averaged over a 100-m² area and 15-cm thickness*

** *Based on chemical toxicity*

It should be recognized that there may be circumstances, especially for subsurface contamination, that could result in the cost overriding the benefit of attempting to reach an ALARA goal. Should this happen, CBR will document why the ALARA goal was knowingly abandoned. It should also be recognized that backfilling may be required (for safety reasons) prior to receiving the confirmation sample laboratory results. In some situations, sample results may surprisingly be higher than the ALARA goals. In this situation, the cost-to-benefit ratio for remediating the backfilled area to meet ALARA goals will normally be prohibitively high.

6.1.2 Chemical Toxicity Assessment

The chemical toxicity effects from uranium exposure are evaluated by assuming the same exposure scenario as that used for the radiation dose assessment. In the Benchmark Dose assessment for the resident farmer scenario, it was assumed that the diet consisted of 25 percent of the meat, fruits, and vegetables grown at the site. No intake of contaminated food through the aquatic or milk pathways was considered probable. Also, the model showed that the contamination would not affect the groundwater quality. Therefore, the same model will be used in assessing the chemical toxicity. The intake from eating meat was shown to be negligible compared to the plant pathway and therefore is not shown here. This is confirmed by the results of the RESRAD calculations shown in Appendix A.

The method and parameters for estimating the human intake of uranium from ingestion are taken from NUREG/CR-5512 Vol. 1 (NRC, 1992). The uptake of uranium in food is a product of the uranium concentration in soil and the soil-to-plant conversion factor. The annual intake in humans is then calculated by multiplying the annual consumption by the uranium concentration in the food. Since the soil-plant conversion factor is based on a dry weight, the annual consumption must be adjusted to a dry-weight basis by multiplying by the dry-weight to wet-weight ratio. Parameters for these calculations are given in Section 6.5.9 of the NUREG/CR-5512. Table 6-2 provides the parameters used in these calculation and results for leafy vegetables, other vegetables, and fruit. Annual intakes of 14 kg/year and 97 kg/year were assumed for leafy vegetables and other vegetables and fruit, respectively. Consistent with Appendix A dose calculations, it was assumed that 25 percent of the food was grown on the site. It was also assumed that the uranium concentration in the garden or orchard was 537 pCi/g. This corresponds to the uranium Benchmark Concentration for surface soils. Using a conversion factor for U-nat of 1 mg = 677 pCi, then 537 pCi/g is equivalent to 793 mg/kg. The human intake shown in the first column of Table 6-2 is equal to the product of the parameters given in the subsequent columns. Table 6-2 shows that the total annual uranium intake from all sources of food from the site is 92 mg/yr.

The two-compartment model of uranium toxicity in the kidney from oral ingestion was used (ICRP, 1995) to predict the burden of uranium in the kidney following chronic uranium ingestion. This model allows for the distribution of the two forms of uranium in the blood, and consists of a kidney with two compartments, as well as several other compartments for uranium distribution, storage and elimination including the skeleton, liver, red blood cells (macrophages) and other soft tissues.

Table 6-2 Annual Intake of Uranium from Ingestion

Human Intake (mg/yr)	Soil Concentration (mg/kg)	Soil to Plant Ratio (mg/kg plant to mg/kg soil)	Annual Consumption (kg)	Dry Weight: Wet Weight Ratio	Food Source
9.4	793	1.7E-2	3.5	0.2	Leafy Vegetables
36	793	1.4E-2	13	0.25	Other Vegetables
6.9	793	4.0E-3	12	0.18	Fruit
52					Total

The total burden to the kidney is the sum of the two compartments. The mathematical representation for the kidney burden of uranium at steady state can be derived as follows:

$$Q_P = \frac{IR \times f_1}{\lambda_P\left(1 - f_{ps} - f_{pr} - f_{pl} - f_{pk} - f_{pk1}\right)}$$

Where:

Q_P = uranium burden in the plasma, μg

IR = dietary consumption rate, mg U/d

f_1 = fractional transfer of uranium from GI tract to blood, unitless

f_{ps} = fractional transfer of uranium from plasma to skeleton, unitless

f_{pr} = fractional transfer of uranium from plasma to red blood cells, unitless

f_{pl} = fractional transfer of uranium from plasma to liver, unitless

f_{pt} = fractional transfer of uranium from plasma to soft tissue, unitless

f_{pk1} = fractional transfer of uranium from plasma to kidney, compartment 1, unitless;

λ_p = biological retention constant in the plasma, d^{-1}.

The burden in kidney compartment 1 is:

$$Q_{k1} = \lambda_P \times Q_P \times \frac{f_{pk1}}{\lambda_{k1}}$$

Where:

Q_{k1} = uranium burden in kidney compartment 1, mg;

λ_{k1} = biological retention constant of uranium in kidney compartment 1, d^{-1}.

Similarly, for compartment 2 in the kidney, the burden is:

$$Q_{k2} = \lambda_P \times Q_P \times \frac{f_{pk2}}{\lambda_{k2}}$$

Where:

Q_{k2} = uranium burden in kidney compartment 2, µg;

λ_{k2} = biological retention constant of uranium in kidney compartment 2, d^{-1};

f_{pk2} = fractional transfer of uranium from plasma to kidney compartment 2, unitless.

The total burden to the kidney is then the sum of the two compartments is:

$$Q_{k1} + Q_{k2} = \frac{IR \times f_1}{\left(1 - f_{ps} - f_{pr} - f_{pl} - f_{pt} - f_{pk1}\right)} \times \left(\frac{f_{pk1}}{\lambda_{k1}} + \frac{f_{pk2}}{\lambda_{k2}}\right)$$

The parameter input values for the two-compartment kidney model include the daily intake of uranium estimated for residents at this site, and the ICRP69 values recommended by the ICRP as listed below (ICRP, 1995). The daily uranium intake rate was estimated to be 0.14 mg/day (52mg/year) from ingestion while residing at this site.

$IR = 0.14$ mg/day
$f_1 = 0.02$
$f_{ps} = 0.105$
$f_{pr} = 0.007$
$f_{pl} = 0.0105$
$f_{pt} = 0.347$
$f_{pk1} = 0.00035$
$f_{pk2} = 0.084$
$\lambda_{k1} = \ln(2)/5$ yrs
$\lambda_{k2} = \ln(2)/7$ days
where $\ln(2) = 0.693\ldots$

Given a daily uranium intake of 0.14 mg/day at this site and the above equation, the calculated uranium in the kidneys is 0.0093 μg U, or a concentration of 0.03 μgU/g kidney. This is three percent of the 1.0 μg U/g value that has generally been assumed to protect the kidney from the toxic effects of uranium. Some researchers have suggested that mild effects may be observable at levels as low as 0.1 μg U/g of kidney tissue. Using 0.1 μg U/g as a criterion, then the intake is thirty percent of the considered unsafe level.

The EPA recently evaluated the chemical toxicity data and found that mild proteinuria has been observed at drinking water levels between 20 and 100 μg/liter. Assuming water intake of 2 liters/day, this corresponds to an intake of 0.04 to 0.2 mg/day. Using animal data and a conservative factor of 100, the EPA arrived at a 30 μg/liter limit for use as a National Primary Drinking Water Standard (Federal Register/Vol.65, No.236/ December 7, 2000). This is equivalent to 0.06 mg/day for the average individual. Naturally, since large diverse populations are potentially exposed to drinking water sources regulated using these standards, the EPA is very conservative in developing limits.

This analysis indicates that a soil limit of 537 pCi/g of U-nat would result in an intake of 0.14 mg/day. Using the most conservative daily limit corresponding to the National Primary Drinking Water standard, a soil limit of 230 pCi/g corresponds to the EPA intake limit from drinking water with a uranium concentration of 0.06 mg/day. Therefore exposure to soils containing 230 pCi/g of U-nat should not result in chemical toxicity effects. Since the roots of a fruit tree would penetrate to a considerable depth, limiting subsurface uranium concentrations to 230 pCi/g will be considered appropriate as well.

6.2 Soil Cleanup and Verification

Gamma surveys will be used to guide the soil remediation efforts. The surveys will identify soil contamination that potentially exceeds the cleanup criteria and will be used to guide the cleanup efforts. After cleanup, the surveys will be used, in conjunction with surface soil sample analyses, to verify that the soil meets the site cleanup criteria. A gamma action level, defined as a gamma count rate level corresponding to the soil cleanup criterion, is used in the interpretation of the data. Normally the action level is conservatively developed to allow only a five percent error rate of exceeding the cleanup criteria at the 95% confidence level.

6.3 Gamma Action Level

The gamma action level is determined from data taken from known contaminated areas of the site, using equipment and methods similar to those that will be used during the soil cleanup verification phase of decommissioning. Verification plans call for sampling all 100-m^2 grid blocks that exceed the gamma action level using a five-point composite sampling procedure. A percentage of the grid blocks with gamma count rates below the action level will also be sampled.

The results of the preliminary site characterization described in Section 3 were used to develop the action level. The gamma survey was conducted in four areas considered to have the potential for being contaminated above cleanup criteria. The survey revealed that the contaminated areas were restricted to areas only a few feet across. The gamma-ray count rate measured above small contaminated areas is significantly lower than those above large areas contaminated at the same level. Therefore, the action level may be overly-conservative when used for assessing large contaminated areas.

An extensive effort at locating additional sampling points was made but, at this time, additional potentially contaminated areas are not evident. Since the contaminated areas were small and the distribution non-uniform, no attempt was made to determine the average count rate and average radionuclide concentration in a 100-m^2 grid block. Instead, the gamma count rate was measured above the soil-sampling location at an 18-inch height above the soil surface. This detector height will be used in the final verification survey.

Table 3-1 in Section 3 provides a summary of the data taken for the purposes of developing an action level along with additional information. The exact sampling locations have been provided in Figures 3-2 through 3-5. Section 2.6 presents the background data and proposes natural background value of 0.55 pCi/g for Ra-226. Figure 6-1 shows the Ra-226 concentration plotted against the gamma count rate using the data in Table 3-1. The linear regression indicates that, on average, a gamma count rate of 17,900 cpm corresponds to 5.55 pCi/g (5 pCi/g above background). This is easily distinguishable from the background count rate of approximately 14,500 cpm. The lower 95% confidence line for the linear regression, based on the available data, shows that 5.5 pCi/g corresponds to slightly less than 14,000 cpm, or approximately equal to the mean background count rate. This lower 95% confidence line therefore does not lead to a practical gamma action level. Until more data are available on which to refine this linear regression, CBR will use 17,900 cpm as the gamma action level for cleanup of areas that are small compared to the 100-m^2 grid block size. This will assure that when averaged over a grid block, the Ra-226 concentration will be less than the 5 pCi/g limit. As indicated above, when the contaminated area is large, the action level will be expected to increase by a few thousand counts per minute. There are no site data, however, on which to obtain an estimate. If large areas are decontaminated, the action level will be used with caution, or a new action level will be developed.

A correlation between the Ludlum Model 19 Micro-R meter and the Ludlum Model 2221/Ludlum Model 44-10 NaI count rate instruments, as shown in Figure 6-2, shows that 17,900 cpm corresponds to about 21 μR/h on the Model 19. While the Model 19

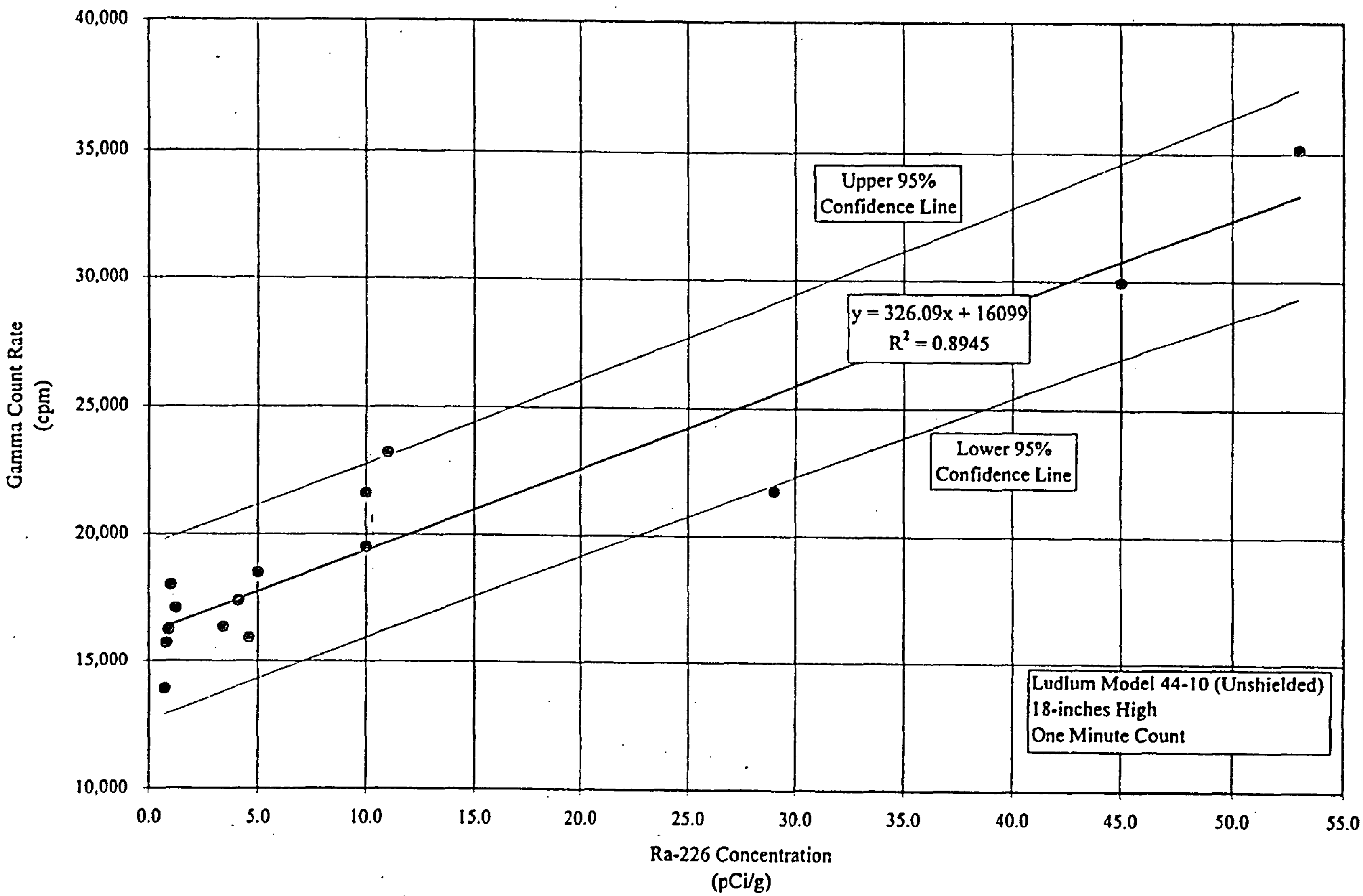

Figure 6-1 Gamma Count Rate vs. Ra-226 Concentration Correlation with Upper and Lower 95% Confidence Lines

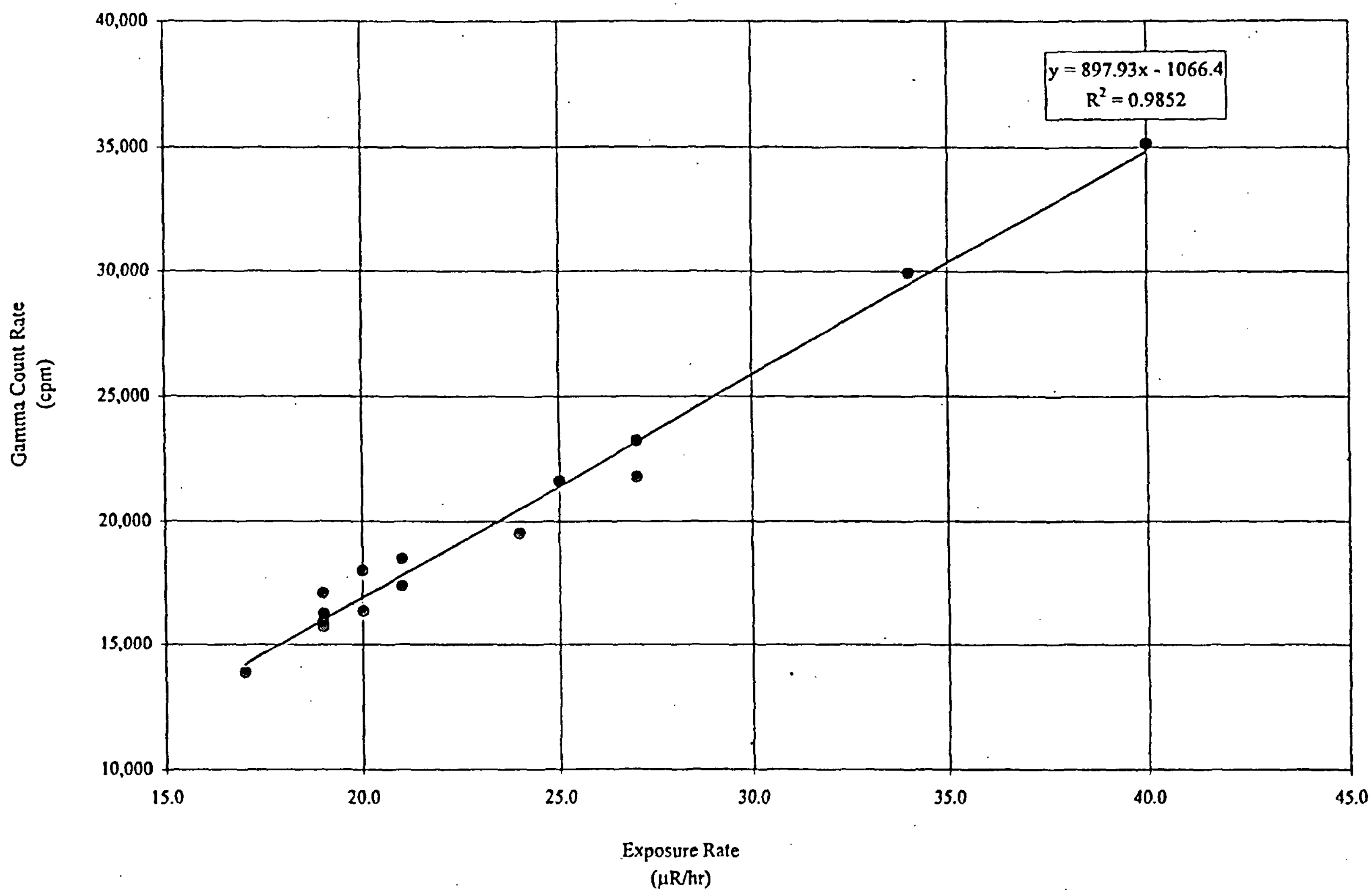

Figure 6-2 Exposure Rate vs. Gamma Count Rate Correlation

may be a useful instrument in some very high exposure rate situations, the factor of approximately five better sensitivity of the Model 44-10 along with the integrating-over-time feature of the Ludlum Model 2221 make it the preferred instrument for use at these low levels. The Model 19 will be used for a rough estimate as to whether an area meets the action level criterion.

At this time, no additional contaminated areas are known to exist where correlation data may be obtained. Therefore, unless areas are identified during remediation, all areas above 17,900 cpm will be remediated or the grid blocks sampled to assure that the cleanup criteria are met. If adequate data are obtained during remediation on which to base a more precise soil cleanup action level corresponding to the cleanup criterion, CBR may choose to petition the NRC for a change in the Decommissioning Plan.

6.4 Gamma Surveys for Characterization and Verification

Two methods are proposed for conducting site gamma surveys, one the GPS-radiological survey system and the second being the equivalent conventional method using a Ludlum 2221 ratemeter/scaler and Model 44-10 detector. Since the methods differ only in data recording and management, there are no apparent differences in the accuracy of the results. The surveys are described and CBR will decide which method to employ.

6.4.1 Gamma Surveys and Mapping Using Global Positioning System

The GPS-radiological surveys will be done using the same or equivalent equipment to that used in the correlation studies. The gamma-mapping system consists of a Ludlum Model 2221 ratemeter/scaler coupled to a Ludlum Model 44-10, a 2-inch by 2-inch NaI(Tl) detector. The digitized radiological count rate data are recorded once every second. The data are transmitted to a Trimble ProXRS GPS receiver which automatically tags the data with the coordinates at the time the data count rate is received. The ProXRS, manufactured by Trimble Navigation, is state-of-the-art mapping grade surveying equipment, employing the use of satellite GPS technology. The accuracy of the coordinates is better than one meter while collecting data.

The data are collected in the GPS data logger and later downloaded into a computer equipped with data management software. The data are then exported into the ArcView GIS file format, or other software for mapping, averaging, and developing isocontours.

A gamma survey will be done over the extent of the affected areas. Gamma count rate contour lines at the action level will be used to define where remediation is required. After the remediation, the area will be resurveyed with the new data added to the database, replacing the obsolete pre-remediation data. This iterative procedure will be applied until all areas are determined to meet the action levels.

In the verification phase, the average count rate over each 100-m^2 grid block is calculated by downloading the data into a data base management computer application. The data records within each grid block are counted, averaged, and assessed as to whether the grid block meets verification criteria.

Function checks for the equipment will be performed at the beginning and end of each work shift using standard operating procedures. In addition, standard operating procedures will be used for operating the GPS-radiological survey equipment.

6.4.2 Radiological Surveys and Mapping Using Conventional Methods

Gamma surveys may be conducted using the same type of radiological survey equipment described above other than the data will be recorded manually and presented on maps with isocontours using computer assisted means. Grid blocks of 33.3-ft by 33.3-ft (approximately 100-m^2 area) will be established over the affected area. In order to determine the average gamma count rate within a grid block, the Ludlum Model 2221/Model 44-10 combination will be used to integrate the count rate while a technician walks the area for one minute. Correlation studies at mill sites have demonstrated that this results in a good correlation with the Ra-226 in the soil.

6.5 Excavation Control Monitoring

Remediation of contaminated soils will be performed by excavation. The purpose of excavation control monitoring is to guide the removal of contaminated material to the point where it is highly probable that an area meets the cleanup criteria. Monitoring equipment and action levels developed in the calibration studies will be used for excavation control monitoring. A technician will monitor the soil after the removal of layers of soil until the instrumentation shows that the levels are below the action level. No documentation of the results is necessary since the verification data will serve to demonstrate compliance with the cleanup standards. For large areas, a GPS based survey may be performed periodically to more accurately assess the progress of the excavation.

For areas exhibiting contamination below the top 15-cm, excavation control monitoring will be performed using the same detector (or equivalent) as used in the calibration study, considering the appropriate action level and adjusting for geometry factors. The cleanup limit for deep excavations where backfill is applied is 15 pCi/g for Ra-226, or the equivalent uranium/radium level developed in the Benchmark Dose Assessment, considering the 230 pCi/g limit for uranium in the surface and subsurface layers based on chemical toxicity.

6.6 Soil Cleanup Verification and Sampling Plan

Existing characterization data indicate that the cleanup of surface soils in the wellfields will be restricted to the cleanup of a few areas where there were known spills and potentially small spills near well heads. Other areas considered potentially contaminated include roads within the well fields. Most of the minor spills are not anticipated to result in measurable levels of contamination. These spill areas have a physical size of a few meters across. The contamination in areas near wells and in pipe trenches may require backfill and thus subsurface soil procedures will apply. All work related to demonstrating compliance with the cleanup criteria will be done using standard operating procedures.

6.6.1 Surface Soil Gamma Survey and Sampling Plan

A final gamma survey will be performed in potentially contaminated areas and areas where cleanup occurred from known spills using the GPS-radiological survey equipment or conventional equipment as described above. A 10-m wide buffer zone will be established around each area . It is anticipated that the boundary of the wellfield containing areas that have been remediated may extend as far as the outermost production well. The 10-m wide buffer zone would in that case lie between the outermost production wells and the monitoring wells that surround the well fields. A gamma-ray survey will be conducted over the entire area, including the buffer zone. The area will be divided in a non-biased manner into grid blocks of approximately 100 m^2 area. For the GPS-radiological survey, a minimum of seven data records in each 100-m^2 grid block will be used to obtain the average gamma count rate for the grid blocks. For conventional surveys, a one-minute integrated count while walking the area will be used as the average count rate.

All grid blocks containing elevated gamma-ray count rates above the gamma action level (including buffer area) will be sampled for compliance with the cleanup criteria. A five-point composite sample of surface soils will be taken in each 100-m^2 grid block. The sample will be analyzed to assure that the Ra-226 and uranium concentration complies with the cleanup criteria.

All of the remaining grid blocks with average gamma count rate ranking in the top ten percent will be sampled. Grid blocks failing the cleanup criteria will be decontaminated and sampled until the grid block passes. If any grid blocks within the top ten percent fail the cleanup criteria, the second ten percent of the grid blocks will be sampled. This will continue until all grid blocks pass within a 10 percent grouping.

In order to meet the cleanup criterion, each grid block must satisfy the inequality,

$$\sum C_i / C_c \leq 1$$

where C_i is the concentration of constituent and C_c is the concentration of the constituent that is equivalent to the Benchmark Dose.

After all sampled grids have met the cleanup criterion, an EPA-recommended statistical test will be done to determine whether the mean of the equality defined above for all grid blocks is 1 or less at the 95 per cent confidence level, using Equation 8-13 of draft NUREG/CR-5849. The EPA recommends that μ_α be compared to the guideline value, where

$$\mu_\alpha = \bar{u} + t_{1-\alpha,df} (s_x/\sqrt{n})$$

and $\bar{u}$ is the mean of the $\sum C_i / C_c$ for each grid block, $t_{1-\alpha,df}$ is the 95% confidence level obtained from Student t Distribution tables where α is the false positive probability, i.e. the probability that μ_α is less than the guideline value if the true mean activity is equal to the guideline value. In this case the guideline value is equal to unity (1). The symbol, df, represents the degrees of freedom (equal to n-1).

Since this represents the mean of a set of biased samples (selected from the grids that have the highest gamma count rate), the passing of this test provides assurance that the cleanup error rate is very low for the entire sample set made up of all the possible grids that could have been sampled.

If the mean of the sample concentrations is less than the criterion but the data fails the statistical test, CBR will follow procedures similar to those recommended in Section 8.6 of draft NUREG/CR-5849. The number of samples will be increased to include the grids with next highest average gamma levels, and the statistical test will be performed again. This will be done until the statistical test is met. In any case, all grid blocks that were sampled and measured to exceed the cleanup criterion will be further decontaminated and resurveyed.

6.6.2 Subsurface Soil Verification Gamma Survey and Sampling Plan

Gamma count rates from the subsurface excavations will be taken at a sufficient frequency to ensure a minimum of seven readings per 100-m^2 of excavated surface. For excavations of less than 100-m^2 area, a minimum of one record per 10-m^2 area will be taken. Data will be recorded and referenced to a drawing of the excavation and/or State Plane Coordinates. The average of the count rate records for each 100-m^2 (or less) will be calculated for comparison against the instrument action level. If the average exceeds the action level, additional excavation may be considered, followed by another gamma survey of the area. For deep trenches where it is unsafe for entry, a scan of the sidewalls and floor will be done by dropping a detector into the excavation to assure that the count rate is uniform.

For linear excavations (trenches), a single 15-cm deep soil sample at approximately one-half the excavation width at 150-ft. intervals will be taken. The sample may be taken with a backhoe where necessary. Each sampling location will be documented.

For excavations other than long trenches, a minimum of one five-point composite sample from the excavation surface will be taken. If the excavation surface exceeds 100 m^2, a five-point composite for each 100 m^2 of excavation surface will be taken. The sample points for the composite will be more or less evenly spaced to provide adequate representative coverage of the area. The sample locations will be documented. Specific dimensions cannot be predetermined due to the likely variability in excavation shape.

All samples will be submitted to a commercial laboratory for analysis for Ra-226 and U-nat. An alternative that may be used is to establish an on-site laboratory. If an on-site laboratory is used, ten percent of the samples will be selected at random and submitted to a commercial laboratory for analysis. Procedures for selecting the commercial laboratory and comparing test results are described in Section 6.7.

6.7 Laboratory Quality Assurance

Verification soil samples will be sent to a commercial laboratory for analysis of Ra-226 and U-nat. The commercial laboratory will be selected using a performance based approach which allows the laboratory the freedom to propose methods for the specific constituents and matrix that meet the measurement quality objectives required by CBR.

Only laboratories that adhere to a well-defined quality assurance (QA) program will be considered as the commercial laboratory to receive the verification samples. The QA program must address the laboratory's organization and management, personnel qualifications, physical facilities, equipment and instrumentation, reference materials, measurement traceability and calibration, analytical method validation, standard operating procedures (SOP), sample receipt, handling, and storage, records, and appropriate licenses.

CBR will select the radiochemistry laboratory that best meets the data quality objectives for verification soil samples. USNRC Regulatory Guides 4.14 and 4.15, provide some information, but this guidance is over 25 years old. ANSI N42.23, Measurement and Associated Instrument Quality Assurance for Radioassay Laboratories describes a system in which quality and traceability of performing laboratory measurements to the national standards can be demonstrated through reference laboratories. The most recent guidance on this subject (NRC, 2001a) has not yet been released for publication, but is expected to be released for use during the third quarter of 2004. This guidance is the Multi-Agency Radiological Laboratory Analytical Protocols Manual (MARLAP) which was developed by a working group with representatives from USNRC, DOD, DOE, EPA, NIST, USGS, FDA and several states. This guidance document is expected to be a primary reference document and thus will be applied to this project plan.

The analytical work performed by the commercial laboratory will be done under a written contract, and includes a scope of work prepared by CBR that defines the data quality objectives. Part of the data quality objectives are the specific analytical sensitivities required by CBR. The anticipated maximum activity levels in each sample is 5 pCi/g Ra-226 and 300 pCi/g U-nat, and their associated daughter products. The minimum sensitivity required for each sample is 0.5 pCi/g dry weight for each analyte, with an estimated overall error of ± 0.5 pCi/g. The contract will also define what is to be required in the data package. At a minimum the data package will include a case narrative, the analytical results, documentation of any deviation from the SOPs, copies of lab personnel notebooks, a chain of custody, a copy of the raw data, initial and continuing instrument and equipment calibration data, and standard and tracer information. This data package contains information equivalent to that required for an EPA Contract Laboratory Program

(CLP)-like level 3 data package, which is the minimum level data package acceptable for verification samples.

A Laboratory QA file shall be maintained to support the selection of the laboratory. The content of the file will include laboratory provided data and audit reports from the following QA activities:

1. The commercial laboratory will provide information needed to assess the quality of the data generated by the laboratory. This may include a copy of the laboratory's quality assurance manual (QAM) and standard operating procedures for the constituents of concern in a soil matrix.

2. CBR will perform an audit of the commercial laboratory before samples are delivered to verify adherence to the requirements of the QAM and SOP's. The laboratory's own QC results such as in-house blanks, duplicates, and spikes will be reviewed. The results from interlaboratory testing programs will be reviewed to obtain a measure of analytical quality and accuracy. Performance evaluation samples should have been prepared from an NIST traceable source. These samples preferably will be of a similar matrix, containing the constituents of concern, with the constituents at anticipated activity levels. Reference material may be obtained from the DOE's Radiological Environmental Sciences Laboratory (RESL) at INEEL (or equivalent). This DOE laboratory is also the NRC's reference laboratory.

U. S. Nuclear Regulatory Commission, Inspection Procedure 84525 will be applied to the results from the interlaboratory comparison program for comparing two data sets. In that procedure, each reference laboratory result is divided by the reported standard deviation to obtain the "resolution". The other lab (CBR's vendor laboratory) result is then divided by the reference laboratory result to obtain the "ratio". The data are considered in agreement if the ratio is within the range given in the following table.

Table 6-3 Criteria for Comparison of Laboratory Results

Resolution	Ratio
< 4	0.40 – 2.5
4 – 7	0.50 – 2.0
8 – 15	0.60 – 1.66
16 – 50	0.75 – 1.33
51 – 200	0.80 – 1.25
> 200	0.85 – 1.18

If significant differences exist, a review will be conducted in order to resolve discrepancies.

7.0 Radiation Safety Program

CBR maintains a performance-based approach to the management of environmental affairs, and employee health and safety. The Environmental Management System (EMS) encompasses licensing, compliance, environmental monitoring, industrial hygiene, and radiation safety. The EMS organization begins with the Company's Board of Directors, and flows down through the President, Senior VP of Operations, Mine Manager, Manager of Health, Safety, and Environmental Affairs, Radiation Safety Officer, and ends with the site workers. The EMS formalizes the company's approach to ES&H management, which operates under the direction of operating procedures, radiation work permits, and a performance-based license condition that allows CBR to make changes to processes or procedures without prior NRC approval. Oversight is provided by the Safety and Environmental Review Panel (SERP), which consists of at least three members of CBR's management team. The SERP is responsible for monitoring any changes to the processes or procedures.

The CBR Environmental, Health and Safety (EHS) staff will monitor decommissioning activities to ensure that occupational radiation exposure levels are kept as low as reasonably achievable. The Radiation Safety Officer (RSO), Radiation Safety Technician, or designee by way of specialized training will be on site during decommissioning activities where potential radiation exposure hazards exist. EHS staff will evaluate radiological hazards to employees and the environment, implementing the necessary controls to maintain exposures ALARA during decommissioning. The EHS staff routinely report to management any departure from safe work practices, any item of noncompliance with accepted practices or procedures, and any need for improvement in the radiation safety programs. They have sufficient authority to terminate work when unsound radiological or work safety practices exist.

7.1 D&D Task Analysis

Most of the decommissioning activities are not significantly different from those conducted during mining operations and, as such, the standard operating procedures (SOP) in the CBR Health Physics Manual (HPM) will be followed. The first task includes cutting and/or removal of contaminated piping and surface equipment, including injection and production feed lines, electrical conduit, well boxes, and well head equipment. Some of the equipment, such as valves, meters, and control fixtures will be surveyed for contamination and salvaged, if possible. Following removal of the surface equipment, buried well field piping will be removed, and the wells will be plugged and abandoned. Finally, any contaminated soils will be removed for disposal. The RSO will evaluate each task and prepare a Radiation Work Permit (RWP) if an SOP is not already in existence. This RWP will be reviewed with employees prior to conducting each task. Slip, trip, and fall hazards will be a concern during dismantling of the piping and any buildings and equipment. All workers will be required to wear hard hats and take other safety measures in accordance with the Mine Safety and Health Administration (MSHA) requirements.

7.2 Personnel Training

All workers employed during decommissioning, whether contractor employees or CBR employees, will be given specialized training for minimizing radiological exposures in addition to industrial safety training.

Initial radiation and industrial safety training for CBR and contractor employees will be conducted as outlined in the HPM and in the EMS Training Manual. This training is in accordance with NRC Reg. Guide 8.31 and the approved MSHA training plan. In addition, new assignment training and indoctrination is required whenever a worker is assigned to an unfamiliar task. The project will also conduct periodic safety meetings.

The extent of contractor's training will be based on the type and degree of hazards applicable to their specific work. At a minimum, they will receive hazard training as outlined in the HPM and in the EMS Training Manual, which covers both radiation and industrial hazards. Additional specialized safety training will be given to all affected employees whenever new or unusual hazards become evident during decommissioning.

7.3 Standard Operating Procedures

The radiation safety program utilized during decommissioning will be based upon the existing ALARA program and the HPM, which have provided a sound radiation safety program during production operations. The HPM, supplemented by any specific RWPs or standing radiation work permits (SRWP) and Decommissioning Procedures will govern the radiation safety program during decommissioning. The CBR health physics standard operating procedures are embedded in the HPM.

7.4 Air Monitoring and Respiratory Protection Programs

The existing airborne radioactivity monitoring program and respiratory protection program will be maintained during decommissioning. The HPM provides guidance for determining and controlling the quantity of airborne material in the work area and the environment. This guidance includes the method to evaluate the need for air sampling, and the selection and location of sampling equipment. It provides sampling procedures for uranium dust and radon daughters. Air sampling is required if the estimated annual intake is greater than 0.1 ALI. D&D tasks will be evaluated by the RSO to determine if air monitoring is required.

The HPM gives guidance on respirator selection, use, care, and maintenance, in the event air monitoring indicates the need for respiratory protection. This program is considered appropriate for the decommissioning work.

7.5 Radiation Work Permit (RWP) Program

All routine tasks will be performed in accordance with the procedures embedded within the HPM. Any non-routine task where the potential for significant exposure to radioactive materials exists, and for which no standing RWP or SOP exists, will require the preparation of a Radiation Work Permit (RWP). Examples of D&D tasks that may require an RWP include cutting, sandblasting, or grinding on any potentially contaminated surface such as pipelines, tanks, vessels, and process equipment.

The RSO may also issue Standing Radiation Work Permits (SRWPs) for periodic or repetitive tasks that require similar radiological protection measures (e.g., piping removal). The SRWP will describe the scope of the work, precautions necessary to maintain radiation exposures to ALARA, and any supplemental radiological monitoring and sampling requirements. The SRWP shall be reviewed and approved in writing by the RSO (or qualified designee in the absence of the RSO) prior to initiation of the work.

ESH staff will review the planned decommissioning activities in order to determine what RWPs are needed, if any. The industrial safety hazards and associated protective measures will also be identified in accordance with MSHA requirements.

7.6 Health Physics Surveys and Dose Calculations

Health physics surveys conducted during decommissioning will be guided by applicable sections of 10 CFR 20 and USNRC Regulatory Guide No. 8.30 entitled "Health Physics Surveys in Uranium Recovery Facilities" and the many applicable Health Physics Manual SOPs.

Health physics surveys can be broadly classified into two categories, those required for contamination control, and those required for employee exposure monitoring. The intent of contamination control is to control the release of radioactive material to the work area, to control personnel exposures in the work place, to prevent the intake of contaminants by the work force, and to identify contaminated areas requiring remediation. The HPM provides guidance on survey methods and procedures, and allowable limits for the unrestricted release of equipment from CBR.

Surveys required for employee exposure monitoring include programs for external monitoring and internal, or bioassay, monitoring. CBR will evaluate the decommissioning tasks and determine appropriate monitoring requirements, consistent with the policy and requirements in the HPM.

7.7 Protective Clothing

There are two types of protective clothing (PPE) available to workers at CBR, disposable and non-disposable. The selection of PPE required will depend on the type of work to be accomplished. If an RWP is written, it will list the necessary PPE which may include coveralls, head covers, gloves, rain suits, and shoe covers. When the potential for contamination is high, the RWP may require rubber boots, plastic gloves, and taping of cuffs and sleeves. The HPM provides guidance regarding the selection of appropriate PPE. It is anticipated that for D&D tasks involving the potential exposure to loose radioactive material, the workers will normally be issued coveralls, gloves, and shoe covers, at a minimum.

7.8 Shipments of Radioactive Materials

Shipments of radioactive equipment and materials will be conducted to meet Department of Transportation (DOT) requirements, as specified under 49 CFR Subchapter C, "Hazardous Materials Regulations". NRC also has regulations governing the shipment of radioactive materials under 10 CFR Parts 20 and 71. Shipment of radioactive materials from CBR is discussed in the HPM. Specific guidance regarding the shipment of byproduct material is also presented.

7.9 Records and Reports

Personnel monitoring and other records required under 10 CFR Part 20, Subpart L will be maintained as a part of the normal mining operations radiation protection program. Specific records on transfer and disposal of byproduct or source material addressed in 10 CFR Part 40, §40.51 will be maintained as required by the current license. Specific records associated with wellfield decommissioning will be retained until the NRC has terminated the license. These records include radiation verification surveys and soil sample results for areas released for unconditional use.

8.0 Environmental Impacts

Normal site production operations will continue during decommissioning of the well fields. Therefore, the operational environmental monitoring program will continue unabated as defined by license conditions and CBR's standard operating procedures. Only those impacts that are incremental to normal operations will be discussed here.

8.1 Land Use

The primary impact on the land use through the life of the project, including decommissioning of the well field, is the loss of grazing capacity. The impact is temporary and will be reversed during decommissioning.

8.2 Air Quality

Air quality impacts from decommissioning activities will be minimal but likely increase from operational status but decrease as the decommissioning progresses. After decommissioning, fugitive dust will decrease due to less road traffic from employees and vendors. The decommissioned well field will eventually be returned to grazing status. Road traffic will increase at various times during decommissioning, particularly with the transport of byproduct and decommissioned materials. Byproduct material shipments will be transported in tarped or enclosed containers, pursuant to DOT regulations and procedures in the HPM. Engine exhaust and dust from local soil disturbances will increase during decommissioning. Measurable levels of radioactive particulate are not anticipated due to the low concentrations of radionuclides in the soil.

8.3 Wildlife

No significant adverse impact to wildlife was noted during operations or is expected during decommissioning. There are no threatened or endangered mammals, birds, reptiles, amphibians, or fish in the well field remediation area. Section 2.8 of the license renewal application (CBR, 1998) discusses the ecology of the area and concludes there has been minimal impact due to mining operations. This is expected to also be the case during remediation of the well field.

8.4 Surface Water

Sediment yields and total runoff may increase for a very short period of time during and immediately following decommissioning and reclamation activities. The impacts to surface waters within and adjacent to the licensed area will not be significant because of the limited size and duration of the disturbance. Efforts to minimize soil erosion will follow CBR's storm water best practices program.

The current surface water sampling (for operations) program will continue as listed in the operational environmental monitoring plan. No additional surface water impoundments are expected to be generated from D&D activities.

8.5 Archaeological Sites

Field investigations in 1982 and 1987 (CBR, 1998) identified 21 possible archeological sites within the permit area. During plant operations these sites have been avoided and not directly impacted. These sites will also be avoided during decommissioning. However, if a new archeological site is discovered, all work in the immediate area will cease until authorization to proceed is received from the NRC.

8.6 Groundwater

Well plugging and abandonment will not adversely affect groundwater during the well field decommissioning phase. As stated in Section 6.2.3.1 of CBR's license renewal application, the objective is to "seal and abandon all wells in such a manner as to assure the groundwater supply is protected and to eliminate any potential physical hazard."

8.7 Environmental Radiological Monitoring

The current environmental radiological effluent monitoring program (for production) will continue per CBR's license requirements. During remediation of the well field, some components and equipment such as pipe, buildings, and valves may be decontaminated by high pressure water and acids, or by sandblasting. Wash water or sandblasting material will be collected and disposed of as byproduct material. Contaminated soils in the decontamination area will be monitored and removed for disposal, if required. No release of contaminated surface water is anticipated.

Excavation of trunklines may generate a small amount of potentially contaminated dust. However, this will be minimized by application of a water spray or misting. Pipe cutting, sand blasting and building demolition may also generate a small amount of dust. The air in the vicinity of these activities will be sampled for particulates as part of the occupational monitoring program. While specific decommissioning activities will result in short-term task-specific employee safety and environmental monitoring, the operational environmental and effluent monitoring program is considered adequate to detect any incremental environmental impacts from wellfield reclamation.

8.8 Non-Radiological Impacts

The potential impacts from non-radiological components of byproduct material from wellfield decommissioning are small. Solutions from decontaminating pipe or other items may be acidic and may harm vegetation if spilled. Normally, these solutions will be collected and placed in the byproduct waste disposal system. Should small quantities spill on the ground, the acids will quickly be neutralized by the soil with little or no long-term effects.

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Wellfield Decommissioning Plan

for

Crow Butte Uranium Project

Appendix A

Radium Benchmark Dose Assessment

Radium Benchmark Dose Assessment

A.1 Introduction

On April 12, 1999, the U.S. Nuclear Regulatory Commission (NRC) issued a Final Rule (64 FR 17506) that requires the use of the existing soil radium standard to derive a dose criterion for the cleanup of byproduct material. The amendment to Criterion 6(6) of 10 CFR Part 40, Appendix A was effective on June 11, 1999. This "benchmark approach" requires that NRC licensees model the site-specific dose from the existing radium standard and then use that dose to determine the allowable quantity of other radionuclides that would result in a similar dose to the average member of the critical group. These determinations must then be submitted to NRC with the site reclamation plan or included in license applications. This Appendix documents the modeling and assumptions made by Crow Butte Resources, Inc. (CBR) to derive a standard for U-nat in soil for the Crow Butte Uranium Project.

Concurrent with publication of the Final Rule, NRC published draft guidance (64 FR 17690) for performing the benchmark dose modeling required to implement the final rule. Final guidance (NRC, 2003) was published as Appendix E to the Standard Review Plan for In Situ Leach License Applications (NUREG-1569). This guidance discusses acceptable models and input parameters. This guidance, guidance from the RESRAD Users Manual (ANL, 2001), and site-specific parameters were used in the modeling as discussed in the following sections.

A.2 Determination of Radium Benchmark Dose

RESRAD Version 6.22 computer code was used to model the Crow Butte site and calculate the annual dose from the current radium cleanup standard. A sensitivity analysis was run for each input parameter that was not based upon local data.

The following supporting documentation for determination of the radium benchmark dose is attached:

- The RESRAD Data Input Basis (Attachment 1) provides a summary of the modeling performed with RESRAD and the values that were used for the input parameters. A discussion of the sensitivity analysis for each parameter is also included. The sensitivity analysis indicated that many of the parameters had little, if any, effect on the maximum dose. The parameters that had a noticeable affect on the maximum dose included the distribution coefficient (K_d) for each radionuclide; the soil density in the contaminated zone; the external gamma shielding factor; the fruit, vegetable and grain consumption rate; the leafy vegetable consumption rate; and the depth of roots. Each of these parameters, the sensitivity analysis and the chosen input value are discussed.
- Selected graphs produced with RESRAD that present the results of the sensitivity analysis performed on the input parameters are attached (Attachment 2).
- A full printout of the final RESRAD modeling results for the resident farmer scenario with the chosen input values is attached (Attachment 3). The printout provides the modeled maximum annual dose for calculated times for the 1,000-year time span and provides a breakdown of the fraction of dose due to each pathway.
- Graphs produced by RESRAD in Attachment 4 provide the modeling results for the maximum dose during the 1,000 year time span. A series of graphs depicts the summed dose for all pathways and the component pathways that contribute to the total dose. Additional graphs show the soil concentration and the dose to source ratio over time for each radionuclide.

The maximum dose from Ra-226 contaminated soil at the 5 pCi/g cleanup standard level, as determined by RESRAD, for the residential farmer scenario was 42.4 mrem/yr. This dose was based upon the 5 pCi/g above background surface (0 to 6-inch) Ra-226 standard and was noted at time, t = 0 years. This dose was used to determine the U-nat soil standard for use at Crow Butte as described in the following section.

A.3 Determination of Natural Uranium Soil Standard

RESRAD was used to determine the concentration of U-nat in soil distinguishable from background that would result in a maximum dose of 42.4 mrem/yr. The method involved modeling the dose from a set concentration of U-nat in soil. This dose was then compared to the radium benchmark dose and scaled to arrive at the maximum allowable U-nat concentration in soil.

For ease of calculations, a preset concentration of 100 pCi/g U-nat was used for modeling the dose. The fractions used were 48.9 percent (or pCi/g) U-234, 48.9 percent (or pCi/g) U-238 and 2.2 percent (or pCi/g) U-235. The distribution coefficients that were selected for each radionuclide were based upon the local soil types. All other input parameters were the same as those used in the Ra-226 benchmark modeling. A sensitivity analysis was conducted of the hydraulic conductivity and other parameters of the unsaturated zone and compared to the baseline case. The results showed no affect on the dose. The RESRAD output showing the input parameters is provided in Attachment 5.

Using a U-nat concentration in soil of 100 pCi/g, RESRAD determined a maximum dose of 7.9 mrem/yr. at time, t = 0 years. The printout of the RESRAD data summary is provided in Attachment 5.

To determine the uranium soil standard, the following formula was used:

$$\text{Uranium Limit} = \left(\frac{100\ \text{pCi/g natural uranium}}{7.9\ \text{mrem/yr. natural uranium dose}}\right) \times 42.4\ \text{mrem/yr radium benchmark dose}$$

$$\text{Uranium Limit} = 537\ \text{pCi/g natural uranium}$$

The U-nat limit is applied to soil cleanup with the Ra-226 limit using the unity rule. To determine whether an area exceeds the cleanup standards, the standards are applied according to the following formula:

$$\left(\frac{\text{Soil Uranium Concentration}}{\text{Soil Uranium Limit}}\right)+\left(\frac{\text{Soil Radium Concentration}}{\text{Soil Radium Limit}}\right)<1$$

This approach will be used at the Crow Butte site to determine the radiological impact on the environment from releases of source and byproduct materials.

A.4 References

ANL, 1993. *"Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil"*, Argonne National Laboratory (for the U.S. Department of Energy), ANL/EAIS-8, 1993. ." Environmental Assessment Division, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439

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CBR, 1995. "Application for Renewal of USNRC Source Materials License SUA-1534." December 1995. Crow Butte Resources, P. O. Box 169, Crawford, Nebraska 69339-0169.

