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TECHNICAL REPORT

Technical Basis for Expedited Processing of Radiation Dose Assessments for NTPR Hiroshima and Nagasaki Participants

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14. ABSTRACT
This report provides the technical basis for development and use of radiation doses for use in expedited processing of Radiation Dose Assessments (RDAs) for Hiroshima and Nagasaki (H&N) veterans in the Nuclear Test Personnel Review (NTPR) Program. The report describes the general nature of RDAs currently conducted for H&N veterans, and the approach used to define three expedited processing groups (EPGs) to include virtually all H&N veterans, including occupation forces and prisoners of war in or near Hiroshima or Nagasaki, Japan in 1945–1946. The report discusses the technical methods and assumptions used for estimating "maximized doses" and upper-bound external, internal, skin, and eye lens doses for each EPG. The results of the dose assessment for each EPG are presented and discussed.

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UNIT CONVERSION TABLE

U.S. customary units to and from international units of measurement*

U.S. Customary Units	Multiply by → / ← Divide by†		International Units
Length/Area/Volume			
inch (in)	2.54	$\times 10^{-2}$	meter (m)
foot (ft)	3.048	$\times 10^{-1}$	meter (m)
yard (yd)	9.144	$\times 10^{-1}$	meter (m)
mile (mi, international)	1.609 344	$\times 10^{3}$	meter (m)
mile (nmi, nautical, U.S.)	1.852	$\times 10^{3}$	meter (m)
barn (b)	1	$\times 10^{-28}$	square meter (m^2)
gallon (gal, U.S. liquid)	3.785 412	$\times 10^{-3}$	cubic meter (m^3)
cubic foot (ft^3)	2.831 685	$\times 10^{-2}$	cubic meter (m^3)
Mass/Density			
pound (lb)	4.535 924	$\times 10^{-1}$	kilogram (kg)
unified atomic mass unit (amu)	1.660 539	$\times 10^{-27}$	kilogram (kg)
pound-mass per cubic foot (lb ft^{-3})	1.601 846	$\times 10^{1}$	kilogram per cubic meter (kg m^{-3})
pound-force (lbf avoirdupois)	4.448 222		newton (N)
Energy/Work/Power			
electron volt (eV)	1.602 177	$\times 10^{-19}$	joule (J)
erg	1	$\times 10^{-7}$	joule (J)
kiloton (kt) (TNT equivalent)	4.184	$\times 10^{12}$	joule (J)
British thermal unit (Btu) (thermochemical)	1.054 350	$\times 10^{3}$	joule (J)
foot-pound-force (ft lbf)	1.355 818		joule (J)
calorie (cal) (thermochemical)	4.184		joule (J)
Pressure			
atmosphere (atm)	1.013 250	$\times 10^{5}$	pascal (Pa)
pound force per square inch (psi)	6.984 757	$\times 10^{3}$	pascal (Pa)
Temperature			
degree Fahrenheit (^oF)	$[T(^oF) - 32]/1.8$		degree Celsius (^oC)
degree Fahrenheit (^oF)	$[T(^oF) + 459.67]/1.8$		kelvin (K)
Radiation			
curie (Ci) [activity of radionuclides]	3.7	$\times 10^{10}$	per second (s^{-1}) [becquerel (Bq)]
roentgen (R) [air exposure]	2.579 760	$\times 10^{-4}$	coulomb per kilogram (C kg^{-1})
rad [absorbed dose]	1	$\times 10^{-2}$	joule per kilogram (J kg^{-1}) [gray (Gy)]
rem [equivalent and effective dose]	1	$\times 10^{-2}$	joule per kilogram (J kg^{-1}) [sievert (Sv)]

*Specific details regarding the implementation of SI units may be viewed at http://www.bipm.org/en/si/.

†Multiply the U.S. customary unit by the factor to get the international unit. Divide the international unit by the factor to get the U.S. customary unit.

2015-11-16

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Executive Summary

Expedited processing of Nuclear Test Personnel Review program radiation dose assessments (RDAs) is an option for certain claims from the Department of Veterans Affairs that require a radiation dose reconstruction. This process allows for timely processing of claims from many veterans, while ensuring that an individual veteran's assigned dose is greater than his actual dose. Claims that are limited to potential exposures associated with participation as World War II Prisoners of War (POW) in Japan or as a member of the post-war occupation forces in the vicinity of Hiroshima and Nagasaki (H&N), Japan, have just recently been included in expedited processing procedures. This technical report was prepared to describe and document the technical basis for radiation doses suitable for use in expedited processing of H&N[1] claims.

The technical basis for H&N expedited processing doses involves the development and analysis of three large Expedited Processing Groups (EPGs) to include essentially all H&N participants. Each EPG includes individuals who share fundamental aspects of a generic exposure scenario, and who can therefore be grouped for purposes of a bounding radiation dose assessment. The three H&N EPGs consist of one EPG for approximately 154,000 Hiroshima participants, a second EPG for approximately 122,000 Nagasaki participants, and a third EPG for approximately 3,000 POWs. The H&N EPGs were developed in a manner similar to that used for EPGs previously developed for participants in U.S. atmospheric nuclear tests conducted at the Pacific Proving Ground and the Nevada Test Site. The organ, skin, and eye (lens) doses calculated for each H&N EPG are based on high-sided and maximized parameter values and assumptions, and their upper bounds are higher than any realistically-calculated upper-bound doses for any member of one of the EPGs. Consequently, the resulting EPG doses described in this report are suitable for use in the expedited processing of the claim for any H&N participant that can be included in one of the H&N EPGs.

For assignment to a veteran, upper-bound total organ and skin doses must not only clearly bound the veteran's actual dose, but also must be well below the dose that could result in a service-connected decision. In order to judge if doses were well below a dose resulting in a service-connected determination, limiting doses (LDs) were identified for all cancer types for organs and three skin cancer types. The LD value is the radiation dose that results in a probability of causation of 40 percent for an organ or skin cancer. The majority of upper-bound radiation doses calculated for 20 internal organs and 11 skin sites for each H&N EPG are less than the applicable LDs, and are thus suitable for use as the basis for expedited processing. Exceptions include skin doses for cases involving certain skin site/cancer combinations for individuals in all three H&N EPGs. In addition, claims for members of the POW EPG involving cancers of the thyroid are not recommended for expedited processing based on the comparison of the POW EPG thyroid total organ dose to the thyroid LD.

[1] The use of "H&N" in this report generally refers to all H&N occupation forces, including occupation troops, POWs, veterans passing through Hiroshima or Nagasaki, and ship-based personnel at either location. Specific definitions of H&N participants are provided in 38 CFR 3.309 (VA, 2015) and apply throughout this report.

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Section 1.

Introduction

Since 2008, the Nuclear Test Personnel Review (NTPR) program has used an approved procedure to expedite the processing of radiation dose assessments (RDAs) for certain claims submitted by the Department of Veterans Affairs (VA) for atmospheric nuclear weapons testing veterans with qualifying participant exposure scenarios. Qualifying claims may be expedited using Standard Operating Procedure (SOP) RA02 (DTRA, 2015a), by assigning pre-determined, group-based, upper-bound dose estimates to veteran claimants. The use of expedited processing procedures allows for timely processing of large numbers of claims while ensuring that an individual veteran's assigned dose is greater than his actual dose.

Veteran claims that involve potential radiation exposure only in the vicinity of Hiroshima or Nagasaki, Japan, in 1945 or 1946 are not included in the expedited processing procedure of SOP RA02 or its predecessors (DTRA, 2015a). These Hiroshima and Nagasaki (H&N[2]) claims primarily involve participation as a World War II Prisoner of War (POW) or as a member of the post-war occupation forces in the vicinity of Hiroshima and Nagasaki. Approximately 280,000 individuals have been identified as potential members of one of these participant groups. Without expedited processing for H&N claims, preparation of veteran-specific exposure scenarios and dose estimates was necessary for DTRA to process the claims. This resulted in additional processing time with no added benefit to claimants.

To address expedited processing for H&N claims, DTRA recently prepared a draft version of SOP RA05 (DTRA, 2015b). That Draft SOP is similar to RA02 in that it includes the assignment of pre-determined, group-based, upper-bound dose estimates to H&N veteran claimants. The basis for the pre-determined doses was established in McKenzie-Carter (2014), which initially described the approach and technical basis to support expedited processing of claims involving H&N exposure scenarios. The purpose of the current report is to further describe relevant participation details of various H&N military units, and to document in more detail the methodology for the estimation of upper-bound external and internal radiation doses to internal organs, and external doses to the skin and the lens of the eye using maximized H&N exposure scenarios. The approach described in this report generally follows the approach used previously for development of the technical basis for expedited processing of claims involving participation in U.S. atmospheric nuclear tests conducted primarily at the Pacific Proving Ground (PPG) and the Nevada Test Site (NTS) (Case et al., 2011a; Case et al., 2011b). Consequently, the doses described herein are suitable for use in the expedited processing of H&N claims.

[2] The use of "H&N" in this report generally refers to all H&N occupation forces, including occupation troops, POWs, veterans passing through Hiroshima or Nagasaki, and ship-based personnel at either location. Specific definitions of H&N participants are provided in 38 CFR 3.309 (VA, 2015) and apply throughout this report.

