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MEMORANDUM FOR: Vandy Miller, Chief
Material Licensing Branch

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SUBJECT: ESTIMATES OF POTENTIAL RADIATION DOSE OF WASTE BURIAL AREA AT VETERANS ADMINISTRATION HOSPITAL, LOS ANGELES, LICENSE NO. 04-00181-04

An estimate of the potential radiation dose to an individual resulting from the buried radioactive material on the VA's property has been calculated and attached to this memo.

In the dose calculations, both external and internal exposure pathways were considered. The internal exposures were calculated based on two projected pathways:

(1) ingestion of food (beef, milk, and vegetables) that is produced on the burial site

(2) inhalation of airborne radioactive material as a result of wind resuspension

The results of the dose calculation are provided in the summary on page 4 of the attached report.

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Enclosure: Estimates of Potential Radiation Dose



Enclosure 2

# Estimates of Potential Radiation Dose

This report shows a calculation of potential radiation dose to an individual from two potential intake pathways resulting from the buried radioactive material on the Veterans Administration property at the Veterans Administration Center, Los Angeles, California.

The report contains the dose calculations from both external and internal exposure pathways. The internal exposures were calculated based on two projected pathways: (1) dietary ingestion of food produced on the burial site and (2) inhalation of airborne radioactive material as a result of wind resuspension. In the course of the dose assessment, not all site-specific parameters were available; therefore, a generally conservative approach was used and this may have resulted in a high estimate of dose.

## I. Models for Estimating Radiation Dose

### A. External Exposure

The basic equation used for estimating the external dose of a radioactive point source emitting gamma radiation is:

$$D\ (R/hr) = \frac{\Gamma \times A \times F}{d^2} B \qquad (1)$$

where D is dose rate R/hr; $\Gamma$ is total gamma exposure rate constant of a radionuclide unit in $\frac{R\text{-}m^2}{hr\text{-}Ci}$; A is the activity of the radionuclide in the media, the unit is Ci; F is the shielding factor of the media; B is the buildup factor of the media, and d is the distance between the source and the radioactive source in media.

### B. Internal Exposure

The internal dose commitment is calculated according to the following basic equation:

$$D = C \times U \times DCF \qquad (2)$$

where D is the dose commitment to a given organ of an individual in mrem/yr; C is the concentration of a radionuclide in the media of exposure in $\mu c/m^3$; U is the usage factor unit in $m^3/yr$, and DCF is the dose conversion factor that converts a given concentration of the radionuclide and the intake rate of that radionuclide to the radiation dose. The unit of DCF is rem/$\mu$Ci.

## II. Radionuclide Source Terms

According to the NRC's records, the radioactive waste materials were buried under 15 feet of dirt in three adjacent locations on hospital controlled property. The locations of the three burial sites, designated as A, B, and C, are shown in figure 1. The essential radioactivity still remaining in each area is summarized in the following table:

Table 1

Essential Radioactivity in the Burial Site, mCi as of 1981

| Location | Size | | Radioactivity mCi | | | |
|---|---|---|---|---|---|---|
| | ($ft^2$) | ($m^2$) | H-3 | C-14 | Cl-36 | Na-22 |
| A | 200 x 50 | 929 | 2.0 | 2.9 | 0 | 0 |
| B | 200 x 400 | 7432 | 316.0 | 12.5 | 0.25 | 0 |
| C | 100 x 400 | 3712 | 122.2 | 37.2 | 0 | 0.009 |
| | | $1.21 \times 10^4$ | 440.2 | 52.6 | 0.26 | 0.009 |

## III. Dose Calculation

### A. External Radiation Dosimetry

Since H-3 and C-14 are low energy beta emitters, and Cl-36 emits 0.51 Mev gamma radiation with 0.003% intensity, the only contributor to the external exposure that will be considered here is radionuclide Na-22. The external exposure rate at 1 meter above the surface from the Na-22 as a point source under 15 feet of soil is calculated by using equation (1) with the following parameters:

$\Gamma = 1.2$[a] $\frac{R}{hr.Ci}$ at 1 meter from a point source

A = the radioactivity in Ci, $9 \times 10^{-6}$ Ci

B[b] = 100 for 15 feet of soil as media

F[b] = $<10^{-10}$

d = 5.57 meters

$$D(R/hr) = \frac{\Gamma \times A \times F \times B}{d^2} = \frac{1.2 \times 9 \times 10^{-6} \times 10^{-10} \times 100}{5.57^2}$$

[a] Radiological Health Handbook, 1970, page 131

[b] Estimates assume that mass absorption coefficient of soil for gamma energy 1.2 Mev is about 0.05 $cm^2/g$.