NRC, 1992. *"Residual Radioactive Contamination from Decommissioning,"* NUREG/CRR-5512 (PNL-7994) Vol. 1, U.S. Nuclear Regulatory Commission, Washington, D. C. 20555

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NRC, 2003. *"Standard Review Plan for In situ Leach Uranium Extraction License Applications."* NUREG-1569. Division of Fuel Cycle Safety and Safeguards, Office of Nuclear Material Safety and Safeguards, U. S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001.

Attachment 1

RESRAD Data Input Basis

Parameters

RESRAD Data Input Basis

Parameters

This document summarizes the data input and modeling scenario that was used to determine the radium benchmark dose for the Crow Butte Project well fields near Crawford, Nebraska. The modeling was performed using RESRAD for Windows Version 6.22 developed by the Environmental Assessment Division at Argonne National Laboratory.

Two possible scenarios for future land having the highest maximum dose to the most critically affected individual were evaluated:

1. The resident farmer scenario where an indoor occupancy time factor of 50% and an outdoor occupancy time factor of 25% is recommended (NRC, 2003).

2. The work at home scenario where a 70% factor for indoor occupancy and a 15% factor for outdoors occupancy is recommended (NRC, 2003).

The scenarios were run using RESRAD after all other parameters in the model were set and a sensitivity analysis had been run. The scenarios were then run with all other factors held constant.

The working at home scenario resulted in a slightly higher maximum dose of 43.0 mrem/year at time = 0 years compared with the resident farmer scenario which resulted in a dose of 42.4 mrem/year at time = 0 years. The resident farmer scenario is, however, the most likely future use of the land within the Crow Butte permit area. Therefore, this scenario was used to determine the radium benchmark dose. The use of the lower maximum dose value will result in a slightly lower uranium soil concentration and thus be conservative.

The following sections describe the data parameters that were used to model site-specific conditions. Where a sensitivity analysis was run on a particular factor, the results are noted.

The data input was based upon four principal sources:

1. The RESRAD Data Collection Handbook (ANL, 1993)

2. The RESRAD Users' Manual (ANL, 2003)

3. The NUREG-1569

4. Crow Butte Resources, Inc. License Renewal Application (LRA) CBR, "Application for Renewal of USNRC Radioactive Source Materials License SUA-1534,"December 1995.

Soil Concentration

1. Lead 210: Used 5.0 pCi/g per the NUREG-1569.

2. Radium 226: Used 5.0 pCi/g regulatory limit as basis for determining benchmark.

Distribution Coefficient (K_d) (values based upon data in RESRAD Handbook)

1. Lead 210: Used a distribution coefficient of 270 cm^3/g for sandy soil based upon soil type at the mine. The RESRAD User's Manual specifies the following values:

   - Sand = 270
   - Loam = 16,000

Sensitivity analysis indicates with a multiple of 100, no appreciable impact on maximum dose using higher K_d. Used values of 2.7, 270 (mid range), and 27,000 which covers the range of potential values at the site based upon sandy and loamy soil types. Graph attached.

2. Radium 226: Used a distribution coefficient of 500 cm^3/g for sandy soil based upon soil type at the mine. The RESRAD User's Manual specifies the following values:

   - Sand = 500
   - Loam = 36,000

Sensitivity analysis indicates with a multiple of 100, no appreciable impact on maximum dose using higher K_d. Used values of 5, 500 (mid range), and 50,000 which covers the range of potential values at the site based upon sandy and loamy soil types. Graph attached.

Contaminated Zone

1. Area: Used default value of 10,000 square meters.

Sensitivity analysis was performed with a 2 multiple (5,000, 10,000 and 20,000 square meters). There was no impact on maximum dose. Graph attached.

2. Thickness: 15 cm (6 inches) based upon regulatory requirement (minimum in RESRAD Handbook)

3. Length parallel to aquifer flow: Default of 100 meters was used and is based upon the square root of a 10,000 square meter contaminated zone.

Sensitivity analysis was performed with a multiple of 5 (20, 100 and 500 square meters). There was no impact on maximum dose. Graph attached.

Cover and Contaminated Zone

1. Cover depth: 0 inches (in accordance with NUREG-1569).

2. Density of contaminated zone: Used the default value of 1.5 g/cc, which corresponds to sandy soil in the RESRAD Handbook. This compares with the soil types at Crow Butte and the engineering data in the Dawes County Soil Survey.

Sensitivity analysis was run using a factor of 1.5 (i.e., 1, 1.5, 2.25) and resulted in changes in the maximum dose with a higher dose projected with a higher density. See graph. However, the standard range given in the Handbook is 1.1 to 1.6 g/cc. 1.5 is the most representative density of the soil types at Crow Butte based upon the Soil Survey as discussed in CBR, 1995.

3. Contaminated zone erosion rate: Used the default value of 0.001 meters/year. NUREG-1569 states that the erosion rate should be lower at uranium recovery sites due to the semi-arid environment. The RESRAD Handbook states that this value should be adequate for screening purposes. It also states that, while water erosion is the primary factor, wind erosion can also be significant.

Sensitivity analysis was run using a multiple of 5 (i.e., 0.0002, 0.001 and 0.005). The lower erosion rate resulted in the total dose remaining at a higher level over a longer period of time. However, there was minimal impact on the maximum dose.

4. Contaminated zone total porosity: Default value of 0.4 is the same as used for the spill impact analysis and is based upon the soil types at Crow Butte and the Soil Survey engineering data.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.2, 0.4 and 0.8). The range given in the RESRAD handbook for sandy and silty soils is 0.25 to 0.53 and is covered in this sensitivity analysis. There was no impact on maximum dose.

5. <u>Contaminated zone field capacity</u>: Default value of 0.2 was used. This value was used because it is at the midpoint of the range for the soil types at Crow Butte.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.4, 0.2 and 0.1). The range given in the RESRAD handbook for sandy and silty soils is 0.01 to 0.46. The maximum value is covered in this range. There was no impact on the maximum dose.

6. <u>Contaminated zone hydraulic conductivity</u>: The range given in RESRAD handbook for silty sand is 1×10^1 to 1×10^4. The soil types in the licensed area are principally Busher loamy very fine sand. The hydraulic conductivity (K_{sat}) in m/yr. given in the RESRAD Manual for loamy sand is 4.93×10^3. Very fine sand is given a K_{sat} of 3.0×10^3 in the RESRAD Handbook. A midrange value of 4.0×10^3 was chosen since site specific data is unavailable.

Sensitivity analysis was run with a multiple of 2 (i.e., 2000, 4000 and 8000 m/yr). There was no impact on maximum dose.

7. <u>Contaminated zone b parameter</u>: Default parameter is 5.3 for silty loam. The RESRAD Handbook and RESRAD Manual specify a value of 4.38 for loamy sand, which corresponds to the soil classification used for the hydraulic conductivity. The range from sand to loam is 4.05 to 5.39.

Sensitivity analysis was run with a multiple of 2 (i.e., 2.19, 4.38, 8.76). There was no impact on maximum dose.

8. <u>Evapotranspiration Coefficient</u>: The RESRAD default value is 0.5. NUREG-1569 suggests that a value of 0.6 to 0.99 for uranium recovery sites is appropriate because

they are located in a semiarid environment. For screening purposes, a mid-value (0.75) was used.

Sensitivity analysis was run with a multiple of 1.33 (i.e., 0.564, 0.75 and 0.998) which is the maximum sensitivity set by RESRAD. There was no impact on the maximum dose.

9. Wind Speed: The RESRAD default is 2 m/s. The average for the Crow Butte site is 4.3 m/s (8.4 knots). Site data was used. No sensitivity analysis was performed since this is actual site data as recommended in NUREG-1569.

10. Precipitation: The RESRAD default is 1 m/yr. The average for the Crow Butte site is 0.39 m/yr. Site data was used. No sensitivity analysis was performed since this is actual site data as recommended in NUREG-1569.

11. Irrigation Rate: The RESRAD default is 0.2 m/yr. The actual site data should be 0 m/yr. since use of irrigation is limited in Dawes County and there is no irrigated land near the mine. Sources of irrigation are expected to be limited in the future. No sensitivity analysis was performed since this is actual site data as recommended in NUREG-1569.

12. Runoff Coefficient: The RESRAD default value is 0.2. This is the value for open rolling land in the RESRAD Handbook and was used for Crow Butte. The potential range in the RESRAD handbook for the site would be 0.1 to 0.4.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.1, 0.2 and 0.4) which covers the potential range for the site. There was no impact on maximum dose.

13. Watershed Area for nearby stream or pond: The RESRAD default value is 1×10^6 m^2. Used the estimated area of the Squaw Creek watershed, which is approximately 14 sections, or 3.63×10^7 m^2.

Although this is actual data for the site, a sensitivity analysis with a multiple of 2 was run (i.e., 1.82, 3.63 and 7.26 x 10^7 m^2). There was no impact on maximum dose.

14. Accuracy: Used the default value of 0.001.

Saturated Zone

1. Density of saturated zone: Used the default value of 1.5 g/cc, which corresponds to sandy soil in the RESRAD Handbook. This compares with the soil types at Crow Butte and the engineering data in the Dawes County Soil Survey.

Sensitivity analysis was run using a factor of 1.5 (i.e., 1, 1.5, 2.25). There were no changes in the maximum dose. See graph. The standard range given in the Handbook is 1.1 to 1.6 g/cc. 1.5 is the most representative density of the soil types at Crow Butte based upon the Soil Survey as discussed in the CBR, 1995.

2. Saturated zone total porosity: Default value of 0.4 is the same as used for the spill impact analysis and is based upon the soil types at Crow Butte and the Soil Survey engineering data.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.2, 0.4 and 0.8). The range given in the RESRAD handbook for sandy and silty soils is 0.25 to 0.53 and is covered in this sensitivity analysis. There was no impact on maximum dose.

3. Saturated zone effective porosity: Default value of 0.2 was used. This value was used because it is at the midpoint of the range for the soil types at Crow Butte.

Sensitivity analysis was run with a multiple of 5 (i.e., 0.04, 0.2 and 1). The range given in the RESRAD handbook for sandy and silty soils is 0.01 to 0.46. The maximum value is covered in this range. There was no impact on the maximum dose.

4. Contaminated zone field capacity: Default value of 0.2 was used. This value was used because it is at the midpoint of the range for the soil types at Crow Butte.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.04, 0.2 and 1). The range given in the RESRAD handbook for sandy and silty soils is 0.01 to 0.46. The maximum value is covered in this range. There was no impact on the maximum dose.

5. Saturated zone hydraulic conductivity: The range given in RESRAD handbook for silty sand is 1×10^1 to 1×10^4. The soil types on Section 19 are principally Busher loamy very fine sand. The hydraulic conductivity (K_{sat}) in m/yr. given in the RESRAD Manual for loamy sand is 4.93×10^3. Very fine sand is given a K_{sat} of 3.0×10^3 in the RESRAD Handbook. A midrange value of 4.0×10^3 was chosen since site specific data is unavailable.

Sensitivity analysis was run with a multiple of 2 (i.e., 2000, 4000 and 8000 m/yr.). There was no impact on maximum dose.

6. Saturated zone hydraulic gradient: The default value of 0.02 was used for screening purposes.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.01, 0.02 and 0.04.). There was no impact on maximum dose.

7. Saturated zone b parameter: Default parameter is 5.3 for silty loam. The RESRAD Handbook and RESRAD Manual specify a value of 4.38 for loamy sand, which corresponds to the soil classification used for the hydraulic conductivity. The range from sand to loam is 4.05 to 5.39.

Sensitivity analysis was run with a multiple of 2 (i.e., 2.19, 4.38, and 8.76). There was no impact on maximum dose.

8. Water Table Drop Rate: The default value of 0.001 m/yr. was used for screening purposes. The site specific drop rate should be similar because there is little consumptive use of groundwater in the immediate area other than ranches that use local wells for domestic and livestock.

Sensitivity analysis was run with a multiple of 10 (i.e., 0.0001, 0.001 and 0.01). There was no impact on maximum dose.

9. Well Pump Intake Depth: The RESRAD default is 10 m. Since the depth to saturated zone is 15 meters and most local wells are completed from 60 to 80 feet, a value of 20 meters was chosen.

Sensitivity analysis was run with a multiple of 2 (i.e., 10m, 20m and 40m). There was no impact on maximum dose

10. Model for Water Transport Parameters: Used non-dispersion per NUREG-1569.

11. Well Pumping Rate: Used default of 250 m^3/yr. (66,000 gal/yr.).

Sensitivity analysis was run with a multiple of 2 (i.e., 125, 250m and 500 m^3/yr.). There was no impact on maximum dose

Unsaturated Zone

1. Unsaturated zone thickness: Used 15 meters (50 ft) per Reg.Guide-1569.

2. Density of unsaturated zone: Used 1.5 g/cc, which is similar to the saturated zone as discussed in NUREG-1569.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.75, 1.5 and 3.0 g/cc) There was no impact on maximum dose.

3. Unsaturated zone total Porosity: The default value of 0.4 is the same as used for the saturated zone as discussed in NUREG-1569.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.2, 0.4 and 0.8). The range given in the RESRAD handbook for sandy and silty soils is 0.25 to 0.53 and is covered in this sensitivity analysis. There was no impact on maximum dose.

4. Unsaturated zone effective porosity: The default value of 0.2 is the same as used for the saturated zone as discussed in NUREG-1569.

Sensitivity analysis was run with a multiple of 1.5 (i.e., 0.3, 0.2 and 0.13). The range given in the RESRAD handbook for sandy and silty soils is 0.01 to 0.46. The maximum value is covered in this range. There was no impact on the maximum dose.

5. Unsaturated zone field capacity: Default value of 0.2 was used. This value was used because it is at the midpoint of the range for the soil types at Crow Butte.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.4, 0.2 and 0.1). The range given in the RESRAD handbook for sandy and silty soils is 0.01 to 0.46. The maximum value is covered in this range. There was no impact on the maximum dose.

6. Unsaturated zone hydraulic conductivity: The range given in the RESRAD handbook for silty sand is 1 x 10^1 to 1 x 10^4. The soil types in the licensed area are principally Busher loamy very fine sand. The hydraulic conductivity (K_{sat}) in m/yr. given in the RESRAD Manual for loamy sand is 4.93 x 10^3. Very fine sand is given a K_{sat} of 3.0 x 10^3 in the RESRAD Handbook. A midrange value of 4.0 x 10^3 and is the same as used for the saturated zone as discussed in NUREG 1569.

Sensitivity analysis was run with a multiple of 2 (i.e., 2000, 4000 and 8000 m/yr.). There was no impact on maximum dose.

7. Saturated zone b parameter: Used 4.28 rather than the default parameter of 5.3. The RESRAD Handbook and RESRAD Manual specify a value of 4.38 for loamy sand, which corresponds to the soil classification used for the hydraulic conductivity. The range from sand to loam is 4.05 to 5.39.

Occupancy

1. Inhalation Rate: Used default value of 8,400 m^3/yr.

2. Mass Loading for Inhalation: Default is 0.0001 g/m^3. Handbook gives a value of 0.0003 g/ m^3 for agricultural generated dust loading.

Sensitivity analysis run with a multiple of 3 (i.e., 0.0001, 0.0003 and 0.0009 g/m^3) which will cover the range from the default value. There was no impact on maximum dose.

3. Exposure Duration: Used default value of 30 years.

4. Indoor dust filtration factor: Used default value of 0.4.

5. External gamma shielding factor: The RESRAD default is 0.7, which assumes that the indoor gamma radiation level is 30% lower than the outdoor gamma radiation

level. NUREG-1569 requires that a value between 0.33 and 0.55 be used. The screening level was set at 0.55. This is a value suitable for a 7-inch thick concrete slab on grade house (NUREG/CR-5512 Vol.3, p 6-25). This is representative of the thickness of the local slab or basement floor thicknesses.

Sensitivity analysis using a 1.5 multiple (i.e., 0.367, 0.55 and 0.825 resulted in a change in the maximum dose. See graph. The low range (0.367) resulted in a maximum dose of approximately 38 mrem/yr compared to a dose of 42 mrem/yr for a shielding factor of 0.55. Based upon the fact that most construction of rural homes in the local area includes a thick concrete basement floor or slab, a shielding factor of 0.55 for the Crow Butte area is justified.

6. Indoor/Outdoor Fractions: Used defaults of 0.5 indoors and 0.25 outdoors for farmer scenario and 0.7 indoors and 0.15 outdoors for the work at home scenario. As discussed above, the resident farmer scenario was chosen as the most likely land use for the foreseeable future (i.e., 200 years).

7. Shape of contaminated zone: NUREG-1569 suggests use of actual shape. However, the shape is unknown at this time. Various shapes were assumed including a rectangle having a length of up to four times the width. The results were independent of these shapes as long as the receptor was centered. When the receptor was at the edge of the area, the dose was reduced significantly as expected. A circular shape was adopted for the modeling.

Ingestion: Dietary

1. **Consumption Rates:**

   A. Fruit, vegetable and grain: RESRAD default is 160 kg/yr. This value was used based upon EPA estimated consumption. NRC Reg. Guide 1.109 has an estimated consumption for an adult of 190 kg/yr. Screening level set at default of 160 kg/yr.

This amount is the total consumption. RESRAD adjusts for contaminated and uncontaminated fractions based upon the size of the contaminated area.

Sensitivity analysis with 1.25 factor (i.e., 152, mid of 190 and high of 237.5 kg/yr) had an impact on maximum dose. This factor covers the range for the consumption discussed in Reg. Guide 1.109. See Graph. Based upon NRC Reg. Guide 1.109, adjusted the consumption to 190 kg/yr.

B. Leafy Vegetable: Used default value of 14 kg/yr. NRC Reg. Guide 1.109 has an estimated consumption for an adult of 64 kg/yr, while NRC estimates for dose from nuclear power plants uses a consumption rate of 30 kg/yr. Screening level for total set at default of 190 kg/yr (see above entry). This amount is the total consumption. RESRAD adjusts for contaminated and uncontaminated fractions based upon the size of the contaminated area.

Sensitivity analysis was run with a multiple of 5 (i.e., 2.8, 14 and 70 kg/yr.) to cover the range of NRC estimated consumption. There was an impact on maximum dose. Based upon these results, the consumption rate was left at the default value of 14 kg/yr. for ALARA purposes.

C. Milk: No consumption of locally produced and consumed milk per NUREG-1569. Dairy operations are not prevalent in the area.

D. Meat and Poultry: Used RESRAD default value of 63 kg/yr. According to NRC Regulatory Guide 1.109 (NRC, 1977), the recommended average value for consumption of meat and poultry is 37 kg/yr for children, 59 kg/yr for teenagers, and 95 kg/yr. for adults.

Sensitivity analysis was run with a multiple of 2 (i.e., 31.5, 63 and 126 kg/yr.) which covers the range between the RESRAD default and the rates in Reg. Guide 1.109. There *was minimal impact on the maximum dose. The default consumption rate from RESRAD was used.*

E. Fish/Seafood: No consumption of locally produced and consumed fish or seafood products was considered as recommended by NUREG-1569.

F. Soil ingestion: Used the RESRAD default value of 36.5 g/yr.

Sensitivity analysis was run with a multiple of 2 (i.e., 18.25, 36.5 and 73 kg/yr). There was minimal impact on the maximum dose. The RESRAD default value was chosen.

G. Drinking water intake: Used the RESRAD default of 510 l/yr. (1.4 L/d) as a screening level. This value is based upon EPA estimates of drinking water intake. The EPA (1990) has suggested that the average adult drinking water consumption rate is 1.4 L/d; the reasonable worst-case value is 2.0 L/d.

Sensitivity analysis was run with a multiple of 2 (i.e., 255, 510 and 1020 L/yr.). There was no impact on the maximum dose. The RESRAD default value was chosen.

2. Contaminated Fractions:

NUREG-1569 states that for sites with over 25 acres (10,117 square meters) of contamination, the fraction of diet from contaminated area should be assumed to be 25% (0.25). A sensitivity analysis on these parameters was not performed based upon the guidance.

A. Water: Used the default value of 1 (i.e., 100% of consumption is from contaminated well water). All current water use in rural areas around the site is from private wells and will likely continue to be in the foreseeable future.

B. Livestock Water: Used default of 1 (i.e., 100% is from contaminated water). All current water use in rural areas around the site is from private wells and will likely continue to be in the foreseeable future.

C. Irrigation Water: Used the RESRAD default of 1 (i.e., 100% is from contaminated water). All current water use in rural areas around the site is from private wells and will likely continue to be in the foreseeable future.

D. Plant food: Used 0.25 as percentage of plant food that is contaminated.

E. Meat: Used 0.25 as percentage of meat that is contaminated.

Ingestion: Nondietary

1. Consumption Rates:

A. Livestock fodder intake for meat: Used the RESRAD default of 68 kg/day.

Sensitivity analysis was run with a multiple of 2 (i.e., 34, 68, and 136 kg/d). There was no significant impact on maximum dose.

B. Livestock water intake for meat: Used the RESRAD default of 50 L/day. According to NRC Regulatory Guide 1.109 (NRC 1977), the water ingestion rate for beef cattle is 50 L/d.

Sensitivity analysis was run with a multiple of 2 (i.e., 25, 50, and 100 L/d). There was no impact on maximum dose.

C. Livestock intake of soil for meat: Used the RESRAD default of 0.5 g/day.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.25, 0.5, and 1 g/d). There was no significant impact on maximum dose.

D. Mass loading for foliar deposition: Used the same value of 0.0003 g/m^3 for agricultural generated dust loading as the inhalation parameter discussed above.

E. Depth of soil mixing layer: Used the RESRAD default of 0.15 meters.

Sensitivity analysis was run with a multiple of 3 (i.e., 0.9, 03, and 0.1 meters). There was a minimal (i.e., less than 1 mrem/yr) impact on maximum dose

F. Depth of roots: Used 0.3 meters as a screening level based upon NUREG-1569 instead of the RESRAD default of 0.9. The root depth varies for different plants. For some plants, such as beets, carrots, lettuce, and so forth, it does not extend below about 0.3 m, which is the basis of the NRC guidance. For others, such as fruit trees, the roots may extend 2 or 3 m below the surface. Tap roots for some crops (e.g., alfalfa) can extend to 5 m. Most of the plant roots from which nutrients are obtained, however, usually extend to less than 1 m below the surface. Due to the common use of grazing crops such as alfalfa in the immediate area surrounding the Crow Butte site, a sensitivity analysis was chosen that would determine the dose using the 0.3 m NRC guidance as the screening level as well as the 0.9 m RESRAD default.

Sensitivity analysis was run with a multiple of 3 (i.e., 0.1, 0.3, and 0.9 meters). There was a significant impact on the maximum dose. Assumption of a shallow root system increased the dose significantly. In a review of the exposure pathways, the plant pathway resulted in approximately 38% of the total maximum dose. The meat pathway, which would be the primary pathway affected by deeper roots such as alfalfa, accounted for approximately 1.4% of the total maximum dose. Therefore, the root depth recommended in the NRC NUREG-1569 was chosen for this parameter.

G. Groundwater fractional usage:

- Drinking water: Used the RESRAD default of 1 (i.e., 100% from well).
- Livestock water: Used the RESRAD default of 1 (i.e., 100% from well).
- Irrigation water: Used the RESRAD default of 1 (i.e., 100% from well).

Storage Times

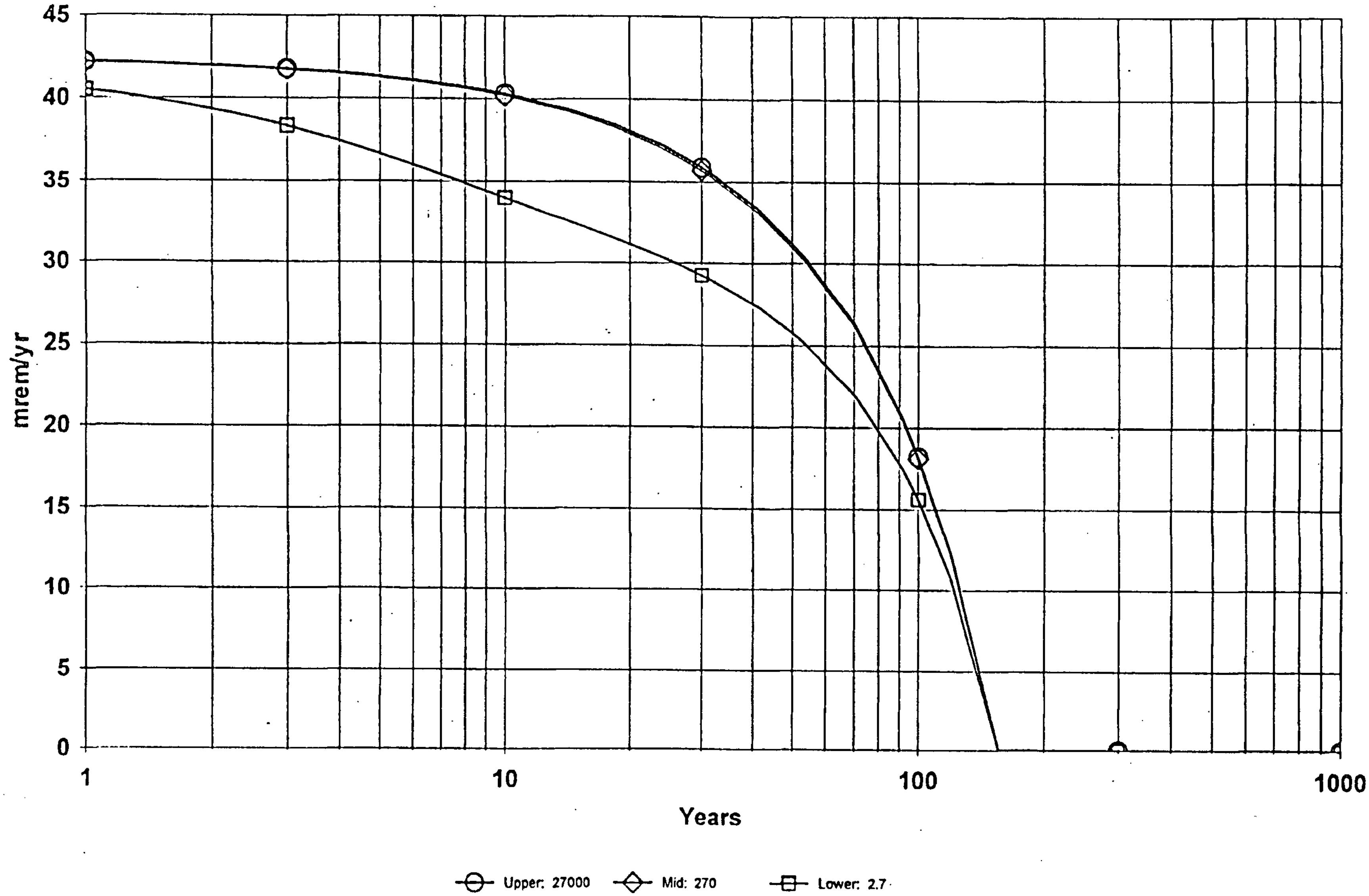
Used the RESRAD default values for all storage times (for vegetables, meats, fodder, etc.).

Radium Benchmark Dose Assessment

Attachment 2

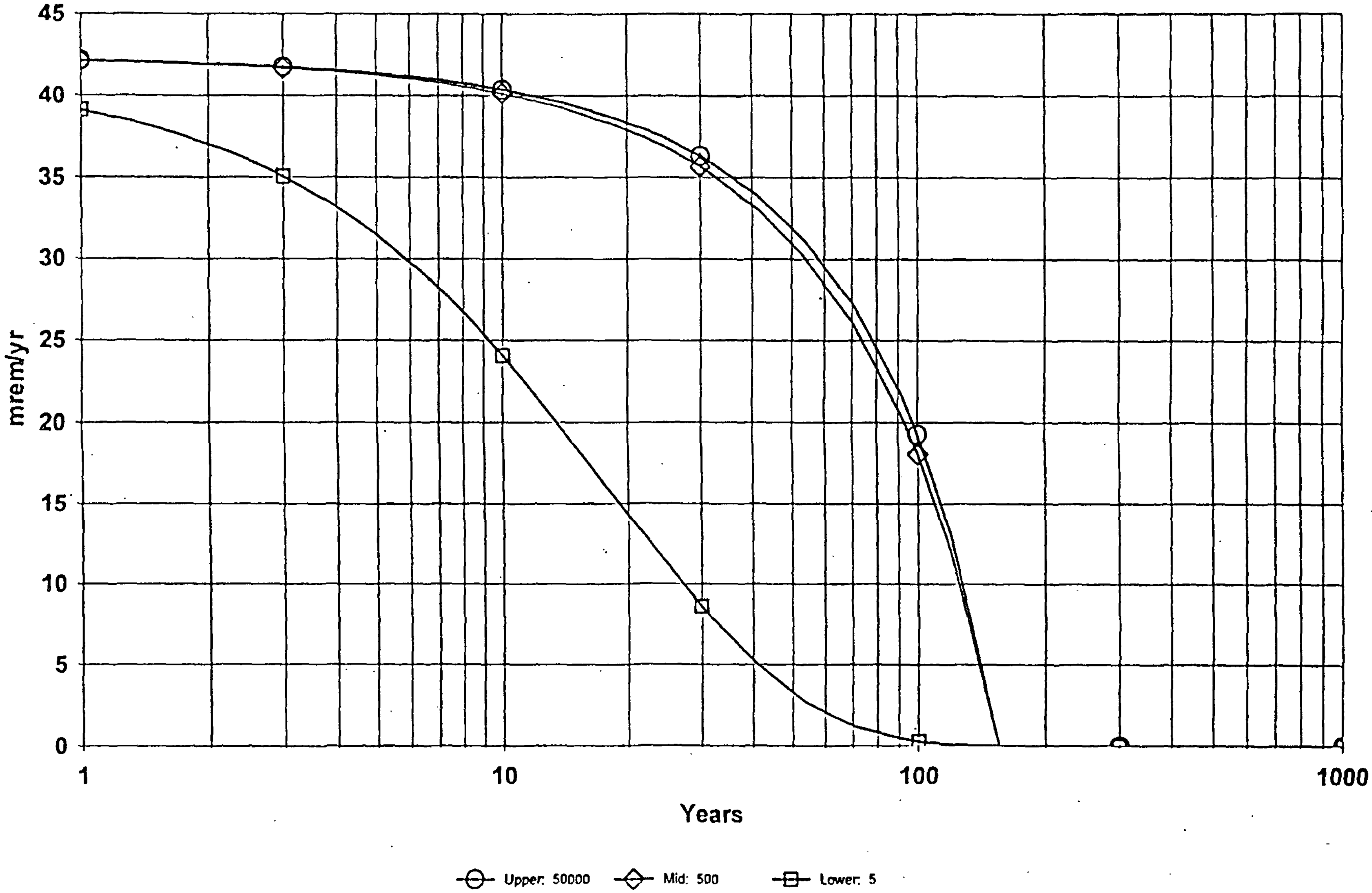
RESRAD Input Parameter
Sensitivity Analysis

DOSE: All Nuclides Summed, All Pathways Summed With SA on Pb-210 Contaminated Zone Distribution Coef.



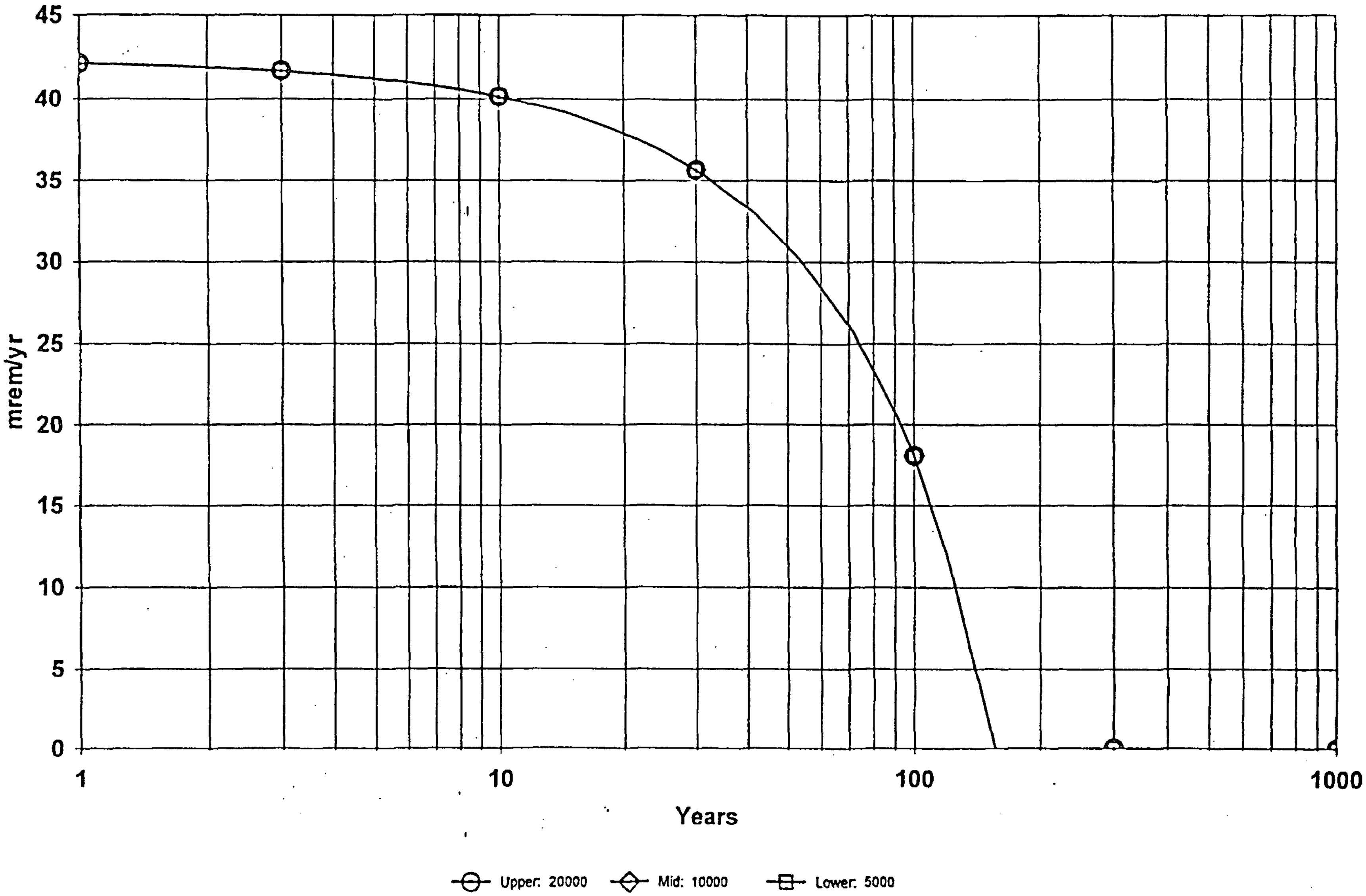
CBR1.rad 02/26/2004 11:07 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Ra-226 Contaminated Zone Distribution Coef.



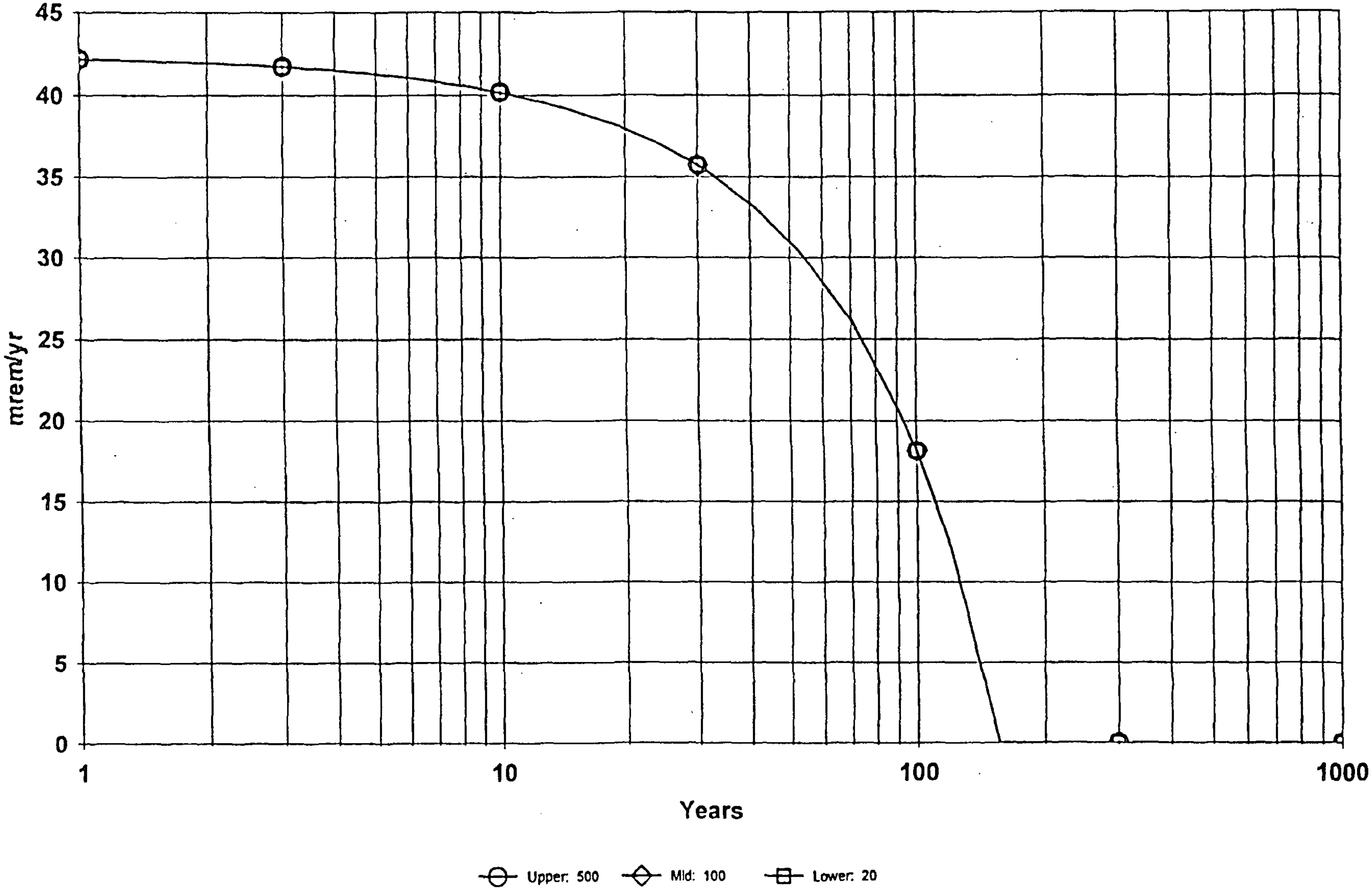
Ra022704.RAD 02/27/2004 09:40 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Area of contaminated zone



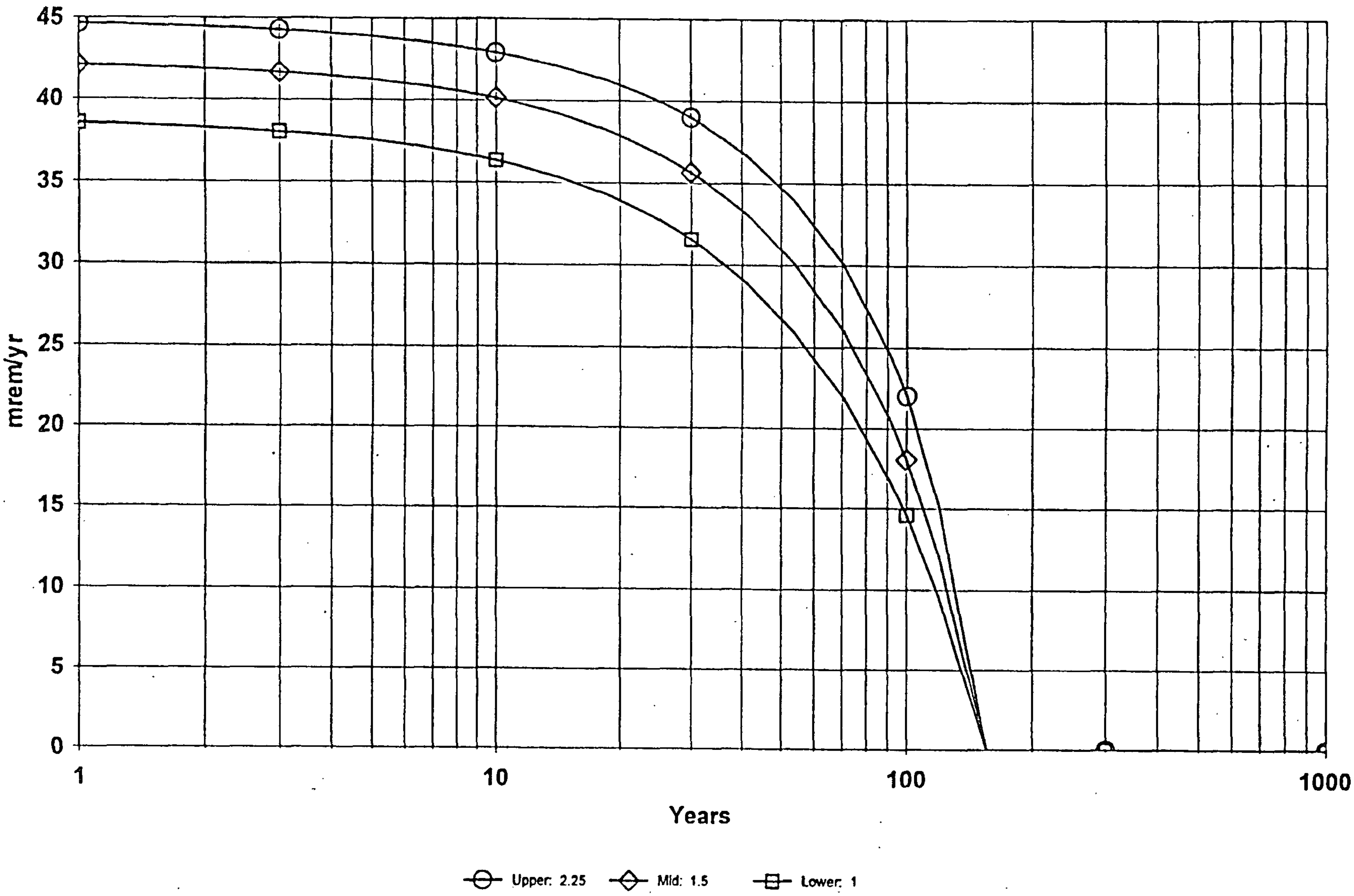
Ra022704.RAD 02/27/2004 09:56 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Length parallel to aquifer flow

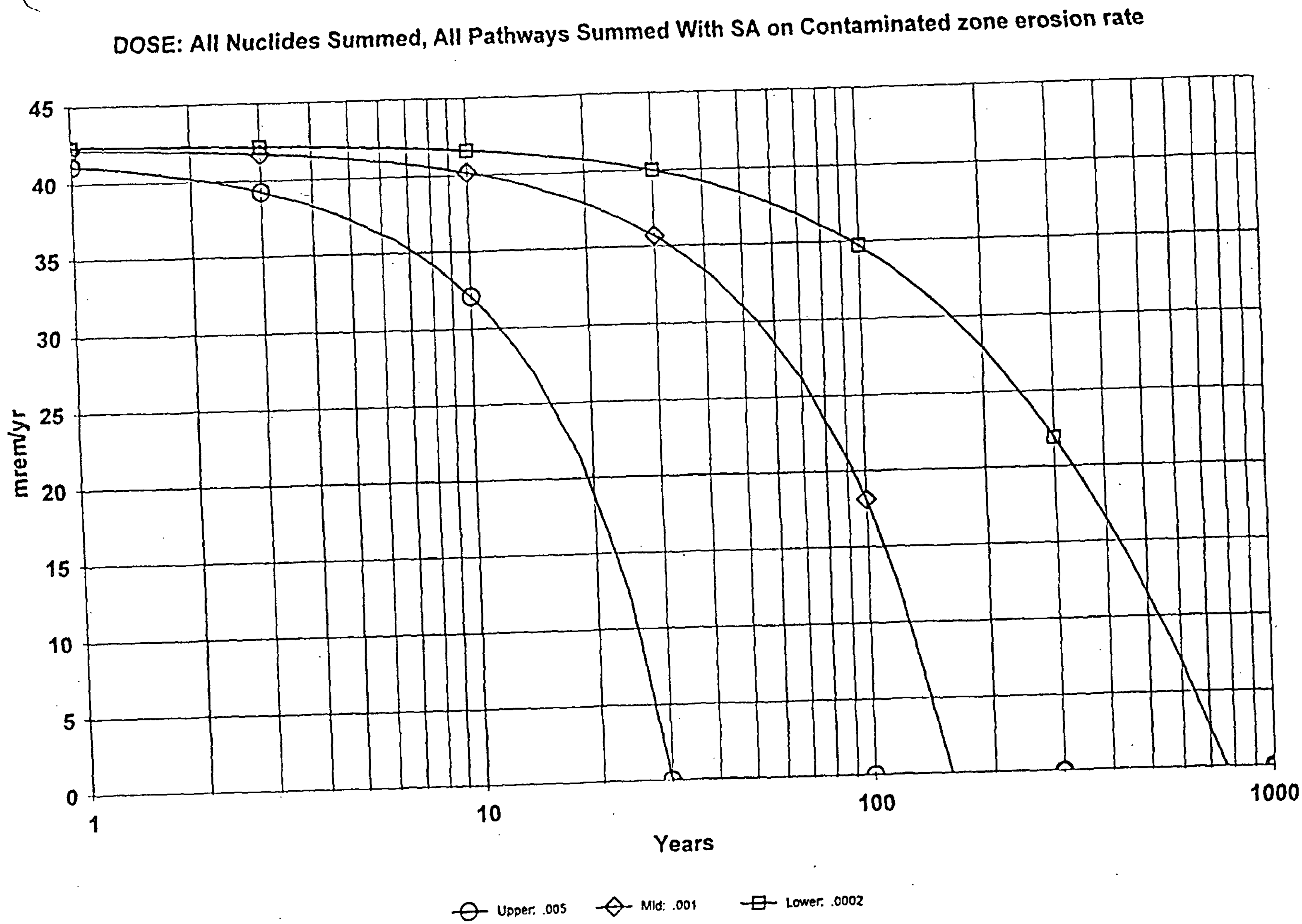


Ra022704.RAD 02/27/2004 15:40 Includes All Pathways

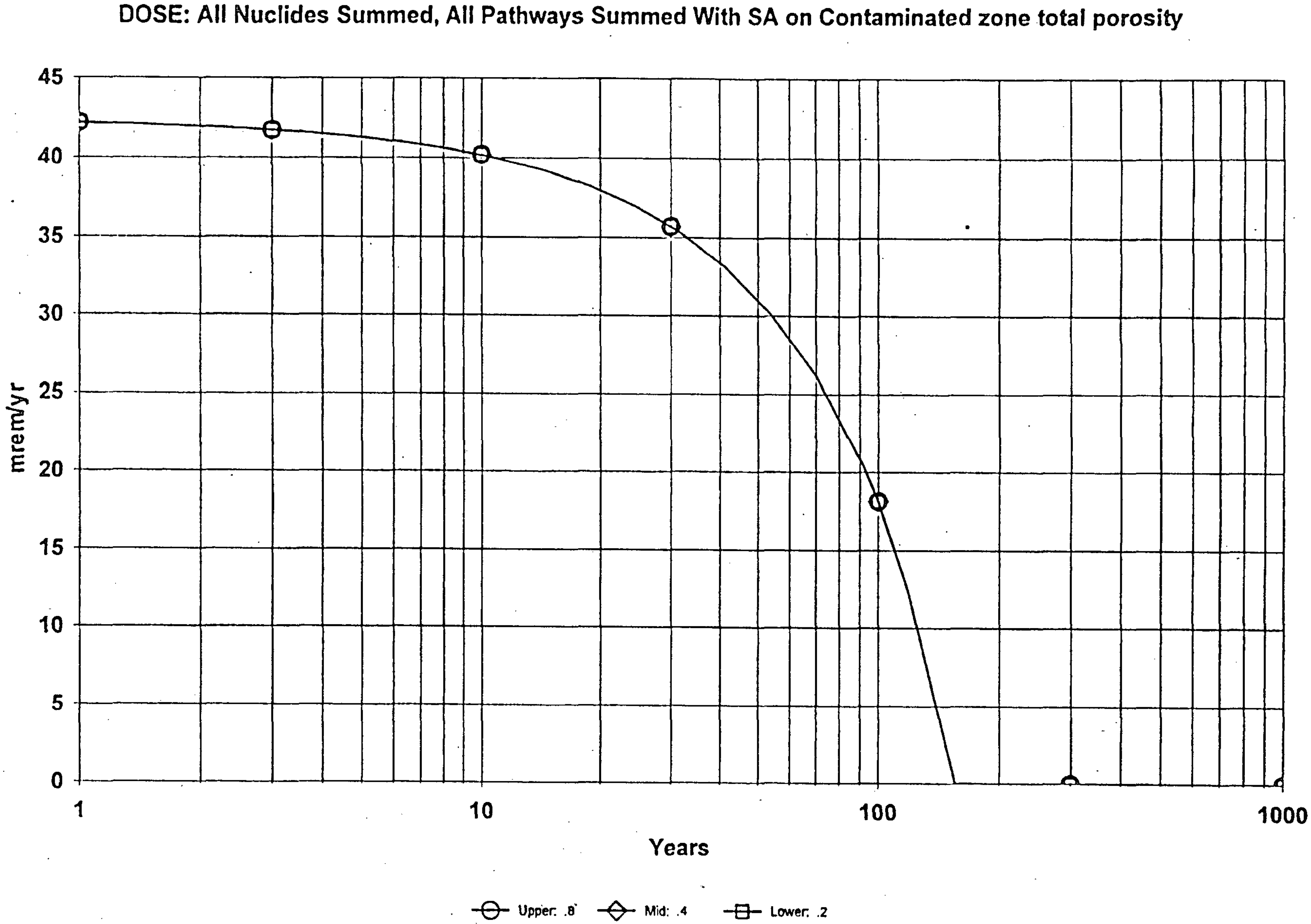
DOSE: All Nuclides Summed, All Pathways Summed With SA on Density of contaminated zone



