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Revisions to the Protective Action Guides Manual for Radiological Incidents

Review Draft

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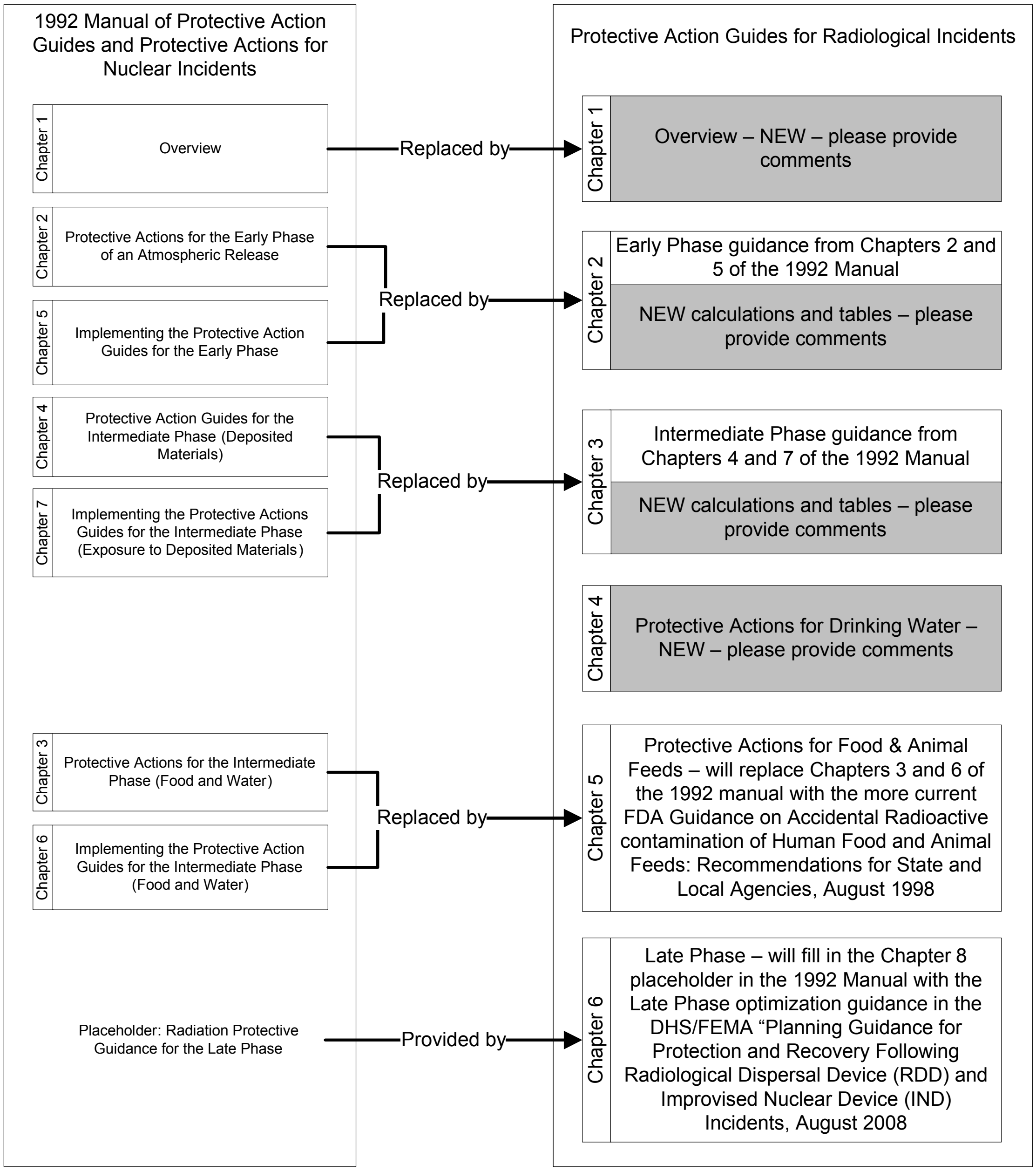
Disclaimer

This guidance is not intended to impact activities occurring under other statutory authorities such as the United State Environmental Protection Agency's Safe Drinking Water Act Maximum Contaminant Levels, Superfund program, the Nuclear Regulatory Commission's decommissioning program, or other federal or state regulatory programs.

As indicated by the use of non-mandatory language such as "may," "should," and "can," this Manual only provides recommendations and does not confer any legal rights or impose any legally binding requirements upon any member of the public, states, or any other federal agency.

Schematic of Fate of 1992 *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents* Content and Relationships to revised *Protective Action Guides for Radiological Incidents*
Note: Sections provided for review are identified by gray highlight in the figure below



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Chapter 1
Overview

1. Overview

1.1 Radiological Incident Phases and Protective Actions

For planning purposes it is convenient to identify three incident time phases that are generally accepted as being common to all radiological incident sequences; within each, different considerations apply to most protective actions. These are termed the Early, Intermediate, and Late Phases. Although these phases cannot be represented by precise periods of time – and may overlap – they provide a useful framework for the considerations involved in emergency response planning.

1.2 The Early Phase

The Early Phase (also referred to as the emergency phase) is the period at the beginning of a radiological incident when immediate decisions for effective use of protective actions are required and must therefore, for most incidents, be based on the status of the incident location and the prognosis for worsening conditions. When available, predictions of radiological conditions in the environment based on an estimate of the source or actual environmental measurements may also be used. Nuclear facilities, for example, have continuous, real-time radioactive effluent monitoring capabilities to monitor radioactive material released to the environment, and may have a network of offsite measurement stations. Protective actions based on the Protective Action Guides (PAGs) may be preceded by precautionary actions during this period. In the case of a transportation accident or a Radiological Dispersal Device (RDD) or an Improvised Nuclear Device (IND) detonation, there might not be sufficient time for protective actions to be implemented to reduce immediate exposure. The Early Phase may last from hours to days.

1.3 The Intermediate Phase

The Intermediate Phase is the period beginning after the source and radiological releases have been brought under control and reliable environmental measurements are available for use as a basis for decisions on additional protective actions. It extends until these additional protective actions are terminated. This phase may overlap the Early and Late Phase and may last from weeks to many months.

1.4 The Late Phase

The Late Phase (also referred to as the Recovery Phase) is the period beginning when recovery actions designed to reduce radiation levels in the environment to final appropriate or required levels are commenced, and ending when all recovery actions have been completed. This period may extend from months to years. It should be noted that during the Late Phase, no specific numerical PAG is provided.

1.5 Types of Protective Actions

The protective actions available to avoid or reduce radiation dose can be categorized as a function of exposure pathway and incident phase. Evacuation and sheltering-in-place (supplemented by bathing and changes of clothing), are the principal protective actions for use during the early phase to protect the public from exposure to direct radiation and inhalation from an airborne plume. It may also be appropriate to initiate protective action for the milk supply during this period, and, in cases in which emergency response plans include procedures for issuing stable iodine to reduce thyroid dose (FEMA 1985, DHS 2008), this may be an appropriate protective action for the early phase.

Some protective actions are not addressed by assignment of a PAG. For example, the control of access to areas is a protective action whose introduction is coupled with a decision to implement one of the other early or intermediate phase protective actions and does not have a separate PAG. Although the use of simple, ad hoc respiratory protection accessible to many emergency responders may be applicable for supplementary protection in some circumstances, this protective action is primarily for use by emergency workers.

There are two types of protective actions during the Intermediate Phase. The first major type consists of relocation and decontamination, which are the principal protective actions for protection of the public from whole-body external exposure due to deposited material and from inhalation of any resuspended radioactive particulate materials during the intermediate and late phases. It is assumed that decisions will be made during the Intermediate Phase and Late Phase concerning whether areas from which the public has been relocated will be decontaminated and reoccupied, or condemned and the occupants permanently relocated. The second major type of protective action during the Intermediate Phase encompasses restrictions on the use of contaminated food and water. This protective action, in particular, may overlap the Early and Late Phases. It should be noted that, during the Late Phase, no specific numerical PAG is provided.

It is necessary to distinguish between evacuation and relocation with regard to incident phases. Evacuation is the urgent removal of people from an area to avoid or reduce high-level, short-term exposure, usually from the plume or deposited activity. Relocation, on the other hand, is the removal or continued exclusion of people (households) from contaminated areas to avoid chronic radiation exposure. In certain cases, some groups that were not previously evacuated will require relocation. Conditions may develop in which some groups who have been evacuated in an emergency may be allowed to return based on the relocation PAG, while others may be converted to relocation status.

Table 1-1. Protective Action Guides (PAGs) for the Early and Intermediate Phases

Phase	Protective Action Recommendation	Protective Action Guide (PAG)
Early	Sheltering-in-place or evacuation of the public[a]	1 to 5 rem (10 – 50 m Sv) projected dose[b]
	Administration of prophylactic drugs - potassium iodide[c, e] Administration of other prophylactic or decorporation agents[d]	5 rem (50 mSv) projected dose to child thyroid[c, e]
Intermediate	Relocation of the public	2 rem (20 mSv) projected dose first year. Subsequent years, 0.5 rem (5 mSv) projected dose[b]
	Food interdiction	0.5 rem (5 mSv) projected dose, or 5 rem (50 mSv) to any individual organ or tissue in the first year, whichever is limiting
	Drinking water interdiction	0.5 rem (5 mSv) projected dose in the first year

[a]Should normally begin at 1 rem (0.01 Sv); take whichever action (or combination of actions) that results in the lowest exposure for the majority of the population. Sheltering may begin at lower levels if advantageous.
[b]Total Effective Dose (TED) - the sum of the effective dose from external radiation exposure and the committed effective dose from inhaled radioactive material.
[c]Provides thyroid protection from radioactive iodine only.
[d]For other information on other radiological prophylactics and medical countermeasures, refer to http://www.fda.gov/cder/drugprepare/default.htm, http:/www.bt.cdc.gov/radiation, or http://www.orau.gov/reacts.
[e]Committed Equivalent Dose(CED). FDA understands that a KI administration program that sets different projected thyroid radioactive dose thresholds for treatment of different population groups may be logistically impractical to implement during a radiological emergency. If emergency planners reach this conclusion, KI may be administered to both children and adults at the lowest intervention threshold (i.e., > 5 rem (0.05 Sv) projected internal thyroid dose in children) (FDA 2001).

Chapter 2
Basis for Calculations for the Early Phase PAGs

2. Basis for Calculations for the Early Phase PAGs

NOTE to the reader: The justification for this PAG remains the same as it was in the 1992 PAG Manual in Chapter 2. It is proposed that the new subsections below be added to that chapter to replace calculations and tables provided in Chapter 5 of the 1992 PAG Manual.

To use the Early Phase PAGs, measured or projected radiation levels must be compared to the Early Phase PAGs. The Early Phase protective actions are sheltering/evacuation at 1 to 5 rem (10 to 50 mSv) Total Effective Dose (TED) and in some communities that use it, administration of potassium iodide (KI) at 5 rem (50 mSv) projected child thyroid Committed Effective Dose (CED). This section provides Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for those radionuclides likely to be important for responding to most types of radiological incidents. The term DCP is used in place of Dose Conversion Factor (DCF) from the 1992 PAG Manual to avoid confusion with the true dose conversion factor that Turbo FRMAC (Sandia National Laboratories) and DCFPAK (K.F. Eckerman and R.W. Leggett) use to convert activity to dose. The DCPs are useful when multiple radionuclides are involved because the total dose from a single exposure pathway will be the sum of the doses calculated for each radionuclide. The DRLs are surrogates for the 1 rem PAG and are directly usable for releases consisting primarily of a single nuclide, in which case the DRL can be compared directly to the measured or calculated concentration. (DRLs can also be used for multiple radionuclides by summing the ratios of the environmental concentration of each nuclide to its respective DRL.) If this sum is equal to or less than unity, the PAG will be exceeded.

This section provides information used in the development of the DCPs and DRLs in Tables 2-1 and 2-5. Section 2.1 provides procedures for calculating DCPs and DRLs for combined exposure pathways. These pathways include:

- Whole-body external exposure to gamma radiation from the plume
- Inhalation from the plume
- Whole-body dose from deposited materials

Procedures for calculating DCPs and DRLs for each of these pathways is further described in Section 2.2-2.4. Section 2.5 provides procedures for calculating DCPs and DRLs for thyroid dose. All the calculations use the current dosimetry models from International Commission on Radiological Protection (ICRP) Publication 60 (ICRP 1991) to Publication 74 (ICRP 1997), which will be referred to as "ICRP 60+."

To apply Tables 2-1 and 2-5 to decisions on implementing PAG protective actions, one may use either the DCPs or DRLs. DCPs are used to calculate the projected composite dose for each radionuclide; these doses are then summed and compared to the PAG. The DRLs may be used by summing the ratios of the concentration of each radionuclide to its corresponding DRL. If the sum of the ratios exceeds unity, the corresponding protective action should be initiated.

The decision of whether evacuation is warranted is based on PAGs of 1 to 5 rem (10 to 50 mSv) TED. A supplemental protective action used in some communities is KI for thyroid protection if radioiodines are present. To calculate the dose appropriately, DCPs are provided in Table 2-1 for effective dose and Table 2-5 are used for equivalent thyroid dose from inhalation of radioiodine, respectively.

2.1 Procedures for Calculating Dose Conversion Parameters and Derived Response Levels for Combined Exposure Pathways

This section provides details of procedures for combined DCP and DRL for three exposure pathways that include: whole body exposure to gamma radiation from the plume; inhalation from the plume; and whole body exposure to gamma radiation from deposited materials. DCPs and DRLs for each of the three major exposure pathways for the early phase are provided. They are all expressed in terms of the time-integrated air concentration at the receptor so they can be conveniently summed over the three exposure pathways to obtain composite DRLs and DCPs for each radionuclide. These composite values are tabulated in Table 2-1 for effective dose and in Table 2-5 for equivalent thyroid dose from inhalation of radioiodines. Early Phase calculations presented in this Chapter 2 are for use during the plume. Following plume passage, Intermediate Phase calculations in Chapter 3 should be used.

The tabulated DCPs and DRLs include assumptions on particle size, deposition velocity, the presence of short-lived daughters, and exposure duration as noted. The existence of more accurate data for individual radionuclides may justify modification of the DCPs and DRLs. The procedures described in this section for developing the DCPs and DRLs for individual exposure pathways may be used to assist with such modifications. The following Table 2-1 provides the combined DCP and DRL for exposure pathways, while Section 2.1.1 and 2.1.2 provide details of their calculations.

Table 2-1. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for Combined[a] Exposure Pathways during the Early Phase of a Radiological Incident

				2009 (ICRP 60+) Values					1992 Values		DCP Comparisons	
No.	Radionuclide	[b]Half-Life (d)	Branch Fraction	**Table 2-2: Equivalent dose from 1 hour submersion in passing plume** (rem·cm^3 per h·µCi)	**Table 2-3:** Committed Effective Dose from inhalation while in the passing plume for 1 hour (rem·cm^3 per h·µCi)	**Table 2-4:** Equivalent Dose from groundshine and Committed Effective Dose from inhalation of resuspended material over 4 days (rem·cm^3 per h·µCi)	DCP (rem·cm^3 per h·µCi)	DRL (µCi·h per cm^3)	DCP Table 5.1 (rem·cm^3 per h·µCi)	DRL Table 5.1 (µCi·h per cm^3)	DCPtotal / by 1992 DCPtotal	DRLtotal / by 1992 DRLtotal
1	Am-241	1.58E+05	-	8.96E+00	3.28E+08	6.78E+04	3.28E+08	3.05E-09	5.30E+08	1.90E-09	0.62	1.60
2	Ba-140/La-140	NA	NA	1.58E+03	2.38E+04	7.96E+03	3.33E+04	3.00E-05	NA	-	-	-
	Ba-140	1.27E+01	1.00E+00	1.07E+02	1.99E+04	6.47E+02	2.06E+04	4.85E-05	5.30E+03	1.90E-04	3.89	0.26
	La-140	1.68E+00	1.00E+00	1.48E+03	3.88E+03	7.31E+03	1.27E+04	7.89E-05	1.10E+04	8.80E-05	1.15	0.90
3	Ce-144/Pr-144/Pr-144m	NA	NA	4.54E+01	1.79E+05	7.17E+02	1.80E+05	5.55E-06	4.50E+05	2.20E-06	0.40	2.52
	Ce-144	2.84E+02	1.00E+00	1.01E+01	1.79E+05	1.06E+02	1.80E+05	5.57E-06	4.50E+05	2.20E-06	0.40	2.53
	Pr-144	1.20E-02	9.82E-01	3.52E+01	6.23E+01	6.11E+02	7.08E+02	1.41E-03	NA	-	-	-
	Pr-144m	5.00E-03	1.78E-02	2.93E+00	0.00E+00	3.93E+01	4.23E+01	2.37E-02	NA	-	-	-
	Pr-144	1.20E-02	9.99E-01	3.52E+01	6.23E+01	6.11E+02	7.08E+02	1.41E-03	NA	-	-	-
4	Cf-252	9.64E+02	-	4.83E-02	1.26E+08	2.60E+04	1.26E+08	7.92E-09	1.90E+08	5.30E-09	0.66	1.49
5	Cm-244	6.61E+03	-	4.52E-02	1.94E+08	4.00E+04	1.94E+08	5.15E-09	3.00E+08	3.40E-09	0.65	1.52
6	Co-60	1.93E+03	-	1.58E+03	1.05E+05	8.67E+03	1.15E+05	8.71E-06	2.70E+05	3.70E-06	0.43	2.36
7	Cs-134	7.53E+02	-	9.39E+02	6.94E+04	5.58E+03	7.60E+04	1.32E-05	6.30E+04	1.60E-05	1.21	0.82
8	Cs-136	1.31E+01	-	1.32E+03	9.46E+03	6.89E+03	1.77E+04	5.66E-05	1.80E+04	5.60E-05	0.98	1.01
9	Cs-137/Ba-137m	NA	NA	3.40E+02	1.33E+05	2.10E+03	1.36E+05	7.36E-06	4.10E+04	2.40E-05	3.31	0.31
	Cs-137	1.10E+04	1.00E+00	1.23E+00	1.33E+05	3.88E+01	1.33E+05	7.49E-06	NA	-	-	-
	Ba-137m	1.77E-03	9.46E-01	3.58E+02	0.00E+00	2.18E+03	2.54E+03	3.94E-04	NA	-	-	-
10	Gd-153	2.42E+02	-	4.14E+01	8.17E+03	3.47E+02	8.56E+03	1.17E-04	2.90E+04	3.40E-05	0.30	3.44
11	I-131	8.04E+00	-	2.25E+02	2.52E+04	1.16E+03	2.65E+04	3.77E-05	5.30E+04	1.90E-05	0.50	1.98
12	I-132	9.58E-02	-	1.40E+03	3.88E+02	2.87E+02	2.07E+03	4.83E-04	4.90E+03	2.00E-04	0.42	2.41
13	I-133	8.67E-01	-	3.67E+02	5.00E+03	6.98E+02	6.07E+03	1.65E-04	1.50E+04	6.80E-05	0.40	2.42
14	I-134	3.65E-02	-	1.62E+03	1.90E+02	1.25E+02	1.94E+03	5.16E-04	3.10E+03	3.30E-04	0.63	1.56
15	I-135/Xe-135m	NA	NA	1.04E+03	1.10E+03	5.74E+02	2.72E+03	3.68E-04	NA	-	-	-
	I-135	2.75E-01	1.00E+00	1.00E+03	1.10E+03	5.50E+02	2.65E+03	3.77E-04	8.10E+03	1.20E-04	0.33	3.14
	Xe-135m	1.06E-02	1.54E-01	2.53E+02	0.00E+00	1.57E+02	4.09E+02	2.44E-03	2.50E+02	4.10E-03	1.64	0.60
16	Ir-192	7.40E+01	-	4.80E+02	2.25E+04	2.88E+03	2.59E+04	3.86E-05	3.80E+04	2.70E-05	0.68	1.43

Table 2-1. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for Combined[a] Exposure Pathways during the Early Phase of a Radiological Incident (continued)

				ICRP 60+ Calculated Values					1992 Values		DCF Comparisons	
No.	**Radionuclide**	**[b]Half-Life (d)**	**Branch Fraction**	**Table 2-2: Equivalent dose from 1 hour submersion in passing plume** (rem·cm^3 per h·µCi)	**Table 2-3:** Committed Effective Dose from inhalation while in the passing plume for 1 hour (rem·cm^3 per h·µCi)	**Table 2-4:** Equivalent Dose from groundshine and Committed Effective Dose from inhalation of resuspended material over 4 days (rem·cm^3 per h·µCi)	**DCP** (rem·cm^3 per h·µCi)	**DRL** (µCi·h per cm^3)	**DCP** Table 5.1 (rem·cm^3 per h·µCi)	**DRL** Table 5.1 (µCi·h per cm^3)	**DCPtotal / by 1992 DCPtotal**	**DRLtotal / by 1992 DRLtotal**
17	Kr-87	5.30E-02	-	5.28E+02	NA	6.04E+01	5.88E+02	1.70E-03	5.10E+02	2.00E-03	1.15	0.85
18	Kr-88/Rb-88	NA	NA	1.73E+03	3.97E+03	3.98E+02	6.11E+03	1.64E-04	NA	-	-	-
	Kr-88	1.18E-01	1.00E+00	1.29E+03	3.88E+03	2.78E+02	5.45E+03	1.83E-04	1.30E+03	7.80E-04	4.19	0.24
	Rb-88	1.24E-02	1.00E+00	4.43E+02	9.40E+01	1.19E+02	6.56E+02	1.52E-03	5.20E+02	1.90E-03	1.26	0.80
19	La-140	1.68E+00	-	1.48E+03	3.88E+03	3.98E+03	9.33E+03	1.07E-04	1.10E+04	8.80E-05	0.85	1.22
20	Mo-99/Tc-99m	NA	NA	1.54E+02	3.44E+03	6.59E+02	4.25E+03	2.35E-04	NA	-	-	-
	Mo-99	2.75E+00	1.00E+00	9.30E+01	3.38E+03	4.23E+02	3.89E+03	2.57E-04	5.20E+03	1.90E-04	0.75	1.35
	Tc-99m	2.51E-01	8.76E-01	6.98E+01	6.84E+01	2.70E+02	4.09E+02	2.45E-03	1.70E+02	6.00E-03	2.40	0.41
21	Np-239	2.36E+00	-	9.24E+01	3.51E+03	3.42E+02	3.94E+03	2.54E-04	3.60E+03	2.80E-04	1.09	0.91
22	Pm-147	9.58E+02	-	1.15E-01	2.38E+04	5.00E+00	2.38E+04	4.21E-05	4.70E+04	2.10E-05	0.51	2.00
23	Pu-238	3.20E+04	-	4.66E-02	3.68E+08	7.58E+04	3.68E+08	2.72E-09	4.70E+08	2.10E-09	0.78	1.30
24	Pu-239	8.79E+06	-	4.63E-02	4.05E+08	8.36E+04	4.05E+08	2.47E-09	5.20E+08	1.90E-09	0.78	1.30
25	Ra-226/Rn-222…	NA	NA	1.11E+03	3.25E+07	1.31E+04	3.25E+07	3.08E-08	NA	-	-	-
	Ra-226	5.84E+05	1.00E+00	3.78E+00	3.24E+07	6.70E+03	3.24E+07	3.09E-08	1.00E+07	9.70E-08	3.24	0.32
	Rn-222	3.82E+00	1.00E+00	2.35E-01	0.00E+00	1.44E+00	1.67E+00	5.97E-01	NA	-	-	-
	Po-218	2.12E-03	1.00E+00	5.60E-03	0.00E+00	3.26E-02	3.82E-02	2.62E+01	NA	-	-	-
	Pb-214	1.86E-02	1.00E+00	1.45E+02	5.00E+04	9.14E+02	5.11E+04	1.96E-05	NA	-	-	-
	Bi-214	1.38E-02	1.00E+00	9.64E+02	5.24E+04	5.43E+03	5.88E+04	1.70E-05	NA	-	-	-
	Po-214	1.90E-09	1.00E+00	5.07E-02	0.00E+00	2.99E-01	3.49E-01	2.86E+00	NA	-	-	-
	At-218	2.31E-05	2.00E-04	1.29E+00	0.00E+00	1.37E+01	1.50E+01	6.67E-02	NA	-	-	-
	Bi-214	1.38E-02	1.00E+00	9.64E+02	5.24E+04	5.43E+03	5.88E+04	1.70E-05	NA	-	-	-
	Po-214	1.90E-09	1.00E+00	5.07E-02	0.00E+00	2.99E-01	3.49E-01	2.86E+00	NA	-	-	-
26	Ru-103/Rh-103m	NA	NA	2.77E+02	1.01E+04	1.64E+03	1.20E+04	8.36E-05	NA	-	-	-
	Ru-103	3.93E+01	1.00E+00	2.77E+02	1.00E+04	1.63E+03	1.20E+04	8.37E-05	1.30E+04	7.70E-05	0.92	1.09
	Rh-103m	3.90E-02	9.97E-01	8.01E-02	9.29E+00	3.22E+00	1.26E+01	7.94E-02	NA	-	-	-

Table 2-1. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for Combined[a] Exposure Pathways during the Early Phase of a Radiological Incident (continued)

				ICRP 60+ Calculated Values					1992 Values		DCF Comparisons	
No.	Radionuclide	[b]Half-Life (d)	Branch Fraction	**Table 2-2: Equivalent dose from 1 hour submersion in passing plume** (rem·cm^3 Per h·µCi)	**Table 2-3:** Committed Effective Dose from inhalation while in the passing plume for 1 hour (rem·cm^3 per h·µCi)	**Table 2-4:** Equivalent Dose from groundshine and Committed Effective Dose from inhalation of resuspended material over 4 days (rem·cm^3 per h·µCi)	DCP (rem·cm^3 per h·µCi)	DRL (µCi·h per cm^3)	DCP Table 5.1 (rem·cm^3 per h·µCi)	DRL Table 5.1 (µCi·h per cm^3)	DCPtotal / by 1992 DCPtotal	DRLtotal / by 1992 DRLtotal
27	Ru-106/Rh-106	NA	NA	1.41E+02	2.25E+05	1.34E+03	2.26E+05	4.42E-06	5.70E+05	1.70E-06	0.40	2.60
	Ru-106	3.68E+02	1.00E+00	0.00E+00	2.25E+05	4.62E+01	2.25E+05	4.45E-06	NA	-	-	-
	Rh-106	3.46E-04	1.00E+00	1.41E+02	0.00E+00	1.29E+03	1.43E+03	6.97E-04	NA	-	-	-
28	Sb-127/Te-127	NA	NA	4.19E+02	6.79E+03	1.84E+03	9.05E+03	1.10E-04	NA	-	-	-
	Sb-127	3.85E+00	1.00E+00	4.15E+02	6.40E+03	1.82E+03	8.63E+03	1.16E-04	9.50E+03	1.10E-04	0.91	1.05
	Te-127	3.90E-01	8.24E-01	4.44E+00	4.77E+02	2.77E+01	5.09E+02	1.97E-03	NA	-	-	-
29	Sb-129/Te-129	NA	NA	9.22E+02	9.55E+02	3.57E+02	2.23E+03	4.48E-04	NA	-	-	-
	Sb-129	1.80E-01	1.00E+00	8.92E+02	8.51E+02	3.35E+02	2.08E+03	4.81E-04	2.00E+03	5.00E-04	1.04	0.96
	Te-129	4.83E-02	7.75E-01	3.80E+01	1.34E+02	2.79E+01	2.00E+02	5.01E-03	1.40E+02	7.00E-03	1.43	0.72
30	Se-75	1.20E+02	-	2.23E+02	4.56E+03	1.34E+03	6.13E+03	1.63E-04	1.20E+04	8.30E-05	0.51	1.97
31	Sr-89	5.05E+01	-	5.81E+00	2.70E+04	2.57E+02	2.73E+04	3.66E-05	5.00E+04	2.00E-05	0.55	1.83
32	Sr-90/Y-90	NA	NA	1.18E+01	5.40E+05	5.32E+02	5.40E+05	1.85E-06	NA	-	-	-
	Sr-90	1.06E+04	1.00E+00	1.31E+00	5.34E+05	1.16E+02	5.35E+05	1.87E-06	1.60E+06	6.40E-07	0.33	2.92
	Y-90	2.67E+00	1.00E+00	1.05E+01	5.11E+03	4.15E+02	5.53E+03	1.81E-04	1.00E+04	9.90E-05	0.55	1.83
33	Sr-91/Y-91m	NA	NA	6.17E+02	1.41E+03	5.50E+02	2.58E+03	3.88E-04	NA	-	-	-
	Sr-91	3.96E-01	1.00E+00	4.35E+02	1.39E+03	3.91E+02	2.21E+03	4.51E-04	2.40E+03	4.20E-04	0.92	1.07
	Y-91m	3.45E-02	5.78E-01	3.15E+02	3.88E+01	2.74E+02	6.28E+02	1.59E-03	NA	-	-	-
34	Te-129m/Te-129	NA	NA	4.55E+01	2.70E+04	4.79E+02	2.76E+04	3.63E-05	NA	-	-	-
	Te-129m	3.36E+01	1.00E+00	2.07E+01	2.70E+04	2.12E+02	2.72E+04	3.68E-05	2.90E+04	3.50E-05	0.94	1.05
	Te-129	4.83E-02	6.50E-01	3.80E+01	1.34E+02	4.12E+02	5.84E+02	1.71E-03	1.40E+02	7.00E-03	4.17	0.24
35	[c]Te-131m/Te-131	NA	NA	9.28E+02	3.66E+03	2.18E+03	6.78E+03	1.48E-04	NA	-	-	-
	[c]Te-131m	1.25E+00	1.00E+00	8.71E+02	3.64E+03	2.03E+03	6.54E+03	1.53E-04	8.60E+03	1.20E-04	0.76	1.27
	Te-131	1.74E-02	2.22E-01	2.55E+02	9.70E+01	7.16E+02	1.07E+03	9.36E-04	NA	-	-	-
36	Te-132/I-132	NA	NA	1.52E+03	7.37E+03	6.12E+03	1.50E+04	6.66E-05	2.00E+04	5.00E-05	0.75	1.33
	Te-132	3.26E+00	1.00E+00	1.24E+02	6.98E+03	5.39E+02	7.64E+03	1.31E-04	1.20E+04	8.50E-05	0.64	1.54
	I-132	9.58E-02	1.00E+00	1.40E+03	3.88E+02	5.58E+03	7.36E+03	1.36E-04	4.90E+03	2.00E-04	1.50	0.68

Table 2-1. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for Combined[a] Exposure Pathways during Early Phase of a Radiological Incident (continued)

No.	Radionuclide	[b]Half-Life (d)	Branch Fraction	ICRP 60+ Calculated Values: **Table 2-2: Equivalent dose from 1 hour submersion in passing plume** (rem·cm³ per h·µCi)	**Table 2-3:** Committed Effective Dose from inhalation while in the passing plume for 1 hour (rem·cm³ per h·µCi)	**Table 2-4:** Equivalent Dose from groundshine and Committed Effective Dose from inhalation of resuspended material over 4 days (rem·cm³ per h·µCi)	DCP (rem·cm³ per h·µCi)	DRL (µCi·h per cm³)	1992 Values: DCP Table 5.1 (rem·cm³ per h·µCi)	DRL Table 5.1 (µCi·h per cm³)	DCF Comparisons: DCPtotal / by 1992 DCPtotal	DRLtotal / by 1992 DRLtotal
37	Tm-170	1.29E+02	-	4.88E+00	3.16E+04	1.05E+02	3.17E+04	3.15E-05	3.20E+04	3.20E-05	0.99	0.98
38	Xe-133	5.24E+00	-	1.77E+01	NA	1.16E+02	1.33E+02	7.51E-03	2.00E+01	5.00E-02	6.66	0.15
39	Xe-135	3.79E-01	-	1.46E+02	NA	1.29E+02	2.75E+02	3.64E-03	1.40E+02	7.00E-03	1.96	0.52
40	Xe-138	9.84E-03	-	7.29E+02	0.00E+00	1.43E+01	7.43E+02	1.35E-03	7.20E+02	1.40E-03	1.03	0.96
41	Y-91	5.85E+01	-	8.27E+00	3.04E+04	2.81E+02	3.07E+04	3.26E-05	5.90E+04	1.70E-05	0.52	1.92
42	Yb-169	3.20E+01	-	1.50E+02	1.01E+04	1.01E+03	1.13E+04	8.85E-05	1.10E+04	8.90E-05	1.03	0.99

[a]Table 2-2 gives Equivalent Dose from 1 hour submersion in passing plume, Table 2-3 gives Committed Effective Dose from inhalation while in the passing plume for 1 hour and Table 2-4 gives Equivalent Dose from 4 days from groundshine and Committed Effective Dose from inhalation of resuspended material over 4 d.

[b]Values from Turbo FRMAC 2.0, RFC 2 (DCFPAK, K. Eckerman).
[c]Te-131m values in this table are subject to change pending further development of new parent-daughter rules.

2.1.1 Dose Conversion Parameter Calculation for Early Phase Table 2-1

The Table 2-1 DCP values for the combined exposure pathways (i.e., 1 hour of plume inhalation, 1 hour of plume submersion, 96 hours of groundshine, and 96 hours of inhalation of resuspended material) are simply the summation of the corresponding values for each radionuclide from Table 2-2 (1 hour of plume submersion), Table 2-3 (1 hour of plume inhalation), and Table 2-4 (96 hours of groundshine and 96 hours of inhalation of resuspended material).

$$DCP_{Combined,E,i} = \sum_{i}^{P+D} \left(DCP_{Submersion,E,i} + DCP_{Inhalation,E,i} + DCP_{groundshine+inh,E,i} \right)$$

Where:

$\sum_{i}^{P+D} =$ represents the summation of values from the parent radionuclide (P) and any short-lived daughter radionuclide(s) (D);

$DCP_{Combined,\ E,\ i} =$ the Dose Conversion Parameter, value for the effective dose rate from all pathways (i.e., combined pathways including 1 h of plume inhalation, 1 h of plume submersion, 96 h of groundshine, and 96 h of inhalation of resuspended material) from exposure to radionuclide *i* and any short-lived daughter radionuclide(s), rem•cm^3 /h·µCi;

$DCP_{Submersion,\ E,\ i} =$ Dose Conversion Parameter, value for the effective dose rate per unit activity from external exposure (i.e., 1 h external exposure from submersion in the plume) to radionuclide *i* and any short-lived daughter radionuclide(s) in the plume, rem·cm^3 / h·µCi, from Table 2-2;

$DCP_{Inhalation,E,i} =$ Dose Conversion Parameter, value for the committed effective dose rate per unit activity from exposure (i.e., 1 h plume inhalation) to radionuclide *i* and any short-lived daughter radionuclide(s), rem·cm^3 / h·µCi, from Table 2-3; and

$DCP_{groundshine+inh,\ E,\ i} =$ Dose Conversion Parameter, effective, value for the dose rate per unit activity from groundshine and the inhalation of resuspended material from radionuclide *i* and any short-lived daughter radionuclide(s) over the Early Phase time period and, rem·cm^3 / h·µCi, from Table 2-4.

2.1.2 Derived Response Level Calculation for Early Phase Table 2-1

The DRL is calculated using the following equation:

$$DRL_{Combined,E,i} = \sum_{i}^{P+D} \left(\frac{PAG}{DCP_{Combined,E,i}} \right), \qquad \frac{\mu Ci \cdot h}{cm^3} = \frac{1\,rem}{rem \cdot cm^3 / h \cdot \mu Ci}$$

Where:

$\sum_{i}^{P+D} =$ represents the summation of values from the parent radionuclide (P) and any short-lived daughter radionuclide(s) (D);

$DRL_{Combined,E,\ i} =$ Derived Response Level, effective, value for the effective dose from all pathways (i.e., combined pathways including 1 h of plume inhalation, 1 h of plume submersion, 96 h of groundshine, and 96 h of inhalation of resuspended material) from exposure to radionuclide *i* and any short-lived daughter radionuclide(s), µCi·h/cm^3;

PAG = EPA's Protective Action Guide, 1 rem for effective dose or 5 rem organ dose; and

$DCP_{Combined,\ E,\ i} =$ Dose Conversion Parameter, value for the effective dose rate from all pathways (i.e., combined pathways including 1 h of plume inhalation, 1 h of plume submersion, 96 h of groundshine, and 96 h of inhalation of resuspended material) from exposure to radionuclide *i* and any short-lived daughter radionuclide(s), rem•cm^3 /h•µCi.

Persons exposed to an airborne particulate plume will receive dose to skin from beta emitters in the plume as well as from those deposited on skin and clothing. Although it is possible to detect beta radiation, it is not practical, for purposes of decisions on evacuation and sheltering-in-place, to determine dose to skin by field measurement of the beta equivalent dose rate near the skin surface. Such doses are determined more practically through calculations based on time-integrated air concentration, an assumed deposition velocity, and an assumed time period between deposition and skin decontamination. For the purpose of evaluation of the relative dose compared to the dose from external gamma exposure and inhalation, DCFs were evaluated using a deposition velocity of 0.1 cm/s and an exposure time before decontamination of 12 hours. Using these protective assumptions, it was determined that skin beta dose should seldom, if ever, be a controlling pathway during the early phase. Therefore, no DCPs or DRLs are listed for skin beta dose.

2.2 External Exposure to Gamma Radiation from the Plume

Table 2-2 provides DCPs and DRLs for external exposure to gamma radiation due to immersion in contaminated air. The values for gamma radiation will provide protective estimates for exposure to an overhead plume. They are derived under the assumption that the plume is correctly approximated by a semi-infinite source.

Table 2-2. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for External Exposure Due to Submersion in Contaminated Air (Assume 1 Hour Exposure Period)

					2009 (ICRP 60+) Values		1992 Values (Table 5.3)		DCF Comparisons	
No.	Radionuclide	[a]**Half-Life (d)**	[1]Branch Fraction	[a]$DC_{Submersion, E}$ (Sv · m^3 per (s · Bq)	$DCP_{Submersion, E}$ (rem·cm^3 per h·µCi)	$DRL_{Submersion, E}$ (µCi·h per cm^3)	$DCF_{Submersion, E}$ (rem·cm^3 per h·µCi)	$DRL_{Submersion, E}$ (µCi·h per cm^3)	$DCP_{Submersion, E}$ / by 1992 DCF_{Inh}	$DRL_{Submersion, E}$ / by 1992 DCF_{Inh}
1	Am-241	1.58E+05	-	6.74E-16	8.96E+00	1.12E-01	1.10E+01	9.20E-02	0.81	1.21
2	Ba-140/La-140	NA	NA	NA	1.58E+03	6.31E-04	NA	NA	NA	NA
	Ba-140	1.27E+01	1.00E+00	8.07E-15	1.07E+02	9.32E-03	1.10E+02	9.30E-03	0.98	1.00
	La-140	1.68E+00	1.00E+00	1.11E-13	1.48E+03	6.77E-04	1.40E+03	7.10E-04	1.05	0.95
3	Ce144/Pr144/Pr144m	NA	NA	NA	4.54E+01	2.07E-02	3.10E+01	3.20E-02	1.47	0.65
	Ce-144	2.84E+02	1.00E+00	7.63E-16	1.01E+01	9.85E-02	1.00E+01	9.70E-02	1.01	1.02
	Pr-144	1.20E-02	9.82E-01	2.65E-15	3.52E+01	2.84E-02	NA	NA	NA	NA
	Pr-144m	5.00E-03	1.78E-02	2.20E-16	2.93E+00	3.42E-01	NA	NA	NA	NA
	Pr-144	1.20E-02	9.99E-01	2.65E-15	3.52E+01	2.84E-02	NA	NA	NA	NA
4	Cf-252	9.64E+02	-	3.63E-18	4.83E-02	2.07E+01	4.30E-02	2.30E+01	1.12	0.90
5	Cm-244	6.61E+03	-	3.40E-18	4.52E-02	2.21E+01	4.80E-02	2.10E+01	0.94	1.05
6	Co-60	1.93E+03	-	1.19E-13	1.58E+03	6.32E-04	1.50E+03	6.70E-04	1.06	0.94
7	Cs-134	7.53E+02	-	7.06E-14	9.39E+02	1.06E-03	9.10E+02	1.10E-03	1.03	0.97
8	Cs-136	1.31E+01	-	9.94E-14	1.32E+03	7.56E-04	1.30E+03	7.80E-04	1.02	0.97
9	Cs-137/Ba-137m	NA	NA	NA	3.40E+02	2.94E-03	3.50E+02	2.90E-03	0.97	1.02
	Cs-137	1.10E+04	1.00E+00	9.28E-17	1.23E+00	8.10E-01	NA	NA	NA	NA
	Ba-137m	1.77E-03	9.46E-01	2.69E-14	3.58E+02	2.80E-03	NA	NA	NA	NA
10	Gd-153	2.42E+02	-	3.11E-15	4.14E+01	2.42E-02	5.10E+01	2.00E-02	0.81	1.21
11	I-131	8.04E+00	-	1.69E-14	2.25E+02	4.45E-03	2.20E+02	4.60E-03	1.02	0.97
12	I-132	9.58E-02	-	1.05E-13	1.40E+03	7.16E-04	1.40E+03	7.40E-04	1.00	0.97
13	I-133	8.67E-01	-	2.76E-14	3.67E+02	2.72E-03	3.50E+02	2.90E-03	1.05	0.94
14	I-134	3.65E-02	-	1.22E-13	1.62E+03	6.16E-04	1.60E+03	6.40E-04	1.01	0.96
15	I-135/Xe135m	NA	NA	NA	1.04E+03	9.60E-04	NA	NA	NA	NA
	I-135	2.75E-01	1.00E+00	7.54E-14	1.00E+03	9.97E-04	9.50E+02	1.10E-03	1.06	0.91

Table 2-2. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for External Exposure Due to Submersion in Contaminated Air (Assume 1 Hour Exposure Period) (continued)

No.	Radionuclide	[a]Half-Life (d)	[1]Branch Fraction	[1]$DC_{Submersion, E}$ ($Sv \cdot m^3$ per $s \cdot Bq$)	2009 (ICRP 60+) Values: $DCP_{Submersion, E}$ ($rem \cdot cm^3$ per $h \cdot \mu Ci$)	2009 (ICRP 60+) Values: $DRL_{Submersion, E}$ ($\mu Ci \cdot h$ per cm^3)	1992 Values (Table 5.3): $DCF_{Submersion, E}$ ($rem \cdot cm^3$ per $h \cdot \mu Ci$)	1992 Values (Table 5.3): $DRL_{Submersion, E}$ ($\mu Ci \cdot h$ per cm^3)	DCF Comparisons: $DCP_{Submersion, E}$ / by 1992 DCF_{Inh}	DCF Comparisons: $DRL_{Submersion, E}$ / by 1992 DCF_{Inh}
	Xe-135m	1.06E-02	1.54E-01	1.90E-14	2.53E+02	3.96E-03	NA	NA	NA	NA
16	Ir-192	7.40E+01	-	3.61E-14	4.80E+02	2.08E-03	4.70E+02	2.10E-03	1.02	0.99
17	Kr-87	5.30E-02	-	3.97E-14	5.28E+02	1.89E-03	5.10E+02	2.00E-03	1.04	0.95
18	Kr-88/Rb-88	NA	NA	NA	1.73E+03	5.77E-04	NA	NA	NA	NA
	Kr-88	1.18E-01	1.00E+00	9.71E-14	1.29E+03	7.74E-04	1.30E+03	7.80E-04	0.99	0.99
	Rb-88	1.24E-02	1.00E+00	3.33E-14	4.43E+02	2.26E-03	4.10E+02	2.50E-03	1.08	0.90
19	La-140	1.68E+00	-	1.11E-13	1.48E+03	6.77E-04	1.40E+03	7.10E-04	1.05	0.95
20	Mo-99/Tc-99m	NA	NA	NA	1.54E+02	6.49E-03	NA	NA	NA	NA
	Mo-99	2.75E+00	1.00E+00	6.99E-15	9.30E+01	1.08E-02	9.10E+01	1.10E-02	1.02	0.98
	Tc-99m	2.51E-01	8.76E-01	5.25E-15	6.98E+01	1.43E-02	7.60E+01	1.30E-02	0.92	1.10
21	Np-239	2.36E+00	-	6.95E-15	9.24E+01	1.08E-02	9.60E+01	1.00E-02	0.96	1.08
22	Pm-147	9.58E+02	-	8.67E-18	1.15E-01	8.67E+00	2.10E-03	4.80E+02	54.91	0.02
23	Pu-238	3.20E+04	-	3.50E-18	4.66E-02	2.15E+01	5.00E-02	2.00E+01	0.93	1.07
24	Pu-239	8.79E+06	-	3.48E-18	4.63E-02	2.16E+01	4.70E-02	2.10E+01	0.98	1.03
25	Ra-226/Rn-222…	NA	NA	NA	1.11E+03	8.98E-04	NA	NA	NA	NA
	Ra-226	5.84E+05	1.00E+00	2.84E-16	3.78E+00	2.65E-01	3.90E+00	2.60E-01	0.97	1.02
	Rn-222	3.82E+00	1.00E+00	1.77E-17	2.35E-01	4.25E+00	NA	NA	NA	NA
	Po-218	2.12E-03	1.00E+00	4.21E-19	5.60E-03	1.79E+02	NA	NA	NA	NA
	Pb-214	1.86E-02	1.00E+00	1.09E-14	1.45E+02	6.90E-03	NA	NA	NA	NA
	Bi-214	1.38E-02	1.00E+00	7.25E-14	9.64E+02	1.04E-03	NA	NA	NA	NA
	Po-214	1.90E-09	1.00E+00	3.81E-18	5.07E-02	1.97E+01	NA	NA	NA	NA
	At-218	2.31E-05	2.00E-04	9.71E-17	1.29E+00	7.74E-01	NA	NA	NA	NA
	Bi-214	1.38E-02	1.00E+00	7.25E-14	9.64E+02	1.04E-03	NA	NA	NA	NA
	Po-214	1.90E-09	1.00E+00	3.81E-18	5.07E-02	1.97E+01	NA	NA	NA	NA