Section 2.

Background Information

This section describes the types of doses used for expedited processing of PPG and NTS cases, and the general nature of H&N RDAs as currently prepared in the NTPR program. These are provided as background information on the expedited processing framework and to provide a context for the dose analyses described in this report.

2.1 NTPR Expedited Processing and Doses

There are two different sets of doses utilized in the expedited processing SOP for NTS and PPG cases (DTRA, 2015a). The two sets of doses are designated as Expedited Processing ("XP") doses and Expedited Processing Group ("EPG") doses. The XP doses are defined for two broad scenario categories, i.e., for PPG participants and NTS participants (DTRA, 2015a). They are based on distributions of doses from the NTPR database of full RDAs as described in Case et al. (2011a), and are judged to bound actual veteran doses. The XP doses are used for assignment to veterans in expedited processing of PPG and NTS claims. Claims involving H&N scenarios are assigned XP doses only if those claims also involve participation in a PPG or NTS operation, and other criteria are met (DTRA, 2015a). In contrast, the EPG doses consist of sets of scenario-based doses that were developed specifically for use in expedited processing of RDAs. Doses were estimated for 32 defined exposure groups participating in various operational series at either PPG or NTS, based on similarity of activities and exposure pathways (Case et al., 2011a). The EPG upper-bound doses are also judged to bound actual veteran doses, but rather than being used for assignment to veterans, EPG doses are used in the expedited processing SOP to help ensure that XP dose assignments are appropriate.

In an effort to produce a set of XP doses for H&N claims, a review of the NTPR database was conducted to characterize the range of upper-bound doses for completed H&N RDAs. Because of the low number of RDAs, and the format of the database entries, not enough information was available to develop a set of H&N XP doses. Therefore, EPG upper-bound doses corresponding to maximized H&N exposure scenarios were developed to support expedited processing of H&N claims. Because of the use of EPGs and EPG doses, the technical information and the maximized doses contained in this report are suitable for use in expedited processing of H&N claims. The specific use of these doses will be addressed in a new revision of NTPR SOP RA05 (DTRA, 2015b).

2.2 General Nature of H&N RDAs

The standard methods used for H&N RDAs form the foundation for development of the technical basis for full expedited processing of NTPR H&N claims. Standard RDA analyses for H&N cases are conducted somewhat differently than the analyses for other NTPR cases, as described in the NTPR/RDA SOP Manual (DTRA, 2008, Appendix A-1). This is due to the very limited information that is available to characterize the H&N radiation environments and participant activities, which is in contrast to what is available for most PPG and NTS participants. Consequently, H&N exposure scenarios are not customized for various participating units to account for specific locations, radiation environments, or activities conducted. The standard H&N RDA analyses require only the specification of known or assumed arrival and

departure dates, generic daily durations of exposure, breathing rate, and identification of the affected organ(s). Values for all other exposure scenario parameters are generic (not specific to a veteran or a unit) and are generally very high-sided. For example, almost all H&N RDA dose estimates are based on no more than two measured radiation exposure rates at each general location (i.e., two measurements for Hiroshima and two for Nagasaki). The standard assumption in H&N RDAs is that the entire time a veteran spent in any contaminated area was in an area at which one of these levels was measured. In reality, these areas of relatively high radiation levels were very small (approximately 0.04 square miles (mi^2). In addition, measurable contamination levels were recorded over only 50 percent of the Hiroshima built-up area and only 14 percent of Nagasaki's (McRaney and McGahan, 1980). Similar to participants at Hiroshima and Nagasaki, dose estimates for POWs are based on a maximum measured exposure rate, from a location approximately 25 mi downwind of Nagasaki on the Shimabara Peninsula. This location is approximately 20 mi upwind of the nearest POW camp (at Kumamoto) and is also well away from all other known POW camps in Japan with surviving POWs (McRaney, 1987).

Another important example of a high-sided scenario assumption used in H&N RDAs is that all Nagasaki participants were assumed to ingest 2 liters per day ($L\ d^{-1}$) of contaminated water from the Nishiyama Reservoir. This assumption is based on the knowledge that this reservoir was one of four reservoirs that provided drinking water to Nagasaki City. The assumed activity concentration of the reservoir water is based on the fallout surface activity estimated for the land surface near Nishiyama Reservoir, and includes a factor to account for potential additions of fallout entrained in runoff from the catchment area surrounding the reservoir. The calculated reservoir water activity concentration does not incorporate any dilution that would result from additions of rain or inflow of runoff water over the period of dose assessment. (DTRA, 2008, Appendix A-1)

Because of the lack of scenario-specific information for H&N case analyses and the resulting use of very high-sided default parameter values, H&N RDA doses are much more conservative than standard NTPR RDAs as completed for most PPG and NTS participants. In addition, few details are available to characterize exposure scenarios for most H&N participants, and consequently there are no distinct H&N cohort scenarios. These high-siding characteristics are reflected in the technical approach to dose estimation for H&N EPGs, as well as in the specific EPG organ, skin, and lens of the eye doses, as described in the following section.

Section 3.

Approach for H&N Expedited Processing Doses

As described above, neither XP nor EPG doses are available in SOP RA02 for use in NTPR processing of H&N claims. Consequently, H&N EPG doses have been developed for use in expedited processing of these claims, and are described in this report. The EPG doses are based on the approved NTPR standard methods and use the same general approach as was used in the development of EPG doses for PPG and NTS veterans, as described below.

3.1 General Approach for EPG Dose Assessments

The general approach for EPG dose assessments was established previously by the process used to develop EPG scenarios and doses for PPG and NTS participants (Case et al., 2011a). The basic steps of the process are listed below.

1) Identify EPG cohorts (simultaneously identify specific exclusion activities)
2) Select a "highest-dose" cohort
3) Modify exposure pathway doses by combining pathway doses from multiple cohorts
4) Replace parameter values with limiting plausible values where possible
5) Calculate EPG doses for each pathway and upper-bound EPG doses using NTPR standard methods supplemented by additional high-sided assumptions

For PPG and NTS EPG development, the above steps were applied using the wide variety of cohort exposure scenarios for PPG and NTS participants. For each cohort, potential exposure pathways, radiation environments, and participant activities were based on cohort-specific assumptions and parameter values to develop reasonably high-sided estimates of cohort doses. This resulted in EPG doses that satisfied the criteria that they are based on dose-maximizing parameter values and assumptions, and that their upper bounds be higher than any realistically calculated veteran's upper-bound doses, while simultaneously maximizing the number of participants included in each EPG. (Case et al., 2011a; Case et al., 2011b)

3.2 Methodology for Determining Composition of H&N EPGs

Because of the very high-sided and generic nature of H&N RDA analyses (Section 2.2), the general EPG steps listed above could not be rigorously applied for the development of H&N EPGs. For example, an H&N "cohort" was necessarily described more loosely than those defined for PPG and NTS, because activities of most participants are not well-documented in the available military records. Therefore, H&N cohorts could not be based on well-defined scenarios of participation activities and exposures of their members. However, it was still possible to develop a basis for H&N EPG development that was more broadly defined than what is used for typical H&N RDA doses, and that relied on categories that would be useful to the NTPR program in processing participation and dose requests from the VA. Consequently, following the five numbered steps above, the general approach to development of H&N EPGs is described below.

1) Initial large groupings of participants at both Hiroshima and Nagasaki were made, based on very general criteria such as time-frame of participation, and assigned location (e.g.,

on land or on a ship). The list below shows the five participant categories that were identified for both Hiroshima and Nagasaki.

- Occupation troops: Individuals assigned to units responsible for the occupation of Hiroshima or Nagasaki during the period August 6, 1945 through early July, 1946. Occupation troops were assigned to units within the organizational structure at each location and were responsible for establishing control of Japan, ensuring compliance with the surrender terms, and conducting activities related to demilitarization, rehabilitation of the infrastructure or deactivation and conversion of war plants or materials. Activities did not include cleanup of any areas or rebuilding any facilities. (VA, 2015; Gladeck and Johnson, 1996; McRaney and McGahan, 1980)
- Ship-based personnel: These individuals were assigned to ships that were in or near the harbor during the occupation period. Responsibilities assigned to these ships included mine sweeping, harbor patrols, loading of POWs for repatriation, ferrying duties, and possibly some shore-based duties.
- Enroute personnel: Individuals that passed through Hiroshima or Nagasaki before or during the occupation period while enroute to or from other locations in Japan.
- POWs: Individuals that were interned as a prisoner of war within 75 mi of Hiroshima or 150 mi of Nagasaki, Japan during World War II and had the opportunity for radiological exposure comparable to that of the Occupation troops at any time during the occupation period.
- Other personnel: Participants that are not obviously in any other H&N participant category. This primarily includes pre-occupation forces present in Japan as early as approximately September 8, 1945, and those remaining beyond the end of the occupation periods. Also included are aircrew members participating on or after August 6 or August 9, 1945, and any participants not assigned to a military unit within the organizational structure of occupation forces at each location.