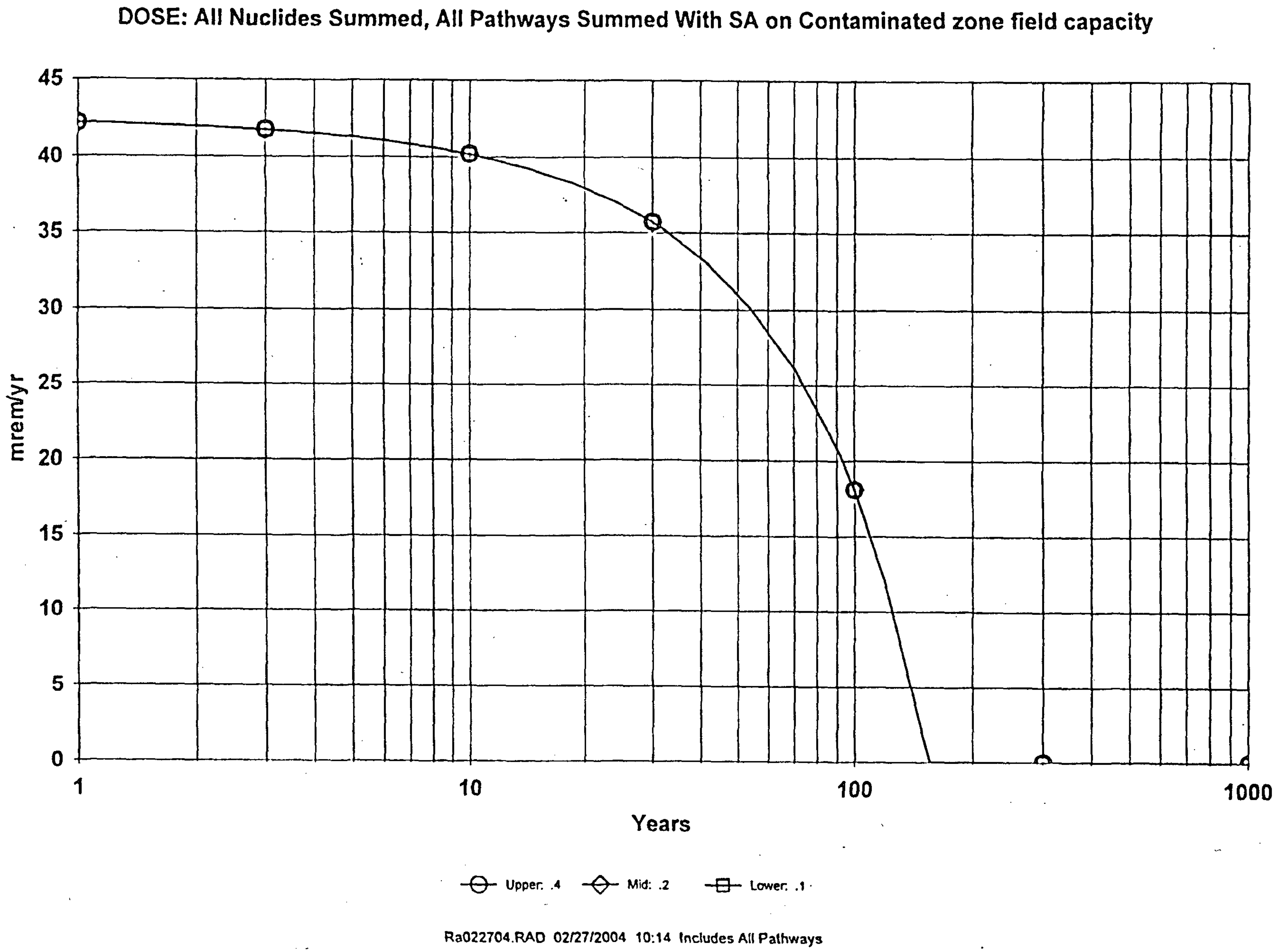
Ra022704.RAD 02/27/2004 09:56 Includes All Pathways



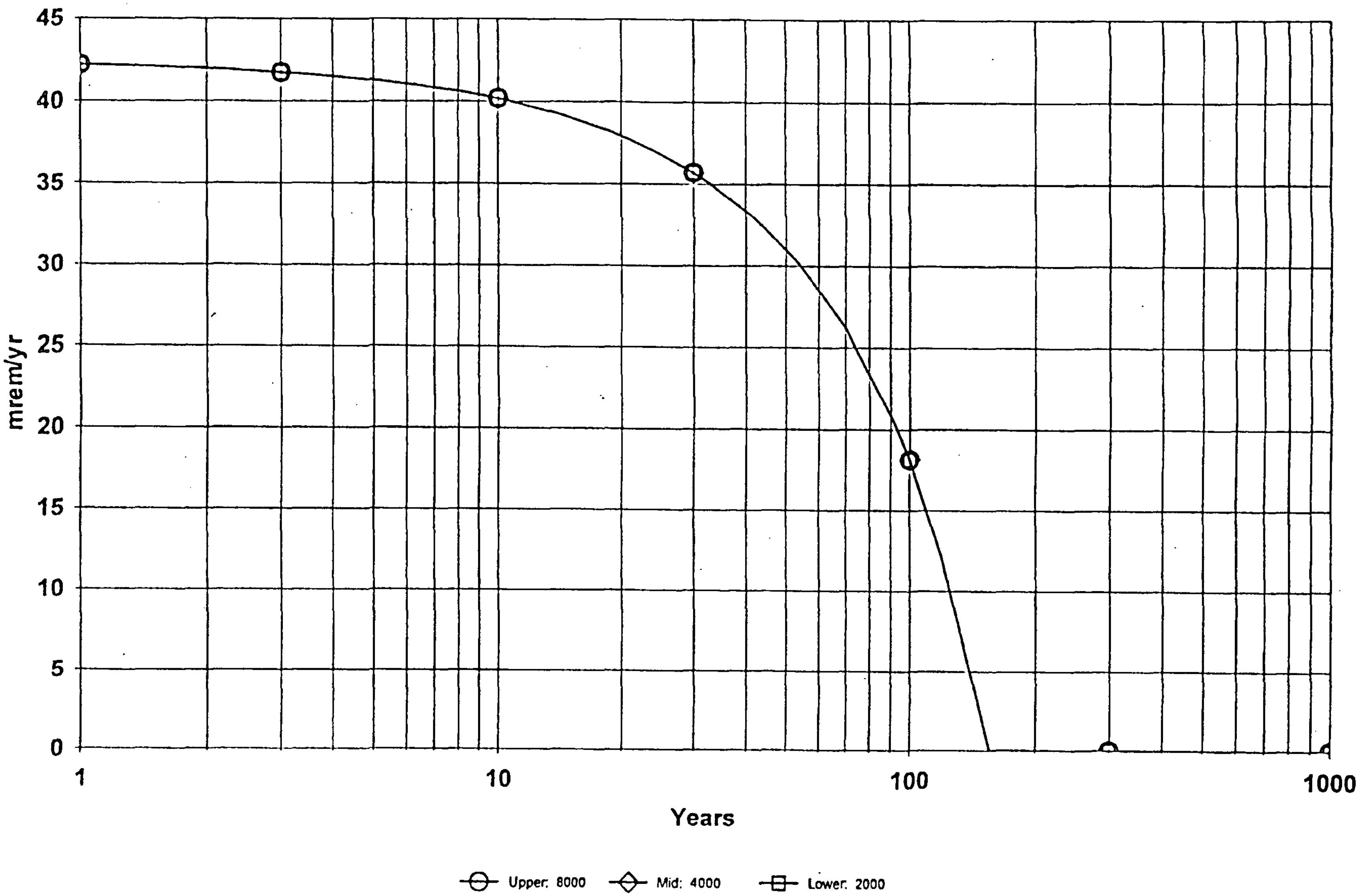
Ra022704.RAD 02/27/2004 10:14 Includes All Pathways



Ra022704.RAD 02/27/2004 10:14 Includes All Pathways

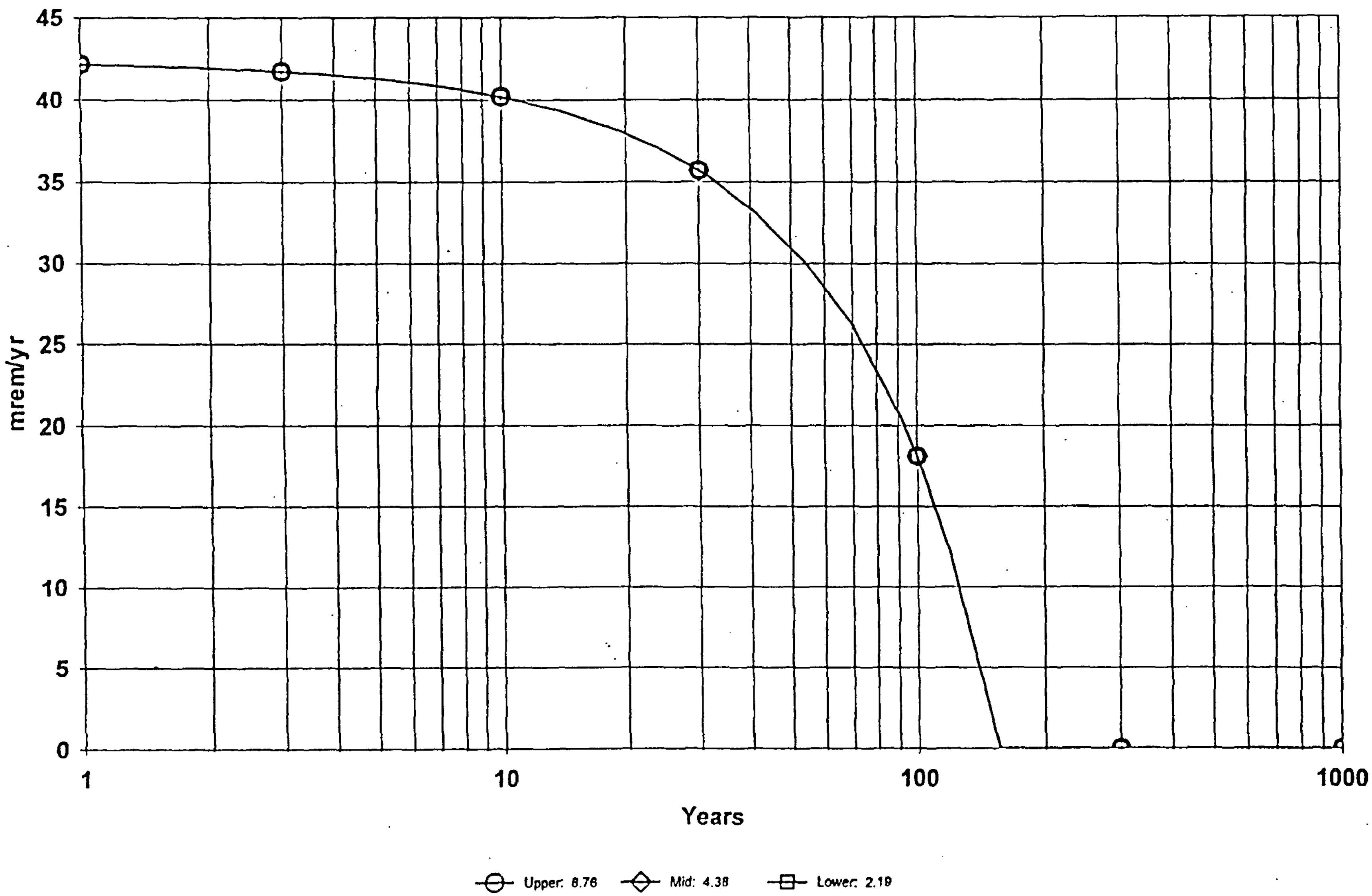

DOSE: All Nuclides Summed, All Pathways Summed With SA on Contaminated zone field capacity
45
40
35
30
25
20
15
10
5
0
mrem/yr
1
10
100
1000
Years
Upper: .4
Mid: .2
Lower: .1
Ra022704.RAD 02/27/2004 10:14 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Contaminated zone hydraulic conductivity



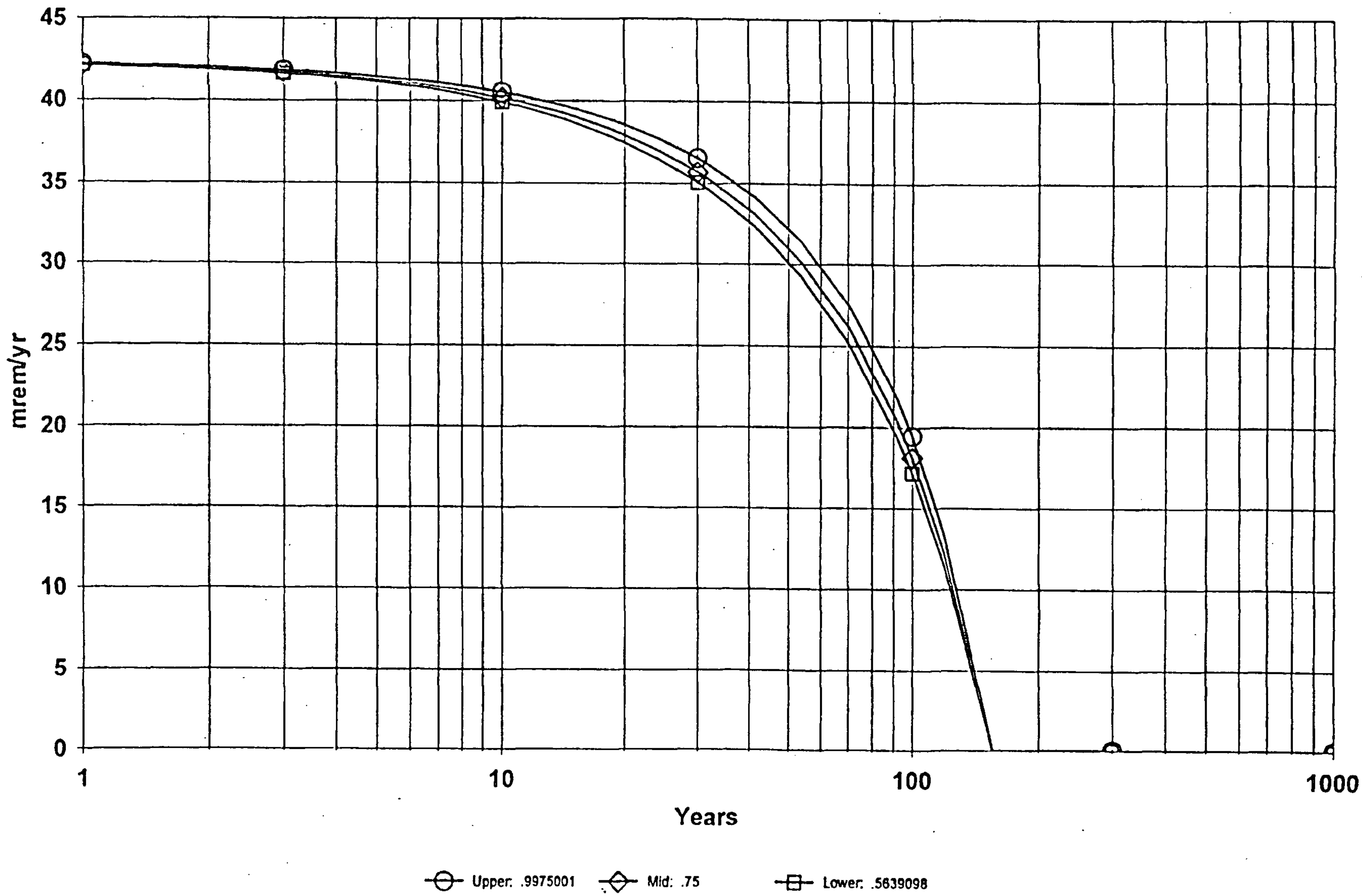
Ra022704.RAD 02/27/2004 10:14 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Contaminated zone b parameter



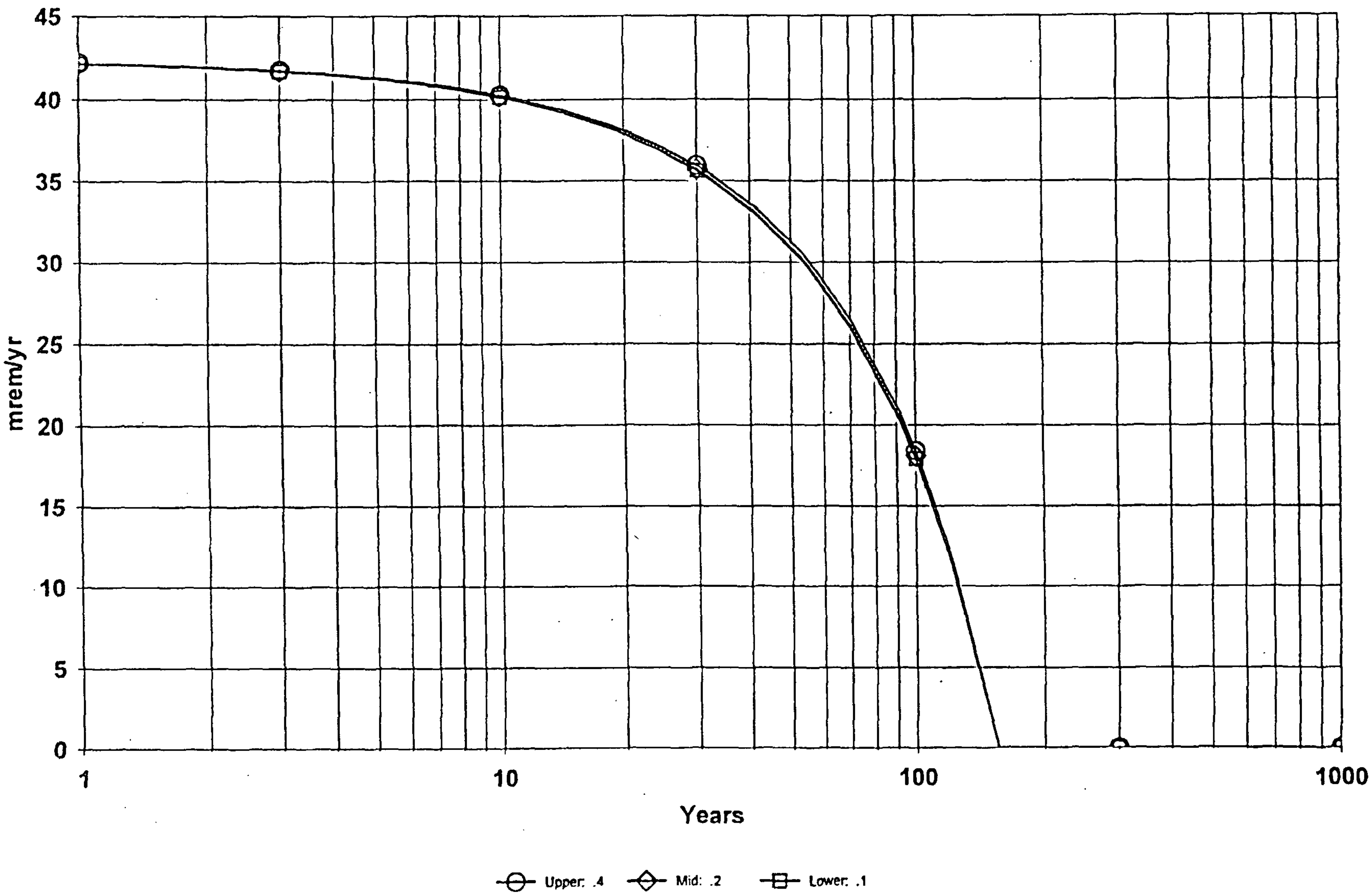
Ra022704.RAD 02/27/2004 10:14 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Evapotranspiration coefficient



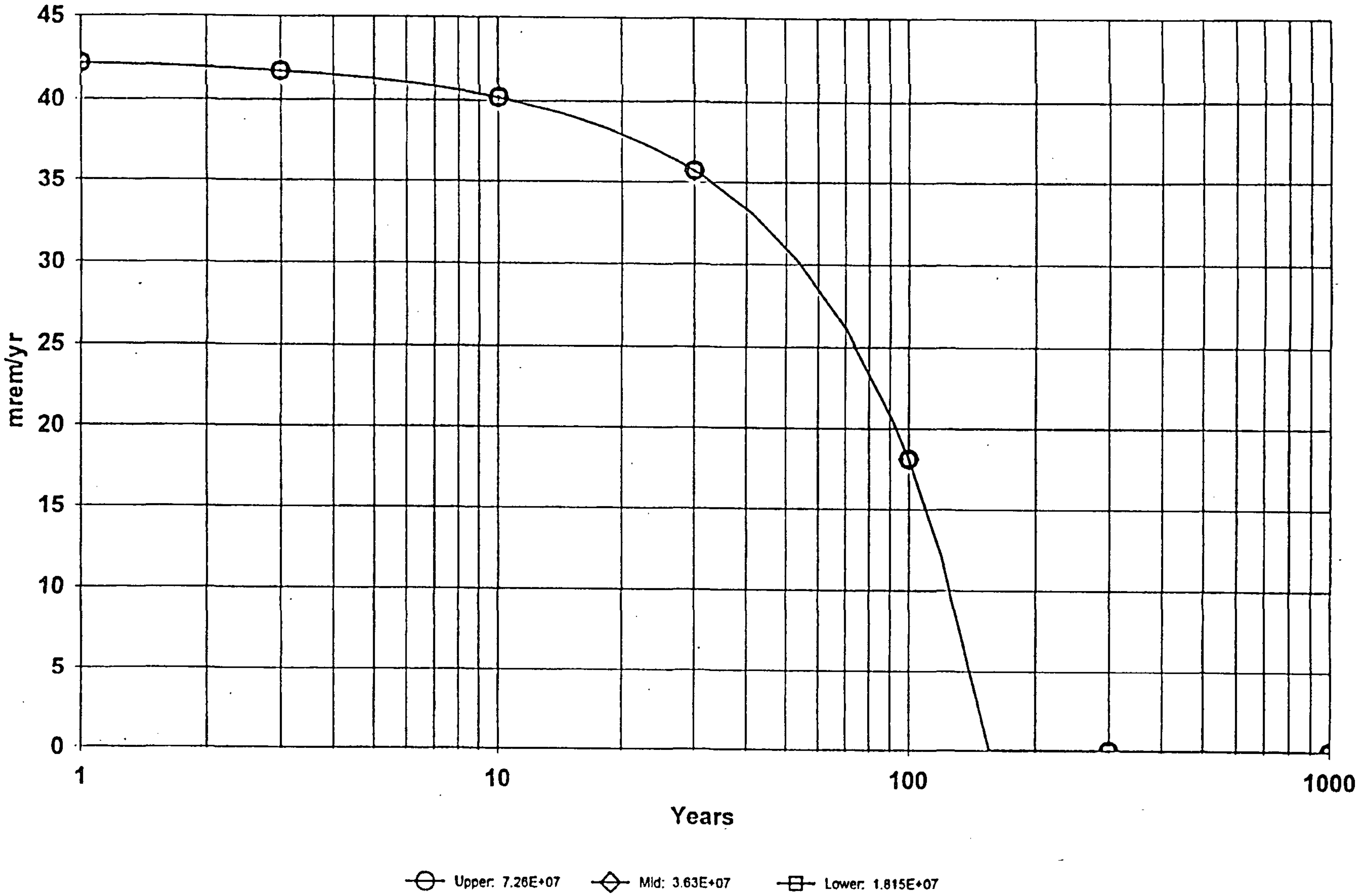
Ra022704.RAD 02/27/2004 10:22 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Runoff coefficient



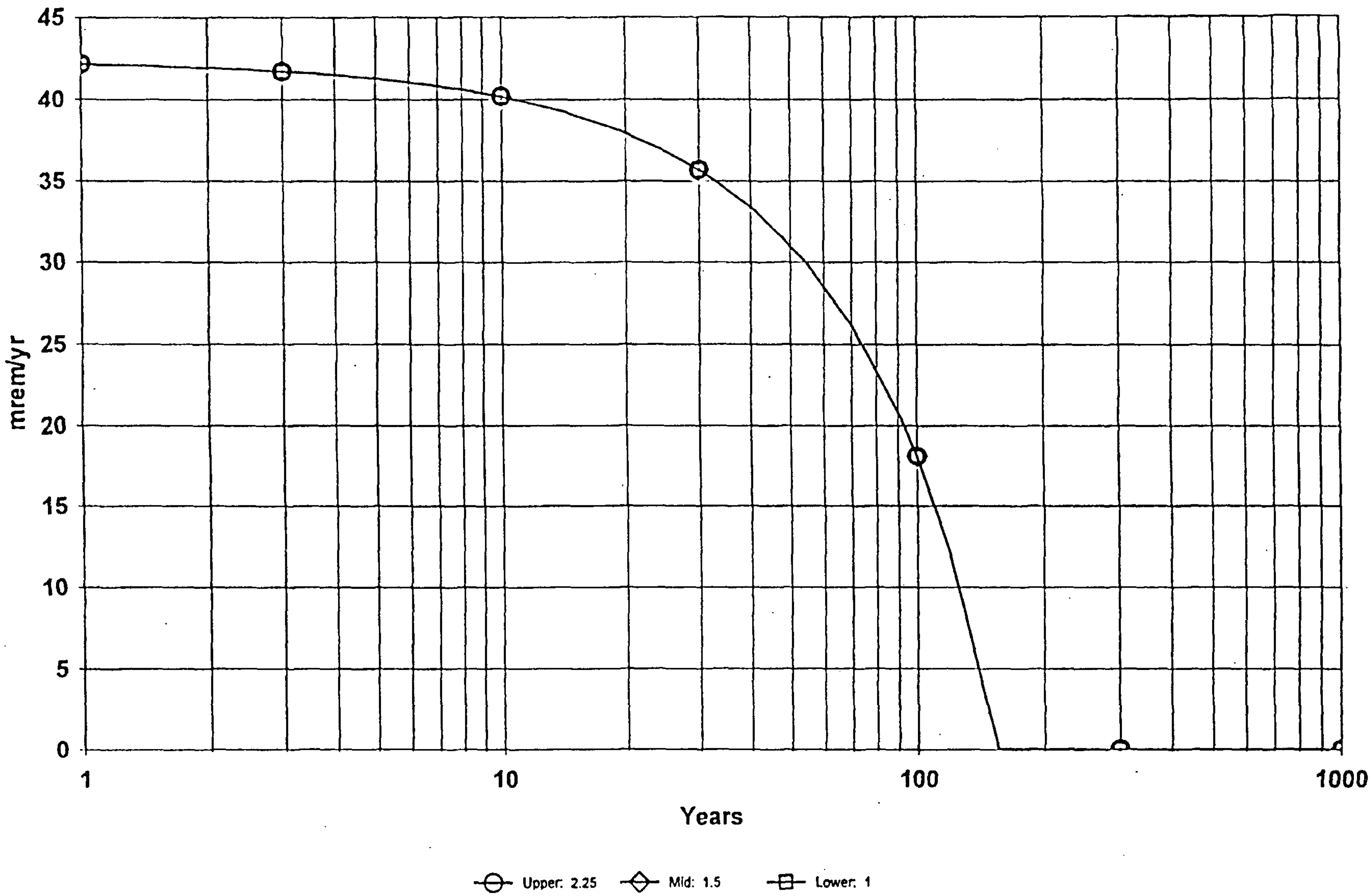
Ra022704.RAD 02/27/2004 10:22 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Watershed area for nearby stream or pond



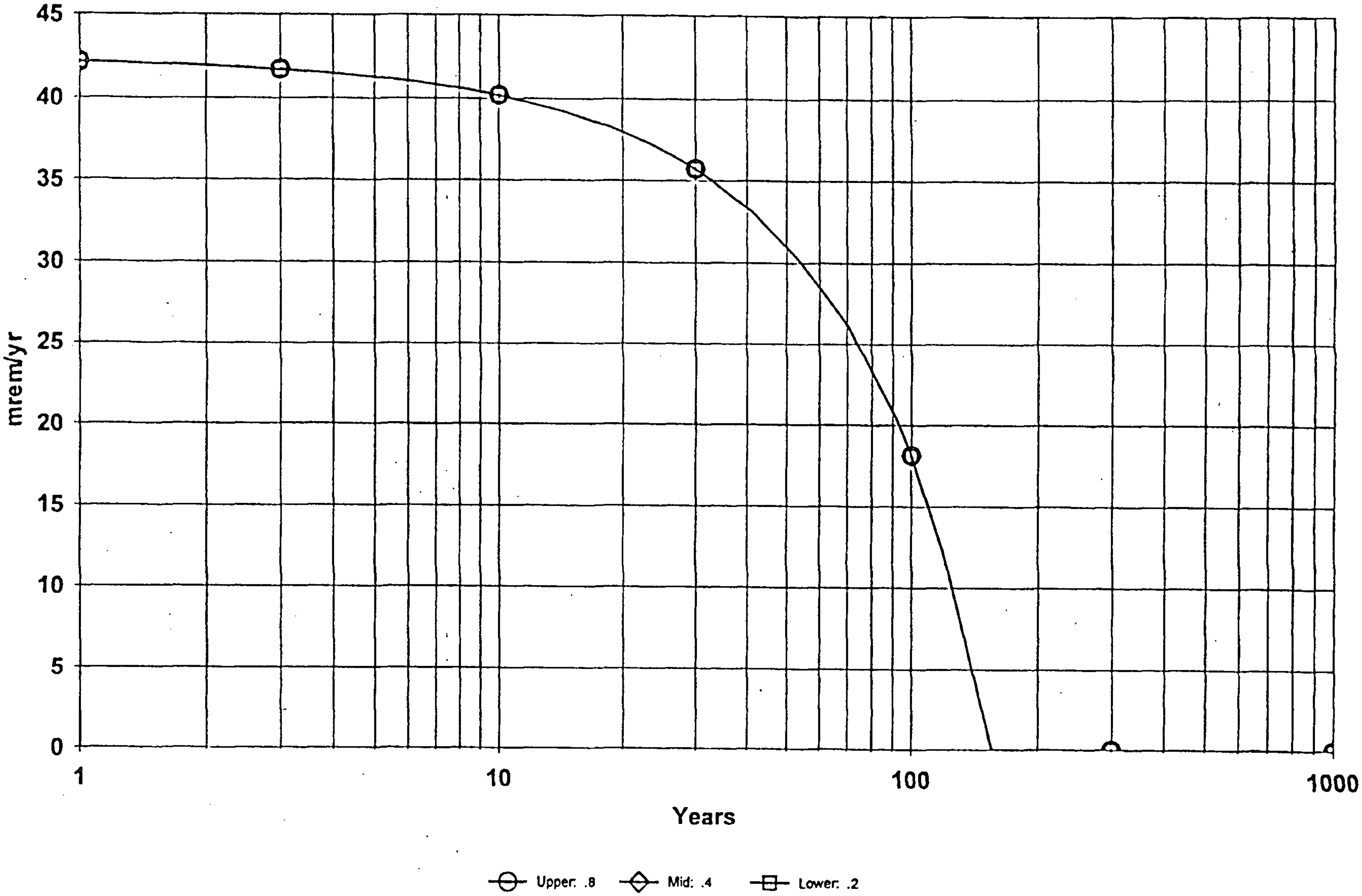
Ra022704.RAD 02/27/2004 10:22 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Density of saturated zone



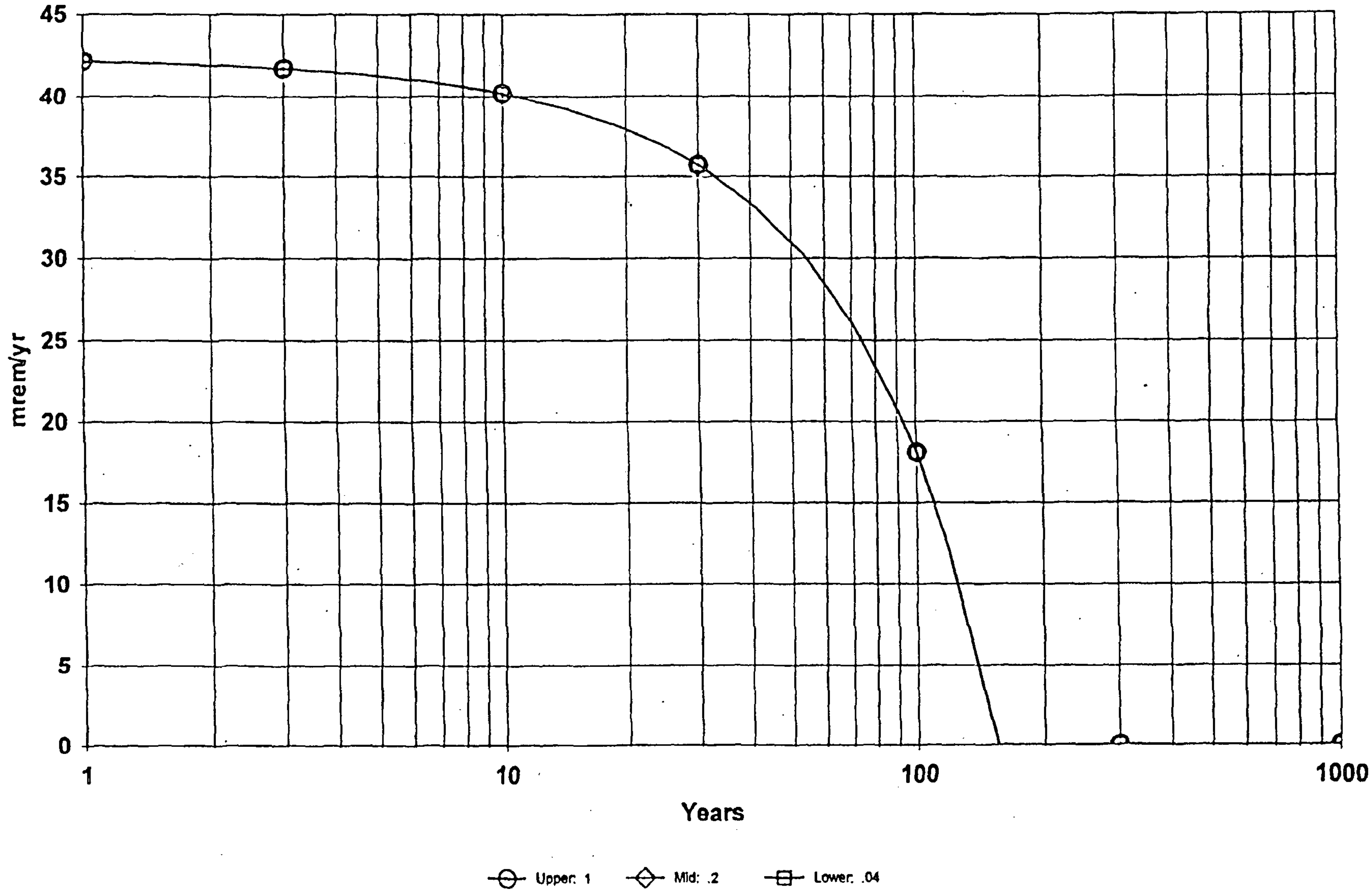
Ra022704.RAD 02/27/2004 10:22 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Saturated zone total porosity

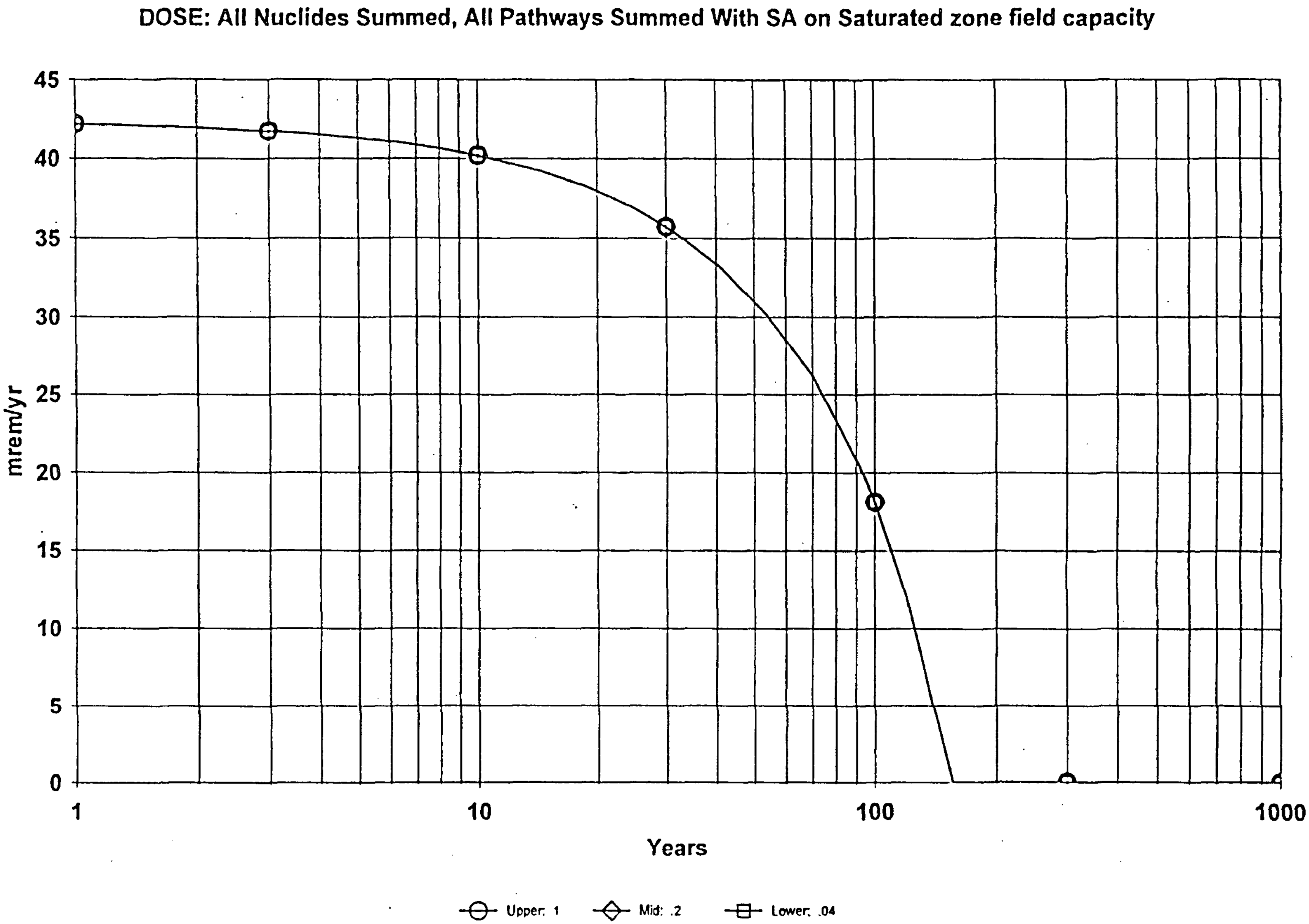


Ra022704.RAD 02/27/2004 10:22 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Saturated zone effective porosity

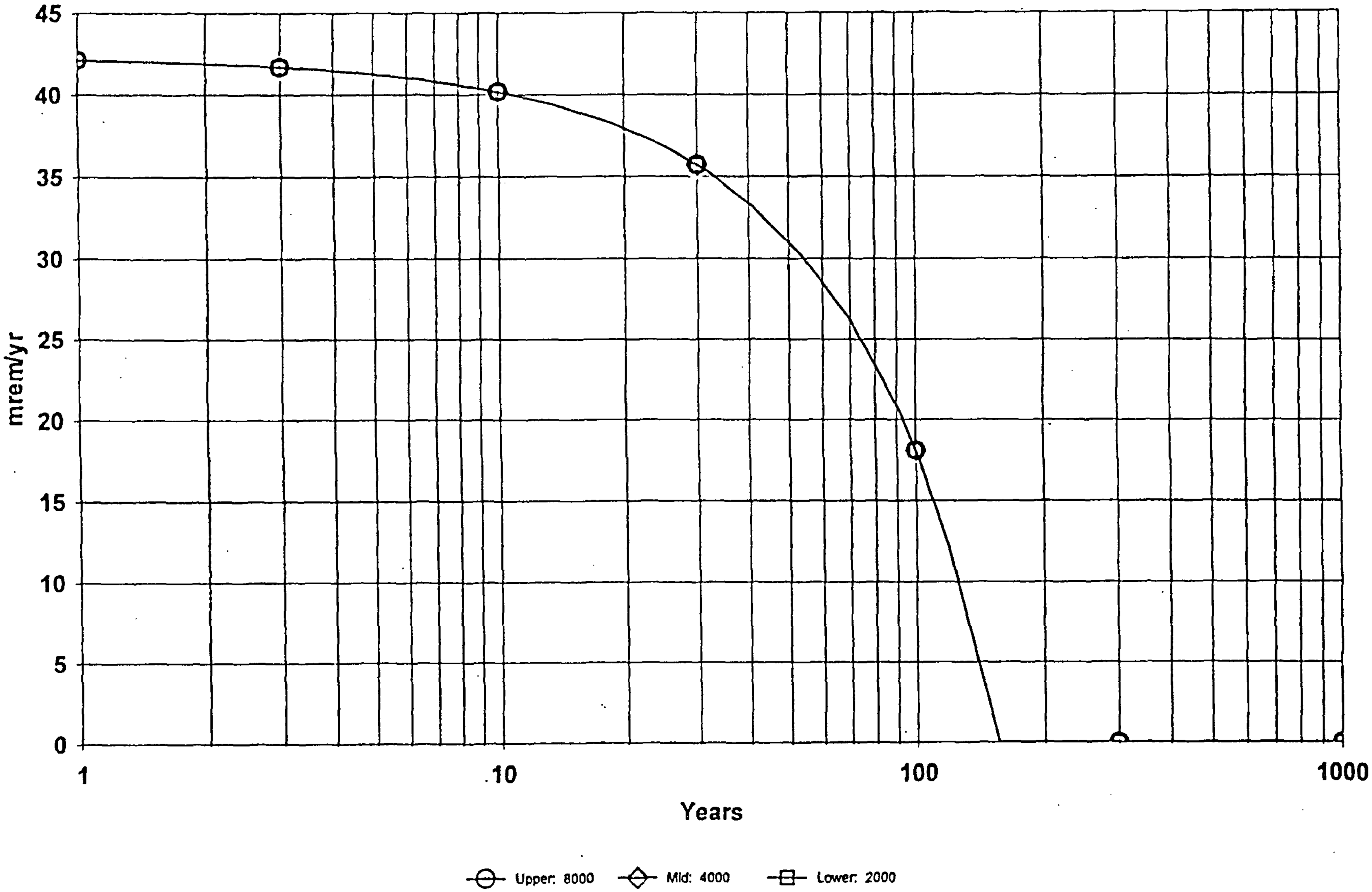


Ra022704.RAD 05/24/2004 16:52 Includes All Pathways



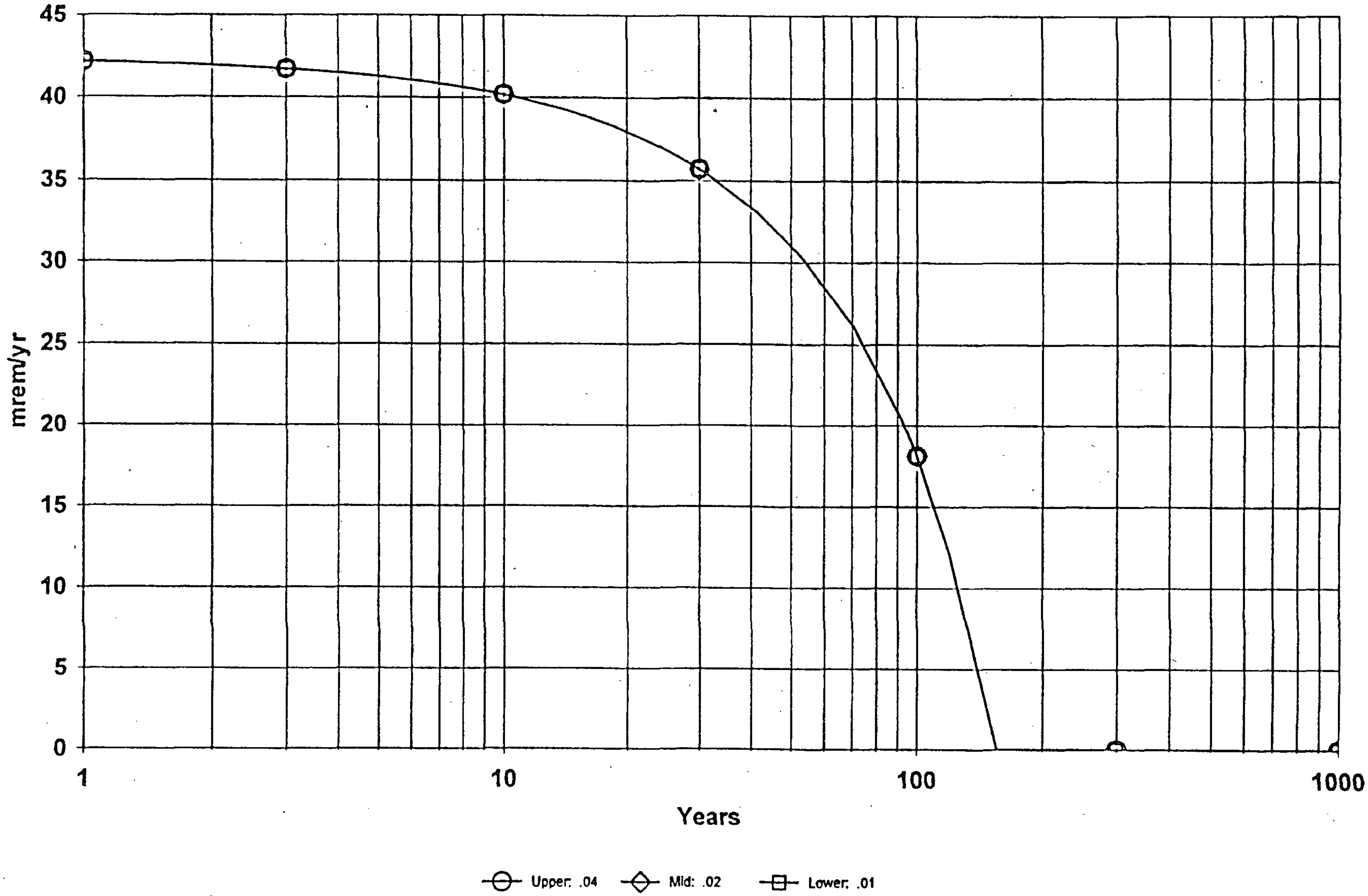
Ra022704.RAD 02/27/2004 16:11 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Saturated zone hydraulic conductivity