Table 2-2. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for External Exposure Due to Submersion in Contaminated Air (Assume 1 Hour Exposure Period) (continued)

					2009 (ICRP 60+) Values		1992 Values (Table 5.3)		DCF Comparisons	
No.	Radionuclide	[a]Half-Life (d)	[a]Branch Fraction	[a]$DC_{Submersion, E}$ ($Sv \cdot m^3$ per ($s \cdot Bq$))	$DCP_{Submersion, E}$ (rem·cm^3 per h·µCi)	$DRL_{Submersion, E}$ (µCi·h per cm^3)	$DCF_{Submersion, E}$ (rem·cm^3 per h·µCi)	$DRL_{Submersion, E}$ (µCi·h per cm^3)	$DCP_{Submersion, E}$ / by 1992 DCF_{Inh}	$DRL_{Submersion, E}$ / by 1992 DCF_{Inh}
26	Ru-103/Rh-103m	NA	NA	NA	2.77E+02	3.61E-03	NA	NA	NA	NA
	Ru-103	3.93E+01	1.00E+00	2.08E-14	2.77E+02	3.61E-03	2.80E+02	3.60E-03	0.99	1.00
	Rh-103m	3.90E-02	9.97E-01	6.02E-18	8.01E-02	1.25E+01	NA	NA	NA	NA
27	Ru-106/Rh-106	NA	NA	NA	1.41E+02	7.09E-03	1.20E+02	8.40E-03	1.17	0.84
	Ru-106	3.68E+02	1.00E+00	0.00E+00	0.00E+00	NA	NA	NA	NA	NA
	Rh-106	3.46E-04	1.00E+00	1.06E-14	1.41E+02	7.09E-03	NA	NA	NA	NA
28	Sb-127/Te-127	NA	NA	NA	4.19E+02	2.39E-03	NA	NA	NA	NA
	Sb-127	3.85E+00	1.00E+00	3.12E-14	4.15E+02	2.41E-03	3.90E+02	2.60E-03	1.06	0.93
	Te-127	3.90E-01	8.24E-01	3.34E-16	4.44E+00	2.25E-01	NA	NA	NA	NA
29	Sb-129/Te-129	NA	NA	NA	9.22E+02	1.08E-03	NA	NA	NA	NA
	Sb-129	1.80E-01	1.00E+00	6.71E-14	8.92E+02	1.12E-03	8.60E+02	1.20E-03	1.04	0.93
	Te-129	4.83E-02	7.75E-01	2.86E-15	3.80E+01	2.63E-02	3.10E+01	3.20E-02	1.23	0.82
30	Se-75	1.20E+02	-	1.68E-14	2.23E+02	4.48E-03	2.30E+02	4.40E-03	0.97	1.02
31	Sr-89	5.05E+01	-	4.37E-16	5.81E+00	1.72E-01	8.20E-02	1.20E+01	70.88	0.01
32	Sr-90/Y-90	NA	NA	NA	1.18E+01	8.45E-02	NA	NA	NA	NA
	Sr-90	1.06E+04	1.00E+00	9.83E-17	1.31E+00	7.65E-01	0.00E+00	0.00E+00	NA	NA
	Y-90	2.67E+00	1.00E+00	7.92E-16	1.05E+01	9.49E-02	0.00E+00	0.00E+00	NA	NA
33	Sr-91/Y-91m	NA	NA	NA	6.17E+02	1.62E-03	NA	NA	NA	NA
	Sr-91	3.96E-01	1.00E+00	3.27E-14	4.35E+02	2.30E-03	4.10E+02	2.40E-03	1.06	0.96
	Y-91m	3.45E-02	5.78E-01	2.37E-14	3.15E+02	3.17E-03	NA	NA	NA	NA
34	Te-129m/Te-129	NA	NA	NA	4.55E+01	2.20E-02	NA	NA	NA	NA
	Te-129m	3.36E+01	1.00E+00	1.56E-15	2.07E+01	4.82E-02	2.00E+01	5.10E-02	1.04	0.95
	Te-129	4.83E-02	6.50E-01	2.86E-15	3.80E+01	2.63E-02	3.10E+01	3.20E-02	1.23	0.82
35	[b]Te-131m/Te-131	NA	NA	NA	9.28E+02	1.08E-03	NA	NA	NA	NA

Table 2-2. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for External Exposure Due to Submersion in Contaminated Air (Assume 1 Hour Exposure Period) (continued)

					2009 (ICRP 60+) Values		**1992 Values (Table 5.3)**		**DCF Comparisons**	
No.	**Radionuclide**	**[a]Half-Life (d)**	**[a]Branch Fraction**	**[a]$DC_{Submersion, E}$ ($Sv \cdot m^3$ per $(s \cdot Bq)$)**	**$DCP_{Submersion, E}$ ($rem \cdot cm^3$ per $h \cdot \mu Ci$)**	**$DRL_{Submersion, E}$ ($\mu Ci \cdot h$ per cm^3)**	**$DCF_{Submersion, E}$ ($rem \cdot cm^3$ per $h \cdot \mu Ci$)**	**$DRL_{Submersion, E}$ ($\mu Ci \cdot h$ per cm^3)**	**$DCP_{Submersion, E}$ / by 1992 DCF_{Inh}**	**$DRL_{Submersion, E}$ / by 1992 DCF_{Inh}**
	[b]Te-131m	1.25E+00	1.00E+00	6.55E-14	8.71E+02	1.15E-03	8.50E+02	1.20E-03	1.02	0.96
	Te-131	1.74E-02	2.22E-01	1.92E-14	2.55E+02	3.92E-03	NA	NA	NA	NA
36	Te-132/I-132	NA	NA	NA	1.52E+03	6.58E-04	NA	NA	NA	NA
	Te-132	3.26E+00	1.00E+00	9.32E-15	1.24E+02	8.07E-03	1.20E+02	8.00E-03	1.03	1.01
	I-132	9.58E-02	1.00E+00	1.05E-13	1.40E+03	7.16E-04	1.40E+03	7.40E-04	1.00	0.97
37	Tm-170	1.29E+02	-	3.67E-16	4.88E+00	2.05E-01	2.70E+00	3.80E-01	1.81	0.54
38	Xe-133	5.24E+00	-	1.33E-15	1.77E+01	5.65E-02	2.00E+01	5.00E-02	0.88	1.13
39	Xe-135	3.79E-01	-	1.10E-14	1.46E+02	6.84E-03	1.40E+02	7.00E-03	1.05	0.98
40	Xe-138	9.84E-03	-	5.48E-14	7.29E+02	1.37E-03	7.10E+02	1.40E-03	1.03	0.98
41	Y-91	5.85E+01	-	6.22E-16	8.27E+00	1.21E-01	2.10E+00	4.70E-01	3.94	0.26
42	Yb-169	3.20E+01	-	1.13E-14	1.50E+02	6.65E-03	1.60E+02	6.10E-03	0.94	1.09

[a]Values from Turbo FRMAC 2.0, RFC 2 (DCFPAK, K. Eckerman)
[b]Te-131m values in this table are subject to change pending further development of new parent-daughter rules.

2.2.1 Dose Conversion Parameter Calculation for Table 2-2

The DCP for the effective dose received from external exposure while submersed in the passing plume is calculated as shown below. It is assumed that the receptor is submersed in the passing plume for 1 hour.

It should be noted that it is assumed that short-lived daughter radionuclides are in secular equilibrium with the parent radionuclide throughout the exposure period and the external dose from any daughter radionuclides is added to parent's dose to derive the total $DCP_{Submersion,\ E}$.

$$DCP_{Submersion,E,i} = \sum_{i}^{P+D} \left(DC_{Submersion,E,i} * CF \right)$$

$$\frac{rem \cdot cm^3}{h \cdot \mu Ci} = \frac{Sv \cdot m3}{s.\ Bq} * \frac{rem \cdot cm^3 / h \cdot Ci}{Sv \cdot m^3 / s \cdot Bq}$$

Where:

$\sum_{i}^{P+D} =$ represents the summation of values from the parent radionuclide (P) and all short-lived daughter radionuclides (D);

$DCP_{Submersion,\ E,\ i} =$ Dose Conversion Parameter, value for the effective dose rate per unit activity from external exposure (i.e., 1 h external exposure from submersion in the plume) to radionuclide *i* and any short-lived daughter radionuclide(s) in the plume, rem·cm^3 / h·µCi;

$DC_{Submersion,E,\ i} =$ Dose Coefficient, value for the effective dose from external exposure to radionuclide *i* from submersion in contaminated plume, Sv/s per Bq/m^3, (values from ICRP 60+ dosimetry models, DCFPAK 2006); and

CF = unit conversion factor, 1.33E+16 rem·cm^3/h·µCi per Sv·m^3/s·Bq.

$$\frac{1.33E16 \dfrac{rem / cm^3}{h / \mu\ Ci}}{\dfrac{Sv / m^3}{s / Bq}} = \frac{Sv / m^3}{s / Bq} * \frac{100\ rem}{Sv} * \frac{Bq}{dps} * \frac{3.7E4 dps}{\mu\ Ci} * \frac{3.6E3 s}{hr} * \frac{(100 cm)^3}{m^3}$$

2.2.2 Derived Response Level Calculation for Table 2-2

The DRL for external exposure for 1 hour while submersed in the passing plume is calculated using the following equation:

$$DRL_{Submersion,E,i} = \sum_{i}^{P+D} \left(\frac{PAG}{DCP_{Submersion,E,i}} \right) \qquad \frac{\mu Ci \cdot h}{cm^3} = \frac{1 rem}{rem \cdot cm^3 / h \cdot \mu Ci}$$

Where:

$\sum_{i}^{P+D} =$ represents the summation of values from the parent radionuclide (P) and any short-lived daughter radionuclide(s) (D);

$DRL_{Submersion,E,i}$ = Derived Response Level, value for the effective dose from external exposure (i.e., 1 h external exposure from submersion in the plume) to radionuclide *i* and any short-lived daughter radionuclide(s), $\mu Ci \cdot h/cm^3$;

PAG = EPA's Protective Action Guide, 1 rem for effective dose or 5 rem organ dose; and

$DCP_{Submersion,E,i}$ = Dose Conversion Parameter, value for the effective dose rate per unit activity from external exposure (i.e., 1 h external exposure from submersion in the plume) to radionuclide *i* and any short-lived daughter radionuclide(s) in the plume, $rem \cdot cm^3 / h \cdot \mu Ci$.

2.3 Inhalation from the Plume

Table 2-3 provides DCPs and DRLs for CED due to inhalation of an airborne plume of radioactive particulate materials. Sections 2.3.1 and 2.3.2 provide methodology for calculating these DCPs and DRLs. It is assumed that the radionuclides are in the chemical and physical form that yields the highest dose, and that the particle size is 1 micrometer (μm) mean aerodynamic diameter (Activity Median Aerodynamic Diameter (AMAD)). For other chemical and physical forms of practical interest, the doses may differ, but in general only by a small factor. If the chemical and/or physical form (i.e., solubility class or particle size) is known or can be predicted, the DCPs for inhalation should be adjusted as appropriate.

The dose factors used to develop the DCPs in Table 2-3 of this Manual are ICRP 60+ values provided in DCFPAK 2006. The breathing rates used to develop the DCPs in Table 2-3 of this Manual are ICRP 66 values (ICRP 1994). Although the DCPs for some radionuclides would be slightly higher for children, the protection in the PAGs and procedures for their application provide an adequate margin for safety. The advantage of using a single source of current data for the development of DCPs for these and any other relevant radionuclides is also a consideration in the selection of this database for use in emergency response applications.

The units given in Table 2.1 of EPA 1988 are converted to the units in Table 2-3 of this Manual, using a breathing rate 9.2E+5 $cm^3 \times h^{-1}$, by the factor:

$$Sv \times Bq^{-1} \times 4.4E + 12 = rem\ per\ \mu Ci \times cm^{-3} \times h$$

The DRLs are simply the reciprocal of the DCP.

2.3.1 Dose Conversion Parameter Calculation for Table 2-3

The effective DCP for inhalation is calculated as shown below. It is assumed that the receptor is exposed to the passing plume for 1 hour.

$$DCP_{Inh,E,i} = \sum_{i}^{P+D} \left(BR * DCF_{Inh,E,i} * CF \right)$$

$$\frac{rem \cdot cm^3}{h \cdot \mu Ci} = \frac{cm^3}{h} * \frac{Sv}{Bq} * \frac{rem \cdot Bq}{Sv \cdot \mu Ci}$$

Where:

$\sum_{i}^{P+D} =$ represents the summation of values from the parent radionuclide (P) and all short-lived daughter radionuclides (D);

$DCP_{Inhalation,E,i}$ = Dose Conversion Parameter, value for the committed effective dose (CED) rate per unit activity from exposure (i.e., 1 h plume inhalation) to radionuclide *i* and any short-lived daughter radionuclide(s), rem·cm^3 / h·µCi;

BR = breathing rate, 9.20E+05 cm^3/h, activity-weighted, average-hourly breathing rate for an adult (from ICRP 66, Table B.16.B (ICRP 1994));

$DCF_{Inh,E,i}$ = inhalation Dose Conversion Factor, value for the committed effective dose from the inhalation of radionuclide *i* (most restrictive lung clearance class) (values from ICRP 60+ dosimetry models, DCFPAK 2006), Sv/Bq; and

CF = unit conversion factor, value to convert Sv/Bq to rem/µCi, 3.70E+06 rem/µCi per Bq/Sv.

$$\frac{3.7E6\,rem / \mu Ci}{Sv / Bq} = \frac{Sv}{Bq} * \frac{10^2\ rem}{Sv} * \frac{Bq}{dps} * \frac{3.7E4\,dps}{Bq}$$

2.3.2 Derived Response Level Calculation for Table 2-3 for Inhalation

The DRL for 1 hour of inhalation in the passing plume is calculated using the following equation:

$$DRL_{Inhalation,E,i} = \sum_{i}^{P+D} \left(\frac{PAG}{DCP_{Inhalation,E,i}} \right), \qquad \frac{\mu Ci \cdot h}{cm^3} = \frac{1\,rem}{rem \cdot cm^3 / h \cdot \mu Ci}$$

Where:

$\sum_{i}^{P+D}$ = represents the summation of values from the parent radionuclide (P) and any short-lived daughter radionuclide(s) (D);

$DRL_{Inhalation,E,\ i}$ = the Derived Response Level, value based on the committed effective dose for exposure (i.e., 1 h plume inhalation) to radionuclide *i* and any short-lived daughter radionuclide(s) in the plume, µCi·h/cm^3;

PAG = EPA's PAG, 1 rem for effective dose; and

$DCP_{Inhalation,E,i}$ = the Dose Conversion Parameter, value for the committed effective dose rate per unit activity from exposure (i.e., 1 h plume inhalation) to radionuclide *i* and any short-lived daughter radionuclide(s), rem·cm^3 / h·µCi.

Table 2-3. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for Inhalation (Assume 1 Hour Exposure Period), based on 1 rem Committed Effective Dose (CED)

						2009 (ICRP 60+) Values		1992 Values (Table 5.4)			DCP Comparisons	
No.	**Radionuclide**	**[a]Half-Life (d)**	[a]Branch Fraction	[a]DCF_{Inh} (Sv/Bq)	[a]ICRP 66 Inhalation Class	$DCP_{Inh, E}$ (rem·cm^3 per h·µCi)	$DRL_{Inh, E}$ (µCi·h per cm^3)	$DCF_{Inh, E}$ (rem·cm^3 per h·µCi)	$DRL_{Inh, E}$ (µCi·h per cm^3)	Lung Clearance Class	$DCP_{Inh, E}$ / by 1992 $DCF_{Inh, E}$	$DRL_{Inh, E}$ / by 1992 $DRL_{Inh, E}$
1	Am-241	1.58E+05	-	9.64E-05	F	3.28E+08	3.05E-09	5.30E+08	1.90E-09	W	0.62	1.60
2	Ba-140/La-140	NA	NA	NA	NA	2.38E+04	4.21E-05	NA	NA	NA	NA	NA
	Ba-140	1.27E+01	1.00E+00	5.84E-09	S	1.99E+04	5.03E-05	4.50E+03	2.20E-04	D	4.42	0.23
	La-140	1.68E+00	1.00E+00	1.14E-09	S	3.88E+03	2.58E-04	5.80E+03	1.70E-04	W	0.67	1.52
3	Ce144/Pr144/Pr144m	NA	NA	NA	NA	1.79E+05	5.57E-06	4.50E+05	2.20E-06	Y	0.40	2.53
	Ce-144	2.84E+02	1.00E+00	5.27E-08	S	1.79E+05	5.57E-06	4.50E+05	2.20E-06	Y	0.40	2.53
	Pr-144	1.20E-02	9.82E-01	1.83E-11	S	6.23E+01	1.61E-02	NA	NA	NA	NA	NA
	Pr-144m	5.00E-03	1.78E-02	0.00E+00	NA	0.00E+00	0.00E+00	NA	NA	NA	NA	NA
	Pr-144	1.20E-02	9.99E-01	1.83E-11	S	6.23E+01	1.61E-02	NA	NA	NA	NA	NA
4	Cf-252	9.64E+02	-	3.71E-05	F	1.26E+08	7.92E-09	1.90E+08	5.30E-09	Y	0.66	1.49
5	Cm-244	6.61E+03	-	5.70E-05	F	1.94E+08	5.15E-09	3.00E+08	3.40E-09	W	0.65	1.52
6	Co-60	1.93E+03	-	3.07E-08	S	1.05E+05	9.57E-06	2.60E+05	3.80E-06	Y	0.40	2.52
7	Cs-134	7.53E+02	-	2.04E-08	S	6.94E+04	1.44E-05	5.60E+04	1.80E-05	D	1.24	0.80
8	Cs-136	1.31E+01	-	2.78E-09	S	9.46E+03	1.06E-04	8.80E+03	1.10E-04	D	1.08	0.96
9	Cs-137/Ba-137m	NA	NA	NA	NA	1.33E+05	7.49E-06	3.80E+04	2.60E-05	D	3.51	0.29
	Cs-137	1.10E+04	1.00E+00	3.92E-08	S	1.33E+05	7.49E-06	NA	NA	NA	NA	NA
	Ba-137m	1.77E-03	9.46E-01	0.00E+00	NA	0.00E+00	0.00E+00	NA	NA	NA	NA	NA
10	Gd-153	2.42E+02	-	2.40E-09	S	8.17E+03	1.22E-04	2.90E+04	3.50E-05	D	0.28	3.50
11	I-131	8.04E+00	-	7.39E-09	F	2.52E+04	3.98E-05	3.90E+04	2.50E-05	D	0.65	1.59
12	I-132	9.58E-02	-	1.14E-10	M	3.88E+02	2.58E-03	4.60E+02	2.20E-03	D	0.84	1.17
13	I-133	8.67E-01	-	1.47E-09	F	5.00E+03	2.00E-04	7.00E+03	1.40E-04	D	0.71	1.43
14	I-134	3.65E-02	-	5.59E-11	S	1.90E+02	5.26E-03	1.60E+02	6.30E-03	D	1.19	0.83
15	I-135/Xe135m	NA	NA	NA	NA	1.10E+03	9.10E-04	NA	NA	NA	NA	NA
	I-135	2.75E-01	1.00E+00	3.23E-10	F	1.10E+03	9.10E-04	1.50E+03	6.80E-04	D	0.73	1.34

Table 2-3. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for Inhalation (Assume 1 Hour Exposure Period), based on 1 rem Committed Effective Dose (CED) (continued)

No.	Radionuclide	aHalf-Life (d)	aBranch Fraction	aDCF$_{Inh}$ (Sv/Bq)	aICRP 66 Inhalation Class	2009 (ICRP 60+) Values: DCP$_{Inh, E}$ (rem·cm^3 per h·µCi)	2009 (ICRP 60+) Values: DRL$_{Inh, E}$ (µCi·h per cm^3)	1992 Values (Table 5.4): DCF$_{Inh, E}$ (rem·cm^3 per h·µCi)	1992 Values (Table 5.4): DRL$_{Inh, E}$ (µCi·h per cm^3)	1992 Values (Table 5.4): Lung Clearance Class	DCF Comparisons: DCP$_{Inh, E}$ / by 1992 DCF$_{Inh, E}$	DCF Comparisons: DRL$_{Inh, E}$ / by 1992 DRL$_{Inh, E}$
	Xe-135m	1.06E-02	1.54E-01	0.00E+00	NA	0.00E+00	0.00E+00	NA	NA	NA	NA	NA
16	Ir-192	7.40E+01	-	6.62E-09	S	2.25E+04	4.44E-05	3.40E+04	3.00E-05	Y	0.66	1.48
17	Kr-87	5.30E-02	-	0.00E+00	NA	NA	NA	NA	NA	NA	NA	NA
18	Kr-88/Rb-88	NA	NA	NA	NA	3.97E+03	2.52E-04	NA	NA	NA	NA	NA
	Kr-88	1.18E-01	1.00E+00	0.00E+00	NA	3.88E+03	2.58E-04	NA	NA	NA	NA	NA
	Rb-88	1.24E-02	1.00E+00	2.76E-11	S	9.40E+01	1.06E-02	1.00E+02	1.00E-02	D	0.94	1.06
19	La-140	1.68E+00	-	1.14E-09	S	3.88E+03	2.58E-04	5.80E+03	1.70E-04	W	0.67	1.52
20	Mo-99/Tc-99m	NA	NA	NA	NA	3.44E+03	2.91E-04	NA	NA	NA	NA	NA
	Mo-99	2.75E+00	1.00E+00	9.92E-10	S	3.38E+03	2.96E-04	4.80E+03	2.10E-04	Y	0.70	1.41
	Tc-99m	2.51E-01	8.76E-01	2.01E-11	S	6.84E+01	1.46E-02	3.90E+01	2.60E-02	D	1.75	0.56
21	Np-239	2.36E+00	-	1.03E-09	S	3.51E+03	2.85E-04	3.00E+03	3.30E-04	W	1.17	0.86
22	Pm-147	9.58E+02	-	6.98E-09	F	2.38E+04	4.21E-05	4.70E+04	2.10E-05	Y	0.51	2.00
23	Pu-238	3.20E+04	-	1.08E-04	F	3.68E+08	2.72E-09	4.70E+08	2.10E-09	W	0.78	1.30
24	Pu-239	8.79E+06	-	1.19E-04	F	4.05E+08	2.47E-09	5.20E+08	1.90E-09	W	0.78	1.30
25	Ra-226/Rn-222…	NA	NA	NA	NA	3.25E+07	3.08E-08	NA	NA	NA	NA	NA
	Ra-226	5.84E+05	1.00E+00	9.51E-06	S	3.24E+07	3.09E-08	1.00E+07	9.70E-08	W	3.24	0.32
	Rn-222	3.82E+00	1.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	NA	NA	NA	NA	NA
	Po-218	2.12E-03	1.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	NA	NA	NA	NA	NA
	Pb-214	1.86E-02	1.00E+00	1.47E-08	S	5.00E+04	2.00E-05	NA	NA	NA	NA	NA
	Bi-214	1.38E-02	1.00E+00	1.54E-08	S	5.24E+04	1.91E-05	NA	NA	NA	NA	NA
	Po-214	1.90E-09	1.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	NA	NA	NA	NA	NA
	At-218	2.31E-05	2.00E-04	0.00E+00	NA	0.00E+00	0.00E+00	NA	NA	NA	NA	NA
	Bi-214	1.38E-02	1.00E+00	1.54E-08	S	5.24E+04	1.91E-05	NA	NA	NA	NA	NA
	Po-214	1.90E-09	1.00E+00	0.00E+00	NA	0.00E+00	0.00E+00	NA	NA	NA	NA	NA

Table 2-3. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for Inhalation (Assume 1 Hour Exposure Period), based on 1 rem Committed Effective Dose (CED) (continued)

						2009 (ICRP 60+) Values		**1992 Values (Table 5.4)**			**DCF Comparisons**	
No.	**Radionuclide**	**[a]Half-Life (d)**	**[a]Branch Fraction**	**[a]DCF_{Inh} (Sv/Bq)**	**[1]ICRP 66 Inhalation Class**	**$DCP_{Inh, E}$ (rem·cm^3 per h·µCi)**	**$DRL_{Inh, E}$ (µCi·h per cm^3)**	**$DCF_{Inh, E}$ (rem·cm^3 per h·µCi)**	**$DRL_{Inh, E}$ (µCi·h per cm^3)**	**Lung Clearance Class**	**$DCP_{Inh, E}$ / by 1992 $DCF_{Inh, E}$**	**$DRL_{Inh, E}$ / by 1992 $DRL_{Inh, E}$**
26	Ru-103/Rh-103m	NA	NA	NA	NA	1.01E+04	9.95E-05	NA	NA	NA	NA	NA
	Ru-103	3.93E+01	1.00E+00	2.95E-09	S	1.00E+04	9.96E-05	1.10E+04	9.30E-05	Y	0.91	1.07
	Rh-103m	3.90E-02	9.97E-01	2.73E-12	S	9.29E+00	1.08E-01	NA	NA	NA	NA	NA
27	Ru-106/Rh-106	NA	NA	NA	NA	2.25E+05	4.45E-06	5.70E+05	1.70E-06	Y	0.39	2.62
	Ru-106	3.68E+02	1.00E+00	6.60E-08	S	2.25E+05	4.45E-06	NA	NA	NA	NA	NA
	Rh-106	3.46E-04	1.00E+00	0.00E+00	NA	0.00E+00	NA	NA	NA	NA	NA	NA
28	Sb-127/Te-127	NA	NA	NA	NA	6.79E+03	1.47E-04	NA	NA	NA	NA	NA
	Sb-127	3.85E+00	1.00E+00	1.88E-09	S	6.40E+03	1.56E-04	7.20E+03	1.40E-04	W	0.89	1.12
	Te-127	3.90E-01	8.24E-01	1.40E-10	S	4.77E+02	2.10E-03	NA	NA	NA	NA	NA
29	Sb-129/Te-129	NA	NA	NA	NA	9.55E+02	1.05E-03	NA	NA	NA	NA	NA
	Sb-129	1.80E-01	1.00E+00	2.50E-10	S	8.51E+02	1.18E-03	7.70E+02	1.30E-03	W	1.11	0.90
	Te-129	4.83E-02	7.75E-01	3.93E-11	S	1.34E+02	7.48E-03	1.10E+02	9.30E-03	D	1.22	0.80
30	Se-75	1.20E+02	-	1.34E-09	S	4.56E+03	2.19E-04	1.00E+04	9.80E-05	W	0.46	2.24
31	Sr-89	5.05E+01	-	7.94E-09	S	2.70E+04	3.70E-05	5.00E+04	2.00E-05	Y	0.54	1.85
32	Sr-90/Y-90	NA	NA	NA	NA	5.40E+05	1.85E-06	NA	NA	NA	NA	NA
	Sr-90	1.06E+04	1.00E+00	1.57E-07	S	5.34E+05	1.87E-06	1.60E+06	6.40E-07	Y	0.33	2.92
	Y-90	2.67E+00	1.00E+00	1.50E-09	S	5.11E+03	1.96E-04	1.00E+04	9.90E-05	Y	0.51	1.98
33	Sr-91/Y-91m	NA	NA	NA	NA	1.41E+03	7.09E-04	NA	NA	NA	NA	NA
	Sr-91	3.96E-01	1.00E+00	4.08E-10	S	1.39E+03	7.20E-04	2.00E+03	5.00E-04	Y	0.69	1.44
	Y-91m	3.45E-02	5.78E-01	1.14E-11	S	3.88E+01	2.58E-02	NA	NA	NA	NA	NA
34	Te-129m/Te-129	NA	NA	NA	NA	2.70E+04	3.70E-05	NA	NA	NA	NA	NA
	Te-129m	3.36E+01	1.00E+00	7.92E-09	S	2.70E+04	3.71E-05	2.90E+04	3.50E-05	W	0.93	1.06
	Te-129	4.83E-02	6.50E-01	3.93E-11	S	1.34E+02	7.48E-03	1.10E+02	9.30E-03	D	1.22	0.80
35	[b]Te-131m/Te-131	NA	NA	NA	NA	3.66E+03	2.73E-04	NA	NA	NA	NA	NA
	[b]Te-131m	1.25E+00	1.00E+00	1.07E-09	M	3.64E+03	2.75E-04	7.70E+03	1.30E-04	W	0.47	2.11
	Te-131	1.74E-02	2.22E-01	2.85E-11	M	9.70E+01	1.03E-02	NA	NA	NA	NA	NA
36	Te-132/I-132	NA	NA	NA	NA	7.37E+03	1.36E-04	1.20E+04	8.50E-05	W	0.61	1.60

Table 2-3. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for Inhalation (Assume 1 Hour Exposure Period), based on 1 rem Committed Effective Dose (CED) (continued)

						2009 (ICRP 60+) Values		1992 Values (Table 5.4)			DCF Comparisons	
No.	Radionuclide	[a]Half-Life (d)	[a]Branch Fraction	[a]DCF_{Inh} (Sv/Bq)	[a]ICRP 66 Inhalation Class	$DCP_{Inh, E}$ (rem·cm^3 per h·µCi)	$DRL_{Inh, E}$ (µCi·h per cm^3)	$DCF_{Inh, E}$ (rem·cm^3 per h·µCi)	$DRL_{Inh, E}$ (µCi·h per cm^3)	Lung Clearance Class	$DCP_{Inh, E}$ / by 1992 $DCF_{Inh, E}$	$DRL_{Inh, E}$ / by 1992 $DRL_{Inh, E}$
	Te-132	3.26E+00	1.00E+00	2.05E-09	M	6.98E+03	1.43E-04	1.10E+04	8.80E-05	W	0.63	1.63
	I-132	9.58E-02	1.00E+00	1.14E-10	M	3.88E+02	2.58E-03	4.60E+02	2.20E-03	D	0.84	1.17
37	Tm-170	1.29E+02	-	9.29E-09	S	3.16E+04	3.16E-05	3.20E+04	3.20E-05	W	0.99	0.99
38	Xe-133	5.24E+00	-	0.00E+00	NA	NA	NA	NA	NA	NA	NA	NA
39	Xe-135	3.79E-01	-	0.00E+00	NA	NA	NA	NA	NA	NA	NA	NA
40	Xe-138	9.84E-03	-	0.00E+00	NA	0.00E+00	NA	NA	NA	NA	NA	NA
41	Y-91	5.85E+01	-	8.93E-09	S	3.04E+04	3.29E-05	5.90E+04	1.70E-05	Y	0.52	1.94
42	Yb-169	3.20E+01	-	2.98E-09	S	1.01E+04	9.86E-05	9.70E+03	1.00E-04	Y	1.05	0.99

[a]Values from Turbo FRMAC 2.0, RFC 2 (DCFPAK, K. Eckerman)
[b]Te-131m values in this table are subject to change pending further development of new parent-daughter rules.

2.4 Dose from Deposited Materials

Table 2-4 provides DCFs and DRLs for four-day exposure to gamma radiation from selected radionuclides following deposition of particulate materials on the ground from a plume. It includes the dose from external exposure to groundshine and the inhalation of resuspended material over the Early Phase (i.e., 0 to 96 hours following release). The deposition velocity for all radionuclides (assumed to be 0.1 cm/s) could vary widely depending on the physical and chemical characteristics of the deposited material and the surface and meteorological conditions. In the case of precipitation, the amount of deposition (and thus the DCFs for this exposure pathway) will be much higher. To account for the in-growth of short-lived daughters in deposited materials after measurements are made, the tabulated values include their contribution to dose over the assumed four-day period of exposure. Because the deposition velocity can be much lower or higher than assumed in developing the DCFs for deposited materials, decision makers are cautioned to pay particular attention to actual measurements of gamma exposure from deposited materials for evacuation decisions after plume passage.

The objective is to calculate DCFs for single radionuclides in terms of effective dose from four days of exposure to gamma radiation from deposited radioactive materials. In order to be able to sum the DCFs with those for other exposure pathways, the DCF is expressed in terms of dose per unit time-integrated air concentration where the deposition from the plume is assumed to occur at approximately the beginning of the incident.

The following section 2.4.1 and its subsections provide calculations for DCP and section 2.4.2 gives details of DRL calculations.

Table 2-4. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for Four-Day Exposure to Gamma Radiation from Selected Radionuclides Following Deposition of Particulate Materials on the Ground from a Plume

											2009 (ICRP 60+) Values		**1992 Values (Table 5.5)**		**DCF Comparisons**	
No.	**Radionuclide**	**[a]Half-Life (d)**	**[a]Branch Fraction**	**[a]$ExDC_{ground}$ ($Sv \cdot m^2$ per $s \cdot Bq$)**	**[a]CRP (h)**	**[a]KP (h/cm)**	**[a]DCF_{Inh} (Sv/Bq)**	**[a]ICRP 66 Inhalation Class**	**$DCP_{groundshine}$ ($rem \cdot cm^3$ per $h \cdot \mu Ci$)**	**DCP_{nh} ($rem \cdot cm^3$ per $h \cdot \mu Ci$)**	**$DCP_{groundshine+Inh}$ ($rem \cdot cm^3$ per $h \cdot \mu Ci$)**	**$DRL_{groundshine+Inh}$ ($\mu Ci \cdot h$ per cm^3)**	**$DCF_{groundshine}$ ($rem \cdot cm^3$ per $h \cdot \mu Ci$)**	**$DRL_{groundshine}$ ($\mu Ci \cdot h$ per cm^3)**	**$DCP_{groundshine+Inh}$ / by 1992 $DCF_{groundshine}$**	**[b]$DRL_{groundshine}$ / by 1992 $DRL_{groundshine}$**
1	Am-241	1.58E+05	-	2.33E-17	95.9	5.73E-07	9.64E-05	F	8.77E+01	6.77E+04	6.78E+04	1.48E-05	1.20E+02	8.50E-03	564.81	0.73
2	Ba-140/La-140	NA	NA						7.95E+03	4.53E+00	7.96E+03	1.26E-04	NA	NA	NA	NA
	Ba-140	1.27E+01	1.00E+00	1.90E-16	86.2	5.30E-07	5.84E-09	S	6.43E+02	3.79E+00	6.47E+02	1.55E-03	7.00E+02	1.40E-03	0.92	0.92
	La-140	1.68E+00	1.00E+00	2.16E-15	86.2	5.30E-07	1.14E-09	S	7.31E+03	7.40E-01	7.31E+03	1.37E-04	4.10E+03	2.40E-04	1.78	1.78
3	Ce144/Pr144/Pr144m	NA	NA						6.80E+02	3.69E+01	7.17E+02	1.39E-03	2.00E+02	5.00E-03	3.58	3.40
	Ce-144	2.84E+02	1.00E+00	1.84E-17	95.4	5.71E-07	5.27E-08	S	6.89E+01	3.69E+01	1.06E+02	9.45E-03	8.50E+01	1.20E-02	1.24	0.81
	Pr-144	1.20E-02	9.82E-01	1.63E-16	95.4	5.71E-07	1.83E-11	S	6.11E+02	1.28E-02	6.11E+02	1.64E-03	NA	NA	NA	NA
	Pr-144m	5.00E-03	1.78E-02	1.05E-17	95.4	5.71E-07	0.00E+00	NA	3.93E+01	0.00E+00	3.93E+01	2.54E-02	NA	NA	NA	NA
	Pr-144	1.20E-02	9.99E-01	1.63E-16	95.4	5.71E-07	1.83E-11	S	6.11E+02	1.28E-02	6.11E+02	1.64E-03	NA	NA	NA	NA
4	Cf-252	9.64E+02	-	5.24E-19	95.8	5.72E-07	3.71E-05	F	1.97E+00	2.60E+04	2.60E+04	3.85E-05	2.50E+00	0.4	10402.91	0.79
5	Cm-244	6.61E+03	-	6.44E-19	95.9	5.73E-07	5.70E-05	F	2.42E+00	4.00E+04	4.00E+04	2.50E-05	3.30E+00	0.31	12129.25	0.73
6	Co-60	1.93E+03	-	2.30E-15	95.8	5.72E-07	3.07E-08	S	8.65E+03	2.15E+01	8.67E+03	1.15E-04	8.90E+03	1.10E-04	0.97	0.97
7	Cs-134	7.53E+02	-	1.48E-15	95.7	5.72E-07	2.04E-08	S	5.56E+03	1.43E+01	5.58E+03	1.79E-04	6.20E+03	1.60E-04	0.90	0.90
8	Cs-136	1.31E+01	-	2.03E-15	86.4	5.31E-07	2.78E-09	S	6.89E+03	1.81E+00	6.89E+03	1.45E-04	7.60E+03	1.30E-04	0.91	0.91
9	Cs-137/Ba-137m	NA	NA						2.07E+03	2.75E+01	2.10E+03	4.76E-04	2.40E+03	4.10E-04	0.88	0.86
	Cs-137	1.10E+04	1.00E+00	2.99E-18	95.9	5.73E-07	3.92E-08	S	1.13E+01	2.75E+01	3.88E+01	2.58E-02	NA	NA	NA	NA
	Ba-137m	1.77E-03	9.46E-01	5.79E-16	95.9	5.73E-07	0.00E+00	NA	2.18E+03	0.00E+00	2.18E+03	4.59E-04	NA	NA	NA	NA
10	Gd-153	2.42E+02	-	9.22E-17	95.4	5.70E-07	2.40E-09	S	3.45E+02	1.68E+00	3.47E+02	2.88E-03	5.00E+02	2.00E-03	0.69	0.69
11	[3]I-131	8.04E+00	-	3.64E-16	81.1	5.07E-07	7.39E-09	F	1.16E+03	4.59E+00	1.16E+03	8.59E-04	1.30E+04	7.40E-05	0.09	0.09
12	I-132	9.58E-02	-	2.20E-15	3.32	3.32E-08	1.14E-10	M	2.87E+02	4.64E-03	2.87E+02	3.49E-03	3.10E+03	3.23E-04	0.09	0.09
13	I-133	8.67E-01	-	6.17E-16	28.8	2.37E-07	1.47E-09	F	6.98E+02	4.27E-01	6.98E+02	1.43E-03	7.30E+03	1.4E-04	0.10	0.10
14	[3]I-134	3.65E-02	-	2.53E-15	1.26	1.26E-08	5.59E-11	S	1.25E+02	8.63E-04	1.25E+02	7.99E-03	1.30E+03	7.50E-04	0.10	0.10
15	I-135/Xe135m	NA	NA						5.74E+02	3.70E-02	5.74E+02	1.74E-03	NA	NA	NA	NA
	I-135	2.75E-01	1.00E+00	1.47E-15	9.53	9.35E-08	3.23E-10	F	5.50E+02	3.70E-02	5.50E+02	1.82E-03	5.70E+03	1.8E-04	NA	NA
	Xe-135m	1.06E-02	1.54E-01	4.19E-16	9.53	9.35E-08	0.00E+00	NA	1.57E+02	0.00E+00	1.57E+02	6.38E-03	NA	NA	NA	NA
16	[3]Ir-192	7.40E+01	-	7.77E-16	94.1	5.65E-07	6.62E-09	S	2.87E+03	4.58E+00	2.88E+03	3.48E-04	3.40E+03	3.00E-04	0.85	0.84
17	Kr-87	5.30E-02	-	8.40E-16	1.83	1.83E-08	0.00E+00	NA	6.04E+01	0.00E+00	6.04E+01	1.66E-02	NA	NA	NA	NA
18	Kr-88/Rb-88	NA	NA						3.98E+02	1.39E-03	3.98E+02	2.51E-03	NA	NA	NA	NA
	Kr-88	1.18E-01	1.00E+00	1.73E-15	4.1	4.10E-08	0.00E+00	NA	2.78E+02	0.00E+00	2.78E+02	3.59E-03	NA	NA	NA	NA

Table 2-4. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for Four-Day Exposure to Gamma Radiation from Selected Radionuclides Following Deposition of Particulate Materials on the Ground from a Plume (continued)

											2009 (ICRP 60+) Values		**1992 Values (Table 5.5)**		**DCF Comparisons**	
No.	**Radionuclide**	**[a]Half-Life (d)**	**[a]Branch Fraction**	**[a]$ExDC_{ground}$ (Sv·m^2 per s·Bq)**	**[a]CRP (h)**	**[a]KP (h/cm)**	**[a]DCF_{Inh} (Sv/Bq)**	**[a]ICRP 66 Inhalation Class**	**$DCF_{groundshine}$ (rem·cm^3 per h·µCi)**	**DCF_{Inh} (rem·cm^3 per h·µCi)**	**$DCP_{groundshine+Inh}$ (rem·cm^3 per h·µCi)**	**$DRL_{groundshine+Inh}$ (µCi·h per cm^3)**	**$DCF_{groundshine}$ (rem·cm^3 per h·µCi)**	**$DRL_{groundshine}$ (µCi·h per cm^3)**	**$DCP_{groundshine+Inh}$ / by 1992 $DCF_{groundshine}$**	**[b]$DRL_{groundshine}$ / by 1992 $DRL_{groundshine}$**
	Rb-88	1.24E-02	1.00E+00	7.41E-16	4.1	4.10E-08	2.76E-11	S	1.19E+02	1.39E-03	1.19E+02	8.38E-03	1.00E+01	9.80E-02	11.93	11.93
19	La-140	1.68E+00	-	2.16E-15	46.9	3.41E-07	1.14E-09	S	3.98E+03	4.76E-01	3.98E+03	2.51E-04	4.10E+03	2.40E-04	0.97	0.97
20	Mo-99/Tc-99m	NA	NA						6.59E+02	5.06E-01	6.59E+02	1.52E-03	NA	NA	NA	NA
	Mo-99	2.75E+00	1.00E+00	1.78E-16	60.4	4.09E-07	9.92E-10	S	4.22E+02	4.97E-01	4.23E+02	2.37E-03	4.00E+02	2.50E-03	1.06	1.06
	Tc-99m	2.51E-01	8.76E-01	1.14E-16	60.4	4.09E-07	2.01E-11	S	2.70E+02	1.01E-02	2.70E+02	3.70E-03	5.30E+01	1.90E-02	5.10	5.10
21	Np-239	2.36E+00	-	1.54E-16	56.4	3.89E-07	1.03E-09	S	3.41E+02	4.91E-01	3.42E+02	2.93E-03	4.50E+02	2.20E-03	0.76	0.76
22	Pm-147	9.58E+02	-	2.80E-20	95.8	5.72E-07	6.98E-09	F	1.05E-01	4.89E+00	5.00E+00	2.00E-01	1.60E-02	6.20E+01	312.37	6.58
23	Pu-238	3.20E+04	-	6.26E-19	95.9	5.73E-07	1.08E-04	F	2.36E+00	7.58E+04	7.58E+04	1.32E-05	3.40E+00	3.00E-01	22305.14	0.69
24	Pu-239	8.79E+06	-	2.84E-19	95.9	5.73E-07	1.19E-04	F	1.07E+00	8.36E+04	8.36E+04	1.20E-05	1.50E+00	6.70E-01	55706.76	0.71
25	Ra-226/Rn-222…	NA	NA						6.35E+03	6.70E+03	1.31E+04	7.66E-05	NA	NA	NA	NA
	Ra-226	5.84E+05	1.00E+00	6.11E-18	95.9	5.73E-07	9.51E-06	S	2.30E+01	6.68E+03	6.70E+03	1.49E-04	3.00E+01	3.30E-02	223.36	0.77
	Rn-222	3.82E+00	1.00E+00	3.82E-19	95.9	5.73E-07	0.00E+00	NA	1.44E+00	0.00E+00	1.44E+00	6.95E-01	NA	NA	NA	NA
	Po-218	2.12E-03	1.00E+00	8.66E-21	95.9	5.73E-07	0.00E+00	NA	3.26E-02	0.00E+00	3.26E-02	3.07E+01	NA	NA	NA	NA
	Pb-214	1.86E-02	1.00E+00	2.40E-16	95.9	5.73E-07	1.47E-08	S	9.04E+02	1.03E+01	9.14E+02	1.09E-03	NA	NA	NA	NA
	Bi-214	1.38E-02	1.00E+00	1.44E-15	95.9	5.73E-07	1.54E-08	S	5.42E+03	1.08E+01	5.43E+03	1.84E-04	NA	NA	NA	NA
	Po-214	1.90E-09	1.00E+00	7.93E-20	95.9	5.73E-07	0.00E+00	NA	2.99E-01	0.00E+00	2.99E-01	3.35E+00	NA	NA	NA	NA
	At-218	2.31E-05	2.00E-04	3.64E-18	95.9	5.73E-07	0.00E+00	NA	1.37E+01	0.00E+00	1.37E+01	7.30E-02	NA	NA	NA	NA
	Bi-214	1.38E-02	1.00E+00	1.44E-15	95.9	5.73E-07	1.54E-08	S	5.42E+03	1.08E+01	5.43E+03	1.84E-04	NA	NA	NA	NA
	Po-214	1.90E-09	1.00E+00	7.93E-20	95.9	5.73E-07	0.00E+00	NA	2.99E-01	0.00E+00	2.99E-01	3.35E+00	NA	NA	NA	NA
26	Ru-103/Rh-103m	NA	NA						1.64E+03	2.02E+00	1.64E+03	6.11E-04	NA	NA	NA	NA
	Ru-103	3.93E+01	1.00E+00	4.49E-16	92.6	5.58E-07	2.95E-09	S	1.63E+03	2.02E+00	1.63E+03	6.12E-04	1.90E+03	5.20E-04	0.86	0.86
	Rh-103m	3.90E-02	9.97E-01	8.86E-19	92.6	5.58E-07	2.73E-12	S	3.22E+00	1.87E-03	3.22E+00	3.10E-01	NA	NA	NA	NA
27	Ru-106/Rh-106	NA	NA						1.29E+03	4.62E+01	1.34E+03	7.46E-04	8.30E+02	1.20E-03	1.61	1.56
	Ru-106	3.68E+02	1.00E+00	0.00E+00	95.5	5.71E-07	6.60E-08	S	0.00E+00	4.62E+01	4.62E+01	2.17E-02	NA	NA	NA	NA
	Rh-106	3.46E-04	1.00E+00	3.45E-16	95.5	5.71E-07	0.00E+00	NA	1.29E+03	0.00E+00	1.29E+03	7.73E-04	NA	NA	NA	NA
28	Sb-127/Te-127	NA	NA						1.84E+03	1.10E+00	1.84E+03	5.44E-04	NA	NA	NA	NA
	Sb-127	3.85E+00	1.00E+00	6.76E-16	68.4	4.48E-07	1.88E-09	S	1.82E+03	1.03E+00	1.82E+03	5.51E-04	1.90E+03	5.20E-04	0.96	0.96
	Te-127	3.90E-01	8.24E-01	1.03E-17	68.4	4.48E-07	1.40E-10	S	2.77E+01	7.69E-02	2.77E+01	3.61E-02	NA	NA	NA	NA
29	Sb-129/Te-129	NA	NA						3.57E+02	2.13E-02	3.57E+02	2.80E-03	NA	NA	NA	NA

