SEQUOYAH NUCLEAR PLANT
ODCM
REVISION 10

INSTRUCTION SHEET

Remove (front/back)	Insert (front/back)
Effective Page Listing Rev. 9 Dates of Revisions	Effective Page Listing Rev. 10 Dates of Revision
21/22	21/22
23/24	23/24
25/26	25/26
Table 2.3	Table 2.3
Sheet 1 of 3	Sheet 1 of 3
Sheet 2 of 3	Sheet 2 of 3
Sheet 3 of 3	Sheet 3 of 3

SEQUOYAH NUCLEAR PLANT
OFFSITE DOSE CALCULATION MANUAL
EFFECTIVE PAGE LISTING
REVISION 10

Page	Revision
TOC 1 through TOC 2	Revision 10
1 through 2	Revision 6
3	Revision 9
4	Original
5	Revision 3
6	Revision 4
7	Revision 8
8 through 9	Revision 5
10	Original
11	Revision 5
12 throuth 13	Revision 9
14	Revision 7
15	Revision 9
15a	Revision 9
16	Revision 9
16a	Revision 8
Table 1.1 (2 pages)	Revision 4
Table 1.2 (2 pages)	Original
Table 1.3 (8 pages)	Revision 4
Table 1.4	Revision 9
Table 1.4A (removed from document)	Revision 9
Table 1.5	Revision 4
Tables 1.6 and 1.7	Revision 5
Table 1.8	Original
Figures 1.1 and 1.2	Original
Figure 1.3	Revision 3
17	Original
18	Revision 2
19	Revision 7
20	Revision 6
21	Revision 9
22	Revision 10
23	Revision 7
24 through 25	Revision 10
26 through 29	Revision 8
Table 2.1 (3 pages)	Revision 7
Table 2.2	Revision 5
Table 2.3 (3 pages)	Revision 10
Table 2.4 a-c	Revision 5
30	Revision 8
Table 3.1-1 (4 pages)	Revision 4
Table 3.1-2	Revision 8
Table 3.1-3	Revision 4
Table 3.2-1 (3 pages)	Revision 4
Figure 3.1-1 through 3.1-2	Revision 4
Figure 3.1-3	Revision 8
Figure 3.1-4 through 3.1-5	Revision 4
Figure 3.1-6 through 3.1-7	Revision 8

Sequoyah Nuclear Plant
Offsite Dose Calculation Manual
Dates of Revisions

Original ODCM	2/29/80*
Revision 1	4/15/80**
Revision 2	10/7/80**
Revision 3	11/3/80, 2/10/81 4/8/81 and 6/4/81**
Revision 4	11/22/82 (10/22/81, 11/28/81 and 4/29/82**
Revision 5	10/21/82**
Revision 6	1/20/83**
Revision 7	3/23/83**
Revision 8	12/16/83**
Revision 9	3/7/84**
Revision 10	4/24/84**

*Low Power license for Sequoyah unit 1
**RARC Meeting date

b. During any calendar year to ≤ 3 mrem to the total body and to ≤ 10 mrem to any organ.

To ensure compliance, cumulative dose calculations will be performed at least once per month according to the following methodology.

2.3.2 <u>Monthly Analysis</u>

Principal radionuclides will be used to conservatively estimate the monthly contribution to the cumulative dose. If the projected dose exceeds the above limits, the methodology in Section 2.3.3 will be implemented. 3

The 11 nuclides (listed below) contribute more than 95 percent of the dose to the total body and the three most critical organs for each pathway. 9 The critical organs considered for fish ingestion are the gastrointestinal tract (GIT), bone, and liver. The critical organs for water ingestion are the GIT, bone, and thyroid. 7

H-3	Co-58	Sr-90	Cs-134
P-32	Co-60	Nb-95	Cs-137
Fe-55	Sr-89	I-131	

A conservative calculation of the monthly dose will be done according to the following procedure. First, the monthly operating report containing the release data will be obtained and the activities released of each of the above eleven radionuclides will be noted. This information will then be used in the following calculations. 3

2.3.2.1 <u>Water Ingestion</u>

The dose to an individual from ingestion of water is described by the following equation.

$$D_j = \frac{1}{.95} \sum_{i=1}^{11} (DCF)_{ij} \cdot I_{ij}, \text{ rem} \qquad (2.11)$$ 5

where:

D_j = dose for the j^{th} organ from eleven radionuclides, rem

j = the organ of interest (bone GI tract and total body).

.95 = conservative correction factor, considering only eleven radionuclides.

DCF_{ij} = critical ingestion dose commitment factor for the j^{th} organ of adult or child from the i^{th} radionuclide rem/μCi, see attached as Table 2.1.

I_{ij} = monthly activity ingested of the i^{th} radionuclide by the critical age group for the j^{th} organ, μCi.

I_{ij} is described by

$$I_{ij} = \frac{A_i \ V_{ij} \ (30)}{Fd \ (7.34 \times 10^{10})} \quad ,\mu Ci \qquad (2.12)$$

where:

A_i = activity released of i^{th} radionuclide during the month, μCi.

V_{ij} = maximum individual's water consumption rate corresponding to the age group selected for the critical DCF_{ij} above (Adult: 2000 mL/d, Child: 1400 mL/d; Regulatory Guide 1.109)

30 = days per month

F = average river flow at Chickamauga Dam for the month (cubic feet per second)

d = fraction of river flow available for dilution (1/5)

7.34×10^{10} = conversion from cubic feet per second to milliliters per month.