Within each of these large groups, "cohorts" were identified based on criteria such as arrival/departure dates, geographic area of responsibility, location of POW camp, and assigned ship.

2) Similar criteria as those for cohort identification (Step #1) were then used to identify the most likely highest-dose cohort within each group. This determination was later confirmed on the basis of scoping dose calculations.
3) Modification of the exposure pathway doses was considered; however, modifications were not made because pathways and associated doses were generally shared by all related cohorts.
4) Only a limited replacement of RDA default parameter values was accomplished because most parameter values were already at or above maximum reasonable values.
5) The existing H&N RDA standard methods were then used to calculate external, internal, skin, and eye lens doses and upper bounds for the highest-dose cohort for each group.

Following a review of the potential exposure scenarios and performing scoping dose calculations for the five participant categories listed above for Hiroshima and Nagasaki participants, it was possible to further combine several of these groups.

For Hiroshima and Nagasaki participants, respectively, a review of known and likely participant activities allowed for the determination that individuals in the Occupation troops, Ship-based personnel, Enroute personnel, and Other personnel categories could be combined into a single EPG for each location. Although general activities of members of these groups may have been different, their activities that may have resulted in exposure to residual radiation were likely similar. Furthermore, the sources of potential radiation exposure of members of these groups were similar. In addition, the following characteristics of specific categories were included in the considerations for final grouping:

- Ship-based personnel had no sources of exposure while on-board ship (including consumption of seawater [McRaney, 1993]), so all potential exposures were the same as or less than the Occupation troops.
- Enroute personnel, by definition, would have spent much less time in Hiroshima or Nagasaki than Occupation troops, and also less time in potentially contaminated areas.
- Other personnel includes individuals who were often present for only a short period (e.g., pre-occupation and POW recovery participants), and therefore had generally less potential for exposures.
- The potential doses for POWs repatriated through Hiroshima were determined to be bounded by POW doses calculated for POWs repatriated through Nagasaki, and so all POWs were combined into a single POW EPG.

The identification, evaluation, and final grouping of participant categories resulted in the three EPGs described below and evaluated in this technical report: two primary EPGs which include most H&N participants, and a single EPG for POWs. These three EPGs are intended to cover all individuals that are confirmed by the NTPR program as participants of the occupation of Hiroshima or Nagasaki, or as former prisoners of war in Japan (VA, 2015). The EPGs are listed below (with participant categories included as indicated), and are also shown in Table 1.

- Hiroshima EPG: includes Occupation troops, Ship-based personnel, Enroute personnel, and most Other personnel
- Nagasaki EPG: includes Occupation troops, Ship-based personnel, Enroute personnel, and most Other personnel
- POW EPG: includes most POWs that were interned or worked near Hiroshima or Nagasaki prior to or during the occupation period

Table 1. Composition of EPGs for Hiroshima and Nagasaki participants

Participant Category*	H&N Expedited Processing Groups		
	Hiroshima	**Nagasaki**	**Prisoners of War**
Occupation troops	Occupation troops in the vicinity of Hiroshima from early September, 1945 through July, 1946	Occupation troops present in the vicinity of Nagasaki, Nishiyama Reservoir, or nearby POW Camps during the period early September, 1945 to July, 1946	n/a
Ship-based personnel	Ship-based personnel near Hiroshima Harbor or City any time from early September, 1945 through July, 1946	Ship-based personnel in the vicinity of Nagasaki Harbor or City for any length of time from early September, 1945 to July, 1946	n/a
Enroute personnel	Individuals passing through Hiroshima any number of times from early September, 1945 through July, 1946	Individuals passing through or near Nagasaki any number of times from early September, 1945 through July, 1946	n/a
Other personnel†	Any participant not in any other category present near Hiroshima on August 6, 1945 or for any length of time from early September, 1945 through July, 1946	Any participants not in another category that were present in the vicinity of Nagasaki or nearby areas on August 9, 1945 or from early September, 1945 to July, 1946	n/a
POWs	n/a	n/a	POWs that were interned or worked near Hiroshima or Nagasaki for any period following August 6, 1945, or were repatriated through Nagasaki

* All H&N participants (VA, 2015), fall into one of the Categories listed as defined in Section 3 unless generally or specifically excluded.

† The Other personnel participant category includes individuals conducting pre-occupation activities, POW recovery teams, aircrew members (including bomb delivery aircraft), and members of other units such as 509 Composite Group, the Manhattan Project Atomic Bomb Investigation Group, and the Strategic Bombing Survey.

3.3 General Assumptions for H&N EPG Dose Calculations

Following the determination of the three H&N EPGs, upper-bound external and internal doses were calculated for each EPG. Organ doses from external and internal exposure pathways were calculated, as well as external doses to the skin and lens of the eye. Except where noted, the dose calculations were based on default assumptions used for H&N RDAs, using NTPR standard methods (DTRA, 2008; DTRA, 2010). Key general assumptions used for the dose calculations in each of the EPGs are described below.

- Exposure rates assumed for the entire areas of contamination in and near Hiroshima and Nagasaki were based on the survey results of the Naval Medical Research Institute (NMRI) for each location. The highest values from NMRI surveys were used and were assumed to be applicable to the entire area of contamination at each location. The NMRI results were used rather than other measurements (e.g., those made by the Manhattan Engineer District), because the NMRI measurements were made at a height of 1 meter (m) and should be representative of whole-body exposure (McRaney and McGahan, 1980).
- Measured and modeled exposure rates for *in situ* (fixed) soil activation were assumed to be unaffected by weathering. These exposure rates were assumed to be reduced only by radiological decay, from the times of the detonations to the end of each EPG exposure scenario.
- Measured and modeled exposure rates for deposited fallout were assumed to be reduced by the combined effects of radiological decay and weathering. Radiological decay was assumed over the time from the detonation to the end of each EPG exposure scenario. The effects of weathering by rainfall were assumed to occur from the time of deposition to the date of the relevant measurement for each EPG exposure scenario. Weathering effects are not normally included in NTPR RDAs but are included in the EPG dose calculations to help ensure that high-sided doses are estimated (see additional discussion in Appendix A).
- Daily duration in contaminated areas for every day of participation in the areas of Hiroshima and Nagasaki was assumed to be either 8 hours per day (h d^{-1}) in the vicinity of ground zero (GZ), or 4 h d^{-1} in areas of fallout, whichever assumption produced the highest dose.
- Exposure rates in the vicinity of GZ were assumed to be entirely due to fixed, *in situ* soil activation products (McRaney and McGahan, 1980; Kerr et al., 2015).
- The area of Hiroshima fallout was assumed to be in the Koi River/Takasu vicinity, and Nagasaki fallout was assumed to have been deposited in the vicinity of the Nishiyama Reservoir and areas further to the east. Fallout[3] was assumed to consist of weapon-specific

[3] Measurements verify that weapon debris including fission products were in the Hiroshima and Nagasaki fallout at these locations (Kerr et al., 2015; McRaney and McGahan, 1980). A mechanism for downwind deposition of lofted activated soil and building material has also been suggested (Kerr et al., 2015). Although the heights of both detonations were well above the height at which significant masses of surface material were pulled up into the cloud, some activated soil and building materials were lofted into the lower portions of the clouds (dust pedestals and stems). However, because characterizations of lofted material have not been accomplished, in addition to the speculative status of potential deposition of lofted material in outlying areas, activated soil is not considered as a component of fallout in this analysis.

bomb debris, fission products, actinides, and activated case material. (McRaney and McGahan, 1980).

- Although fallout is not known to have fallen on any POW camps, POWs were assumed to be in a fallout-contaminated area 24 hours each day. This assumption is based on a fallout measurement made downwind of Nagasaki, in the direction of a POW camp near Kumamoto.
- All time that participants were assumed to spend in a contaminated area was assumed to be outdoors, with no shielding by buildings or other structures.
- To model the suspension of *in situ* neutron-induced soil activation products in the vicinity of GZ, a constant suspension factor of 10^{-4} m^{-1} was used.
- To model the resuspension of fallout, the standard method time-dependent resuspension factor algorithm used for PPG and NTS radiation dose assessments was used (DTRA, 2010).
- External skin and eye doses from gamma and beta radiation from contamination in or on the ground (ground shine) were calculated for a representative set of body skin sites for all EPGs. Doses for these sites were calculated assuming both uncovered (bare) skin and skin covered by a layer of clothing (see Appendix B). The calculation of doses for covered skin sites for Hiroshima and Nagasaki occupation forces is not normally conducted in standard RDAs.
- External skin doses due to dermal and clothing contamination were calculated for the POW EPG, because POWs were assumed to have been exposed to descending fallout.
- For purposes of skin and eye dose calculations, individuals in all H&N EPGs were assumed to be sitting on the ground for one-half of each period spent in a fallout-contaminated area.
- Uncertainty factors of 3× and 10× were used to obtain upper-bound external and internal doses, respectively.

The NTPR default assumptions and parameter values were supplemented by additional EPG-specific assumptions and values in order to help ensure that final upper-bound EPG doses were bounding for all members of each EPG. The EPG-specific assumptions are described in subsequent sections for each EPG.