Table 2-4. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for Four-Day Exposure to Gamma Radiation from Selected Radionuclides Following Deposition of Particulate Materials on the Ground from a Plume (continued)

											2009 (ICRP 60+) Values		1992 Values (Table 5.5)		DCF Comparisons	
No.	Radionuclide	[a]Half-Life (d)	[a]Branch Fraction	[a]$ExDC_{ground}$ (Sv·m² per s·Bq)	[a]CRP (h)	[a]KP (h/cm)	[a]DCF_{Inh} (Sv/Bq)	[a]ICRP 66 Inhalation Class	$DCF_{groundshine}$ (rem·cm³ per h·µCi)	DCF_{Inh} (rem·cm³ per h·µCi)	$DCP_{groundshine+Inh}$ (rem·cm³ per h·µCi)	$DRL_{groundshine+Inh}$ (µCi·h per cm³)	$DCF_{groundshine}$ (rem·cm³ per h·µCi)	$DRL_{groundshine}$ (µCi·h per cm³)	$DCP_{groundshine+Inh}$ / by 1992 $DCF_{groundshine}$	[b]$DRL_{groundshine}$ / by 1992 $DRL_{groundshine}$
	Sb-129	1.80E-01	1.00E+00	1.37E-15	6.23	6.21E-08	2.50E-10	S	3.35E+02	1.90E-02	3.35E+02	2.98E-03	3.70E+02	2.70E-03	0.91	0.91
	Te-129	4.83E-02	7.75E-01	1.14E-16	6.23	6.21E-08	3.93E-11	S	2.79E+01	2.99E-03	2.79E+01	3.59E-02	3.90E+00	0.26	7.15	7.15
30	Se-75	1.20E+02	-	3.61E-16	94.8	5.68E-07	1.34E-09	S	1.34E+03	9.33E-01	1.34E+03	7.44E-04	1.70E+03	5.90E-04	0.79	0.79
31	Sr-89	5.05E+01	-	6.86E-17	93.3	5.61E-07	7.94E-09	S	2.51E+02	5.46E+00	2.57E+02	3.89E-03	5.20E-01	1.9	493.75	483.25
32	Sr-90/Y-90	NA	NA						4.20E+02	1.11E+02	5.32E+02	1.88E-03	NA	NA	NA	NA
	Sr-90	1.06E+04	1.00E+00	1.64E-18	95.9	5.73E-07	1.57E-07	S	6.17E+00	1.10E+02	1.16E+02	8.59E-03	NA	NA	NA	NA
	Y-90	2.67E+00	1.00E+00	1.10E-16	95.9	5.73E-07	1.50E-09	S	4.14E+02	1.05E+00	4.15E+02	2.41E-03	NA	NA	NA	NA
33	Sr-91/Y-91m	NA	NA						5.50E+02	6.60E-02	5.50E+02	1.82E-03	NA	NA	NA	NA
	Sr-91	3.96E-01	1.00E+00	7.27E-16	13.7	1.30E-07	4.08E-10	S	3.91E+02	6.50E-02	3.91E+02	2.56E-03	3.80E+02	2.60E-03	1.03	1.03
	Y-91m	3.45E-02	5.78E-01	5.10E-16	13.7	1.30E-07	1.14E-11	S	2.74E+02	1.82E-03	2.74E+02	3.65E-03	NA	NA	NA	NA
34	Te-129m/Te-129	NA	NA						4.74E+02	5.41E+00	4.79E+02	2.09E-03	NA	NA	NA	NA
	Te-129m	3.36E+01	1.00E+00	5.70E-17	92.1	5.56E-07	7.92E-09	S	2.06E+02	5.40E+00	2.12E+02	4.73E-03	1.40E+02	7.20E-03	1.51	1.47
	Te-129	4.83E-02	6.50E-01	1.14E-16	92.1	5.56E-07	3.93E-11	S	4.12E+02	2.68E-02	4.12E+02	2.43E-03	3.90E+00	0.26	105.71	105.70
35	[d]Te-131m/Te-131	NA	NA						2.18E+03	3.89E-01	2.18E+03	4.58E-04	NA	NA	NA	NA
	[d]Te-131m	1.25E+00	1.00E+00	1.34E-15	38.5	2.95E-07	1.07E-09	M	2.03E+03	3.87E-01	2.03E+03	4.94E-04	3.50E+01	2.80E-02	57.88	57.87
	Te-131	1.74E-02	2.22E-01	4.74E-16	38.5	2.95E-07	2.85E-11	M	7.16E+02	1.03E-02	7.16E+02	1.40E-03	NA	NA	NA	NA
36	Te-132/I-132	NA	NA						6.12E+03	1.14E+00	6.12E+03	1.63E-04	6.70E+03	1.50E-04	0.91	0.91
	Te-132	3.26E+00	1.00E+00	2.12E-16	64.6	4.30E-07	2.05E-09	M	5.38E+02	1.08E+00	5.39E+02	1.86E-03	6.60E+02	1.50E-03	0.82	0.81
	I-132	9.58E-02	1.00E+00	2.20E-15	64.6	4.30E-07	1.14E-10	M	5.58E+03	6.01E-02	5.58E+03	1.79E-04	3.10E+03	3.20E-04	1.80	1.80
37	Tm-170	1.29E+02	-	2.64E-17	94.9	5.68E-07	9.29E-09	S	9.84E+01	6.47E+00	1.05E+02	9.54E-03	2.40E+01	4.10E-02	4.37	4.10
38	Xe-133	5.24E+00	-	3.95E-17	74.5	4.76E-07	0.00E+00	NA	1.16E+02	0.00E+00	1.16E+02	8.66E-03	NA	NA	NA	NA
39	Xe-135	3.79E-01	-	2.50E-16	13.1	1.25E-07	0.00E+00	NA	1.29E+02	0.00E+00	1.29E+02	7.78E-03	NA	NA	NA	NA
40	Xe-138	9.84E-03	-	1.07E-15	0.341	3.41E-09	0.00E+00	NA	1.43E+01	0.00E+00	1.43E+01	6.98E-02	NA	NA	NA	NA
41	Y-91	5.85E+01	-	7.46E-17	93.7	5.63E-07	8.93E-09	S	2.74E+02	6.16E+00	2.81E+02	3.56E-03	1.30E+01	7.80E-02	21.58	21.11
42	Yb-169	3.20E+01	-	2.78E-16	91.9	5.55E-07	2.98E-09	S	1.00E+03	2.03E+00	1.01E+03	9.95E-04	1.30E+03	7.40E-04	0.77	0.77

[a]Values from Turbo FRMAC 2.0, RFC 2 (DCFPAK, K. Eckerman), CRP and KP values only apply to the early phase (first 96 h)
[b]This column compares the ICRP 60 calculated DCF that includes the dose contribution from groundshine and inhalation of resuspended material to the 1992 EPA PAG Manual DCF (ICRP 30) that includes only the dose from only groundshine.
[c]Value listed as EPA's DRL value is not calculated by this spreadsheet, but is as listed in the 1992 EPA PAG Manual.
[d]Te-131m values in this table are subject to change pending further development of new parent-daughter rules.

2.4.1 Dose Conversion Parameter Calculation for Table 2-4

The Table 2-4 DCP ($DCP_{groundshine+inh,\ E}$) is calculated using the equation below. The DCP includes the dose from external exposure to groundshine and the inhalation of resuspended material over the early phase (i.e., 0-96 hours following release).

$$DCP_{groundshine+inh,E,i} = \sum_{i}^{P+D}\left[\left(V_g * ExDC_{ground,E,i} * CF_1 * GRF * CRP_i\right) + \left(V_g * KP_i * BR * DCF_{Inh,E,i} * CF_2\right)\right]$$

$$\frac{rem \cdot cm^3}{h \cdot \mu Ci} = \left(\frac{cm}{h} * \frac{Sv \cdot m^2}{s \cdot Bq} * \frac{rem \cdot cm2 / h \cdot \mu Ci}{Sv \cdot m^2 / s \cdot Bq} * unitless * \frac{e^{-hr/hr}}{1/h}\right) + \left(\frac{cm}{h} * \frac{h}{cm} * \frac{cm^3}{h} * \frac{Sv}{Bq} * \frac{rem / \mu Ci}{Sv / Bq}\right)$$

Where:

$\sum_{i}^{P+D} =$	Represents the summation of values from the parent radionuclide (p) and any short-lived daughter radionuclide(s) (D);
$DCP_{groundshine+inh,\ E,\ i}$ =	Dose Conversion Parameter, effective, value for the dose rate per unit activity from groundshine and the inhalation of resuspended material from radionuclide *i* and any short-lived daughter radionuclide(s) over the Early Phase time period and, rem·cm^3 / h·µCi;
V_g =	deposition velocity for all radionuclides, 360 cm/h (particulates are assumed), (based on Shemel 1980);
$ExDC_{ground,E,i}$ =	External Dose Coefficient, the effective dose rate from the external exposure to radionuclide *i* per unit activity deposited on the ground, Sv·m^2/s·Bq, (values from ICRP 60+ dosimetry models, DCFPAK 2006); and
CF_1 =	Unit Conversion Factor, converts Sv·m^2/s·Bq to rem·cm^2/h·µCi, 1.33E+14 rem·cm^2/h·µCi per Sv·m^2/s·Bq.

$$\frac{1.33E14\, rem \cdot cm^2 / h \cdot \mu Ci}{Sv \cdot m^2 / s \cdot Bq} = \frac{Sv \cdot m^2}{s \cdot Bq} * \frac{10^2\, rem}{Sv} * \frac{\left(10^2\, cm^2\right)^2}{m^2} * \frac{3.6E3 s}{h} * \frac{Bq}{dps} * \frac{3.7E4\, dps}{Bq}$$

GRF =	Ground Roughness Factor, a unitless constant (0.82) that compensates for the fact that the external exposure is not coming from an infinite flat plane (HPS, 2002);
CRP_i =	Combined Removal Parameter, value that adjusts the external (groundshine) dose from radionuclide *i* for radioactive decay and weathering effects that decrease the groundshine dose over the early phase time period, (value from Turbo FRMAC 2.0, RFC 2;
KP_i =	Resuspension Parameter value that adjusts the airborne radioactivity level of radionuclide *i* for radioactive decay and resuspension (value from Turbo FRMAC 2.0, RFC 2, h/cm;
BR =	breathing rate, 9.20E+05 cm^3/h, activity-weighted, average-hourly breathing rate for an adult (Table B.16.B, ICRP 1994);
$DCF_{Inh,E,i}$ =	Inhalation Dose Conversion Factor, effective, value for the effective dose per unit activity from inhalation of radionuclide *i* and for the most restrictive lung clearance class, Sv/Bq, (values from ICRP 60+ dosimetry models, DCFPAK 2006); and

CF_2 = unit conversion factor (CF) converting Sv/Bq to rem/µCi, 3.70E+06 rem/µCi per Bq/Sv.

$$\frac{3.7E6\,rem \big/ \mu Ci}{Sv \big/ Bq} = \frac{Sv}{Bq} * \frac{10^2\ rem}{Sv} * \frac{Bq}{dps}\frac{3.7E4\,dps}{Bq}$$

2.4.1.1 Combined Removal Parameter Calculation for Table 2-4

The CRP adjusts the groundshine dose for radioactive decay and weathering over the time period (i.e., early phase) under consideration. Although weathering has little effect on the groundshine dose over the first 96 hours, it is included to be complete and consistent with the methods used to calculate radiation doses over the other time periods (e.g., first year, second year).

$$CRP_{TP,i} = \int_{T_1}^{T_2} \left(EffXP_{TP,i} * WF_{TP,i} \right) dT \quad , \quad h = h * unitless$$

Where:

$CRP_{TP,i}$ = Combined Removal Parameter, value that adjusts the external (groundshine) dose from radionuclide *i* for radioactive decay and weathering effects which decrease the groundshine dose over the time phase under consideration, h,

$WF_{TP,i}$ = Weathering Factor, value that adjusts the groundshine dose from radionuclide *i* for weathering forces that reduce the radionuclide activity near the surface over time, and, thereby decreases the external dose rate, unitless, and

$EffXP_{TP,i}$ = Effective Exposure Period, value that adjusts the groundshine dose from radionuclide *i* for radioactive decay that occurs over the time phase under consideration, h.

2.4.1.2 Weathering Factor Calculation for Table 2-4

The Weathering Factor (WF) adjusts the external exposure rate for the decrease that occurs over time as the deposited material migrates deeper into the soil column. The WF model was developed using data from the Chernobyl nuclear power plant accident (HPS 2002). It should be noted that This WF model may not be appropriate for the environmental conditions existing in the area under investigation. An alternate WF model may be substituted if the alternate model can be shown to more accurately model the weathering in the area under investigation.

$$WF = 0.4e^{(-1.46E^{-}8 * t)} + 0.6e^{(-4.44E^{-}10 * t)}$$

$$unitless = \left(e^{\left(-\frac{1}{s} * s\right)} \right) + unitless \left(e^{\left(-\frac{1}{s} * s\right)} \right)$$

Where:

0.4 = fraction of material that undergoes rapid weathering, unitless,

0.6 = fraction of material that undergoes slow weathering, unitless,

1.46E-8 = rate constant representing the removal rate for the fraction of material that is rapidly ($t_{1/2}$ = 1.5 y) weathered, s^{-1},

4.44E-10 = rate constant representing the removal rate for the fraction of material that is slowly ($t_{1/2}$ = 50 y) weathered, s^{-1}, and

t = seconds.

2.4.1.3 Effective Exposure Period Calculation for Table 2-4

The Effective Exposure Period (EffXP) adjusts the external (groundshine) dose for radioactive decay over the time phase under consideration and is calculated using the equation below.

$$EffXP_{TP,i} = CF * \int_{T_1}^{T_2} e^{(-T*\lambda_i)} dT \,, \qquad h = \frac{h}{s} * \int_{s}^{s} e^{\left(-s*\frac{1}{s}\right)}$$

Or

$$EffXP_{TP,i} = CF * \left(\frac{e^{(-T_2*\lambda_i)} - e^{(-T_1*\lambda_i)}}{-\lambda_i} \right), \quad h = \frac{h}{s} * \left[\frac{\left(e^{\left(-s*\frac{1}{s}\right)} - e^{\left(-s*\frac{1}{s}\right)} \right)}{-\frac{1}{s}} \right]$$

Where:

CF = Unit conversion factor, 2.77E-04 h/s,

λ_i = Decay constant for radionuclide *i*, s^{-1},

T_1 = Time of the beginning of the integration period, 0 y, and

T_2 = Time of the end of the integration period, 4 days.

2.4.1.4 Combining the Weathering Factor and Effective Exposure Period to Calculate the Combined Removal Parameter for Table 2-4

Ignoring the unit conversion factor of 2.77E-04 h/s and multiplying the WF:

($WF_{TP,i} = 0.4*e^{(-T*1.46E^{-}8)} + 0.6*e^{(-T*4.44E^{-}10)}$) by the EffXP ($EffXP_{TP,i} = e^{(-\lambda_i*T)}$) yields:

$$CRP = e^{(-\lambda_i*T)} **(0.4*e^{(-T*1.46E^{-8})} + 0.6*e^{(-T*4.44E-10)})$$

Which simplifies to:

$$CRP = (0.4*e^{(-T*(\lambda_i+1.46E-8))} + 0.6*e^{(-T*(\lambda_i+4.44E-10))})$$

$$unitless = unitless*\mathrm{e}^{\left(-\left(\frac{1}{s}+\frac{1}{s}\right)*s\right)} + unitless*\mathrm{e}^{\left(-\left(\frac{1}{s}+\frac{1}{s}\right)*s\right)}$$

Integrating over a time period of interest yields the following CRP:

$$CRP = \frac{0.4*(e^{(-T_2*(\lambda_i+1.46E-8))} - e^{(-T_1*(\lambda_i+1.46E-8)})}{-(\lambda_i+1.46E-8)} + \frac{0.6*(e^{(-T_2*(\lambda_i+4.44E-8))} - e^{(-T_1*(\lambda_i+4.44E-8))})}{-(\lambda+4.44E-10)}$$

$$s = \frac{unitless*\left(e^{\left(s*\left(\frac{1}{s}+\frac{1}{s}\right)\right)-\left(s*\left(\frac{1}{s}+\frac{1}{s}\right)\right)}\right)}{-\left(\frac{1}{s}+\frac{1}{s}\right)} + \frac{unitless*\left(e^{\left(s*\left(\frac{1}{s}+\frac{1}{s}\right)\right)-\left(s*\left(\frac{1}{s}+\frac{1}{s}\right)\right)}\right)}{-\left(\frac{1}{s}+\frac{1}{s}\right)}$$

NOTE: If desired (as in Tables 7.2 and 7.5 of the 1992 PAG Manual), the WF can be ignored (turned off) by setting the WF exponent terms to zero. This reduces the previous formula to:

$$CRP = \frac{0.4 * (e^{(-T_2 * (\lambda_i + 0))} - e^{(-T_1 * (\lambda_i + 0))})}{-(\lambda_i + 0)} + \frac{0.6 * (e^{(-T_2 * (\lambda_i + 0))} - e^{(-T_1 * (\lambda_i + 0))})}{-(\lambda_i + 0)}$$

Which further reduces to:

$$CRP = \frac{0.4 * (e^{(-T_2 * \lambda_i)} - e^{(-T_1 * \lambda_i)})}{-\lambda_i} + \frac{0.6 * (e^{(-T_2 * \lambda_i)} - e^{(-T_1 * \lambda_i)})}{-\lambda_i}$$

Because 0.4 + 0.6 =1, the above equation reduces to the following equation which is equivalent to the effective exposure period and only adjusts for radioactive decay:

$$CRP = \frac{(e^{(-T_2 * \lambda_i)} - e^{(-T_1 * \lambda_i)})}{-\lambda_i} = EffXP \quad , \quad s = \frac{\left(s * \frac{1}{s}\right) - \left(s * \frac{1}{s}\right)}{-\left(\frac{1}{s}\right)}$$

2.4.1.5 Resuspension Parameter Calculation for Table 2-4

The Resuspension Parameter (KP) adjusts the inhalation dose for radioactive decay and the time-dependent Resuspension Factor (K) that occurs over the time period under consideration. The KP integral below does not have an exact solution when "K" is in a time-dependent form. Therefore, the integral cannot be solved analytically and must be solved using a software program that capable of numerical integration. It should be noted that the K model described below may not be appropriate for the environmental conditions existing in the area under investigation. An alternate K model may be substituted if the alternate model can be shown to more accurately model the resuspension in the area under investigation.

$$KP_i = CF * \int_{T_1}^{T_2} K * e^{(-\lambda_i * T)} dT \quad , \qquad \frac{h}{cm} = \frac{h/cm}{s/m} * \int_s^s \frac{1}{m} * e^{\left(\frac{-\frac{1}{s} * s}{\frac{1}{s}}\right)}$$

Where:

KP_i =	Resuspension Parameter, adjusts the inhalation dose from radionuclide *i* for radioactive decay and the time-dependent resuspension factor (K), h/cm,
CF =	Unit Conversion Factor (CF), 2.78E-06 h/cm per s/m,

$$\frac{2.78E-6\, h/cm}{s/m} = \frac{s}{m} * \frac{m}{100\, cm} * \frac{h}{3600\, s}$$

T_1 =	Time at the start of the time phase (integration period) under consideration, s,
T_2 =	Time at the end of the time phase (integration period) under consideration, s,
K =	Resuspension Factor, based on the time-varying formula from NCRP Report No. 129, *Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies*, (NCRP 1999), m^{-1},

- K = 1.00E-06 m^{-1} for t <1 d or

- $K = 1.00E\text{-}06\ m^{-1}/t$ for $t > 1$ and $\leq 1{,}000$ d or,
- $K = 1.00E\text{-}09\ m^{-1}$ for $t > 1000$ d.

λ_i = Decay constant for radionuclide *i*, s^{-1}.

2.4.2 Derived Response Level Calculation for Table 2-4

The DRL is calculated using the following equation:

$$DRL_{Groundshine+Inh,E} = \sum_{i}^{P+D} \left(\frac{PAG}{DCP_{Groundshine+Inh,E,i}} \right),$$

$$\frac{\mu Ci \cdot h}{cm^3} = \frac{1\,rem}{rem \cdot cm^3 / h \cdot \mu Ci}$$

Where:

$\sum_{i}^{P+D}$ = represents the summation of values from the parent radionuclide (P) and any short-lived daughter radionuclide(s) (D);

$DRL_{Groundshin,Inh,E}$ = Derived Response Level (DRL), effective, for exposure (i.e., groundshine and inhalation of resuspended material) to the radionuclide and any short-lived daughter radionuclide(s), $\mu Ci \cdot h/cm^3$;

PAG = EPA's PAG, 1 rem effective dose; and

$DCP_{groundshine+inh,E,i}$ = Dose Conversion Parameter (DCP), effective, value for the dose rate per unit activity from groundshine and the inhalation of resuspended material from radionuclide *i* and any short-lived daughter radionuclide(s) over the Early Phase time period and, $rem \cdot cm^3 / h \cdot \mu Ci$.

2.5 Procedures for Calculating Dose Conversion Parameters and Derived Response Levels for Thyroid Dose

To implement the supplemental protective action of KI administration if radioiodines are present, thyroid DCPs and DRLs are provided. The U.S. Food and Drug Administration (FDA) provides recommendations for KI based on age with various dosages. A simplified approach is administering KI to the entire area's population if projected child thyroid doses exceed 5 rem (50 mSv). The following Sections 2.5.1 and 2.5.2 provide details of calculations for DCP and DRL for thyroid dose.

2.5.1 Dose Conversion Parameter Calculation for Thyroid Dose Table 2-5

The DCPs in Table 2-5 are calculated using the same method described in Section 2.3 for Table 2-3, with the following modifications:

- The calculations are carried out only for those radionuclides with the potential to produce significant thyroid doses.
- The calculations are carried out for receptors of the various age groups (i.e., infant/newborn, 1-year-old, 5-year-old, 10-year-old, 15-year-old, and adult male) specified by ICRP 60 (ICRP 1991),
- The calculations are carried out using age-specific, ICRP 66 breathing rates (BR) for the receptors (ICRP 1994).
- The EPA PAG Manual assessments are generally based upon the ICRP activity-weighted, average hourly BR in an attempt to account for the various indoor and outdoor activities (e.g., sleep, rest/sitting, light and heavy activity) engaged in throughout the day. The only time this Manual does not use the activity-weighted, average hourly BR is when the receptor is assumed to be in the plume. Receptors in the plume are assumed to have a light-activity BR = 1.2 m^3/h because it is assumed they are attempting to move out of the plume. The evacuating receptor is assumed to breathe at this elevated rate for a 1-hour duration.

- The calculations are carried out using age-specific, ICRP 60+ inhalation dose conversion factors for the thyroid (not effective dose) ($DCF_{Inh,thy}$) for the receptors.
- The summary version of Table 2-5 only includes the $DCP_{Inh,thy}$ values for the most restrictive age group for each radionuclide.

2.5.2 Derived Response Level Calculation for Thyroid Dose Table 2-5

The DRLs in Table 2-5 are calculated using the same method described above for Table 2-3, with the following modifications:

- The DRLs are based on a PAG of 5 rem to the thyroid.
- The summary version of Table 2-6 only includes the $DRL_{Inh,thy}$ values for the most restrictive age group for each radionuclide.

NOTE: the most restrictive age group for Te-132/I-132, I-131, I-132, I-133, I-134, and I-135 is the 1-year-old and the most restrictive age group for I-125 and I-129 is the 10-year-old.

Table 2-5. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for Inhalation (Assume 1 Hour Exposure Period), based on 5 rem Committed Equivalent Dose (CED) Summary: List of Most Restrictive DCPs and DRLs for all Age Groups [a]

					2009 (ICRP 60+) Values		1992 Values (Table 5.5)		DCF Comparisons	
No.	Radionuclide	[a]Half-Life (d)	$DCF_{Inh, thyroid}$ (Sv/Bq)	Age Group	$DCP_{Inh, thyroid}$ (rem·cm^3 per h·µCi)	$DRL_{Inh, thyroid}$ (µCi·h per cm^3)	$DCP_{Inh, thyroid}$ (rem·cm^3 per h·µCi)	$DRL_{Inh, thyroid}$ (µCi·h per cm^3)	$DCP_{Inh, thyroid}$ / by 1992 $DCP_{Inh, thyroid}$	$DRL_{Inh. Thyroid}$ / by 1992 $DRL_{Inh, thyroid}$
	I-125	60.1	2.25E-07	10-y-old	9.32E+05	5.36E-06	9.60E+05	5.20E-06	0.97	1.03
36	Te-132/I-132	3.26	2.89E-07	1-y-old	3.74E+05	1.34E-05	2.90E+05	1.80E-05	1.29	0.74
	I-129	5.73E+09	1.33E-06	10-y-ld	5.51E+06	9.07E-07	6.90E+06	7.20E-07	0.80	1.26
11	I-131	8.04	1.43E-06	1–y-old	1.85E+06	2.70E-06	1.30E+06	3.90E-06	1.42	0.69
12	I-132	0.0958	1.63E-08	1–y-old	2.11E+04	2.37E-04	7.70E+03	6.50E-04	2.74	0.36
13	I-133	0.867	3.51E-07	1-y-old	4.55E+05	1.10E-05	2.20E+05	2.30E-05	2.07	0.48
14	I-134	0.0365	3.08E-09	1-y-old	3.99E+03	1.25E-03	1.30E+03	3.90E-03	3.07	0.32
15	I-135	0.275	6.98E-08	1–y-ld	9.04E+04	5.53E-05	3.80E+04	1.30E-04	2.38	0.43

Table 2-5a. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for Inhalation (Assume 1 Hour Exposure Period), based on 5 rem Committed Equivalent Dose (CED) (Newborn) [a]

				2009 (ICRP 60+) Values		1992 Values (Table 5.2)		DCF Comparisons	
No.	Radionuclide	[a]Half-Life (d)	$DCF_{Inh, thyroid}$ (Sv/Bq)	$DCP_{Inh, Ht}$ (rem·cm^3 per h·µCi)	$DRL_{Inh, HT}$ (µCi·h per cm^3)	$DCP_{Inh, thyroid}$ (rem·cm^3 per h·µCi)	$DRL_{Inh, thyroid}$ (µCi·h per cm^3)	DCPInh, thyroid / by 1992 DCPInh, thyroid	DRLInh. Thyroid / by 1992 DRLInh, thyroid
	I-125	60.1	4.07E-07	2.86E+05	1.75E-05	9.60E+05	5.20E-06	0.30	3.36
36	Te-132/I-132	3.26	3.56E-07	2.50E+05	2.00E-05	2.90E+05	1.80E-05	0.86	1.11
	I-129	5.73E+09	1.43E-06	1.01E+06	4.97E-06	6.90E+06	7.20E-07	0.15	6.91
11	I-131	8.04E+00	1.43E-06	1.01E+06	4.97E-06	1.30E+06	3.90E-06	0.77	1.28
12	I-132	9.58E-02	1.80E-08	1.27E+04	3.95E-04	7.70E+03	6.50E-04	1.64	0.61
13	I-133	8.67E-01	3.82E-07	2.69E+05	1.86E-05	2.20E+05	2.30E-05	1.22	0.81
14	I-134	3.65E-02	3.40E-09	2.39E+03	2.09E-03	1.30E+03	3.90E-03	1.84	0.54
15	I-135	2.75E-01	7.67E-08	5.39E+04	9.27E-05	3.80E+04	1.30E-04	1.42	0.71

Table 2-5b. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for Inhalation (Assume 1 Hour Exposure Period), based on 5 rem Committed Equivalent Dose (CED) (1-Year-Old Child) [a]

				2009 (ICRP 60+) Values		1992 Values (Table 5.2)		DCF Comparisons	
No.	Radionuclide	[b]Half-Life (d)	$DCF_{Inh, thyroid}$ (Sv/Bq)	$DCP_{Inh, Ht}$ (rem·cm^3 per h·µCi)	$DRL_{Inh, HT}$ (µCi·h per cm^3)	$DCP_{Inh, thyroid}$ (rem·cm^3 per h·µCi)	$DRL_{Inh, thyroid}$ (µCi·h per cm^3)	DCPInh, thyroid / by 1992 DCPInh, thyroid	DRLInh. Thyroid / by 1992 DRLInh, thyroid
	I-125	60.1	4.60E-07	5.96E+05	8.39E-06	9.60E+05	5.20E-06	0.62	1.61
36	Te-132/I-132	3.26	2.89E-07	3.74E+05	1.34E-05	2.90E+05	1.80E-05	1.29	0.74
	I-129	5.73E+09	1.72E-06	2.23E+06	2.24E-06	6.90E+06	7.20E-07	0.32	3.12
11	I-131	8.04E+00	1.43E-06	1.85E+06	2.70E-06	1.30E+06	3.90E-06	1.42	0.69
12	I-132	9.58E-02	1.63E-08	2.11E+04	2.37E-04	7.70E+03	6.50E-04	2.74	0.36
13	I-133	8.67E-01	3.51E-07	4.55E+05	1.10E-05	2.20E+05	2.30E-05	2.07	0.48
14	I-134	3.65E-02	3.08E-09	3.99E+03	1.25E-03	1.30E+03	3.90E-03	3.07	0.32
15	I-135	2.75E-01	6.98E-08	9.04E+04	5.53E-05	3.80E+04	1.30E-04	2.38	0.43

Table 2-5c. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for Inhalation (Assume 1 Hour Exposure Period), based on 5 rem Committed Equivalent Dose (CED) (5-Year-Old Child) [a]

				2009 (ICRP 60+) Values		1992 Values (Table 5.2)		DCF Comparisons	
No.	Radionuclide	[b]Half-Life (d)	$DCF_{Inh, thyroid}$ (Sv/Bq)	$DCP_{Inh, Ht}$ (rem·cm^3 per h·µCi)	$DRL_{Inh, HT}$ (µCi·h per cm^3)	$DCP_{Inh, thyroid}$ (rem·cm^3 per h·µCi)	$DRL_{Inh, thyroid}$ (µCi·h per cm^3)	DCPInh, thyroid / by 1992 DCPInh, thyroid	DRLInh. Thyroid / by 1992 DRLInh, thyroid
	I-125	60.1	2.95E-07	6.21E+05	8.05E-06	9.60E+05	5.20E-06	0.65	1.55
36	Te-132/I-132	3.26	1.37E-07	2.88E+05	1.73E-05	2.90E+05	1.80E-05	0.99	0.96
	I-129	5.73E+09	1.22E-06	2.57E+06	1.95E-06	6.90E+06	7.20E-07	0.37	2.70
11	I-131	8.04E+00	7.29E-07	1.53E+06	3.26E-06	1.30E+06	3.90E-06	1.18	0.84
12	I-132	9.58E-02	7.64E-09	1.61E+04	3.11E-04	7.70E+03	6.50E-04	2.09	0.48
13	I-133	8.67E-01	1.64E-07	3.45E+05	1.45E-05	2.20E+05	2.30E-05	1.57	0.63
14	I-134	3.65E-02	1.44E-09	3.03E+03	1.65E-03	1.30E+03	3.90E-03	2.33	0.42
15	I-135	2.75E-01	3.26E-08	6.86E+04	7.29E-05	3.80E+04	1.30E-04	1.81	0.56

Table 2-5d. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for Inhalation (Assume 1 Hour Exposure Period), based on 5 rem Committed Equivalent Dose (CED) (10-Year-Old Child) [a]

				2009 (ICRP 60+) Values		1992 Values (Table 5.2)		DCF Comparisons	
No.	Radionuclide	[b]Half-Life (d)	$DCF_{Inh, thyroid}$ (Sv/Bq)	$DCP_{Inh, Ht}$ (rem·cm^3 per h·µCi)	$DRL_{Inh, HT}$ (µCi·h per cm^3)	$DCP_{Inh, thyroid}$ (rem·cm^3 per h·µCi)	$DRL_{Inh, thyroid}$ (µCi·h per cm^3)	DCPInh, thyroid / by 1992 DCPInh, thyroid	DRLInh. Thyroid / by 1992 DRLInh, thyroid
	I-125	60.1	2.25E-07	9.32E+05	5.36E-06	9.60E+05	5.20E-06	0.97	1.03
36	Te-132/I-132	3.26	6.13E-08	2.54E+05	1.97E-05	2.90E+05	1.80E-05	0.88	1.09
	I-129	5.73E+09	1.33E-06	5.51E+06	9.07E-07	6.90E+06	7.20E-07	0.80	1.26
11	I-131	8.04E+00	3.70E-07	1.53E+06	3.26E-06	1.30E+06	3.90E-06	1.18	0.84
12	I-132	9.58E-02	3.43E-09	1.42E+04	3.52E-04	7.70E+03	6.50E-04	1.85	0.54
13	I-133	8.67E-01	7.38E-08	3.06E+05	1.63E-05	2.20E+05	2.30E-05	1.39	0.71
14	I-134	3.65E-02	6.48E-10	2.69E+03	1.86E-03	1.30E+03	3.90E-03	2.07	0.48
15	I-135	2.75E-01	1.46E-08	6.05E+04	8.26E-05	3.80E+04	1.30E-04	1.59	0.64

Table 2-5e. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for Inhalation (Assume 1 Hour Exposure Period), based on 5 rem Committed Equivalent Dose (CED) (15-Year-Old Child) [a]

				2009 (ICRP 60+) Values		1992 Values (Table 5.2)		DCF Comparisons	
No.	Radionuclide	[b]Half-Life (d)	$DCF_{Inh, thyroid}$ (Sv/Bq)	$DCP_{Inh, Ht}$ (rem·cm^3 per h·µCi)	$DRL_{Inh, HT}$ (µCi·h per cm^3)	$DCP_{Inh, thyroid}$ (rem·cm^3 per h·µCi)	$DRL_{Inh, thyroid}$ (µCi·h per cm^3)	DCPInh, thyroid / by 1992 DCPInh, thyroid	DRLInh. Thyroid / by 1992 DRLInh, thyroid
	I-125	60.1	1.45E-07	7.40E+05	6.75E-06	9.60E+05	5.20E-06	0.77	1.30
36	Te-132/I-132	3.26	3.82E-08	1.95E+05	2.56E-05	2.90E+05	1.80E-05	0.67	1.42
	I-129	5.73E+09	9.11E-07	4.65E+06	1.07E-06	6.90E+06	7.20E-07	0.67	1.49
11	I-131	8.04E+00	2.23E-07	1.14E+06	4.39E-06	1.30E+06	3.90E-06	0.88	1.13
12	I-132	9.58E-02	2.08E-09	1.06E+04	4.71E-04	7.70E+03	6.50E-04	1.38	0.72
13	I-133	8.67E-01	4.39E-08	2.24E+05	2.23E-05	2.20E+05	2.30E-05	1.02	0.97
14	I-134	3.65E-02	3.94E-10	2.01E+03	2.49E-03	1.30E+03	3.90E-03	1.55	0.64
15	I-135	2.75E-01	8.80E-09	4.49E+04	1.11E-04	3.80E+04	1.30E-04	1.18	0.86

Table 2-5f. Dose Conversion Parameters (DCPs) and Derived Response Levels (DRLs) for Inhalation (Assume 1 Hour Exposure Period), based on 5 rem Committed Equivalent Dose (CED) (Adult Male)[a]

				2009 (ICRP 60+) Values		1992 Values (Table 5.2)		DCF Comparisons	
No.	Radionuclide	[b]Half-Life (d)	$DCF_{Inh, thyroid}$ (Sv/Bq)	$DCP_{Inh, Ht}$ (rem·cm^3 per h·µCi)	$DRL_{Inh, HT}$ (µCi·h per cm^3)	$DCP_{Inh, thyroid}$ (rem·cm^3 per h·µCi)	$DRL_{Inh, thyroid}$ (µCi·h per cm^3)	DCPInh, thyroid / by 1992 DCPInh, thyroid	DRLInh. Thyroid / by 1992 DRLInh, thyroid
	I-125	60.1	1.04E-07	5.77E+05	8.66E-06	9.60E+05	5.20E-06	0.60	1.67
36	Te-132/I-132	3.26	2.50E-08	1.39E+05	3.60E-05	2.90E+05	1.80E-05	0.48	2.00
	I-129	5.73E+09	7.16E-07	3.97E+06	1.26E-06	6.90E+06	7.20E-07	0.58	1.75
11	I-131	8.04E+00	1.47E-07	8.16E+05	6.13E-06	1.30E+06	3.90E-06	0.63	1.57
12	I-132	9.58E-02	1.36E-09	7.55E+03	6.62E-04	7.70E+03	6.50E-04	0.98	1.02
13	I-133	8.67E-01	2.84E-08	1.58E+05	3.17E-05	2.20E+05	2.30E-05	0.72	1.38
14	I-134	3.65E-02	2.59E-10	1.44E+03	3.48E-03	1.30E+03	3.90E-03	1.11	0.89
15	I-135	2.75E-01	5.76E-09	3.20E+04	1.56E-04	3.80E+04	1.30E-04	0.84	1.20

[a] The EPA PAG Manual assessments are generally based upon the ICRP activity-weighted, average-hourly breathing rates (BR) in an attempt to account for the various in-door and out-door activities (e.g., sleep, rest/sitting, light and heavy activity) engaged in throughout the day. The only time the PAG Manual does not use the activity-weighted, average hourly BR is when the receptor is assumed to be in the plume. Receptors in the plume are assumed to have a light-activity BR = 1.2 m^3/h because it is assumed they are attempting to move out of the plume. The evacuating receptor is assumed to breathe at this elevated rate for a 1 hour duration.
[b]Values from Turbo FRMAC 2.0, RFC 2 (DCFPAK, K. Eckerman)

Chapter 3
Basis for Calculations for the Intermediate Phase PAGs

3. Basis for Calculations for the Intermediate Phase PAGs

NOTE to the reader: The justification for this PAG remains the same as it was in the 1992 PAG Manual in Chapter 3. It is proposed that the new subsections below be added to that chapter and replace calculations and tables provided in Chapter 7 of the 1992 PAG Manual.

Intermediate Phase PAGs apply to the first and subsequent years after a radiological incident. Decisions must be made concerning the acceptability of occupation of homes and businesses by the public. The PAG for relocation of the public is 2 rem (20 mSv) in the first year and 0.5 rem (5 mSv) in any subsequent year. The Intermediate Phase dose does not include ingestion of food and water, which have separate provisions.

Keeping below the 0.5 rem (5 mSv) relocation PAG the second year and beyond may be achieved through allowing for the decay of shorter half-life radioisotopes (as would be likely in the case of a nuclear power plant accident), through decontamination efforts, or through other means of controlling public exposures (such as limiting access to certain areas). In the case of an RDD, in which a longer half-life radioisotope would likely be utilized, reductions in dose may prove difficult to achieve. If out-year doses are estimated to remain above 0.5 rem (5 mSv) relocation should be considered.

The primary dose of interest for the Intermediate Phase is the sum of the effective dose from external exposure and CED from inhalation. The exposure periods of interest are the first year and second year after the incident. However, dispersals of alpha-emitting material must be monitored carefully. Examples include INDs or alpha RDDs. In these cases, inhalation of resuspended material is likely to be the dominant exposure pathway. It is possible that there will be little or no associated gamma radiation or beta activity. Alpha survey instruments will be required to monitor alpha-emitting particles, and use of proper measurement techniques is critical.

Calculation of the projected gamma dose from measurements will require knowledge of the principal radionuclides contributing to exposure and their relative abundances. Information on these radiological characteristics can be compiled either through the use of portable gamma spectrometers or by radionuclide analysis of environmental samples. Several measurement locations may be required to determine whether any selective radionuclide deposition occurred as a function of meteorology, surface type, distance from the point of release, or other factors.

The gamma exposure rate may decrease rapidly if deposited materials include a significant fraction of short-lived radionuclides. Therefore, the relationship between instantaneous exposure rate and projected first- and second-year annual doses will change as a function of time and these relationships must be established for the particular mixture of deposited radioactive materials present at the time of the gamma exposure rate measurement. In the specific instance of an RDD or IND, the distribution of residual doses over time will depend largely upon the half-lives of the radionuclides involved and could potentially remain significant over many years. It should be noted that natural attenuation as well as nuclear decay can affect long-term dose assessments.

For incidents involving releases from nuclear power plants, gamma radiation from deposited radioactive materials is expected to be the principal exposure pathway, as noted above. Other pathways should also be evaluated, and their contributions considered, if significant. For example, any time alpha-emitting radionuclides are involved, the inhalation of resuspended material must be considered. Similarly, the skin beta dose may be important for particulates deposited or transferred to the skin, as may be the case for an RDD comprised of Sr-90.

Exposure from ingestion of food and water is normally considered independently of decisions for relocation and decontamination. In rare instances, however, where withdrawal of food and/or water from use would, in itself, create a health risk, relocation may be an appropriate protective action for protection from exposure via ingestion. In this case, the Committed Effective Dose (CED) from ingestion should be added to the projected dose from other exposure pathways for decisions on relocation.

Section 3.1 provides methods for evaluating the projected dose from whole body exposure from surface deposition and resuspended radioactivity. Section 3.2 provides the method and an example for calculating total dose from deposition based on exposure rate values. Section 3.3 provides calculations for skin dose from groundshine and contamination.

3.1 Method Used for Calculation of the Deposition Derived Response Levels and Total Dose Parameters for Table 3-1 and 3-2 Values

This section describes how the Deposition Derived Response Level (Dp_DRL) for the "marker" radionuclide is calculated. A DRL is a level of radioactivity in an environmental medium that would be expected to produce a dose equal to its corresponding PAG. The "marker" radionuclide concept is used to eliminate the need to separately measure the concentration of every radionuclide in the environmental medium because this process is very laborious. Generally a gamma-emitting radionuclide that can easily be identified in the field or laboratory is chosen as the "marker" radionuclide. The "marker" radionuclide DRL specifies the level of radioactivity (pCi/m^2) of the "marker" radionuclide at which the dose from all radionuclides in the mixture (i.e., all parent radionuclides and short-lived daughter radionuclides) will equal the corresponding PAG. Section 3.1.1 provides detailed calculations of Dp_DRL with details of marker radionuclide in a mixture and in secular equilibrium. The Dp_DRL includes the internal dose from the inhalation internal exposure of resuspended material (see section 3.1.2) and the external dose from material deposited on the ground (i.e., groundshine) (see section 3.1.3). Table 3-1 provides values that are corrected for weathering and radioactive decay and Table 3-2 provides values that are not corrected for weathering. Users of these data should decide which values to use based on their confidence in the applicability of the weathering model to their environment.