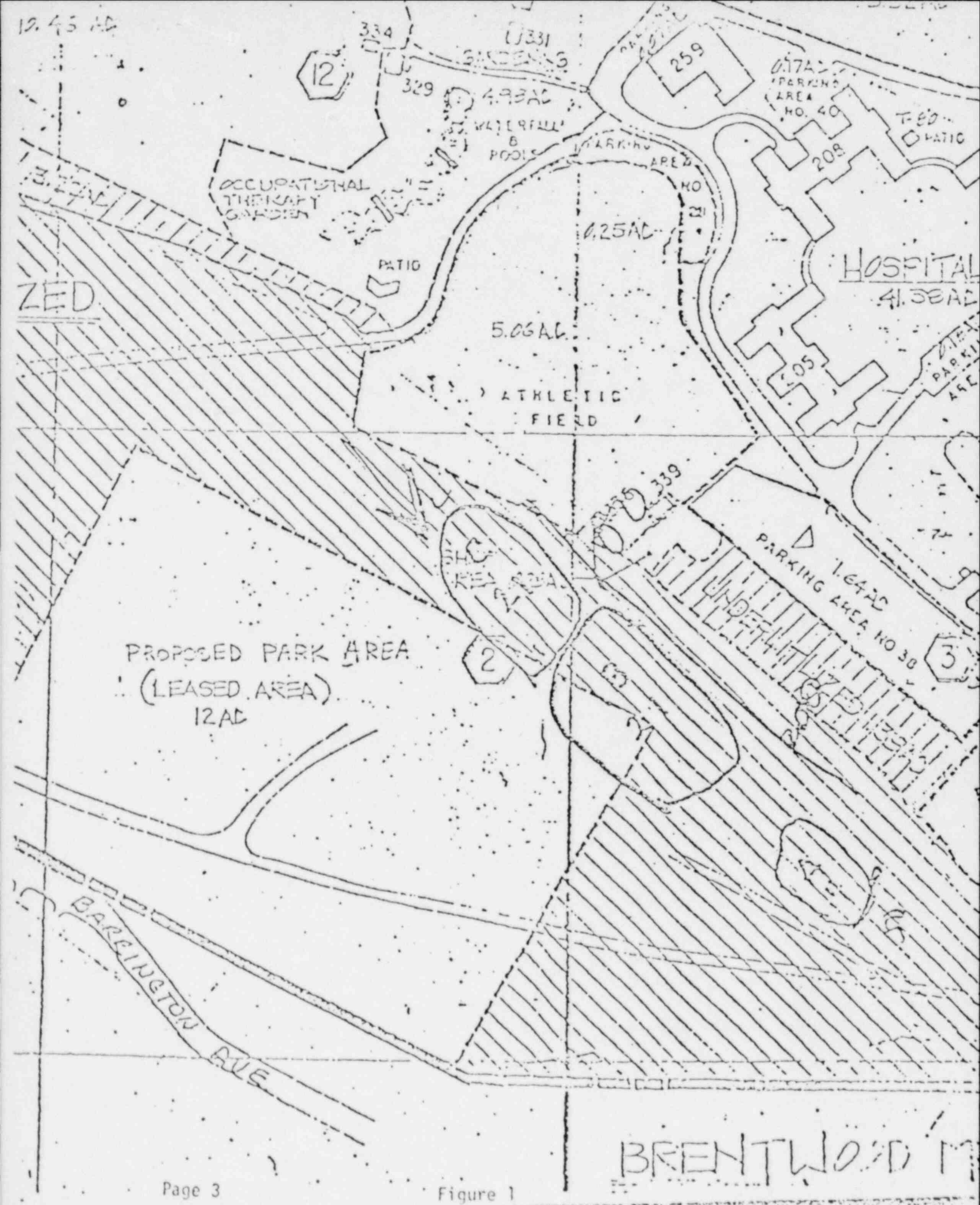
12.45 AC
334
331
329
4.93AC
12
259
0.17AC
PARKING AREA NO. 40
T-ED
PATIO
208
WATERFALL & POOLS
PARKING AREA NO 21
OCCUPATIONAL THERAPY GARDEN
0.25AC
PATIO
ZED
HOSPITAL
41.3EAC
5.06AC
ATHLETIC FIELD
339
PARKING AREA NO 30
1.64AC
PROPOSED PARK AREA
(LEASED AREA)
12AC
2
3
BARRINGTON AVE
BRENTWOOD