Considering the conversion factor from rem to mrem ($\times 10^3$), the dose equation then becomes:

$$D_j = \frac{2.15 \times 10^{-6}}{F} \sum_{i=1}^{11} (V \times DCF)_{ij} \times A_i, \text{ mrem.} \qquad (2.13)$$ 10

2.3.2.2 Fish Ingestion

The dose to an individual from the consumption of fish is described by Equation 2.11. In this case the activity ingested of the i^{th} radionuclide (I_{ij}) is described by

$$I_{ij} = \frac{A_i \; B_i \; M_{ij}}{Fd\;(7.34 \times 10^{10})}, \; \mu Ci \qquad (2.14)$$

where:

A_i = activity released of i^{th} radionuclide during the month, µCi

B_i = effective fish concentration factor for the i^{th} radionuclide $\frac{\mu Ci/g}{\mu Ci/mL}$, see attached as Table 2.2. 5

M_{ij} = amount of fish eaten monthly by maximum individual corresponding to age group selected for the critical DCF_{ij} above (Adult: 1750g, Child: 575g; Regulatory Guide 1.109).

F = average river flow at Chickamauga Dam for month (cubic feet per second)

d = fraction of river flow available for dilution (1/5) 3

7.34×10^{10} = conversion from cubic feet per second to milliliters per month.

The dose equation then becomes

$$D_j = \frac{7.17 \times 10^{-8}}{F} \sum_{i=1}^{11} A_i \; B_i \; (M \cdot DCF)_{ij}, \; \text{mrem} \qquad (2.15)$$ 5

Considering the conversion factor from rem to mrem.

2.3.2.3 Recreation

The total body dose to an individual via the shoreline recreation pathway is described by the following equation. For this calculation, the total dose is estimated based on a calculation for Co-58, Co-60, Cs-134, and Cs-137. These four nuclides are expected to contribute over 95 percent of the recreation dose.

$$D = \frac{1}{0.95} \sum_{i=1}^{4} \frac{[(RDCF)_i \cdot \xi_i \cdot 67]}{8760}, \; \text{mrem} \qquad (2.16)$$ 7

Where:

D = dose to the total body from plant releases, mrem

$\frac{1}{0.95}$ = conservative correction factor for considering only 4 radionuclides

$RDCF_i$ = shoreline recreation dose commitment factor for the i^{th} radionuclide (mrem/yr per $\mu Ci/cm^2$). See attached table 2.3. (Note: For Cs-137, the dose commitment factor for its daughter, Ba-137m, is assumed.)

ξ_i = concentration of i^{th} radionuclide in shoreline sediment ($\mu Ci/cm^2$), as described by the following equation (based on equation A-5 in Regulatory Guide 1.109).

$$\xi_i = 100 \cdot RHL_i \cdot C_i \cdot W\,[1 - \exp(-\lambda_i \cdot t)] \qquad (2.17)$$

Where:

100 = transfer constant defined in Regulatory Guide 1.109

RHL_i = radiological half-life of the i^{th} radioisotope, days, from table 2.1

C_i concentration of i^{th} radionuclide in the Tennessee River, $\mu Ci/mL$. $C_i = A_i/(F \cdot d \cdot 7.34 \times 10^{10})$

A_i = activity released of i^{th} radionuclide during the month, μCi

F = average river flow at Chickamauga Dam for the month, cubic feet per second

d = fraction of river flow available for dilution (1/5)

7.34×10^{10} = conversion from cubic feet per second to milliliters per month.

W = shoreline width factor (0.3 for a lake shore, per table A-2 of Regulatory Guide 1.109)

λ_i = decay constant of the i^{th} radionuclide $= 0.693/RHL_i$

t = buildup time in sediment, assumed 15 years, per Regulatory Guide 1.109

67 = assumed monthly exposure time for maximum individual, h

$= 500\ \frac{h}{yr}$ ($\sim$ 10 h/week) $\cdot$ 0.4 (fractional exposure for worst quarter) $\div$ 3 (months/quarter)

8760 = conversion from year to hours.

0.1 = conversion factor, $m^2 \cdot ml/cm^2 \cdot l$ | 10

The dose equation then becomes

$$D = \frac{1}{F} (0.00692\, A_{Co-60} + 0.00012\, A_{Co-58} + 0.00206\, A_{Cs-134} + 0.00342\, A_{Cs-137}) \quad (2.18)$$ 10

2.3.2.4 Monthly Summary

Calendar quarter doses are first estimated by summing the doses calculated for each month in that quarter. Calendar year doses are first estimated by summing the doses calculated for each month in that year. However, if the annual doses determined in this manner exceed or approach the specification limits, doses calculated for previous quarters with the methodology of section 2.3.3 will be used instead of those quarterly doses estimated by summing monthly results. An annual check will be made to ensure that the monthly dose estimates account for at least 95 percent of the dose calculated by the method described in Section 2.3.3. If less than 95 percent of the dose has been estimated, either a new list of principal isotopes will be prepared or a new correction factor will be used. The latter option will not be used if less than 90 percent of the total dose is predicted.

2.3.2.5 Dose Projections

In accordance with specification 3.11.1.3, dose projections will be performed. This will be done by averaging the calculated dose for the most recent month and the calculated dose for the previous month and assigning that average dose as the projection for the current month.