The Total Dose Parameter for Surface Deposition (TDP_Dp) provides an estimate of the dose received by the receptor from groundshine and the inhalation of resuspended material received, over the time phase under consideration, per unit of radioactivity of radionuclide *i* deposited on the ground (see section 3.1.4). TDP_Dp does not include dose from plume passage (i.e., plume inhalation, plume submersion).

The Deposition Total Dose Parameter (Dp_TDP_DP) is the sum of the external dose from groundshine and the internal (committed effective) dose from inhalation over the time phase under consideration, from the deposited radioactivity level of all parent radionuclides and any short-lived daughter radionuclides (see section 3.1.5). An example calculation of Dp_TDP_DP is provided in section 3.1.6.

3.1.1 Calculation for Deposition Derived Response Level

3.1.1.1 Calculation for Deposition Derived Response Level for Marker Radionuclide in a Radionuclide Mixture

The formula below is used to calculate the Dp_DRL for the "marker" radionuclide. The Dp_DRL varies with the radionuclide mixture, the radionuclide chosen as the "marker," the time phase under consideration, and the applicable PAG.

$$Dp\_DRL_{i,TP} = \frac{PAG_{TP} * Dp_i}{Dp\_TDP\_Dp_{E,i,TP}}, \quad \frac{\mu Ci}{m^2} = \frac{mrem * \frac{\mu Ci}{m^2}}{mrem}$$

Where:

$Dp\_DRL_{i,\ TP}$ =	Deposition Derived Response Level, the level of activity of "marker" radionuclide *i* at which the dose from all radionuclides in mixture would result in a dose equal to the PAG for the time phase (TP) under consideration, μCi/m^2;
Dp_i =	Deposition, the radioactivity level of "marker" radionuclide *i* per unit area of ground, μCi/m^2;
PAG =	EPA's Protective Action Guide, for the time phase under consideration, mrem;
$Dp\_TDP\_Dp_{E,\ i,\ TP}$ =	Deposition Total Dose Parameter for Surface Deposition, the sum of the external dose from groundshine and the internal (committed effective) dose from inhalation of resuspended material received , over the time phase under consideration, from the deposited radioactivity level of all parent radionuclide(s) *i* and any short-lived daughters, mrem; and
TP =	Time Phase, the period of time (i.e., Early Phase, 1^{st}-y, 2^{nd}-y,) over which the assessment is performed.

3.1.1.2 Calculation for Deposition Derived Response Level for a Parent Radionuclide and Any Short-lived Daughters in Secular Equilibrium

$$DP\_DRL_{i,TP} = \frac{PAG_{TP}}{TDP\_Dp_{E,i,TP}}, \frac{\mu Ci}{m^2} = \frac{mrem}{\frac{mrem}{\mu Ci/m^2}}$$

,

Where:

$Dp\_DRL_{i,\ TP}$ =	Deposition Derived Response Level, the level of parent radionuclide *i*, and its short-lived daughter radionuclides in secular equilibrium, at which the dose from all radionuclides result in a dose equal to the PAG for the time phase (TP) under consideration, $\mu Ci/m^2$;
PAG =	EPA's Protective Action Guide for the time phase under consideration, mrem;
$TDP\_Dp_{E,\ i,\ TP}$ =	Total Dose Parameter for Surface Deposition, the sum of the external dose from groundshine and the internal (committed effective) dose from inhalation of resuspended material received, over the time phase under consideration, per unit of radioactivity of radionuclide *i* deposited on the ground, $mrem \cdot m^2/\mu Ci$; and
TP =	Time Phase, the period of time (i.e., early phase, 1^{st}-y, 2^{nd}-y) over which the assessment is performed.

3.1.2 Calculation of Internal Dose Component of the Total Dose Parameter for Surface Deposition

The internal dose component of the DP_DRL includes the total dose parameters for surface deposition. The following sections detail the calculations of the CED component from inhaling the resuspended materials.

3.1.2.1 Effective Dose Parameter Calculation

The equation below is used to calculate the CED component from inhaling the resuspended radioactivity over the time period under consideration.

$$\mathrm{EDP}_{\mathrm{inh,\,E,}\,i,\,TP} = CDF_{\mathrm{inh,\,E,\,i}} * KP_{i,TP}$$

$$\frac{mrem \cdot m^2}{\mu Ci} = \frac{mrem \cdot m^3}{\mu Ci \cdot s} * \frac{s}{m}$$

Where:

$EDP_{inh,\ E,\ i,\ TP}$ =	Effective Dose Parameter, the committed effective dose received per unit activity of radionuclide *i* deposited on the ground from the inhalation of the resuspended radionuclide over the time phase under consideration, $mrem \cdot m^2/\mu Ci$;
$CDF_{inh,\ E,\ i}$ =	Committed Dose Factor, the committed effective dose rate from breathing (at a specified rate) air contaminated with a unit activity of radionuclide *i*, $mrem \cdot m^3/s \cdot \mu Ci$; and
$KP_{i,\ TP}$ =	Resuspension Parameter, value that adjusts the airborne radioactivity level of radionuclide *i* for radioactive decay and resuspension over the time phase under consideration, (value from Turbo FRMAC 2.0, RFC 2), s/m.

3.1.2.2 Committed Dose Factor Calculation

$$\mathrm{CDF}_{\mathrm{inh,\,E,\,i}} = BR * \mathrm{IDCF}_{\mathrm{inh,\,E,\,i}} * CF$$

$$\frac{mrem \cdot m^3}{s \cdot \mu Ci} = \frac{m^3}{s} * \frac{Sv}{Bq} * \frac{mrem \cdot Bq}{\mu Ci \cdot Sv}$$

Where:

$\mathrm{CDF}_{\mathrm{inh,\,E,}\,i}$ =	Committed Dose Factor, the committed effective dose rate from breathing (at a specified rate) air contaminated with a unit activity of radionuclide *i*, mrem·m^3/ s·µCi;
BR =	Breathing Rate, the activity-weighted, average hourly breathed air in per unit time by an adult male (ICRP 1994, Table B.16B), 2.56E-04 m^3/s;
IDCF =	Inhalation Dose Conversion Factor , the committed effective dose conversion factor for radionuclide *i*, (values from ICRP 60+ dosimetry models, DCFPAK 2006), mrem/µCi; and
CF =	Unit Conversion Factor (CF), converts Sv/Bq to mrem/µCi, 3.7E+09 mrem/µCi per Sv/Bq.

$$\frac{3.7E9\, mrem / \mu Ci}{Sv / Bq} = \frac{Sv}{Bq} * \frac{10^5\ mrem}{Sv} * \frac{Bq}{dps} * \frac{3.7E4\, dps}{Bq}$$

3.1.2.3 Resuspension Parameter Calculation

The KP adjusts the inhalation dose for radioactive decay and the time-dependent K that occurs over the time period under consideration. The KP integral below does not have an exact solution when "K" is in a time-dependent form. Therefore, the integral cannot be solved analytically and must be solved using a software program that capable of numerical integration. It should be noted that the K model described below may not be appropriate for all environmental conditions. An alternate K model may be substituted if the alternate model can be shown to more accurately model the resuspension in the area under investigation.

$$KP_{TP,i} = \int_{T_1}^{T_2} \left(K * EffXP_i\right) dT \quad , \quad \frac{s}{m} = \int_s^s \frac{1}{m} * e^{\left(\frac{-\frac{1}{s} * s}{\frac{1}{s}}\right)}$$

Where:

KP_i =	Resuspension parameter, adjusts the inhalation dose from radionuclide *i* for radioactive decay and the time-dependent resuspension factor (K) over the time phase under consideration, h/cm;
CF =	Unit conversion factor, 2.78E-06 h/cm per s/m,

$$\frac{2.78E-6\, h / cm}{s / m} = \frac{s}{m} * \frac{m}{100\, cm} * \frac{h}{3600\, s}$$

T_1 =	Time at the start of the time phase (integration period) under consideration, s,
T_2 =	Time at the end of the time phase (integration period) under consideration, s,
K =	Resuspension factor, based on the time-varying formula from NCRP Report No. 129, *Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies*, (NCRP 1999), m^{-1},

- $K = 1.00E\text{-}06\ m^{-1}$ for t <1 d or
- $K = 1.00E\text{-}06\ m^{-1}/t$ for t >1 and ≤1,000 d or,
- $K = 1.00E\text{-}09\ m^{-1}$ for t >1000 d, and

$EffXP_{TP,\ i}$ = Effective Exposure Period for radionuclide *i* over the time phase under consideration, s^{-1}.

$$EffXP_{TP,i} = \int_{T_1}^{T_2} e^{(-T*\lambda_i)}\, dT \ , \qquad \mathrm{s} = \int_s^s e^{\left(-\mathrm{s}*\frac{1}{s}\right)}$$

Or

$$EffXP_{TP,i} = \frac{e^{(-T_2*\lambda_i)} - e^{(-T_1*\lambda_i)}}{-\lambda_i}, \qquad \mathrm{s} = \frac{\left(e^{\left(-\mathrm{s}*\frac{1}{s}\right)} - e^{\left(-\mathrm{s}*\frac{1}{s}\right)}\right)}{-\frac{1}{s}}$$

Where:
λ_i = Decay constant for radionuclide *i*, s^{-1},
T_1 = the start of the time phase (integration period) under consideration, s, and
T_2 = the end of the time phase (integration period) under consideration, s.

3.1.3 Calculation of External Dose Component of the Total Dose Parameter for Surface Deposition

The equation below is used to calculate the external dose component received from the radionuclides deposited on the ground over the time period under consideration.

3.1.3.1 External Dose Parameter Calculation

The External Dose Parameter for Deposition (ExDP_Dp) gives the effective dose from groundshine per unit activity deposited on the ground over the time period under consideration and adjusted for the ground roughness factor (GRF).

$$\mathrm{ExDP\_Dp}_{ground,E,i,TP} = CRP_{i,\,TP} * ExDF_{ground,E,i}$$

$$\left(\frac{mrem \cdot m^2}{\mu Ci}\right) = (s) * \left(\frac{mrem \cdot m^2}{s \cdot \mu Ci}\right)$$

Where:

$\mathrm{ExDP\_Dp}_{ground,\ E,\ i,\ TP}$ = External Dose Parameter for Deposition, the effective dose from groundshine per unit activity deposited on the ground from radionuclide *i* over the time phase under consideration and adjusted for the GRF, mrem·m^2/ µCi;

$CRP_{i,\ TP}$ = Combined Removal Parameter, value that adjusts the external (groundshine) dose from radionuclide *i* for radioactive decay and weathering effects which decrease the groundshine dose over the time phase under consideration, s; and

$ExDF_{ground,\ E,\ i}$ = External Dose Factor for Deposition, the effective dose rate from the external exposure to radionuclide *i* per unit activity deposited on the ground and adjusted for the ground roughness factor, mrem·m^2/ s·µCi.

Combined Removal Parameter Calculation for Tables 3-2 and 3-3

The Combined Removal Parameter (CRP) adjusts the groundshine dose for radioactive decay and weathering over the time period under consideration.

$$CRP_{i,TP} = \int_{T_1}^{T_2} \left(EffXP_{i,TP} * WF_{i,TP} \right) dT, \quad s = s * unitless$$

Where:

$CRP_{i,\ TP}$ =	Combined Removal Parameter, value that adjusts the external (groundshine) dose from radionuclide *i* for radioactive decay and weathering that decrease the radioactivity over the time phase under consideration, s,
$WF_{i,\ TP}$ =	Weathering Factor, value that adjusts the groundshine dose from radionuclide *i* for weathering forces that reduce the radionuclide activity near the surface over time, and, thereby decreases the external dose rate, unitless, and
$EffXP_{i,\ TP}$ =	Effective Exposure Period, value that adjusts the groundshine dose from radionuclide *i* for radioactive decay that occurs over the time phase under consideration, s.

Weathering Factor Calculation

The WF adjusts the external exposure rate for the decrease that occurs over time as the deposited material migrates deeper into the soil column. The WF model was developed using data from the Chernobyl nuclear power plant accident (HPS 2002). It should be noted that this WF model may not be appropriate for the environmental conditions existing in the area under investigation. An alternate WF model may be substituted if the alternate model can be shown to more accurately model the weathering in the area under investigation.

$$WF = 0.4e^{(-1.46E^{-}8 * t)} + 0.6e^{(-4.44E^{-}10 * t)}$$

$$unitless = \left(e^{\left(-\frac{1}{s} * s\right)} \right) + unitless \left(e^{\left(-\frac{1}{s} * s\right)} \right)$$

Where:

0.4 =	fraction of material that undergoes rapid weathering, unitless,
0.6 =	fraction of material that undergoes slow weathering, unitless,
1.46E-08 =	rate constant representing the removal rate for the fraction of material that is rapidly ($t_{1/2}$ = 1.5 y) weathered, s^{-1},
4.44E-10 =	rate constant representing the removal rate for the fraction of material that is slowly ($t_{1/2}$ = 50 y) weathered, s^{-1}, and
t =	seconds.

Effective Exposure Period Calculation

The EffXP adjusts the groundshine dose for radioactive decay over the time phase under consideration and is calculated using the following equation.

$$EffXP_{TP,i} = \int_{T_1}^{T_2} e^{(-T * \lambda_i)} dT, \qquad s = \int_{s}^{s} e^{\left(-s * \frac{1}{s}\right)}$$

Or

$$EffXP_{TP,i} = \frac{e^{(-T_2 * \lambda_i)} - e^{(-T_1 * \lambda_i)}}{-\lambda_i}, \quad \mathrm{s} = \frac{\left(e^{\left(-\mathrm{s} * \frac{1}{s}\right)} - e^{\left(-\mathrm{s} * \frac{1}{s}\right)} \right)}{-\frac{1}{s}}$$

Where:
λ_i = decay constant for radionuclide *i*, s^{-1},
T_1 = the start of the time phase (integration period) under consideration, s, and
T_2 = the end of the time phase (integration period) under consideration, s.

Combining the Weathering Factor and Effective Exposure Period to Calculate the Combined Removal Parameter

Multiplying the WF ($WF_{TP,i} = 0.4 * e^{(-T * 1.46E^{-}8)} + 0.6 * e^{(-T * 4.44E^{-}10)}$) by the EffXP ($EffXP_{TP,i} = e^{(-\lambda_i * T)}$) yields:

$$CRP = e^{(-\lambda_i * T)} * \left(0.4 * e^{(-T * 1.46E^{-8})} + 0.6 * e^{(-T \; * \; 4.44E^{-}10)} \right)$$

Which simplifies to:

$$CRP = (0.4 * e^{(-T*(\lambda_i + 1.46E-8))} + 0.6 * e^{(-T*(\lambda_i + 4.44E-10))})$$

$$unitless = unitless * \mathrm{e}^{\left(-\left(\frac{1}{s}+\frac{1}{s}\right)*s\right)} + unitless * \mathrm{e}^{\left(-\left(\frac{1}{s}+\frac{1}{s}\right)*s\right)}$$

Integrating over a time period of interest yields the following CRP:

$$CRP = \frac{0.4 * \left(\mathrm{e}^{\left(-T_2 * \left(\lambda_i + 1.46E^{-}8\right)\right)} - \mathrm{e}^{\left(-T_1 * \left(\lambda_i + 1.46E^{-}8\right)\right)} \right)}{-(\lambda_i + 1.46E^{-}8)} + \frac{0.6 * \left(\mathrm{e}^{\left(-T_2 * \left(\lambda_i + 4.44E^{-}8\right)\right)} - \mathrm{e}^{\left(-T_1 * \left(\lambda_i + 4.44E^{-}8\right)\right)} \right)}{-(\lambda_i + 4.44E^{-}10)}$$

$$s = \frac{unitless * \left(e^{\left(s * \left(\frac{1}{s}+\frac{1}{s}\right)\right) - \left(s * \left(\frac{1}{s}+\frac{1}{s}\right)\right)} \right)}{-\left(\frac{1}{s} + \frac{1}{s}\right)} + \frac{unitless * \left(e^{\left(s * \left(\frac{1}{s}+\frac{1}{s}\right)\right) - \left(s * \left(\frac{1}{s}+\frac{1}{s}\right)\right)} \right)}{-\left(\frac{1}{s} + \frac{1}{s}\right)}$$

Adjusting the Groundshine Dose only for Radioactive Decay

If desired (as in Tables 7.2 and 7.5 of the 1992 PAG Manual) the Weathering Factor (WF) can be ignored when calculating the external dose from groundshine. To ignore the WF and to adjust the groundshine dose for only radioactive decay, substitute the EffXP.

$$\mathrm{ExDP\_Dp}_{ground,E,i,TP} = CRP_{i,TP} * ExDF_{ground,E,i}$$

$$\left(\frac{mrem \cdot m^2}{\mu Ci}\right) = (s) * \left(\frac{mrem \cdot m^2}{s \cdot \mu Ci}\right)$$

3.1.3.2 External Dose Factor Calculation

The External Dose Factor (ExDF) gives the effective dose from groundshine per unit activity deposited on the ground and adjusted for the GRF.

$$ExDF_{ground,E,i} = GRF * \mathrm{ExDC}_{ground,E,\mathrm{i}} * CF$$

$$\frac{mrem/m^2}{s/\mu Ci} = unitless * \frac{Sv/m^2}{s/Bq} * \frac{mrem/Bq}{\mu Ci/Sv}$$

Where:

$ExDF_{ground,\ E,\ i}$ =	External Dose Factor for Deposition, the effective dose rate from the external exposure to radionuclide *i* per unit activity deposited on the ground and adjusted for the ground roughness factor, mrem·m^2/ s·µCi,
GRF=	Ground Roughness Factor, a unitless constant (0.82) that compensates for the fact that the external exposure is not coming from an infinite flat plane (HPS, 2002),
$ExDC_{ground,E,i}$ =	External Dose Coefficient, the effective dose rate from the external exposure to radionuclide *i* per unit activity deposited on the ground, Sv·m^2/s·Bq, (values from ICRP 60+ dosimetry models, DCFPAK, 2006), and
CF =	Unit Conversion Factor to convert Sv/Bq to mrem/µCi, 3.7E+09 mrem/µCi per Sv/Bq,

$$\frac{3.7E9\,mrem/\mu Ci}{Sv/Bq} = \frac{Sv}{Bq} * \frac{10^5\ mrem}{Sv} * \frac{Bq}{dps} * \frac{3.7E4\,dps}{Bq}$$

Where:

$ExDP\_Dp_{ground,\ E,\ i,\ TP}$ =	External Dose Parameter for Deposition, the effective dose from groundshine per unit activity deposited on the ground from radionuclide *i* over the time phase under consideration and adjusted for the GRF, mrem·m^2/ µCi;
$CRP_{i,\ TP}$ =	Combined Removal Parameter, value that adjusts the external (groundshine) dose from radionuclide *i* for radioactive decay and weathering effects which decrease the groundshine dose over the time phase under consideration; and
$ExDF_{ground,\ E,\ i}$ =	External Dose Factor for Deposition, the effective dose rate from the external exposure to radionuclide *i* per unit activity deposited on the ground and adjusted for the ground roughness factor, mrem·m^2/ s·µCi.

3.1.4 Total Dose Parameter for Surface Deposition Calculation

The TDP_Dp is the sum of the external dose from groundshine (see section 3.1.3) and the internal (committed effective) dose from inhalation of resuspended material received (see section 3.1.2), over the time phase under consideration, per unit of radioactivity of radionuclide *i* deposited on the ground.

$$\mathrm{TDP\_Dp}_{E,i,\mathrm{TP}} = \mathrm{EDP}_{\mathrm{inh},E,TP,\mathrm{i}} + \mathrm{ExDP\_Dp}_{ground,E,i,TP}$$

$$\frac{mrem \cdot m^2}{\mu Ci} = \frac{mrem \cdot m^2}{\mu Ci} + \frac{mrem \cdot m^2}{\mu Ci}$$

Where:

$TDP\_Dp_{E,\,i,\,TP}$ =	Total Dose Parameter for Surface Deposition, the sum of the external dose from groundshine and the internal (committed effective) dose from inhalation of resuspended material received, over the time phase under consideration, per unit of radioactivity of radionuclide *i* deposited on the ground, mrem·m^2/µCi;
$EDP_{inh,\,E,\,i,\,TP}$ =	Effective Dose Parameter, the committed effective dose received from the inhalation of the resuspended radionuclide *i* over the time phase under consideration and per unit of radioactivity of radionuclide *i* deposited on the ground, mrem·m^2/µCi; and
$ExDP\_Dp_{ground,\,E,\,i,\,TP}$ =	External Dose Parameter for Deposition, the groundshine dose received, over the time phase under consideration, per unit of radioactivity of radionuclide *i* deposited on the ground and adjusted for the ground roughness factor, mrem·m^2/µCi.

3.1.5 Deposition Total Dose Parameter Calculation

The Dp_TDP_DP is the sum of the external dose from groundshine and the internal (committed effective) dose from inhalation of resuspended material received, over the time phase under consideration, from the deposited radioactivity level of all parent radionuclide(s) and any short-lived daughter radionuclides.

$$\mathrm{Dp\_TDP\_Dp}_{E,\,i,TP} = \sum_{i}^{P+D} \left(Dp_i * \mathrm{TDP\_Dp}_{E,\,i,TP} \right)$$

Where:

$\sum_{i}^{P+D}$ =	Represents the summation of values from all parent (P) and short-lived daughter (D) radionuclide(s);
$Dp\_TDP\_Dp_{E,\,i,\,TP}$ =	Deposition Total Dose Parameter for Deposition, the sum of the external dose from groundshine and the internal (committed effective) dose from inhalation of resuspended material received, over the time phase under consideration, from the deposited radioactivity level of all parent radionuclide(s) and any short-lived daughters, mrem;
Dp_i =	Deposition, the radioactivity level of radionuclide *i* per unit area of ground, µCi/m^2; and
$TDP\_Dp_{E,\,i,\,TP}$ =	Total Dose Parameter for Surface Deposition, the sum of the external dose from groundshine and the internal (committed effective) dose from inhalation of resuspended material received, over the time phase under consideration, per unit of radioactivity of radionuclide *i* deposited on the ground, mrem·m^2/µCi (see section 3.1.4).

3.1.6 Example Calculation of Deposition Derived Response Level for a Radionuclide Mixture

Given the radionuclide mixture in Table 3-1 and considering weathering effects, calculate the DP_DRL for a marker radionuclide for the first-year time phase. Generally a radionuclide that is easily detected in the field or in the laboratory is chosen as the marker radionuclide which is used to represent the entire mixture. For this mixture, either I-131 or Cs-137 could be chosen as the marker radionuclide because they have prominent gamma signatures that allow them to be individually detected in a mixture of radionuclides. For this example, Cs-137 is chosen as the marker radionuclide for the DRL calculation. Follow the steps below to calculate the Dp_DRL for the mixture over the first-year time phase using Cs-137 as the marker radionuclide.

1. Multiply the relative activity level of each parent radionuclide (Dp_i) in the mixture by its corresponding TDP_Dp for the time phase under consideration and then sum the products to derive the Deposition Total Dose Parameter for Deposition (Dp_TDP_Dp) for the radionuclide mixture.

$$\mathrm{Dp\_TDP\_Dp}_{E,\,i,TP} = \sum_{i}^{P+D} \left(Dp_i * \mathrm{TDP\_Dp}_{E,\,i,TP} \right)$$

Where:

$\sum_{i}^{P+D} =$	Represents the summation of values from all parent (P) and short-lived daughter (D) radionuclide(s);
$\mathrm{Dp\_TDP\_Dp}_{E,\,i,\,TP} =$	Deposition Total Dose Parameter for Deposition, the sum of the external dose from groundshine and the internal (committed effective) dose from inhalation of resuspended material received, over the time phase under consideration, from the deposited radioactivity level of all parent radionuclide(s) and any short-lived daughters, mrem;
$Dp_i =$	Deposition, the radioactivity level of radionuclide *i* per unit area of ground, pCi/m^2, (from Table 3-1); and
$\mathrm{TDP\_Dp}_{E,\,i,\,TP} =$	Total Dose Parameter, the sum of the external dose from groundshine and the internal (committed effective) dose from inhalation of resuspended material received, over the time phase under consideration, per unit of radioactivity of radionuclide *i* deposited on the ground, (from Table 3-1), mrem·m^2/pCi.

$$\mathrm{Dp\_TDP\_Dp}_{E,\,mix,1st-y} = \sum_{i}^{P+D} \left[\begin{array}{l} \left(Dp_{I131} * \mathrm{TDP\_Dp}_{E,\,I131,1st-y} \right) + \left(Dp_{Te132} * \mathrm{TDP\_Dp}_{E,\,Te132,1st-y} \right) + \\ \left(Dp_{Ru103} * \mathrm{TDP\_Dp}_{E,\,Ru103,1st-y} \right) + \left(Dp_{Ru106} * \mathrm{TDP\_Dp}_{E,\,Ru106,1st-y} \right) + \\ \left(Dp_{Cs134} * \mathrm{TDP\_Dp}_{E,\,Cs-134,1st-y} \right) + \left(Dp_{Cs137} * \mathrm{TDP\_Dp}_{E,\,Cs-137,1st-y} \right) \end{array} \right]$$

$$Dp\_TDP\_Dp_{E,mix,1st-y} = \sum_{i}^{P+D} \left[\begin{array}{l} \left(260\,pCi/m^2 * \dfrac{1.10E-06mrem}{pCi/m^2} \right)_{I131} + \left(3600\,pCi/m^2 * \dfrac{2.97E-06mrem}{pCi/m^2} \right)_{Te132} + \\ \left(220\,pCi/m^2 * \dfrac{2.21E-05mrem}{pCi/m^2} \right)_{Ru103} + \left(50\,pCi/m^2 * \dfrac{2.21E-05mrem}{pCi/m^2} \right)_{Ru106} + \\ \left(68\,pCi/m^2 * \dfrac{1.10E-04mrem}{pCi/m^2} \right)_{Cs134} + \left(44.4\,pCi/m^2 * \dfrac{4.77E-05mrem}{pCi/m^2} \right)_{Cs137} \end{array} \right]$$

$$\mathrm{Dp\_TDP\_Dp}_{E,\,mix,1st-y} = 2.32E-02\,mrem$$

2. Calculate the Dp_DRL for the first-year time phase for Cs-137 as the marker radionuclide using the following equation.

$$DP\_DRL_{Cs-137,1st-y} = \frac{PAG_{1st} - y * Dp_{Cs-137}}{Dp\_TDP\_Dp_{E,mix,1st-y}} = \frac{2000mrem * \frac{44.4pCi}{m^2}}{2.31E-02mrem} = \frac{3.84E+06pCi}{m^2}$$

Where:

$Dp\_DRL_{Cs-137,\ 1st-y}$ =	Deposition Derived Response Level, the level of activity of "marker" radionuclide *i* at which the dose from all radionuclides in mixture would result in a dose equal to the PAG for the time phase (TP) under consideration, $\mu Ci/m^2$;
Dp_{Cs137} =	Deposition, the radioactivity level of "marker" radionuclide *i* per unit area of ground, (from Table 3-1), $\mu Ci/m^2$;
PAG_{1st-y} =	EPA's Protective Action Guide for the time phase under consideration, 2000 mrem; and
$Dp\_TDP\_Dp_{E,\ mix,\ 1st-y}$ =	Deposition Total Dose Parameter for Deposition, the sum of the external dose from groundshine and the internal (committed effective) dose from inhalation of resuspended material received, over the time phase under consideration, from the deposited radioactivity level of all parent radionuclide(s) *i* and any short-lived daughters, 2.31E-06 mrem (from Step 1).

Therefore, the Dp_DRL for Cs-137 that is equal to PAG of 2000 mrem for the first-year time phase is 3.84E+06 pCi/m^2. Areas with Cs-137 deposition activities greater to this value exceed the PAG of 2000 mrem.

Table 3-1. Calculation of Marker Radionuclide (Cs-137) Derived Response Level for a Radionuclide Mixture Based on Measured Isotopic Concentrations - Corrected for the Ground Roughness Factor (GRF), Radioactive Decay and Weathering Effects (WF)

Radio-Nuclide	Half-Life (d)	Branch Fraction	Measured Sample Activity (Dp_i) (pCi Sample)	[4]Estimated Sample Activity (Dp_i) (pCi Sample)	Early Phase: TDP_Dp (mrem per pCi/m^2)	Early Phase: Dpi * TDP_Dp (mrem)	Year One: TDP_Dp (mrem per pCi/m^2)	Year One: Dpi * TDP_Dp (mrem)	Year Two: TDP_Dp (mrem per pCi/m^2)	Year Two: Dpi * TDP_Dp (mrem)
I-131	8.04	-	2.60E+02		3.24E-07	8.41E-05	1.10E-06	2.87E-04	2.01E-20	5.22E-18
Te-132/I-132					1.70E-06	6.13E-03	2.97E-06	1.07E-02	4.76E-40	1.71E-36
Te-132	3.26	1	3.60E+03							
I-132	9.58E-02	1	3.60E+03							
Ru-103/Rh-103m					4.57E-07	1.00E-04	6.49E-06	1.43E-03	8.79E-09	1.93E-06
Ru-103	3.93E+01	1	2.20E+02							
Rh-103m	3.90E-02	0.997		2.19E+02						
Ru-106/Rh-106					3.73E-07	1.87E-05	2.21E-05	1.11E-03	9.56E-06	4.78E-04
Ru-106	3.68E+02	1		5.00E+01						
Rh-106	3.46E-04	1	5.00E+01							
Cs-134	7.53E+02	-	6.80E+01		1.55E-06	1.06E-04	1.10E-04	7.51E-03	6.81E-05	4.63E-03
Cs-137/Ba-137m					5.85E-07	2.60E-05	4.77E-05	2.12E-03	4.03E-05	1.79E-03
Cs-137	1.10E+04	1		4.44E+01						
Ba-137m	1.77E-03	0.946	4.20E+01							
				Dp_TDP_S_{mi}x =		6.47E-03		2.31E-02		6.90E-03
				DRL_{Cs137} =		6.86E+06		3.84E+06		3.22E+06

[1]The data in this table are only examples to demonstrate a calculational process. The results should not be used in prediction of relationships that would exist following a nuclear incident.
[2]Values are based on ICRP 60+ and are corrected for the ground roughness factor (GRF), radioactive decay and weathering effects (WF).
[3]Exposure rate at height of 1 m above ground and at time of deposition and are corrected for Ground Roughness Factor (GRF).
[4]Activity of non-gamma emitting or unmeasured radionuclides inferred from parent/daughter relationships. Short-lived daughters are assumed to be in secular equilibrium with parent radionuclides

Table 3-2. Deposition Derived Response Levels (DP_DRLs) and Total Dose Parameters for Surface Deposition (TDP_Dp) Corrected for Radioactive Decay and Weathering

				[c]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Uncorrected for GRF		[c]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Corrected for GRF		Early Phase		Year One		Year Two	
No.	Radio-Nuclide	[a]Half-Life (d)	Branch Fraction	ExDC (mrem/h per pCi/m²)	ExXC (mR/h per pCi/m²)	ExDF (mrem/h per pCi/m²)	ExXF (mR/h per pCi/m²)	[a,d]DRL (µCi/m²)	[b]TDP_Dp (mrem per pCi/m²)	[a,d]DRL (µCi/m²)	[b]TDP_Dp (mrem per pCi/m²)	[a,d]DRL (µCi/m²)	[b]TDP_Dp (mrem per pCi/m²)
1	Am-241	1.58E+05	-	3.10E-10	4.43E-10	2.54E-10	3.63E-10	5.29E+01	1.89E-05	3.53E+01	5.67E-05	6.91E+01	7.24E-06
2	Ba-140/La-140	NA	NA	3.13E-08	4.48E-08	2.57E-08	3.67E-08	4.52E+02	2.21E-06	1.78E+02	1.12E-05	2.22E+10	2.25E-14
	Ba-140	1.27E+01	1.00E+00	2.53E-09	3.61E-09	2.07E-09	2.96E-09	-	-	-	-	-	-
	La-140	1.68E+00	1.00E+00	2.88E-08	4.11E-08	2.36E-08	3.37E-08	see La-140 listed separately (as parent) below					
3	Ce144/Pr144/Pr144m	NA	NA	2.42E-09	3.45E-09	1.98E-09	2.83E-09	5.01E+03	2.00E-07	1.87E+02	1.07E-05	1.33E+02	3.77E-06
	Ce-144	2.84E+02	1.00E+00	2.45E-10	3.50E-10	2.01E-10	2.87E-10	-	-	-	-	-	-
	Pr-144	1.20E-02	9.82E-01	2.17E-09	3.10E-09	1.78E-09	2.54E-09	-	-	-	-	-	-
	Pr-144m	5.00E-03	1.78E-02	1.40E-10	2.00E-10	1.15E-10	1.64E-10	-	-	-	-	-	-
	Pr-144	1.20E-02	9.99E-01	2.17E-09	3.10E-09	1.78E-09	2.54E-09	-	-	-	-	-	-
4	Cf-252	9.64E+02	-	6.98E-12	9.97E-12	5.72E-12	8.18E-12	1.38E+02	7.25E-06	9.85E+01	2.03E-05	3.39E+02	1.47E-06
5	Cm-244	6.61E+03	-	8.58E-12	1.23E-11	7.04E-12	1.01E-11	8.95E+01	1.12E-05	6.22E+01	3.22E-05	1.60E+02	3.13E-06
6	Co-60	1.93E+03	-	3.06E-08	4.37E-08	2.51E-08	3.58E-08	4.14E+02	2.42E-06	1.06E+01	1.89E-04	3.49E+00	1.43E-04
7	Cs-134	7.53E+02	-	1.97E-08	2.81E-08	1.62E-08	2.31E-08	6.44E+02	1.55E-06	1.81E+01	1.10E-04	7.34E+00	6.81E-05
8	Cs-136	1.31E+01	-	2.70E-08	3.86E-08	2.21E-08	3.16E-08	5.22E+02	1.92E-06	2.01E+02	9.95E-06	1.45E+10	3.45E-14
9	Cs-137/Ba-137m	NA	NA	7.33E-09	1.05E-08	6.01E-09	8.59E-09	1.71E+03	5.85E-07	4.19E+01	4.77E-05	1.24E+01	4.03E-05
	Cs-137	1.10E+04	1.00E+00	3.98E-11	5.69E-11	3.26E-11	4.66E-11	-	-	-	-	-	-
	Ba-137m	1.77E-03	9.46E-01	7.71E-09	1.10E-08	6.32E-09	9.03E-09	-	-	-	-	-	-
10	Gd-153	2.42E+02	-	1.23E-09	1.76E-09	1.01E-09	1.44E-09	1.04E+04	9.62E-08	3.93E+02	5.09E-06	3.25E+02	1.54E-06
11	I-131	8.04E+00	-	4.85E-09	6.93E-09	3.98E-09	5.68E-09	3.09E+03	3.24E-07	1.81E+03	1.10E-06	2.49E+16	2.01E-20
12	I-132	9.58E-02	-	2.93E-08	4.19E-08	2.40E-08	3.43E-08	1.25E+04	8.00E-08	2.51E+04	7.97E-08	NA	NA
13	I-133	8.67E-01	-	8.22E-09	1.17E-08	6.74E-09	9.63E-09	5.15E+03	1.94E-07	9.89E+03	2.02E-07	1.76E+130	2.84E-134
14	I-134	3.65E-02	-	3.37E-08	4.81E-08	2.76E-08	3.95E-08	2.86E+04	3.50E-08	5.72E+04	3.50E-08	NA	NA
15	I-135/Xe135m	NA	NA	2.05E-08	2.92E-08	1.68E-08	2.40E-08	6.26E+03	1.60E-07	1.25E+04	1.60E-07	NA	NA
	I-135	2.75E-01	1.00E+00	1.96E-08	2.80E-08	1.61E-08	2.30E-08	-	-	-	-	-	-
	Xe-135m	1.06E-02	1.54E-01	5.58E-09	7.97E-09	4.58E-09	6.54E-09	-	-	-	-	-	-

Table 3-2. Deposition Derived Response Levels (DP_DRLs) and Total Dose Parameters for Surface Deposition (TDP_Dp) Corrected for Radioactive Decay and Weathering (continued)

				[c] Initial Dose and Exposure Rates at 1 m Above Ground Surface - Uncorrected for GRF		[c] Initial Dose and Exposure Rates at 1 m Above Ground Surface - Corrected for GRF		Early Phase		Year One		Year Two	
No.	Radio-Nuclide	[a] Half-Life (d)	Branch Fraction	ExDC (mrem/h per pCi/m²)	ExXC (mR/h per pCi/m²)	ExDF (mrem/h per pCi/m²)	ExXF (mR/h per pCi/m²)	[a,d] DRL (µCi/m²)	[b] TDP_Dp (mrem per pCi/m²)	[a,d] DRL (µCi/m²)	[b] TDP_Dp (mrem per pCi/m²)	[a,d] DRL (µCi/m²)	[b] TDP_Dp (mrem per pCi/m²)
16	Ir-192	7.40E+01	-	1.04E-08	1.49E-08	8.53E-09	1.22E-08	1.25E+03	8.00E-07	9.95E+01	2.01E-05	8.90E+02	5.62E-07
17	Kr-87	5.30E-02	-	1.12E-08	1.60E-08	9.18E-09	1.31E-08	5.94E+04	1.68E-08	1.19E+05	1.68E-08	NA	NA
18	Kr-88/Rb-88	NA	NA	3.29E-08	4.70E-08	2.70E-08	3.85E-08	9.04E+03	1.11E-07	1.81E+04	1.10E-07	NA	NA
	Kr-88	1.18E-01	1.00E+00	2.30E-08	3.29E-08	1.89E-08	2.69E-08	-	-	-	-	-	-
	Rb-88	1.24E-02	1.00E+00	9.87E-09	1.41E-08	8.09E-09	1.16E-08	-	-	-	-	-	-
19	La-140	1.68E+00	-	2.88E-08	4.11E-08	2.36E-08	3.37E-08	9.03E+02	1.11E-06	1.46E+03	1.37E-06	1.31E+68	3.82E-72
20	Mo-99/Tc-99m	NA	NA	3.70E-09	5.29E-09	3.04E-09	4.34E-09	5.45E+03	1.83E-07	6.93E+03	2.89E-07	1.85E+43	2.70E-47
	Mo-99	2.75E+00	1.00E+00	2.37E-09	3.39E-09	1.94E-09	2.78E-09	-	-	-	-	-	-
	Tc-99m	2.51E-01	8.76E-01	1.52E-09	2.17E-09	1.25E-09	1.78E-09	9.25E+04	1.08E-08	1.85E+05	1.08E-08	NA	NA
21	Np-239	2.36E+00	-	2.05E-09	2.93E-09	1.68E-09	2.40E-09	1.05E+04	9.52E-08	1.46E+04	1.37E-07	1.96E+50	2.55E-54
22	Pm-147	9.58E+02	-	3.73E-13	5.33E-13	3.06E-13	4.37E-13	7.17E+05	1.39E-09	3.34E+05	5.99E-09	2.93E+05	1.71E-09
23	Pu-238	3.20E+04	-	8.34E-12	1.19E-11	6.84E-12	9.77E-12	4.73E+01	2.11E-05	3.27E+01	6.12E-05	8.16E+01	6.13E-06
24	Pu-239	8.79E+06	-	3.78E-12	5.40E-12	3.10E-12	4.43E-12	4.29E+01	2.33E-05	2.97E+01	6.73E-05	7.36E+01	6.79E-06
25	Ra-226/Rn-222…	NA	NA	2.25E-08	3.21E-08	1.84E-08	2.63E-08	2.76E+02	3.62E-06	1.30E+01	1.53E-04	3.91E+00	1.28E-04
	Ra-226	5.84E+05	1.00E+00	8.14E-11	1.16E-10	6.67E-11	9.54E-11	-	-	-	-	-	-
	Rn-222	3.82E+00	1.00E+00	5.09E-12	7.27E-12	4.17E-12	5.96E-12	-	-	-	-	-	-
	Po-218	2.12E-03	1.00E+00	1.15E-13	1.64E-13	9.43E-14	1.35E-13	-	-	-	-	-	-
	Pb-214	1.86E-02	1.00E+00	3.20E-09	4.57E-09	2.62E-09	3.75E-09	-	-	-	-	-	-
	Bi-214	1.38E-02	1.00E+00	1.92E-08	2.74E-08	1.57E-08	2.25E-08	-	-	-	-	-	-
	Po-214	1.90E-09	1.00E+00	1.06E-12	1.51E-12	8.69E-13	1.24E-12	-	-	-	-	-	-
	At-218	2.31E-05	2.00E-04	4.85E-11	6.93E-11	3.98E-11	5.68E-11	-	-	-	-	-	-
	Bi-214	1.38E-02	1.00E+00	1.92E-08	2.74E-08	1.57E-08	2.25E-08	-	-	-	-	-	-
	Po-214	1.90E-09	1.00E+00	1.06E-12	1.51E-12	8.69E-13	1.24E-12	-	-	-	-	-	-
26	Ru-103/Rh-103m	NA	NA	5.99E-09	8.56E-09	4.91E-09	7.02E-09	2.19E+03	4.57E-07	3.08E+02	6.49E-06	5.69E+04	8.79E-09
	Ru-103	3.93E+01	1.00E+00	5.98E-09	8.54E-09	4.90E-09	7.01E-09	-	-	-	-	-	-

Table 3-2. Deposition Derived Response Levels (DP_DRLs) and Total Dose Parameters for Surface Deposition (TDP_Dp) Corrected for Radioactive Decay and Weathering (continued)

				[c]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Uncorrected for GRF		[c]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Corrected for GRF		Early Phase		Year One		Year Two	
No.	Radio-Nuclide	[a]Half-Life (d)	Branch Fraction	ExDC (mrem/h per pCi/m^2)	ExXC (mR/h per pCi/m^2)	ExDF (mrem/h per pCi/m^2)	ExXF (mR/h per pCi/m^2)	[a,d]DRL (µCi/m^2)	[b]TDP_Dp (mrem per pCi/m^2)	[a,d]DRL (µCi/m^2)	[b]TDP_Dp (mrem per pCi/m^2)	[a,d]DRL (µCi/m^2)	[b]TDP_Dp (mrem per pCi/m^2)
	Rh-103m	3.90E-02	9.97E-01	1.18E-11	1.69E-11	9.68E-12	1.38E-11	-	-	-	-	-	-
27	Ru-106/Rh-106	NA	NA	4.60E-09	6.57E-09	3.77E-09	5.39E-09	2.68E+03	3.73E-07	9.04E+01	2.21E-05	5.23E+01	9.56E-06
	Ru-106	3.68E+02	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-	-	-	-	-	-
	Rh-106	3.46E-04	1.00E+00	4.60E-09	6.57E-09	3.77E-09	5.39E-09	-	-	-	-	-	-
28	Sb-127/Te-127	NA	NA	9.12E-09	1.30E-08	7.48E-09	1.07E-08	1.95E+03	5.13E-07	2.01E+03	9.95E-07	2.06E+31	2.43E-35
	Sb-127	3.85E+00	1.00E+00	9.01E-09	1.29E-08	7.39E-09	1.06E-08	-	-	-	-	-	-
	Te-127	3.90E-01	8.24E-01	1.37E-10	1.96E-10	1.12E-10	1.60E-10	-	-	-	-	-	-
29	Sb-129/Te-129	NA	NA	1.95E-08	2.78E-08	1.60E-08	2.28E-08	1.01E+04	9.90E-08	2.01E+04	9.95E-08	NA	NA
	Sb-129	1.80E-01	1.00E+00	1.83E-08	2.61E-08	1.50E-08	2.14E-08	-	-	-	-	-	-
	Te-129	4.83E-02	7.75E-01	1.52E-09	2.17E-09	1.25E-09	1.78E-09	-	-	-	-	-	-
30	Se-75	1.20E+02	-	4.81E-09	6.87E-09	3.94E-09	5.63E-09	2.67E+03	3.75E-07	1.48E+02	1.35E-05	3.56E+02	1.40E-06
31	Sr-89	5.05E+01	-	9.14E-10	1.31E-09	7.49E-10	1.07E-09	1.40E+04	7.14E-08	1.59E+03	1.26E-06	7.00E+04	7.14E-09
32	Sr-90/Y-90	NA	NA	1.49E-09	2.13E-09	1.22E-09	1.75E-09	6.76E+03	1.48E-07	2.05E+02	9.76E-06	6.13E+01	8.16E-06
	Sr-90	1.06E+04	1.00E+00	2.19E-11	3.13E-11	1.80E-11	2.57E-11	-	-	-	-	-	-
	Y-90	2.67E+00	1.00E+00	1.47E-09	2.10E-09	1.21E-09	1.72E-09	1.39E+04	7.19E-08	1.80E+04	1.11E-07	8.54E+44	5.85E-49
33	Sr-91/Y-91m	NA	NA	1.36E-08	1.94E-08	1.12E-08	1.59E-08	6.54E+03	1.53E-07	1.31E+04	1.53E-07	NA	NA
	Sr-91	3.96E-01	1.00E+00	9.69E-09	1.38E-08	7.95E-09	1.14E-08	-	-	-	-	-	-
	Y-91m	3.45E-02	5.78E-01	6.79E-09	9.70E-09	5.57E-09	7.95E-09	-	-	-	-	-	-
34	Te-129m/Te-129	NA	NA	1.75E-09	2.50E-09	1.43E-09	2.05E-09	7.50E+03	1.33E-07	1.23E+03	1.63E-06	6.75E+05	7.41E-10
	Te-129m	3.36E+01	1.00E+00	7.59E-10	1.08E-09	6.22E-10	8.89E-10	-	-	-	-	-	-
	Te-129	4.83E-02	6.50E-01	1.52E-09	2.17E-09	1.25E-09	1.78E-09	4.80E+05	2.08E-09	9.59E+05	2.09E-09	NA	NA
35	[d]Te-131m/Te-131	NA	NA	1.93E-08	2.76E-08	1.58E-08	2.26E-08	1.64E+03	6.10E-07	2.93E+03	6.83E-07	6.90E+90	7.25E-95
	[d]Te-131m	1.25E+00	1.00E+00	1.79E-08	2.56E-08	1.47E-08	2.10E-08	-	-	-	-	-	-
	Te-131	1.74E-02	2.22E-01	6.32E-09	9.03E-09	5.18E-09	7.40E-09	3.21E+05	3.12E-09	6.42E+05	3.12E-09	NA	NA
36	Te-132/I-132	NA	NA	3.21E-08	4.59E-08	2.63E-08	3.76E-08	5.87E+02	1.70E-06	6.74E+02	2.97E-06	1.05E+36	4.76E-40

Table 3-2. Deposition Derived Response Levels (DP_DRLs) and Total Dose Parameters for Surface Deposition (TDP_Dp) Corrected for Radioactive Decay and Weathering (continued)

No.	Radio-Nuclide	[a]Half-Life (d)	Branch Fraction	[c]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Uncorrected for GRF: ExDC (mrem/h per pCi/m^2)	[c]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Uncorrected for GRF: ExXC (mR/h per pCi/m^2)	[c]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Corrected for GRF: ExDF (mrem/h per pCi/m^2)	[c]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Corrected for GRF: ExXF (mR/h per pCi/m^2)	Early Phase: [a,d]DRL ($\mu Ci/m^2$)	Early Phase: [b]TDP_Dp (mrem per pCi/m^2)	Year One: [a,d]DRL ($\mu Ci/m^2$)	Year One: [b]TDP_Dp (mrem per pCi/m^2)	Year Two: [a,d]DRL ($\mu Ci/m^2$)	Year Two: [b]TDP_Dp (mrem per pCi/m^2)
	Te-132	3.26E+00	1.00E+00	2.82E-09	4.03E-09	2.31E-09	3.30E-09	-	-	-	-	-	-
	I-132	9.58E-02	1.00E+00	2.93E-08	4.19E-08	2.40E-08	3.43E-08	-	-	-	-	-	-
37	Tm-170	1.29E+02	-	3.52E-10	5.03E-10	2.89E-10	4.12E-10	3.43E+04	2.92E-08	1.92E+03	1.04E-06	4.02E+03	1.24E-07
38	Xe-133	5.24E+00	-	5.26E-10	7.51E-10	4.31E-10	6.16E-10	3.11E+04	3.22E-08	2.56E+04	7.81E-08	6.74E+24	7.42E-29
39	Xe-135	3.79E-01	-	3.33E-09	4.76E-09	2.73E-09	3.90E-09	2.79E+04	3.58E-08	5.59E+04	3.58E-08	NA	NA
40	Xe-138	9.84E-03	-	1.43E-08	2.04E-08	1.17E-08	1.68E-08	2.51E+05	3.98E-09	5.02E+05	3.98E-09	NA	NA
41	Y-91	5.85E+01	-	9.94E-10	1.42E-09	8.15E-10	1.16E-09	1.28E+04	7.81E-08	1.27E+03	1.57E-06	2.83E+04	1.77E-08
42	Yb-169	3.20E+01	-	3.70E-09	5.29E-09	3.03E-09	4.33E-09	3.58E+03	2.79E-07	6.08E+02	3.29E-06	4.85E+05	1.03E-09

[a]Values from Turbo FRMAC 2.0, RFC 2, based on ICRP 60+ dosimetry model (DCFPAK, K. Eckerman).
[b]TDP (Total Dose Parameter), includes Equivalent Dose from groundshine and Committed Effective Dose from inhalation of resuspended material, corrected for radioactive decay and weathering.
[c]Values from Turbo FRMAC 2.0, RFC 2, based on ICRP 60+ dosimetry model.
[d]Te-131m values in this table are subject to change pending further development of new parent-daughter rules.