3.4 General EPG Exclusions Based on Participant Scenarios

The following individuals/activities are generally excluded from the expedited processing groups, based on the potential for exposure scenarios that may exceed the assumed EPG scenario conditions.

- Personnel permanently assigned to Radiation Safety (RadSafe) duties
- Individuals with unique exposures not normally encountered by Hiroshima and Nagasaki participants that could lead to increased exposure (e.g., routine consumption of local food)

3.5 Organ and Skin EPG Exclusions Based on Limiting Doses

Some organ or skin doses calculated for H&N EPGs using the conservative methodology described in the following sections could be near or above the level that could result in service-connected determinations. To be useful, upper-bound doses that result from the EPG approach

described in this technical report must be well below the dose that could result in service-connected determinations. Consistent with the previous EPG analyses (Case et al., 2011a), this report defines "well below the dose that could result in compensation" as the dose that produces a probability of causation for cancers of 40 percent at the upper 99 percent credibility limit for exposure at age 18 years, and diagnosis of cancer at either age 50 years or after an appropriate elapsed time following exposure. This dose is defined as the "Limiting Dose" (LD) for each organ or skin cancer, and is used to compare with upper-bound doses resulting from the EPG methodologies.

Values for LDs for internal organs have previously been determined using NIOSH-IREP (NIOSH, 2014) and are tabulated in Case et al. (2011a). Because LD values for skin cancers are not known to be documented elsewhere, NIOSH-IREP was used to calculate LD values specifically for this report for each of the three skin cancer models available in NIOSH-IREP. Skin cancer LDs were determined using input to NIOSH-IREP that is consistent with the LDs documented in Case et al. (2011a), i.e., gamma doses entered as acute doses from photons with energy > 250 keV, beta doses from electrons with energy > 15 keV, exposure at age 18 years, and attained age of 50 years. Furthermore, the LDs for skin cancers vary according to the ethnicity of an individual. The values in this report were estimated using the Ethnic Origin choice of "White-Non-Hispanic" in NIOSH-IREP. The LDs estimated using an Ethnic Origin choice of "Black" in NIOSH-IREP are about 90 percent (melanoma), and about 50 percent (basal cell and squamous cell carcinoma) of the values listed for White-Non-Hispanic. (NIOSH, 2014)

For each EPG, Total Organ Doses (TODs) were calculated by adding the upper-bound external dose and the upper-bound internal doses (alpha and beta+gamma) for 20 standard organs, and then rounding up to two significant digits. Upper-bound skin doses (beta+gamma) were also calculated for 11 representative skin sites and the lens of the eye. Any TOD or upper-bound skin or eye lens dose that exceeds the applicable LD or other applicable reference dose[4] is not recommended for use in expedited processing of a specific veteran's claim. In addition, any organs or skin cancers that do not have associated LDs listed in this report are not recommended for expedited processing unless surrogate organs exist. The TODs and upper-bound skin doses that exceed the applicable LD are identified as necessary in subsequent sections.

Some NTPR standard organs are used as surrogate organs for more than one tissue or organ, some of which have different LDs. For example, liver is the surrogate organ for both gallbladder (LD = 11 rem) and liver (LD = 7.7 rem). Similarly, ET Region is the surrogate organ for esophagus (LD = 22 rem), larynx (LD = 67 rem), and several tissues and organs in the oral cavity such as tongue, parotid gland, and pharynx (LD = 66 rem). In these cases, the lowest of these multiple LDs for any standard organ is the LD that is compared to the H&N EPG dose for each NTPR standard organ in subsequent sections. For example, the LD used for liver is 7.7 rem (the lower of 11 and 7.7 rem), and the LD used for ET Region is 22 rem (the lowest of 22, 66, and 67 rem). (Case et al., 2011a)

[4] By definition, LDs are applicable only to cancers. However, doses that are similar to LDs have been identified for certain non-cancer conditions. This includes a thyroid dose range of 25–36 rem for thyroid nodular disease, and an eye lens dose of 28 rem for posterior subcapsular cataracts. (DTRA, 2015a)

Section 4.

Expedited Processing Doses for Hiroshima Participants

4.1 Description of the Hiroshima EPG

The Hiroshima EPG consists of U.S. forces that were present in or near Hiroshima, Japan for any length of time, primarily from September 8, 1945 to July 1, 1946. Also included are aircrew members that were airborne over Hiroshima on or after August 6, 1945 (McRaney and Weitz, 1980). The date of September 8, 1945 corresponds to the approximate date of initial landings of a POW recovery team, at a location more than 100 mi east of Hiroshima near Wakayama, Japan (Kerr, 1980). Occupation troops first landed near Hiroshima 28 days later, on October 6, 1945. The end date of July 1, 1946 corresponds to the latest reasonable departure date found in the NTPR participant database (NTPR, 2013a).

Approximately 154,000 individuals are listed as Hiroshima participants in the NTPR participant database; a breakout of this population is shown in Table 2. (NTPR, 2013a).

Table 2. Hiroshima participant categories and numbers of individuals

Category	Approximate Number of Individuals	Comments
Occupation troops	37,100	Over 400 named units
Ship-based personnel	67,400	Includes over 500 ships, comprising U.S. military, Liberty, Victory, and merchant ships
Enroute personnel	48,800	Individuals passing through the Hiroshima area, generally short stay times
Other personnel	300	Includes, for example, members of the 509 Composite Group, Manhattan Project Atomic Bomb Investigation Group, and unidentified unit affiliations

There are no specific exclusions for the Hiroshima EPG. Therefore, all individuals described in Table 2. other than those with general exclusions (Section 3.4) are considered to be included in the Hiroshima EPG. However, there are certain EPG/organ combinations that may not be appropriate for expedited processing based on the Hiroshima EPG doses in this report, as identified in a subsequent section.

4.2 Highest-Dose Cohort Scenario for Hiroshima EPG

Military units responsible for the occupation of western Honshu (including Hiroshima) were initially from the 41st Division, followed by units of the 24th Division. The 162nd Infantry

Regiment and the 186th Infantry Regiment (41st Division) landed near Hiroshima over October 6–7, 1945, and were responsible for the occupation of the Hiroshima area until early December, 1945. These troops were billeted at the Kure Submarine Base (11 mi southeast of Hiroshima) or at a bivouac location at Kaidaichi, about 5 mi southeast of the center of Hiroshima. In early December, 1945, the 34th Infantry Regiment (24th Division), replaced the 162nd and 186th Regiments of the 41st Division in the Hiroshima area. Only one Company of the 34th Regiment was in the immediate vicinity of Hiroshima, and that Company was quartered on a small island in the river delta just south of Hiroshima. On March 6, 1946, the 34th Regiment was relieved of its responsibilities by Australian troops. The arrival of the Australian troops ended the U.S. occupation responsibilities at Hiroshima (McRaney and McGahan, 1980).

Using previous dose estimates (DTRA, 2008; McRaney and McGahan, 1980), supplemented with current calculations based on the arrival/departure dates and areas of responsibility among the military units described above that were present at or near Hiroshima during the occupation period, the highest-dose unit was determined to be a generic unit of the 34th Regiment present in the Hiroshima area from early December, 1945, until March 6, 1946. Certain elements of the exposure scenario for the 34th Regiment were maximized for the EPG dose analysis as described below.

4.3 Hiroshima EPG Scenario and Parameter Assumptions

To estimate upper-bound doses for the Hiroshima EPG, calculations were accomplished using NTPR standard methods including the general assumptions and parameter values described in Section 3.3. Additional specific parameter values used in the Hiroshima EPG dose assessment include the following (DTRA, 2008, Appendix A-1).

- The highest iso-contour exposure rate of 0.069 milliroentgen per hour (mR h^{-1}) measured in Hiroshima on November 1, 1945 by a team from the NMRI is used as the basis for the exposure rate for entire time in the vicinity of GZ. This exposure rate was assumed to be due to *in situ* neutron-induced soil activation products.
- The highest exposure rate of 0.042 mR h^{-1} measured in the Koi River/Takasu area west of Hiroshima on November 1, 1945 by the NMRI team is used as the basis for the exposure rate for the entire time near Koi River/Takasu. This exposure rate was assumed to be due to fallout deposited in the area.

Two additional maximizing assumptions were incorporated into the Hiroshima EPG assessment. Based on a review of the NTPR participant database (NTPR, 2013a), the duration of participation near Hiroshima was extended to span the longest reasonable duration for any Hiroshima participant. Also, the assumed breathing rate of participants is 2 m^3 h^{-1}, based on the assumption of personnel activities consisting of a mix of 50 percent light activity and 50 percent moderate activity (Case et al., 2011b). These assumptions, which maximize the EPG dose calculations as compared to the standard Hiroshima RDA calculations, are further specified in Table 3.

Table 3. Maximized exposure pathways for the Hiroshima EPG

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factor
EXTERNAL and INTERNAL		
Duration of participation	Participants were assumed to have been present in the vicinity of Hiroshima.	Participation is from Sep 8, 1945 through Jul 1, 1946 (296 days) instead of the more typical duration of 30–60 days.
INTERNAL		
Inhalation of suspended or resuspended contaminants	Participants may have inhaled suspended soil activation products in vicinity of GZ or fallout in the Koi/Takasu area.	Breathing rate is 2 $m^3 h^{-1}$ instead of the NTPR RDA default value of 1.2 $m^3 h^{-1}$.