2.3.3 Quarterly and Annual Analysis

A complete analysis utilizing the total estimated liquid releases for each calendar quarter will be performed and reported as required in section 6.9 of the technical specifications. This analysis will replace values calculated using section 2.3.2 methodology and will also include an approximation of population doses.

2.3.3.1 Individual Doses

The dose to the j^{th} organ of the maximum individual from m nuclides, D_j, is described by

$$D_j = \sum_{k=1}^{5} \sum_{i=1}^{m} D_{ijk}, \text{ rem} \quad (2.19)$$

$$= \sum_{i=1}^{m} \sum_{k=1}^{2} [(IDCF)_{ij} \times 1_{ik}] + \sum_{k=3}^{5} [(RDCF)_{ijk} \cdot \xi_{ik} \cdot T_k \cdot \phi] \quad (2.20)$$

where:

D_{ijk} = dose to the j^{th} organ from the i^{th} radionuclide, via the k^{th} exposure pathway, rem.

j = the organ of interest (bone, GI tract, thyroid, liver, total body, and skin.)

k = exposure pathway of interest: (1) water ingestion, (2) fish ingestion, (3) shoreline recreation, (4) above-water recreation, (5) in-water recreation.

$(IDCF)_{ij}$ = ingestion dose commitment factor for the j^{th} organ from the i^{th} radionuclide, rem/μCi. For the combination of pathways considered and the nuclide mix expected, the maximum exposed individual will be an adult or child. Table 2.1 is a list of ingestion dose factors for the two age groups.

I_{ik} = the activity ingested of the i^{th} radionuclide, via the k^{th} exposure pathway, μCi.

$$I_{i1} = C_i V_n \qquad (2.21)$$

For the fish pathway

$$I_{i2} = C_i B_i M \qquad (2.22)$$

C_i = concentration of the i^{th} radionuclide in the Tennessee River, μCi/mL 5

$$C_i = A_i/(F_\ell d) \qquad (2.23)$$

A_i = activity released of i^{th} radionuclide during the release period, μCi.

F_ℓ = total river flow at location ℓ during period, mL.

ℓ = location of interest (for dose to the maximum individual the first down-river exposure point is used. For the population dose, various down-river locations are used to account for the total exposed population. Table 2.4a gives the river location of public water supplies; tables 2.4b and 2.4c give the boundaries of the various reaches in which concentrations are calculated for the fish and recreation pathways.)

d = fraction of river flow available for dilution (1/5 above Chickamauga Dam, 1 below the dam).

V = average rate of water consumption per Regulatory Guide 1.109.

For maximum individual:

Adult - 2000 mL/d
Child - 1400 mL/d

Table 2.5
Recreation Dose Factors*

NUCLIDE	SWIMMING (MREM/YEAR PER UCI/ML) BONE	GI	THYROID	TB	LIVER	SKIN	SHORELINE (MREM/YEAR PER UCI/SQUARE CENTIMETER) BONE	GI	THYROID	TB	LIVER	SKIN
H-3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
C-14	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NA-22	3.14E+07	2.49E+07	2.30E+07	2.67E+07	2.27E+07	3.16E+07	2.76E+06	2.19E+06	2.01E+06	2.33E+06	1.99E+06	2.76E+06
NA-24	5.66E+07	5.92E+07	6.22E+07	5.39E+07	4.80E+07	6.15E+07	3.96E+06	4.10E+06	4.28E+06	3.76E+06	3.33E+06	4.29E+06
P-32	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CR-51	5.43E+05	3.07E+05	3.30E+05	3.79E+05	3.09E+05	4.56E+05	5.45E+04	3.08E+04	3.39E+04	3.61E+04	3.10E+04	4.69E+04
MN-54	1.16E+07	8.57E+06	7.35E+06	9.66E+06	8.26E+06	1.24E+07	1.04E+06	7.69E+05	6.60E+05	8.69E+05	7.42E+05	1.11E+06
MN-56	2.33E+07	2.14E+07	1.82E+07	2.07E+07	1.81E+07	2.54E+07	1.89E+06	1.69E+06	1.44E+06	1.66E+06	1.45E+06	2.05E+06
FE-55	3.16E+01	3.47E+01	6.94E+00	1.66E+02	1.47E-01	3.16E+03	2.71E+01	2.96E+01	5.96E+00	1.44E+02	1.26E-01	2.71E+03
FE-59	1.64E+07	1.38E+07	1.23E+07	1.45E+07	1.23E+07	1.76E+07	1.36E+06	1.15E+06	1.02E+06	1.20E+06	1.02E+06	1.46E+06
CO-57	2.71E+06	9.80E+05	1.69E+06	1.48E+06	1.13E+06	1.75E+06	2.32E+05	1.02E+05	1.76E+05	1.55E+05	1.17E+05	1.94E+05
CO-58	1.38E+07	1.03E+07	8.72E+06	1.13E+07	9.66E+06	1.43E+07	1.25E+06	9.36E+05	3.00E+05	1.03E+06	8.82E+05	1.30E+06
CO-60	3.46E+07	3.02E+07	2.73E+07	3.11E+07	2.62E+07	3.67E+07	2.23E+06	2.46E+06	2.23E+06	2.54E+06	2.14E+06	3.00E+06
NI-63	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NI-65	7.65E+06	6.66E+06	6.50E+06	6.94E+06	5.34E+06	7.93E+06	6.18E+05	5.52E+05	5.22E+05	5.60E+05	4.71E+05	6.41E+05
CU-64	2.63E+06	2.20E+06	1.85E+06	2.23E+06	1.92E+06	2.67E+06	2.71E+05	2.11E+05	1.78E+05	2.14E+05	1.84E+05	2.59E+05
ZN-65	7.99E+06	6.47E+06	5.58E+06	6.96E+06	5.90E+06	8.67E+06	6.75E+05	5.48E+05	4.71E+05	5.88E+05	4.95E+05	7.40E+05
ZN-69	9.55E+01	6.49E+01	6.09E+01	7.12E+01	6.00E+01	8.51E+01	9.40E+00	6.39E+00	6.00E+00	7.01E+00	5.90E+00	8.38E+00
AS-74	1.70E+05	1.30E+05	1.40E+05	1.40E+05	1.10E+05	1.60E+05	1.36E+06	1.10E+06	1.16E+06	1.12E+06	9.40E+05	1.33E+06
AS-76	8.31E+04	6.68E+04	7.04E+04	6.83E+04	5.73E+04	8.12E+04	6.82E+05	5.48E+05	5.78E+05	5.60E+05	4.70E+05	6.65E+05
BR-83	1.12E+05	8.64E+04	7.24E+04	8.81E+04	7.59E+04	1.06E+05	1.07E+04	8.29E+03	6.95E+03	8.45E+03	7.28E+03	1.02E+04
BR-84	2.46E+07	2.42E+07	2.59E+07	2.28E+07	2.03E+07	2.69E+07	1.80E+06	1.73E+06	1.79E+06	1.65E+06	1.46E+06	1.96E+06
BR-85	2.66E+05	2.11E+05	1.81E+05	2.39E+05	2.04E+05	3.07E+05	2.55E+04	1.88E+04	1.61E+04	2.13E+04	1.82E+04	2.74E+04
KR-83M	5.24E+02	1.22E+02	1.22E+02	9.46E+02	3.71E+01	1.13E+04	4.33E+02	1.16E+02	5.97E+01	9.65E+02	1.12E+01	1.23E+04
KR-85M	3.21E+06	1.36E+06	1.97E+06	1.93E+06	1.50E+06	2.30E+06	3.30E+05	1.39E+05	2.02E+05	1.99E+05	1.54E+05	2.39E+05
KR-85	3.34E+04	2.59E+04	2.17E+04	2.62E+04	2.26E+04	3.14E+04	3.22E+03	2.49E+03	2.09E+03	2.53E+03	2.18E+03	3.03E+03
RB-86	1.29E+06	1.04E+06	8.73E+05	1.12E+06	9.50E+05	1.42E+06	1.10E+05	8.79E+04	7.40E+04	9.50E+04	8.06E+04	1.20E+05
RB-88	8.99E+06	9.16E+06	6.10E+06	8.32E+06	7.33E+06	9.90E+06	6.77E+05	6.82E+05	5.97E+05	6.24E+05	5.49E+05	7.46E+05
RB-89	2.69E+07	2.67E+07	2.41E+07	2.61E+07	2.27E+07	3.17E+07	2.27E+06	2.06E+06	1.85E+06	2.04E+06	1.77E+06	2.49E+06