Figure 1

$= 3.48 \times 10^{-15}$ R/hr

$= 3.48 \times 10^{-9}$ μR/hr

$= 3.05 \times 10^{-11}$ R/yr

B. Internal Radiation Dosimetry

1. Inhalation Mode

Radiation dosimetry to an individual in each of the three burial locations is calculated based on the assumption that in each location the buried material, mixed with 1 meter of soil, was brought to the surface during the reclamation project, and the top 1.0 cm layer of the contaminated soil became airborne by the process of resuspension. The calculated dose commitment to an individual from inhaling the contaminated air is expressed in the following table:

Table II

Dose Inhalation

| Location | Dose[a] (mrem/yr) due to the radionuclide | | | |
|---|---|---|---|---|
| | H-3 (whole body) | C-14 (bone) | Cl-36 (whole body) | Na-22 (whole body) |
| A | 1.3E-7 | 2.04E-6 | 0 | 0 |
| B | 2.5E-6 | 1.2E-6 | 6.7E-8 | 0 |
| C | 2.3E-6 | 6.8E-6 | 0 | 1.1E-10 |

2. Ingestion Mode

The radiation dose calculation from the ingestion pathway is based on the conservative assumption that all the food consumed by one individual either grew on or was produced on these sites after a reclamation project. The dose commitment to an individual from ingestion of food (beef, milk, and vegetables) contaminated via resuspension and by root uptake was calculated and expressed in

[a] The dose calculation is provided in Appendix A of this report.

the following table:

Table III

Dose Commitment Resulting from Ingestion Pathway

| Radionuclides | Dose to Critical Organ[a] | |
|---|---|---|
| | Bone Marrow Dose (mrem/yr) | Whole Body (mrem/yr) |
| H-3 | | $7.4 \times 10^{-6}$ |
| C-14 | $1.1 \times 10^{-3}$ | |
| Cl-36 | | 1.5 |
| Na-22 | | $3.2 \times 10^{-4}$ |

IV. Summary

1. For the dose due to external radiation exposure, the calculated result indicates a dose level of $3.5 \times 10^{-9}$ ur/hr at 1 meter above the surface. This exposure is about $1/10^9$ of the dose rate from the background external level which is about 10 ur/hr. Na-22 has a radioactive half-life of 2.6 years. The exposure rate is decreased by a factor of 0.8 each year; therefore, long term health effect is not anticipated.

2. For the dose due to inhalation of contaminated resuspended air, the results indicate that: in location A, the dose to the total body (for H-3) is $1.3 \times 10^{-7}$ mrem/yr, and the dose to the bone (for C-14) is $2.04 \times 10^{-6}$ mrem/yr; in location B, the dose to the total body (for H-3 and Cl-36) is $2.6 \times 10^{-6}$ mrem/yr, and dose to the bone (for C-14) is $1.2 \times 10^{-6}$ mrem/yr; and in location C, the dose to the total body (for H-3 and Na-22) is $2.3 \times 10^{-6}$ mrem/yr, and dose to the bone (for C-14) is $6.8 \times 10^{-6}$ mrem/yr.

3. For the dose due to ingestion pathway, the results indicate the dose to the total body (for H-3, Cl-36 and Na-22) to be 1.5 mrem/yr and dose to the bone marrow (for C-14) to be $1.1 \times 10^{-3}$ mrem/yr.

4. The calculated maximum individual internal exposure (ingestion and inhalation) is on the order of 1.5 mrem/yr to the whole body, or about 1/60 of the dose from natural background radiation.

[a] The dose calculation is provided in Appendix B of this report.

# Appendix A

## Dose Calculation From Inhalation Mode

The dose is calculated by equation (2) with the following parameters:

1. The calculated contaminated soil concentration and resuspension airborne concentration of radioactivity is expressed in the following table:

Table A-1

Concentration in Soil and Air

| Location | Calculated Soil Concentration $\frac{\mu c}{g}$ | | | | Calculated resuspended concentration[a], $\mu c/m^3$ | | | |
|---|---|---|---|---|---|---|---|---|
| | H-3 | C-14 | Cl-36 | Na-22 | H-3 | C-14 | Cl-36 | Na-22 |
| A | 8.6E-7[b] | 1.2E-6 | 0 | 0 | 1.1E-10[c] | 1.6E-10 | 0 | 0 |
| B | 1.7E-5 | 6.8E-7 | 1.4E-8 | 0 | 2.1E-9 | 8.5E-11 | 1.7E-12 | 0 |
| C | 1.5E-5 | 4E-6 | 0 | 9.7E-10 | 1.9E-9 | 5E-10 | 0 | 1.2E-13 |

2. Dose conversion factors, DCF, for inhalation mode are obtained from Oak Ridge National Laboratory publication ORNL-4992, "A Methodology for Calculating Radiation Dose from Radioactivity Release to the Environment." They are:

DCF for H-3 (total body as critical organ) is
$1.5 \times 10^{-4}$ rem/$\mu$c

for C-14 (bone as critical organ) is
$1.7 \times 10^{-3}$ rem/$\mu$c

for Cl-36 (total body as critical organ) is
$4.8 \times 10^{-3}$ rem/$\mu$c

for Na-22 (total body as critical organ) is
$1.1 \times 10^{-2}$ rem/$\mu$c

[a] The resuspension factor, $5 \times 10^{-9}$ 1/m, is obtained from NRC publication NUREG-0707, "A Methodology for Calculating Residual Radioactivity Levels Following Decommissioning," page 9.

[b] Read as $8.6 \times 10^{-7}$, soil concentration $\frac{\mu c}{g} = \frac{2 \times 10^3 \ \mu c}{929 \ m^2} \times \frac{10^{-6} \ m^3}{cm^3} \Big/ 2.5 \ g/cm^3$ (soil density)

[c] $1.10 \times 10^{-10} \frac{\mu c}{m^3} = 8.6 \times 10^{-7} \frac{\mu c}{g} \times 2.5 \frac{g}{cm^3}$ soil density x 1 cm surface soil x $5 \times 10^{-9}$ 1/m (resuspension factor) x $\frac{10^4 \ cm^2}{m^2}$

3. An individual's breathing rate is 8000 $m^3$/yr.

Dose due to inhalation mode is calculated by equation (2):

i) for burial site A: $D_{H-3} = C \times U \times DCF$

$= 1.1 \times 10^{-10}$ $\mu c/m^3 \times 8000$ $m^3 yr \times 1.5 \times 10^{-4}$ $\frac{rem}{\mu c}$

$= 1.3 \times 10^{-7}$ mrem/yr (whole body)

$D_{C-14} = 1.5 \times 10^{-10}$ $\mu c/m^3 \times 8000$ $m^3/yr \times 1.7 \times 10^{-3}$ rem/$\mu c$

$= 2.04 \times 10^{-6}$ mrem/yr (bone)

$D_{Cl-36} = 0$

$D_{Na-22} = 0$

ii) for burial site B: $D_{H-3} = 2.5 \times 10^{-6}$ mrem/yr (whole body)

$D_{C-14} = 1.2 \times 10^{-6}$ mrem/yr (bone)

$D_{Cl-36} = 6.7 \times 10^{-8}$ mrem/yr (whole body)

$D_{Na-22} = 0$

iii) for burial site C: $D_{H-3} = 2.3 \times 10^{-6}$ mrem/yr (whole body)

$D_{C-14} = 6.8 \times 10^{-6}$ mrem/yr (bone)

$D_{Cl-36} = 0$

$D_{Na-22} = 1.1 \times 10^{-10}$ mrem/yr (whole body)

# Appendix B

## Dose Calculation for Ingestion Pathway

1. For H-3 and C-14

The estimated dose due to ingestion pathway of H-3 and C-14 is calculated based on the assumption that the food and drinking water are in equilibrium with the specific activity of H-3 in the atmosphere, and the specific activity of C-14 in human tissue is equal to the average steady state value in the atmosphere. The methodology of the calculation is presented fully in ORNL-4992, "A Methodology for Calculating Radiation Dose from Radioactivity Release to the Environment." The dose conversion rates for H-3 and C-14 given under the conditions described above are $3.68 \times 10^{9}$ mrem $yr^{-1}$ per $Cm^{-3}$ and $2.2 \times 10^{+12}$ mrem $yr^{-1}$ per Ci $m^{-3}$, respectively. The maximum airborne concentration of radioactivity for H-3 and C-14 are given in Table B-1. Therefore, the dose due to ingestion of H-3 is:

$$D_{H-3} = 3.68 \times 10^{-9} \frac{\text{mrem}}{\text{yr}} \times \frac{\text{m}^3}{\text{Ci}} \times 2 \times 10^{-15} \frac{\text{Ci}}{\text{m}^3}$$
$$= 7.4 \times 10^{-5} \text{ mrem/yr (whole body)}$$

$$D_{C-14} = 2.2 \times 10^{12} \frac{\text{mrem}}{\text{yr}} \times \frac{\text{m}^3}{\text{Ci}} \times 5 \times 10^{-16} \frac{\text{Ci}}{\text{m}^3}$$
$$= 1.1 \times 10^{-3} \text{ mrem/yr (bone marrow)}$$