Table 3-3. Deposition Derived Response Levels (Dp_DRLs) and Total Dose Parameters for Surface Deposition (Dp_TDP) Corrected for Radioactive Decay (Not Corrected for Weathering)

				[c]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Uncorrected for GRF		[c]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Corrected for GRF		Early Phase		Year One		Year Two	
No.	Radio-Nuclide	[a]Half-Life (d)	[a]Branch Fraction	ExDC (mrem/h per pCi/m^2)	ExXC (mR/h per pCi/m^2)	ExDF (mrem/h per pCi/m^2)	ExXF (mR/h per pCi/m^2)	[a,d]DRL (µCi/m^2)	[b]TDP_Dp (mrem per pCi/m^2)	[a,d]DRL (µCi/m^2)	[b]TDP_Dp (mrem per pCi/m^2)	[a,d]DRL (µCi/m^2)	[b]TDP_Dp (mrem per pCi/m^2)
1	Am-241	1.58E+05	-	3.10E-10	4.43E-10	2.54E-10	3.63E-10	5.29E+01	1.89E-05	3.52E+01	5.68E-05	6.49E+01	7.70E-06
2	Ba-140/La-140	NA	NA	3.13E-08	4.48E-08	2.57E-08	3.67E-08	4.51E+02	2.22E-06	1.77E+02	1.13E-05	1.86E+10	2.69E-14
	Ba-140	1.27E+01	1.00E+00	2.53E-09	3.61E-09	2.07E-09	2.96E-09	-	-	-	-	-	-
	La-140	1.68E+00	1.00E+00	2.88E-08	4.11E-08	2.36E-08	3.37E-08	see La-140 listed separately (as parent) below					
3	Ce144/Pr144/Pr144m	NA	NA	2.42E-09	3.45E-09	1.98E-09	2.83E-09	5.01E+03	2.00E-07	1.73E+02	1.15E-05	1.06E+02	4.73E-06
	Ce-144	2.84E+02	1.00E+00	2.45E-10	3.50E-10	2.01E-10	2.87E-10	-	-	-	-	-	-
	Pr-144	1.20E-02	9.82E-01	2.17E-09	3.10E-09	1.78E-09	2.54E-09	-	-	-	-	-	-
	Pr-144m	5.00E-03	1.78E-02	1.40E-10	2.00E-10	1.15E-10	1.64E-10	-	-	-	-	-	-
	Pr-144	1.20E-02	9.99E-01	2.17E-09	3.10E-09	1.78E-09	2.54E-09	-	-	-	-	-	-
4	Cf-252	9.64E+02	-	6.98E-12	9.97E-12	5.72E-12	8.18E-12	1.38E+02	7.25E-06	9.85E+01	2.03E-05	3.37E+02	1.48E-06
5	Cm-244	6.61E+03	-	8.58E-12	1.23E-11	7.04E-12	1.01E-11	8.95E+01	1.12E-05	6.22E+01	3.22E-05	1.60E+02	3.13E-06
6	Co-60	1.93E+03	-	3.06E-08	4.37E-08	2.51E-08	3.58E-08	4.14E+02	2.42E-06	9.70E+00	2.06E-04	2.76E+00	1.81E-04
7	Cs-134	7.53E+02	-	1.97E-08	2.81E-08	1.62E-08	2.31E-08	6.44E+02	1.55E-06	1.66E+01	1.20E-04	5.82E+00	8.59E-05
8	Cs-136	1.31E+01	-	2.70E-08	3.86E-08	2.21E-08	3.16E-08	5.21E+02	1.92E-06	1.99E+02	1.01E-05	1.21E+10	4.13E-14
9	Cs-137/Ba-137m	NA	NA	7.33E-09	1.05E-08	6.01E-09	8.59E-09	1.71E+03	5.85E-07	3.84E+01	5.21E-05	9.82E+00	5.09E-05
	Cs-137	1.10E+04	1.00E+00	3.98E-11	5.69E-11	3.26E-11	4.66E-11	-	-	-	-	-	-
	Ba-137m	1.77E-03	9.46E-01	7.71E-09	1.10E-08	6.32E-09	9.03E-09	-	-	-	-	-	-
10	Gd-153	2.42E+02	-	1.23E-09	1.76E-09	1.01E-09	1.44E-09	1.04E+04	9.62E-08	3.65E+02	5.48E-06	2.60E+02	1.92E-06
11	I-131	8.04E+00	-	4.85E-09	6.93E-09	3.98E-09	5.68E-09	3.08E+03	3.25E-07	1.80E+03	1.11E-06	2.09E+16	2.39E-20
12	I-132	9.58E-02	-	2.93E-08	4.19E-08	2.40E-08	3.43E-08	1.25E+04	8.00E-08	2.51E+04	7.97E-08	NA	NA
13	I-133	8.67E-01	-	8.22E-09	1.17E-08	6.74E-09	9.63E-09	5.15E+03	1.94E-07	9.88E+03	2.02E-07	1.49E+130	3.36E-134
14	I-134	3.65E-02	-	3.37E-08	4.81E-08	2.76E-08	3.95E-08	2.86E+04	3.50E-08	5.72E+04	3.50E-08	NA	NA
15	I-135/Xe135m	NA	NA	2.05E-08	2.92E-08	1.68E-08	2.40E-08	6.25E+03	1.60E-07	1.25E+04	1.60E-07	NA	NA
	I-135	2.75E-01	1.00E+00	1.96E-08	2.80E-08	1.61E-08	2.30E-08	-	-	-	-	-	-
	Xe-135m	1.06E-02	1.54E-01	5.58E-09	7.97E-09	4.58E-09	6.54E-09	-	-	-	-	-	-

Table 3-3. Deposition Derived Response Levels (Dp_DRLs) and Total Dose Parameters for Surface Deposition (Dp_TDP) Corrected for Radioactive Decay (Not Corrected for Weathering) (continued)

No.	Radio-Nuclide	[a]Half-Life (d)	[a]Branch Fraction	[c]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Uncorrected for GRF: ExDC (mrem/h per pCi/m^2)	[c]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Uncorrected for GRF: ExXC (mR/h per pCi/m^2)	[c]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Corrected for GRF: ExDF (mrem/h per pCi/m^2)	[c]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Corrected for GRF: ExXF (mR/h per pCi/m^2)	Early Phase: [a,d]DRL (µCi/m^2)	Early Phase: [b]TDP_Dp (mrem per pCi/m^2)	Year One: [a,d]DRL (µCi/m^2)	Year One: [b]TDP_Dp (mrem per pCi/m^2)	Year Two: [a,d]DRL (µCi/m^2)	Year Two: [b]TDP_Dp (mrem per pCi/m^2)
16	Ir-192	7.40E+01	-	1.04E-08	1.49E-08	8.53E-09	1.22E-08	1.25E+03	8.00E-07	9.50E+01	2.11E-05	7.25E+02	6.90E-07
17	Kr-87	5.30E-02	-	1.12E-08	1.60E-08	9.18E-09	1.31E-08	5.94E+04	1.68E-08	1.19E+05	1.68E-08	NA	NA
18	Kr-88/Rb-88	NA	NA	3.29E-08	4.70E-08	2.70E-08	3.85E-08	9.04E+03	1.11E-07	1.81E+04	1.10E-07	NA	NA
	Kr-88	1.18E-01	1.00E+00	2.30E-08	3.29E-08	1.89E-08	2.69E-08	-	-	-	-	-	-
	Rb-88	1.24E-02	1.00E+00	9.87E-09	1.41E-08	8.09E-09	1.16E-08	-	-	-	-	-	-
19	La-140	1.68E+00	-	2.88E-08	4.11E-08	2.36E-08	3.37E-08	9.02E+02	1.11E-06	1.46E+03	1.37E-06	1.10E+68	4.55E-72
20	Mo-99/Tc-99m	NA	NA	3.70E-09	5.29E-09	3.04E-09	4.34E-09	5.44E+03	1.84E-07	6.92E+03	2.89E-07	1.56E+43	3.21E-47
	Mo-99	2.75E+00	1.00E+00	2.37E-09	3.39E-09	1.94E-09	2.78E-09	-	-	-	-	-	-
	Tc-99m	2.51E-01	8.76E-01	1.52E-09	2.17E-09	1.25E-09	1.78E-09	9.24E+04	1.08E-08	1.85E+05	1.08E-08	NA	NA
21	Np-239	2.36E+00	-	2.05E-09	2.93E-09	1.68E-09	2.40E-09	1.05E+04	9.52E-08	1.46E+04	1.37E-07	1.65E+50	3.03E-54
22	Pm-147	9.58E+02	-	3.73E-13	5.33E-13	3.06E-13	4.37E-13	7.17E+05	1.39E-09	3.24E+05	6.17E-09	2.40E+05	2.08E-09
23	Pu-238	3.20E+04	-	8.34E-12	1.19E-11	6.84E-12	9.77E-12	4.73E+01	2.11E-05	3.27E+01	6.12E-05	8.15E+01	6.13E-06
24	Pu-239	8.79E+06	-	3.78E-12	5.40E-12	3.10E-12	4.43E-12	4.29E+01	2.33E-05	2.97E+01	6.73E-05	7.35E+01	6.80E-06
25	Ra-226/Rn-222…	NA	NA	2.25E-08	3.21E-08	1.84E-08	2.63E-08	2.76E+02	3.63E-06	1.20E+01	1.67E-04	3.09E+00	1.62E-04
	Ra-226	5.84E+05	1.00E+00	8.14E-11	1.16E-10	6.67E-11	9.54E-11	-	-	-	-	-	-
	Rn-222	3.82E+00	1.00E+00	5.09E-12	7.27E-12	4.17E-12	5.96E-12	-	-	-	-	-	-
	Po-218	2.12E-03	1.00E+00	1.15E-13	1.64E-13	9.43E-14	1.35E-13	-	-	-	-	-	-
	Pb-214	1.86E-02	1.00E+00	3.20E-09	4.57E-09	2.62E-09	3.75E-09	-	-	-	-	-	-
	Bi-214	1.38E-02	1.00E+00	1.92E-08	2.74E-08	1.57E-08	2.25E-08	-	-	-	-	-	-
	Po-214	1.90E-09	1.00E+00	1.06E-12	1.51E-12	8.69E-13	1.24E-12	-	-	-	-	-	-
	At-218	2.31E-05	2.00E-04	4.85E-11	6.93E-11	3.98E-11	5.68E-11	-	-	-	-	-	-
	Bi-214	1.38E-02	1.00E+00	1.92E-08	2.74E-08	1.57E-08	2.25E-08	-	-	-	-	-	-
	Po-214	1.90E-09	1.00E+00	1.06E-12	1.51E-12	8.69E-13	1.24E-12	-	-	-	-	-	-
26	Ru-103/Rh-103m	NA	NA	5.99E-09	8.56E-09	4.91E-09	7.02E-09	2.19E+03	4.57E-07	3.00E+02	6.67E-06	4.70E+04	1.06E-08

Table 3-3. Deposition Derived Response Levels (Dp_DRLs) and Total Dose Parameters for Surface Deposition (Dp_TDP) Corrected for Radioactive Decay (Not Corrected for Weathering) (continued)

				[c]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Uncorrected for GRF		[c]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Corrected for GRF		Early Phase		Year One		Year Two	
No.	Radio-Nuclide	[a]Half-Life (d)	[a]Branch Fraction	ExDC (mrem/h per pCi/m^2)	ExXC (mR/h per pCi/m^2)	ExDF (mrem/h per pCi/m^2)	ExXF (mR/h per pCi/m^2)	[a,d]DRL (µCi/m^2)	[b]TDP_Dp (mrem per pCi/m^2)	[a,d]DRL (µCi/m^2)	[b]TDP_Dp (mrem per pCi/m^2)	[a,d]DRL (µCi/m^2)	[b]TDP_Dp (mrem per pCi/m^2)
	Ru-103	3.93E+01	1.00E+00	5.98E-09	8.54E-09	4.90E-09	7.01E-09	-	-	-	-	-	-
	Rh-103m	3.90E-02	9.97E-01	1.18E-11	1.69E-11	9.68E-12	1.38E-11	-	-	-	-	-	-
27	Ru-106/Rh-106	NA	NA	4.60E-09	6.57E-09	3.77E-09	5.39E-09	2.68E+03	3.73E-07	8.36E+01	2.39E-05	4.16E+01	1.20E-05
	Ru-106	3.68E+02	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-	-	-	-	-	-
	Rh-106	3.46E-04	1.00E+00	4.60E-09	6.57E-09	3.77E-09	5.39E-09	-	-	-	-	-	-
28	Sb-127/Te-127	NA	NA	9.12E-09	1.30E-08	7.48E-09	1.07E-08	1.95E+03	5.13E-07	2.01E+03	9.95E-07	1.74E+31	2.87E-35
	Sb-127	3.85E+00	1.00E+00	9.01E-09	1.29E-08	7.39E-09	1.06E-08	-	-	-	-	-	-
	Te-127	3.90E-01	8.24E-01	1.37E-10	1.96E-10	1.12E-10	1.60E-10	-	-	-	-	-	-
29	Sb-129/Te-129	NA	NA	1.95E-08	2.78E-08	1.60E-08	2.28E-08	1.01E+04	9.90E-08	2.01E+04	9.95E-08	NA	NA
	Sb-129	1.80E-01	1.00E+00	1.83E-08	2.61E-08	1.50E-08	2.14E-08	-	-	-	-	-	-
	Te-129	4.83E-02	7.75E-01	1.52E-09	2.17E-09	1.25E-09	1.78E-09	-	-	-	-	-	-
30	Se-75	1.20E+02	-	4.81E-09	6.87E-09	3.94E-09	5.63E-09	2.67E+03	3.75E-07	1.39E+02	1.44E-05	2.87E+02	1.74E-06
31	Sr-89	5.05E+01	-	9.14E-10	1.31E-09	7.49E-10	1.07E-09	1.40E+04	7.14E-08	1.53E+03	1.31E-06	5.76E+04	8.68E-09
32	Sr-90/Y-90	NA	NA	1.49E-09	2.13E-09	1.22E-09	1.75E-09	6.75E+03	1.48E-07	1.88E+02	1.06E-05	4.85E+01	1.03E-05
	Sr-90	1.06E+04	1.00E+00	2.19E-11	3.13E-11	1.80E-11	2.57E-11	-	-	-	-	-	-
	Y-90	2.67E+00	1.00E+00	1.47E-09	2.10E-09	1.21E-09	1.72E-09	1.39E+04	7.19E-08	1.80E+04	1.11E-07	7.20E+44	6.94E-49
33	Sr-91/Y-91m	NA	NA	1.36E-08	1.94E-08	1.12E-08	1.59E-08	6.54E+03	1.53E-07	1.31E+04	1.53E-07	NA	NA
	Sr-91	3.96E-01	1.00E+00	9.69E-09	1.38E-08	7.95E-09	1.14E-08	-	-	-	-	-	-
	Y-91m	3.45E-02	5.78E-01	6.79E-09	9.70E-09	5.57E-09	7.95E-09	-	-	-	-	-	-
34	Te-129m/Te-129	NA	NA	1.75E-09	2.50E-09	1.43E-09	2.05E-09	7.49E+03	1.34E-07	1.20E+03	1.67E-06	5.59E+05	8.94E-10
	Te-129m	3.36E+01	1.00E+00	7.59E-10	1.08E-09	6.22E-10	8.89E-10	-	-	-	-	-	-
	Te-129	4.83E-02	6.50E-01	1.52E-09	2.17E-09	1.25E-09	1.78E-09	4.80E+05	2.08E-09	9.59E+05	2.09E-09	NA	NA
35	[d]Te-131m/Te-131	NA	NA	1.93E-08	2.76E-08	1.58E-08	2.26E-08	1.64E+03	6.10E-07	2.93E+03	6.83E-07	5.82E+90	8.59E-95
	[d]Te-131m	1.25E+00	1.00E+00	1.79E-08	2.56E-08	1.47E-08	2.10E-08	-	-	-	-	-	-
	Te-131	1.74E-02	2.22E-01	6.32E-09	9.03E-09	5.18E-09	7.40E-09	3.21E+05	3.12E-09	6.42E+05	3.12E-09	NA	NA

Table 3-3. Deposition Derived Response Levels (Dp_DRLs) and Total Dose Parameters for Surface Deposition (Dp_TDP) Corrected for Radioactive Decay (Not Corrected for Weathering) (continued)

				[c]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Uncorrected for GRF		[c]Initial Dose and Exposure Rates at 1 m Above Ground Surface – Corrected for GRF		Early Phase		Year One		Year Two	
No.	Radio-Nuclide	[a]Half-Life (d)	[a]Branch Fraction	ExDC (mrem/h per pCi/m^2)	ExXC (mR/h per pCi/m^2)	ExDF (mrem/h per pCi/m^2)	ExXF (mR/h per pCi/m^2)	[a,d]DRL (µCi/m^2)	[b]TDP_Dp (mrem per pCi/m^2)	[a,d]DRL (µCi/m^2)	[b]TDP_Dp (mrem per pCi/m^2)	[a,d]DRL (µCi/m^2)	[b]TDP_Dp (mrem per pCi/m^2)
36	Te-132/I-132	NA	NA	3.21E-08	4.59E-08	2.63E-08	3.76E-08	5.87E+02	1.70E-06	6.73E+02	2.97E-06	8.86E+35	5.64E-40
	Te-132	3.26E+00	1.00E+00	2.82E-09	4.03E-09	2.31E-09	3.30E-09	-	-	-	-	-	-
	I-132	9.58E-02	1.00E+00	2.93E-08	4.19E-08	2.40E-08	3.43E-08	-	-	-	-	-	-
37	Tm-170	1.29E+02	-	3.52E-10	5.03E-10	2.89E-10	4.12E-10	3.42E+04	2.92E-08	1.80E+03	1.11E-06	3.24E+03	1.54E-07
38	Xe-133	5.24E+00	-	5.26E-10	7.51E-10	4.31E-10	6.16E-10	3.11E+04	3.22E-08	2.55E+04	7.84E-08	5.67E+24	8.82E-29
39	Xe-135	3.79E-01	-	3.33E-09	4.76E-09	2.73E-09	3.90E-09	2.79E+04	3.58E-08	5.58E+04	3.58E-08	NA	NA
40	Xe-138	9.84E-03	-	1.43E-08	2.04E-08	1.17E-08	1.68E-08	2.51E+05	3.98E-09	5.02E+05	3.98E-09	NA	NA
41	Y-91	5.85E+01	-	9.94E-10	1.42E-09	8.15E-10	1.16E-09	1.28E+04	7.81E-08	1.22E+03	1.64E-06	2.32E+04	2.16E-08
42	Yb-169	3.20E+01	-	3.70E-09	5.29E-09	3.03E-09	4.33E-09	3.57E+03	2.80E-07	5.94E+02	3.37E-06	4.02E+05	1.24E-09

[a]Values from Turbo FRMAC 2.0, RFC 2, based on ICRP 60+ dosimetry model (DCFPAK, K. Eckerman).
[b]TDP (Total Dose Parameter), includes Equivalent Dose from groundshine and Committed Effective Dose from inhalation of resuspended material, corrected for radioactive decay.
[c]Values from Turbo FRMAC 2.0, RFC 2, based on ICRP 60+ dosimetry model.
[d]Te-131m values in this table are subject to change pending further development of new parent-daughter rules.

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3.2 Calculating Total Dose Parameter Based on Exposure Rate Values

Total Dose Parameter for Exposure Rate (TDP_XR) values are provided for the EPA time phases (i.e., early, first year, second year). As described below (Section 3.2.1), TDP_XR values can be used to estimate the Total Effective Dose (TED) that an adult receptor would receive over each of the three time phases, based on the initial exposure rate reading at 1 m above the surface. Section 3.2.2 shows example of using the TED. Section 3.2.2 provides the method to calculate activity-weighted Total Dose Parameter for exposure rate values for a radionuclide mixture, (TDP_XR), which is applied in an example in section 3.2.4. Sections 3.2.5 and 3.2.6 provide further examples of calculation of TED and DRL for a mixture

3.2.1 Method Used to Calculate Exposure Rate Values for a Deposited Radionuclide and any Short-Lived Daughter Radionuclides in Secular Equilibrium

The following method is used to calculate TDP_XR values.

$$TDP\_XR_{E,i,TP} = \frac{PAG_{E,TP}}{DRL\_Dp_{E,i,TP}} * \frac{1}{ExXF_{ground,\,E,i}} \;,\quad \frac{mrem}{mR/h} = \frac{mrem}{\mu Ci/m^2} * \frac{\mu Ci/m^2}{mR/h}$$

Where:

$TDP\_XR_{E,\,i,\,TP}$ =	Total Dose Parameter for Exposure Rate, the sum of the external dose from groundshine and the internal (committed effective) dose from inhalation of resuspended material received, over the time phase under consideration, per unit of exposure rate (at a height of 1 m) of radionuclide *i*, and any short-lived daughters, mrem per mR/h;
PAG =	EPA's Protective Action Guide for the time phase under consideration, mrem;
$Dp\_DRL_{E,\,i,\,TP}$ =	Deposition Derived Response Level, the level of activity of "marker" radionuclide *i* at which the dose from radionuclide *i*, and any short-lived daughter radionuclides, would result in a dose equal to the PAG for the time phase under consideration, (as calculated above or from Table 3-2 or 3-3 depending on whether or not weathering adjustment is desired), µCi/m^2;
$ExXF_{ground,\,E,\,i}$ =	External Exposure Factor (effective), defined below; and
TP =	Time Phase, the period of time (i.e., early phase, 1st-y, 2nd-y) over which the assessment is performed.

$$ExXF_{ground,E,i} = \sum_{i}^{P+D}\left(\frac{ExDC_{E,i} * CF_1}{DXCF} * GRF\right)$$

Where:

$\sum_{i}^{P+D}$ =	Represents the summation of values from the parent radionuclide (P) and any short-lived daughter radionuclide(s) (D);
$ExXF_{ground,\,E,\,i}$ =	External Exposure Factor (effective), the exposure rate (adjusted for ground roughness) due to radionuclide *i*, and any short-lived daughters, per unit activity deposited on the ground, mR/h per µCi/m^2;
$ExDC_{ground,\,E,i}$ =	External Dose Coefficient (effective), the effective dose rate from the external exposure to radionuclide *i* per unit activity deposited on the ground, Sv·m^2/s·Bq, (values from ICRP 60+ dosimetry models (DCFPAK, 2006));
DXCF =	Dose to Exposure Conversion Factor, 0.7 mrem/mR (EPA, 1992, p. 7-11),
CF_1 =	Unit Conversion Factor, 1.33E+13 mrem·m^2/y·µCi per Sv·m^2/s·Bq,

$$\frac{1.33E13\,mrem\cdot m^2 \big/ h\cdot \mu Ci}{Sv\cdot m^2 \big/ s\cdot Bq} = \frac{Sv\cdot m^2}{s\cdot Bq} * \frac{10^5\,mrem}{Sv} * \frac{3600\,s}{h} * \frac{Bq}{dps} * \frac{3.7E4dps}{\mu Ci}$$; and

GRF = Ground Roughness Factor, a unitless constant (0.82) that compensates for the fact that the external exposure is not coming from an infinite flat plane (HPS 2002).

Table 3-4a. Calculation of Total Dose Parameters Based on Exposure Rate (TDP_XR) - Corrected for the Ground Roughness Factor (GRF), Radioactive Decay, and Weathering (continued)

No.	Radio-Nuclide	[1]Half-Life (d)	Branch Fraction	[3]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Corrected for GRF: ExDF (mrem/hr per pCi/m^2)	ExXF (mR/hr per pCi/m^2)	Early Phase: [1]DRL (µCi/m^2)	[2]TDP_XR (mrem per mR/hr)	Year One: [1]DRL (µCi/m^2)	[2]TDP_XR (mrem per mR/hr)	Year Two: [1]DRL (µCi/m^2)	[2]TDP_XR (mrem per mR/hr)
1	Am-241	1.58E+05	-	2.54E-10	3.63E-10	5.29E+01	5.21E+04	3.53E+01	1.56E+05	6.91E+01	1.99E+04
2	Ba-140/La-140	NA	NA	2.57E-08	3.67E-08	4.52E+02	6.03E+01	1.78E+02	3.06E+02	2.22E+10	6.14E-07
	Ba-140	1.27E+01	1.00E+00	2.07E-09	2.96E-09	-	-	-	-	-	-
	La-140	1.68E+00	1.00E+00	2.36E-08	3.37E-08	see La-140 listed separately (as parent) below					
3	Ce144/Pr144/Pr144m	NA	NA	1.98E-09	2.83E-09	5.01E+03	7.05E+01	1.87E+02	3.78E+03	1.33E+02	1.33E+03
	Ce-144	2.84E+02	1.00E+00	2.01E-10	2.87E-10	-	-	-	-	-	-
	Pr-144	1.20E-02	9.82E-01	1.78E-09	2.54E-09	-	-	-	-	-	-
	Pr-144m	5.00E-03	1.78E-02	1.15E-10	1.64E-10	-	-	-	-	-	-
	Pr-144	1.20E-02	9.99E-01	1.78E-09	2.54E-09	-	-	-	-	-	-
4	Cf-252	9.64E+02	-	5.72E-12	8.18E-12	1.38E+02	8.86E+05	9.85E+01	2.48E+06	3.39E+02	1.80E+05
5	Cm-244	6.61E+03	-	7.04E-12	1.01E-11	8.95E+01	1.11E+06	6.22E+01	3.20E+06	1.60E+02	3.11E+05
6	Co-60	1.93E+03	-	2.51E-08	3.58E-08	4.14E+02	6.74E+01	1.06E+01	5.26E+03	3.49E+00	4.00E+03
7	Cs-134	7.53E+02	-	1.62E-08	2.31E-08	6.44E+02	6.73E+01	1.81E+01	4.79E+03	7.34E+00	2.95E+03
8	Cs-136	1.31E+01	-	2.21E-08	3.16E-08	5.22E+02	6.06E+01	2.01E+02	3.15E+02	1.45E+10	1.09E-06
9	Cs-137/Ba-137m	NA	NA	6.01E-09	8.59E-09	1.71E+03	6.81E+01	4.19E+01	5.56E+03	1.24E+01	4.69E+03
	Cs-137	1.10E+04	1.00E+00	3.26E-11	4.66E-11	-	-	-	-	-	-
	Ba-137m	1.77E-03	9.46E-01	6.32E-09	9.03E-09	-	-	-	-	-	-
10	Gd-153	2.42E+02	-	1.01E-09	1.44E-09	1.04E+04	6.67E+01	3.93E+02	3.53E+03	3.25E+02	1.07E+03
11	I-131	8.04E+00	-	3.98E-09	5.68E-09	3.09E+03	5.70E+01	1.81E+03	1.94E+02	2.49E+16	3.53E-12
12	I-132	9.58E-02	-	2.40E-08	3.43E-08	1.25E+04	2.33E+00	2.51E+04	2.32E+00	NA	NA
13	I-133	8.67E-01	-	6.74E-09	9.63E-09	5.15E+03	2.02E+01	9.89E+03	2.10E+01	1.76E+130	2.95E-126
14	I-134	3.65E-02	-	2.76E-08	3.95E-08	2.86E+04	8.86E-01	5.72E+04	8.86E-01	NA	NA
15	I-135/Xe135m	NA	NA	1.68E-08	2.40E-08	6.26E+03	6.67E+00	1.25E+04	6.68E+00	NA	NA
	I-135	2.75E-01	1.00E+00	1.61E-08	2.30E-08	-	-	-	-	-	-
	Xe-135m	1.06E-02	1.54E-01	4.58E-09	6.54E-09	-	-	-	-	-	-
16	Ir-192	7.40E+01	-	8.53E-09	1.22E-08	1.25E+03	6.57E+01	9.95E+01	1.65E+03	8.90E+02	4.61E+01
17	Kr-87	5.30E-02	-	9.18E-09	1.31E-08	5.94E+04	1.28E+00	1.19E+05	1.28E+00	NA	NA

Table 3-4a. Calculation of Total Dose Parameters Based on Exposure Rate (TDP_XR) - Corrected for the Ground Roughness Factor (GRF), Radioactive Decay, and Weathering (continued)

				[3]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Corrected for GRF		Early Phase		Year One		Year Two	
No.	Radio-Nuclide	[1]Half-Life (d)	Branch Fraction	ExDF (mrem/hr per pCi/m^2)	ExXF (mR/hr per pCi/m^2)	[1]DRL (µCi/m^2)	[2]TDP_XR (mrem per mR/hr)	[1]DRL (µCi/m^2)	[2]TDP_XR (mrem per mR/hr)	[1]DRL (µCi/m^2)	[2]TDP_XR (mrem per mR/hr)
18	Kr-88/Rb-88	NA	NA	2.70E-08	3.85E-08	9.04E+03	2.87E+00	1.81E+04	2.87E+00	NA	NA
	Kr-88	1.18E-01	1.00E+00	1.89E-08	2.69E-08	-	-	-	-	-	-
	Rb-88	1.24E-02	1.00E+00	8.09E-09	1.16E-08	-	-	-	-	-	-
19	La-140	1.68E+00	-	2.36E-08	3.37E-08	9.03E+02	3.28E+01	1.46E+03	4.06E+01	1.31E+68	1.13E-64
20	Mo-99/Tc-99m	NA	NA	3.04E-09	4.34E-09	5.45E+03	4.23E+01	6.93E+03	6.66E+01	1.85E+43	6.23E-39
	Mo-99	2.75E+00	1.00E+00	1.94E-09	2.78E-09	-	-	-	-	-	-
	Tc-99m	2.51E-01	8.76E-01	1.25E-09	1.78E-09	9.25E+04	6.07E+00	1.85E+05	6.07E+00	NA	NA
21	Np-239	2.36E+00	-	1.68E-09	2.40E-09	1.05E+04	3.97E+01	1.46E+04	5.70E+01	1.96E+50	1.06E-45
22	Pm-147	9.58E+02	-	3.06E-13	4.37E-13	7.17E+05	3.19E+03	3.34E+05	1.37E+04	2.93E+05	3.91E+03
23	Pu-238	3.20E+04	-	6.84E-12	9.77E-12	4.73E+01	2.16E+06	3.27E+01	6.26E+06	8.16E+01	6.27E+05
24	Pu-239	8.79E+06	-	3.10E-12	4.43E-12	4.29E+01	5.26E+06	2.97E+01	1.52E+07	7.36E+01	1.53E+06
25	Ra-226/Rn-222…	NA	NA	1.84E-08	2.63E-08	2.76E+02	1.37E+02	1.30E+01	5.82E+03	3.91E+00	4.86E+03
	Ra-226	5.84E+05	1.00E+00	6.67E-11	9.54E-11	-	-	-	-	-	-
	Rn-222	3.82E+00	1.00E+00	4.17E-12	5.96E-12	-	-	-	-	-	-
	Po-218	2.12E-03	1.00E+00	9.43E-14	1.35E-13	-	-	-	-	-	-
	Pb-214	1.86E-02	1.00E+00	2.62E-09	3.75E-09	-	-	-	-	-	-
	Bi-214	1.38E-02	1.00E+00	1.57E-08	2.25E-08	-	-	-	-	-	-
	Po-214	1.90E-09	1.00E+00	8.69E-13	1.24E-12	-	-	-	-	-	-
	At-218	2.31E-05	2.00E-04	3.98E-11	5.68E-11	-	-	-	-	-	-
	Bi-214	1.38E-02	1.00E+00	1.57E-08	2.25E-08	-	-	-	-	-	-
	Po-214	1.90E-09	1.00E+00	8.69E-13	1.24E-12	-	-	-	-	-	-
26	Ru-103/Rh-103m	NA	NA	4.91E-09	7.02E-09	2.19E+03	6.51E+01	3.08E+02	9.25E+02	5.69E+04	1.25E+00
	Ru-103	3.93E+01	1.00E+00	4.90E-09	7.01E-09	-	-	-	-	-	-
	Rh-103m	3.90E-02	9.97E-01	9.68E-12	1.38E-11	-	-	-	-	-	-
27	Ru-106/Rh-106	NA	NA	3.77E-09	5.39E-09	2.68E+03	6.92E+01	9.04E+01	4.11E+03	5.23E+01	1.77E+03
	Ru-106	3.68E+02	1.00E+00	0.00E+00	0.00E+00	-	-	-	-	-	-
	Rh-106	3.46E-04	1.00E+00	3.77E-09	5.39E-09	-	-	-	-	-	-
28	Sb-127/Te-127	NA	NA	7.48E-09	1.07E-08	1.95E+03	4.80E+01	2.01E+03	9.31E+01	2.06E+31	2.27E-27

Table 3-4a. Calculation of Total Dose Parameters Based on Exposure Rate (TDP_XR) - Corrected for the Ground Roughness Factor (GRF), Radioactive Decay, and Weathering (continued)

				[3]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Corrected for GRF		Early Phase		Year One		Year Two	
No.	Radio-Nuclide	[1]Half-Life (d)	Branch Fraction	ExDF (mrem/hr per pCi/m^2)	ExXF (mR/hr per pCi/m^2)	[1]DRL (μCi/m^2)	[2]TDP_XR (mrem per mR/hr)	[1]DRL (μCi/m^2)	[2]TDP_XR (mrem per mR/hr)	[1]DRL (μCi/m^2)	[2]TDP_XR (mrem per mR/hr)
	Sb-129	1.80E-01	1.00E+00	1.50E-08	2.14E-08	-	-	-	-	-	-
	Te-129	4.83E-02	7.75E-01	1.25E-09	1.78E-09	-	-	-	-	-	-
30	Se-75	1.20E+02	-	3.94E-09	5.63E-09	2.67E+03	6.65E+01	1.48E+02	2.40E+03	3.56E+02	2.49E+02
31	Sr-89	5.05E+01	-	7.49E-10	1.07E-09	1.40E+04	6.67E+01	1.59E+03	1.17E+03	7.00E+04	6.67E+00
32	Sr-90/Y-90	NA	NA	1.22E-09	1.75E-09	6.76E+03	8.46E+01	2.05E+02	5.58E+03	6.13E+01	4.67E+03
	Sr-90	1.06E+04	1.00E+00	1.80E-11	2.57E-11	-	-	-	-	-	-
	Y-90	2.67E+00	1.00E+00	1.21E-09	1.72E-09	1.39E+04	4.18E+01	1.80E+04	6.45E+01	8.54E+44	3.40E-40
33	Sr-91/Y-91m	NA	NA	1.12E-08	1.59E-08	6.54E+03	9.59E+00	1.31E+04	9.57E+00	NA	NA
	Sr-91	3.96E-01	1.00E+00	7.95E-09	1.14E-08	-	-	-	-	-	-
	Y-91m	3.45E-02	5.78E-01	5.57E-09	7.95E-09	-	-	-	-	-	-
34	Te-129m/Te-129	NA	NA	1.43E-09	2.05E-09	7.50E+03	6.52E+01	1.23E+03	7.95E+02	6.75E+05	3.62E-01
	Te-129m	3.36E+01	1.00E+00	6.22E-10	8.89E-10	-	-	-	-	-	-
	Te-129	4.83E-02	6.50E-01	1.25E-09	1.78E-09	4.80E+05	1.17E+00	9.59E+05	1.17E+00	NA	NA
35	Te-131m/Te-131	NA	NA	1.58E-08	2.26E-08	1.64E+03	2.70E+01	2.93E+03	3.02E+01	6.90E+90	3.20E-87
	Te-131m	1.25E+00	1.00E+00	1.47E-08	2.10E-08	-	-	-	-	-	-
	Te-131	1.74E-02	2.22E-01	5.18E-09	7.40E-09	3.21E+05	4.21E-01	6.42E+05	4.21E-01	NA	NA
36	Te-132/I-132	NA	NA	2.63E-08	3.76E-08	5.87E+02	4.53E+01	6.74E+02	7.89E+01	1.05E+36	1.27E-32
	Te-132	3.26E+00	1.00E+00	2.31E-09	3.30E-09	-	-	-	-	-	-
	I-132	9.58E-02	1.00E+00	2.40E-08	3.43E-08	-	-	-	-	-	-
37	Tm-170	1.29E+02	-	2.89E-10	4.12E-10	3.43E+04	7.07E+01	1.92E+03	2.53E+03	4.02E+03	3.02E+02
38	Xe-133	5.24E+00	-	4.31E-10	6.16E-10	3.11E+04	5.22E+01	2.56E+04	1.27E+02	6.74E+24	1.20E-19
39	Xe-135	3.79E-01	-	2.73E-09	3.90E-09	2.79E+04	9.19E+00	5.59E+04	9.17E+00	NA	NA
40	Xe-138	9.84E-03	-	1.17E-08	1.68E-08	2.51E+05	2.38E-01	5.02E+05	2.38E-01	NA	NA
41	Y-91	5.85E+01	-	8.15E-10	1.16E-09	1.28E+04	6.71E+01	1.27E+03	1.35E+03	2.83E+04	1.52E+01
42	Yb-169	3.20E+01	-	3.03E-09	4.33E-09	3.58E+03	6.44E+01	6.08E+02	7.59E+02	4.85E+05	2.38E-01

[1]Values from Turbo FRMAC 2.0, RFC 2, based on ICRP 60+ dosimetry model (DCFPAK, K. Eckerman).
[2]TDP_X include Equivalent Dose from groundshine and Committed Effective Dose from inhalation of resuspended material, corrected for radioactive decay and weathering.