SR-89	1.88E+03	1.41E+03	1.18E+03	1.58E+03	1.35E+03	2.05E+03	1.65E+02	1.24E+02	1.04E+02	1.40E+02	1.19E+02	1.31E+02
SR-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SR-91	9.71E+06	7.32E+06	6.32E+06	8.17E+06	6.95E+06	1.04E+07	8.56E+05	6.43E+05	5.56E+05	7.19E+05	6.13E+05	9.13E+05
SR-92	1.66E+07	1.68E+07	1.59E+07	1.70E+07	1.43E+07	1.93E+07	1.50E+06	1.35E+06	1.28E+06	1.37E+06	1.15E+06	1.55E+06
Y-90	1.10E+00	2.90E-01	1.11E-01	1.32E+00	2.77E-02	1.05E+01	7.97E-01	2.17E-01	7.60E-02	9.65E-01	1.91E-02	7.87E+00
Y-91	4.99E+04	4.25E+04	3.77E+04	4.43E+04	3.75E+04	5.33E+04	4.12E+03	3.51E+03	3.11E+03	3.66E+03	3.10E+03	4.41E+03
Y-91M	7.83E+06	6.02E+06	5.06E+06	6.21E+06	5.34E+06	7.53E+06	7.48E+05	5.74E+05	4.83E+05	5.93E+05	5.10E+05	7.20E+05
Y-92	3.51E+06	2.80E+06	2.49E+06	3.02E+06	2.57E+06	3.72E+06	3.02E+05	2.39E+05	2.12E+05	2.59E+05	2.20E+05	3.19E+05
Y-93	1.30E+06	1.10E+06	9.91E+05	1.10E+06	9.42E+05	1.33E+06	1.10E+05	8.91E+04	8.17E+04	9.13E+04	7.77E+04	1.10E+05
ZR-95	1.04E+07	7.78E+06	6.64E+06	8.56E+06	7.32E+06	1.06E+07	9.56E+05	7.13E+05	6.08E+05	7.84E+05	6.71E+05	9.88E+05
ZR-97	2.57E+06	2.04E+06	1.67E+06	2.18E+06	1.86E+06	2.62E+06	2.23E+05	1.74E+05	1.50E+05	1.88E+05	1.60E+05	2.27E+05
NB-95	1.08E+07	8.01E+06	6.84E+06	8.87E+06	7.59E+06	1.12E+07	9.62E+05	7.31E+05	6.24E+05	8.09E+05	6.92E+05	1.02E+06
NB-95M	1.17E+06	5.59E+05	7.04E+05	7.59E+05	5.90E+05	9.51E+05	1.22E+05	5.66E+04	7.17E+04	8.05E+04	5.98E+04	1.23E+05
NB-97	9.40E+06	7.11E+06	6.03E+06	7.61E+06	6.52E+06	9.43E+06	6.77E+05	6.63E+05	5.62E+05	7.10E+05	6.08E+05	8.79E+05
NB-97M	1.03E+07	7.67E+06	6.54E+06	8.44E+06	7.22E+06	1.06E+07	9.42E+05	7.03E+05	5.99E+05	7.73E+05	6.61E+05	9.74E+05
MO-99	2.41E+06	1.63E+06	1.52E+06	1.87E+06	1.57E+06	2.34E+06	2.27E+05	1.51E+05	1.43E+05	1.75E+05	1.47E+05	2.21E+05
TC-99	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TC-99M	2.74E+06	1.03E+06	1.69E+06	1.55E+06	1.18E+06	1.83E+06	2.83E+05	1.07E+05	1.74E+05	1.60E+05	1.21E+05	1.93E+05
RU-103	7.05E+06	5.44E+06	4.57E+06	5.51E+06	4.75E+06	6.60E+06	6.81E+05	5.25E+05	4.41E+05	5.32E+05	4.58E+05	6.37E+05
RU-105	1.15E+07	8.32E+06	7.34E+06	9.16E+06	7.79E+06	1.14E+07	1.06E+06	7.78E+05	6.88E+05	8.57E+05	7.29E+05	1.06E+06
RU-106	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RH103M	3.73E+03	4.68E+02	1.27E+03	2.82E+03	3.92E+02	1.27E+04	1.74E+03	2.10E+02	5.66E+02	1.36E+03	1.63E+02	6.42E+03
RH-105	1.35E+06	7.36E+05	8.38E+05	9.39E+05	7.64E+05	1.12E+06	1.35E+05	7.59E+04	8.41E+04	9.43E+04	7.67E+04	1.13E+05
RH105M	6.12E+05	2.18E+05	3.75E+05	3.42E+05	2.51E+05	4.51E+05	7.05E+04	2.30E+04	4.10E+04	4.11E+04	2.66E+04	7.39E+04
RH-106	2.99E+06	2.30E+06	1.96E+06	2.41E+06	2.07E+06	2.93E+06	2.31E+05	2.16E+05	1.84E+05	2.25E+05	1.94E+05	2.74E+05
AG110M	3.87E+07	2.97E+07	2.68E+07	3.28E+07	2.79E+07	4.03E+07	3.41E+06	2.61E+06	2.35E+06	2.88E+06	2.45E+06	3.55E+06
AG-111	4.03E+05	2.32E+05	2.51E+05	2.63E+05	2.31E+05	3.39E+05	4.03E+04	2.32E+04	2.51E+04	2.63E+04	2.31E+04	3.39E+04
SB-122	6.06E+04	6.27E+04	6.58E+04	6.31E+04	5.26E+04	7.73E+04	6.83E+05	5.31E+05	5.57E+05	5.35E+05	4.46E+05	6.54E+05
SB-124	2.61E+07	2.26E+07	2.07E+07	2.29E+07	1.98E+07	2.71E+07	2.15E+06	1.86E+06	1.69E+06	1.90E+06	1.64E+06	2.25E+06
SB-127	1.01E+07	7.39E+06	6.47E+06	6.03E+06	6.65E+06	9.91E+06	9.52E+05	6.94E+05	6.09E+05	7.55E+05	6.43E+05	9.31E+05
TE125M	2.47E+05	2.93E+04	1.74E+05	1.35E+05	4.71E+04	3.39E+05	4.60E+04	9.06E+03	2.32E+04	2.50E+04	8.75E+03	6.29E+04