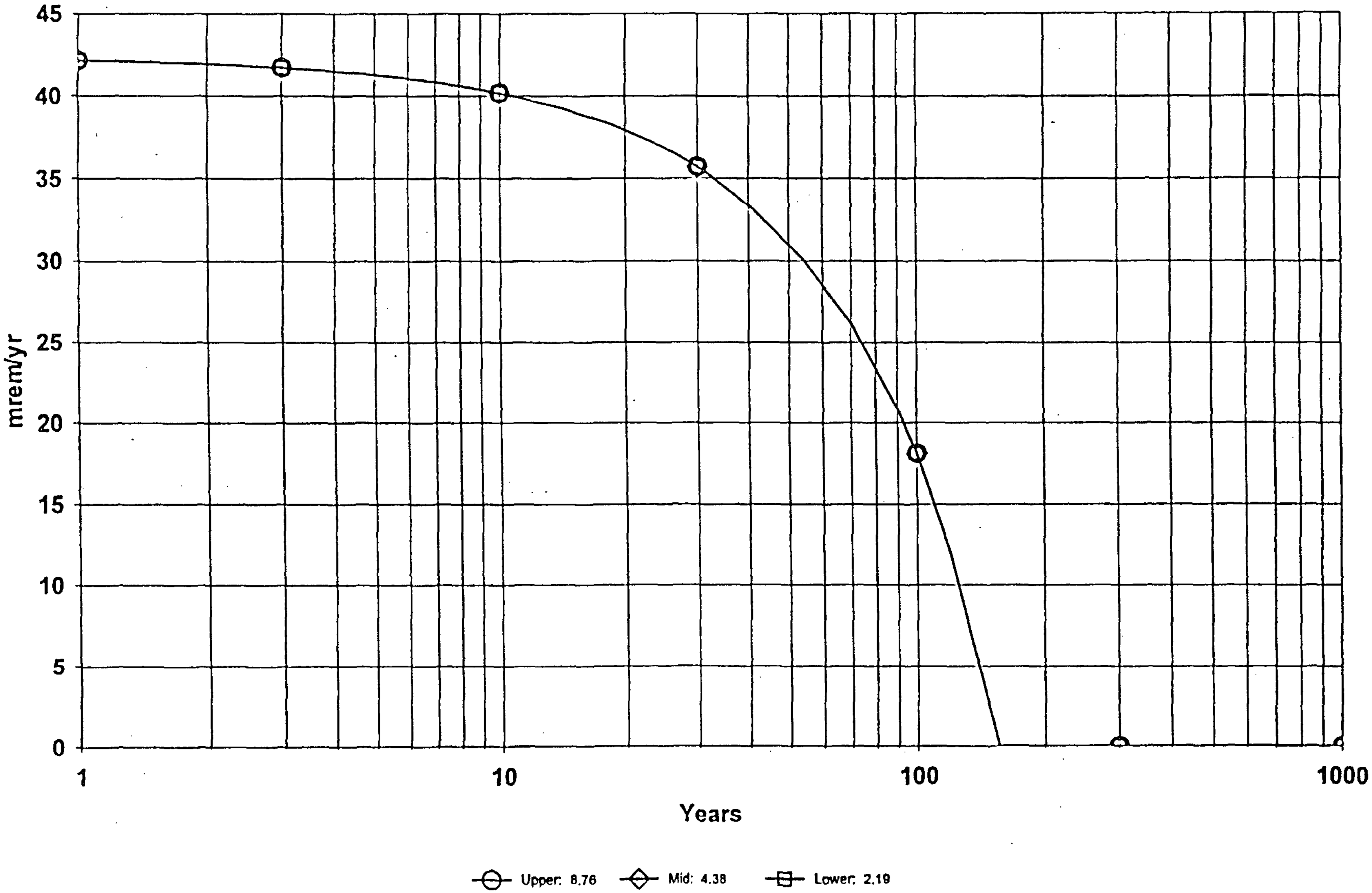
Ra022704.RAD 02/27/2004 15:34 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Saturated zone hydraulic gradient



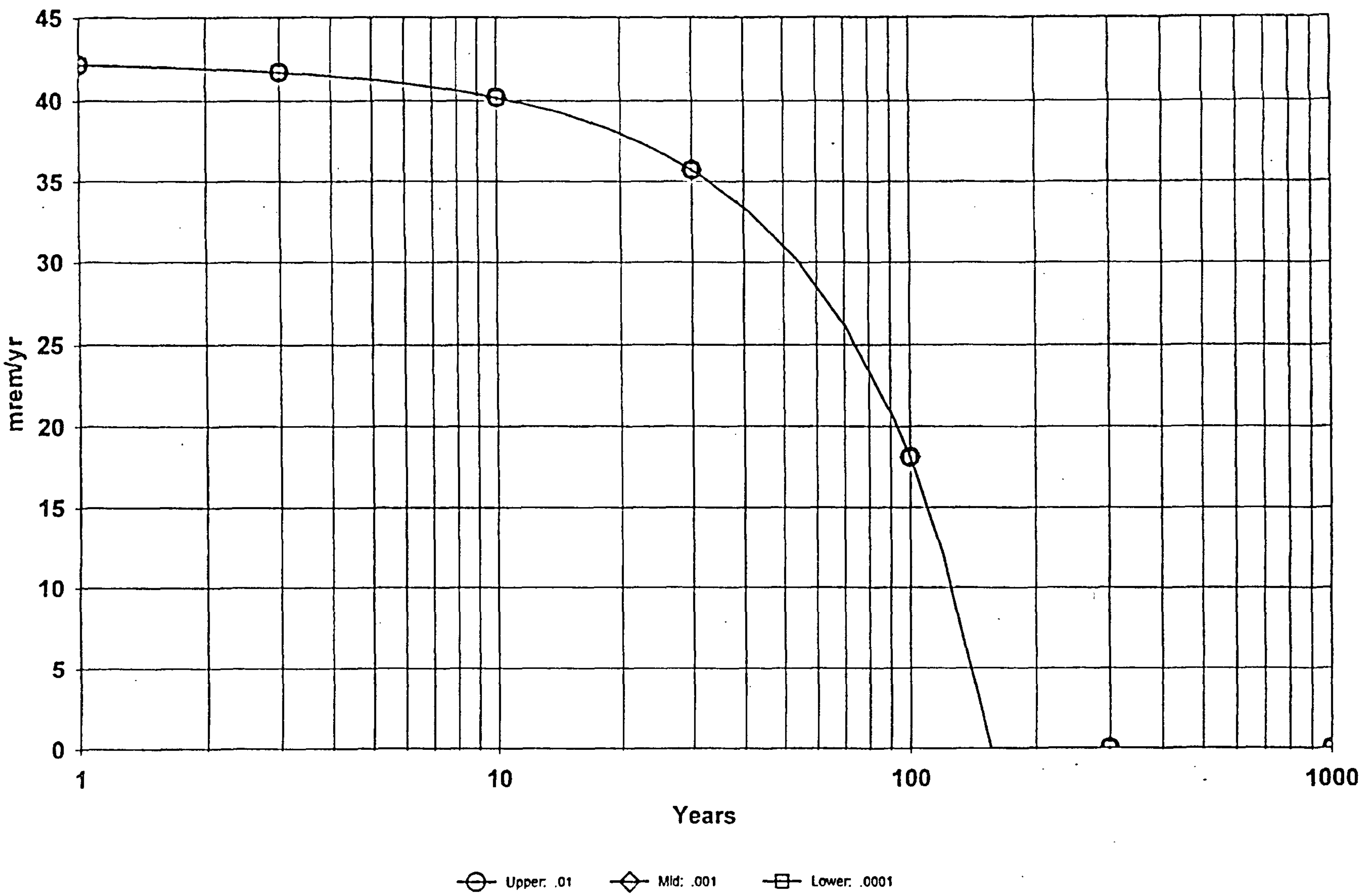
Ra022704.RAD 02/27/2004 10:35 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Saturated zone b parameter



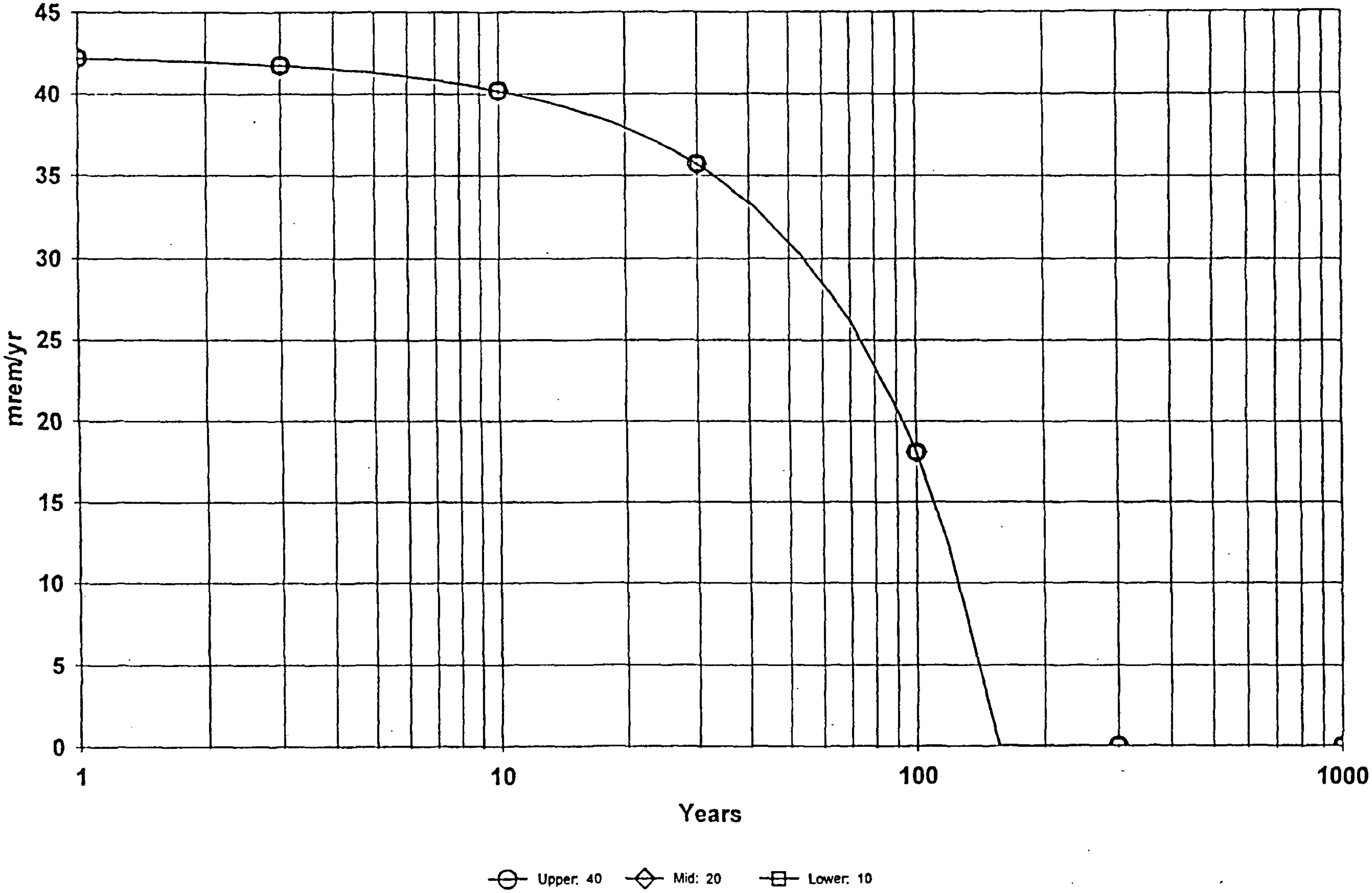
Ra022704.RAD 02/27/2004 10:35 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Water table drop rate

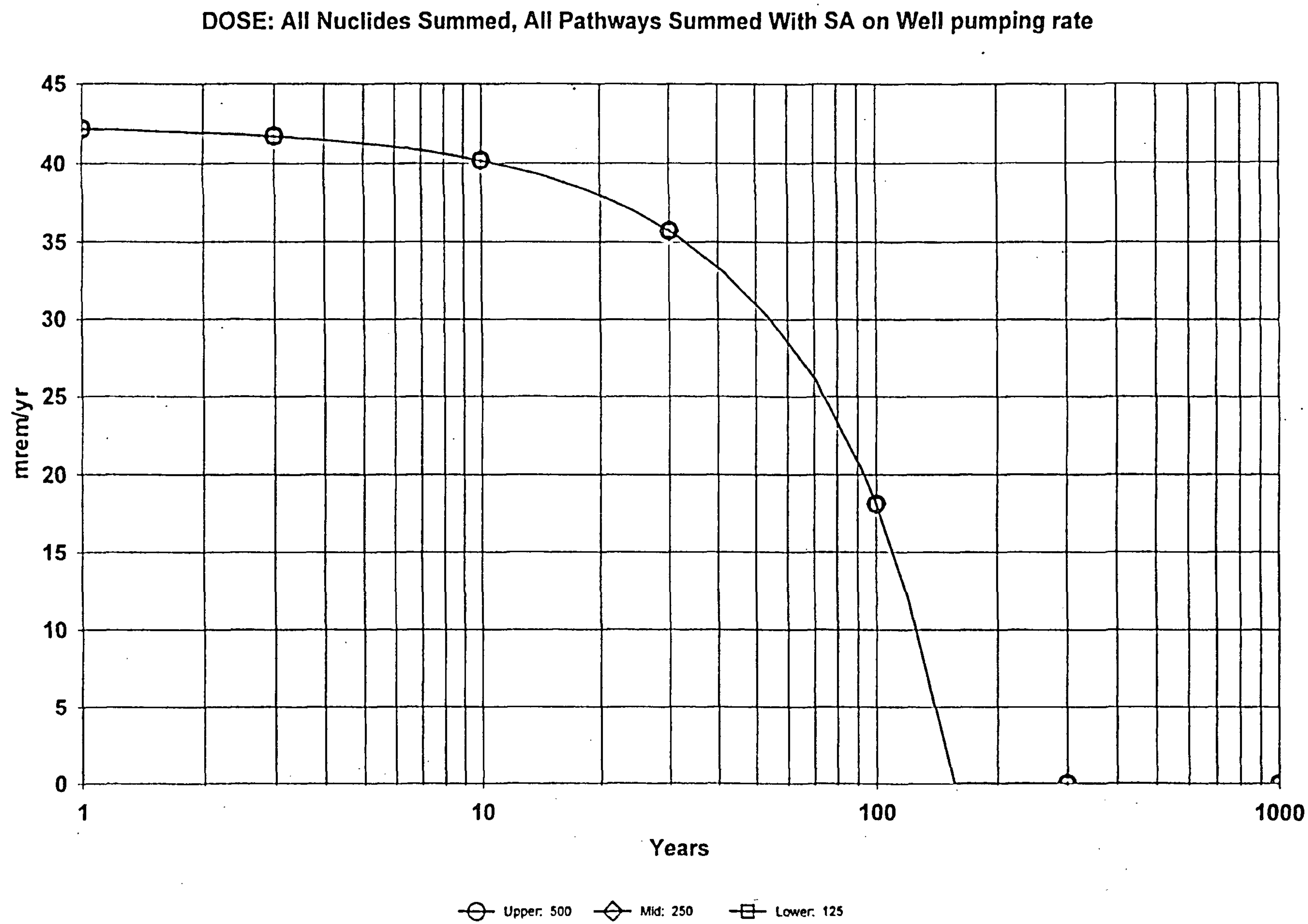


Ra022704.RAD 02/27/2004 10:35 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Well pump intake depth

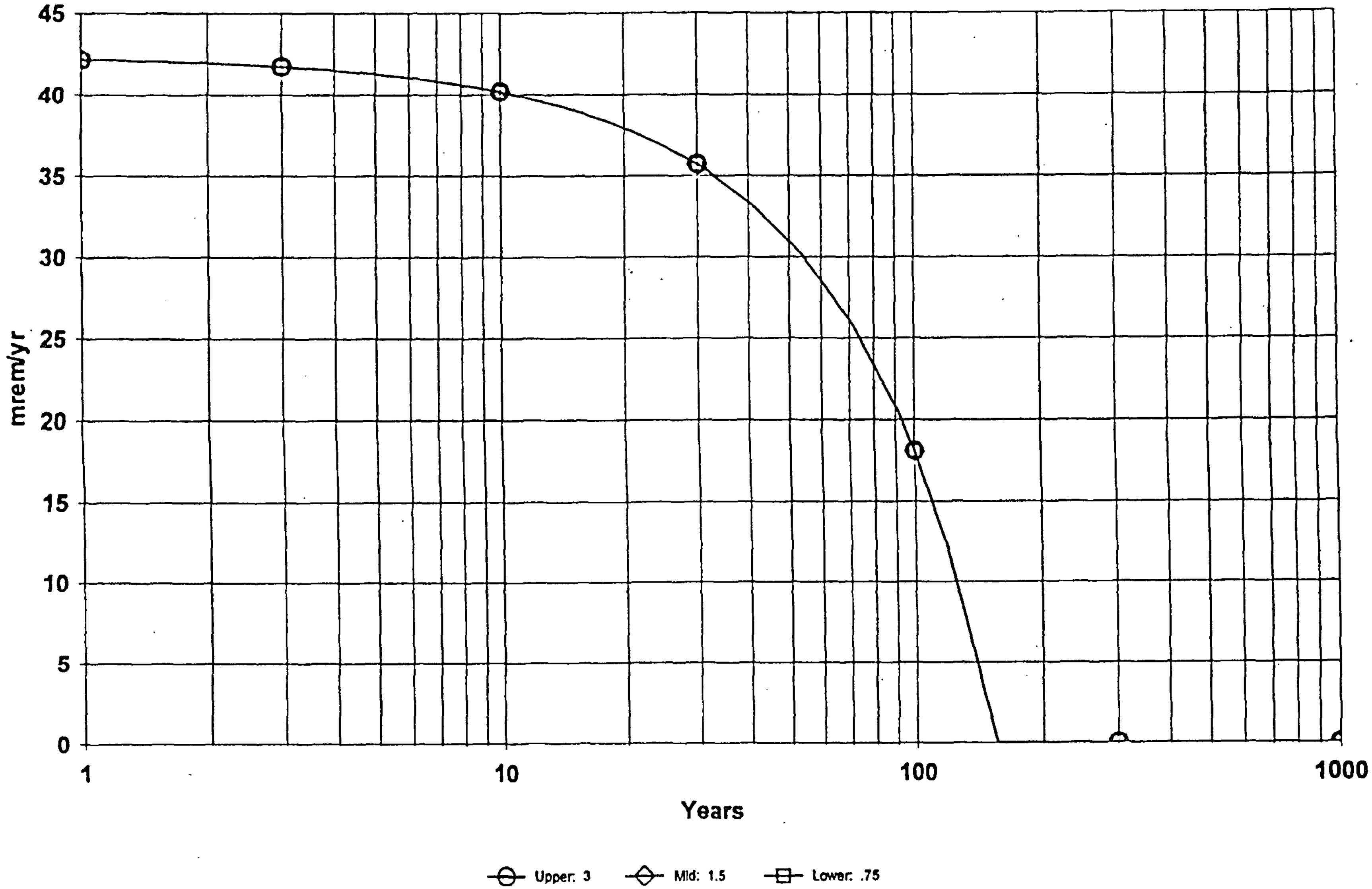


Ra022704.RAD 02/27/2004 10:35 Includes All Pathways



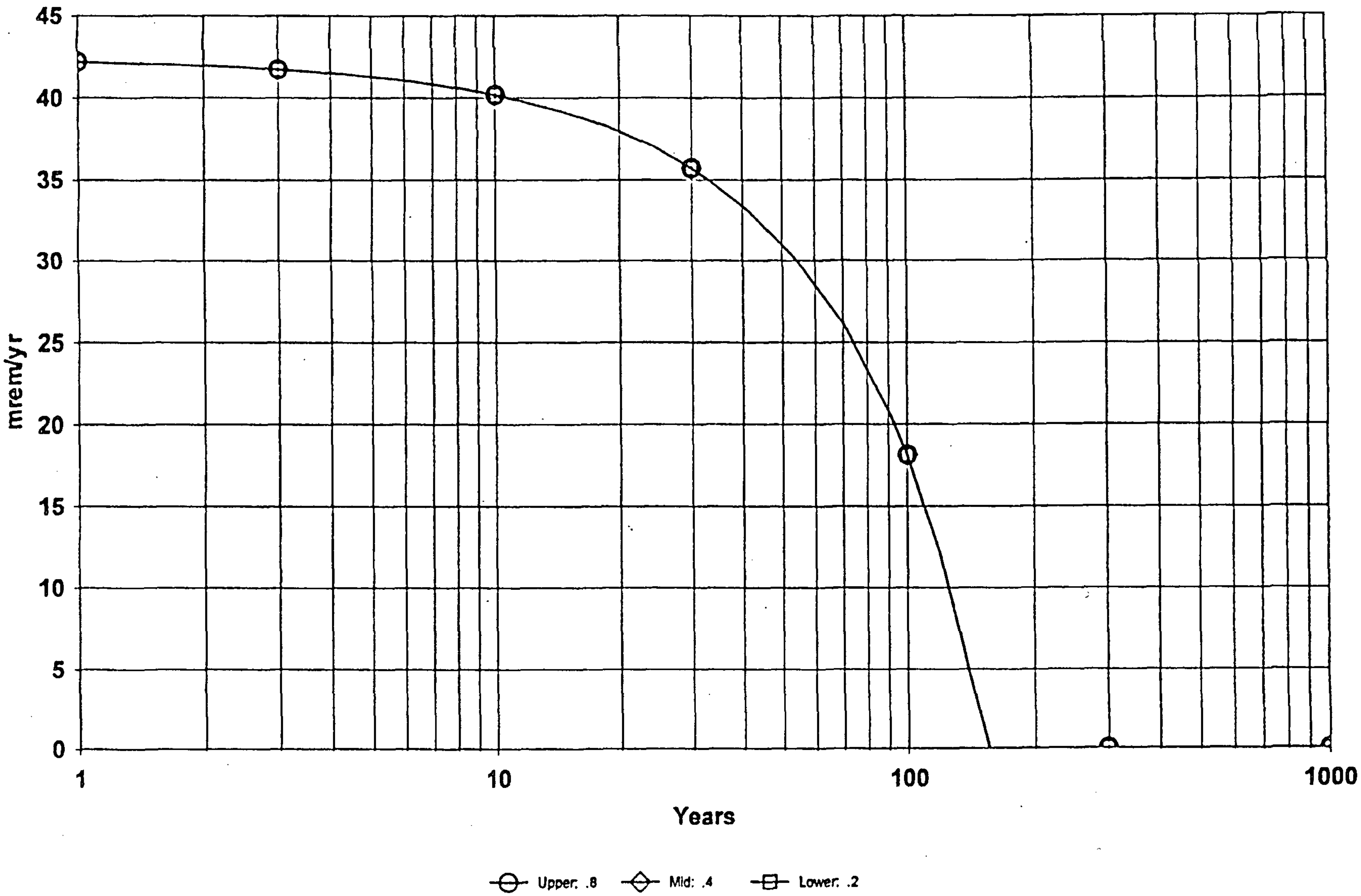
Ra022704.RAD 02/27/2004 10:35 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Density of Unsaturated Zone 1



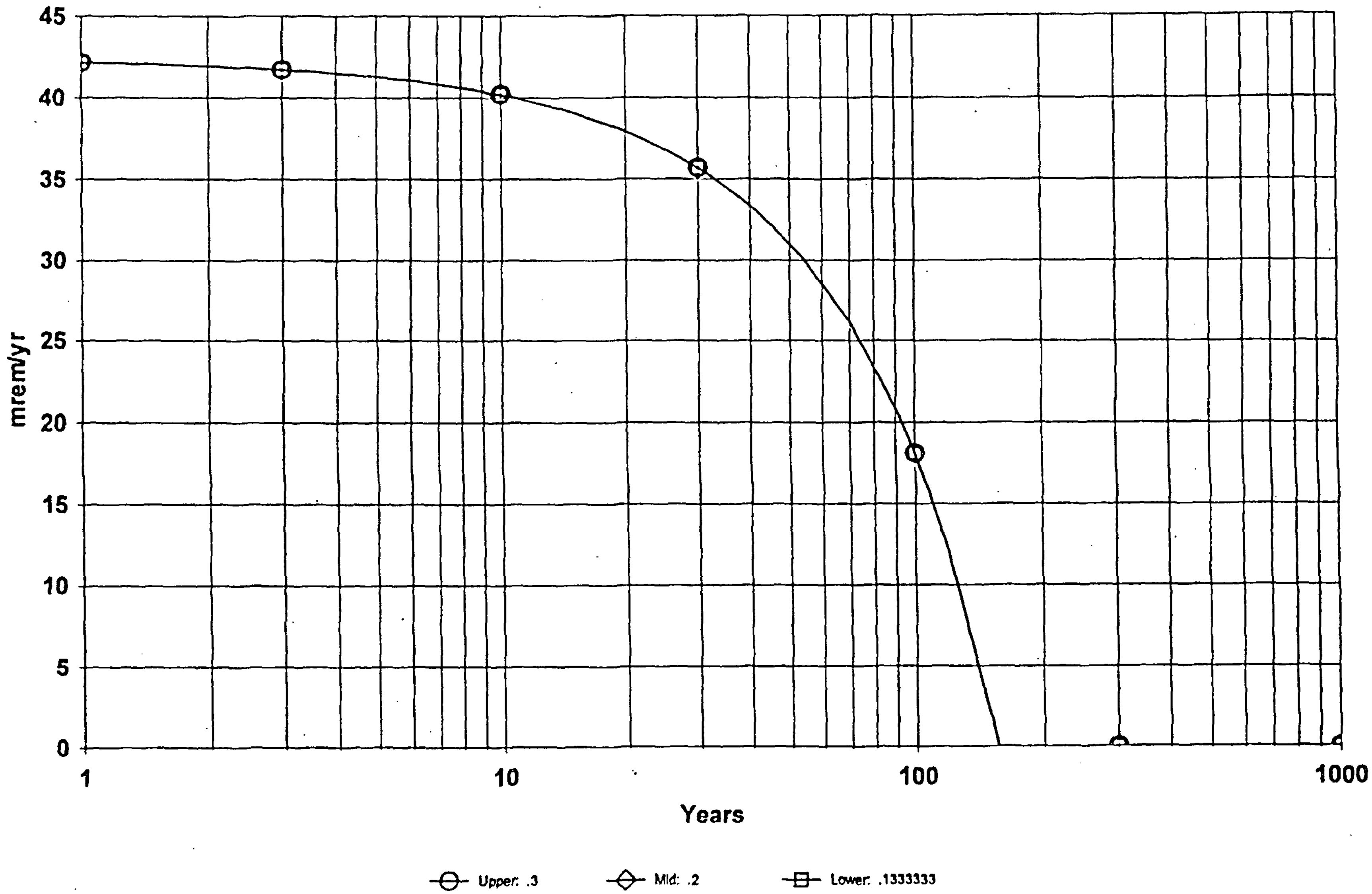
Ra022704.RAD 05/24/2004 17:32 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Total Porosity of Unsaturated Zone 1



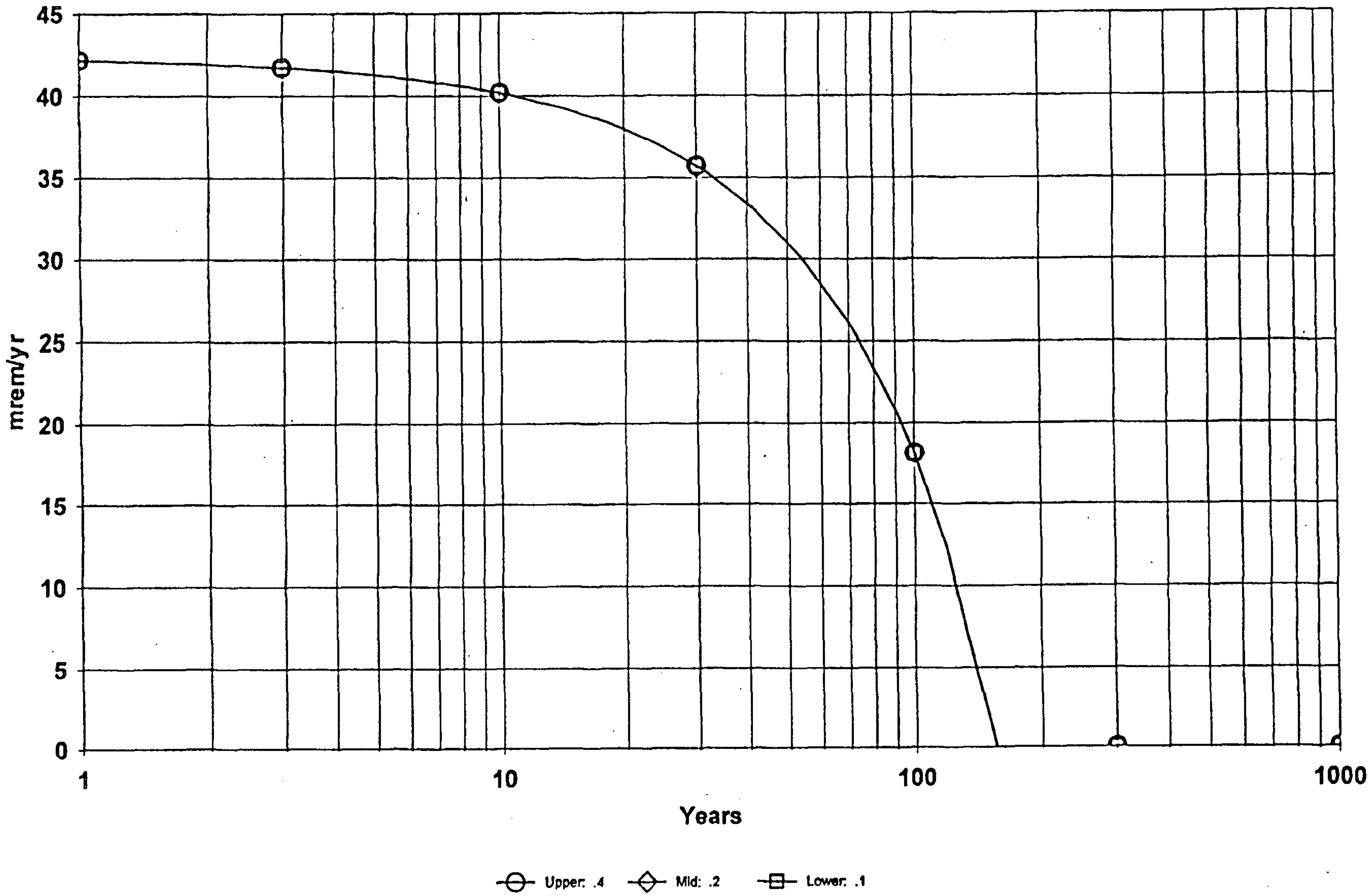
Ra022704.RAD 05/24/2004 17:32 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Effective Porosity of Unsaturated Zone 1



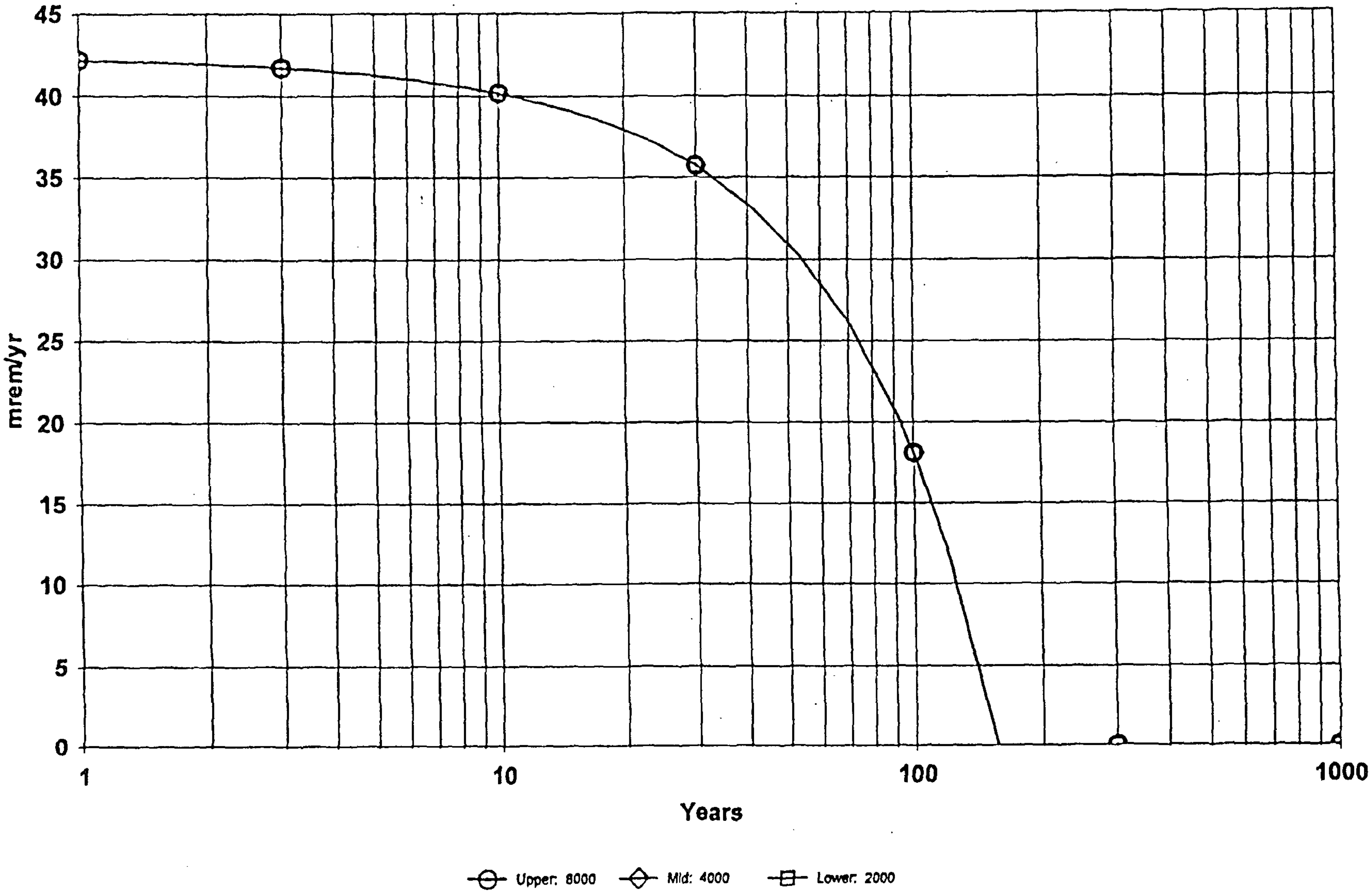
Ra022704.RAD 05/24/2004 17:32 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Field Capacity of Unsaturated Zone 1



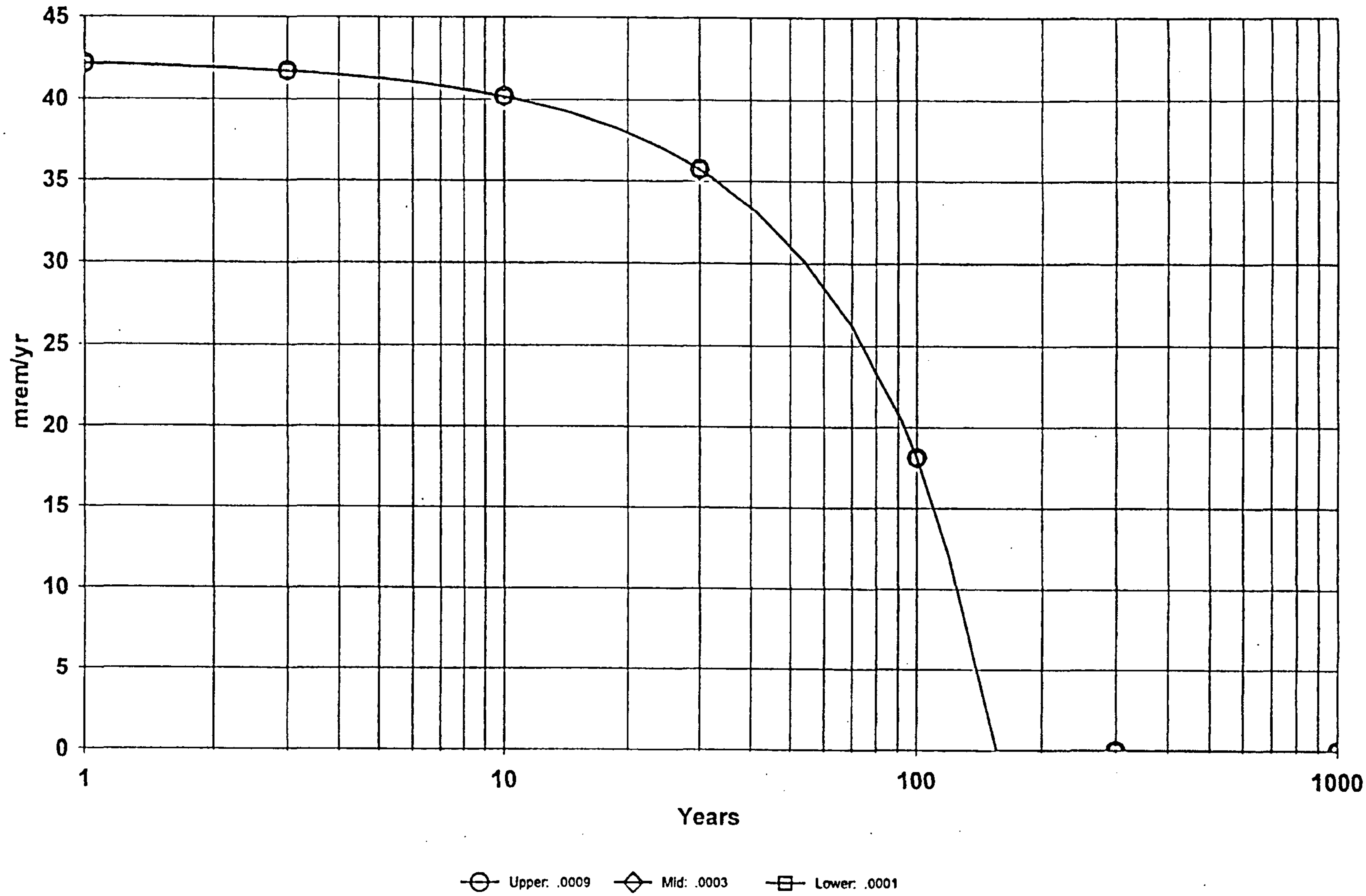
Ra022704.RAD 05/24/2004 17:32 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Hydraulic Conductivity of Unsaturated Zone 1



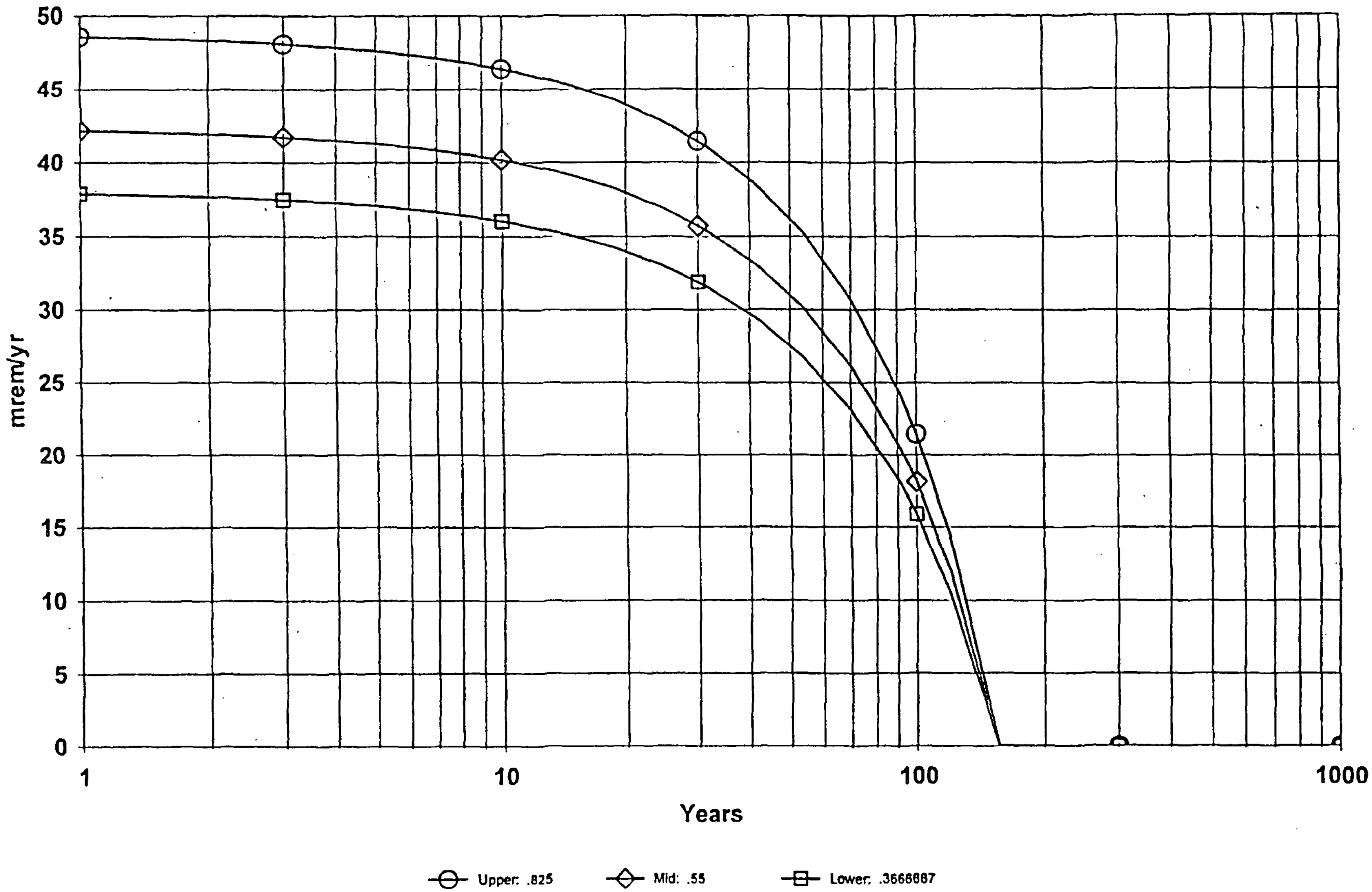
Ra022704.RAD 05/24/2004 17:32 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Mass loading for inhalation



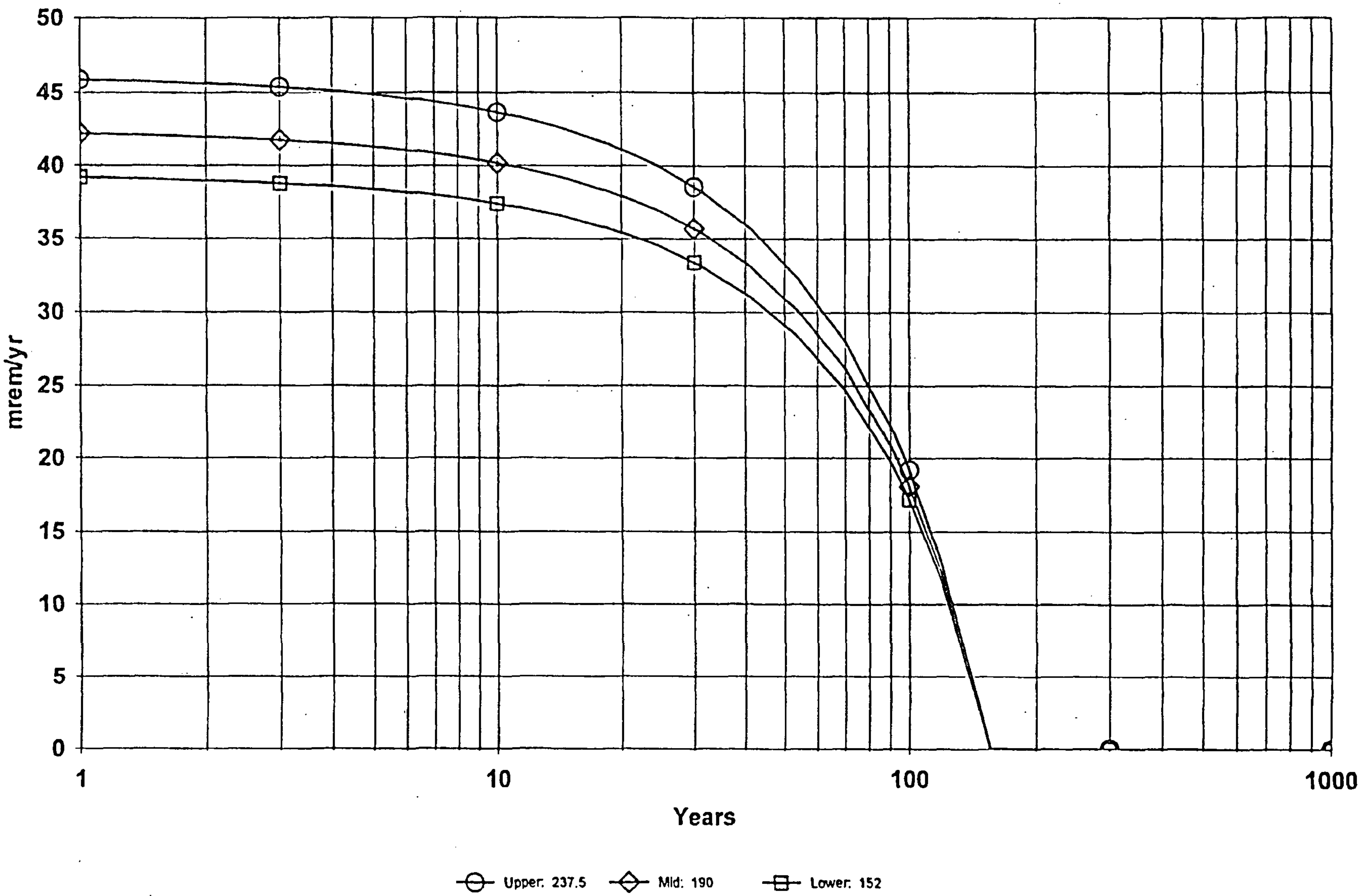
Ra022704.RAD 02/27/2004 14:38 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on External Gamma Shielding factor