2. For Cl-36 and Na-22

a. Ingestion dose from vegetable intake

1. Root uptake

Dose commitment, mrem

= Concentration in soil, μCi/g (see Table B-1)

x $B_{iv}$, bioaccumulation factor (see Table B-2)

x $1.94 \times 10^{5}$ g/yr (vegetable intake per yr)

x dose conversion factor rem/μCi (see Table B-3)

x $10^{3}$ mrem/rem

2. Resuspension

Dose commitment, mrem

= Concentration in soil, μCi/g (see Table B-1)

x $2.5 \times 10^{4}$ g of soil/$m^2$ x $5 \times 10^{-3}$ $m^{-1}$ (resuspension factor)

x $10^{-2}$ m/sec (deposition factor)

x 3.15 x $10^7$ sec/yr x $\frac{\mu Ci/day}{\mu Ci/m^2\text{-day}}$ (see Table B-3)

x dose conversion factor, rem/$\mu$Ci (see Table B-3)

x $10^3$ mrem/rem

b. Ingestion dose from meat intake

1. Root uptake

Dose, mrem = Conc. in soil, $\mu$Ci/g (see Table B-1)

x $B_{iv}$, bioaccumulation factor, (see Table B-2) x $F_f \frac{d}{kg}$ (see Table B-2)

x $10^4$ g/day (grass eaten) x 94 kg/year (meat intake)

x DCF rem/$\mu$Ci (see Table B-3) x $10^3$ mrem/rem

2. Resuspension

Dose mrem

= Conc. in soil, $\mu$c/g (see Table B-1)

x 2.5 x $10^4$ g of soil/$m^2$ x 5 x $10^{-9}$ $m^{-1}$ (resuspension factor)

x $10^{-2}$ m/sec (deposition factor)

x 3.15 x $10^7$ sec/yr x $\frac{\mu Ci/day}{\mu Ci/m^2\text{-day}}$ (see Table B-3)

x DCF rem/$\mu$Ci (see Table B-3) x $10^{-3}$ mrem/rem

c. Ingestion from milk intake

1. Root uptake

Dose, mrem = Conc. in soil, $\mu$Ci/g (see Table B-1)

x bioaccumulation factor, $B_{iv}$ (see Table B-2)

x $10^4$ g/day (grass intake) x transfer coefficient Fm, day/ℓ (see Table B-2) x 0.31 ℓ/day of milk

x 365 day/year x DCF rem/$\mu$c (see Table B-3)

x $10^3$ mrem/rem

2. Resuspension

Dose, mrem = Conc. in soil, μCi/g x $2.5 \times 10^4$ g of soil/$m^2$

x $5 \times 10^{-9}$ $m^{-1}$ (resuspension factor) x $10^{-2}$ m/sec (deposition factor)

x $3.15 \times 10^7$ sec/yr x $\frac{\mu Ci/day}{\mu Ci/m^2\text{-day}}$ (see Table B-3)

x DCF rem/μCi (see Table B-3) x $10^3$ mrem/rem

Table B-1

Maximum Concentration in Soil and Air
(data are obtained from Table A-1)

| Radionuclide | Conc. in Soil, μCi/g | Conc. in Air, $Ci/m^3$ |
|---|---|---|
| Cl-36 | 1.4E-8 | ----- |
| Na-22 | 9.7E-10 | ----- |
| H-3 | ------- | 2E-15 |
| C-14 | ------- | 5E-16 |

Table B-2

The Veg/Soil Bioaccumulation Factor, $B_{iv}$, and
Transfer Coefficients, Fm (Milk) $F_f$ (Meats)

| Radionuclide | $B_{iv}$[a] veg/soil | Fm,[a] day/ℓ | $F_f$[a] day/kg |
|---|---|---|---|
| Cl-36 | 50 | 1.7E-2 | 8E-2 |
| Na-22 | 5.2E-2 | 4E-2 | 3E-2 |

[a]NRC Reg. Guide 1.109 and Ng, UCRL-50163, Part IV.

Table B-3

Dose Conversion Factor[a], rem/μCi for
Ingestion Mode and Radionuclide Transfer Factor[b]

| Radionuclide | DCF* rem/μCi | $\frac{\mu Ci/day}{\mu Ci/day\text{-}m}$ |
|---|---|---|
| Cl-36 | 7.9E-3 | 50 |
| Na-22 | 1.8E-2 | 50 |

[a]ORNL-4992, Table 4-3 pp. 4-90

[b]The transfer factor for Cl-36 and Na-22 were assumed to be 50 for vegetable, meat, or milk intake. This assumption was chosen conservatively with the aid of the intake transfer factor for radionuclide with mass number larger than 27. (Table 2-8, ORNL-4992)