NUCLIDE	SWIMMING (MREM/YEAR PER UCI/ML) BONE	GI	THYROID	TB	LIVER	SKIN	SHORELINE (MREM/YEAR PER UCI/SQUARE CENTIMETER) BONE	GI	THYROID	TB	LIVER	SKIN
TE-127	7.84E+04	5.17E+04	4.92E+04	5.77E+04	4.93E+04	6.89E+04	7.74E+03	5.10E+03	4.92E+03	5.69E+03	4.77E+03	6.80E+03
TE127M	6.91E+04	1.33E+04	3.45E+04	3.62E+04	1.25E+04	9.89E+04	1.31E+04	2.54E+03	6.60E+03	7.21E+03	2.44E+03	1.86E+04
TE-129	8.68E+05	6.12E+05	5.58E+05	6.67E+05	5.60E+05	8.33E+05	6.52E+04	5.27E+04	5.43E+04	6.50E+04	5.37E+04	8.28E+04
TE129M	4.72E+05	3.23E+05	2.94E+05	3.71E+05	3.02E+05	5.03E+05	4.39E+04	3.09E+04	2.98E+04	3.71E+04	2.88E+04	5.38E+04
TE-131	6.79E+06	4.21E+06	4.37E+06	4.99E+06	4.13E+06	6.11E+06	6.49E+05	3.94E+05	4.16E+05	4.71E+05	3.88E+05	5.78E+05
TE131M	2.06E+07	1.53E+07	1.39E+07	1.70E+07	1.45E+07	2.12E+07	1.64E+06	1.35E+06	1.23E+06	1.51E+06	1.28E+06	1.89E+06
TE-132	4.27E+06	1.92E+06	2.54E+06	2.63E+06	2.04E+06	3.32E+06	4.55E+05	1.96E+05	2.68E+05	2.83E+05	2.12E+05	3.60E+05
I-129	2.25E+05	4.84E+04	1.19E+05	1.15E+05	4.75E+04	2.49E+05	5.02E+04	1.07E+04	2.67E+04	2.57E+04	1.03E+04	5.70E+04
I-130	3.09E+07	2.33E+07	2.00E+07	2.50E+07	2.14E+07	3.08E+07	2.38E+06	2.17E+06	1.86E+06	2.32E+06	1.99E+06	2.86E+06
I-131	5.22E+06	3.93E+06	3.92E+06	4.54E+06	3.77E+06	5.47E+06	6.16E+05	3.87E+05	3.38E+05	4.49E+05	3.72E+05	5.41E+05
I-132	3.23E+07	2.45E+07	2.16E+07	2.66E+07	2.29E+07	3.32E+07	2.91E+06	2.20E+06	1.93E+06	2.41E+06	2.06E+06	2.99E+06
I-133	8.96E+06	6.90E+06	5.89E+06	7.18E+06	6.16E+06	8.69E+06	8.44E+05	6.49E+05	5.54E+05	6.75E+05	5.79E+05	8.17E+05
I-134	3.67E+07	2.84E+07	2.49E+07	3.11E+07	2.65E+07	3.89E+07	3.22E+06	2.46E+06	2.16E+06	2.71E+06	2.32E+06	3.40E+06
I-135	2.19E+07	1.95E+07	1.75E+07	1.96E+07	1.67E+07	2.33E+07	1.78E+06	1.57E+06	1.41E+06	1.58E+06	1.35E+06	1.89E+06
XE133M	6.05E+05	2.36E+05	3.55E+05	3.71E+05	2.61E+05	5.27E+05	8.09E+04	2.81E+04	4.65E+04	4.77E+04	3.05E+04	7.71E+04
XE-133	5.52E+05	2.53E+05	4.84E+05	4.24E+05	2.74E+05	5.73E+05	1.11E+05	3.17E+04	6.28E+04	5.57E+04	3.39E+04	8.27E+04
XE135M	6.41E+06	4.94E+06	4.15E+06	5.04E+06	4.33E+06	6.08E+06	6.21E+05	4.75E+05	4.01E+05	4.87E+05	4.17E+05	5.90E+05
XE-135	4.54E+06	2.28E+06	2.76E+06	3.02E+06	2.40E+06	3.63E+06	4.59E+05	2.29E+05	2.79E+05	3.04E+05	2.41E+05	3.67E+05
CS-134	2.22E+07	1.67E+07	1.43E+07	1.81E+07	1.55E+07	2.26E+07	2.04E+06	1.54E+06	1.32E+06	1.67E+06	1.43E+06	2.08E+06
CS-135	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-136	3.10E+07	2.26E+07	2.03E+07	2.55E+07	2.15E+07	3.21E+07	2.77E+06	2.00E+06	1.81E+06	2.26E+06	1.91E+06	2.85E+06
CS-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-138	3.29E+07	3.03E+07	2.66E+07	2.98E+07	2.56E+07	3.46E+07	2.62E+06	2.37E+06	2.23E+06	2.35E+06	2.02E+06	2.74E+06
BA137M	6.56E+06	6.45E+06	5.48E+06	6.92E+06	5.93E+06	8.59E+06	8.01E+05	6.02E+05	5.12E+05	6.47E+05	5.54E+05	8.04E+05
BA-139	7.49E+05	3.44E+05	4.73E+05	4.66E+05	3.60E+05	5.55E+05	7.61E+04	3.38E+04	4.75E+04	4.67E+04	3.57E+04	5.62E+04
BA-140	2.29E+06	1.60E+06	1.46E+06	1.73E+06	1.46E+06	2.10E+06	2.29E+05	1.56E+05	1.46E+05	1.71E+05	1.42E+05	2.13E+05
BA-141	1.31E+07	8.90E+06	8.96E+06	1.02E+07	8.49E+06	1.22E+07	1.21E+06	7.97E+05	8.15E+05	9.26E+05	7.70E+05	1.12E+06
BA-142	1.51E+07	1.11E+07	1.02E+07	1.24E+07	1.04E+07	1.54E+07	1.34E+06	9.38E+05	9.03E+05	1.10E+06	9.17E+05	1.36E+06
LA-140	3.20E+07	2.91E+07	2.73E+07	2.86E+07	2.46E+07	3.31E+07	2.60E+06	2.32E+06	2.18E+06	2.32E+06	1.98E+06	2.67E+06
LA-142	3.74E+07	3.80E+07	3.72E+07	3.47E+07	3.10E+07	4.10E+07	2.75E+06	2.73E+06	2.64E+06	2.53E+06	2.52E+06	3.00E+06
CE-141	1.59E+06	5.94E+05	9.70E+05	9.01E+05	6.75E+05	1.09E+06	1.69E+05	6.20E+04	1.02E+05	9.52E+04	7.07E+04	1.16E+05
CE-143	4.54E+06	2.64E+06	2.79E+06	3.22E+06	2.60E+06	4.00E+06	4.66E+05	2.61E+05	2.83E+05	3.24E+05	2.57E+05	4.07E+05
CE-144	4.18E+05	1.42E+05	2.51E+05	2.26E+05	1.63E+05	2.81E+05	4.64E+04	1.55E+04	2.76E+04	2.50E+04	1.76E+04	3.18E+04
PR-143	1.26E-01	9.38E-02	8.00E-02	1.03E-01	6.83E-02	1.30E-01	1.15E-02	8.60E-03	7.33E-03	9.45E-03	8.09E-03	1.19E-02
PR-144	4.40E+05	4.24E+05	3.74E+05	3.97E+05	3.30E+05	4.75E+05	3.46E+04	3.24E+04	2.87E+04	3.10E+04	2.72E+04	3.71E+04
PR144M	1.42E+05	3.32E+04	7.19E+04	6.95E+04	3.23E+04	1.25E+05	2.28E+04	5.33E+03	1.15E+04	1.12E+04	5.17E+03	2.06E+04
ND-147	2.33E+06	1.34E+06	1.44E+06	1.57E+06	1.25E+06	1.93E+06	2.47E+05	1.35E+05	1.50E+05	1.62E+05	1.27E+05	2.03E+05
PM-147	7.66E+01	2.76E+01	4.92E+01	4.26E+01	3.23E+01	4.93E+01	8.17E+00	2.92E+00	5.11E+00	4.43E+00	3.36E+00	5.17E+00
PM-149	1.98E+05	1.12E+05	1.23E+05	1.39E+05	1.13E+05	1.69E+05	1.98E+04	1.11E+04	1.22E+04	1.38E+04	1.12E+04	1.67E+04
SM-147	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SM-151	1.69E+01	2.20E+00	5.68E+00	1.33E+01	1.61E+00	6.78E+01	7.60E+00	1.04E+00	2.56E+00	6.24E+00	7.22E-01	3.55E+01
SM-153	1.25E+06	3.89E+05	7.21E+05	6.33E+05	4.25E+05	8.08E+05	1.57E+05	4.71E+04	8.79E+04	7.83E+04	5.07E+04	1.04E+05
EU-155	1.35E+06	4.28E+05	7.98E+05	6.81E+05	4.78E+05	8.21E+05	1.54E+05	4.82E+04	8.98E+04	7.73E+04	5.35E+04	9.49E+04
TA-182	2.42E+05	1.90E+05	1.80E+05	2.04E+06	1.66E+05	2.44E+05	1.94E+06	1.41E+06	1.45E+06	1.63E+06	1.35E+06	1.96E+06
W-187	7.25E+06	5.09E+06	4.57E+06	5.55E+06	4.68E+06	6.81E+06	6.99E+05	4.84E+05	4.39E+05	5.30E+05	4.45E+05	6.52E+05
PB-210	3.69E+04	9.75E+03	1.71E+04	1.76E+04	9.16E+03	3.27E+04	5.31E+03	1.46E+03	2.42E+03	3.05E+03	1.28E+03	1.43E+04
PB-212	2.89E+06	1.26E+06	1.72E+06	1.78E+06	1.36E+06	2.13E+06	2.99E+05	1.29E+05	1.78E+05	1.83E+05	1.40E+05	2.25E+05
PB-214	4.29E+06	2.39E+06	2.65E+06	2.95E+06	2.39E+06	3.55E+06	4.32E+05	2.39E+05	2.66E+05	2.96E+05	2.39E+05	3.61E+05
BI-212	2.59E+06	2.08E+06	1.89E+06	2.22E+06	1.90E+06	2.69E+06	2.25E+05	1.79E+05	1.61E+05	1.92E+05	1.63E+05	2.36E+05
BI-214	2.10E+07	1.89E+07	1.69E+07	1.37E+07	1.62E+07	2.23E+07	1.71E+06	1.51E+06	1.35E+06	1.51E+06	1.31E+06	1.81E+06
PO-212	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PO-214	1.54E+03	1.14E+03	9.75E+02	1.27E+03	1.09E+03	1.62E+03	1.39E+02	1.03E+02	8.84E+01	1.15E+02	9.85E+01	1.46E+02
PO-216	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PO-218	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 2.3 (Continued)