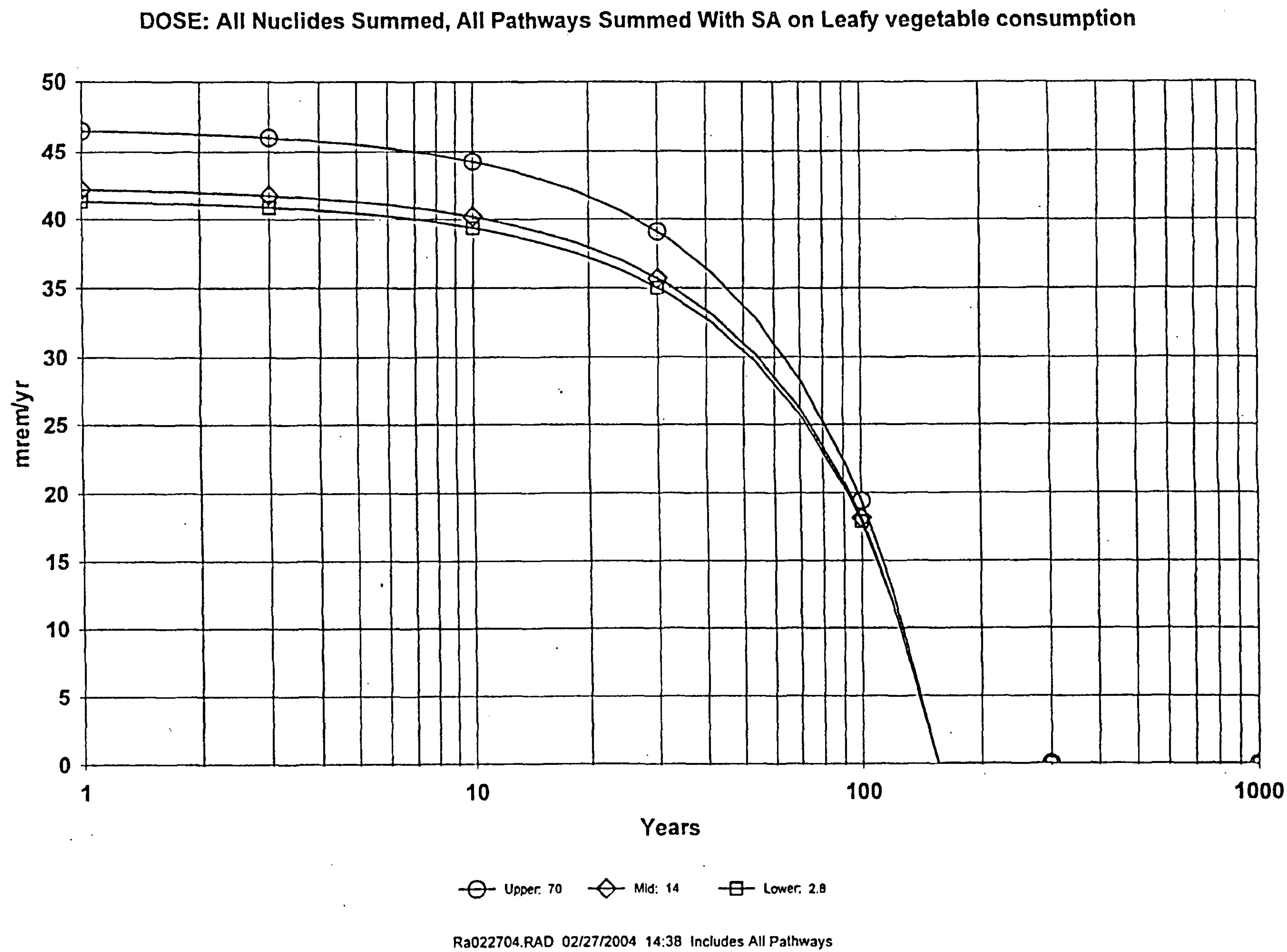


Ra022704.RAD 02/27/2004 14:38 Includes All Pathways

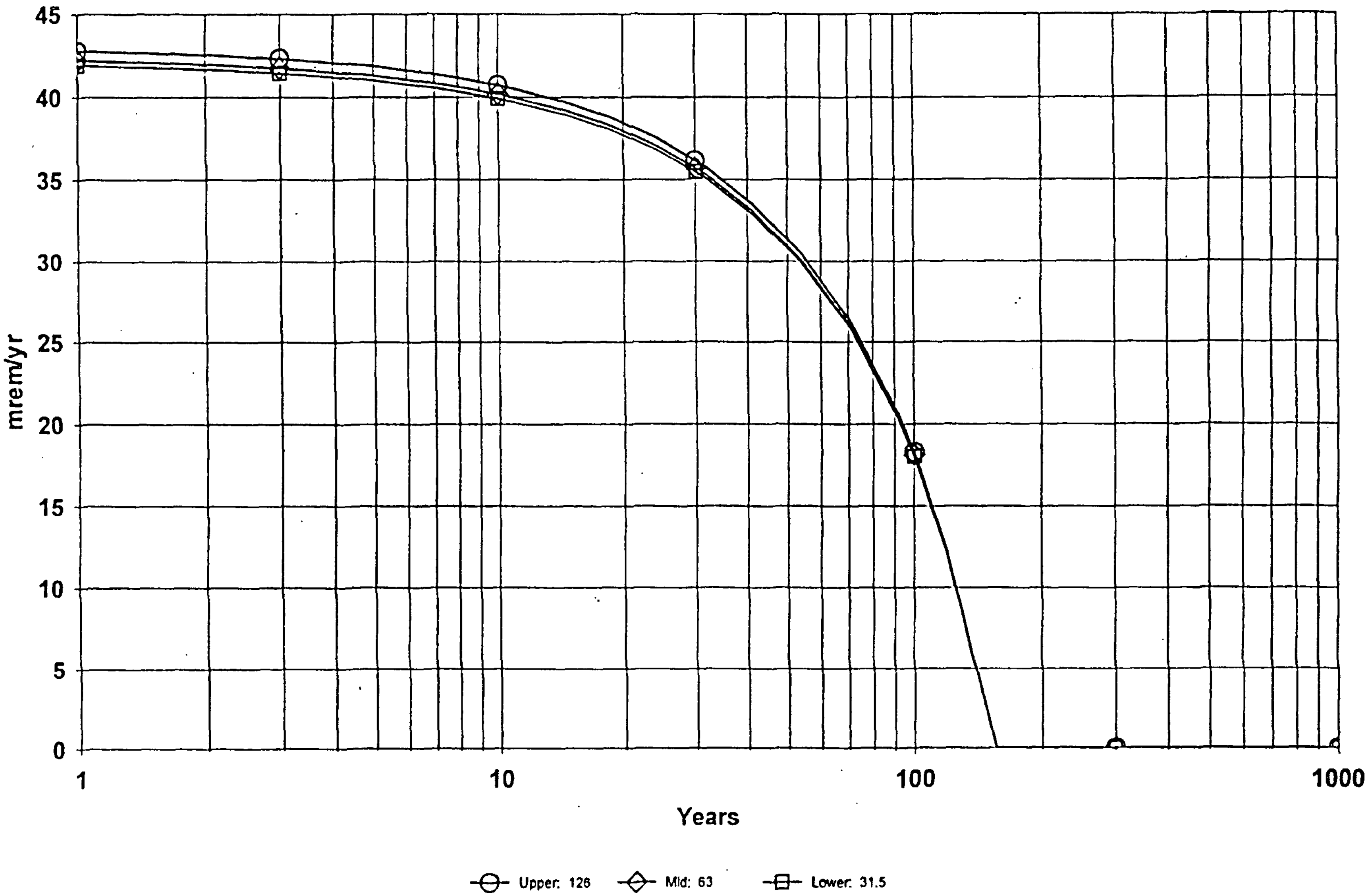
DOSE: All Nuclides Summed, All Pathways Summed With SA on Fruit, vegetable, and grain consumption



Ra022704.RAD 02/27/2004 14:38 Includes All Pathways

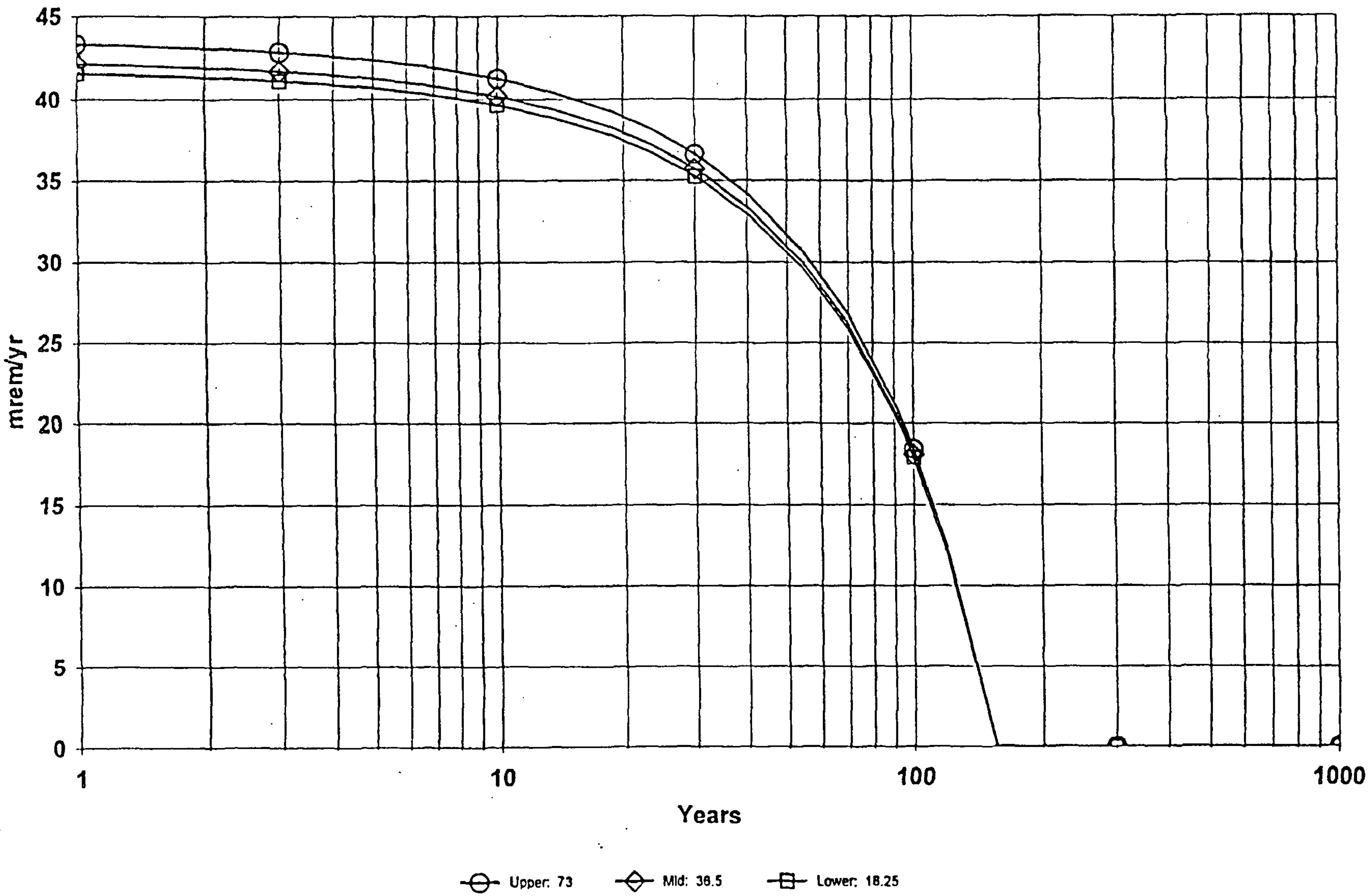

DOSE: All Nuclides Summed, All Pathways Summed With SA on Leafy vegetable consumption
50
45
40
35
30
25
20
15
10
5
0
mrem/yr
1
10
100
1000
Years
Upper: 70
Mid: 14
Lower: 2.8
Ra022704.RAD 02/27/2004 14:38 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Meat and poultry consumption



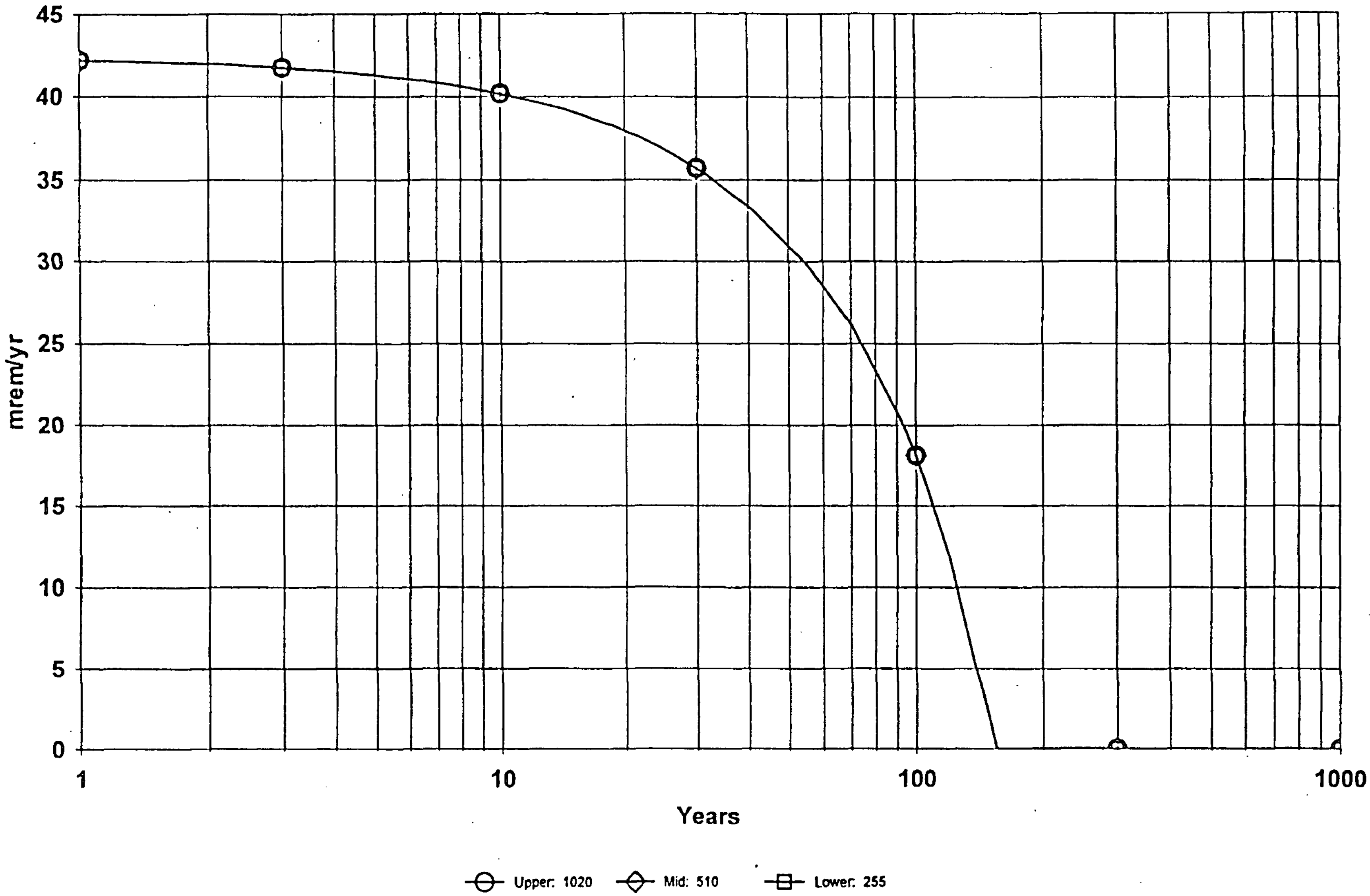
Ra022704.RAD 02/27/2004 14:38 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Soil ingestion



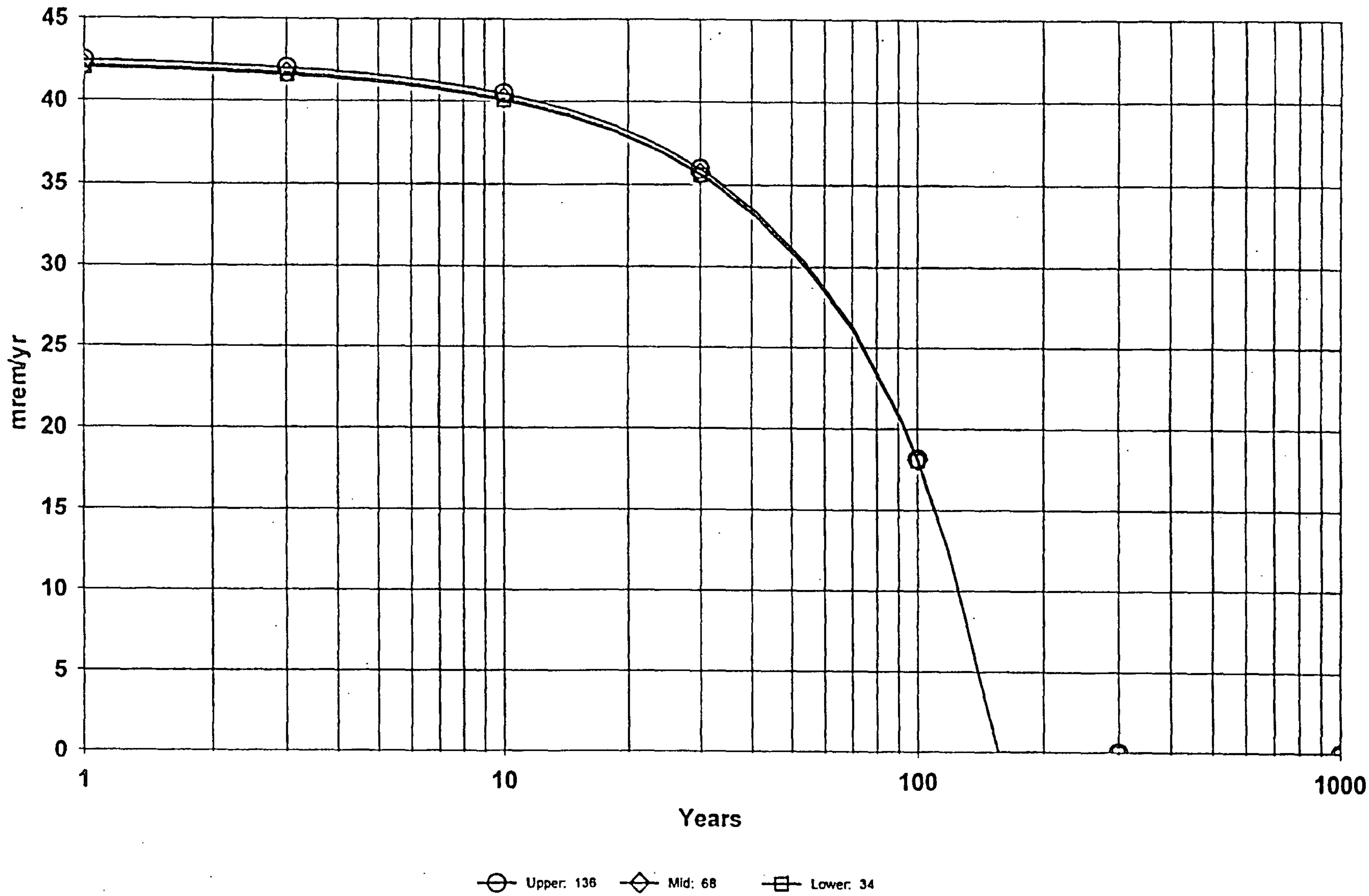
Ra022704.RAD 02/27/2004 11:01 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Drinking water intake



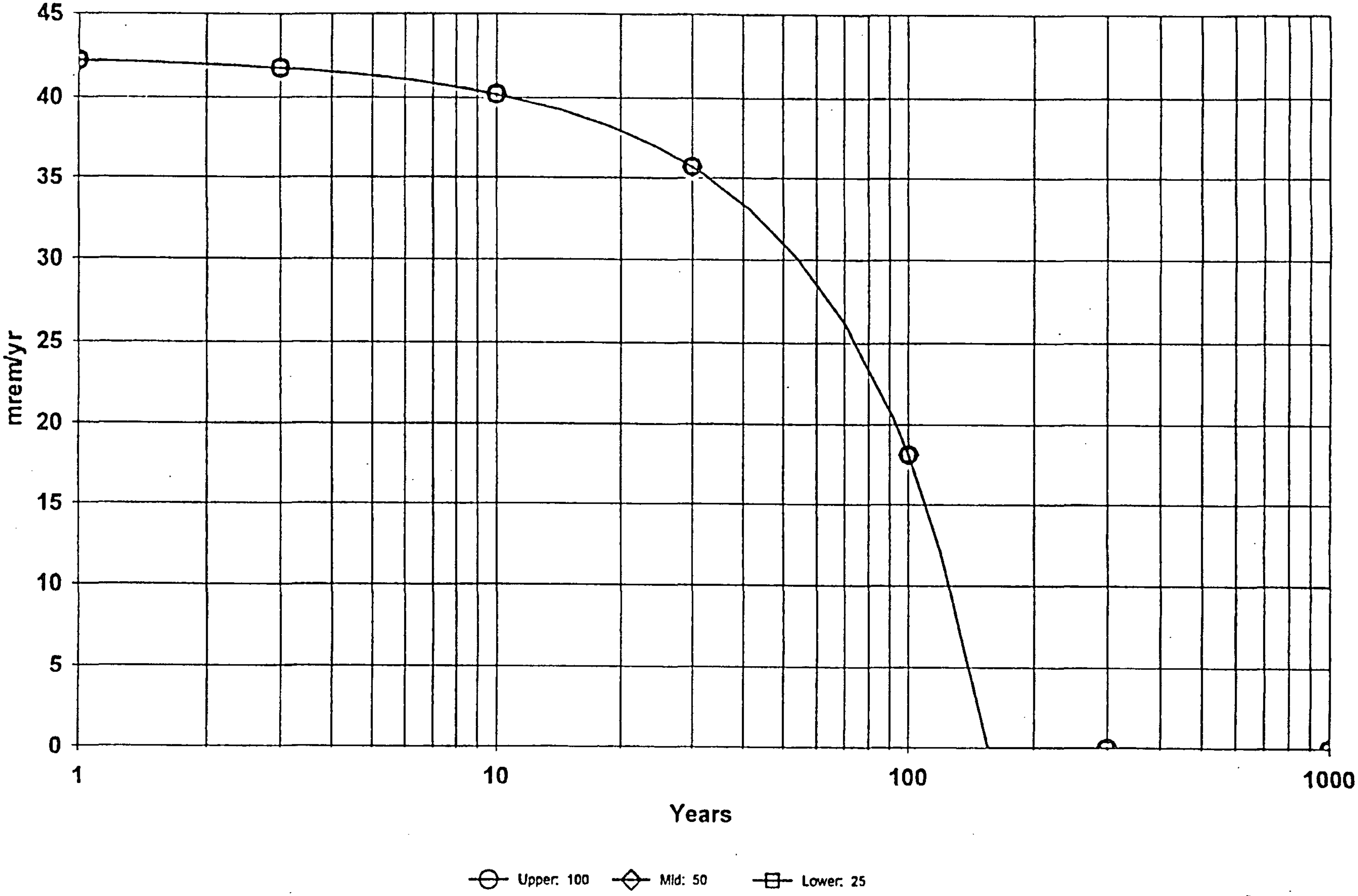
Ra022704.RAD 02/27/2004 11:01 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Livestock fodder intake for meat



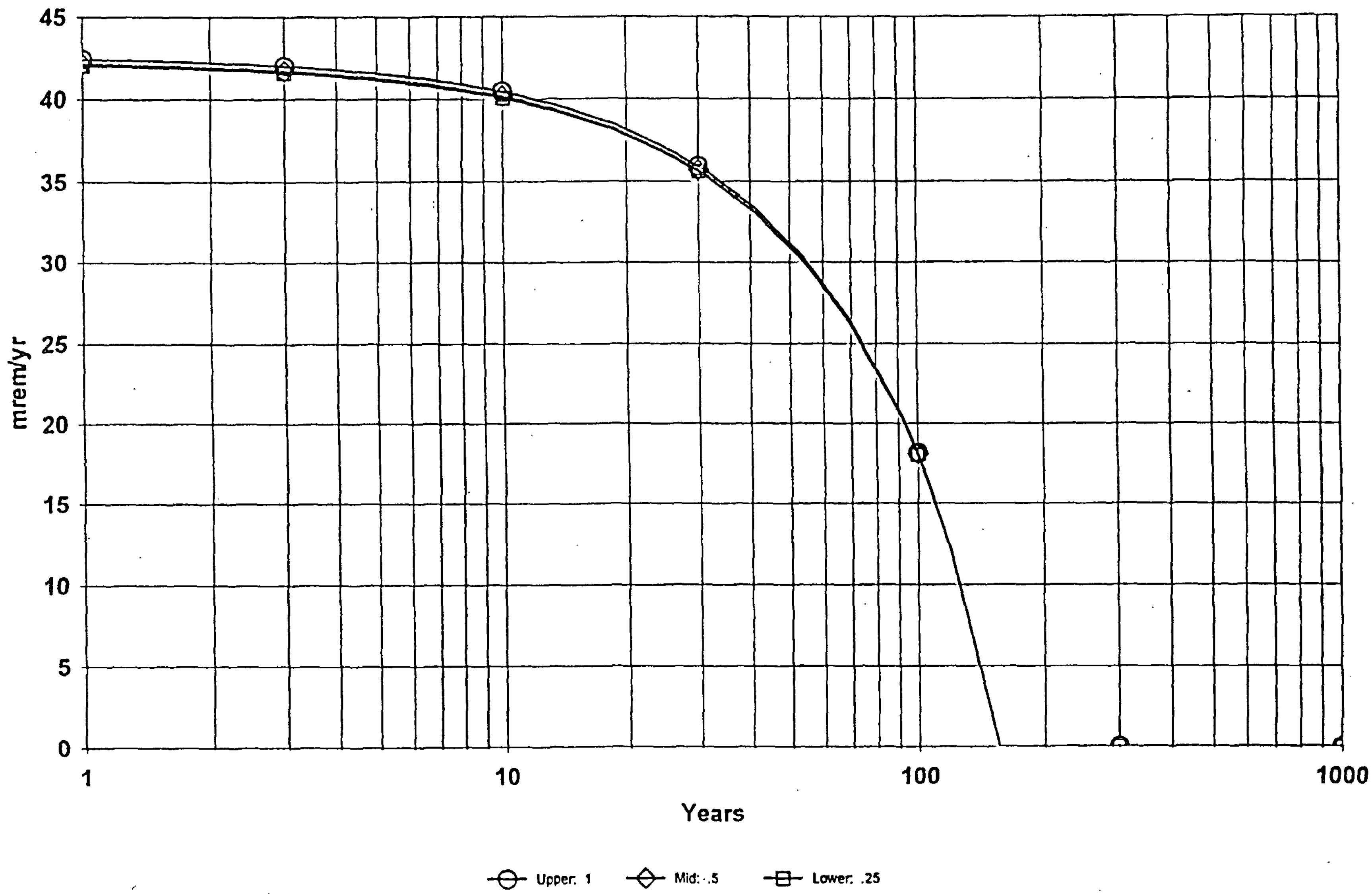
Ra022704.RAD 02/27/2004 11:01 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Livestock water intake for meat



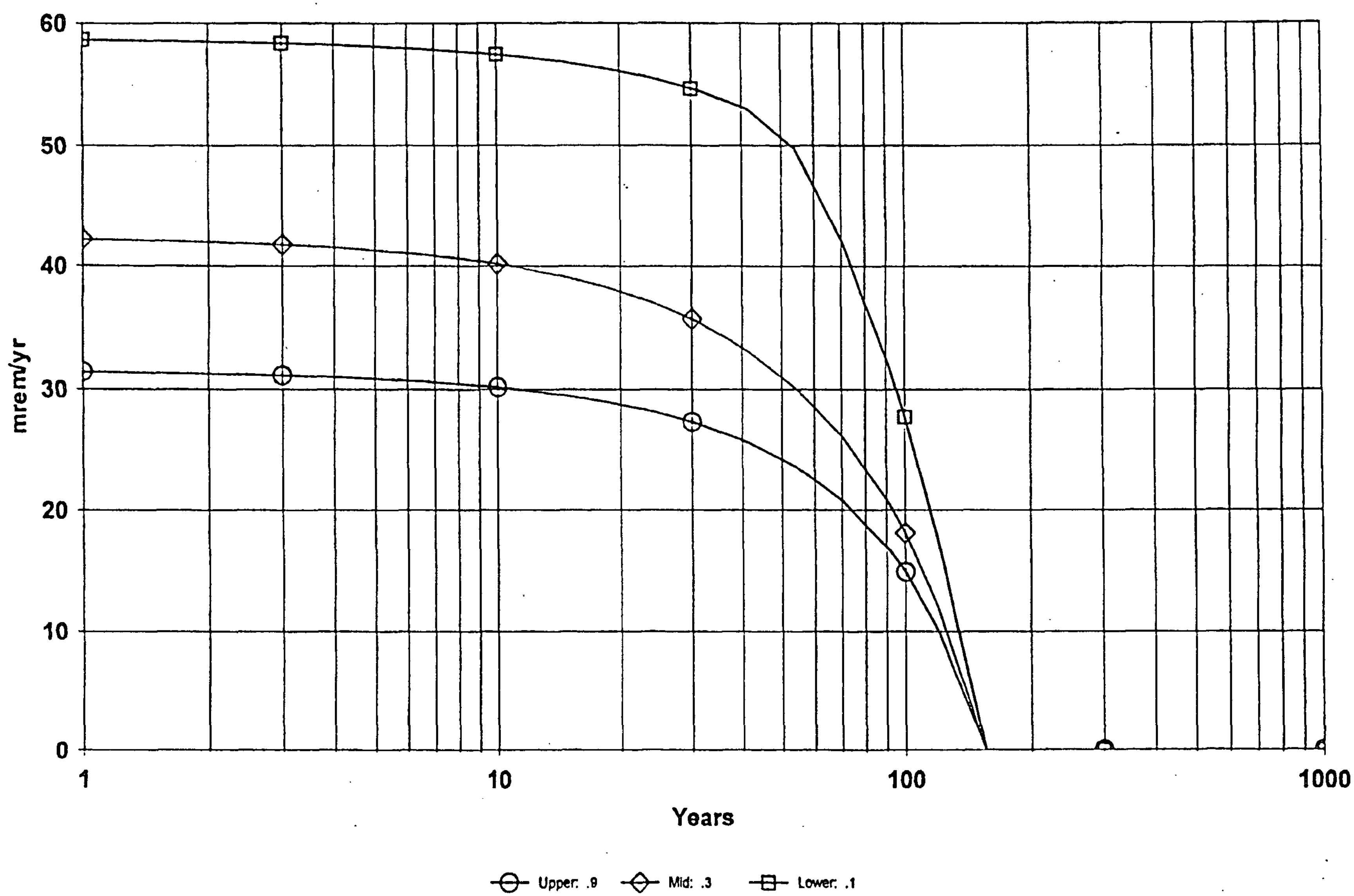
Ra022704.RAD 02/27/2004 11:01 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Livestock intake of soil



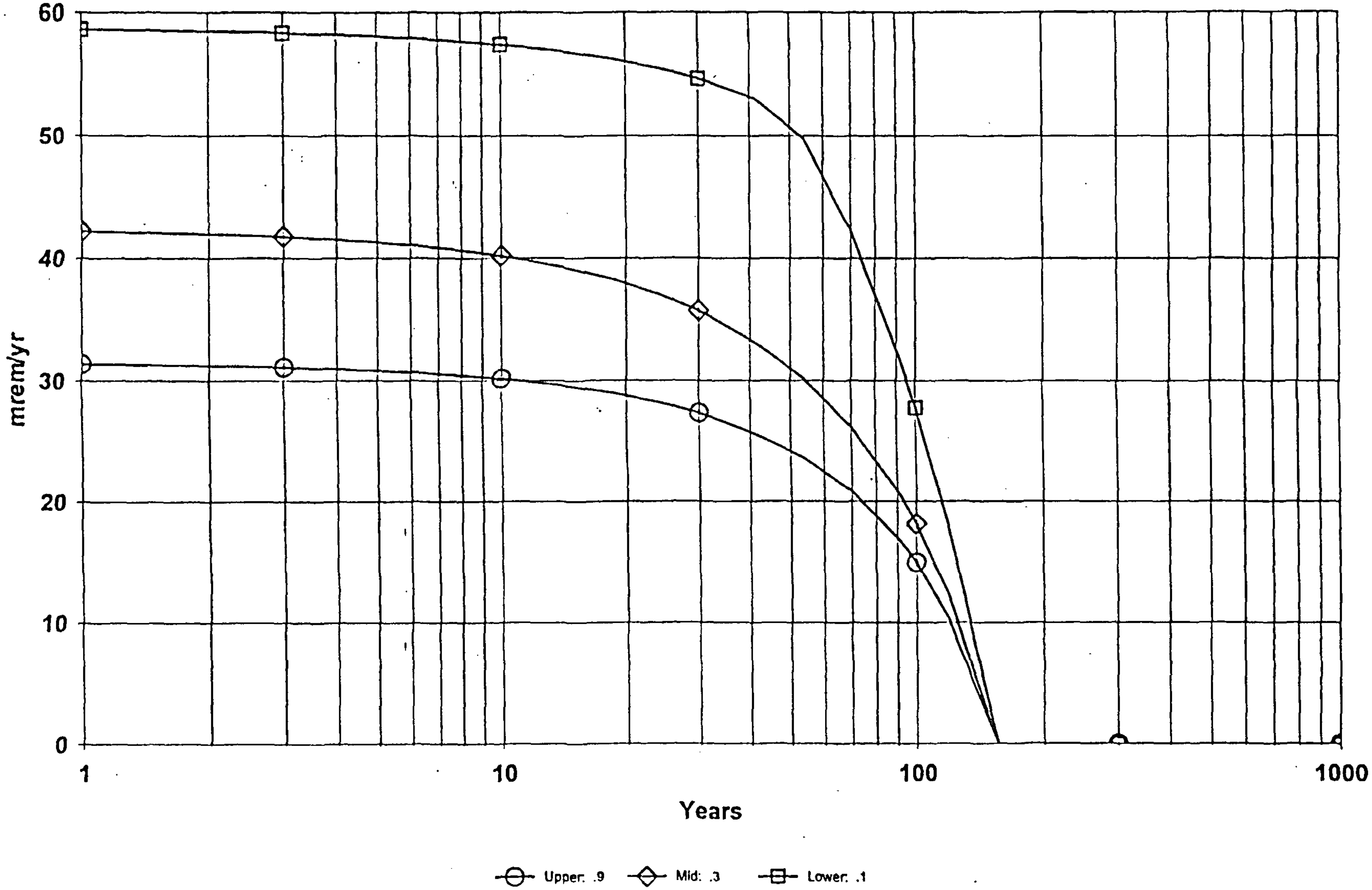
Ra022704.RAD 02/27/2004 11:01 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Depth of roots



Ra022704.RAD 05/25/2004 08:46 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Depth of roots



Ra022704.RAD 02/27/2004 11:09 Includes All Pathways

Radium Benchmark Dose Assessment

Attachment 3

RESRAD Model Output
Radium

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Dose Conversion Factor (and Related) Parameter Summary
File: HEAST 1995 Morbidity

	Parameter	Current Value	Default	Parameter Name
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Pb-210+D	2.320E-02	2.320E-02	DCF2(1)
B-1	Ra-226+D	8.600E-03	8.600E-03	DCF2(2)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Pb-210+D	7.270E-03	7.270E-03	DCF3(1)
D-1	Ra-226+D	1.330E-03	1.330E-03	DCF3(2)
D-34	Food transfer factors:			
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(1,1)
D-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(1,2)
D-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(1,3)
D-34				
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(2,1)
D-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(2,2)
D-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(2,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIOFAC(1,1)
D-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(1,2)
D-5				
D-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIOFAC(2,1)
D-5	Ra-226+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(2,2)

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
[illegible]	Area of contaminated zone (m**2)	1.000E+04	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	1.500E-01	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	1.000E+02	2.500E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Pb-210	5.000E+00	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Ra-226	5.000E+00	0.000E+00	---	S1(2)
R012	Concentration in groundwater (pCi/L): Pb-210	not used	0.000E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(2)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.500E+00	1.500E+00	---	DENSCZ
P	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R	Contaminated zone total porosity	4.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	2.000E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	4.000E+03	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	4.380E+00	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	4.300E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	7.500E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	3.900E-01	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	0.000E+00	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	3.630E+07	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	1.000E-03	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	1.500E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	4.000E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	2.000E-01	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	4.000E+03	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	4.380E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	2.000E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R0	Well pumping rate (m**3/yr)	2.500E+02	2.500E+02	---	UW

Site-Specific Parameter Summary (continued)

	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
	Number of unsaturated zone strata	1	1	---	NS
R015	Unsat. zone 1, thickness (m)	1.500E+01	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.500E+00	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	4.000E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	2.000E-01	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	4.380E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	4.000E+03	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Pb-210				
R016	Contaminated zone (cm**3/g)	2.700E+02	1.000E+02	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	2.700E+02	1.000E+02	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	2.700E+02	1.000E+02	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.283E-03	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R016	Distribution coefficients for Ra-226				
R016	Contaminated zone (cm**3/g)	5.000E+02	7.000E+01	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+02	7.000E+01	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	5.000E+02	7.000E+01	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	6.931E-04	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R017	Inhalation rate (m**3/yr)	8.400E+03	8.400E+03	---	INHALR
	Mass loading for inhalation (g/m**3)	3.000E-04	1.000E-04	---	MLINH
	Exposure duration	3.000E+01	3.000E+01	---	ED
	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	5.500E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	5.000E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	2.500E-01	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R0	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	1.900E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	1.400E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	6.300E+01	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	5.100E+02	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	1.000E+00	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R	Contamination fraction of livestock water	1.000E+00	1.000E+00	---	FLW
R0	Contamination fraction of irrigation water	1.000E+00	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	2.500E-01	-1	---	FPLANT
R018	Contamination fraction of meat	2.500E-01	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	5.000E-01	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	3.000E-04	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	3.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	7.000E-01	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	1.500E+00	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	1.100E+00	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	1.700E-01	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	2.500E-01	2.500E-01	---	TE(2)
R	Growing Season for Fodder (years)	8.000E-02	8.000E-02	---	TE(3)
R	Translocation Factor for Non-Leafy	1.000E-01	1.000E-01	---	TIV(1)

Site-Specific Parameter Summary (continued)

	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
[illegible]	Translocation Factor for Leafy	1.000E+00	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	1.000E+00	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	2.000E+01	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
C14	DCF correction factor for gaseous forms of C14	not used	8.894E+01	---	CO2F
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
[illegible]	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
[illegible]	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
[illegible]	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
[illegible]	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR1
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)
[illegible]	Number of graphical time points	32	---	---	NPTS
	Maximum number of integration points for dose	17	---	---	LYMAX

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
T11	Maximum number of integration points for risk	257	---	---	KYMAX

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	active
4 -- meat ingestion	active
5 -- milk ingestion	suppressed
6 -- aquatic foods	suppressed
7 -- drinking water	active
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	active

Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	10000.00 square meters	Pb-210	5.000E+00
Thickness:	0.15 meters	Ra-226	5.000E+00
Cover Depth:	0.00 meters		

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 1.000E+02 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	4.237E+01	4.216E+01	4.172E+01	4.018E+01	3.570E+01	1.810E+01	0.000E+00	0.000E+00
M(t):	4.237E-01	4.216E-01	4.172E-01	4.018E-01	3.570E-01	1.810E-01	0.000E+00	0.000E+00

Maximum TDOSE(t): 4.237E+01 mrem/yr at t = 0.000E+00 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	1.528E-02	0.0004	1.027E-02	0.0002	0.000E+00	0.0000	9.096E+00	0.2147	3.778E-01	0.0089	0.000E+00	0.0000	9.759E-01	0.0230
Ra-226	2.457E+01	0.5798	4.028E-03	0.0001	0.000E+00	0.0000	6.927E+00	0.1635	2.027E-01	0.0048	0.000E+00	0.0000	1.966E-01	0.0046
Total	2.458E+01	0.5802	1.430E-02	0.0003	0.000E+00	0.0000	1.602E+01	0.3781	5.805E-01	0.0137	0.000E+00	0.0000	1.172E+00	0.0277

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.048E+01	0.2472
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.190E+01	0.7528
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.237E+01	1.0000

* [illegible]f all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	1.479E-02	0.0004	9.879E-03	0.0002	0.000E+00	0.0000	8.748E+00	0.2075	3.634E-01	0.0086	0.000E+00	0.0000	9.385E-01	0.0223
Ra-226	2.449E+01	0.5809	4.309E-03	0.0001	0.000E+00	0.0000	7.154E+00	0.1697	2.130E-01	0.0051	0.000E+00	0.0000	2.247E-01	0.0053
Total	2.451E+01	0.5812	1.419E-02	0.0003	0.000E+00	0.0000	1.590E+01	0.3772	5.764E-01	0.0137	0.000E+00	0.0000	1.163E+00	0.0276

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.007E+01	0.2389
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.209E+01	0.7611
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.216E+01	1.0000

›f all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Pb-210	1.385E-02	0.0003	9.135E-03	0.0002	0.000E+00	0.0000	8.089E+00	0.1939	3.360E-01	0.0081	0.000E+00	0.0000	8.678E-01	0.0208
Ra-226	2.433E+01	0.5832	4.827E-03	0.0001	0.000E+00	0.0000	7.561E+00	0.1812	2.312E-01	0.0055	0.000E+00	0.0000	2.768E-01	0.0066
Total	2.435E+01	0.5835	1.396E-02	0.0003	0.000E+00	0.0000	1.565E+01	0.3751	5.672E-01	0.0136	0.000E+00	0.0000	1.145E+00	0.0274

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.316E+00	0.2233
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.241E+01	0.7767
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.172E+01	1.0000

* ...of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	1.101E-02	0.0003	6.935E-03	0.0002	0.000E+00	0.0000	6.141E+00	0.1528	2.551E-01	0.0063	0.000E+00	0.0000	6.588E-01	0.0164
Ra-226	2.376E+01	0.5914	6.247E-03	0.0002	0.000E+00	0.0000	8.636E+00	0.2150	2.805E-01	0.0070	0.000E+00	0.0000	4.217E-01	0.0105
Total	2.377E+01	0.5917	1.318E-02	0.0003	0.000E+00	0.0000	1.478E+01	0.3678	5.356E-01	0.0133	0.000E+00	0.0000	1.081E+00	0.0269

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.073E+00	0.1760
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.311E+01	0.8240
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.018E+01	1.0000

...of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Pb-210	5.691E-03	0.0002	3.110E-03	0.0001	0.000E+00	0.0000	2.754E+00	0.0771	1.144E-01	0.0032	0.000E+00	0.0000	2.954E-01	0.0083
Ra-226	2.196E+01	0.6153	7.917E-03	0.0002	0.000E+00	0.0000	9.611E+00	0.2693	3.338E-01	0.0093	0.000E+00	0.0000	6.083E-01	0.0170
Total	2.197E+01	0.6154	1.103E-02	0.0003	0.000E+00	0.0000	1.237E+01	0.3464	4.482E-01	0.0126	0.000E+00	0.0000	9.037E-01	0.0253

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.172E+00	0.0889
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.252E+01	0.9111
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.570E+01	1.0000

* ...of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Pb-210	4.873E-04	0.0000	1.337E-04	0.0000	0.000E+00	0.0000	1.184E-01	0.0065	4.923E-03	0.0003	0.000E+00	0.0000	1.270E-02	0.0007
Ra-226	1.284E+01	0.7097	4.082E-03	0.0002	0.000E+00	0.0000	4.613E+00	0.2549	1.667E-01	0.0092	0.000E+00	0.0000	3.328E-01	0.0184
Total	1.284E+01	0.7097	4.216E-03	0.0002	0.000E+00	0.0000	4.731E+00	0.2614	1.716E-01	0.0095	0.000E+00	0.0000	3.455E-01	0.0191

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.367E-01	0.0076
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.796E+01	0.9924
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.810E+01	1.0000

›f all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

* ·f all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

of all water independent and dependent pathways.

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Parent	Product (j)	Branch Fraction*	DSR(j,t) (mrem/yr)/(pCi/g) t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Pb-210	Pb-210	1.000E+00	2.095E+00	2.015E+00	1.863E+00	1.415E+00	6.345E-01	2.733E-02	0.000E+00	0.000E+00
Ra-226	Ra-226	1.000E+00	6.341E+00	6.315E+00	6.260E+00	6.069E+00	5.494E+00	2.989E+00	0.000E+00	0.000E+00
Ra-226	Pb-210	1.000E+00	3.846E-02	1.028E-01	2.207E-01	5.525E-01	1.011E+00	6.028E-01	0.000E+00	0.000E+00
Ra-226	∑DSR(j)		6.380E+00	6.417E+00	6.481E+00	6.621E+00	6.505E+00	3.592E+00	0.000E+00	0.000E+00

*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter: CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
The DSR includes contributions from associated (half-life ≤ 0.5 yr) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 1.000E+02 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Pb-210	4.773E+01	4.963E+01	5.367E+01	7.069E+01	1.576E+02	3.659E+03	*7.631E+13	*7.631E+13
Ra-226	1.567E+01	1.558E+01	1.543E+01	1.510E+01	1.537E+01	2.784E+01	*9.882E+11	*9.882E+11

*At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 0.000E+00 years

Nuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Pb-210	5.000E+00	0.000E+00	2.095E+00	4.773E+01	2.095E+00	4.773E+01
Ra-226	5.000E+00	15.93 ± 0.03	6.654E+00	1.503E+01	6.380E+00	1.567E+01

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Pb-210	Pb-210	1.000E+00	1.048E+01	1.007E+01	9.316E+00	7.073E+00	3.172E+00	1.367E-01	0.000E+00	0.000E+00
Pb-210	Ra-226	1.000E+00	1.923E-01	5.138E-01	1.103E+00	2.763E+00	5.054E+00	3.014E+00	0.000E+00	0.000E+00
Pb-210	∑DOSE(j)		1.067E+01	1.059E+01	1.042E+01	9.835E+00	8.226E+00	3.151E+00	0.000E+00	0.000E+00
Ra-226	Ra-226	1.000E+00	3.171E+01	3.157E+01	3.130E+01	3.034E+01	2.747E+01	1.494E+01	0.000E+00	0.000E+00

BRF(i) is the branch fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	S(j,t), pCi/g t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Pb-210	Pb-210	1.000E+00	5.000E+00	4.841E+00	4.537E+00	3.617E+00	1.894E+00	1.965E-01	3.034E-04	4.391E-14
Pb-210	Ra-226	1.000E+00	0.000E+00	1.528E-01	4.436E-01	1.320E+00	2.926E+00	4.249E+00	3.548E+00	1.613E+00
Pb-210	∑S(j):		5.000E+00	4.994E+00	4.981E+00	4.937E+00	4.819E+00	4.446E+00	3.548E+00	1.613E+00
Ra-226	Ra-226	1.000E+00	5.000E+00	4.994E+00	4.983E+00	4.944E+00	4.834E+00	4.467E+00	3.566E+00	1.621E+00

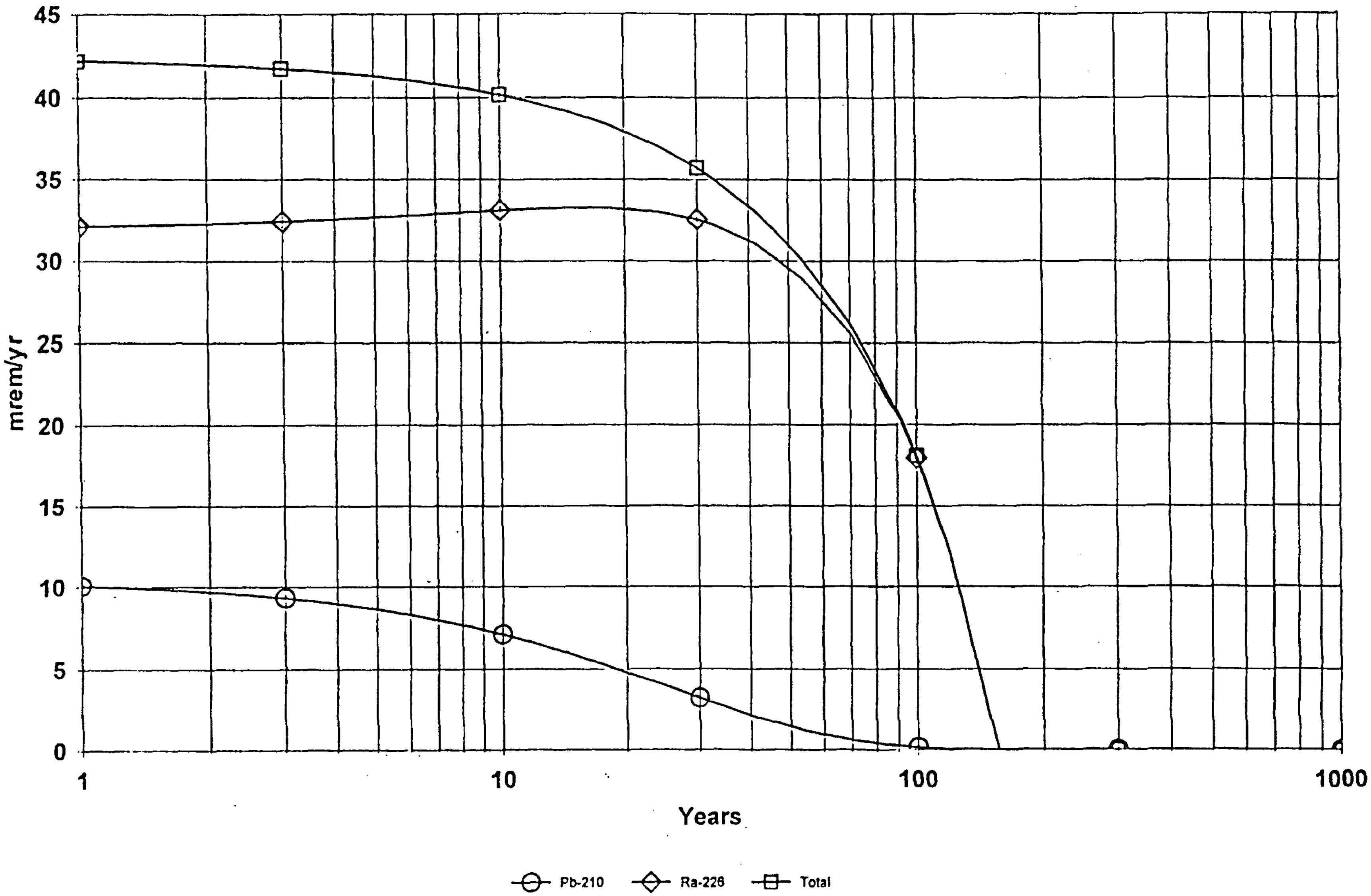
BRF(i) is the branch fraction of the parent nuclide.