4.4 Summary of Hiroshima EPG Doses and Upper Bounds

4.4.1. Hiroshima EPG Organ Doses

The external and internal and corresponding upper-bound doses for the Hiroshima EPG were calculated for the standard NTPR organs using the assumptions and parameter values described above. The resulting doses are shown in Table 4. The Hiroshima EPG TODs for standard organs and comparison with applicable LDs are shown in Table 5. All TODs in Table 5 are less than the applicable LD by more than an order of magnitude.

4.4.2. Hiroshima EPG Skin Doses

Skin doses were calculated for 11 representative skin sites for members of the Hiroshima EPG using the assumptions and parameter values described above. A summary of these skin doses, corresponding upper-bound doses, and comparisons with LD values for three skin cancers are shown in Table 6. With the exception of the dose for uncovered skin on the foot or ankle, total upper-bound skin doses for all skin sites in Table 6 are less than all LDs.

4.4.3. Hiroshima EPG Eye (lens) Dose

External doses for the lens of the eye were calculated for the Hiroshima EPG using the assumptions and parameter values described above. The resulting total upper-bound external dose (beta plus gamma) to the lens of the eye is 0.23 rem. This dose is well below the dose of 28 rem judged to be “as likely as not” to result in posterior subcapsular cataracts (DTRA, 2015a).

4.5 Organ and Skin Site Exclusions for the Hiroshima EPG

To determine organ and skin exclusions, EPG TODs and total upper-bound skin doses were compared with the LD values as described above. Based on this comparison, certain claims involving skin cancers are not recommended for EPG processing based on the EPG doses. Specifically, the upper-bound skin dose calculated for bare skin on the foot or ankle should not be assigned in expedited processing of claims involving malignant melanoma or basal cell carcinoma.

Table 4. Hiroshima EPG external and internal organ doses and upper bounds

External Source	External Dose (rem)		External Upper-bound Dose (rem)	
Residual gamma radiation	0.074		0.22	
NTPR Standard Organ	**Internal Dose (rem)**		**Internal Upper-bound Dose (rem)**	
	Alpha*	**Beta+Gamma**	**Alpha***	**Beta+Gamma**
Adrenals	-	0.005	-	0.051
Bone surface	-	0.003	0.001	0.026
Brain	-	0.001	-	0.010
Breast	-	0.005	-	0.051
Stomach wall	-	0.003	-	0.032
Small intestine wall	-	0.002	-	0.024
Upper large intestine wall	-	0.004	-	0.038
Lower large intestine wall	-	0.007	-	0.069
Kidneys	-	0.002	-	0.025
Liver	-	0.005	-	0.053
Extra-thoracic region	-	0.033	-	0.34
Lung	-	0.064	-	0.64
Muscle	-	0.003	-	0.026
Pancreas	-	0.004	-	0.041
Red marrow	-	0.003	-	0.032
Spleen	-	0.004	-	0.041
Testes	-	0.001	-	0.009
Thymus	-	0.006	-	0.060
Thyroid	-	0.002	-	0.025
Urinary bladder wall	-	0.001	-	0.013

* A dash indicates that the calculated dose is less than 0.001 rem.

Table 5. Hiroshima EPG TOD and applicable LD values

NTPR Standard Organ	Total Organ Dose* (rem)	Limiting Dose† (rem)
Adrenals	0.28	30
Bone surface	0.25	32
Brain	0.24	30
Breast	0.28	36
Stomach wall	0.26	18
Small intestine wall	0.25	44
Upper large intestine wall	0.26	26
Lower large intestine wall	0.29	26
Kidneys	0.25	31
Liver	0.28	7.7
Extra-thoracic region	0.57	22
Lung	0.87	30
Muscle	0.25	34
Pancreas	0.27	61
Red marrow	0.26	14
Spleen	0.27	44
Testes	0.23	41
Thymus	0.29	41
Thyroid	0.25	5.1
Urinary bladder wall	0.24	33

***** TODs are calculated by adding the upper-bound external dose and the upper-bound internal doses (alpha and beta+gamma) from Table 4, and rounding up to two significant digits.

† The LDs correspond to a 40 percent probability of causation. Each value shown is the lowest LD for any organ for which the indicated NTPR standard organ is used (see Section 3.5).

Table 6. Hiroshima EPG total external skin doses and LD values

Skin Site	Total External Dose (rem)*		Total Upper-bound External Dose (rem)*		Limiting Dose (rem)†		
	Bare Sites	Covered Sites	Bare Sites	Covered Sites	MM	BCC	SCC
foot/ankle	2.5	1.1	7.3	3.1	4.2	4.1	195
calf/shin	1.2	0.65	3.4	2.0			
knee	0.66	0.46	2.0	1.4			
hand/ mid-thigh	0.48	0.35	1.5	1.1			
waist	0.41	0.31	1.3	0.93			
forearm	0.41	0.31	1.3	0.93			
lower back/ stomach	0.33	0.25	0.97	0.75			
upper back/ upper arm/ mid-chest	0.27	0.22	0.81	0.64			
neck	0.25	0.20	0.75	0.60			
face/nose/ ear/head	0.23	0.19	0.69	0.56			
top of head	0.21	0.17	0.63	0.51			

* Doses are rounded up with two significant digits displayed.

† LDs correspond to a 40 percent probability of causation for malignant melanoma (MM), basal cell carcinoma (BCC), and squamous cell carcinoma (SCC), and were calculated as described in Section 3.5.

Section 5.

Expedited Processing Doses for Nagasaki Participants

5.1 Description of the Nagasaki EPG

The Nagasaki EPG consists of most U.S. military participants that were present in or near Nagasaki, Japan for any length of time from as early as about September 8, 1945 to early July, 1946. Also included are aircrew members that were airborne over Nagasaki on or after August 9, 1945 (McRaney and Weitz, 1980). The date of September 8, 1945 corresponds to the approximate date that mine-sweeping operations began in Nagasaki Harbor (McRaney, 1987). A POW recovery team with a detachment of Marine guards landed at Nagasaki on September 11, 1945, and an advance party of Occupation troops landed near Nagasaki on September 16, 1945; the remainder of the Nagasaki Occupation troops landed during the period September 23–28, 1945 (McRaney and McGahan, 1980). The end date of the EPG period corresponds to the latest reasonable departure date determined from the documented occupation history, and the latest reasonable departure date found in DNA 5512F (McRaney and McGahan, 1980) and the NTPR participant database (NTPR, 2013b).

Approximately 122,000 individuals are listed as Nagasaki participants in the NTPR participant database; a breakout of this population is shown in Table 7.

Table 7. Nagasaki participant categories and numbers of individuals

Category	Approximate Number of Individuals	Comments
Occupation troops	14,200	Over 100 named units
Ship-based personnel	106,000	Includes over 350 ships, comprising U.S. military, Liberty, Victory, and merchant ships
Enroute personnel	20	Individuals passing through the Nagasaki area, generally short stay times
Other personnel	1,630	Includes, for example, members of: Manhattan Project Atomic Bomb Investigation Group; the Strategic Bomb Survey Tokyo; Naval Mobile Construction Battalions 43 and 70; and unidentified unit affiliations

There are no specific exclusions associated with the Nagasaki EPG. However, there are certain EPG/organ combinations that may not be appropriate for expedited processing based on the Nagasaki EPG doses in this report, as identified in a subsequent section.

5.2 Highest-Dose Cohort Scenario for the Nagasaki EPG

The occupation of the Nagasaki area was assigned to the 2nd Marine Division, 5th Amphibious Corps of the Sixth Army. The 2nd Division was organized into several functional groups (by task and assigned areas), as follows:

- Support Group (Division troops, Service troops, Engineer troops)
- Regimental Combat Team 2 (RCT-2)
- Regimental Combat Team 6 (RCT-6)
- Regimental Combat Team 8 (RCT-8)
- Artillery Group
- 2nd Tank Battalion
- Marine Observation Squadron #2

The 2nd Division units assigned to each of the above functional groups changed somewhat over the course of the occupational period. Most units assigned to the 2nd Division experienced large turnover of personnel during the occupation period. Therefore it is very unlikely that many 2nd Division personnel remained in the Nagasaki area for the duration of the occupation period. Units assigned to areas potentially experiencing fallout (primarily near the Nishiyama Reservoir and in the vicinity of Kumamoto) had the potential to accrue the largest doses. These units are RCT-2, RCT-8, and the Artillery group as described below.