Table 3-4b. Calculation of Total Dose Parameters Based on Exposure Rate (TDP_XR) - Corrected for the Ground Roughness Factor (GRF) and Radioactive Decay; Not Corrected for Weathering Effects

				[3]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Corrected for GRF		Early Phase		Year One		Year Two	
No.	Radio-Nuclide	[1]Half-Life (d)	[1]Branch Fraction	ExDF (mrem/hr per pCi/m^2)	ExXF (mR/hr per pCi/m^2)	[1]DRL (µCi/m^2)	[2]TDP_XR (mrem per mR/hr)	[1]DRL (µCi/m^2)	[2]TDP_XR (mrem per mR/hr)	[1]DRL (µCi/m^2)	[2]TDP_XR (mrem per mR/hr)
1	Am-241	1.58E+05	-	2.54E-10	3.63E-10	5.29E+01	5.21E+04	3.52E+01	1.56E+05	6.49E+01	2.12E+04
2	Ba-140/La-140	NA	NA	2.57E-08	3.67E-08	4.51E+02	6.04E+01	1.77E+02	3.08E+02	1.86E+10	7.32E-07
	Ba-140	1.27E+01	1.00E+00	2.07E-09	2.96E-09	-	-	-	-	-	-
	La-140	1.68E+00	1.00E+00	2.36E-08	3.37E-08	see La-140 listed separately (as parent) below		-	-	-	-
3	Ce144/Pr144/Pr144m	NA	NA	1.98E-09	2.83E-09	5.01E+03	7.05E+01	1.73E+02	4.08E+03	1.06E+02	1.67E+03
	Ce-144	2.84E+02	1.00E+00	2.01E-10	2.87E-10	-	-	-	-	-	-
	Pr-144	1.20E-02	9.82E-01	1.78E-09	2.54E-09	-	-	-	-	-	-
	Pr-144m	5.00E-03	1.78E-02	1.15E-10	1.64E-10	-	-	-	-	-	-
	Pr-144	1.20E-02	9.99E-01	1.78E-09	2.54E-09	-	-	-	-	-	-
4	Cf-252	9.64E+02	-	5.72E-12	8.18E-12	1.38E+02	8.86E+05	9.85E+01	2.48E+06	3.37E+02	1.81E+05
5	Cm-244	6.61E+03	-	7.04E-12	1.01E-11	8.95E+01	1.11E+06	6.22E+01	3.20E+06	1.60E+02	3.11E+05
6	Co-60	1.93E+03	-	2.51E-08	3.58E-08	4.14E+02	6.74E+01	9.70E+00	5.75E+03	2.76E+00	5.05E+03
7	Cs-134	7.53E+02	-	1.62E-08	2.31E-08	6.44E+02	6.73E+01	1.66E+01	5.22E+03	5.82E+00	3.72E+03
8	Cs-136	1.31E+01	-	2.21E-08	3.16E-08	5.21E+02	6.07E+01	1.99E+02	3.18E+02	1.21E+10	1.31E-06
9	Cs-137/Ba-137m	NA	NA	6.01E-09	8.59E-09	1.71E+03	6.81E+01	3.84E+01	6.06E+03	9.82E+00	5.93E+03
	Cs-137	1.10E+04	1.00E+00	3.26E-11	4.66E-11	-	-	-	-	-	-
	Ba-137m	1.77E-03	9.46E-01	6.32E-09	9.03E-09	-	-	-	-	-	-
10	Gd-153	2.42E+02	-	1.01E-09	1.44E-09	1.04E+04	6.67E+01	3.65E+02	3.80E+03	2.60E+02	1.33E+03
11	I-131	8.04E+00	-	3.98E-09	5.68E-09	3.08E+03	5.71E+01	1.80E+03	1.96E+02	2.09E+16	4.21E-12
12	I-132	9.58E-02	-	2.40E-08	3.43E-08	1.25E+04	2.33E+00	2.51E+04	2.32E+00	NA	NA
13	I-133	8.67E-01	-	6.74E-09	9.63E-09	5.15E+03	2.02E+01	9.88E+03	2.10E+01	1.49E+130	3.48E-126
14	I-134	3.65E-02	-	2.76E-08	3.95E-08	2.86E+04	8.86E-01	5.72E+04	8.86E-01	NA	NA
15	I-135/Xe135m	NA	NA	1.68E-08	2.40E-08	6.25E+03	6.68E+00	1.25E+04	6.68E+00	NA	NA
	I-135	2.75E-01	1.00E+00	1.61E-08	2.30E-08	-	-	-	-	-	-
	Xe-135m	1.06E-02	1.54E-01	4.58E-09	6.54E-09	-	-	-	-	-	-
16	Ir-192	7.40E+01	-	8.53E-09	1.22E-08	1.25E+03	6.57E+01	9.50E+01	1.73E+03	7.25E+02	5.66E+01
17	Kr-87	5.30E-02	-	9.18E-09	1.31E-08	5.94E+04	1.28E+00	1.19E+05	1.28E+00	NA	NA

Table 3-4b. Calculation of Total Dose Parameters Based on Exposure Rate (TDP_X) - Corrected for the Ground Roughness Factor (GRF) and Radioactive Decay; Not Corrected for Weathering Effects (continued)

				[3]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Corrected for GRF		Early Phase		Year One		Year Two	
No.	Radio-Nuclide	[1]Half-Life (d)	[1]Branch Fraction	ExDF (mrem/hr per pCi/m^2)	ExXF (mR/hr per pCi/m^2)	[1]DRL (µCi/m^2)	[2]TDP_XR (mrem per mR/hr)	[1]DRL (µCi/m^2)	[2]TDP_XR (mrem per mR/hr)	[1]DRL (µCi/m^2)	[2]TDP_XR (mrem per mR/hr)
18	Kr-88/Rb-88	NA	NA	2.70E-08	3.85E-08	9.04E+03	2.87E+00	1.81E+04	2.87E+00	NA	NA
	Kr-88	1.18E-01	1.00E+00	1.89E-08	2.69E-08	-	-	-	-	-	-
	Rb-88	1.24E-02	1.00E+00	8.09E-09	1.16E-08	-	-	-	-	-	-
19	La-140	1.68E+00	-	2.36E-08	3.37E-08	9.02E+02	3.29E+01	1.46E+03	4.06E+01	1.10E+68	1.35E-64
20	Mo-99/Tc-99m	NA	NA	3.04E-09	4.34E-09	5.44E+03	4.24E+01	6.92E+03	6.67E+01	1.56E+43	7.39E-39
	Mo-99	2.75E+00	1.00E+00	1.94E-09	2.78E-09	-	-	-	-	-	-
	Tc-99m	2.51E-01	8.76E-01	1.25E-09	1.78E-09	9.24E+04	6.08E+00	1.85E+05	6.07E+00	NA	NA
21	Np-239	2.36E+00	-	1.68E-09	2.40E-09	1.05E+04	3.97E+01	1.46E+04	5.70E+01	1.65E+50	1.26E-45
22	Pm-147	9.58E+02	-	3.06E-13	4.37E-13	7.17E+05	3.19E+03	3.24E+05	1.41E+04	2.40E+05	4.77E+03
23	Pu-238	3.20E+04	-	6.84E-12	9.77E-12	4.73E+01	2.16E+06	3.27E+01	6.26E+06	8.15E+01	6.28E+05
24	Pu-239	8.79E+06	-	3.10E-12	4.43E-12	4.29E+01	5.26E+06	2.97E+01	1.52E+07	7.35E+01	1.54E+06
25	Ra-226/Rn-222…	NA	NA	1.84E-08	2.63E-08	2.76E+02	1.38E+02	1.20E+01	6.32E+03	3.09E+00	6.14E+03
	Ra-226	5.84E+05	1.00E+00	6.67E-11	9.54E-11	-	-	-	-	-	-
	Rn-222	3.82E+00	1.00E+00	4.17E-12	5.96E-12	-	-	-	-	-	-
	Po-218	2.12E-03	1.00E+00	9.43E-14	1.35E-13	-	-	-	-	-	-
	Pb-214	1.86E-02	1.00E+00	2.62E-09	3.75E-09	-	-	-	-	-	-
	Bi-214	1.38E-02	1.00E+00	1.57E-08	2.25E-08	-	-	-	-	-	-
	Po-214	1.90E-09	1.00E+00	8.69E-13	1.24E-12	-	-	-	-	-	-
	At-218	2.31E-05	2.00E-04	3.98E-11	5.68E-11	-	-	-	-	-	-
	Bi-214	1.38E-02	1.00E+00	1.57E-08	2.25E-08	-	-	-	-	-	-
	Po-214	1.90E-09	1.00E+00	8.69E-13	1.24E-12	-	-	-	-	-	-
26	Ru-103/Rh-103m	NA	NA	4.91E-09	7.02E-09	2.19E+03	6.51E+01	3.00E+02	9.50E+02	4.70E+04	1.52E+00
	Ru-103	3.93E+01	1.00E+00	4.90E-09	7.01E-09	-	-	-	-	-	-
	Rh-103m	3.90E-02	9.97E-01	9.68E-12	1.38E-11	-	-	-	-	-	-
27	Ru-106/Rh-106	NA	NA	3.77E-09	5.39E-09	2.68E+03	6.92E+01	8.36E+01	4.44E+03	4.16E+01	2.23E+03
	Ru-106	3.68E+02	1.00E+00	0.00E+00	0.00E+00	-	-	-	-	-	-
	Rh-106	3.46E-04	1.00E+00	3.77E-09	5.39E-09	-	-	-	-	-	-
28	Sb-127/Te-127	NA	NA	7.48E-09	1.07E-08	1.95E+03	4.80E+01	2.01E+03	9.31E+01	1.74E+31	2.69E-27

Table 3-4b. Calculation of Total Dose Parameters Based on Exposure Rate (TDP_X) - Corrected for the Ground Roughness Factor (GRF) and Radioactive Decay; Not Corrected for Weathering Effects (continued)

No.	Radio-Nuclide	[1]Half-Life (d)	[1]Branch Fraction	[3]Initial Dose and Exposure Rates at 1 m Above Ground Surface - Corrected for GRF: ExDF (mrem/hr per pCi/m²)	ExXF (mR/hr per pCi/m²)	Early Phase: [1]DRL (µCi/m²)	Early Phase: [2]TDP_XR (mrem per mR/hr)	Year One: [1]DRL (µCi/m²)	Year One: [2]TDP_XR (mrem per mR/hr)	Year Two: [1]DRL (µCi/m²)	Year Two: [2]TDP_XR (mrem per mR/hr)
	Sb-127	3.85E+00	1.00E+00	7.39E-09	1.06E-08	-	-	-	-	-	-
	Te-127	3.90E-01	8.24E-01	1.12E-10	1.60E-10	-	-	-	-	-	-
29	Sb-129/Te-129	NA	NA	1.60E-08	2.28E-08	1.01E+04	4.34E+00	2.01E+04	4.36E+00	NA	NA
	Sb-129	1.80E-01	1.00E+00	1.50E-08	2.14E-08	-	-	-	-	-	-
	Te-129	4.83E-02	7.75E-01	1.25E-09	1.78E-09	-	-	-	-	-	-
30	Se-75	1.20E+02	-	3.94E-09	5.63E-09	2.67E+03	6.65E+01	1.39E+02	2.55E+03	2.87E+02	3.09E+02
31	Sr-89	5.05E+01	-	7.49E-10	1.07E-09	1.40E+04	6.67E+01	1.53E+03	1.22E+03	5.76E+04	8.11E+00
32	Sr-90/Y-90	NA	NA	1.22E-09	1.75E-09	6.75E+03	8.48E+01	1.88E+02	6.09E+03	4.85E+01	5.90E+03
	Sr-90	1.06E+04	1.00E+00	1.80E-11	2.57E-11	-	-	-	-	-	-
	Y-90	2.67E+00	1.00E+00	1.21E-09	1.72E-09	1.39E+04	4.18E+01	1.80E+04	6.45E+01	7.20E+44	4.03E-40
33	Sr-91/Y-91m	NA	NA	1.12E-08	1.59E-08	6.54E+03	9.59E+00	1.31E+04	9.57E+00	NA	NA
	Sr-91	3.96E-01	1.00E+00	7.95E-09	1.14E-08	-	-	-	-	-	-
	Y-91m	3.45E-02	5.78E-01	5.57E-09	7.95E-09	-	-	-	-	-	-
34	Te-129m/Te-129	NA	NA	1.43E-09	2.05E-09	7.49E+03	6.52E+01	1.20E+03	8.14E+02	5.59E+05	4.37E-01
	Te-129m	3.36E+01	1.00E+00	6.22E-10	8.89E-10	-	-	-	-	-	-
	Te-129	4.83E-02	6.50E-01	1.25E-09	1.78E-09	4.80E+05	1.17E+00	9.59E+05	1.17E+00	NA	NA
35	Te-131m/Te-131	NA	NA	1.58E-08	2.26E-08	1.64E+03	2.70E+01	2.93E+03	3.02E+01	5.82E+90	3.80E-87
	Te-131m	1.25E+00	1.00E+00	1.47E-08	2.10E-08	-	-	-	-	-	-
	Te-131	1.74E-02	2.22E-01	5.18E-09	7.40E-09	3.21E+05	4.21E-01	6.42E+05	4.21E-01	NA	NA
36	Te-132/I-132	NA	NA	2.63E-08	3.76E-08	5.87E+02	4.53E+01	6.73E+02	7.90E+01	8.86E+35	1.50E-32
	Te-132	3.26E+00	1.00E+00	2.31E-09	3.30E-09	-	-	-	-	-	-
	I-132	9.58E-02	1.00E+00	2.40E-08	3.43E-08	-	-	-	-	-	-
37	Tm-170	1.29E+02	-	2.89E-10	4.12E-10	3.42E+04	7.09E+01	1.80E+03	2.69E+03	3.24E+03	3.74E+02
38	Xe-133	5.24E+00	-	4.31E-10	6.16E-10	3.11E+04	5.22E+01	2.55E+04	1.27E+02	5.67E+24	1.43E-19
39	Xe-135	3.79E-01	-	2.73E-09	3.90E-09	2.79E+04	9.19E+00	5.58E+04	9.19E+00	NA	NA
40	Xe-138	9.84E-03	-	1.17E-08	1.68E-08	2.51E+05	2.38E-01	5.02E+05	2.38E-01	NA	NA
41	Y-91	5.85E+01	-	8.15E-10	1.16E-09	1.28E+04	6.71E+01	1.22E+03	1.41E+03	2.32E+04	1.85E+01
42	Yb-169	3.20E+01	-	3.03E-09	4.33E-09	3.57E+03	6.46E+01	5.94E+02	7.77E+02	4.02E+05	2.87E-01

[1]Values from Turbo FRMAC 2.0, RFC 2, based on ICRP 60+ dosimetry model (DCFPAK, K. Eckerman).
[2]TDP_X include Equivalent Dose from groundshine and Committed Effective Dose from inhalation of resuspended material, corrected for radioactive decay and weathering.

3.2.2 *Example of Using Total Dose Parameter for Exposure Rate to Estimate the Dose from a Deposited Radionuclide and any Short-Lived Daughter Radionuclides in Secular Equilibrium*

The following equation can be used to estimate the TED that an adult receptor would receive over each of the three time phases, based on the initial exposure rate reading at 1 m above the surface.

$$TED_{i,TP} = ExXR_i * TDP\_XR_{E,i,TP} \quad , \quad mrem = \frac{mR}{h} * \frac{mrem}{mR/h}$$

Where:

$TED_{i,TP}$ =	Total Effective Dose , the sum of the external dose from groundshine and the internal (committed effective) dose from inhalation of resuspended radionuclide *i*, and any short-lived daughter radionuclides, over the time phase of interest, mrem;
$ExXR_i$ =	External Exposure Rate, initial exposure rate of the radionuclide *i* deposited on the ground that is adjusted for the GRF and measured at a height of 1 m, mR/h; and
$TDP\_XR_{E,i,TP}$ =	Total Dose Parameter for Exposure Rate, the sum of the external dose from groundshine and the internal (committed effective) dose from inhalation of resuspended material received, over the time phase under consideration, per unit of exposure rate (at a height of 1 m) of radionuclide *i*, and any short-lived daughters, mrem per mR/h.

Use Table 3-4a to estimate the TED for the 1^{st}-year from deposited ^{137}Cs if the initial exposure rate reading was 2.0 mR/hr.

$$TED_{Cs137,1st-y} = \frac{2.0mR}{h} * \frac{5.56E3mrem}{mR/h} = 11{,}120mrem$$

3.2.3 *Method Used to Calculate Activity-Weighted Total Dose Parameter for Exposure Rate Values for a Radionuclide Mixture*

Tables 3-4c and 3-4d provide the activity-weighted TDP_XR values for a radionuclide mixture which are based on the measured isotopic concentrations in samples. The TDP_XR values are for material which has been deposited on the surface (ground) and include the effective dose from groundshine and the committed effective dose from the inhalation of resuspended material. The TDP_XR values do not include the in-plume dose (i.e., inhalation, air submersion). The TDP_XR values in Table 3-4c are adjusted for the GRF, radioactive decay and weathering effects. The TDP_XR values in Table 3-4d are adjusted for the GRF and radioactive decay, but are not adjusted for WF.

Table 3-4c. [a,b]Example Calculation of Activity-Weighted Total Dose Parameters for Exposure Rate for a Radionuclide Mixture Based on Measured Isotopic Concentrations - Corrected for the Ground Roughness Factor, Radioactive Decay and Weathering Effects

Radio-Nuclide	[c]Half-Life (d)	Branch Fraction	[c]Initial Exposure Rate, ExXC (mR/h per pCi/m²)	Measured Sample Activity (Dp_i) (pCi Sample)	[d]Estimated Sample Activity (Dp_i) (pCi Sample)	[e]Calculated Exposure Rate at 1 m, ExXR (mR/h)	Early Phase		Year One		Year Two	
							TDP_XR at 1 m (mrem per mR/h)	TED (mrem)	TDP_XR at 1 m (mrem per mR/h)	TED (mrem)	TDP_XR at 1 m (mrem per mR/h)	TED (mrem)
I-131	8.04	-	5.68E-09	2.60E+02		1.48E-06	5.70E+01	8.41E-05	1.94E+02	2.87E-04	3.53E-12	5.22E-18
Te-132/I-132							4.53E+01	6.13E-03	7.89E+01	1.07E-02	1.27E-32	1.71E-36
Te-132	3.26	1	3.30E-09	3.60E+03		1.19E-05						
I-132	9.58E-02	1	3.43E-08	3.60E+03		1.24E-04						
Ru-103/Rh-103m							6.51E+01	1.00E-04	9.25E+02	1.43E-03	1.25E+00	1.93E-06
Ru-103	3.93E+01	1	7.01E-09	2.20E+02		1.54E-06						
Rh-103m	3.90E-02	0.997	1.38E-11		2.19E+02	3.03E-09						
Ru-106/Rh-106							6.92E+01	1.87E-05	4.11E+03	1.11E-03	1.77E+03	4.78E-04
Ru-106	3.68E+02	1	0.00E+00		5.00E+01	0.00E+00						
Rh-106	3.46E-04	1	5.39E-09	5.00E+01		2.69E-07						
Cs-134	7.53E+02	-	2.31E-08	6.80E+01		1.57E-06	6.73E+01	1.06E-04	4.79E+03	7.51E-03	2.95E+03	4.63E-03
Cs-137/Ba-137m							6.81E+01	2.60E-05	5.56E+03	2.12E-03	4.69E+03	1.79E-03
Cs-137	1.10E+04	1	4.66E-11		4.44E+01	2.07E-09						
Ba-137m	1.77E-03	0.946	9.03E-09	4.20E+01		3.79E-07						
					Mixture Totals ($ExXR_{mix}$) =	1.41E-04		6.47E-03		2.31E-02		6.90E-03
					TDP_XR for Mixture ($TDP\_XR_{mixture}$) =		4.60E+01		1.64E+02		4.91E+01	

[a]The data in this table are only examples to demonstrate a calculational process. The results should not be used in prediction of relationships that would exist following a nuclear incident.
[b]Values are based on ICRP 60+ and are corrected for the ground roughness factor (GRF), radioactive decay and weathering effects (WCF).
[c]Exposure rate at height of 1 m above ground and at time of deposition and are corrected for ground roughness factor (GRF).
[d]Activity of non-gamma emitting or unmeasured radionuclides inferred from parent/daughter relationships. Short-lived daughters are assumed to be in secular equilibrium with parent radionuclides
[e]Values corrected for ground roughness factor (GRF).

Table 3-4d. [a,b]Example Calculation of the Activity-Weighted Total Dose Parameters for Exposure Rate for a Radionuclide Mixture Based on Measured Isotopic Concentrations - Corrected for the Ground Roughness Factor and Radioactive Decay; Not Corrected for Weathering Effects

Radio-Nuclide	[c]Half-Life (d)	Branch Fraction	[c]Initial Exposure Rate, ExXC (mR/h per pCi/m^2)	Measured Sample Activity (Dp_i) (pCi Sample)	[d]Estimated Sample Activity (Dp_i) (pCi Sample)	[e]Calculated Exposure Rate at 1 m, ExXR (mR/h)	Early Phase		Year One		Year Two	
							TDP_XR at 1 m (mrem per mR/h)	TED (mrem)	TDP_XR at 1 m (mrem per mR/h)	TED (mrem)	TDP_XR at 1 m (mrem per mR/h)	TED (mrem)
I-131	8.04	-	5.68E-09	2.60E+02		1.48E-06	5.71E+01	8.44E-05	1.96E+02	2.89E-04	4.21E-12	6.22E-18
Te-132/I-132							4.53E+01	6.13E-03	7.89E+01	1.07E-02	1.27E-32	1.71E-36
Te-132	3.26	1	3.30E-09	3.60E+03		1.19E-05						
I-132	9.58E-02	1	3.43E-08	3.60E+03		1.24E-04						
Ru-103/Rh-103m							6.51E+01	1.00E-04	9.50E+02	1.47E-03	1.52E+00	2.34E-06
Ru-103	3.93E+01	1	7.01E-09	2.20E+02		1.54E-06						
Rh-103m	3.90E-02	0.997	1.38E-11		2.19E+02	3.03E-09						
Ru-106/Rh-106							6.92E+01	1.87E-05	4.44E+03	1.20E-03	2.23E+03	6.01E-04
Ru-106	3.68E+02	1	0.00E+00		5.00E+01	0.00E+00						
Rh-106	3.46E-04	1	5.39E-09	5.00E+01		2.69E-07						
Cs-134	7.53E+02	-	2.31E-08	6.80E+01		1.57E-06	6.73E+01	1.06E-04	5.22E+03	8.19E-03	3.72E+03	5.84E-03
Cs-137/Ba-137m							6.81E+01	2.60E-05	6.06E+03	2.31E-03	5.93E+03	2.26E-03
Cs-137	1.10E+04	1	4.66E-11		4.44E+01	2.07E-09						
Ba-137m	1.77E-03	0.946	9.03E-09	4.20E+01		3.79E-07						
					Mixture Totals =	1.41E-04		6.47E-03		2.41E-02		8.71E-03
					TDP_XR for Mixture ($TDP\_XR_{mixture}$) =		4.60E+01		1.72E+02		6.19E+01	

[a]The data in this table are only examples to demonstrate a calculational process. The results should not be used in prediction of relationships that would exist following a nuclear incident.
[b]Values are based on ICRP 60+ and are corrected for the ground roughness factor (GRF), radioactive decay and weathering effects (WCF).
[c]Exposure rate at height of 1 m above ground and at time of deposition and are corrected for ground roughness factor (GRF).
[d]Activity of non-gamma emitting or unmeasured radionuclides inferred from parent/daughter relationships. Short-lived daughters are assumed to be in secular equilibrium with parent radionuclides
[e]Values corrected for ground roughness factor (GRF).

The following steps can be used to develop TDP_XR_{mix} values for a radionuclide mixture and to calculate projected future doses from gamma exposure rate measurements for individual radionuclides and for radionuclide mixtures.

1. Using spectral analysis of gamma emissions from an environmental sample of deposited radioactivity, determine the relative abundance of the principal gamma emitting radionuclides. It may be necessary to analyze uniform samples/measurements from several different locations to determine if the relative concentration of each radionuclide remains constant. The results of the various samples/measurements must be identically expressed as the activity of each radionuclide per surface are (e.g., pCi/m^2). As necessary, include the radioactivity of daughter radionuclides that are in secular equilibrium with their parent radionuclide(s), making sure to adjust the daughter activities for the branching fraction.

2. Multiply the measured or inferred activity (Dp_i) of each radionuclide from Step 1 by the corresponding External Exposure Coefficient (ExXC) (mR/h per pCi/m^2), from Table 3-1, which has been adjusted for the GRF to determine each radionuclide's contribution to the total exposure rate (mR/h) of the mixture. Sum the results for each radionuclide to obtain the total exposure rate from the deposited radionuclide mixture.

$$ExXR_{mix} = \sum_{i}^{P+D}\left(Dp_i * ExXC_i\right), \qquad \frac{mR}{h} = \frac{pCi}{m^2} * \frac{mR/h}{pCi/m^2}$$

Where:

$\sum_{i}^{P+D} =$ Represents the summation of values from all parent radionuclides (P) and any short-lived daughters (D) in secular equilibrium in the mixture;

$ExXR_{mix} =$ External Exposure Rate of the mixture, activity-weighted initial exposure rate of the radionuclide mixture deposited on the ground that is adjusted for the Ground Roughness Factor and measured at a height of 1 m, mR/h;

$Dp_i =$ Deposited activity concentration, the measured or estimated activity of radionuclide *i*, pCi/m^2; and

$ExXC_i =$ External Exposure Coefficient, the external exposure coefficient of radionuclide *i* deposited on the ground that is adjusted for the GRF and measured at a height of 1 m, mR/h per pCi/m^2.

3. Multiply the initial External Exposure Rate (ExXR) of each radionuclide in the mixture by the radionuclide's TDP_XR for the time phase of interest (early, first year, second year) to determine the TED that would be received by a receptor that remains in the contaminated area over the time period of interest. Sum the TED from the individual radionuclides to determine the TED from the deposited radionuclide mixture.

$$TED_{mix,TP} = \sum_{i}^{P+D}(ExXR_i * TDP\_XR_{E,i,TP}), \qquad mrem = \frac{mR}{h} * \frac{mrem}{mR/h}$$

Where:

$\sum_{i}^{P+D} =$ Represents the summation of values from all parent radionuclides (P) and any short-lived daughters (D) in secular equilibrium in the mixture;

$TED_{mix,\,TP} =$ Total Effective Dose, the sum of the external dose from groundshine and the internal (committed effective) dose from inhalation of resuspended radionuclide *i*, and any short-lived daughter radionuclides, over the time phase of interest, mrem;

$ExXR_i$ =	External exposure rate, initial exposure rate of the radionuclide *i* deposited on the ground that is adjusted for the GRF and measured at a height of 1 m, mR/h; and
$TDP\_XR_{E,i,TP}$ =	Total Dose Parameter for Exposure Rate, the sum of the external dose from groundshine and the internal (committed effective) dose from inhalation of resuspended material received, over the time phase under consideration, per unit of initial exposure rate (at a height of 1 m) of radionuclide *i*, and any short-lived daughters, mrem per mR/h.

4. Divide the total dose, effective for the mixture ($TED_{mix,TP}$) for the time phase of interest, from Step 3, by the activity-weighted initial exposure rate of the radionuclide mixture ($ExXR_{mix}$), from Step 2, to determine the total dose parameter for external exposure from the radionuclide mixture (TDP_XR_{mix}) for the time phase of interest.

$$TDP\_XR_{mix,TP} = \frac{TED_{mix,TP}}{ExXR_{mix}} \quad , \quad \frac{mrem}{mR/h} = \frac{mrem}{mR/h}$$

Table 3-6c and 3-6d provide the TDP_XR_i values over each of the three time phases for each radionuclide, and any short-lived daughters in secular equilibrium, in the radionuclide mixture. Table 3-4c and 3-4d also provide the TDP_XR_{mix} values for the entire radionuclide mixture over each of the three time phases.

3.2.4 Example Calculation of the Total Dose Parameter for Exposure Rate for a Mixture

Considering weathering effects, calculate the TDP_XR_{mix} for the mixture in Table 3-4c for the first-year time phase. Column 7 of Table 3-4c indicates that the initial total exposure rate of the radionuclide mixture is 1.41E-4 mR/h and Column 11 indicates this initial exposure rate equates to a projected dose of 2.31E-2 mrem over the first year. Therefore, the first-year TDP_XR for the mixture is:

$$TDP\_XR_{mix,1st-y} = \frac{TED_{mix,1st-y}}{ExXR_{mix}} = \frac{2.31E-2 mrem}{1.41E-4 mR/h} = \frac{163.8 mrem}{mR/h}$$

Where:

$TDP\_XR_{mix,1st-y}$ =	Total Dose Parameter for Exposure Rate, the sum of the external dose from groundshine and the internal (committed effective) dose from inhalation of resuspended material received, over the 1^{st}-y time phase, per unit of initial exposure rate (at a height of 1 m) of radionuclide *i*, and any short-lived daughters, mrem per mR/h;
$TED_{mix,1st-y}$ =	Total Effective Dose, the sum of the external dose from groundshine and the internal (committed effective) dose from inhalation of resuspended radionuclide *i*, and any short-lived daughter radionuclides, over the 1st-y time phase of interest, (from Table 3-3a) mrem; and
$ExXR_{mix}$ =	External Exposure Rate, initial exposure rate of the radionuclide mixture deposited on the ground that is adjusted for the GRF and measured at a height of 1 m, (from Table 3-4a) mR/h.

Therefore for this mixture, the projected dose over the first-year time phase is 164 mrem for each mR/h measured at the beginning of the period.

3.2.5 Example Calculation of the Total Effective Dose for a Mixture

Any measured exposure rate at 1 m above the deposited mixture can be multiplied by the TDP_XR for the time phase of interest to estimate the dose over that time phase. Based on the mixture in Table 3-4c and considering weathering effects, estimate the receptor's dose over the first-year time phase if the initial exposure rate at the point of interest is measured to be 12 mR/h.

$$TED_{mix,1st-y} = ExXR * TDP\_XR_{mix,1st-y} = \frac{12mR}{h} * \frac{163.8mrem}{mR/h} = 1{,}966mrem$$

Where:
All terms are as described above.

3.2.6 Example Calculation of the Derived Response Level for Exposure Rate for a Mixture

The DRL for the mixture can be expressed in terms of the initial exposure rate. Considering weathering effects, determine the derived response level for the mixture in Table 3-4a for the first-year time phase.

$$DRL\_XR_{mix,1st-y} = \frac{PAG_{1st-y}}{TDP\_X_{mix,1st-y}} = \frac{2000mrem}{\frac{163.8mrem}{mR/h}} = \frac{12.2mR}{h}.$$

Where:

$DRL\_XR_{mix,\ 1st-y}$ =	Derived Response Level for Exposure Rate for the mixture over the 1^{st}-y time phase, mR/h;
PAG_{1st-y} =	Applicable PAG for the 1^{st}-y time phase; and
$TDP\_XR_{mix,\ 1st-y}$ =	Total Dose Parameter for Exposure Rate, the sum of the effective dose from groundshine and the internal (committed effective) dose from inhalation of resuspended material received, over the 1^{st}-y time phase, per unit of initial exposure rate (at a height of 1 m) of radionuclide *i*, and any short-lived daughters, (from Table 3-4c) mrem per mR/h.

Therefore, for this mixture, an initial exposure rate reading of 12.2 mR/h represents the approximate boundary for the 2 rem (20 mSv) relocation PAG.

3.3 Calculation of Skin Dose from Groundshine and Contamination

3.3.1 Calculation of Skin Dose from Groundshine and Contamination - Groundshine Dose Adjusted for Radioactive Decay and Weathering

This section specifies the method to adjust the total skin equivalent dose for both radioactive decay and weathering effects. The total skin dose conversion factors estimate the total skin equivalent dose (HTotal, skin) that is received over the first-year period from materials deposited on the ground. Table 3-4a (including correction for weathering effects) and Table 3-4b (does not include correction for weathering effects) provide the dose conversion factors for the total skin equivalent dose (Hskin) that is received over the first-year period from materials deposited on the ground. The total skin equivalent dose includes dose contributions from groundshine and from material deposited directly on the skin surface (i.e., skin contamination).

3.3.1.1 Calculation of Skin Dose from Groundshine - Groundshine Dose Adjusted for Radioactive Decay and Weathering

The equation below is used to estimate the skin equivalent dose received from groundshine over the first-year period after deposition. It is assumed that the receptor is exposed to ground shine for 2080 hours during the first-year period (EPA 1989). It is further assumed the receptor is not exposed continuously over the exposure period, but is exposed intermittently for some period of time (e.g., 2080 hours) during the year. Therefore, it is necessary to use the Average Combined Removal Parameter (AvCRP) integrated over the time period of interest, rather than the CRP for the time period of interest, to estimate the groundshine dose over the first year.

$$H_{groundshine,skin,i,TP} = ExDC_{groundshine,skin,i} * CF_1 * GRF * AvCRP_{i,TP} * (AXP\_Dp_{groundshine} * CF_2)$$

$$H_{groundshine,skin,i} = \frac{Sv \cdot m2}{s \cdot Bq} * \frac{1.17E17 \, {}^{mrem \cdot m^2}\!/_{y \cdot \mu Ci}}{{}^{Sv \cdot m^2}\!/_{s \cdot Bq}} * unitless * unitless * \left(h * \frac{y}{h}\right) = {}^{mrem \cdot m^2}\!/_{\mu Ci}$$

Where:

$H_{groundshine,skin,i,TP}$ =	Equivalent dose to the skin from groundshine per unity activity of radionuclide *i* deposited on the ground and over the 1st-y time period, mrem·m²/μCi,
$ExDC_{groundshine,skin,i}$ =	External Dose Coefficient, value for the external equivalent dose to the skin per unity activity of radionuclide *i* deposited on the ground, Sv·m²/s·Bq, (values from ICRP 60+ dosimetry models (DCFPAK, 2006),
CF_1 =	Unit Conversion Factor, 1.17E+17 mrem·m²/y·μCi per Sv·m²/s·Bq,

$$\frac{1.17E17 \, {}^{mrem \cdot m^2}\!/_{y \cdot \mu Ci}}{{}^{Sv \cdot m^2}\!/_{s \cdot Bq}} = \frac{Sv \cdot m^2}{s \cdot Bq} * \frac{10^5 \, mrem}{Sv} * \frac{3.15E7s}{y} * \frac{Bq}{dps} * \frac{3.7E4dps}{\mu Ci}$$

GRF =	Ground Roughness Factor, a unitless constant (0.82) that compensates for the fact that the external exposure is not coming from an infinite flat plane (HPS 2002),
$AvCRP_{i,\,TP}$ =	Average Combined Removal Parameter, value that adjusts the external (groundshine) dose from radionuclide *i* for radioactive decay and weathering effects which decrease the groundshine dose over the time phase under consideration (see below for details of calculation method), h,
CF_2 =	Unit Conversion Factor to convert the hours to years, 1.14E-04 y/h, and
$AXP\_Dp_{groundshine}$ =	Annual Exposure Parameter for Deposition, the period of time over the 1st y during which receptor is assumed to be exposed to groundshine, 2080 h, (p. 12, EPA 1989).

Calculation of Average Combined Removal Parameter

The AvCRP is integrated over the time period of interest (i.e., first year) and is calculated using the following equation:

$$AvCRP_{i,TP} = \frac{\int_{T_1}^{T_2} \left(EffXP_{i,TP} * WF_{i,TP}\right) * CF}{\int_{T_1}^{T_2} dT} = \frac{CRP_{i,TP} * CF}{T_2 - T_1}$$

$$unitless = \frac{h * \frac{y}{h}}{y}$$

Where:

$AvCRP_{i, TP}$ =	Average Combined Removal Parameter, value that represents the average adjustment for the external dose (groundshine) from radionuclide *i* for radioactive decay and weathering over the time period of interest, h;
$CRP_{TP, i}$ =	Combined Removal Parameter, the value which adjusts the external (groundshine) dose from radionuclide *i* for radioactive decay and weathering, h,;
CF =	Unit Conversion Factor to convert the hours to years, 1.14E-04 y/h;
T_1 =	Time of the beginning of the integration period, 0 y; and
T_2 =	Time of the end of the integration period, 1 y.

Table 3-3c provides the TDP_XR values for radionuclides, in units of mrem per mR/h. TDP_XR values include the effective dose from groundshine and committed effective dose from the inhalation of resuspended material, and are adjusted for the ground roughness, radioactive decay and weathering effects. Table 3-3d provides the TDP_XR values for radionuclides, in units of mrem per mR/h, that are adjusted only for the ground roughness and radioactive decay (i.e., weathering effects are not considered). TDP_XR values are provided for the EPA time phases (i.e., early, first year, and second year). As described below, TDP_XR values can be used to estimate the TED that an adult receptor would receive over each of the three time phases, based on the initial exposure rate reading at 1 m above the surface.

3.3.1.2 Calculation of Skin Dose from Skin Contamination over the First Year

The method below is used to estimate the skin equivalent dose that is received over the first year from radioactive contamination deposited on the surface of the skin. It is assumed that the receptor has contamination on their skin for 800 hours during the first year after deposition (EPA 1989). It is also assumed that the fraction of the contamination on the surface (e.g., ground) that is on the receptor's skin is 0.0625 for the maximally exposed receptor and 0.00625 for the average exposed receptor. Finally, using the logic presented in Section 3.2.1.1, the AvCRP and not the CRP must be used to adjust the material that is available to be deposited on the skin for radioactive decay and weathering effects.

$$H_{contam,skin,i,TP} = DRCF_{contam,skin,i,TP} * CF_1 * SSF_{contam} * AvCRP_{i,TP} * (AXP\_C_{contam} * CF)$$

$$H_{contam,i,TP} = \frac{Sv \cdot cm^2}{y \cdot Bq} * \frac{3.70E5 \; {}^{mrem \cdot m^2}\!\big/_{y \cdot \mu Ci}}{{}^{Sv \cdot cm^2}\!\big/_{y \cdot Bq}} * unitless * unitless * \left(h * \frac{y}{h}\right) = {}^{mrem \cdot m^2}\!\big/_{\mu Ci}$$

Where:

$H_{contam,skin,i, TP}$ =	Equivalent dose to the skin per unit activity of radionuclide *i* deposited on the external surface of the skin (contamination) and over the 1^{st}-y time period, mrem·m^2/µCi;
$DRCF_{contam,skin,i,TP}$ =	Dose-Rate Conversion Factor, value the represents the equivalent dose to the skin from the electrons from radionuclide *i* deposited on the external surface of the skin and over the 1^{st}-y time period (Health Physics 53(2), p. 135-141, 1987), Sv·cm^2/y·Bq;
CF_1 =	Unit Conversion Factor, 3.70E+05 mrem / µCi/m^2 per Sv / Bq/cm^2;
SSF_{contam} =	Surface to Skin Factor for contamination, the fraction of the contamination on the surface (e.g., ground) that is deposited on the skin, 0.00625 or 0.0625 (unitless) (p. 32, EPA 1989);
$AvCRP_{i, TP}$ =	Average Combined Removal Parameter, value that represents the average adjustment for the external dose (groundshine) from radionuclide *i* for radioactive decay and weathering over the time period of interest (see Section 3.2.1.1 for details of calculation method), h;
CF =	Unit Conversion Factor to convert the hours to years, 1.14E-04 y/h; and

AXP_C$_{contam}$ = Annual Exposure Parameter for Contamination on the Skin, the period of time over the first year during which receptor is assumed to have contamination on the surface of their skin, 800 h, (p. 11, EPA 1989).

3.3.1.3 Calculation of Total Skin Dose Conversion Factor from Ground Shine and Skin Contamination over the First Year

The DCFs for the total skin equivalent dose that is received over the first-year period from materials deposited on the ground is derived by summing the equivalent doses from groundshine and contamination on the surface of the skin.

$$H_{Total,skin,i,TP} = H_{groundshine,skin,i,TP} + H_{contamination,skin,i,TP}$$

$$\frac{mrem \cdot m^2}{\mu Ci} = \frac{mrem \cdot m^2}{\mu Ci} + \frac{mrem \cdot m^2}{\mu Ci}$$

Where:

$H_{Total,\ skin,i,\ TP}$ = Total Equivalent dose to the skin per unit activity of radionuclide *i* deposited on the surface (e.g., ground) and over the 1st-y time period, mrem·m^2/μCi;

$H_{groundshine,skin,i,TP}$ = Equivalent dose to the skin from groundshine per unity activity of radionuclide *i* deposited on the ground and over the 1st-y time period, mrem·m^2/μCi; and

$H_{contam,skin,i,\ TP}$ = Equivalent dose to the skin from radioactive material deposited on the skin (contamination) per unit activity of radionuclide *i* deposited on the surface (ground) and over the 1st-y time period, mrem·m^2/μCi.

3.3.2 Calculation of Skin Dose from Groundshine and Contamination – Dose Adjusted Only for Radioactive Decay (i.e., Weathering Factor not Applied)

If desired the weathering factor (WF) can be ignored when calculating the total equivalent doses ($D_{Total,\ skin,i,\ TP}$) for Table 3-5b. To ignore the WF and to adjust the $D_{Total,\ skin,i,\ TP}$ for only radioactive decay, substitute the EffXP for the CRP to calculate the Average Effective Exposure Period (AvEffXP) instead of the AvCRP.

The AvEffXP is integrated over the time period of interest (i.e., first year) and is calculated using the following equation:

$$AvEffXP_{i,TP} = \frac{\int_{T_1}^{T_2} \left(EffXP_{i,TP}\right) * CF}{\int_{T_1}^{T_2} dT} = \frac{\int_{T_1}^{T_2} e^{(-T * \lambda_i)} dT * CF}{\int_{T_1}^{T_2} dT} = \frac{\left(\frac{e^{(-T_2 * \lambda_i)} - e^{(-T_1 * \lambda_i)}}{-\lambda_i}\right) * CF}{T_2 - T_1}$$

$$unitless = \frac{h * \frac{y}{h}}{y}$$

Where:

$AvEffXP_{i,\ TP}$ = Average Effective Exposure Period term integrated over the time period of interest (i.e., 1st-y), value that represents the average radioactive decay adjustment of the groundshine dose from radionuclide *i* over the time period of interest, unitless;

$EffXP_{i,\,TP}$ =	Effective Exposure Period, value that adjusts the groundshine dose from radionuclide *i* for radioactive decay that occurs over the time period under consideration, h;
λ_i =	Decay constant for radionuclide *i*, h^{-1};
CF =	Unit Conversion Factor to convert the hours to years, 1.14E-04 y/h;
T_1 =	Time of the beginning of the integration period, 0 y; and
T_2 =	Time of the end of the integration period, 1 y.