CALC.EXE execution time = 0.71 seconds

Attachment 4

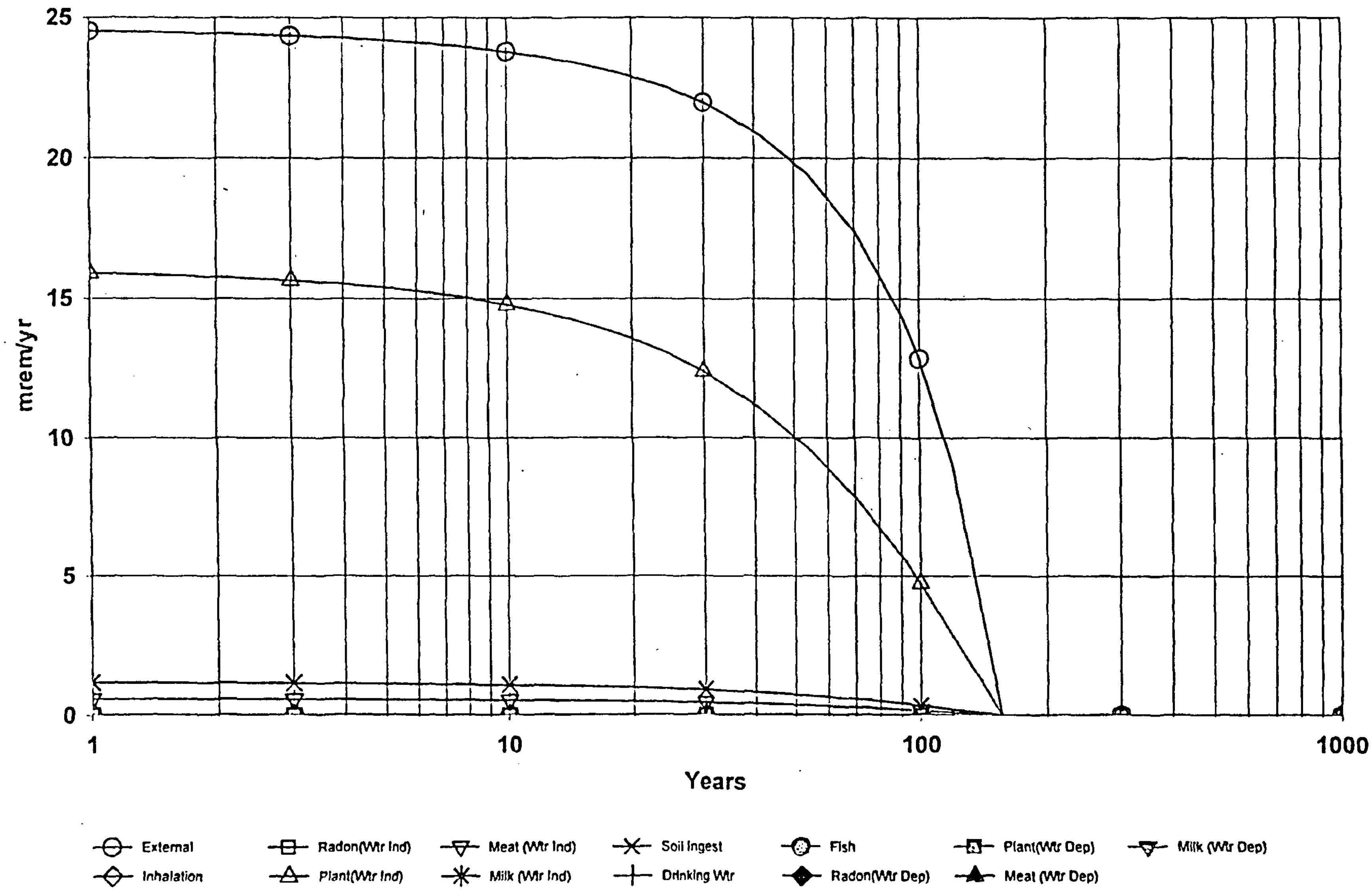
RESRAD Model Output
Standard Graphics

DOSE: All Nuclides Summed, All Pathways Summed



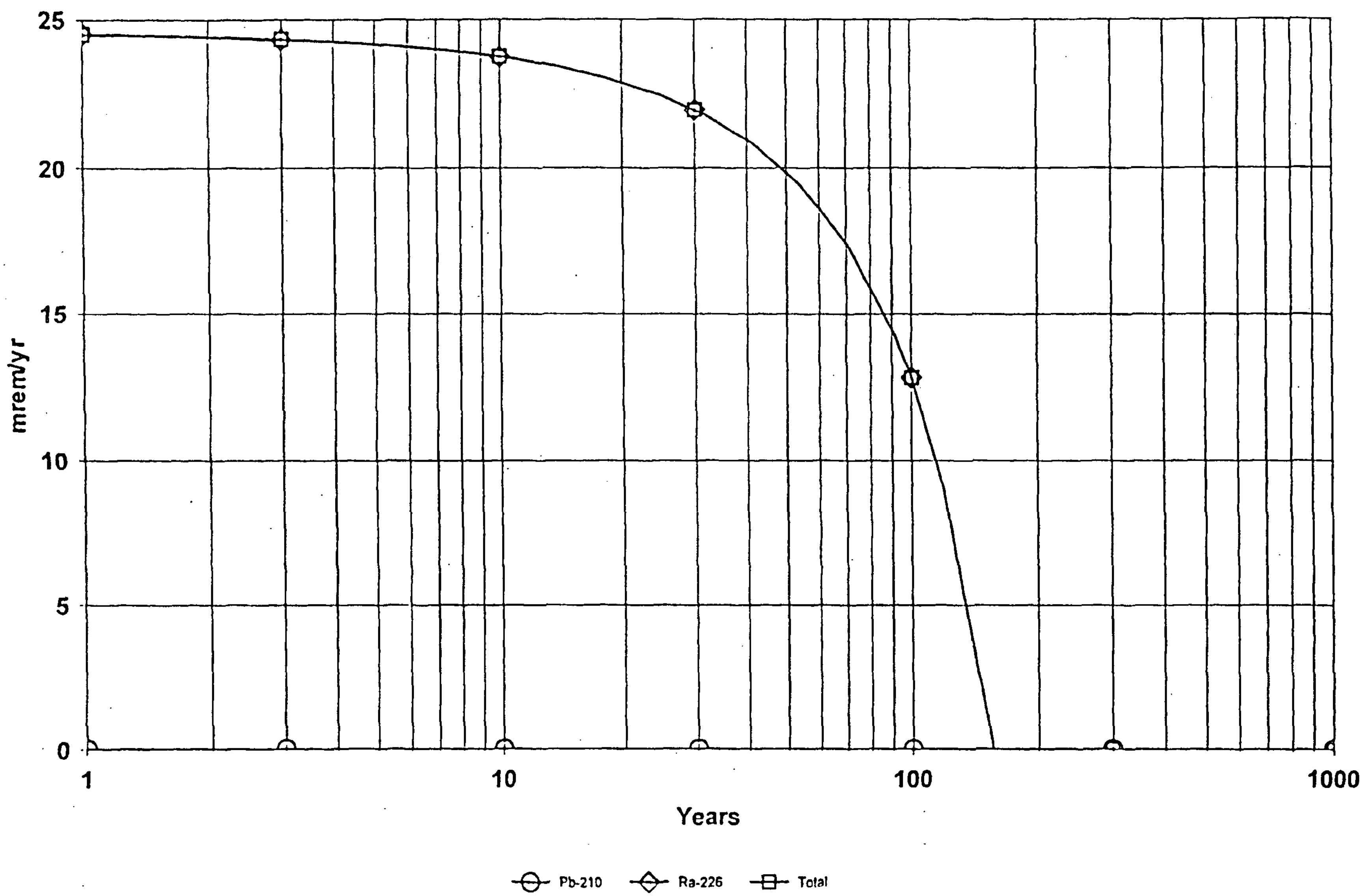
Ra022704.RAD 03/05/2004 10:01 Includes All Pathways

DOSE: All Nuclides Summed, Component Pathways



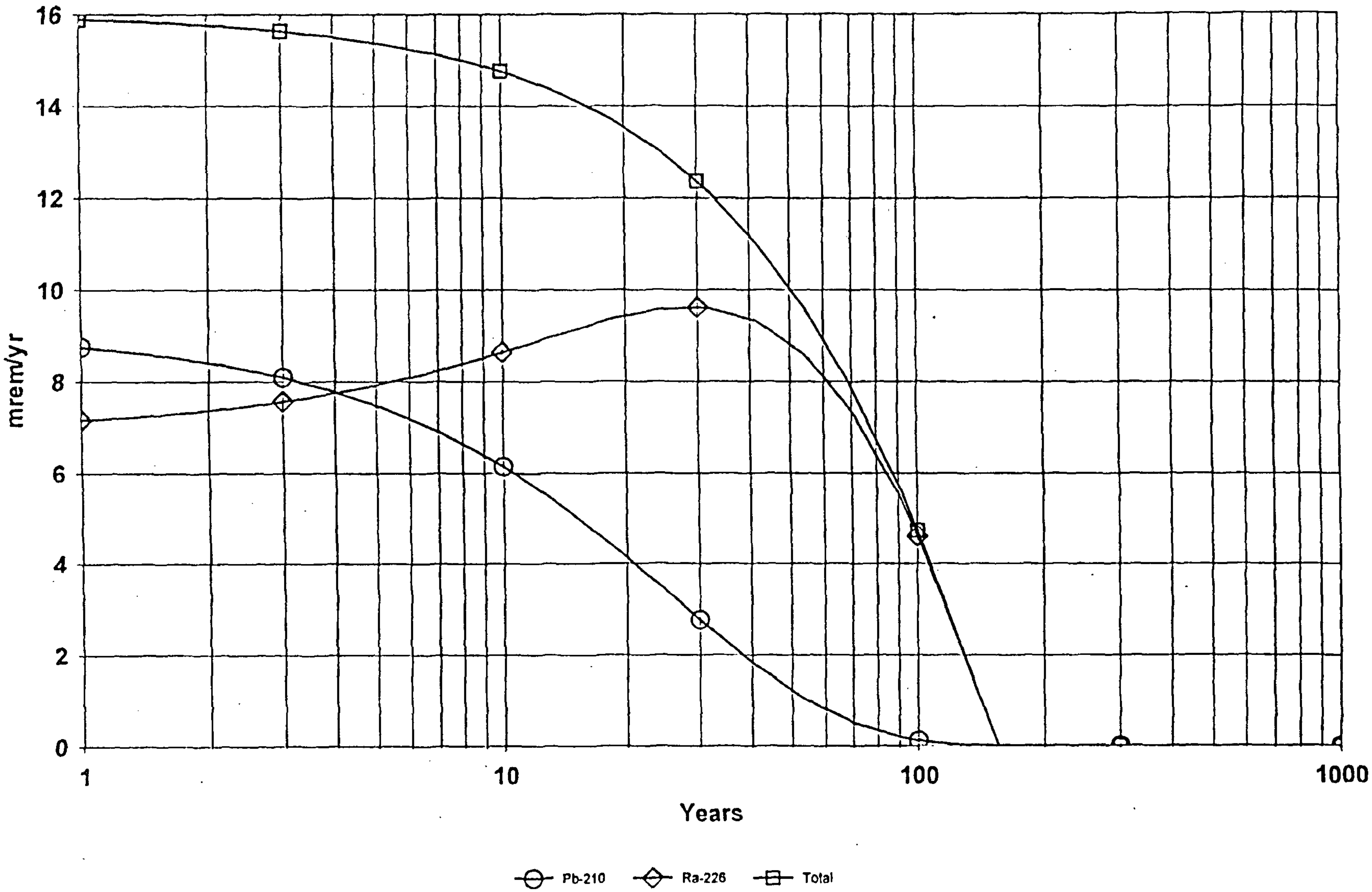
Ra022704.RAD 03/05/2004 10:01

DOSE: All Nuclides Summed, External



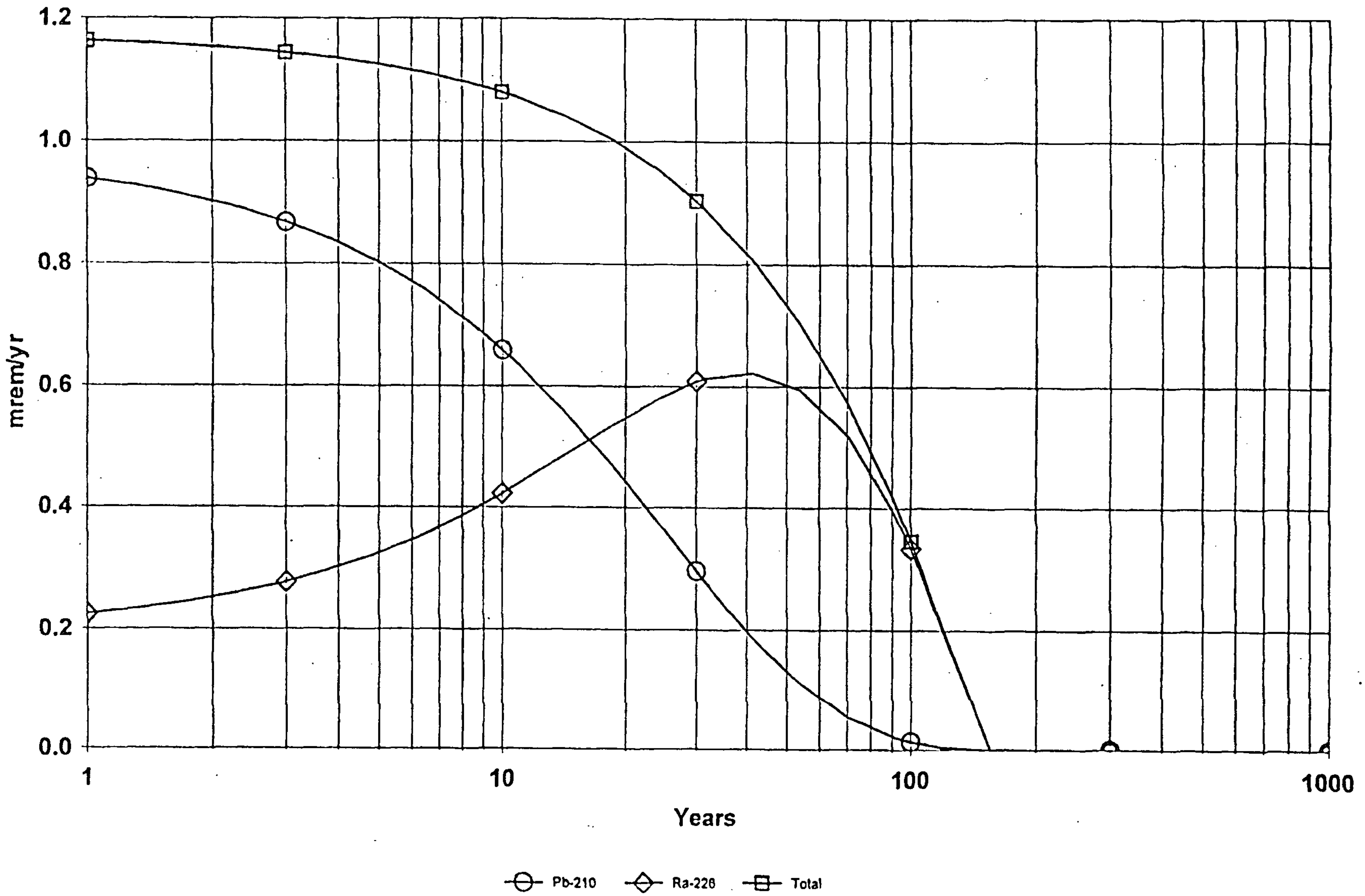
Ra022704.RAD 03/05/2004 10:01 Pathways: External

DOSE: All Nuclides Summed, Plant(Wtr Ind)

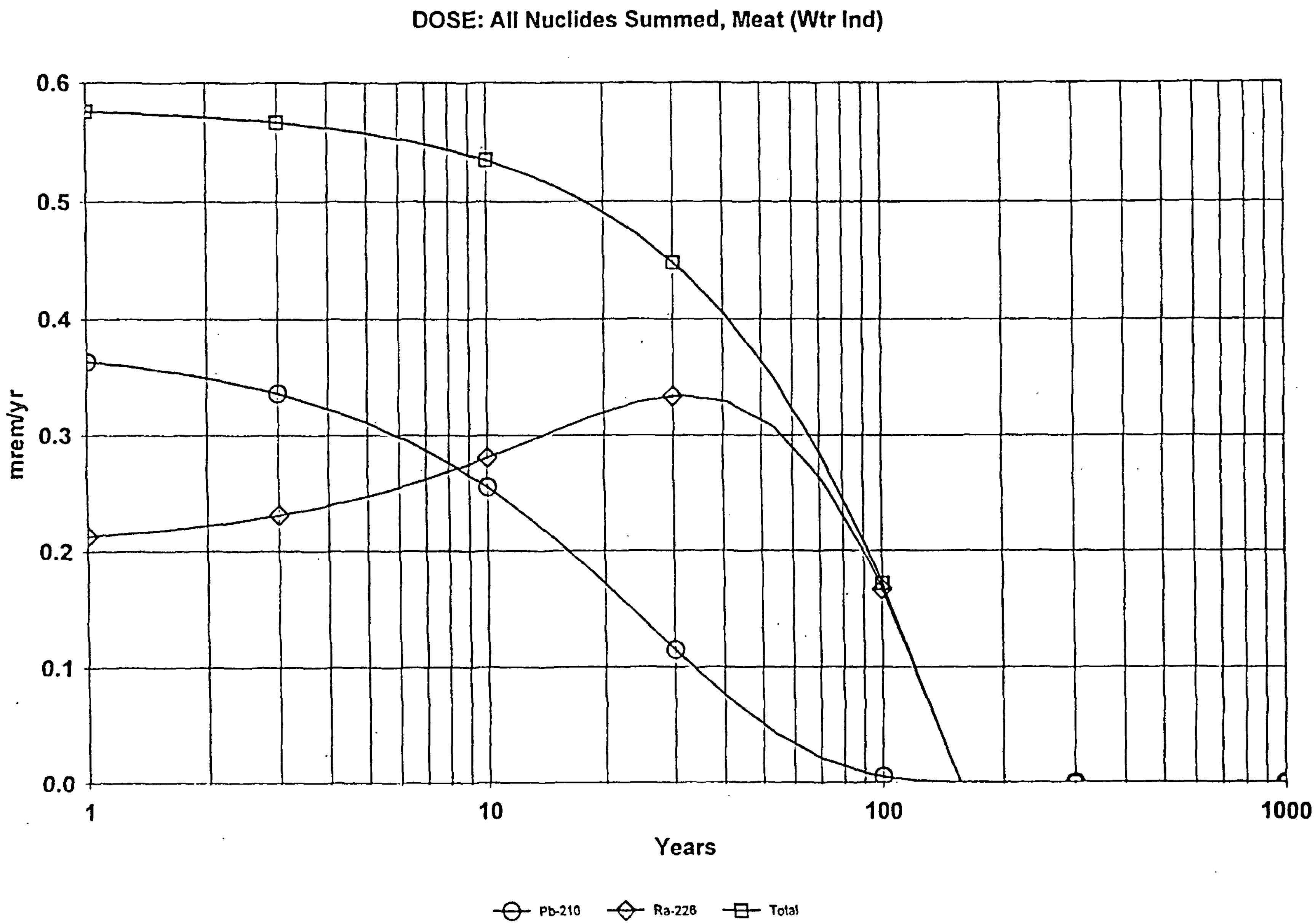


Ra022704.RAD 03/05/2004 10:01 Pathways: Plant(Wtr Ind)

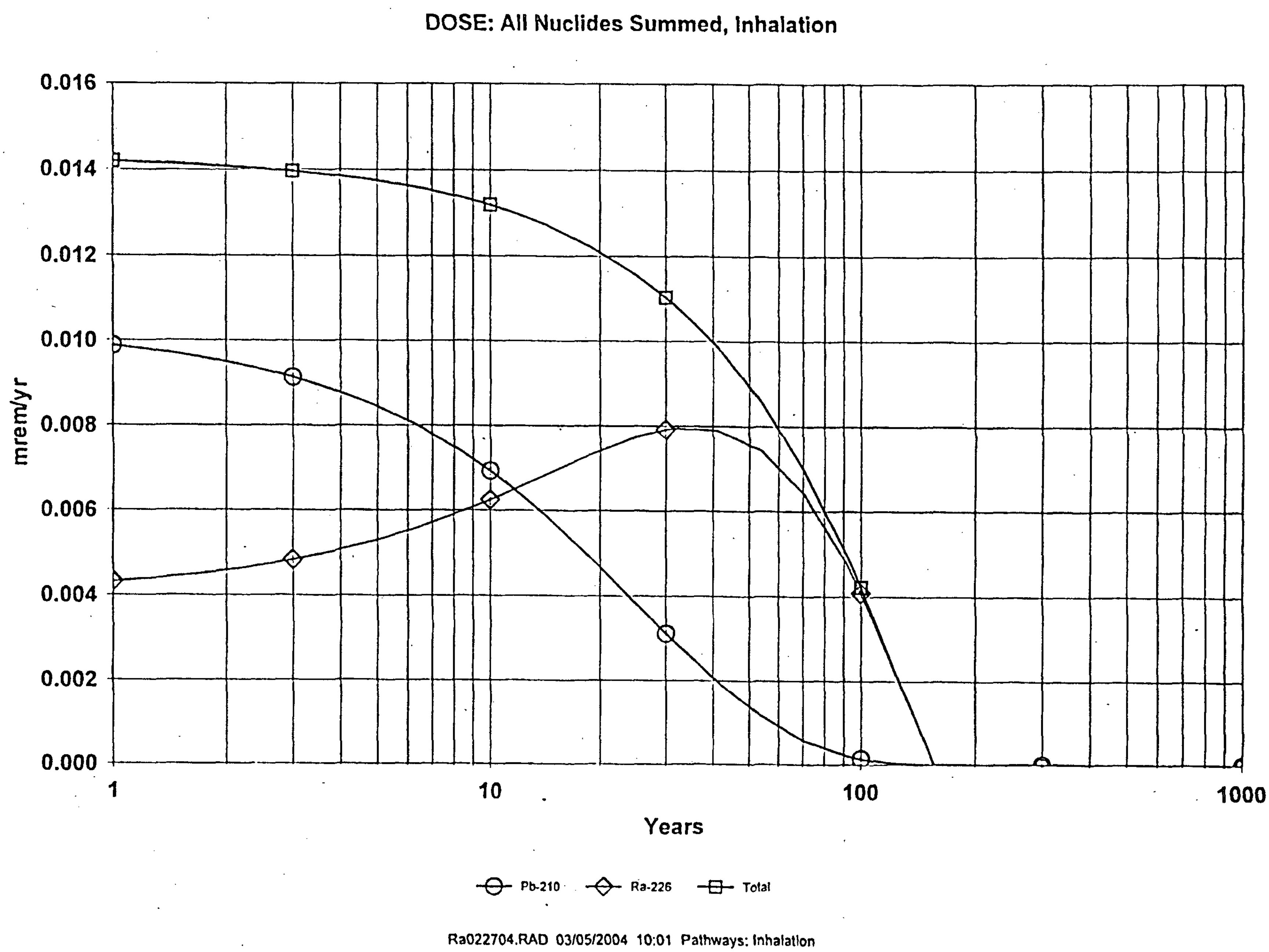
DOSE: All Nuclides Summed, Soil Ingest



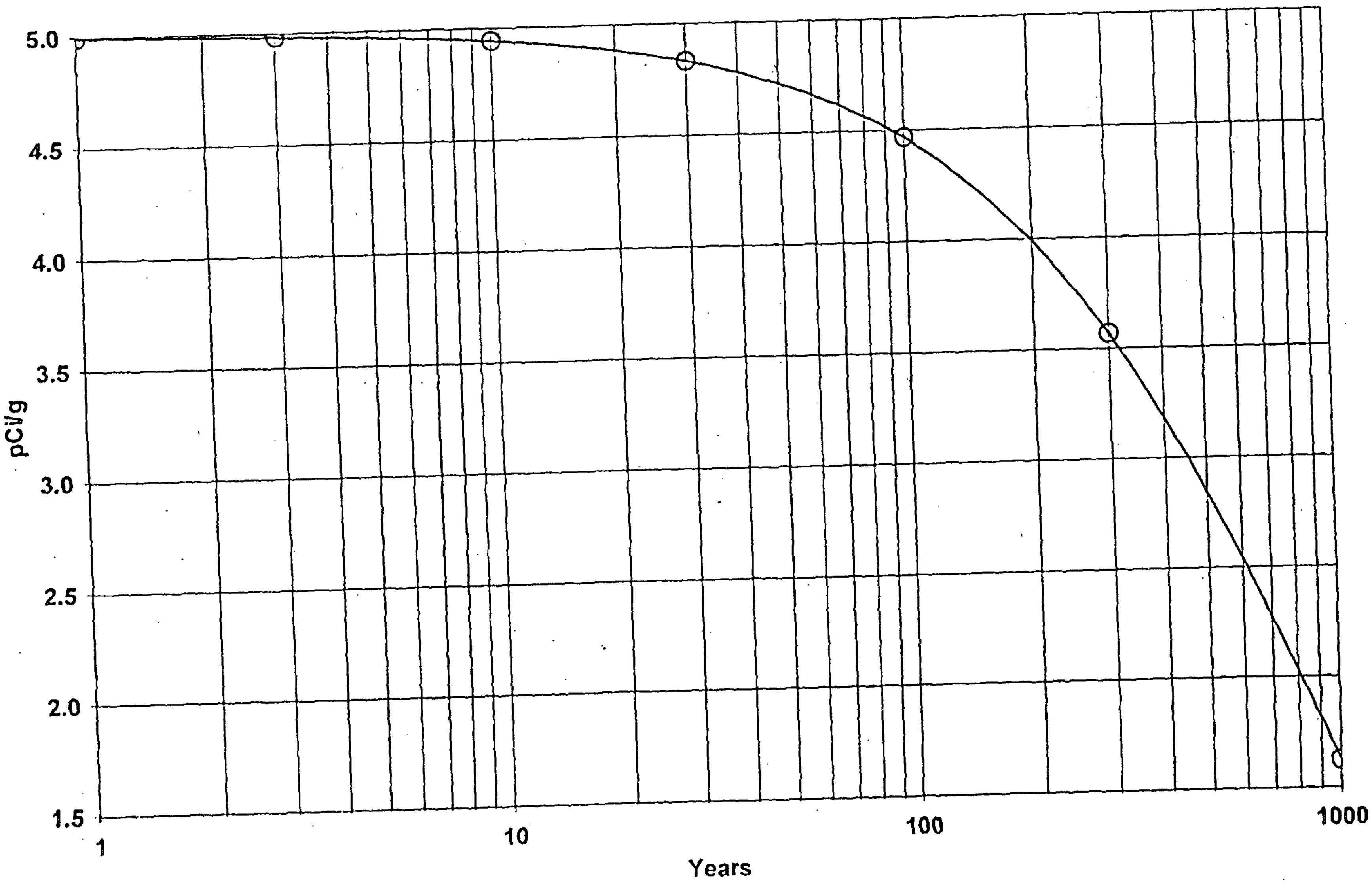
Ra022704.RAD 03/05/2004 10:01 Pathways: Soil Ingest



Ra022704.RAD 03/05/2004 10:01 Pathways: Meat (Wtr Ind)

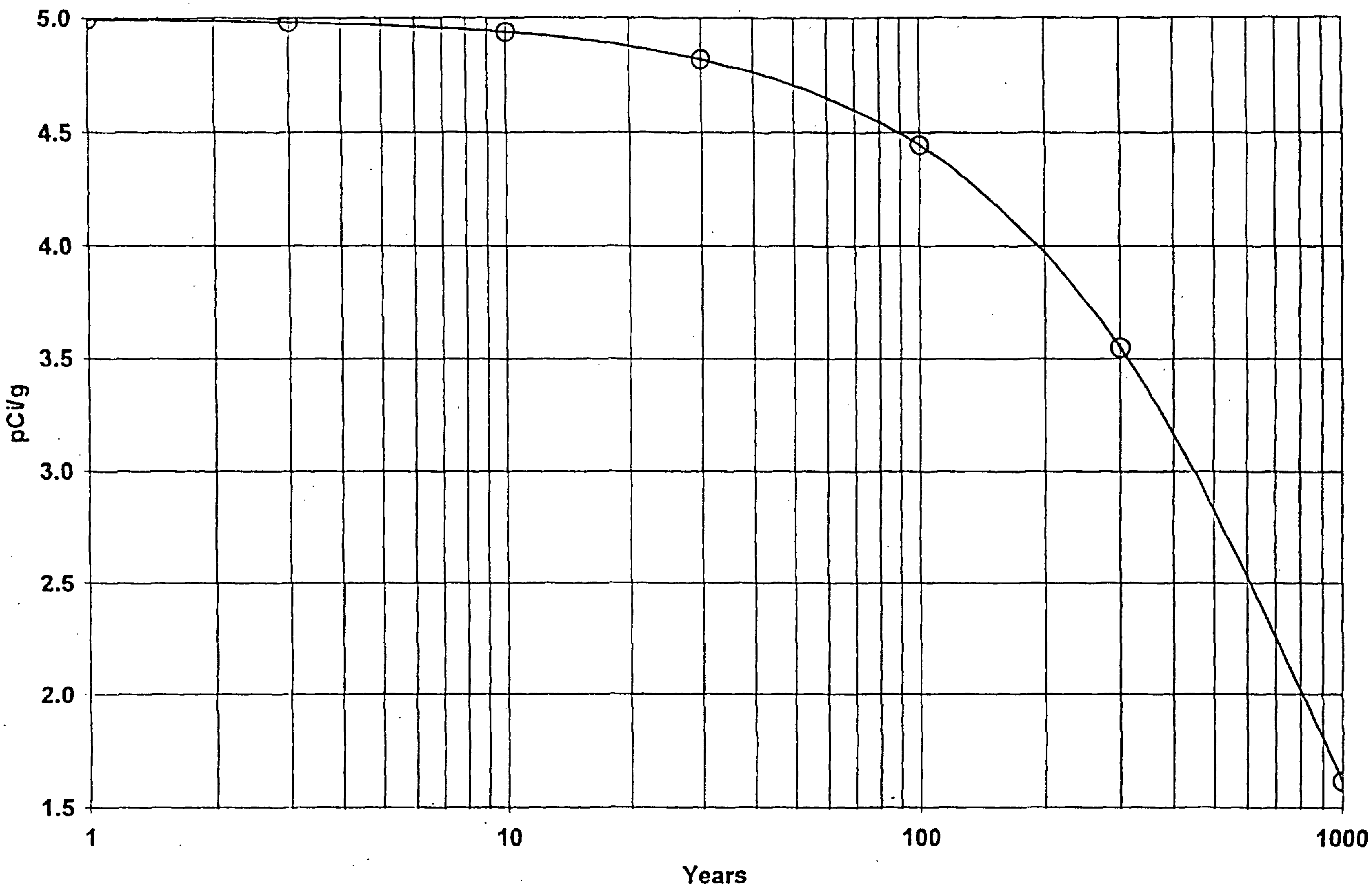

DOSE: All Nuclides Summed, Inhalation
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
mrem/yr
1
10
100
1000
Years
Pb-210
Ra-226
Total
Ra022704.RAD 03/05/2004 10:01 Pathways: Inhalation

CONCENTRATION: Ra-226, Contaminated Zone Soil

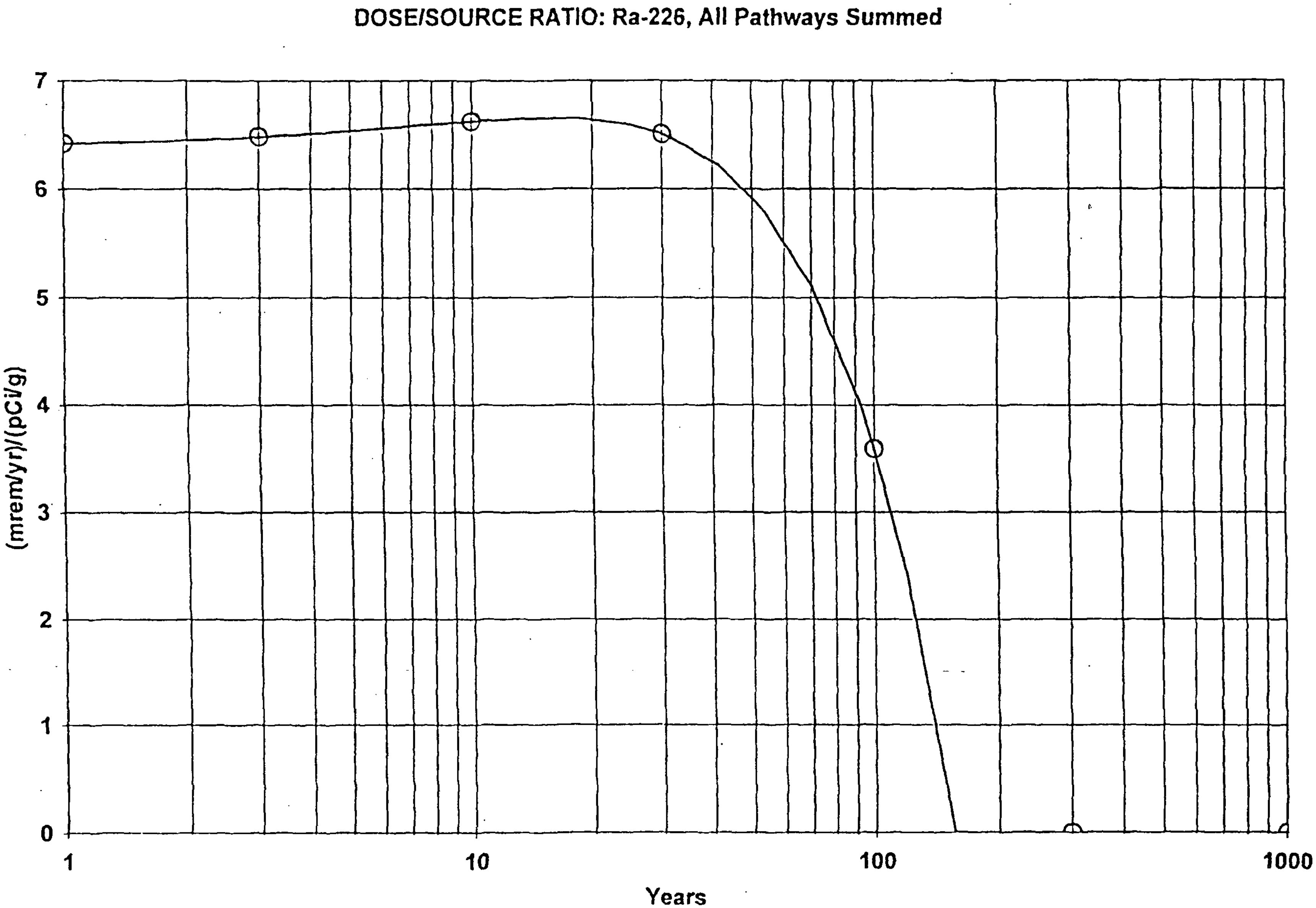


Ra022704.RAD 03/05/2004 10:01

CONCENTRATION: Pb-210, Contaminated Zone Soil

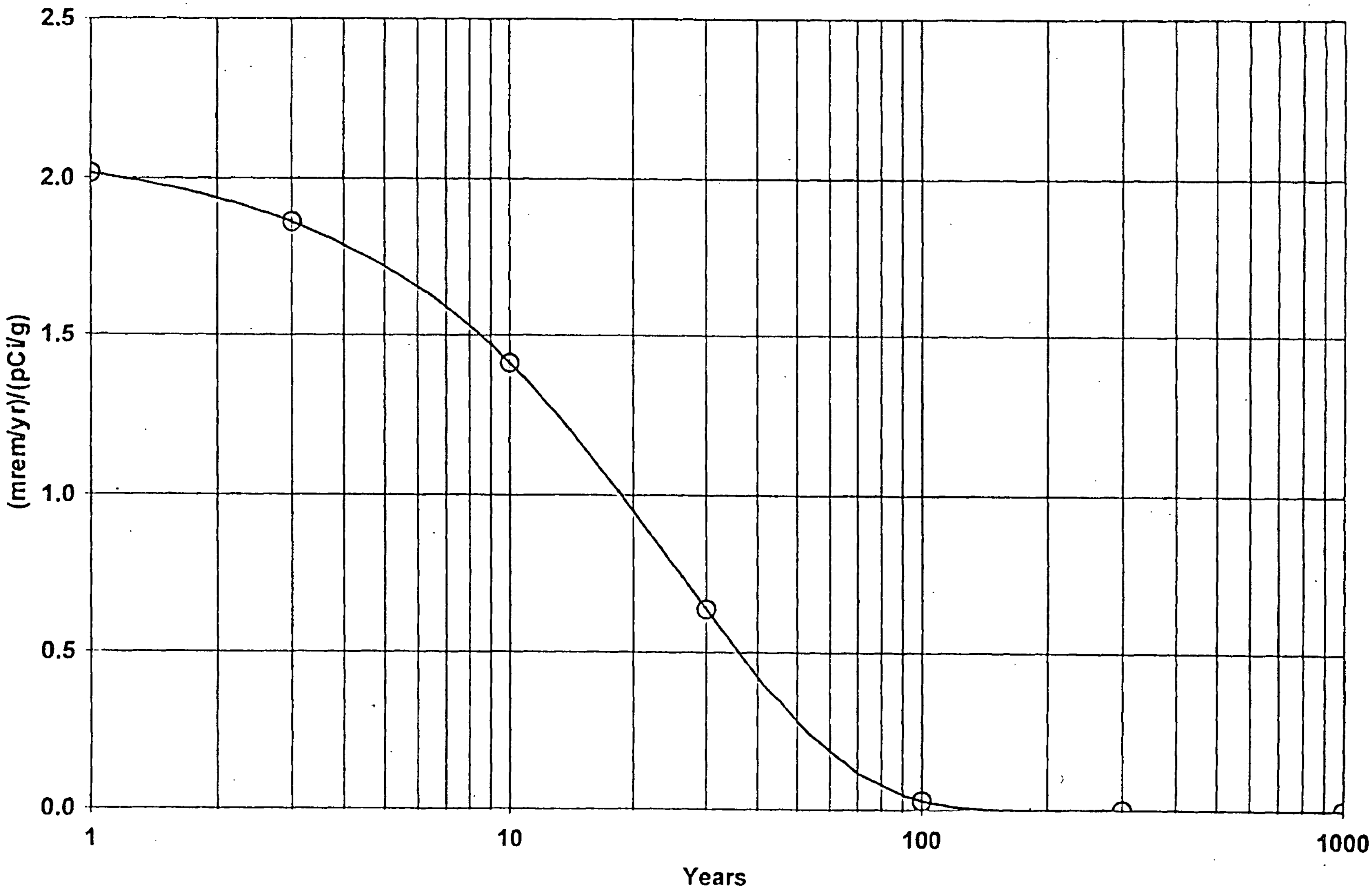


Ra022704.RAD 03/05/2004 10:01



Ra022704.RAD 03/05/2004 10:01 Includes All Pathways

DOSE/SOURCE RATIO: Pb-210, All Pathways Summed



Ra022704.RAD 03/05/2004 10:01 Includes All Pathways

Radium Benchmark Dose Assessment

Attachment 5

RESRAD Model Output
Uranium Analysis

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Dose Conversion Factor (and Related) Parameter Summary
File: HEAST 1995 Morbidity

[illegible]	Parameter	Current Value	Default	Pa
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Ac-227+D	6.720E+00	6.720E+00	DCF
B-1	Pa-231	1.280E+00	1.280E+00	DCF
B-1	Pb-210+D	2.320E-02	2.320E-02	DCF
B-1	Ra-226+D	8.600E-03	8.600E-03	DCF
B-1	Th-230	3.260E-01	3.260E-01	DCF
B-1	U-234	1.320E-01	1.320E-01	DCF
B-1	U-235+D	1.230E-01	1.230E-01	DCF
B-1	U-238+D	1.180E-01	1.180E-01	DCF
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Ac-227+D	1.480E-02	1.480E-02	DCF
D-1	Pa-231	1.060E-02	1.060E-02	DCF
D-1	Pb-210+D	7.270E-03	7.270E-03	DCF
D-1	Ra-226+D	1.330E-03	1.330E-03	DCF
D-1	Th-230	5.480E-04	5.480E-04	DCF
D-1	U-234	2.830E-04	2.830E-04	DCF
D-1	U-235+D	2.670E-04	2.670E-04	DCF
D-1	U-238+D	2.690E-04	2.690E-04	DCF
D-34	Food transfer factors:			
D-34	Ac-227+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF
[illegible]	Ac-227+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.000E-05	2.000E-05	RTF
[illegible]	Ac-227+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-05	2.000E-05	RTF
D-34				
D-34	Pa-231 , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF
D-34	Pa-231 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.000E-03	5.000E-03	RTF
D-34	Pa-231 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF
D-34				
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF
D-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF
D-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF
D-34				
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF
D-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF
D-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF
D-34				
D-34	Th-230 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF
D-34	Th-230 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF
D-34	Th-230 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF
D-34				
D-34	U-234 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF
D-34	U-234 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF
D-34	U-234 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF
D-34				
D-34	U-235+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF
D-34	U-235+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF
[illegible]	U-235+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF

Dose Conversion Factor (and Related) Parameter Summary (continued)
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[illegible]u	Parameter	Current Value	Default	Pa
D-34	U-238+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF
D-34	U-238+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF
D-34	U-238+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Ac-227+D , fish	1.500E+01	1.500E+01	BIO
D-5	Ac-227+D , crustacea and mollusks	1.000E+03	1.000E+03	BIO
D-5				
D-5	Pa-231 , fish	1.000E+01	1.000E+01	BIO
D-5	Pa-231 , crustacea and mollusks	1.100E+02	1.100E+02	BIO
D-5				
D-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIO
D-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIO
D-5				
D-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIO
D-5	Ra-226+D , crustacea and mollusks	2.500E+02	2.500E+02	BIO
D-5				
D-5	Th-230 , fish	1.000E+02	1.000E+02	BIO
D-5	Th-230 , crustacea and mollusks	5.000E+02	5.000E+02	BIO
D-5				
D-5	U-234 , fish	1.000E+01	1.000E+01	BIO
D-5	U-234 , crustacea and mollusks	6.000E+01	6.000E+01	BIO
[illegible]				
[illegible]	U-235+D , fish	1.000E+01	1.000E+01	BIO
[illegible]5	U-235+D , crustacea and mollusks	6.000E+01	6.000E+01	BIO
[illegible]				
D-5	U-238+D , fish	1.000E+01	1.000E+01	BIO
D-5	U-238+D , crustacea and mollusks	6.000E+01	6.000E+01	BIO

Site-Specific Parameter Summary

[illegible]	Parameter	User Input	Default	Used by RESRAD (If different from user input)
R011	Area of contaminated zone (m**2)	1.000E+04	1.000E+04	---
R011	Thickness of contaminated zone (m)	1.500E-01	2.000E+00	---
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---
R011	Basic radiation dose limit (mrem/yr)	1.000E+02	2.500E+01	---
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---
R011	Times for calculations (yr)	not used	0.000E+00	---
R011	Times for calculations (yr)	not used	0.000E+00	---
R012	Initial principal radionuclide (pCi/g): U-234	4.890E+01	0.000E+00	---
R012	Initial principal radionuclide (pCi/g): U-235	2.200E+00	0.000E+00	---
R012	Initial principal radionuclide (pCi/g): U-238	4.890E+01	0.000E+00	---
R012	Concentration in groundwater (pCi/L): U-234	not used	0.000E+00	---
R012	Concentration in groundwater (pCi/L): U-235	not used	0.000E+00	---
R012	Concentration in groundwater (pCi/L): U-238	not used	0.000E+00	---
R013	Cover depth (m)	0.000E+00	0.000E+00	---
[illegible]	Density of cover material (g/cm**3)	not used	1.500E+00	---
[illegible]	Cover depth erosion rate (m/yr)	not used	1.000E-03	---
R013	Density of contaminated zone (g/cm**3)	1.500E+00	1.500E+00	---
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---
R013	Contaminated zone total porosity	4.000E-01	4.000E-01	---
R013	Contaminated zone field capacity	2.000E-01	2.000E-01	---
R013	Contaminated zone hydraulic conductivity (m/yr)	4.000E+03	1.000E+01	---
R013	Contaminated zone b parameter	4.380E+00	5.300E+00	---
R013	Average annual wind speed (m/sec)	4.300E+00	2.000E+00	---
R013	Humidity in air (g/m**3)	not used	8.000E+00	---
R013	Evapotranspiration coefficient	7.500E-01	5.000E-01	---
R013	Precipitation (m/yr)	3.900E-01	1.000E+00	---
R013	Irrigation (m/yr)	0.000E+00	2.000E-01	---
R013	Irrigation mode	overhead	overhead	---
R013	Runoff coefficient	2.000E-01	2.000E-01	---
R013	Watershed area for nearby stream or pond (m**2)	3.630E+07	1.000E+06	---
R013	Accuracy for water/soil computations	1.000E-03	1.000E-03	---
R014	Density of saturated zone (g/cm**3)	1.500E+00	1.500E+00	---
R014	Saturated zone total porosity	4.000E-01	4.000E-01	---
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---
R014	Saturated zone field capacity	2.000E-01	2.000E-01	---
R014	Saturated zone hydraulic conductivity (m/yr)	4.000E+03	1.000E+02	---
R014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	---
R014	Saturated zone b parameter	4.380E+00	5.300E+00	---
[illegible]	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---
[illegible]	Well pump intake depth (m below water table)	2.000E+01	1.000E+01	---
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	

Site-Specific Parameter Summary (continued)

hu	Parameter	User Input	Default	Used b (If different
R014	Well pumping rate (m**3/yr)	2.500E+02	2.500E+02	-
R015	Number of unsaturated zone strata	1	1	-
R015	Unsat. zone 1, thickness (m)	1.500E+01	4.000E+00	-
R015	Unsat. zone 1, soil density (g/cm**3)	1.500E+00	1.500E+00	-
R015	Unsat. zone 1, total porosity	4.000E-01	4.000E-01	-
R015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	-
R015	Unsat. zone 1, field capacity	2.000E-01	2.000E-01	-
R015	Unsat. zone 1, soil-specific b parameter	4.380E+00	5.300E+00	-
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	4.000E+03	1.000E+01	-
R016	Distribution coefficients for U-234			
R016	Contaminated zone (cm**3/g)	3.500E+01	5.000E+01	-
R016	Unsaturated zone 1 (cm**3/g)	3.500E+01	5.000E+01	-
R016	Saturated zone (cm**3/g)	3.500E+01	5.000E+01	-
R016	Leach rate (/yr)	0.000E+00	0.000E+00	9.86
R016	Solubility constant	0.000E+00	0.000E+00	not
R016	Distribution coefficients for U-235			
R016	Contaminated zone (cm**3/g)	3.500E+01	5.000E+01	-
R016	Unsaturated zone 1 (cm**3/g)	3.500E+01	5.000E+01	-
R016	Saturated zone (cm**3/g)	3.500E+01	5.000E+01	-
R016	Leach rate (/yr)	0.000E+00	0.000E+00	9.86
6	Solubility constant	0.000E+00	0.000E+00	not
6	Distribution coefficients for U-238			
6	Contaminated zone (cm**3/g)	3.500E+01	5.000E+01	-
R016	Unsaturated zone 1 (cm**3/g)	3.500E+01	5.000E+01	-
R016	Saturated zone (cm**3/g)	3.500E+01	5.000E+01	-
R016	Leach rate (/yr)	0.000E+00	0.000E+00	9.86
R016	Solubility constant	0.000E+00	0.000E+00	not
R016	Distribution coefficients for daughter Ac-227			
R016	Contaminated zone (cm**3/g)	2.000E+01	2.000E+01	-
R016	Unsaturated zone 1 (cm**3/g)	2.000E+01	2.000E+01	-
R016	Saturated zone (cm**3/g)	2.000E+01	2.000E+01	-
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.72
R016	Solubility constant	0.000E+00	0.000E+00	not
R016	Distribution coefficients for daughter Pa-231			
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	-
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01	-
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	-
R016	Leach rate (/yr)	0.000E+00	0.000E+00	6.91
R016	Solubility constant	0.000E+00	0.000E+00	not
R016	Distribution coefficients for daughter Pb-210			
R016	Contaminated zone (cm**3/g)	2.700E+02	1.000E+02	-
R016	Unsaturated zone 1 (cm**3/g)	2.700E+02	1.000E+02	-
I	Saturated zone (cm**3/g)	2.700E+02	1.000E+02	-
6	Leach rate (/yr)	0.000E+00	0.000E+00	1.28
6	Solubility constant	0.000E+00	0.000E+00	not

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used (If different
R016	Distribution coefficients for daughter Ra-226			
R016	Contaminated zone (cm**3/g)	5.000E+02	7.000E+01	-
R016	Unsaturated zone 1 (cm**3/g)	5.000E+02	7.000E+01	-
R016	Saturated zone (cm**3/g)	5.000E+02	7.000E+01	-
R016	Leach rate (/yr)	0.000E+00	0.000E+00	6.93
R016	Solubility constant	0.000E+00	0.000E+00	not
R016	Distribution coefficients for daughter Th-230			
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	-
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	-
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	-
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.77
R016	Solubility constant	0.000E+00	0.000E+00	not
R017	Inhalation rate (m**3/yr)	8.400E+03	8.400E+03	-
R017	Mass loading for inhalation (g/m**3)	3.000E-04	1.000E-04	-
R017	Exposure duration	3.000E+01	3.000E+01	-
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	-
R017	Shielding factor, external gamma	5.500E-01	7.000E-01	-
R017	Fraction of time spent indoors	5.000E-01	5.000E-01	-
R017	Fraction of time spent outdoors (on site)	2.500E-01	2.500E-01	-
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows ci
R017	Radii of shape factor array (used if FS = -1):			
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	-
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	-
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	-
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	-
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	-
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	-
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	-
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	-
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	-
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	-
R017	Fractions of annular areas within AREA:			
R017	Ring 1	not used	1.000E+00	-
R017	Ring 2	not used	2.732E-01	-
R017	Ring 3	not used	0.000E+00	-
R017	Ring 4	not used	0.000E+00	-
R017	Ring 5	not used	0.000E+00	-
R017	Ring 6	not used	0.000E+00	-
R017	Ring 7	not used	0.000E+00	-
R017	Ring 8	not used	0.000E+00	-
R017	Ring 9	not used	0.000E+00	-
R017	Ring 10	not used	0.000E+00	-
R017	Ring 11	not used	0.000E+00	-
R017	Ring 12	not used	0.000E+00	-
R018	Fruits, vegetables and grain consumption (kg/yr)	1.900E+02	1.600E+02	