Occupation troops landed at various locations in and near Nagasaki Harbor over the period September 23–28, 1945. The initial responsibility for Nagasaki City was assigned to RCT-2, which relieved the Marine security guards assigned to the POW recovery operation. The RCT-2 zone of occupation responsibility included all of the city of Nagasaki on the east side of Nagasaki harbor, as well as the areas east, northeast, and southwest of the city (including the area around Nishiyama Reservoir). On September 28, 1945, RCT-2 began sending patrols throughout its area of responsibility. RCT-2 operated in its zone of responsibility until October 30–November 12, 1945, when the elements of RCT-2 moved to areas at and more than 100 mi from Nagasaki. During this period of RCT-2's departure from Nagasaki, the Artillery Group was reassigned from Isahaya, approximately 12 mi northeast of Nagasaki, to the areas of responsibility vacated by RCT-2, starting as early as November 2, 1945. RCT-8 was also initially assigned to Isahaya, and on October 8, 1945 was reassigned to the Kumamoto area where it apparently remained until departure. Members of the Artillery Group and limited other 2nd Division troops remained in the vicinity of Nagasaki until approximately June 26, 1946. (McRaney and McGahan, 1980)

The identification of a highest-dose cohort for the Nagasaki EPG is based on the known areas of responsibilities of the above functional groups. RCT-2 and the Artillery Group were the groups that shared responsibility for the area that included the Nishiyama Reservoir, and RCT-8 was assigned to Kumamoto for a portion of the occupation period. In general, these three groups had the potential for the highest doses from residual radiation because of the assumed fallout near Nishiyama Reservoir and Kumamoto. Based on screening calculations accomplished for exposure scenarios involving these three groups, the highest-dose cohort was determined to be the Artillery Group.

5.3 Nagasaki EPG Scenario and Parameter Assumptions

To estimate upper-bound doses for the Nagasaki EPG, calculations were accomplished using NTPR standard methods including the general assumptions and parameter values described in Section 3.3. Additional specific parameter values used in the Nagasaki EPG dose assessment include the following (DTRA, 2008, Appendix A-1).

- The highest iso-contour exposure rate of 0.069 mR h^{-1} measured in Nagasaki on October 21, 1945 by an NMRI team is used as the basis for the exposure rate for the entire time in the vicinity of GZ. This exposure rate was assumed to be due to *in situ* neutron-induced soil activation products.
- The highest exposure rate of 1.080 mR h^{-1} measured near Nishiyama Reservoir on October 21, 1945 by an NMRI team is used as the basis for the exposure rate for the entire time in the area of Nishiyama Reservoir. This exposure rate was assumed to be due to fallout deposited in the area.
- A consumption rate of 2 L d^{-1} of water from the Nishiyama Reservoir was assumed for all participants.

Two additional maximizing assumptions were incorporated into the Nagasaki EPG dose assessment. The duration of participation was extended to span the longest reasonable duration for any Nagasaki participant in the Artillery Group. The duration was based on the documented history of this group (McRaney and McGahan, 1980), and also on a review of the NTPR participant database (NTPR, 2013b). Also, the assumed breathing rate is 2 m^3 h^{-1}, based on the assumption of personnel activities consisting of a mix of 50 percent light activity and 50 percent moderate activity (Case et al., 2011b). These assumptions maximize the EPG dose calculations as compared to the standard Nagasaki RDA calculations, and are further specified in Table 8.

Table 8. Maximized exposure pathways for the Nagasaki EPG

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factor
EXTERNAL and INTERNAL		
Duration of participation	Participants were assumed to have been present in the vicinity of Nagasaki.	Participation is from Sep 24, 1945 through Jun 26, 1946 (277 days) instead of a more typical 30–60 days.
Daily time in contaminated areas	Participants may have been present near GZ area or in the vicinity of fallout east of Nagasaki near Nishiyama Reservoir	Sep 24–Nov 2, 1945: 8 h d^{-1} in vicinity of GZ Nov 2, 1945–Jun 26, 1946: 8 h d^{-1} in vicinity of GZ, or* 4 h d^{-1} in vicinity of Nishiyama Reservoir
INTERNAL		
Inhalation of suspended or resuspended contaminants	Participants may have inhaled suspended soil activation products in vicinity of GZ or fallout near Nishiyama Reservoir.	Breathing rate is 2 m^3 h^{-1} instead of the NTPR RDA default value of 1.2 m^3 h^{-1}.

* Exposure pathway doses are calculated for each dose location assumption, and the highest of each is selected as the dose for each exposure pathway.

5.4 Summary of Nagasaki EPG Doses and Upper Bounds

5.4.1. Nagasaki EPG Organ Doses

The external and internal doses and corresponding upper-bound doses for the Nagasaki EPG were calculated for the standard NTPR organs using the assumptions and parameter values described above. The resulting doses are shown in Table 9. The relatively large internal doses for bone surface and liver result primarily from the inhalation of resuspended fallout near the Nishiyama Reservoir, whereas the relatively large doses for upper and lower large intestine walls result primarily from the ingestion of fallout in drinking water assumed to come from the Nishiyama Reservoir.

The Nagasaki EPG TODs for standard organs and comparisons with applicable LDs are shown in Table 10. All TODs in Table 10 are less than the applicable LD.

Table 9. Nagasaki EPG external and internal organ doses and upper bounds

External Source	External Dose (rem)		External Upper-bound Dose (rem)	
Residual gamma radiation	0.25		0.74	
NTPR Standard Organ	**Internal Dose (rem)**		**Internal Upper-bound Dose (rem)**	
	Alpha	**Beta+Gamma**	**Alpha**	**Beta+Gamma**
Adrenals	0.003	0.031	0.030	0.32
Bone surface	1.6	0.26	17	2.6
Brain	0.003	0.023	0.030	0.24
Breast	0.003	0.025	0.030	0.25
Stomach wall	0.003	0.090	0.031	0.90
Small intestine wall	0.003	0.19	0.032	1.9
Upper large intestine wall	0.004	0.83	0.043	8.4
Lower large intestine wall	0.007	2.3	0.068	23
Kidneys	0.007	0.036	0.070	0.36
Liver	0.40	0.047	3.6	0.47
Extra-thoracic region	0.012	0.050	0.12	0.50
Lung	0.024	0.15	0.25	1.6
Muscle	0.003	0.030	0.030	0.31
Pancreas	0.003	0.033	0.030	0.33
Red marrow	0.080	0.13	0.81	1.3
Spleen	0.003	0.030	0.030	0.31
Testes	0.023	0.030	0.23	0.29
Thymus	0.003	0.030	0.030	0.27
Thyroid	0.003	0.22	0.030	2.3
Urinary bladder wall	0.003	0.046	0.030	0.47

Table 10. Nagasaki EPG TOD and applicable LD values

NTPR Standard Organ	Total Organ Dose* (rem)	Limiting Dose† (rem)
Adrenals	1.1	30
Bone surface	21	32
Brain	1.1	30
Breast	1.1	36
Stomach wall	1.7	18
Small intestine wall	2.7	44
Upper large intestine wall	9.2	26
Lower large intestine wall	24	26
Kidneys	1.2	31
Liver	4.9	7.7
Extra-thoracic region	1.4	22
Lung	2.6	30
Muscle	1.1	34
Pancreas	1.1	61
Red marrow	2.9	14
Spleen	1.1	44
Testes	1.3	41
Thymus	1.1	41
Thyroid	3.1	5.1
Urinary bladder wall	1.3	33

***** TODs are calculated by adding the upper-bound external dose and the upper-bound internal doses (alpha and beta+gamma) from Table 9, and rounding up to two significant digits.

† The LDs correspond to a 40 percent probability of causation. Each value shown is the lowest LD for any disease for which the indicated NTPR standard organ is used (see Section 3.5).

5.4.2. Nagasaki EPG Skin Doses

Skin doses were calculated for 11 representative skin sites for members of the Nagasaki EPG using the assumptions and parameter values described above. A summary of these skin doses, corresponding upper-bound doses, and comparisons with LD values are shown in Table 11.

5.4.3. Nagasaki EPG Eye (lens) Dose

External doses for the lens of the eye were calculated for the Nagasaki EPG using the assumptions and parameter values described above. The resulting total upper-bound external dose (beta plus gamma) to the lens of the eye is 1.8 rem. This dose is well below the dose of 28 rem judged to be “as likely as not” to result in posterior subcapsular cataracts (DTRA, 2015a).

Table 11. Nagasaki EPG total external skin doses and LD values

Skin Site	Total External Dose (rem)*		Total Upper-bound External Dose (rem)*		Limiting Dose (rem)†		
	Bare Sites	Covered Sites	Bare Sites	Covered Sites	MM	BCC	SCC
foot/ankle	23	9.4	68	28	4.2	4.1	195
calf/shin	11	5.9	31	18			
knee	6.0	4.1	18	13			
hand/ mid-thigh	4.5	3.3	14	9.7			
waist	3.9	3.0	12	8.8			
forearm	3.9	3.0	12	8.8			
lower back/ stomach	3.2	2.5	9.5	7.3			
upper back/ upper arm/ mid-chest	2.8	2.2	8.2	6.4			
neck	2.6	2.1	7.7	6.1			
face/nose/ ear/head	2.4	2.0	7.2	5.8			
top of head	2.2	1.8	6.6	5.3			

* Doses are rounded up with two significant digits displayed.

† LDs correspond to a 40 percent probability of causation for malignant melanoma (MM), basal cell carcinoma (BCC), and squamous cell carcinoma (SCC), and were calculated as described in Section 3.5.