Table 3-5a. Calculation of Total Skin Dose from Contamination on the Ground (Correcting for Radioactive Decay and Weathering Effects)

		Groundshine Dose to Skin					Skin Contamination Dose				Total Skin Dose			Comparison to 1992 Values		
Radio-Nuclide	Branch Fraction	External Skin DCF[1] (Sv/s per Bq/m^2)	External Skin DCP (mrem/y per μCi/m^2)	External Skin DCF corrected for GRF (mrem/y per μCi/m^2)	[2]CRP for first year (corrects for rad. decay & WCF) (h)	[4]External Skin DCF (corrected for GRCF, rad. decay & WCF) (mrem/y per μCi/m^2)	Electron dose-rate factor at depth of 7 mg/cm^2 for contamination on skin[3] (Sv/y per Bq/cm^2)	Electron dose-rate factor at depth of 7 mg/cm^2 for contamination on skin (mrem/y per μCi/m^2)	Electron dose-rate factor corrected for skin to ground contamination ratio (mrem/y per μCi/m^2)	[5]Electron dose-rate factors for skin contam. contamination corrected for WCF & decay (mrem/y per μCi/m^2)	Total Skin Dose Groundshine + skin contamination (mrem/y per μCi/m^2)	Total Skin Dose Groundshine + skin contamination (mrem/y per pCi/m^2)	Total Skin Dose Groundshine + skin contamination Parent + Progeny (mrem/y per pCi/m^2)	1992 Value (mrem/y per μCi/m^2)	1992 Value (mrem/y per pCi/m^2)	Calculated Value Divided by 1992 Value
Co-58	NA	1.14E-15	1.33E+02	1.09E+02	2.28E+03	6.73E+00	2.80E-03	1.04E+03	6.48E+00	1.54E-01	6.89E+00	6.89E-06		1.20E-01	1.20E-07	57.39
Co-60	NA	2.76E-15	3.22E+02	2.64E+02	7.54E+03	5.39E+01	9.90E-03	3.66E+03	2.29E+01	1.80E+00	5.57E+01	5.57E-05		4.20E-01	4.20E-07	132.64
Se-75	NA	4.76E-16	5.55E+01	4.55E+01	3.44E+03	4.24E+00	8.40E-04	3.11E+02	1.94E+00	6.97E-02	4.31E+00	4.31E-06		NA	NA	NA
Rb-86	NA	7.72E-15	9.00E+02	7.38E+02	6.37E+02	1.27E+01	2.00E-02	7.40E+03	4.63E+01	3.07E-01	1.30E+01	1.30E-05		6.30E+01	6.30E-05	0.21
Kr-87	NA	1.35E-14	1.57E+03	1.29E+03	1.83E+00	6.40E-02	No data available	0.00E+00	0.00E+00	0.00E+00	6.40E-02	6.40E-08		NA	NA	NA
Kr-88	Na	4.43E-15	5.16E+02	4.23E+02	4.10E+00	4.71E-02	No data available	0.00E+00	0.00E+00	0.00E+00	4.71E-02	4.71E-08		NA	NA	NA
Sr-89	NA	6.66E-15	7.76E+02	6.37E+02	1.68E+03	2.90E+01	2.00E-02	7.40E+03	4.63E+01	8.10E-01	2.98E+01	2.98E-05		1.50E+02	1.50E-04	0.20
Sr-90	NA	1.40E-16	1.63E+01	1.34E+01	7.94E+03	2.88E+00	1.60E-02	5.92E+03	3.70E+01	3.06E+00	5.94E+00	5.94E-06		1.20E+01	1.20E-05	0.50
Y-90	1	1.05E-14	1.22E+03	1.00E+03	7.94E+03	2.16E+02	2.10E-02	7.77E+03	4.86E+01	4.02E+00	2.20E+02	2.20E-04				
Sr90/Y90	NA												2.26E-04	NA	NA	NA
Y-90, parent	NA	1.05E-14	1.22E+03	1.00E+03	9.21E+01	2.51E+00	2.10E-02	7.77E+03	4.86E+01	4.66E-02	2.55E+00	2.55E-06		2.20E+02	2.20E-04	0.01
Sr-91	NA	7.53E-15	8.78E+02	7.20E+02	1.37E+01	2.67E-01	2.00E-02	7.40E+03	4.63E+01	6.61E-03	2.74E-01	2.74E-07		NA	NA	NA
Y-91	NA	6.92E-15	8.07E+02	6.61E+02	1.92E+03	3.44E+01	2.00E-02	7.40E+03	4.63E+01	9.26E-01	3.53E+01	3.53E-05		1.60E+02	1.60E-04	0.22
Zr-95	NA	8.91E-16	1.04E+02	8.52E+01	2.08E+03	4.80E+00	1.20E-02	4.44E+03	2.78E+01	6.02E-01	5.40E+00	5.40E-06		7.20E-01	7.20E-07	7.50
Nb-95	0.993	9.05E-16	1.05E+02	8.65E+01	2.08E+03	4.88E+00	2.30E-03	8.51E+02	5.32E+00	1.15E-01	4.99E+00	4.99E-06		NA	NA	NA
Nb-95m	6.98E-03	1.09E-16	1.27E+01	1.04E+01	2.08E+03	5.87E-01	1.60E-02	5.92E+03	3.70E+01	8.02E-01	1.39E+00	1.39E-06		NA	NA	NA
Nb-95	1	9.05E-16	1.05E+02	8.65E+01	2.08E+03	4.88E+00	2.30E-03	8.51E+02	5.32E+00	1.15E-01	4.99E+00	4.99E-06		NA	NA	NA
Zr95/Nb95/Nb95m/Nb95													1.04E-05	NA	NA	NA
Nb-95, parent		9.05E-16	1.05E+02	8.65E+01	1.19E+03	2.79E+00	2.30E-03	8.51E+02	5.32E+00	6.60E-02	2.86E+00	2.86E-06		6.10E-01	6.10E-07	4.68

Table 3-5a. Calculation of Total Skin Dose from Contamination on the Ground (Correcting for Radioactive Decay and Weathering Effects) (continued)

		Groundshine Dose to Skin					Skin Contamination Dose				Total Skin Dose			Comparison to 1992 Values		
Radio-Nuclide	Branch Fraction	External Skin DCF[1] (Sv/s per Bq/m²)	External Skin DCP (mrem/y per µCi/m²)	External Skin DCF corrected for GRF (mrem/y per µCi/m²)	[2]CRP for first year (corrects for rad. decay & WCF) (h)	[4]External Skin DCF (corrected for GRCF, rad. decay & WCF) (mrem/y per µCi/m²)	Electron dose-rate factor at depth of 7 mg/cm² for contamination on skin[3] (Sv/y per Bq/cm²)	Electron dose-rate factor at depth of 7 mg/cm² for contamination on skin (mrem/y per µCi/m²)	Electron dose-rate factor corrected for skin to ground contamination ratio (mrem/y per µCi/m²)	[5]Electron dose-rate factors for skin contam. contamination corrected for WCF & decay (mrem/y per µCi/m²)	Total Skin Dose Groundshine + skin contamination (mrem/y per µCi/m²)	Total Skin Dose Groundshine + skin contamination (mrem/y per pCi/m²)	Total Skin Dose Groundshine + skin contamination Parent + Progeny (mrem/y per pCi/m²)	1992 Value (mrem/y per µCi/m²)	1992 Value (mrem/y per pCi/m²)	Calculated Value Divided by 1992 Value
Mo-99	NA	3.76E-15	4.38E+02	3.59E+02	9.50E+01	9.25E-01	1.90E-02	7.03E+03	4.39E+01	4.35E-02	9.69E-01	9.69E-07		4.40E+00	4.40E-06	0.22
Tc-99m	0.876	1.44E-16	1.68E+01	1.38E+01	9.50E+01	3.54E-02	2.10E-03	7.77E+02	4.86E+00	4.81E-03	4.02E-02	4.02E-08				
Tc99	1	Note: Tc99 not considered because its T1/2= 2.13E5 y and is too long to be in equilibrium														
Tc99	0.124	Note: Tc99 not considered because its T1/2= 2.13E5 y and is too long to be in equilibrium														
Mo99/Tc99m													1.00E-06	NA	NA	NA
Tc-99m, parent		1.44E-16	1.68E+01	1.38E+01	8.68E+00	3.24E-03	2.10E-03	7.77E+02	4.86E+00	4.39E-04	3.68E-03	3.68E-09		7.70E-03	7.70E-09	0.48
Rh-105	NA	1.76E-16	2.05E+01	1.68E+01	5.10E+01	2.33E-02	1.30E-02	4.81E+03	3.01E+01	1.60E-02	3.92E-02	3.92E-08		6.50E-02	6.50E-08	0.60
Ru-103	NA	6.16E-16	7.18E+01	5.89E+01	1.32E+03	2.11E+00	5.80E-03	2.15E+03	1.34E+01	1.85E-01	2.29E+00	2.29E-06		6.80E-01	6.80E-07	3.37
Ru-106	NA	0.00E+00	0.00E+00	0.00E+00	5.86E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		NA	NA	NA
Rh-106	1	1.42E-14	1.66E+03	1.36E+03	5.86E+03	2.16E+02	2.20E-02	8.14E+03	5.09E+01	3.11E+00	2.19E+02	2.19E-04		NA	NA	NA
Ru106/Rh106	NA												2.19E-04	6.40E-01	6.40E-07	341.67
Rh-106, parent		1.42E-14	1.66E+03	1.36E+03	1.20E-02	4.41E-04	2.20E-02	8.14E+03	5.09E+01	6.36E-06	4.48E-04	4.48E-10		NA	NA	NA
Sb-127	NA	2.85E-15	3.32E+02	2.72E+02	1.33E+02	9.82E-01	1.80E-02	6.66E+03	4.16E+01	5.77E-02	1.04E+00	1.04E-06		3.40E+00	3.40E-06	0.31
Te-127	0.824	5.40E-16	6.29E+01	5.16E+01	1.33E+02	1.86E-01	1.60E-02	5.92E+03	3.70E+01	5.13E-02	2.37E-01	2.37E-07				
Sb127/Te127													1.24E-06	NA	NA	NA
Te-127, parent	NA	5.40E-16	6.29E+01	5.16E+01	1.35E+01	1.89E-02	1.60E-02	5.92E+03	3.70E+01	5.21E-03	2.41E-02	2.41E-08		1.00E+00	1.00E-06	0.02
Te-127m	NA	5.20E-17	6.06E+00	4.97E+00	3.21E+03	4.32E-01	4.70E-03	1.74E+03	1.09E+01	3.64E-01	7.96E-01	7.96E-07		7.80E-01	7.80E-07	1.02

Table 3-5a. Calculation of Total Skin Dose from Contamination on the Ground (Correcting for Radioactive Decay and Weathering Effects) (continued)

Radio-Nuclide	Branch Fraction	Groundshine Dose to Skin: External Skin DCF[a] (Sv/s per Bq/m^2)	External Skin DCP (mrem/y per µCi/m^2)	External Skin DCF corrected for GRF (mrem/y per µCi/m^2)	[b]CRP for first year (corrects for rad. decay & WCF) (hr)	[d]External Skin DCF (corrected for GRCF, rad. decay & WCF) (mrem/y per µCi/m^2)	Skin Contamination Dose: Electron dose-rate factor at depth of 7 mg/cm^2 for contamination on skin[c] (Sv/y per Bq/cm^2)	Electron dose-rate factor at depth of 7 mg/cm^2 for contamination on skin (mrem/y per µCi/m^2)	Electron dose-rate factor corrected for skin to ground contamination ratio (mrem/y per µCi/m^2)	[e]Electron dose-rate factors for skin contam. contamination corrected for WCF & decay (mrem/y per µCi/m^2)	Total Skin Dose: Total Skin Dose Groundshine + skin contamination (mrem/y per µCi/m^2)	Total Skin Dose Groundshine + skin contamination (mrem/y per pCi/m^2)	Total Skin Dose Groundshine + skin contamination Parent + Progeny (mrem/y per pCi/m^2)	Comparison to 1992 Values: 1992 Value (mrem/y per µCi/m^2)	1992 Value (mrem/y per pCi/m^2)	Calculated Value Divided by 1992 Value
Te-127	0.976	5.40E-16	6.29E+01	5.16E+01	3.21E+03	4.49E+00	1.60E-02	5.92E+03	3.70E+01	1.24E+00	5.73E+00	5.73E-06		NA	NA	NA
Te127m/Te127													6.39E-06	NA	NA	NA
Sb-129	NA	5.10E-15	5.94E+02	4.87E+02	6.23E+00	8.23E-02	1.70E-02	6.29E+03	3.93E+01	2.55E-03	8.49E-02	8.49E-08		NA	NA	NA
Te-129	0.775	5.74E-15	6.69E+02	5.49E+02	6.23E+00	9.26E-02	2.00E-02	7.40E+03	4.63E+01	3.00E-03	9.56E-02	9.56E-08		NA	NA	NA
Sb129/Te129													1.59E-07	NA	NA	NA
Te-129m	NA	2.27E-15	2.65E+02	2.17E+02	1.13E+03	6.64E+00	1.30E-02	4.81E+03	3.01E+01	3.54E-01	7.00E+00	7.00E-06		3.40E+01	3.40E-05	0.21
Te-129	0.65	5.74E-15	6.69E+02	5.49E+02	1.13E+03	1.68E+01	2.00E-02	7.40E+03	4.63E+01	5.45E-01	1.73E+01	1.73E-05		NA	NA	NA
I-129	0.35	Note: I-129 not considered because its T1/2 = 1.57E7 y and is too long to be in equilibrium														
Te129m/Te129	NA												1.83E-05	NA	NA	NA
Te-129, parent		5.74E-15	6.69E+02	5.49E+02	1.67E+00	2.48E-02	2.00E-02	7.40E+03	4.63E+01	8.05E-04	2.56E-02	2.56E-08		5.00E-01	5.00E-07	0.05
Te-131m	NA	2.20E-15	2.56E+02	2.10E+02	4.32E+01	2.46E-01	1.50E-02	5.55E+03	3.47E+01	1.56E-02	2.62E-01	2.62E-07		2.90E-01	2.90E-07	0.90
I-131	0.778	Note: I-131 not considered because its T1/2 = 8.04 d and is longer than Te131m T1/2 of 1.25 d.														
Xe-131m	1.11E-02	Note: Xe131m not considered because it is I131 progeny (and its T1/2 = 11.9 d and is longer than Te131m T1/2 of 1.25 d.														
Te-131	0.222	8.36E-15	9.74E+02	7.99E+02	4.32E+01	9.36E-01	2.30E-02	8.51E+03	5.32E+01	2.40E-02	9.60E-01	9.60E-07				
I-131	1	Note: I-131 not considered because its T1/2 = 8.04 d and is longer than Te131m T1/2 of 1.25 d.														
Xe-131m	1.11E-02	Note: Xe-131m not considered because it is I-131 progeny (and its T1/2 = 11.9 d and is longer than Te-131m[e] T1/2 of 1.25 d.														
[e]Te131m/Te131													4.75E-07	NA	NA	NA
Te-132	NA	2.99E-16	3.48E+01	2.86E+01	1.13E+02	8.75E-02	7.00E-03	2.59E+03	1.62E+01	1.91E-02	1.07E-01	1.07E-07		5.40E-03	5.40E-09	19.74

Table 3-5a. Calculation of Total Skin Dose from Contamination on the Ground (Correcting for Radioactive Decay and Weathering Effects) (continued)

		Groundshine Dose to Skin					Skin Contamination Dose				Total Skin Dose			Comparison to 1992 Values		
Radio-Nuclide	Branch Fraction	External Skin DCF[a] (Sv/s per Bq/m^2)	External Skin DCP (mrem/y per µCi/m^2)	External Skin DCF corrected for GRF (mrem/y per µCi/m^2)	[b]CRP for first year (corrects for rad. decay & WCF) (h)	[d]External Skin DCF (corrected for GRCF, rad. decay & WCF) (mrem/y per µCi/m^2)	Electron dose-rate factor at depth of 7 mg/cm^2 for contamination on skin[c] (Sv/y per Bq/m^2)	Electron dose-rate factor at depth of 7 mg/cm^2 for contamination on skin (mrem/y per µCi/m^2)	Electron dose-rate factor corrected for skin to ground contamination ratio (mrem/y per µCi/m^2)	[e]Electron dose-rate factors for skin contam. contamination corrected for WCF & decay (mrem/y per µCi/m^2)	Total Skin Dose Groundshine + skin contamination (mrem/y per µCi/m^2)	Total Skin Dose Groundshine + skin contamination (mrem/y per pCi/m^2)	Total Skin Dose Groundshine + skin contamination Parent + Progeny (mrem/y per pCi/m^2)	1992 Value (mrem/y per µCi/m^2)	1992 Value (mrem/y per pCi/m^2)	Calculated Value Divided by 1992 Value
I-132	1	7.54E-15	8.79E+02	7.21E+02	1.13E+02	2.21E+00	1.90E-02	7.03E+03	4.39E+01	5.18E-02	2.26E+00	2.26E-06		NA	NA	NA
Te132/I132	NA												2.37E-06	NA	NA	NA
I-132, parent		7.54E-15	8.79E+02	7.21E+02	3.32E+00	6.48E-02	1.90E-02	7.03E+03	4.39E+01	1.52E-03	6.64E-02	6.64E-08		5.00E+01	5.00E-05	0.00
I-131	NA	6.43E-16	7.49E+01	6.15E+01	2.77E+02	4.61E-01	1.50E-02	5.55E+03	3.47E+01	1.00E-01	5.62E-01	5.62E-07		8.50E-01	8.50E-07	0.66
I-133	NA	4.55E-15	5.30E+02	4.35E+02	3.00E+01	3.54E-01	1.90E-02	7.03E+03	4.39E+01	1.37E-02	3.67E-01	3.67E-07		NA	NA	NA
[f]Xe-133	NA	6.93E-17	8.08E+00	6.62E+00	1.81E+02	3.25E-02	No data available	0.00E+00	0.00E+00	0.00E+00	3.25E-02	3.25E-08		NA	NA	NA
I-134	NA	9.85E-15	1.15E+03	9.41E+02	1.26E+00	3.22E-02	2.00E-02	7.40E+03	4.63E+01	6.08E-04	3.28E-02	3.28E-08		NA	NA	NA
I-135	NA	4.83E-15	5.63E+02	4.62E+02	9.53E+00	1.19E-01	1.80E-02	6.66E+03	4.16E+01	4.14E-03	1.23E-01	1.23E-07		NA	NA	NA
Cs-134	NA	2.17E-15	2.53E+02	2.07E+02	6.85E+03	3.85E+01	1.20E-02	4.44E+03	2.78E+01	1.98E+00	4.05E+01	4.05E-05		2.60E+01	2.60E-05	1.56
[f]Xe-135	NA	2.09E-15	2.44E+02	2.00E+02	1.31E+01	7.09E-02	No data available	0.00E+00	0.00E+00	0.00E+00	7.09E-02	7.09E-08		NA	NA	NA
Cs-136	NA	2.54E-15	2.96E+02	2.43E+02	4.49E+02	2.95E+00	1.30E-02	4.81E+03	3.01E+01	1.41E-01	3.10E+00	3.10E-06		1.40E-01	1.40E-07	22.11
Cs-137	NA	2.75E-16	3.21E+01	2.63E+01	7.94E+03	5.66E+00	1.40E-02	5.18E+03	3.24E+01	2.68E+00	8.34E+00	8.34E-06		NA	NA	NA
Ba-137m	0.946	1.65E-15	1.92E+02	1.58E+02	7.94E+03	3.39E+01	2.10E-03	7.77E+02	4.86E+00	4.02E-01	3.43E+01	3.43E-05		NA	NA	NA
Cs-137/Ba-137m													4.08E-05	2.10E+01	2.10E-05	1.94
Ba-137m, parent		1.65E-15	1.92E+02	1.58E+02	6.14E-02	2.62E-04	2.10E-03	7.77E+02	4.86E+00	3.11E-06	2.66E-04	2.66E-10		NA	NA	NA
[f]Xe-138	NA	7.65E-15	8.92E+02	7.31E+02	3.41E-01	6.76E-03	No data available				6.76E-03	6.76E-09		NA	NA	NA
Ba-140	NA	1.95E-15	2.27E+02	1.86E+02	4.37E+02	2.21E+00	1.70E-02	6.29E+03	3.93E+01	1.79E-01	2.39E+00	2.39E-06		9.10E+00	9.10E-06	0.26
La-140	1	8.24E-15	9.60E+02	7.88E+02	4.37E+02	9.33E+00	2.00E-02	7.40E+03	4.63E+01	2.11E-01	9.54E+00	9.54E-06		NA	NA	NA

Table 3-5a. Calculation of Total Skin Dose from Contamination on the Ground (Correcting for Radioactive Decay and Weathering Effects) (continued)

		Groundshine Dose to Skin					Skin Contamination Dose				Total Skin Dose			Comparison to 1992 Values		
Radio-Nuclide	Branch Fraction	External Skin DCF[a] (Sv/s per Bq/m^2)	External Skin DCP (mrem/y per µCi/m^2)	External Skin DCF corrected for GRF (mrem/y per µCi/m^2)	[b]CRP For first year (corrects for rad. decay & WCF) (h)	[d]External Skin DCF (corrected for GRCF, rad. decay & WCF) (mrem/y per µCi/m^2)	Electron dose-rate factor at depth of 7 mg/cm^2 for contamination on skin[c] (Sv/y per Bq/cm^2)	Electron dose-rate factor at depth of 7 mg/cm^2 for contamination on skin (mrem/y per µCi/m^2)	Electron dose-rate factor corrected for skin to ground contamination ratio (mrem/y per µCi/m^2)	[e]Electron dose-rate factors for skin contam. contamination corrected for WCF & decay (mrem/y per µCi/m^2)	Total Skin Dose Groundshine + skin contamination (mrem/y per µCi/m^2)	Total Skin Dose Groundshine + skin contamination (mrem/y per pCi/m^2)	Total Skin Dose Groundshine + skin contamination Parent + Progeny (mrem/y per pCi/m^2)	1992 Value (mrem/y per µCi/m^2)	1992 Value (mrem/y per pCi/m^2)	Calculated Value Divided by 1992 Value
Ba-140/La-140													1.19E-05	NA	NA	NA
La-140	NA	8.24E-15	9.60E+02	7.88E+02	5.80E+01	1.24E+00	2.00E-02	7.40E+03	4.63E+01	2.80E-02	1.27E+00	1.27E-06		1.20E+01	1.20E-05	0.11
Ce-141	NA	1.32E-16	1.54E+01	1.26E+01	1.10E+03	3.76E-01	1.70E-02	6.29E+03	3.93E+01	4.51E-01	8.27E-01	8.27E-07		6.60E-01	6.60E-07	1.25
Ce-143	NA	3.99E-15	4.65E+02	3.81E+02	4.76E+01	4.92E-01	1.90E-02	7.03E+03	4.39E+01	2.18E-02	5.14E-01	5.14E-07		2.30E+00	2.30E-06	0.22
Ce-144	NA	2.61E-17	3.04E+00	2.49E+00	5.38E+03	3.64E-01	8.90E-03	3.29E+03	2.06E+01	1.15E+00	1.52E+00	1.52E-06		NA	NA	NA
Pr-144	9.82E-01	1.27E-14	1.48E+03	1.21E+03	5.38E+03	1.77E+02	2.20E-02	8.14E+03	5.09E+01	2.85E+00	1.80E+02	1.80E-04		NA	NA	NA
Pr-144m	1.78E-02	2.67E-17	3.11E+00	2.55E+00	5.38E+03	3.72E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.72E-01	3.72E-07		NA	NA	NA
Pr-144	9.99E-01	1.27E-14	1.48E+03	1.21E+03	5.38E+03	1.77E+02	2.20E-02	8.14E+03	5.09E+01	2.85E+00	1.80E+02	1.80E-04		NA	NA	NA
Ce-144/Pr-144/Pr-144m													1.81E-04	8.70E-01	8.70E-07	208.43
Pr-143	NA	2.00E-15	2.33E+02	1.91E+02	4.65E+02	2.41E+00	1.80E-02	6.66E+03	4.16E+01	2.02E-01	2.61E+00	2.61E-06		1.30E+01	1.30E-05	0.20
Pm-147	NA	1.20E-19	1.40E-02	1.15E-02	7.08E+03	2.20E-03	5.40E-03	2.00E+03	1.25E+01	9.22E-01	9.24E-01	9.24E-07		NA	NA	NA
Nd-147	NA	1.10E-15	1.28E+02	1.05E+02	3.77E+02	1.07E+00	1.70E-02	6.29E+03	3.93E+01	1.55E-01	1.23E+00	1.23E-06		4.30E+00	4.30E-06	0.29
Gd-153	NA	1.41E-16	1.64E+01	1.35E+01	5.05E+03	1.84E+00	1.10E-03	4.07E+02	2.54E+00	1.34E-01	1.98E+00	1.98E-06		NA	NA	NA
Yb-169	AN	3.66E-16	4.27E+01	3.50E+01	1.08E+03	1.02E+00	8.80E-03	3.26E+03	2.04E+01	2.29E-01	1.25E+00	1.25E-06		NA	NA	NA
[f]Tm-170	NA	2.12E-15	2.47E+02	2.03E+02	3.60E+03	1.98E+01	No data available	0.00E+00	0.00E+00	0.00E+00	1.98E+01	1.98E-05		NA	NA	NA
Ir-192	NA	1.21E-15	1.41E+02	1.16E+02	2.37E+03	7.43E+00	1.70E-02	6.29E+03	3.93E+01	9.71E-01	8.40E+00	8.40E-06		NA	NA	NA
Ra-226	NA	8.12E-18	9.46E-01	7.76E-01	8.03E+03	1.69E-01	4.20E-04	1.55E+02	9.71E-01	8.13E-02	2.50E-01	2.50E-07		NA	NA	NA
Rn-222	1.00E+00	5.20E-19	6.06E-02	4.97E-02	8.03E+03	1.08E-02	No data available	0.00E+00	0.00E+00	0.00E+00	1.08E-02	1.08E-08		NA	NA	NA
Po-218	1.00E+00	1.17E-20	1.36E-03	1.12E-03	8.03E+03	2.43E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.43E-04	2.43E-10		NA	NA	NA

Table 3-5a. Calculation of Total Skin Dose from Contamination on the Ground (Correcting for Radioactive Decay and Weathering Effects) (continued)

		Groundshine Dose to Skin					Skin Contamination Dose				Total Skin Dose			Comparison to 1992 Values		
Radio-Nuclide	Branch Fraction	External Skin DCF[a] (Sv/s per Bq/m^2)	External Skin DCP (mrem/y per µCi/m^2)	External Skin DCF corrected for GRF (mrem/y per µCi/m^2)	[b]CRP for first year (corrects for rad. decay & WCF) (hr)	[d]External Skin DCF (corrected for GRCF, rad. decay & WCF) (mrem/y per µCi/m^2)	Electron dose-rate factor at depth of 7 mg/cm^2 for contamination on skin[c] (Sv/y per Bq/cm^2)	Electron dose-rate factor at depth of 7 mg/cm^2 for contamination on skin (mrem/y per µCi/m^2)	Electron dose-rate factor corrected for skin to ground contamination ratio (mrem/y per µCi/m^2)	[e]Electron Dose-rate factors for skin contam. contamination corrected for WCF & decay (mrem/y per µCi/m^2)	Total Skin Dose Groundshine + skin contamination (mrem/y per µCi/m^2)	Total Skin Dose Groundshine + skin contamination (mrem/y per pCi/m^2)	Total Skin Dose Groundshine + skin contamination Parent + Progeny (mrem/y per pCi/m^2)	1992 Value (mrem/y per µCi/m^2)	1992 Value (mrem/y per pCi/m^2)	Calculated Value divided by 1992 Value
Pb-214	1.00E+00	9.10E-16	1.06E+02	8.70E+01	8.03E+03	1.89E+01	2.20E-02	8.14E+03	5.09E+01	4.26E+00	2.32E+01	2.32E-05		NA	NA	NA
Bi-214	1.00E+00	8.48E-15	9.88E+02	8.10E+02	8.03E+03	1.76E+02	2.00E-02	7.40E+03	4.63E+01	3.87E+00	1.80E+02	1.80E-04		NA	NA	NA
Po-214	1.00E+00	1.09E-19	1.27E-02	1.04E-02	8.03E+03	2.27E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.27E-03	2.27E-09		NA	NA	NA
At-218	2.00E-04	2.32E-17	2.70E+00	2.22E+00	8.03E+03	4.83E-01	No data available	0.00E+00	0.00E+00	0.00E+00	4.83E-01	4.83E-07		NA	NA	NA
Bi-214	1.00E+00	8.48E-15	9.88E+02	8.10E+02	8.03E+03	1.76E+02	2.00E-02	7.40E+03	4.63E+01	3.87E+00	1.80E+02	1.80E-04		NA	NA	NA
Po-214	1.00E+00	1.09E-19	1.27E-02	1.04E-02	8.03E+03	2.27E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.27E-03	2.27E-09		NA	NA	NA
[f]Ra-226/Rn-222/Po-218/At-218													2.04E-04	NA	NA	NA
Pu-238	NA	9.64E-18	1.12E+00	9.21E-01	8.00E+03	2.00E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-01	2.00E-07		NA	NA	NA
Pu-239	NA	3.67E-18	4.28E-01	3.51E-01	8.03E+03	7.63E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.63E-02	7.63E-08		NA	NA	NA
Np-239	NA	2.63E-16	3.07E+01	2.51E+01	8.14E+01	5.55E-02	2.30E-02	8.51E+03	5.32E+01	4.51E-02	1.01E-01	1.01E-07		3.40E-02	3.40E-08	2.96
Am-241	NA	8.32E-17	9.70E+00	7.95E+00	8.02E+03	1.73E+00	2.20E-05	8.14E+00	5.09E-02	4.25E-03	1.73E+00	1.73E-06		4.60E-02	4.60E-08	37.67
Cm-244	NA	8.70E-18	1.01E+00	8.31E-01	7.88E+03	1.78E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.78E-01	1.78E-07		NA	NA	NA
Cf-252	NA	5.75E-18	6.70E-01	5.50E-01	7.09E+03	1.06E-01	4.80E-06	1.78E+00	1.11E-02	8.20E-04	1.06E-01	1.06E-07		NA	NA	NA

[a]From FGR Report #12, Table III.3 (EPA 1993)
[b]From Turbo FRMAC 2.0, RFC 2 (DCFPAK, K. Eckerman).
[c]From Kocher & Eckerman, Health Physics 53(2), p. 135 - 141, 1987)
[d]Assume exposure period to groundshine = 2080 h/y.
[e]Assume exposure period to contamination uniformly distributed on the skin = 800 h/y.
[f]Total does not include dose from contamination on the skin if Electron Dose-Rate Factors not available.
[e]Te-131m values in the tables are subject to change pending further development of new parent-daughter rules.

Table 3-5b. Calculation of Total Skin Dose from Contamination on the Ground (Correcting only for Radioactive Decay)

		Groundshine Dose to Skin					Skin Contamination Dose				Total Skin Dose			Comparison to 1992 Values		
Radio-Nuclide	Branch Fraction	External Skin DCF[a] (Sv/s per Bq/m^2)	External Skin DCP (mrem/y per $\mu Ci/m^2$)	External Skin DCF corrected for GRCF (mrem/y per $\mu Ci/m^2$)	First-year EffXP[b] from TF 2.0, 2 - only corrects for decay TF 2.0, 2 (h)	[d]External Skin DCF corrected for GRF, WCF & decay (mrem/y per $\mu Ci/m^2$)	Electron dose-rate factor at depth of 7 mg/cm^2 for contamination on skin[c] (Sv/y per Bq/cm^2)	Electron dose-rate factor at depth of 7 mg/cm^2 for contamination on skin (mrem/y per $\mu Ci/m^2$)	Electron dose-rate factor corrected for skin to ground contamination ratio (mrem/y per $\mu Ci/m^2$)	[e]Electron dose-rate factors for skin contam. contamination corrected for WCF and decay (mrem/y per $\mu Ci/m^2$)	Total Skin Dose Groundshine + skin contamination (mrem/y per $\mu Ci/m^2$)	Total Skin Dose Groundshine + skin contamination (mrem/y per pCi/m^2)	Total Skin Dose Groundshine + skin contamination Parent + Progeny (mrem/y per pCi/m^2)	1992 Value (mrem/y per $\mu Ci/m^2$)	1992 Value (mrem/y per pCi/m^2)	Calculated Value divided by 1992 Value
Co-58	NA	1.14E-15	1.33E+02	1.09E+02	2.38E+03	7.03E+00	2.80E-03	1.04E+03	6.48E+00	1.61E-01	7.19E+00	7.19E-06		1.47E-01	1.47E-07	4.89E+01
Co-60	NA	2.76E-15	3.22E+02	2.64E+02	8.21E+03	5.87E+01	9.90E-03	3.66E+03	2.29E+01	1.96E+00	6.07E+01	6.07E-05		5.60E-01	5.60E-07	1.08E+02
Se-75	NA	4.76E-16	5.55E+01	4.55E+01	3.65E+03	4.50E+00	8.40E-04	3.11E+02	1.94E+00	7.39E-02	4.57E+00	4.57E-06		NA	NA	NA
Rb-86	NA	7.72E-15	9.00E+02	7.38E+02	6.46E+02	1.29E+01	2.00E-02	7.40E+03	4.63E+01	3.11E-01	1.32E+01	1.32E-05		6.70E+01	6.70E-05	1.97E-01
Kr-87	NA	1.35E-14	1.57E+03	1.29E+03	1.83E+00	6.40E-02	No data available	0.00E+00	0.00E+00	0.00E+00	6.40E-02	6.40E-08		NA	NA	NA
Kr-88	Na	4.43E-15	5.16E+02	4.23E+02	4.10E+00	4.71E-02	No data available	0.00E+00	0.00E+00	0.00E+00	4.71E-02	4.71E-08		NA	NA	NA
Sr-89	NA	6.66E-15	7.76E+02	6.37E+02	1.74E+03	3.00E+01	2.00E-02	7.40E+03	4.63E+01	8.39E-01	3.09E+01	3.09E-05		1.60E+02	1.60E-04	1.93E-01
Sr-90	NA	1.40E-16	1.63E+01	1.34E+01	8.66E+03	3.14E+00	1.60E-02	5.92E+03	3.70E+01	3.34E+00	6.48E+00	6.48E-06		1.70E+01	1.70E-05	3.81E-01
Y-90	1	1.05E-14	1.22E+03	1.00E+03	8.66E+03	2.36E+02	2.10E-02	7.77E+03	4.86E+01	4.38E+00	2.40E+02	2.40E-04				
Sr90/Y90	NA												2.46E-04	NA	NA	NA
Y-90, parent	NA	1.05E-14	1.22E+03	1.00E+03	9.23E+01	2.51E+00	2.10E-02	7.77E+03	4.86E+01	4.67E-02	2.56E+00	2.56E-06		2.90E+02	2.90E-04	8.82E-03
Sr-91	NA	7.53E-15	8.78E+02	7.20E+02	1.37E+01	2.67E-01	2.00E-02	7.40E+03	4.63E+01	6.61E-03	2.74E-01	2.74E-07		NA	NA	NA
Y-91	NA	6.92E-15	8.07E+02	6.61E+02	2.00E+03	3.59E+01	2.00E-02	7.40E+03	4.63E+01	9.64E-01	3.68E+01	3.68E-05		1.90E+02	1.90E-04	1.94E-01
Zr-95	NA	8.91E-16	1.04E+02	8.52E+01	2.17E+03	5.01E+00	1.20E-02	4.44E+03	2.78E+01	6.28E-01	5.64E+00	5.64E-06		8.30E-01	8.30E-07	6.79E+00
Nb-95	0.993	9.05E-16	1.05E+02	8.65E+01	2.17E+03	5.09E+00	2.30E-03	8.51E+02	5.32E+00	1.20E-01	5.21E+00	5.21E-06		NA	NA	NA
Nb-95m	6.98E-03	1.09E-16	1.27E+01	1.04E+01	2.17E+03	6.13E-01	1.60E-02	5.92E+03	3.70E+01	8.37E-01	1.45E+00	1.45E-06		NA	NA	NA
Nb-95	1	9.05E-16	1.05E+02	8.65E+01	2.17E+03	5.09E+00	2.30E-03	8.51E+02	5.32E+00	1.20E-01	5.21E+00	5.21E-06		NA	NA	NA
Zr-95/Nb-95/Nb-95m/Nb-95													1.09E-05	NA	NA	NA
Nb-95, parent		9.05E-16	1.05E+02	8.65E+01	1.22E+03	2.86E+00	2.30E-03	8.51E+02	5.32E+00	6.76E-02	2.93E+00	2.93E-06		7.40E-01	7.40E-07	3.96E+00
Mo-99	NA	3.76E-15	4.38E+02	3.59E+02	9.52E+01	9.27E-01	1.90E-02	7.03E+03	4.39E+01	4.36E-02	9.71E-01	9.71E-07		4.60E+00	4.60E-06	2.11E-01

Table 3-5b. Calculation of Total Skin Dose from Contamination on the Ground (Correcting only for Radioactive Decay) (continued)

		Groundshine Dose to Skin					Skin Contamination Dose				Total Skin Dose			Comparison to 1992 Values		
Radio-Nuclide	Branch Fraction	External Skin DCF[a] (Sv/s per Bq/m²)	External Skin DCP (mrem/y per µCi/m²)	External Skin DCF corrected for GRCF (mrem/y per µCi/m²)	First-year EffXP[b] from TF 2.0, 2 - only corrects for decay TF 2.0, 2 (h)	[d]External Skin DCF corrected for GRF, WCF & decay (mrem/y per µCi/m²)	Electron dose-rate factor at depth of 7 mg/cm² for contamination on skin[c] (Sv/y per Bq/cm²)	Electron dose-rate factor at depth of 7 mg/cm² for contamination on skin (mrem/y per µCi/m²)	Electron dose-rate factor corrected for skin to ground contamination ratio (mrem/y per µCi/m²)	[e]Electron dose-rate factors for skin contam. contamination corrected for WCF and decay (mrem/y per µCi/m²)	Total Skin Dose Groundshine + skin contamination (mrem/y per µCi/m²)	Total Skin Dose Groundshine + skin contamination (mrem/y per pCi/m²)	Total Skin Dose Groundshine + skin contamination Parent + Progeny (mrem/y per pCi/m²)	1992 Value (mrem/y per µCi/m²)	1992 Value (mrem/y per pCi/m²)	Calculated Value Divided by 1992 Value
Tc-99m	0.876	1.44E-16	1.68E+01	1.38E+01	9.52E+01	3.55E-02	2.10E-03	7.77E+02	4.86E+00	4.82E-03	4.03E-02	4.03E-08				
Tc-99	1	Note: Tc-99 not considered because its T1/2= 2.13E5 y and is too long to be in equilibrium														
Tc-99	0.124	Note: Tc-99 not considered because its T1/2= 2.13E5 y and is too long to be in equilibrium														
Mo-99/Tc-99m													1.01E-06	NA	NA	NA
Tc-99m, parent		1.44E-16	1.68E+01	1.38E+01	8.69E+00	3.24E-03	2.10E-03	7.77E+02	4.86E+00	4.40E-04	3.68E-03	3.68E-09		7.70E-03	7.70E-09	4.78E-01
Rh-105	NA	1.76E-16	2.05E+01	1.68E+01	5.10E+01	2.33E-02	1.30E-02	4.81E+03	3.01E+01	1.60E-02	3.92E-02	3.92E-08		6.60E-02	6.60E-08	5.94E-01
Ru-103	NA	6.16E-16	7.18E+01	5.89E+01	1.36E+03	2.17E+00	5.80E-03	2.15E+03	1.34E+01	1.90E-01	2.36E+00	2.36E-06		7.80E-01	7.80E-07	3.03E+00
Ru-106	NA	0.00E+00	0.00E+00	0.00E+00	6.34E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		NA	NA	NA
Rh-106	1	1.42E-14	1.66E+03	1.36E+03	6.34E+03	2.33E+02	2.20E-02	8.14E+03	5.09E+01	3.36E+00	2.37E+02	2.37E-04		NA	NA	NA
Ru-106/Rh-106	NA												2.37E-04	8.70E-01	8.70E-07	2.72E+02
Rh-106, parent		1.42E-14	1.66E+03	1.36E+03	1.20E-02	4.41E-04	2.20E-02	8.14E+03	5.09E+01	6.36E-06	4.48E-04	4.48E-10		NA	NA	NA
Sb-127	NA	2.85E-15	3.32E+02	2.72E+02	1.33E+02	9.82E-01	1.80E-02	6.66E+03	4.16E+01	5.77E-02	1.04E+00	1.04E-06		3.40E+00	3.40E-06	3.06E-01
Te-127	0.824	5.40E-16	6.29E+01	5.16E+01	1.33E+02	1.86E-01	1.60E-02	5.92E+03	3.70E+01	5.13E-02	2.37E-01	2.37E-07		NA	NA	NA
Sb-127/Te-127													1.24E-06	NA	NA	NA
Te-127, parent	NA	5.40E-16	6.29E+01	5.16E+01	1.35E+01	1.89E-02	1.60E-02	5.92E+03	3.70E+01	5.21E-03	2.41E-02	2.41E-08		1.00E+00	1.00E-06	2.41E-02
Te-127m	NA	5.20E-17	6.06E+00	4.97E+00	3.40E+03	4.58E-01	4.70E-03	1.74E+03	1.09E+01	3.85E-01	8.43E-01	8.43E-07		9.50E-01	9.50E-07	8.88E-01
Te-127	0.976	5.40E-16	6.29E+01	5.16E+01	3.40E+03	4.76E+00	1.60E-02	5.92E+03	3.70E+01	1.31E+00	6.07E+00	6.07E-06		NA	NA	NA
Te-127m/Te-127													6.77E-06	NA	NA	NA

Table 3-5b. Calculation of Total Skin Dose from Contamination on the Ground (Correcting only for Radioactive Decay) (continued)

		Groundshine Dose to Skin					Skin Contamination Dose				Total Skin Dose			Comparison to 1992 Values		
Radio- Nuclide	Branch Fraction	External Skin DCF[a] (Sv/s per Bq/m^2)	External Skin DCP (mrem/y per $\mu Ci/m^2$)	External Skin DCF corrected for GRCF (mrem/y per $\mu Ci/m^2$)	First-year EffXP[b] from TF 2.0, 2 - only corrects for decay TF 2.0, 2 (h)	[d]External Skin DCF corrected for GRF, WCF & decay (mrem/y per $\mu Ci/m^2$)	Electron dose-rate factor at depth of 7 mg/cm^2 for contamination on skin[c] (Sv/y per Bq/cm^2)	Electron dose-rate factor at depth of 7 mg/cm^2 for contamination on skin (mrem/y per $\mu Ci/m^2$)	Electron dose-rate factor corrected for skin to ground contamination ratio (mrem/y per $\mu Ci/m^2$)	[e]Electron dose-rate factors for skin contam. contamination corrected for WCF and decay (mrem/y per $\mu Ci/m^2$)	Total Skin Dose Groundshine + skin contamination (mrem/y per $\mu Ci/m^2$)	Total Skin Dose Groundshine + skin contamination (mrem/y per pCi/m^2)	Total Skin Dose Groundshine + skin contamination Parent + Progeny (mrem/y per pCi/m^2)	1992 Value (mrem/y per $\mu Ci/m^2$)	1992 Value (mrem/y per pCi/m^2)	Calculated Value Divided by 1992 Value
Sb-129	NA	5.10E-15	5.94E+02	4.87E+02	6.23E+00	8.23E-02	1.70E-02	6.29E+03	3.93E+01	2.55E-03	8.49E-02	8.49E-08		NA	NA	NA
Te-129	0.775	5.74E-15	6.69E+02	5.49E+02	6.23E+00	9.26E-02	2.00E-02	7.40E+03	4.63E+01	3.00E-03	9.56E-02	9.56E-08		NA	NA	NA
Sb-129/Te-129													1.59E-07	NA	NA	NA
Te-129m	NA	2.27E-15	2.65E+02	2.17E+02	1.16E+03	6.82E+00	1.30E-02	4.81E+03	3.01E+01	3.64E-01	7.18E+00	7.18E-06		3.60E+01	3.60E-05	2.00E-01
Te-129	0.65	5.74E-15	6.69E+02	5.49E+02	1.16E+03	1.72E+01	2.00E-02	7.40E+03	4.63E+01	5.59E-01	1.78E+01	1.78E-05				
I-129	0.35	Note: I-129 not considered because its T1/2 = 1.57E7 y and is too long to be in equilibrium														
Te-129m/Te-129	NA												1.88E-05	NA	NA	NA
Te-129, parent		5.74E-15	6.69E+02	5.49E+02	1.67E+00	2.48E-02	2.00E-02	7.40E+03	4.63E+01	8.05E-04	2.56E-02	2.56E-08		5.00E-01	5.00E-07	5.13E-02
[g]Te-131m	NA	2.20E-15	2.56E+02	2.10E+02	4.33E+01	2.47E-01	1.50E-02	5.55E+03	3.47E+01	1.57E-02	2.62E-01	2.62E-07		2.90E-01	2.90E-07	9.05E-01
I-131	0.778	Note: I-131 not considered because its $t_{1/2}$ = 8.04 d and is longer than Te131m $t_{1/2}$ of 1.25 d.														
Xe-131m	1.11E-02	Note: Xe-131m not considered because it is I-131 progeny (and its $t_{1/2}$ = 11.9 d and is longer than [g]Te131m $t_{1/2}$ of 1.25 d.														
Te-131	0.222	8.36E-15	9.74E+02	7.99E+02	4.33E+01	9.38E-01	2.30E-02	8.51E+03	5.32E+01	2.40E-02	9.62E-01	9.62E-07				
I-131	1	Note: I-131 not considered because its $t_{1/2}$ = 8.04 d and is longer than Te-131m $t_{1/2}$ of 1.25 d.														
Xe-131m	1.11E-02	Note: Xe131m not considered because it is I-131 progeny (and its $t_{1/2}$ = 11.9 d and is longer than Te-131m $t_{1/2}$ of 1.25 d.														
Te-131m/Te-131													4.76E-07	NA	NA	NA
Te-132	NA	2.99E-16	3.48E+01	2.86E+01	1.13E+02	8.75E-02	7.00E-03	2.59E+03	1.62E+01	1.91E-02	1.07E-01	1.07E-07		5.40E-03	5.40E-09	1.97E+01
I-132	1	7.54E-15	8.79E+02	7.21E+02	1.13E+02	2.21E+00	1.90E-02	7.03E+03	4.39E+01	5.18E-02	2.26E+00	2.26E-06				
Te-132/I-132	NA												2.37E-06	NA	NA	NA
I-132, parent		7.54E-15	8.79E+02	7.21E+02	3.32E+00	6.48E-02	1.90E-02	7.03E+03	4.39E+01	1.52E-03	6.64E-02	6.64E-08		5.00E+01	5.00E-05	1.33E-03
I-131	NA	6.43E-16	7.49E+01	6.15E+01	2.78E+02	4.63E-01	1.50E-02	5.55E+03	3.47E+01	1.01E-01	5.64E-01	5.64E-07		8.70E-01	8.70E-07	6.48E-01

Table 3-7a. Calculation of Total Skin Dose from Contamination on the Ground (Correcting only for Radioactive Decay) (continued)

		Groundshine Dose to Skin					Skin Contamination Dose				Total Skin Dose			Comparison to 1992 Values		
Radio-Nuclide	Branch Fraction	External Skin DCF[a] (Sv/s per Bq/m^2)	External Skin DCP (mrem/y per µCi/m^2)	External Skin DCF corrected for GRCF (mrem/y per µCi/m^2)	First-year EffXP[b] From TF 2.0, 2 - only Corrects for Decay TF 2.0, 2 (h)	[d]External Skin DCF corrected for GRF, WCF & decay (mrem/y per µCi/m^2)	Electron dose-rate factor at depth of 7 mg/cm^2 for contamination on skin[c] (Sv/y per Bq/cm^2)	Electron dose-rate factor at depth of 7 mg/cm^2 for contamination on skin (mrem/y per µCi/m^2)	Electron dose-rate factor corrected for skin to ground contamination ratio (mrem/y per µCi/m^2)	[e]Electron dose-rate factors for skin contam. contamination corrected for WCF and decay (mrem/y per µCi/m^2)	Total Skin Dose Groundshine + skin contamination (mrem/y per µCi/m^2)	Total Skin Dose Groundshine + skin contamination (mrem/y per pCi/m^2)	Total Skin Dose Groundshine + skin contamination Parent + Progeny (mrem/y per pCi/m^2)	1992 Value (mrem/y per µCi/m^2)	1992 Value (mrem/y per pCi/m^2)	Calculated Value Divided by 1992 Value
I-133	NA	4.55E-15	5.30E+02	4.35E+02	3.00E+01	3.54E-01	1.90E-02	7.03E+03	4.39E+01	1.37E-02	3.67E-01	3.67E-07		NA	NA	NA
[f]Xe-133	NA	6.93E-17	8.08E+00	6.62E+00	1.82E+02	3.27E-02	No data available	0.00E+00	0.00E+00	0.00E+00	3.27E-02	3.27E-08		NA	NA	NA
I-134	NA	9.85E-15	1.15E+03	9.41E+02	1.26E+00	3.22E-02	2.00E-02	7.40E+03	4.63E+01	6.08E-04	3.28E-02	3.28E-08		NA	NA	NA
I-135	NA	4.83E-15	5.63E+02	4.62E+02	9.54E+00	1.19E-01	1.80E-02	6.66E+03	4.16E+01	4.14E-03	1.24E-01	1.24E-07		NA	NA	NA
Cs-134	NA	2.17E-15	2.53E+02	2.07E+02	7.44E+03	4.18E+01	1.20E-02	4.44E+03	2.78E+01	2.15E+00	4.40E+01	4.40E-05		3.30E+01	3.30E-05	1.33E+00
[f]Xe-135	NA	2.09E-15	2.44E+02	2.00E+02	1.31E+01	7.09E-02	No data available	0.00E+00	0.00E+00	0.00E+00	7.09E-02	7.09E-08		NA	NA	NA
Cs-136	NA	2.54E-15	2.96E+02	2.43E+02	4.54E+02	2.99E+00	1.30E-02	4.81E+03	3.01E+01	1.42E-01	3.13E+00	3.13E-06		3.70E-01	3.70E-07	8.46E+00
Cs-137	NA	2.75E-16	3.21E+01	2.63E+01	8.66E+03	6.17E+00	1.40E-02	5.18E+03	3.24E+01	2.92E+00	9.09E+00	9.09E-06		NA	NA	NA
Ba-137m	0.946	1.65E-15	1.92E+02	1.58E+02	8.66E+03	3.70E+01	2.10E-03	7.77E+02	4.86E+00	4.38E-01	3.75E+01	3.75E-05		NA	NA	NA
Cs-137/Ba-137m													4.45E-05	2.90E+01	2.90E-05	1.54E+00
Ba-137m, parent		1.65E-15	1.92E+02	1.58E+02	6.14E-02	2.62E-04	2.10E-03	7.77E+02	4.86E+00	3.11E-06	2.66E-04	2.66E-10		NA	NA	NA
[f]Xe-138	NA	7.65E-15	8.92E+02	7.31E+02	3.41E-01	6.76E-03	No data available	0.00E+00	0.00E+00	0.00E+00	6.76E-03	6.76E-09		NA	NA	NA
Ba-140	NA	1.95E-15	2.27E+02	1.86E+02	4.41E+02	2.23E+00	1.70E-02	6.29E+03	3.93E+01	1.81E-01	2.41E+00	2.41E-06		9.60E+00	9.60E-06	2.51E-01
La-140	1	8.24E-15	9.60E+02	7.88E+02	4.41E+02	9.41E+00	2.00E-02	7.40E+03	4.63E+01	2.13E-01	9.63E+00	9.63E-06		NA	NA	NA
Ba-140/La-140													1.20E-05	NA	NA	NA
La-140	NA	8.24E-15	9.60E+02	7.88E+02	5.81E+01	1.24E+00	2.00E-02	7.40E+03	4.63E+01	2.80E-02	1.27E+00	1.27E-06		1.30E+01	1.30E-05	9.76E-02
Ce-141	NA	1.32E-16	1.54E+01	1.26E+01	1.12E+03	3.83E-01	1.70E-02	6.29E+03	3.93E+01	4.59E-01	8.42E-01	8.42E-07		7.10E-01	7.10E-07	1.19E+00
Ce-143	NA	3.99E-15	4.65E+02	3.81E+02	4.76E+01	4.92E-01	1.90E-02	7.03E+03	4.39E+01	2.18E-02	5.14E-01	5.14E-07		2.30E+00	2.30E-06	2.23E-01