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used b (If different
R018	Leafy vegetable consumption (kg/yr)	1.400E+01	1.400E+01	-
R018	Milk consumption (L/yr)	not used	9.200E+01	-
R018	Meat and poultry consumption (kg/yr)	6.300E+01	6.300E+01	-
R018	Fish consumption (kg/yr)	not used	5.400E+00	-
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	-
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	-
R018	Drinking water intake (L/yr)	5.100E+02	5.100E+02	-
R018	Contamination fraction of drinking water	1.000E+00	1.000E+00	-
R018	Contamination fraction of household water	not used	1.000E+00	-
R018	Contamination fraction of livestock water	1.000E+00	1.000E+00	-
R018	Contamination fraction of irrigation water	1.000E+00	1.000E+00	-
R018	Contamination fraction of aquatic food	not used	5.000E-01	-
R018	Contamination fraction of plant food	2.500E-01	-1	-
R018	Contamination fraction of meat	2.500E-01	-1	-
R018	Contamination fraction of milk	not used	-1	-
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	-
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	-
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	-
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	-
R019	Livestock soil intake (kg/day)	5.000E-01	5.000E-01	-
R019	Mass loading for foliar deposition (g/m**3)	3.000E-04	1.000E-04	-
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	-
R019	Depth of roots (m)	3.000E-01	9.000E-01	-
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	-
R019	Household water fraction from ground water	not used	1.000E+00	-
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00	-
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	-
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	7.000E-01	7.000E-01	-
R19B	Wet weight crop yield for Leafy (kg/m**2)	1.500E+00	1.500E+00	-
R19B	Wet weight crop yield for Fodder (kg/m**2)	1.100E+00	1.100E+00	-
R19B	Growing Season for Non-Leafy (years)	1.700E-01	1.700E-01	-
R19B	Growing Season for Leafy (years)	2.500E-01	2.500E-01	-
R19B	Growing Season for Fodder (years)	8.000E-02	8.000E-02	-
R19B	Translocation Factor for Non-Leafy	1.000E-01	1.000E-01	-
R19B	Translocation Factor for Leafy	1.000E+00	1.000E+00	-
R19B	Translocation Factor for Fodder	1.000E+00	1.000E+00	-
R19B	Dry Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	-
R19B	Dry Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	-
R19B	Dry Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	-
R19B	Wet Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	-
R19B	Wet Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	-
R19B	Wet Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	-
R19B	Weathering Removal Constant for Vegetation	2.000E+01	2.000E+01	-
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	-
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	-
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	-
	Fraction of vegetation carbon from air	not used	9.800E-01	-
	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	-

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used (If different
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	-
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	-
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	-
C14	Fraction of grain in milk cow feed	not used	2.000E-01	-
C14	DCF correction factor for gaseous forms of C14	not used	8.894E+01	-
STOR	Storage times of contaminated foodstuffs (days):			
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	-
STOR	Leafy vegetables	1.000E+00	1.000E+00	-
STOR	Milk	1.000E+00	1.000E+00	-
STOR	Meat and poultry	2.000E+01	2.000E+01	-
STOR	Fish	7.000E+00	7.000E+00	-
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	-
STOR	Well water	1.000E+00	1.000E+00	-
STOR	Surface water	1.000E+00	1.000E+00	-
STOR	Livestock fodder	4.500E+01	4.500E+01	-
R021	Thickness of building foundation (m)	not used	1.500E-01	-
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	-
R021	Total porosity of the cover material	not used	4.000E-01	-
R021	Total porosity of the building foundation	not used	1.000E-01	-
R021	Volumetric water content of the cover material	not used	5.000E-02	-
R021	Volumetric water content of the foundation	not used	3.000E-02	-
R021	Diffusion coefficient for radon gas (m/sec):			
R021	in cover material	not used	2.000E-06	-
R021	in foundation material	not used	3.000E-07	-
R021	in contaminated zone soil	not used	2.000E-06	-
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	-
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	-
R021	Height of the building (room) (m)	not used	2.500E+00	-
R021	Building interior area factor	not used	0.000E+00	-
R021	Building depth below ground surface (m)	not used	-1.000E+00	-
R021	Emanating power of Rn-222 gas	not used	2.500E-01	-
R021	Emanating power of Rn-220 gas	not used	1.500E-01	-
TITL	Number of graphical time points	32	---	-
TITL	Maximum number of integration points for dose	17	---	-
TITL	Maximum number of integration points for risk	513	---	-

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	active
4 -- meat ingestion	active
5 -- milk ingestion	suppressed
6 -- aquatic foods	suppressed
7 -- drinking water	active
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	suppressed

Contaminated Zone Dimensions	
Area:	10000.00 square meters
Thickness:	0.15 meters
Cover Depth:	0.00 meters

Initial Soil Concentrations, pCi/g	
U-234	4.890E+01
U-235	2.200E+00
U-238	4.890E+01

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 1.000E+02 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.00
TDOSE(t):	7.898E+00	7.791E+00	7.578E+00	6.874E+00	5.153E+00	1.485E+00	0.000E+00	0.00
M(t):	7.898E-02	7.791E-02	7.578E-02	6.874E-02	5.153E-02	1.485E-02	0.000E+00	0.00

Maximum TDOSE(t): 7.898E+00 mrem/yr at t = 0.000E+00 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) an
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.
U-234	9.872E-03	0.0012	5.781E-01	0.0732	0.000E+00	0.0000	8.766E-01	0.1110	4.307E-02	0.0055
U-235	8.127E-01	0.1029	2.424E-02	0.0031	0.000E+00	0.0000	3.727E-02	0.0047	1.842E-03	0.0002
U-238	3.375E+00	0.4273	5.168E-01	0.0654	0.000E+00	0.0000	8.332E-01	0.1055	4.094E-02	0.0052
Total	4.198E+00	0.5315	1.119E+00	0.1417	0.000E+00	0.0000	1.747E+00	0.2212	8.586E-02	0.0109

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) an
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
l	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) an
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 year

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	9.775E-03	0.0013	5.686E-01	0.0730	0.000E+00	0.0000	8.622E-01	0.1107	4.237E-02	0.0054
U-235	8.040E-01	0.1032	2.384E-02	0.0031	0.000E+00	0.0000	3.678E-02	0.0047	1.844E-03	0.0002
U-238	3.337E+00	0.4283	5.083E-01	0.0652	0.000E+00	0.0000	8.196E-01	0.1052	4.028E-02	0.0052
Total	4.150E+00	0.5327	1.101E+00	0.1413	0.000E+00	0.0000	1.719E+00	0.2206	8.449E-02	0.0108

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) an
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) an
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.
U-234	9.587E-03	0.0013	5.500E-01	0.0726	0.000E+00	0.0000	8.340E-01	0.1100	4.099E-02	0.0054
U-235	7.870E-01	0.1039	2.308E-02	0.0030	0.000E+00	0.0000	3.582E-02	0.0047	1.846E-03	0.0002
U-238	3.260E+00	0.4302	4.916E-01	0.0649	0.000E+00	0.0000	7.927E-01	0.1046	3.896E-02	0.0051
Total	4.057E+00	0.5353	1.065E+00	0.1405	0.000E+00	0.0000	1.663E+00	0.2194	8.179E-02	0.0108

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) an
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
..l	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) an
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 year

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.
U-234	8.984E-03	0.0013	4.888E-01	0.0711	0.000E+00	0.0000	7.412E-01	0.1078	3.643E-02	0.0053
U-235	7.298E-01	0.1062	2.057E-02	0.0030	0.000E+00	0.0000	3.264E-02	0.0047	1.837E-03	0.0003
U-238	3.004E+00	0.4371	4.369E-01	0.0636	0.000E+00	0.0000	7.045E-01	0.1025	3.462E-02	0.0050
Total	3.743E+00	0.5445	9.463E-01	0.1377	0.000E+00	0.0000	1.478E+00	0.2151	7.289E-02	0.0106

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) an
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
[illegible]1	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.000[illegible]

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) an
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground		Inhalation		Radon		Plant		Meat	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	7.655E-03	0.0015	3.439E-01	0.0667	0.000E+00	0.0000	5.214E-01	0.1012	2.562E-02	0.0050
U-235	5.840E-01	0.1133	1.469E-02	0.0029	0.000E+00	0.0000	2.477E-02	0.0048	1.703E-03	0.0003
U-238	2.356E+00	0.4573	3.073E-01	0.0596	0.000E+00	0.0000	4.955E-01	0.0962	2.435E-02	0.0047
Total	2.948E+00	0.5721	6.659E-01	0.1292	0.000E+00	0.0000	1.042E+00	0.2021	5.168E-02	0.0100

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) an
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
..l	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

..n of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) an
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 year

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	5.111E-03	0.0034	7.161E-02	0.0482	0.000E+00	0.0000	1.089E-01	0.0734	5.345E-03	0.0036
U-235	2.140E-01	0.1442	3.308E-03	0.0022	0.000E+00	0.0000	6.774E-03	0.0046	6.964E-04	0.0005
U-238	8.041E-01	0.5416	6.381E-02	0.0430	0.000E+00	0.0000	1.029E-01	0.0693	5.061E-03	0.0034
Total	1.023E+00	0.6892	1.387E-01	0.0934	0.000E+00	0.0000	2.186E-01	0.1473	1.110E-02	0.0075

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) an
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.000

*Sum of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) an
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground		Inhalation		Radon		Plant		Meat	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) an
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Dependent Pathways

Radio-Nuclide	Water		Fish		Radon		Plant		Meat	
	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
..l	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

..n of all water independent and dependent pathways.

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) an
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 year

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) an
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
[illegible]l	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.000

*Sum of all water independent and dependent pathways.

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Parent (i)	Product (j)	Branch Fraction*	DSR(j,t) (mrem/yr)/(pCi/g) t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+
U-234	U-234	1.000E+00	3.851E-02	3.788E-02	3.664E-02	3.257E-02	2.293E-02	4.793E-03	0.000E+
U-234	Th-230	1.000E+00	2.722E-07	7.968E-07	1.808E-06	4.980E-06	1.127E-05	1.143E-05	0.000E+
U-234	Ra-226	1.000E+00	4.014E-09	2.830E-08	1.485E-07	1.269E-06	9.239E-06	4.666E-05	0.000E+
U-234	Pb-210	1.000E+00	1.434E-11	1.855E-10	1.926E-09	4.292E-08	7.206E-07	5.689E-06	0.000E+
U-234	∑DSR(j)		3.851E-02	3.788E-02	3.665E-02	3.258E-02	2.295E-02	4.857E-03	0.000E+
U-235	U-235	1.000E+00	4.054E-01	4.009E-01	3.920E-01	3.621E-01	2.867E-01	1.013E-01	0.000E+
U-235	Pa-231	1.000E+00	3.847E-05	1.183E-04	2.716E-04	7.372E-04	1.560E-03	1.210E-03	0.000E+
U-235	Ac-227	1.000E+00	3.673E-07	2.347E-06	1.138E-05	8.310E-05	4.157E-04	7.009E-04	0.000E+
U-235	∑DSR(j)		4.054E-01	4.010E-01	3.923E-01	3.629E-01	2.886E-01	1.032E-01	0.000E+
U-238	U-238	1.000E+00	1.048E-01	1.034E-01	1.007E-01	9.166E-02	6.944E-02	2.086E-02	0.000E+
U-238	U-234	1.000E+00	5.444E-08	1.609E-07	3.635E-07	9.695E-07	1.982E-06	1.366E-06	0.000E+
U-238	Th-230	1.000E+00	2.606E-13	1.766E-12	9.008E-12	7.299E-11	4.633E-10	1.364E-09	0.000E+
U-238	Ra-226	1.000E+00	2.820E-15	4.267E-14	4.938E-13	1.240E-11	2.539E-10	3.787E-09	0.000E+
U-238	Pb-210	1.000E+00	8.516E-18	2.256E-16	4.989E-15	3.234E-13	1.565E-11	3.944E-10	0.000E+
U-238	∑DSR(j)		1.048E-01	1.034E-01	1.007E-01	9.166E-02	6.945E-02	2.086E-02	0.000E+

*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter: CUMBRF(j
The DSR includes contributions from associated (half-life ≤ 0.5 yr) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 1.000E+02 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	
U-234	2.597E+03	2.640E+03	2.729E+03	3.069E+03	4.358E+03	2.059E+04	*6.245E+09	*
U-235	2.466E+02	2.494E+02	2.549E+02	2.755E+02	3.465E+02	9.687E+02	*2.160E+06	*
U-238	9.545E+02	9.672E+02	9.932E+02	1.091E+03	1.440E+03	4.794E+03	*3.360E+05	*

*At specific activity limit

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 0.000E+00 years

Nuclide (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
U-234	4.890E+01	0.000E+00	3.851E-02	2.597E+03	3.851E-02	2.597E+03
U-235	2.200E+00	0.000E+00	4.054E-01	2.466E+02	4.054E-01	2.466E+02
U-238	4.890E+01	0.000E+00	1.048E-01	9.545E+02	1.048E-01	9.545E+02

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+
U-234	U-234	1.000E+00	1.883E+00	1.852E+00	1.792E+00	1.593E+00	1.121E+00	2.344E-01	0.000E+
U-234	U-238	1.000E+00	2.662E-06	7.870E-06	1.777E-05	4.741E-05	9.693E-05	6.679E-05	0.000E+
U-234	∑DOSE(j)		1.883E+00	1.852E+00	1.792E+00	1.593E+00	1.121E+00	2.345E-01	0.000E+
Th-230	U-234	1.000E+00	1.331E-05	3.896E-05	8.839E-05	2.435E-04	5.513E-04	5.590E-04	0.000E+
Th-230	U-238	1.000E+00	1.274E-11	8.635E-11	4.405E-10	3.569E-09	2.265E-08	6.672E-08	0.000E+
Th-230	∑DOSE(j)		1.331E-05	3.896E-05	8.839E-05	2.435E-04	5.513E-04	5.591E-04	0.000E+
Ra-226	U-234	1.000E+00	1.963E-07	1.384E-06	7.261E-06	6.208E-05	4.518E-04	2.282E-03	0.000E+
Ra-226	U-238	1.000E+00	1.379E-13	2.086E-12	2.415E-11	6.064E-10	1.242E-08	1.852E-07	0.000E+
Ra-226	∑DOSE(j)		1.963E-07	1.384E-06	7.261E-06	6.208E-05	4.518E-04	2.282E-03	0.000E+
Pb-210	U-234	1.000E+00	7.011E-10	9.070E-09	9.419E-08	2.099E-06	3.524E-05	2.782E-04	0.000E+
Pb-210	U-238	1.000E+00	4.164E-16	1.103E-14	2.440E-13	1.582E-11	7.651E-10	1.929E-08	0.000E+
Pb-210	∑DOSE(j)		7.011E-10	9.070E-09	9.419E-08	2.099E-06	3.524E-05	2.782E-04	0.000E+
U-235	U-235	1.000E+00	8.919E-01	8.819E-01	8.624E-01	7.967E-01	6.306E-01	2.229E-01	0.000E+
Pa-231	U-235	1.000E+00	8.463E-05	2.602E-04	5.974E-04	1.622E-03	3.431E-03	2.662E-03	0.000E+
Ac-227	U-235	1.000E+00	8.080E-07	5.164E-06	2.504E-05	1.828E-04	9.145E-04	1.542E-03	0.000E+
U-238	U-238	1.000E+00	5.123E+00	5.056E+00	4.923E+00	4.482E+00	3.396E+00	1.020E+00	0.000E+

BRF(i) is the branch fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	S(j,t), pCi/g t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+
U-234	U-234	1.000E+00	4.890E+01	4.842E+01	4.747E+01	4.430E+01	3.637E+01	1.822E+01	2.531E+
U-234	U-238	1.000E+00	0.000E+00	1.373E-04	4.038E-04	1.256E-03	3.093E-03	5.167E-03	2.154E-
U-234	∑S(j):		4.890E+01	4.842E+01	4.747E+01	4.431E+01	3.637E+01	1.823E+01	2.534E+
Th-230	U-234	1.000E+00	0.000E+00	4.380E-04	1.301E-03	4.191E-03	1.143E-02	2.795E-02	4.216E-
Th-230	U-238	1.000E+00	0.000E+00	6.199E-10	5.506E-09	5.844E-08	4.620E-07	3.322E-06	1.016E-
Th-230	∑S(j):		0.000E+00	4.380E-04	1.301E-03	4.191E-03	1.143E-02	2.796E-02	4.217E-
Ra-226	U-234	1.000E+00	0.000E+00	9.500E-08	8.488E-07	9.194E-06	7.703E-05	6.761E-04	3.451E-
Ra-226	U-238	1.000E+00	0.000E+00	8.964E-14	2.395E-12	8.554E-11	2.084E-09	5.464E-08	6.155E-
Ra-226	∑S(j):		0.000E+00	9.500E-08	8.488E-07	9.194E-06	7.704E-05	6.762E-04	3.451E-
Pb-210	U-234	1.000E+00	0.000E+00	9.773E-10	2.582E-08	8.879E-07	1.955E-05	3.872E-04	2.885E-
Pb-210	U-238	1.000E+00	0.000E+00	6.928E-16	5.494E-14	6.301E-12	4.161E-10	2.670E-08	4.868E-
Pb-210	∑S(j):		0.000E+00	9.773E-10	2.582E-08	8.879E-07	1.955E-05	3.872E-04	2.885E-
U-235	U-235	1.000E+00	2.200E+00	2.178E+00	2.136E+00	1.993E+00	1.636E+00	8.202E-01	1.140E-
Pa-231	U-235	1.000E+00	0.000E+00	4.616E-05	1.362E-04	4.280E-04	1.086E-03	2.016E-03	1.160E-
Ac-227	U-235	1.000E+00	0.000E+00	7.249E-07	6.246E-06	5.976E-05	3.589E-04	1.196E-03	8.300E-
U-238	U-238	1.000E+00	4.890E+01	4.842E+01	4.747E+01	4.431E+01	3.637E+01	1.823E+01	2.534E+

BRF(i) is the branch fraction of the parent nuclide.

RESCALC.EXE execution time =   0.55 seconds

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NEBRASKA STATE HISTORICAL SOCIETY
1500 R STREET, P.O.BOX 82554, LINCOLN, NE 68501-2554
(402) 471-3270 Fax: (402) 471-3100 1-800-833-6747 www.nebraskahistory.org

17 December 2007

Rhonda Grantham
Crow Butte Resources
86 Crow Butte Road
P.O. 169
Crawford, NE 69339

Re: Three Crow Permit Area
Crow Butte Resources
Dawes and Sioux Counties
H.P. #0302-033-01

Dear Ms. Grantham:

The cultural resources survey report (Spath 2007) on the above referenced project has been reviewed by this office. We concur that archaeological sites 25DW302, 25DW303, 25DW304, 25DW305, 25DW306, 25DW307, 25DW308, 25DW309, 25DW310, 25DW311, 25DW312, 25DW313, 25DW314, and 25DW315 are not eligible for the National Register of Historic Places. Therefore, no archaeological, architectural, or historic context property resources will be affected by the proposed project. This review does not constitute the opinions of any Tribes that may have an interest in Traditional Cultural Properties potentially affected by this project.

Sincerely,

Terry Steinacher
H.P. Archaeologist

Concurrence:

L. Robert Puschendorf
Deputy NeSHPO

Cc: Spath

ARCADIS
Infrastructure, environment, facilities

Imagine the result

CROW BUTTE RESOURCES THREE CROW PERMIT AREA CLASS III CULTURAL RESOURCE INVENTORY DAWES AND SIOUX COUNTIES, NEBRASKA

Prepared for:

Crow Butte Resources, Inc.
Crawford, Nebraska

Project # GC0021130001

Prepared by:

ARCADIS U.S.
Highlands Ranch, Colorado

December 2007

REPORT

CROW BUTTE RESOURCES
THREE CROW PERMIT AREA
CLASS III CULTURAL RESOURCE INVENTORY
DAWES AND SIOUX COUNTIES, NEBRASKA

Prepared for:

Crow Butte Resources, Inc
Crawford, Nebraska

Project # GC0021130001

Carl Späth, PhD
Principal Investigator
ARCADIS U.S.
630 Plaza Drive, Suite 100
Highlands Ranch, Colorado

December 2007

Abstract

Crow Butte Resources, Inc. is preparing a license amendment application to expand its uranium mining operations to the Three Crow Permit Area southwest of Crawford, Nebraska. ARCADIS archaeologists surveyed a 2,100-acre area that may be impacted by the proposed mine development for the presence of cultural resources. Eleven historic sites, one isolated historic artifact, and two isolated prehistoric artifacts were located and identified. The historic sites are three artifact scatters, two farm complexes, two rural residences, two collapsed buildings, a collapsed windmill and water tank, and an isolated piece of farm machinery. The individual artifacts are a historic fraternal medallion and two prehistoric flakes. None of these sites are distinctive or outstanding, and all of the sites are recommended as not eligible for the National Register of Historic Places. No further cultural resource work is recommended for this proposed permit area.

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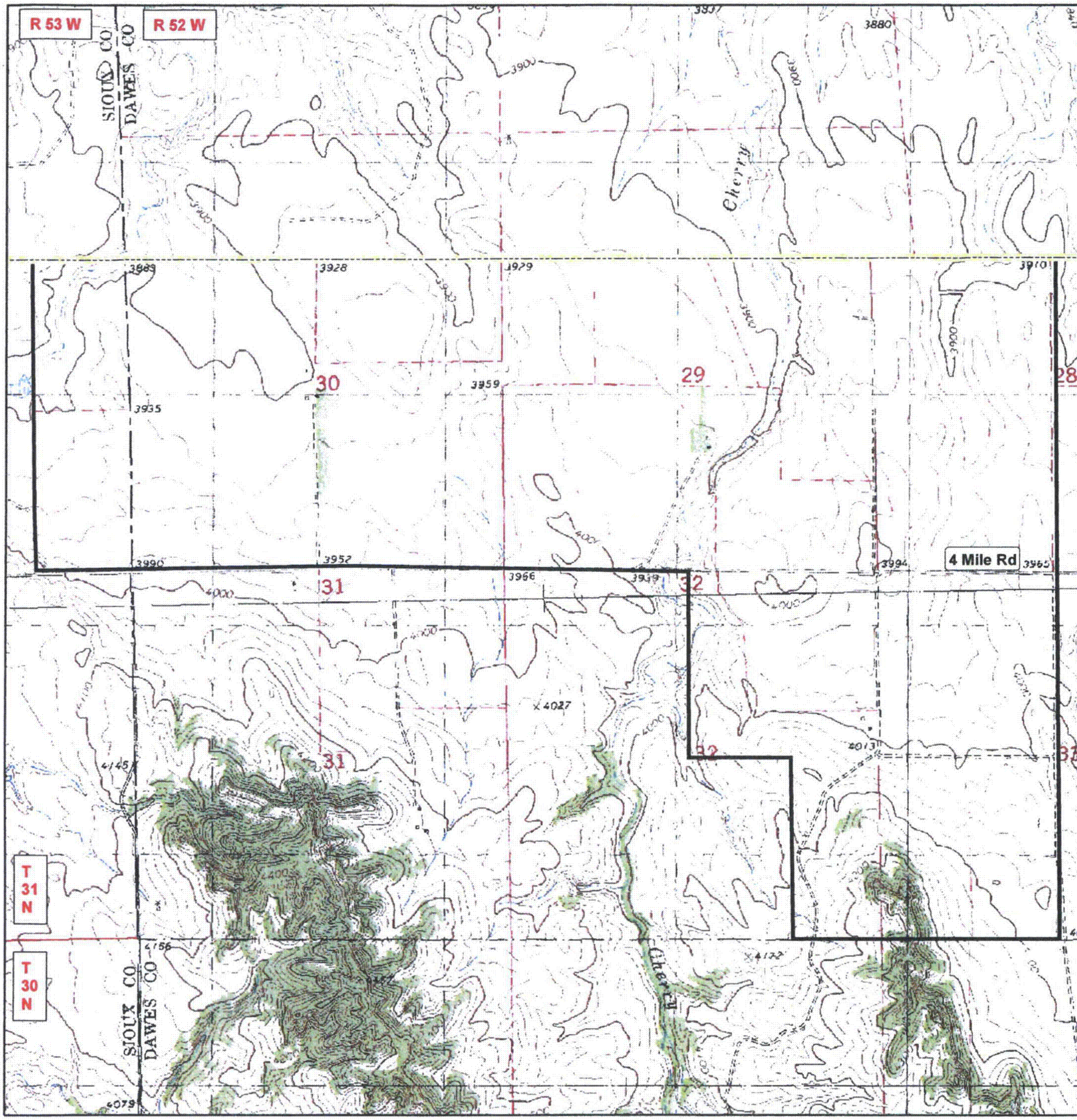
Figures

Appendices



Legend

Fort Robinson State Park Boundary

Three Crow Permit Area

0 250 500 1,000 METERS

0 500 1,000 2,000 3,000 FEET

Scale 1:24,000

Source: USGS 7.5' Quadrangles
Crawford & Dead Man's Creek, NE

Projection: NAD 1927 UTM Zone 13

Crow Butte Resources, Inc.
Three Crow Permit Area

FIGURE 1
Cultural Resources
Survey Area

ANALYSIS AREA: DAWES & SIOUX COUNTIES, NE	
Date: 11/19/2007	File: R:/../GC002113/../ProjectArea.mxd
Prepared By: KMW	Layout: R:/../GC002113/../ProjectArea.pdf

Crow Butte Three Crow Permit Area Cultural Resource Inventory Report

PROJECT DESCRIPTION

ARCADIS U.S., Inc. (ARCADIS) conducted an intensive pedestrian cultural resource inventory of approximately 2,100 acres south-southwest of Crawford, Nebraska. This inventory was completed for Crow Butte Resources, Inc. (Crow Butte) in support of a license amendment application. The project area is located in portions of Sections 28, 29, 30, 32, and 33, T31N, R52W, Dawes County, and Section 25, T31N, R52W, Sioux County, Nebraska (**Figure 1**). This location can be found on the U.S. Geological Survey (USGS) Crawford (1980) and the USGS Dead Mans Creek (1980) 7.5-minute topographic quadrangles.

This project involves federal licensing of uranium mining administered by the Nuclear Regulatory Commission. In accordance with policies and regulations implementing Section 106 of the National Historic Preservation Act (NHPA), as amended, the cultural resource inventory was completed to locate, identify, and evaluate any cultural resources that might be affected by the proposed undertaking. The inventory was completed by ARCADIS archaeologists Gregory Newberry, Michael Landem, Karla Whittenburg, Sam Cason, Steve Snyder, and Brent Slensker between January 9 and January 15, 2006. All field documentation, original records, and copies of this report are on file at the ARCADIS office in Highlands Ranch, Colorado.

The license amendment addresses the Three Crow Permit Area, a 2,100-acre area encompassing potential future mine developments south-southwest of the Town of Crawford and immediately south of the Fort Robinson State Park. The entire area was surveyed intensively for the presence of cultural resources that might be impacted by mining development and operations.

The objective of this cultural resource inventory was to locate and record any cultural resources that might be within the area of potential effects (APE) of the proposed project, and to provide recommendations of eligibility to the National Register of Historic Places (Register). Management recommendations for treatment of any discovered resources were to be made in accordance with their recommended Register evaluations and potential impacts.

AFFECTED ENVIRONMENT

The Three Crow area is on gentle to moderately rolling terrain south of the White River and north of pine-covered ridges separating the White River from Starvation Gulch and other tributaries of the Niobrara River. The northern portion of the project area is an elevated rolling plain above the White River valley. The southeastern portion of the project area is in the foothill breaks, below a high, pine-covered bluff. The highest point in the study area is a high sandstone ridge with very steep slopes (more than 100 percent grade). Cherry Creek and Bozle Creek run through portions of the project area. Both are ephemeral tributaries of the White River that had no running water during the fieldwork. Approximately 85 percent of the survey area is under cultivation, and many of the fields were freshly plowed. Exceptions are the moderately steep slopes adjacent to the drainages and the high ridge in the southeast portion o the survey block. Small areas along Cherry Creek did not appear to have been plowed and had intact surfaces. Dense grasses grow along the drainages with a few sporadic cottonwood trees and riparian shrubs. With the exception of cultivation, there were no major disturbances such as pipelines, well pads, or transmission lines.

Sediments are dominated by older Quaternary eolian sediments, predominantly loess. These sediments appear to be more than 20 centimeters deep in many places. There are localized exposures of fine-grained and cross-bedded sandstones in the drainage cuts, often accompanied by sandstone cobbles and gravels. There are a few moderately to well developed alluvial terraces along Cherry Creek. These localized deposits have been truncated by ephemeral stream flow and provided some exposures of subsurface sediments along the intact landforms.

The common large mammals found in the area are elk and deer. Bison were also present in the area historically. Small mammals include many small burrowing rodents.

BACKGROUND INFORMATION

RECORDS SEARCH

An architectural and structural properties search was conducted through the Nebraska State Historic Preservation Office (SHPO), and an archaeological site search was completed through the Archeology Division of the Nebraska State Historical Society. These records searches were completed to identify previous investigations and known archaeological and historical sites in the Three Crow permit area. The architectural and structural properties search did not identify any documented historic buildings or structures in the permit area. However, the SHPO pointed out that a number of buildings were shown on the USGS topographic map, and that it was likely that some of them may need to be recorded as historic buildings. The archaeological site search did not show any formal archaeological investigations within the permit area. The initial site and records search did show two previous survey areas east of the project area near State Highway 2/71 and one known site, also east of the project area.

Updated searches were completed through SHPO and the Archeology Division in November 2007. The architectural and structural properties search again did not identify any documented historic buildings or structures in the permit area. The archaeological records search did not identify any new archaeological investigations or any newly documented sites.

CULTURAL SETTING

Today the Crawford area is known for its hunting, and nomadic hunters utilized the area long before the arrival of Europeans. Deer, elk, pronghorn antelope, and game birds are still common. Bison, which were once numerous in the area, were exterminated in the late 1800s. The gravels of the White River and its tributaries yield good quality cherts and quartzites that were used by prehistoric groups to manufacture stone tools. These cherts and quartzites are similar to materials common in the Spanish Diggings and Hartville Uplift areas of southeast Wyoming.

PREHISTORIC CONTEXT

The prehistoric archaeology of the Central Plains is conventionally divided into five traditions that are characterized by common patterns of technology and lifestyle. These traditions are Paleoindian (9,000 to 12,000 years ago), Archaic (2,000 to 9,000 years ago), Plains Woodland (1,000 to 2,000 years ago), Plains Village (600 to 1,000 years ago), and Postcontact (100 to 400 years ago). In many respects the traditions of northwestern Nebraska are more akin to the Northwestern Plains traditions. Aspects of the stone tool technology of these regions are shared, but the pottery and settled villages that characterize the cultures of eastern Nebraska are absent. The nomadic traditions contemporary with Plains Woodland and Plains Village are often grouped together as Late Prehistoric. Each of these traditions is briefly characterized in the following paragraphs.

Evidence of the Paleoindian tradition begins with the end of the last Ice Age about 12,000 years ago. Several complexes of relatively large, well made, bifacially chipped stone tools that share common traits over large areas characterize the tradition. Some distinctive stone types, such as Yellowstone obsidian, Knife River flint, Alibates chert, Hartville Uplift chert, and Spanish Diggings quartzite, were preferred raw materials for these tools, and are found in sites far from their source areas. The majority of known sites are large game kill sites or butchering sites, although a number of small campsites and burials have also been documented. The earlier complexes of this tradition are often associated with mammoths, camels, and extinct species of bison. Later complexes are associated with modern types of game animals, including small animals, and an increasing use of wild plant resources, foreshadowing patterns that would be typical of the subsequent Archaic tradition.

The Archaic tradition began about 9,000 years ago. Although there are widely shared attributes in bifacially chipped stone tools, they tend to be less finely made than their Paleoindian predecessors and exhibit more local variation, and ground stone implements become much more common. Chipped stone tools in this tradition were also typically made of locally available stone types. The sites exhibit evidence of more diverse hunting and foraging, utilizing both large and small game species and a wide range of wild plant resources. The evidence indicates a continued nomadic lifestyle, but the prevalence of local resources and the reduced similarities in certain tool styles over large areas suggest that the movement of people was more localized.

The Woodland tradition began about 2,000 years ago and is marked by innovations in technology, subsistence, and settlement. Elements of this emerging tradition were borrowed or brought from cultural traditions in the woodlands regions east of Nebraska. Among the technological changes was the widespread appearance of small bifacial points for arrows. Earlier points had been larger forms used on hand-held spears, darts thrown with atlatls, and comparatively large arrows used with simple bows. A second technological change was the appearance of fired clay (ceramic) vessels for storage and cooking. An accompanying change in settlement in some areas was the emergence of semi-permanent dwellings in sites that were occupied year-round, or re-occupied seasonally. A Woodland trait shared with traditions farther east is the emergence of elaborate burials in earthen mounds. Nomadic Plains Woodland groups shared aspects of the biface and ceramic technology, but are not associated with semi-permanent dwellings or elaborate mound burials.

The Plains Village tradition emerged in this region about 1,000 years ago. In areas that had been characterized by semi-permanent dwellings and mound burials during the Woodland tradition, there was a marked change in subsistence and material culture. In contrast, there was little evident change in the subsistence patterns of nomadic groups. A major change in the subsistence of sedentary groups was the intense use of garden horticulture based on maize, beans, and squash. Hunting and wild plants continued to be important as well, but garden horticulture became an important source of storable food surplus. Pits for storage of food and tools are often found below the floors of habitations.

The Postcontact period began approximately 400 years ago with the first Spanish colonies in the American Southwest and the establishment of permanent Northern European colonies for the fur trade in eastern North America. The early influences of European presence are virtually invisible in the archaeology of the Central Plains. Even as the fur trade expanded westward and the Spanish expanded northward, physical evidence of European presence is sparse. But by the early eighteenth century, trade goods have spread into areas that no European is known to have visited, virtually all Native American cultures are directly or indirectly affected by the fur trade or Spanish missions, and Old World diseases have crept across the continent. Soon firearms would reach the Plains from fur trading forts, large numbers of horses would be available in the region, and European traders would begin visiting Native villages and establishing trading forts. The early smoothbore trade guns were loud, but of no great advantage to the nomadic plains tribes. They were inaccurate and took a long time to reload. The horse was firmly established in Plains Indian culture before the breach-loading rifle was available in the mid-1800s. The historically documented groups of western Nebraska include Apache, Lakota, Crow, Kiowa, Cheyenne, Arapaho, and Pawnee. These groups were nomadic or semi-nomadic hunters involved in the fur and hide trade. The Lakota, Crow, Cheyenne, and Arapaho, were only a few generations removed from more sedentary village traditions, and the Pawnee were still village dwellers or closely associated with sedentary villages. These historical groups embody the classic Plains Equestrian stereotype of the American Indian. Occasionally, individual free trappers from eastern tribes such as the Iroquois or Delaware are noted in accounts of the region, but in terms of material remains, these individuals would be indistinguishable from trappers of European or mixed ancestry.

HISTORIC CONTEXT

Sustained European presence in northwestern Nebraska began with the fur trade. James Bordeaux established a small trading post along the White River in 1837. In 1841, Louis Chartran managed a competing trading post near modern Chadron. The European traders had been preceded in the region by Native American middlemen, including Lakota and Cheyenne bands, who were involved in traditional Native American trade systems and trade with Europeans. The primary products sought for the European markets in this period were furs and hides. The Europeans produced blankets, cloth, metal implements, tobacco pipes, and trinkets, such as beads, for the Native Americans. Popular metal items included pots, knives, and arrow points. Trade guns were also produced in quantity, but were not a popular item among the Plains tribes. These single-shot, muzzle-loading guns were not very accurate and were not easily reloaded on horseback. Archaeological sites of this period other than the documented trading posts and other clearly identifiable European sites are typically identified as Postcontact Native American sites.

After the trade in furs diminished in the 1850s, farmers began to settle the region. In the early 1870s, the settlement that would become Chadron was established at the confluence of the White River and Chadron Creek and in 1874, Fort Robinson was established about 25 miles to the west of Chadron along the White

River. Fort Robinson was established to protect the Red Cloud Indian Agency after it was moved from the Platte River in Wyoming, and also to protect the Sidney to Deadwood wagon road. The fort was named for a lieutenant who was killed that year by Indians from the Red Cloud Agency. The first Red Cloud Indian Agency had been established in 1868 in Wyoming at the end of Red Cloud's War in the Powder River Basin. Red Cloud was an Ogallala Lakota leader who opposed the Bozeman Trail from Fort Laramie to the Montana gold fields. Other Lakota bands, as well as Cheyenne and Arapaho, also supported Red Cloud in his opposition to the trail.

In 1877, Crazy Horse and a large band of Lakota warriors surrendered at Fort Robinson. Although Sitting Bull's Hunkpapa Lakota and other followers were still free in Canada, the surrender of Crazy Horse marked the end of the US Army's Powder River campaign. Four months later, while being escorted through the fort, Crazy Horse was killed. Later that year, the Red Cloud Agency was moved to a new site on the Missouri River. Fort Robinson remained. Troops from Fort Robinson were involved in the capture of Dull Knife and the Cheyenne Outbreak of 1879. Later they were involved in the Pine Ridge Campaign and the battle of Wounded Knee.

A small civilian settlement developed northeast of the fort. In 1886, the Fremont, Elkhorn and Missouri Valley Railroad (FE&MVR), then a subsidiary of the Chicago and Northwestern Railroad, established depots at the fort and at the small settlement that would become Crawford. Three years later, the Chicago, Burlington, and Quincy Railroad (CB&Q) also built through Crawford. With a railroad to haul freight to the Black Hills, the Sidney to Deadwood wagon road was no longer economically viable, and was abandoned. Early Crawford was dominated by saloons and gambling houses, but it soon became an important center for ranchers and farmers.

Fort Robinson remained a cavalry post until 1919, and with access to the nearby railroads, this fort surpassed Fort Laramie in importance in the region. Even after it was no longer a cavalry post, it remained an important training and breeding center for army horses and mules. Between 1935 and 1939, the U.S. Olympic Equestrian team trained at Fort Robinson. In 1943, a German prisoner-of-war camp was built between the post and the Town of Crawford. After the war, military activities at Fort Robinson were phased out, and in 1948, it was turned over to the U.S. Department of Agriculture for use as a beef research station.

The old FE&MVR tracks, now operated by the Union Pacific (UP), pass through Fort Robinson on the north side of the White River, about 1.5 miles north of the Three Crow area. The CB&Q, now the BNSF, is about 3 miles to the northeast. State Route 2 and 31, running south from Crawford through Marsland, is about 1.5 miles east of the Three Crow area. The land has been cultivated for wheat and alfalfa for many years. The General Land Office (GLO) plat maps for this township indicate that there were once small wagon roads in this area. Some of the roads ended within the area, suggesting that they may have been local roads for obtaining wood or other resources. Few traces of prehistoric settlements, early historic roads, or the military history of the area are likely to be preserved in the upland areas away from the White River and its larger tributaries. Much of what remains will be artifacts scattered through plowed fields and later historical features associated with farming and ranching.

STATEMENT OF OBJECTIVES

Following state and federal policies and regulations implementing the NHPA, this project area was inventoried to identify any cultural resources within the APE of the proposed project. Any discovered cultural resources were to be evaluated for eligibility to the Register under the Criteria for Eligibility (36 CFR 60.4 a-d). Register eligibility is evaluated in terms of the integrity of the resource and: (a) its association with significant events or patterns in history or prehistory; (b) its association with the specific contributions of individuals significant in our past; (c) its engineering, artistic, or architectural values; or (d) its information potential for important research questions in history or prehistory.

Prehistoric resources are most often evaluated under Criterion d for their potential to yield information important in prehistory. Significant information potential in a prehistoric site requires that the site contain intact cultural deposits or discrete activity areas that can be securely associated with a temporal period or discrete cultural group. The potential for intact deposits or cultural/temporal associations may be inferred from surface evidence of cultural features or undisturbed Holocene deposits, and the presence of temporally or culturally diagnostic artifacts. Historic resources may be evaluated under any of the Criteria. However, in the absence of structural features or documented association with significant historic events or the important contributions of persons significant in history, historical resources more than 50 years old are evaluated under essentially the same criteria as prehistoric resources.

Based on information available from files searches and previous research experience in the area, ARCADIS anticipated that prehistoric and historic cultural resources would be present but would consist of a small number of prehistoric and historical artifact scatters. A slightly higher proportion of artifacts or features was expected near the drainages (Spring Creek and White River). At least two historic farming complexes with standing buildings or foundations were noted on the aerial photographs and topographic maps.

METHODS

The entire project area, including the high ridge in the southeast portion of the project area, was surveyed by parallel pedestrian transects oriented to cardinal directions and spaced at 30-meter intervals. Special attention was paid to high probability areas and eroded surfaces such as ridge tops and cutbanks. Surface visibility was very good to excellent (75 to 90 percent) over most of the survey area. There were a few fields with slightly higher or denser stubble or weeds, and the grasses and forbs on uncultivated areas near the drainages were low and open. Dense grasses along the drainage courses limited visibility to 25 to 50 percent in some areas. The only areas of higher and denser vegetation where visibility was fair to good were within historical sites (around historical buildings and foundations). Surface visibility and weather were excellent for the discovery, documentation, and evaluation of cultural resources. Weather was somewhat variable, but generally consisted of cold, windy, but mostly clear days. During the first day of survey, there were some remnant patches of snow in protected areas, but by the following day they were melted.

Discovered cultural materials were classified as sites or isolated finds, were documented on Nebraska State Historical Society Archeological Site Survey forms, and their locations were plotted on 7.5-minute USGS topographic maps. The locations were also plotted on 1:12,000 scale orthophoto maps, and readings were taken of the location with a hand-held Trimble XT global positioning system (GPS) unit. An isolated find consists of five or fewer surface artifacts with no associated cultural features and minimal potential deposition. A site consists of five or more artifacts within 50 meters of one another, or at least one cultural or structural feature. The same Archeological Site Survey form is used for both sites and isolated finds, but site sketch plans were not drawn for isolated artifacts. The full extent of each site was established, a site sketch plan was drawn, and photographs were taken of the site area and any distinctive features. Any distinctive or diagnostic artifacts were drawn to scale and photographed. Artifacts were not collected unless they were distinctive and unusual, and could not be adequately documented in the field.

RESULTS

Eleven historic sites, one isolated historic artifact and two isolated prehistoric artifacts were located and identified. The historic sites are three artifact scatters, two farm complexes, two rural residences, two collapsed buildings, a windmill and water tank, and an isolated piece of farm machinery. The individual artifacts are a historic fraternal medallion and two prehistoric flakes. Site photographs are provided in **Appendix A**.

25DW302

This site consists of a single piece of chert debitage (**Figures 2 and 3**) 140 meters south of the Fort Robinson State Park boundary. It is in a broad, open valley east of an unnamed tributary of the White River (**Figure 4**). Vegetation is limited to winter wheat stubble, and the surrounding land had been recently plowed. Sediments consist of more than 20 cm of silty loam derived from old eolian deposits. Agriculture is the only substantial impact to the site area.

The artifact is a piece of chert shatter. It is light tan with small red inclusions and has a maximum length of 36 mm. This single artifact is by definition not eligible for the Register.

25DW303

This site is an isolated historic medallion (**Figure 5**) found in a driveway 360 meters north of 4 Mile Road. The surrounding land is mostly level with a very slight slope to the north. The artifact was discovered at the edge of the road within the ditch disturbance (**Figure 6**). Fields along the road had been recently plowed and were covered with winter wheat stubble. There is a windbreak tree row on the east side of the road. Sediments consist of more than 20 cm of silty loam that have been extensively churned by road construction and plowing.

The artifact is a decorative medal from the Knights of Pythias, inscribed with dates of the 50th Convention in Lincoln, Nebraska, May 12 through 13, 1914. A manufacturer's stamp on the back of the medal reads "Schwaab S&S Co., Milwaukee." A member of the Knights of Pythias explained:

> "Years ago, all national fraternities used the skull and crossbones to signify the mortality of man, as compared to the immortality of the Supreme Being which we all ask our prospective members to believe in. The Knights of Pythias is a non-sectarian fraternity in that we do not specify any particular religion or denomination. We have ceased to use that symbol many years ago. The colors blue, red, and yellow are the colors of the Order... F.C. and B. stand for FRIENDSHIP, CHARITY, and BENEVOLENCE - the three cardinal principles upon which the Order was based when it was founded in 1864." (Personal communication between Greg Newberry and Alfred A. Saltzman Supreme Lodge Knights of Pythias, Supreme Secretary, January 16, 2006)

25DW304

This is an isolated modified flake (**Figures 7 and 8**) found on a gentle ridge on the west side of Cherry Creek. The artifact is in a cultivated field (**Figure 9**). The immediate area and surrounding land had been extensively plowed. Sediment consists of more than 20 cm of silty loam derived from old eolian deposits. The land had not been cultivated recently, but the area has a long history of agriculture.

The artifact is a modified flake fragment of tan chert with amorphous grey mottling. One lateral edge has minimal unifacial retouch, and the artifact measures 39 by 20 by 5 mm thick. This single artifact is not eligible for the Register.

25DW305

This site is a historic and modern dump east of Cherry Creek and south of the 4 Mile Road. It is in the bottom of an ephemeral tributary of Cherry Creek (**Figure 10**). Sediments consist of more than 40 cm of alluvial silty sand overlying exposures of sandstone bedrock. Vegetation is native short grasses and small forbs. Except for stream bank erosion, there are no major impacts to the site. The view from the site is limited due to the site's low position in the drainage.

Cultural material consists of a large debris pile along a headcut in the drainage. Most of the debris consists of rough hewn lumber (1-by-6, 2-by-4, and 4-by-6-inch boards). Additional debris includes Sanitary cans, broken shovels and rakes, clear glass condiment jars, brown glass bottles, pull-tab beer cans, sheep fence, barbed wire, red brick, mammal bone, aluminum pie plates, barbed wire, and the body of a late 1930s or 1940s truck. The location of the debris suggests that it may have been put there as erosion control to prevent the advance of the headcut.

Cultural materials represent typical discard from farm and ranch operations. The earliest materials date to the first half of the twentieth century, but much of the household debris is modern. The dump is not known to be associated with any important historical persons, and it is not likely to yield useful information concerning historic lifeways. The site is recommended to be not eligible for the Register.

25DW306

This site is a historic farm 0.5 mile south of the 4 Mile Road. It is at the base of a slope leading up to steep, pine-covered bluffs to the south. The surrounding land has been plowed and planted with winter wheat. This immediate area is overgrown with grasses, but has likely been previously disturbed by agriculture. There are several large cottonwood trees around the perimeter of the site. Sediment consists of more than 10 cm of silty loam derived from old eolian deposits and slopewash from the adjacent bluffs. Disturbances consist of plowing, vehicle traffic, fence construction, and livestock trampling. The view from this site encompasses the slopes below the bluff and a modern residence to the east. The White River valley is visible far to the north.

Cultural material consists of a single residential structural remnant (**Figures 11 and 12**). The house is framed with full dimension lumber (2-by-4, 2-by-6, 2-by-8-inch boards) and set on a foundation formed of log posts set upright at the corners. The exterior is sheathed in 1 by 8 shiplap boards, covered in some places with rolled asphalt material. The roof is a low front-gable with shake shingles. The footprint is ell-shaped measuring roughly 30 by 20 feet. There are three windows and two doors, all broken or missing. The flooring is finished with tongue-and-groove boards. The house was wired for electricity, but there is no evidence of any other utilities. The roof is partially collapsed, and the interior of the house is exposed to the weather and elements. Few artifacts were observed. A small amount of modern debris is scattered around the house, but the only potential historic artifacts noted were two pieces of undecorated ironware.

This site has no known associations with any important historic events or persons, and the house is in poor condition. Furthermore, it is not likely to provide useful information concerning historic lifeways. The site is recommended to be not eligible for the Register.

25DW307

This site is an occupied modern farm complex with no evident historic structures or artifacts. It is located at the foot of the north-facing slope of a ridge. All of the buildings on the site appear to be modern (post-1950s).There are windbreak tree rows along the north and south ends of the site. Buildings and structures on the site include a side-gable main house with a small addition, a two-car garage, a smaller garage or shed, a grain bin, a front-gable shed, a large Quonset (equipment shed), and a barn or stable with an attached corral. The field crew did not have permission to enter this occupied property. Consequently, the site was not recorded in detail.

25DW308

This site is a historic farm complex approximately 190 meters south of the Fort Robinson State Park boundary. It is on a broad, rounded ridge between Cherry Creek and Bozle Creek in a rolling plain. The immediate site area is covered with high grasses. Most of the surrounding terrain has been extensively cultivated. There are several small cottonwood trees and a few evergreens in the yard (**Figure 13**). Sediments consist of more than 10 cm of silty loam derived from very old eolian deposits and heavily disturbed by agriculture. The view from this complex is expansive and encompasses much of the White River valley, the surrounding bluffs, Fort Robinson, and Crawford (**Figure 14**). There are no major industrial disturbances in the immediate vicinity, and the site retains a strong integrity of historical feeling, association, and setting.