5.5 Organ and Skin Site Exclusions for the Nagasaki EPG

To determine organ and skin exclusions, EPG TODs and total upper-bound skin doses were compared with the LD values as described above. Based on this comparison, certain claims involving skin cancers are not recommended for EPG processing based on the EPG doses. Specifically, all of the upper-bound skin doses are greater than the LDs for malignant melanoma and basal cell carcinoma and should not be assigned in expedited processing of claims involving these skin cancers.

Section 6.

Expedited Processing Doses for Prisoner of War Claimants

6.1 Description of the POW EPG

The H&N POW EPG consists of POWs that were interned or worked in Japan near Hiroshima or Nagasaki starting on or before August 6, 1945. Most of these POWs were evacuated from Japan via Hiroshima or Nagasaki before the end of September, 1945 (McRaney and McGahan, 1980). There are approximately 3,000 POWs identified in the NTPR database (NTPR, 2013a; NTPR, 2013b), although McRaney (1987) indicates a total of about 3,700 POWs were evacuated from the two locations. The NTPR database contains about 500 POWs that passed through Hiroshima and about 2,400 POWs that passed through Nagasaki.

The only specific exclusion for the POW EPG is for any individual that worked in Hiroshima or Nagasaki during the period between the bombings of these cities and the arrival of the U.S. military personnel in early September, 1945.

6.2 Highest-Dose Cohort Scenario for the POW EPG

At the time of the bombings, numerous POW camps were located in Japan, including a considerable number of camps on western Honshu, Kyushu, and Shikoku within 100 mi of Hiroshima and/or Nagasaki. The closest camps to Hiroshima and Nagasaki with surviving U.S. POWs were 6 mi or more from the cities. The liberation and rapid evacuation of American and allied POWs from these camps was a priority mission soon after the end of World War II. The port city of Wakayama (160 mi east of Hiroshima) was used to evacuate all POWs from western Honshu and the island of Shikoku. POWs in camps in these areas were processed at Wakayama and were embarked on evacuation ships from September 12–15, 1945. Nagasaki was the processing center for the evacuation for POWs in camps on Kyushu. The first trainload of POWs arrived at the Nagasaki processing center about 2 mi south of the Nagasaki ground zero on September 13, 1945. The Nagasaki center processed three trainloads of POWs per day, and all POWs were evacuated via Nagasaki by September 23, 1945. (McRaney and McGahan, 1980; McRaney, 1987)

Downwind fallout from the Hiroshima detonation was not detected in the direction of any POW camps. Light fallout from the Nagasaki detonation occurred at considerable distances east of Nagasaki, in the general direction of several POW camps. Readings above background were recorded by an NMRI survey approximately 25 miles east of the Nagasaki GZ, and fallout was detected by Japanese scientists in Kumamoto but no levels were reported. Based on the prevailing winds, the POW camp at Kumamoto is the most likely camp for any significant fallout. An NMRI measurement on Shimabara Peninsula, at a location about 25 miles downwind from Nagasaki, was assumed to apply to the camp near Kumamoto. The Kumamoto POW camp is across the Shimabara Bay from the measurement location, about 20 mi further downwind from the measurement location. Based on the possibility of fallout occurring, the POWs at the Kumamoto POW camp form the highest-dose cohort for the POW EPG. Exposure pathways for POWs include exposure to fallout at the camp, and exposure to residual radiation while enroute to evacuation processing centers. (McRaney, 1987)

6.3 POW EPG Scenario and Parameter Assumptions

POWs did not accrue doses from neutrons or initial gamma radiation. This is because all POW camps with surviving American POWs were located at least 6 mi from the ground zero of either detonation, and at this distance radiation levels from initial radiations were undetectable (DTRA, 2010). In addition, no POWs that were in Hiroshima or Nagasaki at the time of the bombings are known to have survived the detonations. (DTRA, 2008; McRaney, 1987)

To estimate upper-bound doses for the POW EPG, calculations were conducted using NTPR standard methods, including the general assumptions and parameter values described in Section 3.3. Additional specific parameter values used in the POW EPG dose assessment are listed below (DTRA, 2008, Appendix A-1; DTRA, 2010). Additional details on the skin dose methodology used are included in Appendix B.

- The highest exposure rate of 0.020 mR h^{-1} measured by an NMRI team on October 21, 1945 at a location on the Shimabara Peninsula about 20 mi upwind of the Kumamoto POW Camp is used as the basis for the exposure rate for the entire time POWs spent in the Kumamoto POW Camp area. This exposure rate was assumed to be due to fallout from the Nagasaki weapon deposited in the area of the Kumamoto POW Camp, based on the prevailing winds on August 9, 1945.
- The highest iso-contour exposure rate of 0.069 mR h^{-1} measured in Nagasaki on October 21, 1945 by an NMRI team at a location near Nagasaki GZ is used as the basis for the exposure rate for the one day POWs were assumed to be in the Nagasaki area for repatriation. This exposure rate was assumed to be due to neutron-induced soil activation products.
- Members of the POW EPG were assumed to inhale descending fallout near Kumamoto between H+7 and H+8; the doses for this pathway are estimated using the high-sided simplification described in NTPR Standard Method ID01 (DTRA, 2010).
- Members of the POW EPG were assumed to have ingested fallout that was deposited on a 9-inch diameter dinner plate over a 15-minute period during the 1-hour period of descending fallout.
- Skin and clothing contamination doses are included from both descending and resuspended fallout, with the assumption that contamination remains on the skin or clothing for 12 hours prior to washing off. The skin dose conversion factor used for dermal contamination is 900 rad h^{-1} per Ci m^{-2}. For skin covered by a layer of clothing, a clothing modification factor of 0.4 was assumed, and the rounded skin dose conversion factor used is 400 rad h^{-1} per Ci m^{-2} (DTRA, 2007, ED04).

Several additional maximizing assumptions were incorporated into the POW EPG dose assessment. The maximum duration at the Kumamoto POW camp was assumed, with the further assumption that a full day was spent in Nagasaki. Also, the assumed breathing rate is 2 m^3 h^{-1}, used for consistency with the other H&N EPG analyses. These assumptions, which maximize the EPG dose calculations as compared to the standard POW RDA calculations, are further specified in Table 12.

Table 12. Maximized exposure pathways for the POW EPG

Exposure Pathway	Basis for Exposure Pathway	Maximizing Factor
EXTERNAL and INTERNAL		
Duration of participation	EPG members were assumed to have been present at the Kumamoto POW Camp.	Maximum post-detonation time at Kumamoto POW Camp, from Aug 9–Sep 22, 1945 (44 days), plus one full day in Nagasaki on the last day of POW processing (Sep 23, 1945)
Daily time in contaminated areas	EPG members may have been present in the vicinity of fallout near the Kumamoto POW Camp.	Aug 9–Sep 22, 1945: 24 h d^{-1} in vicinity of fallout near Kumamoto POW Camp; Sep 23, 1945: 8 h d^{-1} in vicinity of Nagasaki GZ
INTERNAL		
Inhalation of suspended or resuspended contaminants	EPG members may have inhaled fallout near Kumamoto and suspended soil activation products for one day while passing through Nagasaki.	Individuals were assumed to inhale suspended soil activation products while in Nagasaki. Breathing rate is 2 m^3 h^{-1} instead of the NTPR RDA default value of 1.2 m^3 h^{-1}.

6.4 Summary of POW EPG Doses and Upper Bounds

6.4.1. POW EPG Organ Doses

The external and internal organ doses and corresponding upper-bound organ doses for the H&N POW EPG were calculated for the standard NTPR organs using the assumptions and parameter values described above. The resulting doses are shown in Table 13. The relatively large internal alpha dose for bone surface is primarily due to the inhalation of resuspended fallout. The three relatively large internal beta+gamma doses (for upper and lower large intestine wall, and thyroid) result primarily from the internal dose due to the ingestion of fallout deposited on a plate.

The POW EPG TODs for standard organs and comparisons with applicable LDs are shown in Table 14. Except for thyroid, all TODs in Table 14 are less than the applicable LD.

Table 13. POW EPG external and internal organ doses and upper bounds

External Source	External Dose (rem)	External Upper-bound Dose (rem)
Residual gamma radiation	0.74	2.2

NTPR Standard Organ	Internal Dose (rem)		Internal Upper-bound Dose (rem)	
	Alpha*	Beta+Gamma	Alpha	Beta+Gamma
Adrenals	-	0.007	0.004	0.074
Bone surface	0.20	0.029	2.0	0.30
Brain	-	0.004	0.004	0.040
Breast	-	0.004	0.004	0.044
Stomach wall	-	0.16	0.004	1.6
Small intestine wall	-	0.24	0.004	2.4
Upper large intestine wall	-	0.74	0.004	7.4
Lower large intestine wall	-	1.1	0.004	12
Kidneys	0.001	0.019	0.009	0.20
Liver	0.043	0.017	0.43	0.18
Extra-thoracic region	0.002	0.15	0.020	1.5
Lung	0.004	0.17	0.043	1.7
Muscle	-	0.008	0.004	0.078
Pancreas	-	0.011	0.004	0.11
Red marrow	0.010	0.016	0.097	0.17
Spleen	-	0.008	0.004	0.085
Testes	0.003	0.006	0.028	0.060
Thymus	-	0.005	0.004	0.053
Thyroid	-	1.7	0.004	18
Urinary bladder wall	-	0.048	0.004	0.48

* A dash indicates that the calculated dose is less than 0.001 rem.