Table 3-5b. Calculation of Total Skin Dose from Contamination on the Ground (Correcting only for Radioactive Decay) (continued)

		Groundshine Dose to Skin					Skin Contamination Dose				Total Skin Dose			Comparison to 1992 Values		
Radio-Nuclide	Branch Fraction	External Skin DCF[a] (Sv/s per Bq/m²)	External Skin DCP (mrem/y per µCi/m²)	External Skin DCF corrected for GRCF (mrem/y per µCi/m²)	First-year EffXP[b] From TF 2.0, 2 - only Corrects for decay TF 2.0, 2 (h)	[d]External Skin DCF corrected for GRF, WCF & decay (mrem/y per µCi/m²)	Electron dose-rate factor at depth of 7 mg/cm² for contamination on skin[c] (Sv/y per Bq/cm²)	Electron dose-rate factor at depth of 7 mg/cm² for contamination on skin (mrem/y per µCi/m²)	Electron dose-rate factor corrected for skin to ground contamination ratio (mrem/y per µCi/m²)	[e]Electron dose-rate factors for skin contam. contamination corrected for WCF and decay (mrem/y per µCi/m²)	Total Skin Dose Groundshine + skin contamination (mrem/y per µCi/m²)	Total Skin Dose Groundshine + skin contamination (mrem/y per pCi/m²)	Total Skin Dose Groundshine + skin contamination Parent + Progeny (mrem/y per pCi/m²)	1992 Value (mrem/y per µCi/m²)	1992 Value (mrem/y per pCi/m²)	Calculated Value Divided by 1992 Value
Ce-144	NA	2.61E-17	3.04E+00	2.49E+00	5.80E+03	3.92E-01	8.90E-03	3.29E+03	2.06E+01	1.24E+00	1.64E+00	1.64E-06		NA	NA	NA
Pr-144	9.82E-01	1.27E-14	1.48E+03	1.21E+03	5.80E+03	1.91E+02	2.20E-02	8.14E+03	5.09E+01	3.08E+00	1.94E+02	1.94E-04		NA	NA	NA
Pr-144m	1.78E-02	2.67E-17	3.11E+00	2.55E+00	5.80E+03	4.01E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.01E-01	4.01E-07		NA	NA	NA
Pr-144	9.99E-01	1.27E-14	1.48E+03	1.21E+03	5.80E+03	1.91E+02	2.20E-02	8.14E+03	5.09E+01	3.08E+00	1.94E+02	1.94E-04		NA	NA	NA
Ce-144/Pr-144/Pr-144m													1.95E-04	1.10E+00	1.10E-06	1.78E+02
Pr-143	NA	2.00E-15	2.33E+02	1.91E+02	4.70E+02	2.44E+00	1.80E-02	6.66E+03	4.16E+01	2.04E-01	2.64E+00	2.64E-06		1.40E+01	1.40E-05	1.89E-01
Pm-147	NA	1.20E-19	1.40E-02	1.15E-02	7.70E+03	2.39E-03	5.40E-03	2.00E+03	1.25E+01	1.00E+00	1.00E+00	1.00E-06		NA	NA	NA
Nd-147	NA	1.10E-15	1.28E+02	1.05E+02	3.80E+02	1.08E+00	1.70E-02	6.29E+03	3.93E+01	1.56E-01	1.24E+00	1.24E-06		4.50E+00	4.50E-06	2.75E-01
Gd-153	NA	1.41E-16	1.64E+01	1.35E+01	5.43E+03	1.98E+00	1.10E-03	4.07E+02	2.54E+00	1.44E-01	2.13E+00	2.13E-06		NA	NA	NA
Yb-169	AN	3.66E-16	4.27E+01	3.50E+01	1.11E+03	1.05E+00	8.80E-03	3.26E+03	2.04E+01	2.35E-01	1.29E+00	1.29E-06		NA	NA	NA
[f]Tm-170	NA	2.12E-15	2.47E+02	2.03E+02	3.83E+03	2.10E+01	No data available	0.00E+00	0.00E+00	0.00E+00	2.10E+01	2.10E-05		NA	NA	NA
Ir-192	NA	1.21E-15	1.41E+02	1.16E+02	2.48E+03	7.77E+00	1.70E-02	6.29E+03	3.93E+01	1.02E+00	8.79E+00	8.79E-06		NA	NA	NA
Ra-226	NA	8.12E-18	9.46E-01	7.76E-01	8.76E+03	1.84E-01	4.20E-04	1.55E+02	9.71E-01	8.87E-02	2.73E-01	2.73E-07		NA	NA	NA
Rn-222	1.00E+00	5.20E-19	6.06E-02	4.97E-02	8.76E+03	1.18E-02	No data available	0.00E+00	0.00E+00	0.00E+00	1.18E-02	1.18E-08		NA	NA	NA
Po-218	1.00E+00	1.17E-20	1.36E-03	1.12E-03	8.76E+03	2.66E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.66E-04	2.66E-10		NA	NA	NA
Pb-214	1.00E+00	9.10E-16	1.06E+02	8.70E+01	8.76E+03	2.07E+01	2.20E-02	8.14E+03	5.09E+01	4.65E+00	2.53E+01	2.53E-05		NA	NA	NA
Bi-214	1.00E+00	8.48E-15	9.88E+02	8.10E+02	8.76E+03	1.93E+02	2.00E-02	7.40E+03	4.63E+01	4.23E+00	1.97E+02	1.97E-04		NA	NA	NA
Po-214	1.00E+00	1.09E-19	1.27E-02	1.04E-02	8.76E+03	2.47E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.47E-03	2.47E-09		NA	NA	NA
At-218	2.00E-04	2.32E-17	2.70E+00	2.22E+00	8.76E+03	5.27E-01	No data available	0.00E+00	0.00E+00	0.00E+00	5.27E-01	5.27E-07		NA	NA	NA
Bi-214	1.00E+00	8.48E-15	9.88E+02	8.10E+02	8.76E+03	1.93E+02	2.00E-02	7.40E+03	4.63E+01	4.23E+00	1.97E+02	1.97E-04		NA	NA	NA
Po-214	1.00E+00	1.09E-19	1.27E-02	1.04E-02	8.76E+03	2.47E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.47E-03	2.47E-09		NA	NA	NA

Table 3-5b. Calculation of Total Skin Dose from Contamination on the Ground (Correcting only for Radioactive Decay) (continued)

		Groundshine Dose to Skin					Skin Contamination Dose				Total Skin Dose			Comparison to 1992 Values		
Radio-Nuclide	Branch Fraction	External Skin DCF[a] (Sv/s per Bq/m^2)	External Skin DCP (mrem/y per $\mu Ci/m^2$)	External Skin DCF corrected for GRCF (mrem/y per $\mu Ci/m^2$)	First-year EffXP[b] from TF 2.0, 2 - only corrects for decay TF 2.0, 2 (h)	[d]External Skin DCF corrected for GRF, WCF & decay (mrem/y per $\mu Ci/m^2$)	Electron dose-rate factor at depth of 7 mg/cm^2 for contamination on skin[c] (Sv/y per Bq/cm^2)	Electron dose-rate factor at depth of 7 mg/cm^2 for contamination on skin (mrem/y per $\mu Ci/m^2$)	Electron dose-rate factor corrected for skin to ground contamination ratio (mrem/y per $\mu Ci/m^2$)	[e]Electron dose-rate factors for skin contam. contamination corrected for WCF and decay (mrem/y per $\mu Ci/m^2$)	Total Skin Dose Groundshine + skin contamination (mrem/y per $\mu Ci/m^2$)	Total Skin Dose Groundshine + skin contamination (mrem/y per pCi/m^2)	Total Skin Dose Groundshine + skin contamination Parent + Progeny (mrem/y per pCi/m^2)	1992 Value (mrem/y per $\mu Ci/m^2$)	1992 Value (mrem/y per pCi/m^2)	Calculated Value Divided by 1992 Value
[f]Ra-226/Rn-222/Po-218/At-218													2.22E-04	NA	NA	NA
Pu-238	NA	9.64E-18	1.12E+00	9.21E-01	8.73E+03	2.18E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.18E-01	2.18E-07		NA	NA	NA
Pu-239	NA	3.67E-18	4.28E-01	3.51E-01	8.76E+03	8.33E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.33E-02	8.33E-08		NA	NA	NA
Np-239	NA	2.63E-16	3.07E+01	2.51E+01	8.15E+01	5.55E-02	2.30E-02	8.51E+03	5.32E+01	4.52E-02	1.01E-01	1.01E-07		3.40E-02	3.40E-08	2.96E+00
Am-241	NA	8.32E-17	9.70E+00	7.95E+00	8.75E+03	1.89E+00	2.20E-05	8.14E+00	5.09E-02	4.64E-03	1.89E+00	1.89E-06		6.40E-02	6.40E-08	2.95E+01
Cm-244	NA	8.70E-18	1.01E+00	8.31E-01	8.59E+03	1.94E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.94E-01	1.94E-07		NA	NA	NA
Cf-252	NA	5.75E-18	6.70E-01	5.50E-01	7.70E+03	1.15E-01	4.80E-06	1.78E+00	1.11E-02	8.91E-04	1.16E-01	1.16E-07		NA	NA	NA

[a]From FGR Report #12, Table III.3 (EPA 1993)
[b]From Turbo FRMAC 2.0, RFC 2 (DCFPAK, K. Eckerman).
[c]From Kocher & Eckerman, Health Physics 53(2), p. 135 - 141, 1987)
[d]Assume exposure period to groundshine = 2080 h/y.
[e]Assume exposure period to contamination uniformly distributed on the skin = 800 hours during the year.
[f]Total does not include dose from contamination on the skin if Electron Dose-Rate Factors not available.
[g]Te-131m values in the tables are subject to change pending further development of new parent-daughter rules

Chapter 4
Intermediate Phase Protective Action Guide for Drinking Water

4. Intermediate Phase Protective Action Guide for Drinking Water

4.1 Introduction

The drinking water PAG for the intermediate phase of a radiological response is 0.5 rem whole-body committed effective dose (CED) in the first year after a radiation incident. Similar to the PAGs for the early and intermediate phases discussed in Chapters 2 and 3, the drinking water PAG indicates a level of projected exposure at which protective action should be taken to prevent, reduce, or limit a person's radiation dose during a radiological incident. This guidance is not related to the Safe Drinking Water Act Maximum Contaminant Levels (MCLs) and should not serve as a substitute for them.

The drinking water PAG is separate from and does not impact EPA's Safe Drinking Water Act MCLs. The drinking water PAG only applies for up to a one-year time period during the Intermediate Phase of a radiological emergency. The fact that PAGs for water are designed for the Intermediate Phase, however, should not preclude reasonable precautionary measures (e.g., closing water intakes and using available stored water) during the early phase. The goal is to keep the dose to the public as low as reasonably achievable.

The drinking water PAG only applies to ingested water after a radiation incident. EPA has considered the potential radiation dose that people could receive from various uses of contaminated water, including showering and bathing. These activities generally represent a smaller risk than drinking contaminated water and are covered by the more general intermediate phase PAGs presented in Chapter 3. However, people typically shower and bathe using the same source of water that they use to drink. As a result, protection of a community's drinking water supply will also protect the source of water used for virtually all other needs.

The drinking water PAG is primarily intended to guide planning and decision-making efforts during the early and intermediate phases of a radiological emergency when surface water supplies are particularly vulnerable to contamination from deposition of radioactive materials from the air. Some incidents may contaminate ground water, though this is much less likely. In addition, the time required for ground water to become contaminated would be sufficient enough to plan for and implement protective actions. Actions to protect the water supply may be implemented at other levels and at any time following a radiological incident. Reducing radiation doses below Safe Drinking Water Act MCLs, as soon as practicable, is encouraged.

This chapter identifies the projected level of radiation exposure at which protective actions are needed to protect the public from drinking water contaminated with radioactive material. As the drinking water PAG is expressed as a numerical dose level, the tables in this chapter are needed to determine the measured concentrations of radionuclides, or DRLs, in drinking water that correspond to EPA's drinking water PAG. The DRLs are provided as a point of reference to aid emergency response personnel in their decision-making. After a particular situation stabilizes and becomes more clearly defined, local authorities may wish to modify the level of drinking water exposure they consider to be appropriate based upon a desire to implement optimized longer-term dose reduction strategies. In other words, the dose level associated with the drinking water pathway may be controlled to levels below 0.5 rem (5 mSv), depending on the characteristics of an individual community.

4.1.1 Justification for the Intermediate Phase Drinking Water PAG

Water distribution systems all incorporate reserve and storage capacity. During the Early Phase of the incident it is unlikely that contamination could affect water which is directly available for consumption through distribution systems. It would take some time for radionuclides to be deposited from the plume into the water supply system and then subsequently distributed. During the Early Phase, recommendations to the public (e.g., about drinking tap water while sheltering-in-place) should reflect these considerations. In the Early Phase, the public should be advised that the water is potable unless otherwise informed. Note that an instance in which the drinking water PAG may need to be applied during the Early Phase is in the event of direct radiological contamination of a water system.

Due to the fact that it will take some time after the radioactive airborne plume passes to determine the full extent of any contamination to surface water bodies, actions to protect drinking water supplies would likely be put in place during the Intermediate Phase of a radiological incident. In fact, it is unlikely that emergency response personnel will have the results from radiation measurements of water supplies until well after the plume has passed.

There are a variety of protective actions that should be considered during the Intermediate Phase of a radiological incident. EPA has set the drinking water PAG at a level consistent with the recommendations given in Chapter 3 of the 1992 PAGs Manual. EPA recommends a drinking water protective action guide of 0.5 rem CED in the first year. It is assumed that Safe Drinking Water Act (SDWA 1996) levels should be achieved within the first year. Local authorities should consult with their state drinking water primacy agency about returning to compliance with Safe Drinking Water Act MCLs.

In recommending this PAG, EPA considered the principles identified as the basis for PAGs. One of these principles is to "require optimization to balance protection with other important factors and ensure that actions taken result in more benefit than harm." EPA also considered consistency with other PAGs already established. The recommended drinking water PAG of 0.5 rem (5 mSv) is consistent with FDA guidance for food ingestion and with international guidance (ICRP 1991).

Estimates of risk of one year of exposure at the recommended drinking water PAG are in the range of risks that EPA has generally considered for protecting the public and are consistent with the upper limits of risk associated with current radionuclide drinking water standards, which assume lifetime exposure. EPA considers these dose and risk levels preventive of acute effects while reducing risk of chronic effects from radiation exposure during a radiological emergency. The time period of one year is also consistent with the time period recommended by the FDA PAGs for food.

Section 4.2 provides possible actions to be considered for community water supplies that may be affected by a radiological incident. For implementing the drinking water PAG in a radiological emergency, Section 4.3 provides the calculations for projecting radiation dose using the DRL equations and concentration of various radionuclides in drinking water, while Section 4.4 discusses which radionuclides were considered in the tables of drinking water DRLs. Section 4.5 provides specific guidance for applying the generic DRLs and Section 4.6 deals with DRLs for multiple radionuclides that may be deposited in the water supply.

4.2 Possible Actions for Protecting Drinking Water

In the case that water supplies may be affected by a radiological incident and that projected radiation doses from drinking contaminated water could exceed 0.5 rem (5 mSv) in the first year, actions to protect the communities should be taken. The first year is used since the Intermediate Phase of a radiological incident response may last weeks to months, depending on the severity of the incident. Projected Intermediate Phase doses are usually calculated assuming a one-year exposure.

Any of the actions described below may be taken alone or in combination, depending upon the nature of the emergency and the characteristics of the local water system. Consideration of these and other options during emergency planning provides the opportunity to develop state and local emergency plans and implementation procedures that reflect the unique needs of a particular community. Advance planning can provide clarity during the process of making key decisions quickly during a radiological emergency.

To ensure effectiveness of protective actions taken, emergency response plans should include a comprehensive radiological surveillance program. This program will monitor the concentration of radionuclides in the drinking water and will provide an indication of whether any action is necessary or if the actions being taken are effective. The emergency response plan should also include a strategy for keeping the community informed of the actions being taken and ensuring that people understand their role in carrying them out.

It should be noted that use of water tankers and bottled water are the best actions until municipal systems are verified to be unaffected. These actions may be escalated initially in response to a large incident that destroys water treatment and processing. This would virtually eliminate the need to evaluate drinking water supplies in the early stages of the intermediate phase.

Examples of these and other possible protective actions to protect drinking water are discussed in the following subsections.

4.2.1 Wait for Flow-By

If radionuclides are deposited from the atmosphere over a river, a section of the water can become contaminated, and can be repeatedly contaminated as rain re-deposits radioactive particles. As this section flows down the river, this section of contaminated water is called a plume; the behavior of this plume would be similar to an atmospheric or airborne plume of radiation.

The 'wait for flow-by' action calls for closing down any source intake valves along the path of the plume of contaminated water. While the intake valve is closed, no contaminated water can enter the water supply system, therefore the contaminated water is allowed to flow by the system. During this time, the system's existing storage capacity may be depended upon. Large systems usually possess 12 to 24 hours of water storage capacity. If the stored water supplies could be depleted before the affected valves can be reopened, treatment of the contaminated water while using available stored water supplies should be considered. This assumes that the treatment technology will be in place or readily accessible. In the event of no other option, contaminated water could be temporarily replaced with large quantities of purchased uncontaminated water.

4.2.2 Ration Clean Water Supplies

Rationing uncontaminated water is a potential protective action during the Intermediate Phase of a radiological incident response. This may be a useful option if water reserves can provide each individual in the community with 1 L (0.264G, about 1 qt) of water per day until the contaminated plume has passed, the contaminated water is treated, or the water supply system has returned to normal operating conditions. If this option is chosen, it is important that contamination is isolated from the system or is in a single area of the system and efficient methods for rationing are in place. Rationing water might also be required if water treatment capabilities are limited. Consider a scheme to ration water as part of emergency planning efforts.

4.2.3 Treat Contaminated Water

Various treatment options exist for reducing or eliminating the contamination of drinking water by man-made radionuclides. Only a small percentage of all water systems treat specifically for radionuclides. However, typical technologies used to treat water for other contaminants can reduce the concentration of radioactivity. These technologies include coagulation/filtration, ion exchange, lime softening, and reverse osmosis. Their actual removal efficiency depends on the radionuclide and the type of treatment.

4.2.4 Activate Existing Connections to Neighboring Systems

If the water supply system is part of a larger, regional supply system, activation of existing connections to a neighboring area could be considered for the Intermediate Phase. Most large water systems can establish connections with other large systems for emergency purposes. As in many cases, this option may have already been considered during emergency planning. If this option is implemented, steps must be taken to ensure that the "clean" systems do not become contaminated from water backflow.

Smaller water supply systems (i.e., that serve between 10,000 and 75,000 people), or sparsely populated or rural areas, may not be connected to a neighboring system. In this case, regionalization may be a part of emergency planning to explore. This involves connecting smaller systems to larger systems, thus forming a regional water supply system. This is obviously a long-term proposition, but it does have the added advantage of reducing system vulnerability to water shortages or water quality problems other than those resulting from a radiological incident.

4.2.5 Establish Pipeline Connections to Closest Sources/Systems

Running a pipeline from a "clean" water supply system to various distribution centers located throughout the affected community is a routine means of providing clean water. For example, when water mains must be repaired or cleaned of debris, community water needs have been met through the assembly of temporary pipes and hoses. For medium- to long-term emergencies, the construction of a temporary pipeline could be cost-effective. PVC pipe, fire hoses, and steel pipe have been used to provide emergency drinking water for periods of up to 2 months when service has been disrupted by earthquakes, drought, or bacterial contamination.

4.2.6 Import Water in Tanker Trucks

If an uncontaminated source of water is close to the affected area, it may be more efficient to arrange to transport water from that source by truck, rail, or barge to distribution centers located throughout the community. The most significant obstacle for the use of this option is the cleanliness and availability of transport vehicles. State and local laws may also affect this option.

4.2.7 Import Bottled Water

Importing bottled water into the affected community is another possible option. The water may come from a nearby water supply system or from a local spring water bottling company. This option may be cost-effective during an emergency if water is needed quickly and if the length of the emergency does not merit long-term action, such as the construction of a temporary pipeline.

4.3 Projecting Radiation Doses Using Derived Response Levels

DRLs are concentrations of radionuclides in water that correspond to EPA's drinking water PAG of 0.5 rem (5 mSv) in the first year. A radiological surveillance program will provide information regarding the concentration of various radionuclides in drinking water. This information can be used along with the tables provided in this chapter to determine whether the drinking water PAG is likely to be exceeded.

The drinking water PAG is separate from and does not impact EPA's Safe Drinking Water Act MCLs. Local authorities should consult with their state drinking water primacy agency about returning to compliance with Safe Drinking Water Act MCLs.

Although event-specific DRLs are derived based on the unique characteristics of the radiological emergency that has occurred and a specific community's preferred water system, such calculations can be difficult and time-consuming, requiring large amounts of data and specialized expertise in hydrology and water resource management. Instead, EPA has developed generic DRLs for use as a guide for decision-making in emergency planning and response activities. These generic DRLs can also be used during an actual emergency until there is sufficient time or a need to develop event-specific DRLs.

Table 4-1 presents generic DRLs for radionuclides likely to contaminate a water supply during a radiological emergency. This is the same list of radionuclides included in Chapters 2 and 3, with the exception of the very short-lived nuclides (half-life less than 1 day) and the noble gases. Short-lived radionuclides undergo radioactive decay at a speed that makes their deposition into the water supply unlikely.

EPA derived the DRLs by calculating the radionuclide concentrations in water that will result in a radiation dose of 0.5 rem (5 mSv) CED in the first year, assuming the members of the exposed population each consume 2 L (0.52 gal) of water per day for an entire year.

The DRLs may be calculated using the following formula:

$$DRL = \frac{HL}{hI\ (1 - e^{-LT})}$$

Where:

DRL=	the Derived Response Level (pCi/L);
H =	the PAG (mrem)
L =	the radionuclide's radioactive decay constant
h =	Dose Conversion Factor (mrem/pCi ingested)
T =	exposure time or interdiction time (d)
I =	the daily water intake (L/d)

This equation simplifies the removal of radiation from a water supply following a contaminating incident. For example, if a radiological incident results in the contamination of the water in a reservoir, then the radionuclide concentration will decline with the effective half-life of the radionuclide in the reservoir.

The assumed water intake rate, *I*, is another variable that will influence the DRLs. The water intake rate is assumed to be 2.0 L/d (0.528 gal/d), which represents the water intake of the upper 90th percentile of the U.S. population. The larger the assumed daily water consumption, the lower the DRLs. The DRLs are also affected by the assumed exposure time, *T*. In this analysis, *T* is assumed to be 1 year. Effectively, the longer the assumed exposure time, the lower the DRLs. The first year is used since the Intermediate Phase of a radiological incident response may last weeks to months, depending on the severity of the incident. Projected Intermediate Phase doses are usually calculated assuming a one-year exposure.

The 1-year exposure period assures that protective actions would be in place long enough for water monitoring to reveal a decline in the concentrations of radionuclides in the drinking water supply and/or other variables affecting the potential radiation dose to members of the community. Using a 1-year basis for the DRLs also reduces the uncertainty due to the inability to predict the temporal variations in rain storm events over a shorter period.

4.4 Derived Response Levels for Radionuclides in Drinking Water

The final step in developing the drinking water PAG was to calculate DRLs. These levels will allow emergency response personnel to determine whether the radionuclide concentrations in water are likely to exceed the drinking water PAG of 0.5 rem (5 mSv).

Table 5-3 in ICRP 1984 presents the DRLs for the air exposure pathway. For inhalation, even relatively short-lived radionuclides are of concern due to the short time from a release to an exposure via the airborne pathways .For the drinking water pathway, there is substantial delay between the contaminating event and exposure. For example, the typical turnover rate of a reservoir is 1 year. Accordingly, the list of radionuclides for the drinking water PAG was constructed from the list in Table 5-3 in ICRP 1984 by deleting the radionuclides with half-lives less than 1 day. This option was selected for the drinking water PAG because it includes a comprehensive list of potentially important radionuclides and is consistent with the approach used in developing the implementation guidance for the air exposure PAGs. Table 4-1 provides the actual list of these radionuclides and their associated DRLs. The "Without Radioactive Decay" column should be used when the situation indicates a radionuclide concentration may not decrease via radioactive decay due to being in secular equilibrium with a parent radionuclide and/or the source is continuously contaminating the water source.

4.5 Applying the Generic Derived Response Levels

EPA derived generic DRLs to assist in planning and, in the event of a radiological emergency, quick and effective execution of protective actions. Although event-specific DRLs would reduce some of the uncertainty associated with generic DRLs, it would require real-time analysis that might be difficult to obtain or cause a delay in taking action if time-sequenced data needed to be gathered. However, incident-specific DRLs may be developed; the generic values included in this Manual are only intended to act as a guide for decision-making.

DRLs can be used to trigger and guide the response to an incident that results in, or that could result in, the contamination of drinking water supplies. For example, action might be taken to protect water supplies as soon as notification of a radiological release is received. Data can then be obtained from monitoring programs, and field measurement programs can be expanded to include drinking water samples. Such programs could include sampling and analysis of water upstream and downstream of a water supply system and in storage within the supply system.

Comparison of these data to the DRLs in Table 4-1 can inform judgments regarding the need to implement protective actions. Once it is determined that the potential exists for the PAG to be exceeded, actions can be initiated or revised based on the results of comparison of environmental data to Table 4-1. It is important to remember that such actions are likely to be event-specific. However, consideration of various strategies during emergency planning will allow quick and effective decisions to be made in the case of an actual incident.

Developing a reasonably accurate model for predicting the movement of radionuclides from a watershed to their ultimate fate in a reservoir or other water body is a very difficult problem. The uncertainty of precipitation events represents a major obstacle to credibly predicting this movement. Rain may fall in almost any pattern of frequency and intensity. This leads to great uncertainty in predicting the magnitude of dilution in streams and lakes, the lateral movement of a contaminant due to erosion, or the vertical movement of a contaminant due to percolation in a watershed. Therefore, decisions on protective action must be based on measurements rather than calculations alone. A radiological environmental surveillance program in place to collect up-to-date information concerning the concentrations of radionuclides in water supplies is vital.

4.6 Derived Response Levels for Multiple Radionuclides

In the case that multiple radionuclides are found in the water supply, divide the actual concentration of each radionuclide in water by its DRL of 0.5 rem (5 mSv). This gives a fraction of the allowed amount in water for each radionuclide. If the sum of the fractions is 1 or less, the total of the radionuclides is less than the PAG of 0.5 rem. (See the fractions rule, as follows):

$$F = \sum_{i}^{n} \frac{C_i}{DRL_i}$$

Where:

F	=	the sum of fractions
C_i	=	the concentration of radionuclide, i, in the water supply (pCi/L)
DRL_i	=	the Derived Response Level for the i^{th} radionuclide (pCi/L)

For example, assume that as a result of a nuclear power plant accident, a water supply is contaminated with 100,000 pCi/L of I-131, 12,000 pCi/L of Cs-137, and 3,500 pCi/L of Sr-90.

The DRLs in Table 4-1 for radioactive decay only are 267,000; 13,800; and 6,730 respectively. The sum of fractions rule would result in the following:

F = 100,000/267,000 + 12,000/13,800 + 3,500/6,730 = 0.37 + 0.87 + 0.52 = 1.76

Based on this, the radionuclide contamination levels exceed the DRL for this combination of radionuclides, assuming depletion by radioactive decay only. As such, actions to protect drinking water would be recommended.

If F is greater than one, the DRL is exceeded. Intervention is recommended until such time that the radionuclide concentrations decline below the DRL and that decision makers are certain that the radionuclide concentrations will not increase above the DRL in the future.

Table 4-1. Derived Response Levels (DRLs) Associated with a Committed Effective Dose (CED) of 0.5 rem Resulting from 1 Year of Ingestion

			Normalized mrem per pCi/L (CED)		DRLs (pCi/L)	
Radionuclide	Radioactive Decay Constant 1/d	DCF mrem/μCi	Without Radioactive Decay	With Radioactive Decay Only	Without Radioactive Decay	With Radioactive Decay Only
H-3	1.54E-04	1.55E-01	1.13E-04	1.10E-04	4.42E+06	4.54E+06
C-14	3.31E-07	2.15E+00	1.57E-03	1.57E-03	3.19E+05	3.19E+05
Na-22	7.29E-04	1.18E+01	8.61E-03	7.56E-03	5.80E+04	6.61E+04
P-32	4.85E-02	8.88E+00	6.48E-03	3.66E-04	7.71E+04	1.37E+06
P-33	2.73E-02	9.10E-01	6.64E-04	6.67E-05	7.53E+05	7.50E+06
S-35	7.93E-03	2.87E+00	2.10E-03	6.84E-04	2.39E+05	7.31E+05
Cl-36	6.30E-09	3.44E+00	2.51E-03	2.51E-03	1.99E+05	1.99E+05
K-40	1.48E-12	2.28E+01	1.66E-02	1.66E-02	3.00E+04	3.00E+04
Ca-45	4.25E-03	2.63E+00	1.92E-03	9.75E-04	2.60E+05	5.13E+05
Sc-46	8.27E-03	5.48E+00	4.00E-03	1.26E-03	1.25E+05	3.97E+05
Ti-44	3.16E-05	2.15E+01	1.57E-02	1.56E-02	3.19E+04	3.20E+04
V-48	4.27E-02	7.33E+00	5.35E-03	3.43E-04	9.34E+04	1.46E+06

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Radionuclide	Radioactive Decay Constant 1/d	DCF mrem/μCi	Without Radioactive Decay	With Radioactive Decay Only	Without Radioactive Decay	With Radioactive Decay Only
Cr-51	2.50E-02	1.43E-01	1.04E-04	1.14E-05	4.79E+06	4.37E+07
Mn-54	2.22E-03	2.67E+00	1.95E-03	1.34E-03	2.57E+05	3.74E+05
Fe-55	7.03E-04	1.23E+00	8.98E-04	7.92E-04	5.57E+05	6.31E+05
Fe-59	1.56E-02	6.62E+00	4.83E-03	8.46E-04	1.03E+05	5.91E+05
Co-58	9.79E-03	2.77E+00	2.02E-03	5.50E-04	2.47E+05	9.09E+05
Co-60	3.60E-04	1.27E+01	9.27E-03	8.69E-03	5.39E+04	5.76E+04
Ni-63	1.98E-05	5.63E-01	4.11E-04	4.10E-04	1.22E+06	1.22E+06
Zn-65	2.84E-03	1.46E+01	1.07E-02	6.64E-03	4.69E+04	7.54E+04
Ge-68	2.41E-03	4.77E+00	3.48E-03	2.32E-03	1.44E+05	2.16E+05
Se-75	5.79E-03	9.66E+00	7.05E-03	2.93E-03	7.09E+04	1.70E+05
Rb-86	3.71E-02	1.04E+01	7.59E-03	5.61E-04	6.59E+04	8.92E+05
Sr-89	1.37E-02	9.51E+00	6.94E-03	1.38E-03	7.20E+04	3.63E+05
Sr-90	6.52E-05	1.03E+02	7.52E-02	7.43E-02	6.65E+03	6.73E+03
Y-90	2.60E-01	9.96E+00	7.27E-03	7.66E-05	6.88E+04	6.53E+06
Y-91	1.18E-02	8.77E+00	6.40E-03	1.47E-03	7.81E+04	3.41E+05
Zr-93	1.24E-09	4.11E+00	3.00E-03	3.00E-03	1.67E+05	1.67E+05
Zr-95	1.08E-02	3.56E+00	2.60E-03	6.46E-04	1.92E+05	7.73E+05
Nb-94	9.35E-08	6.44E+00	4.70E-03	4.70E-03	1.06E+05	1.06E+05
Nb-95	1.97E-02	2.18E+00	1.59E-03	2.21E-04	3.14E+05	2.26E+06
Mo-99	2.52E-01	2.24E+00	1.64E-03	1.78E-05	3.06E+05	2.81E+07
Tc-99	8.91E-09	2.38E+00	1.74E-03	1.74E-03	2.88E+05	2.88E+05
Ru-103	1.76E-02	2.72E+00	1.99E-03	3.09E-04	2.52E+05	1.62E+06
Ru/Rh-106	1.88E-03	2.59E+01	1.89E-02	1.37E-02	2.64E+04	3.65E+04
Ag-110m	2.77E-03	1.03E+01	7.52E-03	4.73E-03	6.65E+04	1.06E+05
Cd-109	1.49E-03	7.40E+00	5.40E-03	4.17E-03	9.26E+04	1.20E+05
Cd-113m	1.40E-04	8.51E+01	6.21E-02	6.06E-02	8.05E+03	8.26E+03
In-114m	1.40E-02	1.51E+01	1.10E-02	2.14E-03	4.54E+04	2.33E+05
Sn-113	6.02E-03	2.73E+00	1.99E-03	8.06E-04	2.51E+05	6.20E+05
Sn-123	5.36E-03	7.77E+00	5.67E-03	2.49E-03	8.82E+04	2.01E+05
Sn-125	7.19E-02	1.14E+01	8.32E-03	3.17E-04	6.01E+04	1.58E+06
Sn-126	8.25E-09	1.77E+01	1.29E-02	1.29E-02	3.87E+04	3.87E+04
Sb-124	1.15E-02	9.40E+00	6.86E-03	1.61E-03	7.29E+04	3.11E+05
Sb-126	5.59E-02	9.10E+00	6.64E-03	3.26E-04	7.53E+04	1.54E+06
Sb-127	1.80E-01	6.18E+00	4.51E-03	6.87E-05	1.11E+05	7.28E+06
Te-127	1.78E+00	6.25E-01	4.56E-04	7.02E-07	1.10E+06	7.12E+08
Te-129	1.43E+01	2.33E-01	1.70E-04	3.26E-08	2.94E+06	1.53E+10
Te-129m	2.06E-02	1.10E+01	8.03E-03	1.07E-03	6.23E+04	4.68E+05
Te-131m	5.55E-01	7.22E+00	5.27E-03	2.60E-05	9.49E+04	1.92E+07
Te/I-132	2.13E-01	1.41E+01	1.03E-02	1.32E-04	4.86E+04	3.78E+06
I-125	1.15E-02	5.70E+01	4.16E-02	9.76E-03	1.20E+04	5.12E+04
I-129	1.21E-10	3.92E+02	2.86E-01	2.86E-01	1.75E+03	1.75E+03
I-131	8.62E-02	8.07E+01	5.89E-02	1.87E-03	8.49E+03	2.67E+05
Cs-134	9.20E-04	7.11E+01	5.19E-02	4.41E-02	9.63E+03	1.13E+04
Cs-136	5.29E-02	1.14E+01	8.32E-03	4.31E-04	6.01E+04	1.16E+06
Cs/Ba-137	6.33E-05	5.03E+01	3.67E-02	3.63E-02	1.36E+04	1.38E+04
Ba-133	1.77E-04	5.66E+00	4.13E-03	4.00E-03	1.21E+05	1.25E+05

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Radionuclide	Radioactive Decay Constant 1/d	DCF mrem/μCi	Without Radioactive Decay	With Radioactive Decay Only	Without Radioactive Decay	With Radioactive Decay Only
Ba-140	5.44E-02	9.62E+00	7.02E-03	3.54E-04	7.12E+04	1.41E+06
La-140	4.13E-01	7.48E+00	5.46E-03	3.62E-05	9.16E+04	1.38E+07
Ce-141	2.13E-02	2.63E+00	1.92E-03	2.47E-04	2.60E+05	2.03E+06
Ce-143	5.04E-01	4.15E+00	3.03E-03	1.65E-05	1.65E+05	3.04E+07
Ce/Pr-144	2.44E-03	1.94E+01	1.42E-02	9.38E-03	3.53E+04	5.33E+04
Nd-147	6.31E-02	4.00E+00	2.92E-03	1.27E-04	1.71E+05	3.94E+06
Pm-145	1.07E-04	4.29E-01	3.13E-04	3.07E-04	1.60E+06	1.63E+06
Pm-147	7.23E-04	9.66E-01	7.05E-04	6.20E-04	7.09E+05	8.07E+05
Pm-149	3.13E-01	3.68E+00	2.69E-03	2.35E-05	1.86E+05	2.13E+07
Pm-151	5.86E-01	2.71E+00	1.98E-03	9.25E-06	2.53E+05	5.41E+07
Sm-151	2.11E-05	3.63E-01	2.65E-04	2.64E-04	1.89E+06	1.89E+06
Eu-152	1.42E-04	5.07E+00	3.70E-03	3.61E-03	1.35E+05	1.39E+05
Eu-154	2.16E-04	7.55E+00	5.51E-03	5.30E-03	9.07E+04	9.43E+04
Eu-155	3.83E-04	1.21E+00	8.83E-04	8.24E-04	5.66E+05	6.07E+05
Gd-153	2.86E-03	1.03E+00	7.52E-04	4.67E-04	6.65E+05	1.07E+06
Tb-160	9.59E-03	5.96E+00	4.35E-03	1.21E-03	1.15E+05	4.15E+05
Ho-166m	1.58E-06	7.33E+00	5.35E-03	5.35E-03	9.34E+04	9.35E+04
Tm-170	5.39E-03	4.89E+00	3.57E-03	1.56E-03	1.40E+05	3.20E+05
Yb-169	2.17E-02	2.63E+00	1.92E-03	2.42E-04	2.60E+05	2.06E+06
Hf-181	1.63E-02	4.15E+00	3.03E-03	5.08E-04	1.65E+05	9.84E+05
Ta-182	6.03E-03	5.70E+00	4.16E-03	1.68E-03	1.20E+05	2.97E+05
W-187	6.96E-01	2.33E+00	1.70E-03	6.70E-06	2.94E+05	7.47E+07
Ir-192	9.36E-03	5.07E+00	3.70E-03	1.05E-03	1.35E+05	4.77E+05
Au-198	2.57E-01	3.81E+00	2.78E-03	2.96E-05	1.80E+05	1.69E+07
Hg-203	1.49E-02	7.07E+00	5.16E-03	9.45E-04	9.69E+04	5.29E+05
Tl-204	5.02E-04	4.40E+00	3.21E-03	2.93E-03	1.56E+05	1.70E+05
Pb-210	8.51E-05	2.58E+03	1.88E+00	1.85E+00	2.65E+02	2.70E+02
Bi-207	4.99E-05	4.70E+00	3.43E-03	3.40E-03	1.46E+05	1.47E+05
Bi-210	1.38E-01	4.85E+00	3.54E-03	7.03E-05	1.41E+05	7.11E+06
Po-210	5.01E-03	4.48E+03	3.27E+00	1.50E+00	1.53E+02	3.33E+02
Ra-226	1.19E-06	1.04E+03	7.59E-01	7.59E-01	6.59E+02	6.59E+02
Ac-227	8.72E-05	1.19E+03	8.69E-01	8.55E-01	5.76E+02	5.85E+02
Th-227	3.70E-02	3.34E+01	2.44E-02	1.81E-03	2.05E+04	2.77E+05
U-235	2.70E-12	1.73E+02	1.26E-01	1.26E-01	3.96E+03	3.96E+03
U-238	4.25E-13	1.65E+02	1.20E-01	1.20E-01	4.15E+03	4.15E+03
Np-237	8.87E-10	3.96E+02	2.89E-01	2.89E-01	1.73E+03	1.73E+03
Np-239	2.94E-01	2.95E+00	2.15E-03	2.01E-05	2.32E+05	2.49E+07
Pu-236	6.66E-04	3.22E+02	2.35E-01	2.09E-01	2.13E+03	2.40E+03
Pu-238	2.16E-05	8.44E+02	6.16E-01	6.14E-01	8.12E+02	8.15E+02
Pu-239	7.89E-08	9.29E+02	6.78E-01	6.78E-01	7.37E+02	7.37E+02
Pu-240	2.90E-07	9.29E+02	6.78E-01	6.78E-01	7.37E+02	7.37E+02
Pu-241	1.32E-04	1.76E+01	1.28E-02	1.25E-02	3.89E+04	3.99E+04
Pu-242	5.04E-09	8.81E+02	6.43E-01	6.43E-01	7.77E+02	7.77E+02
Am-241	4.39E-06	7.55E+02	5.51E-01	5.51E-01	9.07E+02	9.08E+02
Am-242m	1.25E-05	7.07E+02	5.16E-01	5.15E-01	9.69E+02	9.71E+02
Am-243	2.57E-07	7.51E+02	5.48E-01	5.48E-01	9.12E+02	9.12E+02

Table 4-1. Derived Response Levels (DRLs) Associated with a Committed Effective Dose (CED) of 0.5 rem Resulting from 1 Year of Ingestion

			Normalized mrem per pCi/L (CED)		DRLs (pCi/L)	
Radionuclide	Radioactive Decay Constant 1/d	DCF mrem/μCi	Without Radioactive Decay	With Radioactive Decay Only	Without Radioactive Decay	With Radioactive Decay Only
Cm-242	4.26E-03	4.33E+01	3.16E-02	1.60E-02	1.58E+04	3.12E+04
Cm-243	6.66E-05	5.51E+02	4.02E-01	3.97E-01	1.24E+03	1.26E+03
Cm-244	1.05E-04	4.55E+02	3.32E-01	3.26E-01	1.51E+03	1.53E+03
Cm-245	2.23E-07	7.70E+02	5.62E-01	5.62E-01	8.90E+02	8.90E+02
Cm-246	4.01E-07	7.66E+02	5.59E-01	5.59E-01	8.94E+02	8.94E+02
Cf-252	7.19E-04	3.52E+02	2.57E-01	2.26E-01	1.95E+03	2.21E+03

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Acronyms

AMAD	Activity Median Aerodynamic Diameter
AvCRP	Average Combined Removal Parameter
AvEffXP	Average Effective Exposure Period
CDF	Committed Dose Factor
CED	Committed Effective Dose
CRP	Combined Removal Parameter
DCP	Dose Conversion Parameter
Dp_DRL	Deposition Derived Response Level
Dp_TDP_Dp	Deposition Total Dose Parameter
DRL	Derived Response Level
EffXP	Effective Exposure Period
ExXC	External Exposure Coefficient
ExDF	External Dose Factor
ExDP_Dp	External Dose Parameter for Deposition
ExXR	External Exposure Rate
FDA	U.S. Food and Drug Administration
GRF	Ground Roughness Factor
ICRP	International Commission on Radiological Protection
IND	Improvised Nuclear Device
K	Resuspension Factor
KI	Potassium Iodide
KP	Resuspension Parameter
PAG	Protective Action Guide
RDD	Radiological Dispersal Device
TED	Total Effective Dose
TDP_Dp	Total Dose Parameter for Surface Deposition
TDP_XR	Total Dose Parameter for Exposure Rate