The complex consists of six historic buildings (two residences and four outbuildings), a dispersed debris scatter, and several implements and facilities. Structure 1 (S1) is a deteriorated residence (**Figure 15**). It consists of an end-gable building and a gable ell addition. Its overall dimensions are approximately 40 by 30 feet. The house is set on a concrete slab foundation and is constructed mainly of concrete blocks with concrete plaster on the exterior. The gabled roof is covered with shake shingles. The interior has wood paneling and carpet. There are six metal-frame casement windows and two exterior doors. All of the windows and doors have intact frames, but the window panes and door panels are broken or missing. The house is wired for electricity and has indoor plumbing. No stove or fireplace is evident. The house may have been constructed before 1950. The interior finishing suggests it was abandoned in the late 1960s or early 1970s. Much of the building is intact, but there are holes in the walls and roof. The building is a simple rural vernacular style with no distinctive architectural traits or embellishments.

S2 is also a deteriorated residence (**Figure 16**). The house has a roughly rectangular footprint measuring approximately 30 by 60 feet. It consists of an ell-gabled building with four shed-roof additions. The house is constructed of milled dimensional lumber with a plaster and lath interior and horizontal clapboard exterior. The foundation is mortared stone sill. The additions are cinder block, and there is a small excavated cellar under one of the additions. The roofs are shake shingle. Finish flooring in much of the house is tongue-and-groove lumber. This building is mostly collapsed. Two of the northern walls have toppled, and the entire roof has collapsed. Windows and doors are missing, and the interior is filled with fallen debris and remnants of bed frames and oil-burning heaters. Construction materials are consistent with 1930s to 1940s patterns, and the building appears to have been in disrepair for a long period. The house is in very poor structural condition.

S3 is a mostly intact barn that measures approximately 20 by 24 feet (**Figures 17 and 18**). It was constructed with a heavy timber frame and sheathed with milled lumber. The side-gable roof is covered with galvanized corrugated metal sheets. There are three large openings to accommodate livestock and equipment. The barn does not appear to have been recently maintained but is mostly intact.

Feature 1 (F1) and F2 are two adjacent concrete foundation remnants (**Figures 19 and 20**). They are low, rectangular sills. There is very little structural debris, and it is likely that the collapsed structures have been pushed into one of the outlying debris piles to the west of the complex. F1 measures approximately 20 by 30 feet and F2 measures 25 by 30 feet.

There is a cistern (F3) between S2 and S3 (**Figure 21**). It consists of a semi-subterranean tank enclosed in a rectangular cement box that occupies approximately 8 by 8 feet. There is a collapsed metal windmill frame to the north of S3 that was likely attached to the well hole adjacent to the cistern.

F4 is a rectangular concrete slab covered by a large pile of heavy timbers and milled lumber (**Figure 22**). It appears to be the foundation of an outbuilding that has collapsed and was subsequently cleaned up by pushing the debris to the center of the foundation. Wall and roofing remnants are totally disarticulated and there is little left of the building. The footprint is 20 by 32 feet.

There are very few artifacts on the site. There is only a thinly dispersed scatter of debris between the residential buildings, including clear glass, sheet metal, and barbed wire. Beyond the western yard of the complex there are several piles of structural debris, including cement blocks, fence posts, milled lumber, sheet metal, and wire. A wire nail and purple glass fragments were found adjacent to S3, and the metal bed frames and oil heater in S2 likely date to the 1940s or 1950s. Along the fence south of S3 there is a small cluster of machinery parts, including sheet metal shrouds, and a coil of barbed wire (**Figure 23**).

The site is no longer in use. S2 was likely the first residential structure, and was probably abandoned in favor of the later residence, S1. S2, F1, F12, and F4 are totally collapsed. The site is not known to be associated with important historical figures or events. This site is recommended to be not eligible for the Register.

25DW309

This site includes the remains of two historical structures, a wellhead, three debris piles, and a dispersed scatter of artifacts located approximately 20 meters south of the Fort Robinson State Park boundary. It is on a broad, rounded ridge on the west side of Bozle Creek (**Figure 24**). A tributary of Bozle Creek runs along the west side of the landform, and an earthen dam forms a stock pond in the drainage. Sediments consist of more than 10 cm of silty loam that have been disturbed by cultivation. Vegetation within the site consists of high grasses, and the surrounding land has been cultivated. There is a lone cottonwood tree at the north end of the site adjacent to the State Park fence line. The view from the site is expansive and encompasses a portion of the White River valley, the surrounding bluffs, Fort Robinson, and Crawford. There are no major industrial disturbances in the immediate vicinity, and the site retains a strong historical feeling, association and integrity of setting.

F1 is a shallow, 20-foot-diameter depression with a mounded pile of milled lumber and sheet metal in its center (**Figure 25**). The lumber includes 2-by-4-inch and 2-by-6-inch boards, and tongue-and-groove floorboards. There are no articulated structural elements within the debris, and the feature appears to be a push pile from a demolished structure. There is no discernible foundation.

F2 is a similar debris pile, 24 feet in diameter (**Figure 26**). It consists of more than 50 pieces of rough hewn timbers, 2-by-4 and 2-by-6-inch milled lumber, sheet metal, wire nails, and barbed wire. It appears to be a mound of debris from corrals and structures. No foundation was observed.

F3 is a collapsed building that may have been a shed reused as a stock shelter (**Figure 27**). It consists of a floor remnant constructed of 2-by 4, 2-by-6, and 1-by-12-inch lumber, mostly articulated, and resting on stone, cement, and red brick piers at its corners. It measures 14 by 16 feet. There is a large pile of milled lumber on the floor, but there are no apparent walls or roofing materials present.

F4 is a semi-subterranean structure, possibly a root cellar or privy. It consists of collapsed wall remnants in a depression that measures 15 by 17 feet and 36 inches deep (**Figure 28**). Building materials include rough hewn logs, 2-by-4 and 1-by-10-inch lumber, and a tongue-and-groove paneled door with metal hinges. The structure is completely collapsed. There is a possible entrance along the south side. In addition, there is a square, red brick chimney remnant in the center of the debris.

A few artifacts, including two Sanitary cans, a hole-in-top can, sheet metal fragments, barbed wire, and bailing wire, are scattered around the edges of the site. Two Nebraska license plates with 1926 and 1927 dates were found adjacent to F5 (**Figure 29**).

All of the structures present at this site are totally collapsed. Furthermore, there are few artifacts and no evidence of buried archaeological deposits. The site is not known to be associated with any important historic events or figures, and it is not likely to yield useful information concerning historic lifeways. The site is recommended to be not eligible for the Register.

25DW310

This site is an isolated historic plow south of the Fort Robinson State Park boundary (**Figure 30**). It is on the shoulder of a broad ridge east of Cherry Creek. Much of the surrounding land has been recently plowed, but the immediate site area is overgrown by high grasses. Sediments consist of more than 10 cm of silty loam derived from old windblown deposits. The site area has likely been plowed in the past. There is a fallen fence line running east west to the north of the site, and a two-track road runs down the ridge south of the site. Several exposures of calcined sandstone bedrock outcrop below the site on the slope of the ridge. The view from this site encompasses a portion of the White River Valley, and Crawford is visible to the northeast. Other than the fence and two-track, there are no major disturbances to the immediate site area.

The plow is a horse-draw type with a wooden tree and single metal-rimmed wheel for controlling the plow depth. There is a smaller wheel for the plow angle and a metal seat for the operator. The blade is approximately 36 inches long, and there are several armatures and levels for adjusting the blade depth and angle. The device is very rusted but mostly intact. An embossed emblem on the seat reads " P.S.Co YOUNGSTOWN.O PAT.APDFOR". This isolated implement is recommended to be not eligible for the Register.

25DW311

This site is a historic debris scatter south of the Fort Robinson State Park boundary. It is on the east side of an ephemeral tributary of Bozle Creek, on the western shoulder of a broad ridge (**Figure 31**). There is a fence line running east-west across the southern site boundary and a faint two-track running along the northern boundary. The site area is overgrown with high grasses. Much of the surrounding land has been extensively cultivated, and the field south of the fence line has been plowed recently. Sediments consist of overturned silty loam derived from old eolian deposits. There are thin, localized deposits of calcined sandstone cobbles on the lower shoulder of the ridge, indicating limited deposition. The view from this site encompasses a portion of the White River Valley, and Crawford is visible to the northeast. There are few industrial intrusions in the immediate viewshed.

Cultural material consists of a small cluster of burned bone, a purple glass candy dish fragment (**Figure 32**), and a fuel can. The bone is located under the fence, which likely explains why it has not been completely displaced by plowing. The specimens represent a small or medium sized mammal, possibly pig or goat. The purple glass fragment was found near the bone. The flattened fuel can is north of the fence.

There is very little cultural material at this site, and there is no evidence of buried cultural deposits or intact archaeological features. The site is not known to be associated with important historical figures or events, nor is it likely to provide useful information concerning historic lifeways. This site is recommended to be not eligible for the Register.

25DW312

This site is a fallen windmill on a broad ridge west of Bozle Creek. It is on the east flank of the landform on a gentle slope. The surrounding area appears to be regularly plowed, but the field was fallow at the time of recording. High grasses cover much of the site area, but there are recently tilled fields nearby. Sediments consist of more than 10 cm of silty loam, derived from old eolian deposits and disturbed by cultivation. With the exception of plowing, there are no major impacts to the site. The view from this site encompasses the upper reaches of Bozle Creek below the high bluffs to the south, and Crawford is visible to the northeast. A modern farm and residence is visible about 0.5 mile to the east.

Cultural material consists of a collapsed windmill tower, part of the mechanism (**Figure 34**), a reservoir tank, and some debris (**Figure 33**). The tower is constructed of wood and is completely collapsed on the south side of the tank. There is a cement-lined well between the tower and the tank. The reservoir is formed of a milled lumber frame lined with galvanized sheet metal. There are fragments of the superstructure within the tank including milled lumber, guy wires, sheet metal, and portions of the blades. A manufacturer stamp on a pipe fragment indicated that the mill was produced by Dempster Mill Mfg (**Figure 35**). A single clear glass bottle was found in the tank. The bottle has an irregular, asymmetrical base seam that suggests it was manufactured in the early 1900s before the regular use of fully automated bottling machines.

The windmill is completely collapsed. It does not display any distinctive construction characteristics and is not known to be associated with any important historic events or figures. This site is recommended to be not eligible for the Register.

25DW313

This site is a historic trash dump south of the Fort Robinson State Park boundary. It is situated on the east side of Cherry Creek, at the headcut of an arroyo that descends west toward the creek (**Figures 36 and 37**). Slopes rise gently to the east, climbing toward the crest of a broad ridge and rolling plains. Most of the surrounding land has been extensively cultivated, but the moderate slope surrounding the site appears to have been spared from plowing. Vegetation consists of high grasses and a few yucca in sandy deposits. Sediments consist of more than 20 cm of silty loam derived from old eolian deposits. Sandstone gravel and cobble outcrops suggest that deposition is localized along the slope. The view from this site is expansive and includes a modern residence to the southwest, the Cherry Creek drainage, the White River valley, and Fort Robinson to the northwest. There is little to blemish the integrity of the historic setting and the viewshed contributes to a strong historical feeling.

Cultural material consists of a trash dump at the head of the drainage. Debris is mounded along the perimeter and scattered down the base of the drainage. Household materials consist of: oil burning heaters; bed frames; Sanitary cans; a few solder dot cans; clear, brown, green, red, and purple bottle glass fragments; plumbing fixtures (toilet tanks and seats, an old shower stall); brown glass bleach bottles; and an electric coffee maker. Other materials include fence posts, barbed wire, tan bricks, cement blocks, fuel cans, enameled-steel wash basins, milled lumber, galvanized sheet metal, chicken feeders, and various machine parts. The earliest temporal indicators are purple glass and two Nebraska license plates (1933 and 1934). Recent debris includes plastic electric coffee makers, a barbeque grill, and modern cans. There are thousands of artifacts at the site. There are numerous dump episodes evident in the discrete mounds of debris, and the site is most likely related to the abandoned farm 100 meters to the northeast.

This site is typical of historic dumps in the region and is not likely to yield useful information concerning historic lifeways. The site has no known association with any important historical events or personalities. The site is recommended to be not eligible for the Register.

25DW314

This site is an isolated historic structure on a rolling plain 130 meters south of the Fort Robinson State Park boundary. It is on a gentle, west-facing slope that descends to Cherry Creek. The immediate site area is overgrown with dense wheatgrass, alfalfa, and a few scattered yucca. The site area has not been plowed, but the surrounding land has been extensively cultivated. Sediments consist of more than 20 cm of silty loam derived from old eolian deposits. A narrow, bladed road runs along the southwestern site boundary, but there are no recent disturbances within the site area. The view from the site encompasses the western White River valley and a portion of the Cherry Creek drainage.

Cultural material consists of a single dilapidated structural remnant (**Figures 38 and 39**). It appears to be an outbuilding, likely associated with the abandoned farm 100 meters to the east. What remains of the structure is a concrete sill outlining a 20-by-30 foot rectangular area open to the southwest. The concrete was poured in place. The sills are about 4 feet high and 10 inches wide. The structure was built into a shallow excavation in the hill slope. Several large, rough-hewn logs may have been roof supports. There are remnants of roofing material scattered upslope from the sill including 2-by-4 inch framing, 1-by-12 inch sheathing, and rolled asphalt roofing material. The structure may have been used as a vehicle shed, livestock shed, or storage building. It is mostly collapsed and has weak structural integrity.

This structure is a basic farm-related outbuilding and has no unique architectural characteristics. It is not known to be associated with any important historical events or personalities, and the site is not likely to yield useful information concerning historic lifeways. The site is recommended to be not eligible for the Register.

25DW315

This site is a farm and ranch complex (**Figure 40**) 450 meters south of the Fort Robinson State Park boundary. An unnamed ephemeral tributary of the White River runs south-to-north west of the site. Slopes rise to the east to a low ridge above Cherry Creek farther to the east. The site area has been extensively modified by agricultural activities, and the surrounding land is wheat and alfalfa fields. Sediments consist of silty loam that has been disturbed by cultivation. The view from this site encompasses a portion of the White River valley and Fort Robinson is visible to the north.

The complex consists of an occupied residence, an abandoned house, several outbuildings, livestock facilities, and modern debris. Portions of the residence, abandoned house, and several outbuildings are historic. Other outbuildings (sheds and barns) are modern, and the complex is still in use.

S1 is a barn that appears to have been brought in from elsewhere (**Figures 41 and 42**). The building occupies and area 30 by 32 feet. It is constructed of 2-by-4-inch and 4-by-4-inch framing, sheathed in 1-by-8-inch shiplap siding, and the roof is sheathed with corrugated sheet metal. The building rests on cement blocks at the corners. There are four stalls in the interior.

S2 is the main residence (**Figure 43**). It has a rectangular footprint measuring 60 by 30 feet. There are four rooms, a pantry, and a sun room. The living room is the original structure built in the early twentieth century, and the other rooms are subsequent additions. The composite building was constructed of cement blocks and dimensional lumber framing. The exterior has recently been sheathed with metal siding, and the metal roof is a recent improvement. The windows have likewise been recently replaced.

S3 is a barn with no foundation (**Figure 44**). It occupies and area 15 by 30 feet and is constructed of dimensional lumber framing with shiplap siding. It has a side-gable roof and shed addition covered with corrugated sheet metal. The barn has a loft and four rooms or stalls in the interior. This building is dilapidated and leaning precariously, and the roof is sagging.

S4 is an abandoned house with four rooms (**Figures 45 and 46**). It is cross-gabled with an ell-shaped footprint of approximately 32 by 32 feet. Most of the building is constructed of dimensional lumber framing with shiplap siding. The roof is covered with shake shingles. The house is wired for electricity and has indoor plumbing, as well as two chimneys. Most of the doors and windows are broken or absent, but there is still furniture in many of the rooms. Judging from the interior décor, the house was likely abandoned in the late 1960s or 1970s. The house is in very poor condition. Portions of the roof are sagging and collapsed, and the interior is exposed to the elements in many areas. Much of the interior paneling is collapsed and deteriorating.

S5 is a well house (**Figures 47 and 48**). It consists of a water tank resting on a concrete foundation and closed in a wooden frame. The exterior is framed with 2-by-4-inch lumber with shiplap siding. The gabled roof is made of shiplap boards. It measures approximately 8 by 8 feet. Much of the framing and sheathing is very deteriorated, and the structure appears to be twisting and on the verge of collapse. It has poor structural integrity.

S6 is a gabled pole loafing shed (**Figures 49 and 50**) that measures 50 by 20 feet. It is constructed of rough-hewn logs, and 2-by-4-inch, 4-by-4-inch, and 1-by-4-inch milled lumber. Most of the walls are missing, and the partially collapsed roof is sheathed in corrugated sheet metal. The shed appears to have been wired for electricity in the past but is no longer in use. The building is in very poor condition and has poor structural integrity.

Very few historic artifacts were observed within the complex. Several farm implements were observed along the western site boundary including plows, combines, manure spreaders, a tractor, and a seeder (**Figures 51 through 54**).

All of the historic features at this site are in very poor condition. The site is not known to be associated with important historical events of persons, and is not likely to yield useful information concerning historic lifeways. It is recommended to be not eligible for the Register.

EVALUATION AND RECOMMENDATIONS

A 2,100-acre area that may be impacted by the proposed mine development was surveyed for the presence of cultural resources. Eleven historic sites, one isolated historic artifact and two isolated prehistoric artifacts were located and identified. The historic sites are three artifact scatters, two farm complexes, two rural residences, two collapsed buildings, a windmill and water tank, and an isolated piece of farm machinery. The individual artifacts are a historic fraternal medallion and two prehistoric flakes. None of these sites are distinctive or outstanding, and all of the sites are recommended as not eligible for the Register. No further cultural resource work is recommended for this project area. In the event that unanticipated cultural artifacts, features, or human remains are encountered during development or operation of the project, work in the immediate area of the discovery must be stopped, and a qualified archaeologist must be contacted to assess the discovery.

APPENDIX A
PROJECT PHOTOGRAPHS

Figure 2: 25DW302. Close-up of dorsal side of the isolated artifact.
Greg Newberry, 1-11-06.

Figure 3: 25DW302. Close-up of ventral side of the isolated artifact.
Greg Newberry, 1-11-06.

Figure 4: 25DW302. View north over plowed field where the isolated artifact was found. Greg Newberry, 1-11-06.

Figure 5: 25DW303. Close-up of historic medallion. Greg Newberry, 1-11-06.

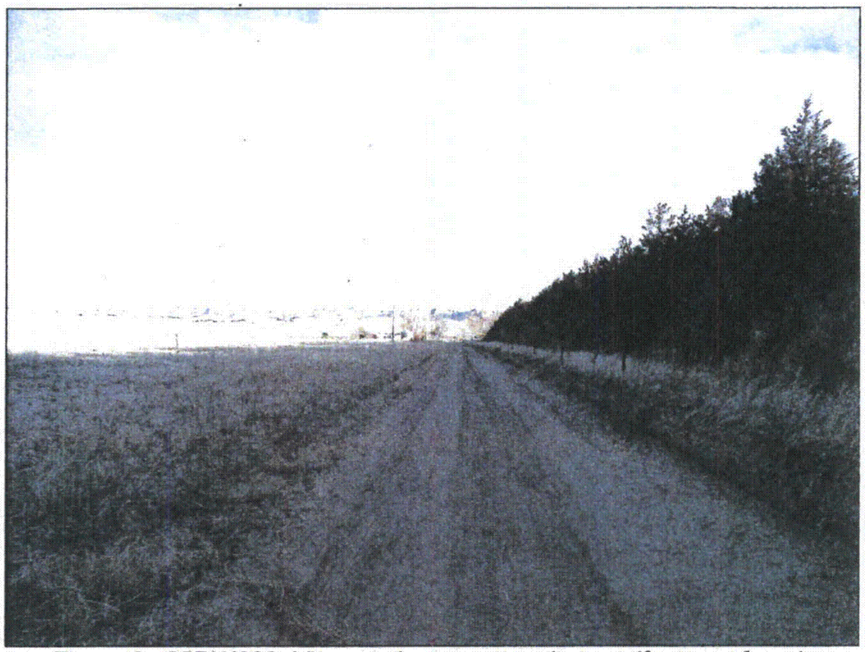


Figure 6: 25DW303. View north over area where artifact was found.
Greg Newberry, 1-11-06.

Figure 7: 25DW304. Dorsal view of modified flake.
Greg Newberry, .1-15-06

Figure 8: 25DW304. Ventral view of modified flake.
Greg Newberry, 1-15-06.

Figure 9: 25DW304. View north over setting where artifact was found.
Greg Newberry, 1-15-06.

Figure 10: 25DW305. View northwest over debris in head of drainage.
Greg Newberry, 1-14-06.

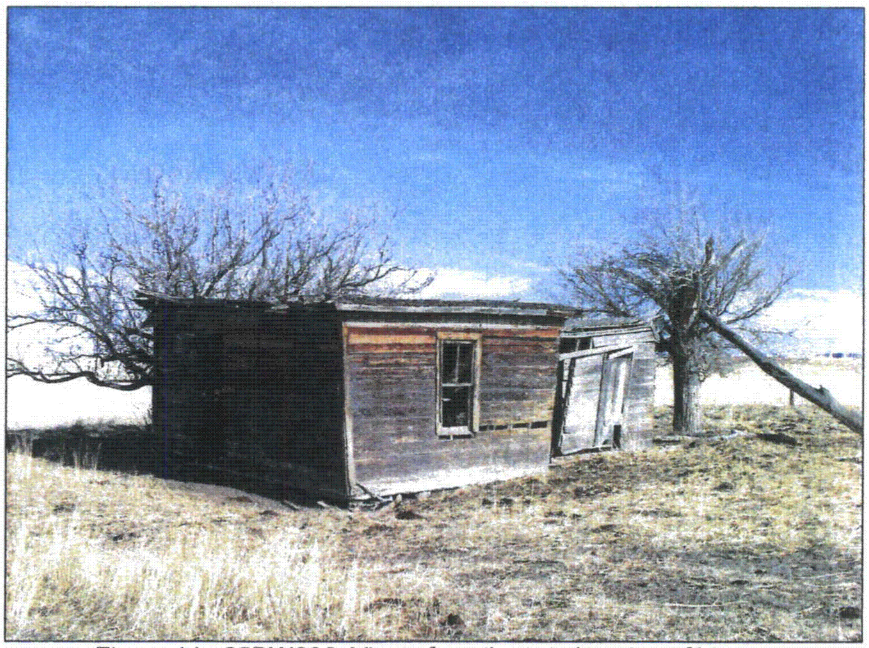


Figure 11: 25DW306. View of southwest elevation of house.
Greg Newberry 1-14-06.

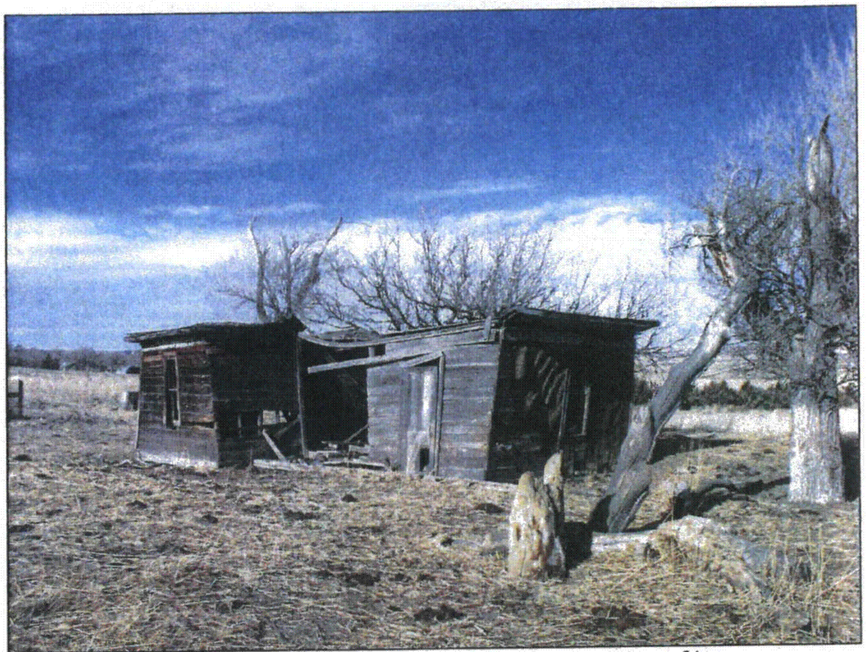


Figure 12: 25DW306. View of southeast elevation of house.
Greg Newberry 1-14-06.

Figure 13: 25DW308. View northeast over site area with S1 visible at right and S2 visible in the left background. Sam Cason, 1-12-06.

Figure 14: 25DW308. View northwest over site. S3 is visible at the right. Sam Cason 1-12-06.

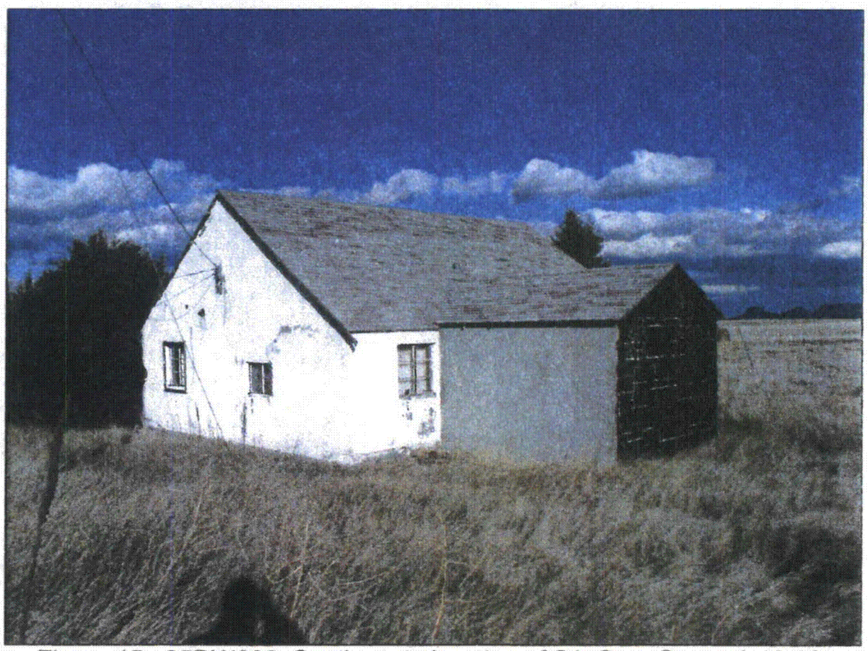


Figure 15: 25DW308. Southwest elevation of S1. Sam Cason 1-12-06.


Figure 16: 25DW308. View northeast to ruins of S2. Sam Cason 1-12-06.


Figure 17: 25DW308. Northeast elevation of S3. Sam Cason 1-12-06.

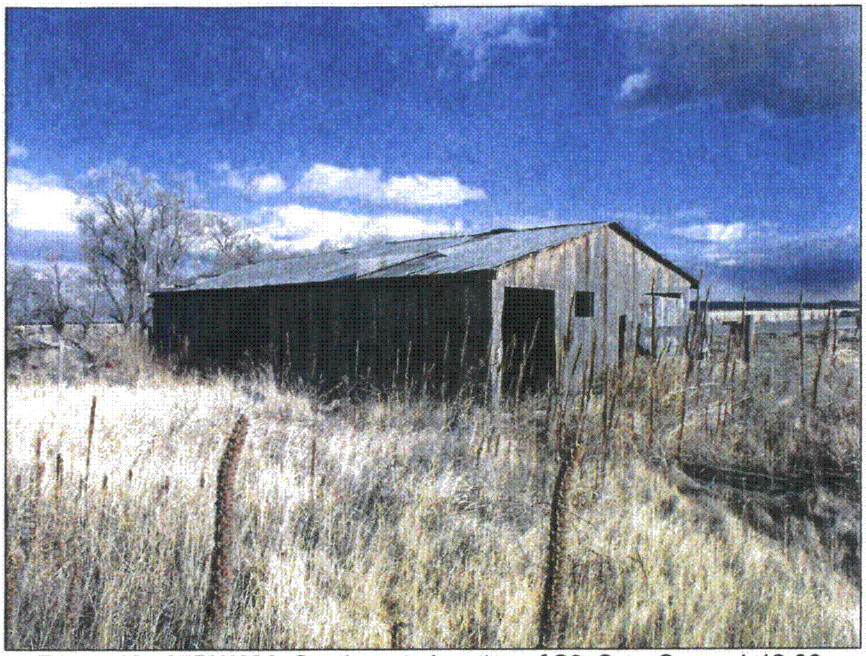


Figure 18: 25DW308. Southwest elevation of S3. Sam Cason 1-12-06.

Figure 19: 25DW308. View northwest over F1. Sam Cason 1-12-06.

Figure 20: 25DW308. View northwest over F2. Sam Cason 1-12-06.

Figure 21: 25DW308. View southwest over cistern, F3. Sam Cason 1-12-06.

Figure 22: 25DW308. View northeast over F4. Sam Cason 1-12-06.

Figure 23: 25DW308. Abandoned farm machinery. Sam Cason 1-12-06.

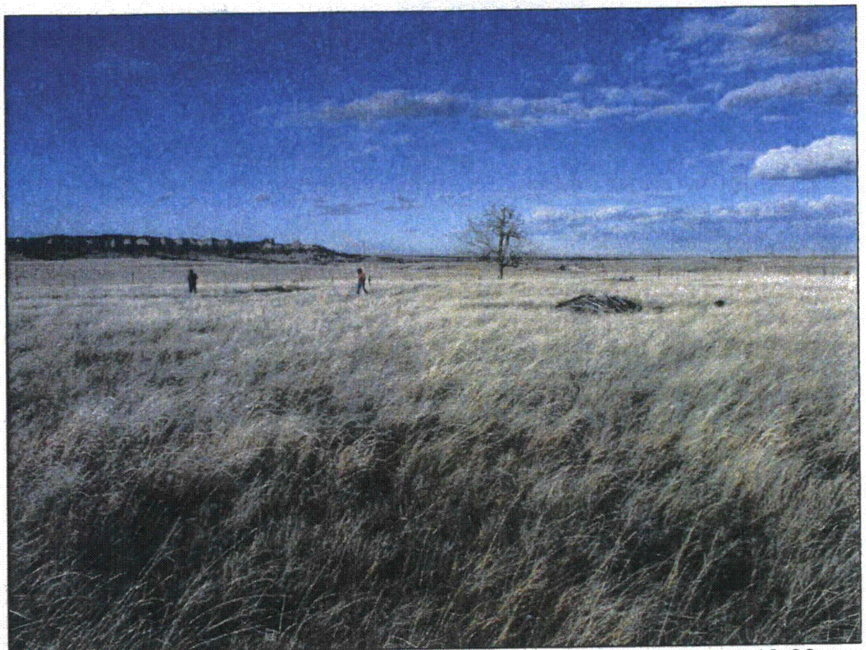


Figure 24: 25DW309. View north over site area. Sam Cason 1-12-06.

Figure 25: 25DW309. View northeast over F1. Sam Cason 1-12-06.


Figure 26: 25DW309. View north over F2. Sam Cason 1-12-06.


Figure 27: 25DW309. View north over F3. Sam Cason 1-12-06.

Figure 28: 25DW309. View north over F4. Sam Cason 1-12-06.

Figure 29: 25DW309. View north to F5. Sam Cason 1-12-06.

Figure 30: 25DW310. View of horse-drawn plow. Sam Cason 1-13-06.

Figure 31: 25DW311. View southwest over site area with Bozle Creek in background. Karla Whittenburg 1-13-06.

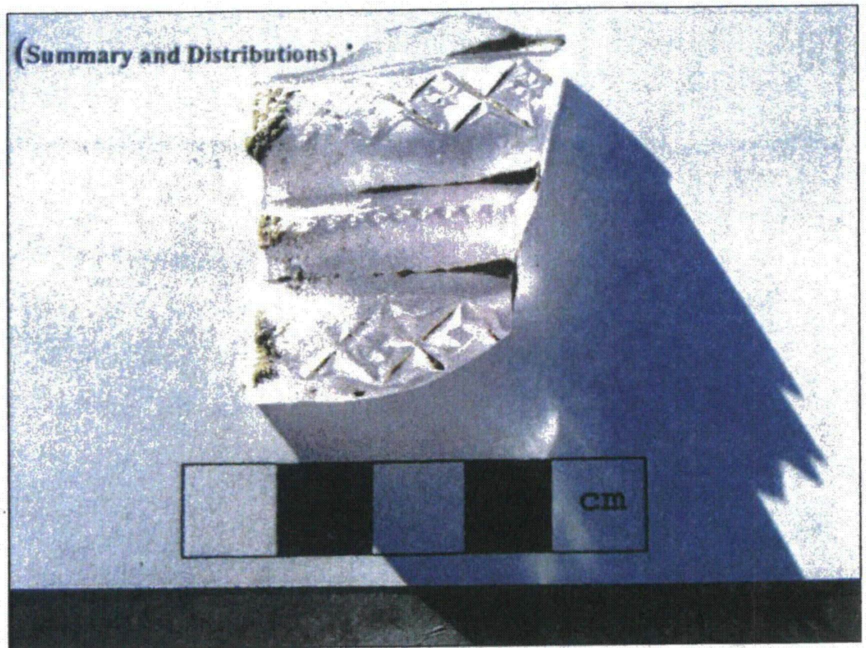


Figure 32: 25DW311. Close-up of purple (SCA) glass fragment.
Karla Whittenburg 1-13-06.


Figure 33: 25DW312. View northwest to collapsed windmill and water tank.
Karla Whittenburg 1-13-06.

Figure 34: 25DW312. Close-up of remnant of windmill mechanism and gears. Karla Whittenburg 1-13-06.

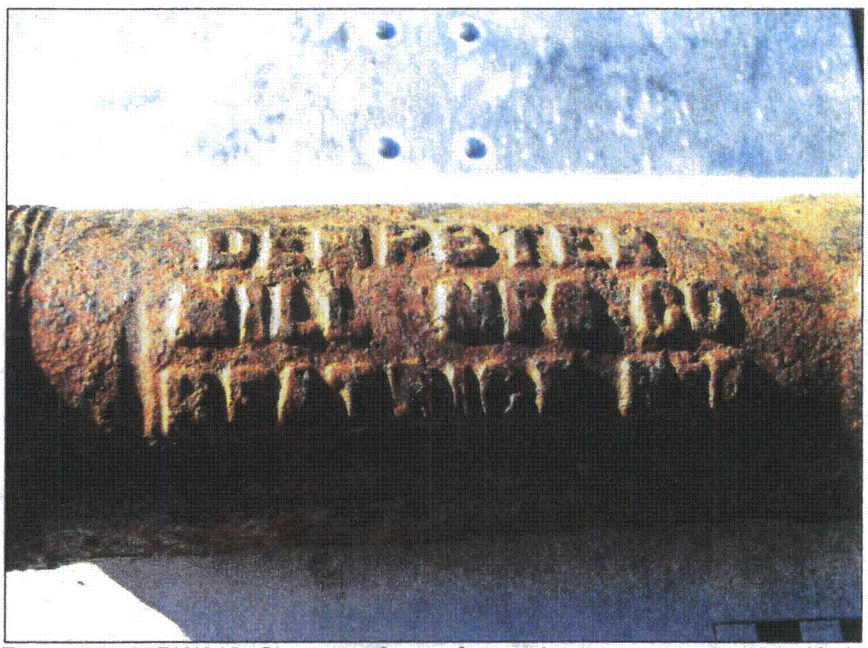


Figure 35: 25DW312. Close-up of manufacturer's stamp on water pipe. Karla Whittenburg, 1-13-06.

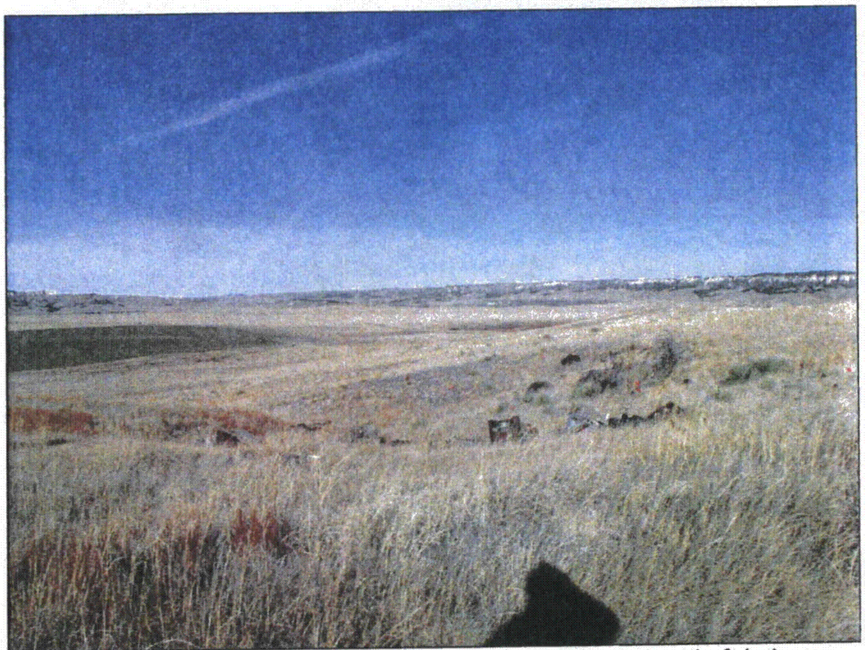


Figure 36: 25DW313. View northwest over site area in head of drainage. Karla Whittenburg, 1-13-06.


Figure 37: 25DW313. View east over site area looking up the drainage. Karla Whittenburg, 1-13-06.

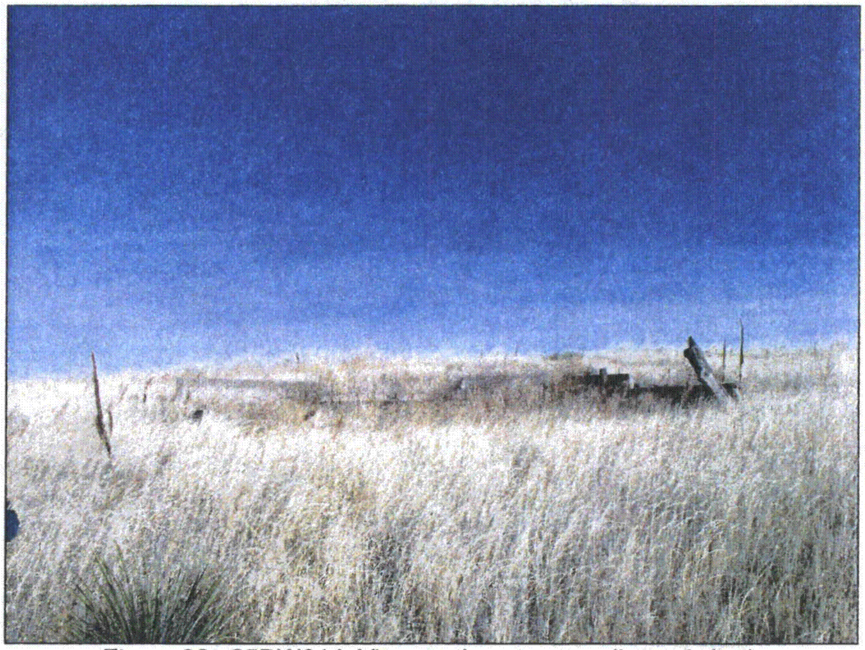


Figure 38: 25DW314. View northeast over collapsed shed.
Karla Whittenburg, 1-13-06.

Figure 39: 25DW314. View northwest over concrete sill foundation.
Karla Whittenburg, 1-13-06.


Figure 40: 25DW315. View north over site area. Sam Cason, 1-14-06.


Figure 41: 25DW315. Northwest elevation of S1. Sam Cason, 1-14-06.

Figure 42: 25DW315. Southeast elevation of S1. Sam Cason, 1-14-06.

Figure 43: 25DW315. Southwest elevation of S2. Sam Cason, 1-14-06.

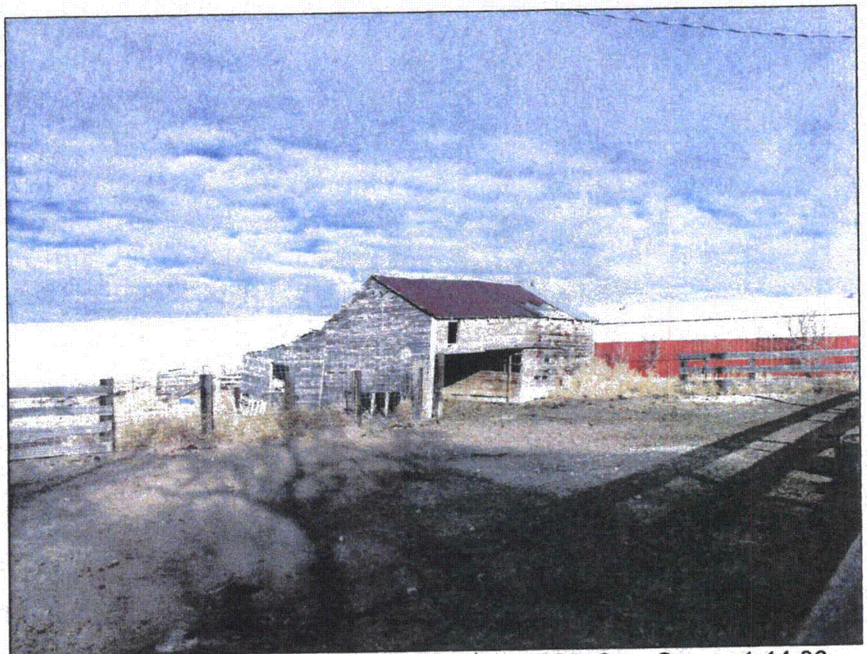


Figure 44: 25DW315. Southwest elevation of S3. Sam Cason, 1-14-06.

Figure 45: 25DW315. Northwest elevation of S4. Sam Cason, 1-14-06.

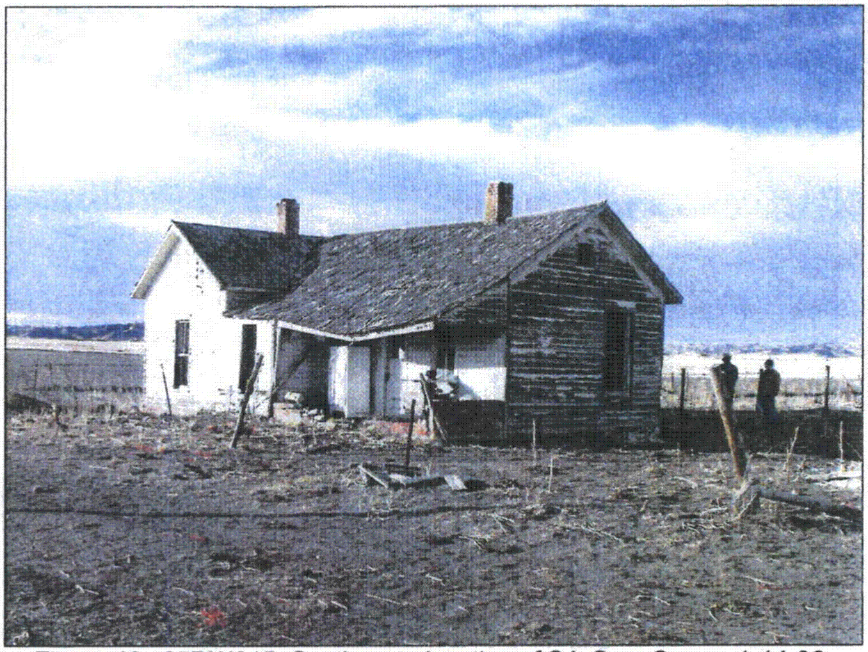


Figure 46: 25DW315. Southeast elevation of S4. Sam Cason, 1-14-06.

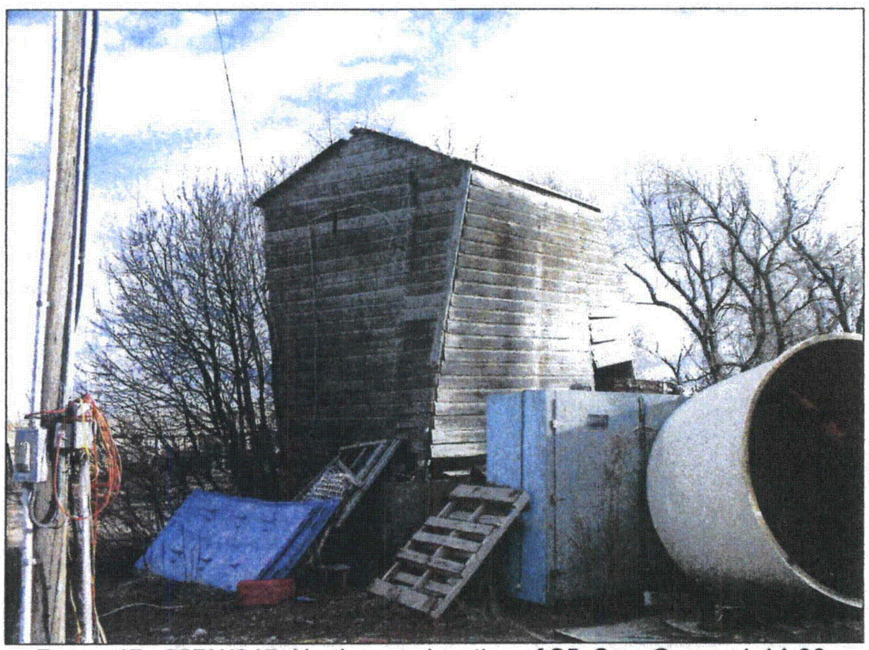


Figure 47: 25DW315. Northwest elevation of S5. Sam Cason, 1-14-06.

Figure 48: 25DW315. South elevation of S5. Sam Cason, 1-14-06.

Figure 49: 25DW315. Northeast elevation of S6. Sam Cason, 1-14-06.

Figure 50: 25DW315. Southwest elevation of S6. Sam Cason, 1-14-06.

Figure 51: 25DW315. Horse-drawn farm equipment. Sam Cason, 1-14-06.

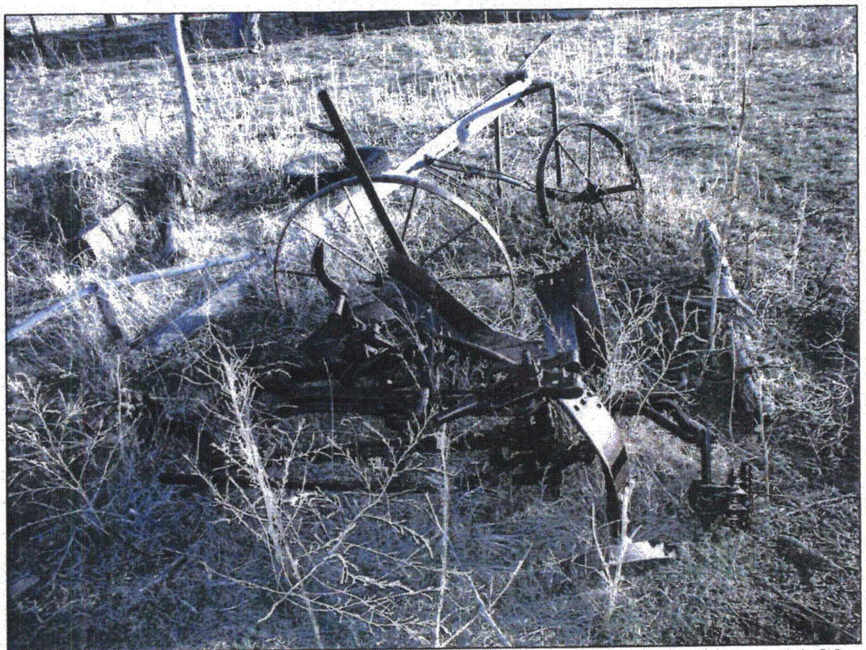


Figure 52: 25DW315. Horse-drawn farm equipment. Sam Cason, 1-14-06.

Figure 53: 25DW315. Horse-drawn farm equipment at site.
Sam Cason, 1-14-06.

Figure 54: 25DW315. Horse-drawn farm equipment. Sam Cason, 1-14-06.

APPENDIX B
SITE LOCATION MAP

Contents withheld under 10 CFR 2.390
NHPA Section 304 (16 U.S.C. 470w-3(a))
Nebraska Public Records Statutes (Neb. Rev. Stat. 84-712.05(13))

APPENDIX C
SITE FORMS

Contents withheld under 10 CFR 2.390
NHPA Section 304 (16 U.S.C. 470w-3(a))
Nebraska Public Records Statutes (Neb. Rev. Stat. 84-712.05(13))