NUCLIDE	SWIMMING (MREM/YEAR PER UCI/ML) BONE	GI	THYROID	TB	LIVER	SKIN
RA-224	1.87E+05	8.92E+04	1.13E+05	1.21E+05	9.45E+04	1.45E+05
RA-226	1.37E+05	5.79E+04	8.19E+04	8.21E+04	6.26E+04	9.45E+04
RA-228	6.53E-05	9.39E-05	1.88E-05	4.53E-04	3.96E-07	8.53E-03
AC-228	1.32E+07	9.95E+06	5.99E+06	1.10E+07	9.30E+06	1.37E+07
TH-228	4.33E+04	1.54E+04	2.56E+04	2.41E+04	1.74E+04	3.33E+04
TH-230	3.79E+03	2.66E+03	4.78E+03	4.83E+03	3.07E+03	1.00E+04
TH-232	3.51E+03	1.20E+03	2.03E+03	2.21E+03	1.23E+03	6.31E+03
TH-234	1.90E+05	6.00E+04	1.10E+05	9.53E+04	6.63E+04	1.12E+05
PA-234	2.89E+07	2.07E+07	1.92E+07	2.34E+07	1.98E+07	2.93E+07
U-234	2.77E+03	8.30E+02	1.78E+03	1.80E+03	6.36E+02	4.05E+03
U-238	9.69E+02	2.47E+02	3.46E+02	6.02E+02	1.97E+02	5.91E+03
NP-238	7.50E+06	5.74E+06	4.77E+06	6.38E+06	5.43E+06	8.32E+06
NP-239	3.44E+06	1.40E+06	2.14E+06	2.02E+06	1.57E+06	2.43E+06
PU-238	9.79E+02	2.32E+02	3.16E+02	1.00E+03	1.67E+02	8.46E+03
PU-239	1.39E+03	4.51E+02	7.98E+02	9.42E+02	5.05E+02	3.87E+03
PU-240	1.01E+03	2.33E+02	3.34E+02	9.90E+02	1.79E+02	8.10E+03
PU-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PU-242	8.25E+02	1.93E+02	2.83E+02	7.96E+02	1.52E+02	6.40E+03
AM-241	5.01E+05	1.43E+05	2.47E+05	2.37E+05	1.42E+05	3.12E+05
AM-242	3.05E+05	1.04E+05	1.95E+05	1.62E+05	1.21E+05	1.96E+05
AM-243	1.22E+06	3.71E+05	6.70E+05	5.97E+05	3.96E+05	7.28E+05
CM-242	1.09E+03	2.95E+02	2.97E+02	1.14E+03	1.56E+02	9.49E+03
CM-243	2.57E+06	1.06E+06	1.59E+06	1.53E+06	1.13E+06	1.85E+06
CM-244	6.91E+02	2.00E+02	1.25E+02	9.01E+02	5.13E+01	2.47E+03

NUCLIDE	SHORELINE (MREM/YEAR PER UCI/SQUARE CENTIMETER) BONE	GI	THYROID	TB	LIVER	SKIN
RA-224	1.90E+04	9.04E+03	1.15E+04	1.22E+04	9.58E+03	1.49E+04
RA-226	1.41E+04	5.94E+03	8.41E+03	8.45E+03	6.41E+03	1.05E+04
RA-228	7.89E-05	3.58E-05	1.74E-05	4.19E-04	3.68E-07	7.89E-03
AC-228	1.17E+06	8.65E+05	7.86E+05	9.64E+05	8.14E+05	1.23E+06
TH-228	4.75E+03	1.67E+03	2.74E+03	2.95E+03	1.84E+03	8.88E+03
TH-230	1.11E+03	3.53E+02	5.44E+02	6.92E+02	3.39E+02	5.36E+03
TH-232	5.95E+02	1.70E+02	2.53E+02	6.10E+02	1.45E+02	5.44E+03
TH-234	2.14E+04	6.70E+03	1.23E+04	1.11E+04	7.33E+03	1.94E+04
PA-234	2.61E+06	1.83E+06	1.72E+06	2.10E+06	1.77E+06	2.69E+06
U-234	5.71E+02	1.46E+02	1.85E+02	7.43E+02	1.00E+02	7.34E+03
U-238	3.32E+02	8.41E+01	7.05E+01	5.46E+02	2.97E+01	6.06E+03
NP-238	6.30E+05	4.99E+05	4.12E+05	5.54E+05	4.69E+05	7.65E+05
NP-239	3.59E+05	1.45E+05	2.22E+05	2.13E+05	1.62E+05	2.90E+05
PU-238	4.77E+02	1.42E+02	7.02E+01	7.97E+02	2.54E+01	8.55E+03
PU-239	2.33E+02	8.55E+01	9.52E+01	3.60E+02	5.44E+01	3.32E+03
PU-240	4.65E+02	1.36E+02	7.17E+01	7.64E+02	2.69E+01	8.14E+03
PU-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PU-242	3.68E+02	6.23E+01	5.81E+01	6.03E+02	2.22E+01	6.41E+03
AM-241	6.40E+04	1.61E+04	3.11E+04	3.16E+04	1.79E+04	5.77E+04
AM-242	3.32E+04	1.11E+04	2.07E+04	1.80E+04	1.29E+04	2.97E+04
AM-243	1.37E+05	4.16E+04	7.49E+04	6.79E+04	4.42E+04	9.30E+04
CM-242	6.06E+02	2.02E+02	7.14E+01	9.05E+02	2.57E+01	9.00E+03
CM-243	2.68E+05	1.09E+05	1.64E+05	1.62E+05	1.22E+05	2.33E+05
CM-244	5.22E+02	1.76E+02	4.96E+01	8.07E+02	1.34E+01	8.15E+03

*Dose Factors taken from Kocher, D. C., "Dose-Rate Conversion Factors for External Exposure to Photon and Electron Radiation from Radionuclides Occurring in Routine Releases from Nuclear Fuel Cycle Facilities," Health Physics, Volume 38, Number 4, April 1980.