Table 14. POW EPG TOD and applicable LD values

NTPR Standard Organ	Total Organ Dose* (rem)	Limiting Dose† (rem)
Adrenals	2.3	30
Bone surface	4.6	32
Brain	2.3	30
Breast	2.3	36
Stomach wall	3.9	18
Small intestine wall	4.7	44
Upper large intestine wall	9.7	26
Lower large intestine wall	15	26
Kidneys	2.5	31
Liver	2.9	7.7
Extra-thoracic region	3.8	22
Lung	4.0	30
Muscle	2.3	34
Pancreas	2.4	61
Red marrow	2.5	14
Spleen	2.3	44
Testes	2.3	41
Thymus	2.3	41
Thyroid	21	5.1
Urinary bladder wall	2.7	33

***** TODs are calculated by adding the upper-bound external dose and the upper-bound internal doses (alpha and beta+gamma) from Table 13, and rounding up to two significant digits.

† The LDs correspond to a 40 percent probability of causation. Each value shown is the lowest LD for any disease for which the indicated NTPR standard organ is used (see Section 3.5).

6.4.2. POW EPG Skin Doses

Skin doses were calculated for 11 representative skin sites (both covered and bare) for members of the H&N POW EPG using the assumptions and parameter values described previously. A summary of total skin doses, corresponding upper-bound doses, and comparisons with LD values are shown in Table 15. As described above, the H&N POW EPG skin doses include doses from skin and clothing contamination, and some body sites exhibit high interception and retention fractions for descending and resuspended fallout (Appendix B). In addition, higher uncertainty factors are associated with these doses as compared to ground shine doses. These characteristics can result in large upper-bound doses, as noted in Table 15.

Table 15. POW EPG total external skin doses and LD values

Skin Site	Total External Dose (rem)*		Total Upper-bound External Dose (rem)*		Limiting Dose (rem)†		
	Bare Sites	Covered Sites	Bare Sites	Covered Sites	MM	BCC	SCC
foot/ankle	‡	53	‡	160	4.2	4.1	195
calf/shin	52	31	170	95			
knee	43	22	150	72			
hand/ mid-thigh	44	18	170	70			
waist	‡	17	‡	66			
forearm	36	16	140	58			
lower back/ stomach	21	14	130	62			
upper back/ upper arm/ mid-chest	20	13	130	60			
neck	‡	12	‡	59			
face/nose/ ear/head	11	12	45	58			
top of head	58	11	‡	57			

* Doses are rounded up with two significant digits displayed.
† LDs correspond to a 40 percent probability of causation for malignant melanoma (MM), basal cell carcinoma (BCC), and squamous cell carcinoma (SCC), and were calculated as described in Section 3.5.
‡ These doses are greater than the LD for all three skin cancers.

6.4.3. POW EPG Eye (lens) Dose

External doses for the lens of the eye were calculated for the POW EPG using the assumptions and parameter values described above. The resulting total upper-bound external dose (beta plus gamma) to the lens of the eye is 4.1 rem. This dose is well below the dose of 28 rem judged to be "as likely as not" to result in posterior subcapsular cataracts (DTRA, 2015a).

6.5 Organ and Skin Site Exclusions for the POW EPG

To determine organ and skin exclusions, POW EPG TODs and total upper-bound skin doses were compared with the LD values as described above. Based on this comparison, certain claims are not recommended for POW expedited processing based on the EPG doses. Specifically, the thyroid TOD should not be assigned in expedited processing of claims involving thyroid cancers. In addition, all of the upper-bound skin doses are greater than the LDs for malignant melanoma and basal cell carcinoma and should not be assigned in expedited

processing of claims involving these skin cancers for any skin site. Finally, several upper-bound skin doses are greater than all LDs as indicated in Table 15.

Section 7.

References

Apostoaei, A.I. and D.C. Kocher, 2010. *Radiation Doses to Skin from Dermal Contamination.* DTRA-TR-09-16, SENES Oak Ridge. Oak Ridge, TN. October.

Case, D. R., Chehata, M., Dunavant, J. D., Egbert, S. D., Mason, C. L., McKenzie-Carter, M. A., Singer, H. A., and Weitz, R. L., 2011a. *A Technical Approach to Expedited Processing of NTPR Radiation Dose Assessments*. DTRA-TR-10-29, Defense Threat Reduction Agency. Fort Belvoir, VA. October 17.

Case, D. R., Chehata, M., Dunavant, J. D., Mason, C. L., McKenzie-Carter, M. A., Singer, H. A., and Weitz, R. L., 2011b. *Compendium of Proposed NTPR Expedited Processing Groups*. DTRA-TR-11-01, Defense Threat Reduction Agency. Fort Belvoir, VA. November 30.

DTRA (Defense Threat Reduction Agency), 2007. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.0.* Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2008. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.2.* DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. October 31.

DTRA (Defense Threat Reduction Agency), 2010. *Standard Operating Procedures Manual for Radiation Dose Assessment, Revision 1.3/1.3a.* DTRA-SOP-10-01, Defense Threat Reduction Agency, Fort Belvoir, VA. January 31/March 31.

DTRA (Defense Threat Reduction Agency), 2015a. *Expedited Processing of Radiation Dose Assessments for Atmospheric Nuclear Weapons Testing Veterans*, NTPR Standard Operating Procedure RA02, Revision 2.2, Defense Threat Reduction Agency, Fort Belvoir, VA. June 30.

DTRA (Defense Threat Reduction Agency), 2015b. *Expedited Processing of Radiation Dose Assessments for NTPR Hiroshima and Nagasaki Veterans*, NTPR Standard Operating Procedure RA05, Draft Revision 1.1, Defense Threat Reduction Agency, Fort Belvoir, VA. June 23.

Gladeck, F. and Johnson, A., 1996. *For the Record—A History of the Nuclear Test Personnel Review Program, 1978 – 1993*. JAYCOR (for Defense Nuclear Agency), Alexandria VA. March.

Kerr, G. D., 1980. "Defense Nuclear Agency Report dated 5 October 1979 on *General Dosage Reconstruction, Marine Occcupation (sic) of Japan, 1945–1946*." Intra-Laboratory Correspondence from G. D. Kerr to C.R. Richmond. Oak Ridge National Laboratory. June 4.

Kerr, G.D., Egbert, S.D., Al-Nabulsi, I., Bailiff, I.K., Beck, H.L., Belukha, I.G., Cockayne, J.E., Cullings, H.M., Eckerman, K.F., Granovskaya, E., Grant, E.J., Hoshi, M., Kaul, D.C., Kryuchkov, V., Mannis, D., Ohtaki, M., Otani, K., Shinkarev, S., Simon, S.L., Spriggs,

G.D., Stepanenko, V.F., Stricklin, D., Weiss, J.F., Weitz, R.L., Woda, C., Worthington, P.R., Yamamoto, K., Young, R.W., 2015. "Workshop Report on Atomic Bomb Dosimetry – Review of Dose Related Factors for the Evaluation of Exposures to Residual Radiation at Hiroshima and Nagasaki," *Health Physics*, 109(6):582–600.

McKenzie-Carter, M. A., 2014. *Technical Basis for Expedited Processing of Radiation Dose Assessments for NTPR Hiroshima and Nagasaki Participants.* NTPR-TM-14-02. Defense Threat Reduction Agency, Fort Belvoir, VA. November 14.

McRaney, W., 1987. "Radiation Doses Received by American Prisoners of War in Japan." Memorandum to File. Science Applications International Corporation. April 17.

McRaney, W., 1993. "Radiological Hazard Associated with Use/Consumption of Seawater in the Vicinity of Hiroshima and Nagasaki, Japan, During Fall of 1945." Memorandum to DNA/RARP-NTPR (M. Owais). Science Applications International Corporation, McLean, VA. August 10.

McRaney, W. and McGahan, J., 1980. *Radiation Dose Reconstruction U.S. Occupation Forces in Hiroshima and Nagasaki, Japan, 1945-1946.* DNA-5512F. Science Applications, Inc. McLean, VA. August 6.

McRaney and Weitz, 1980. "Radiation Dose Estimate for Aircrew Members Over Hiroshima/Nagasaki, Japan." Memorandum to File. Science Applications, Inc., McLean, VA. November 13.

NIOSH (National Institute of Occupational Safety and Health), 2014. *User's Guide for the Interactive RadioEpidemiological Program (NIOSH-IREP).* Version 5.7.1, Oak Ridge Center for Risk Analysis, July. Available at: https://www.niosh-irep.com/irep_niosh/

NTPR, 2013a. "Hiroshima Units," E-mail from H. Gaugler (L-3) to M. Chehata (Leidos). L-3 Communications, Reston, VA. November 1.

NTPR, 2013b. "Leidos Nagasaki Units by Individual," E-mail from H. Gaugler (L-3) to M. McKenzie-Carter (Leidos). L-3 Communications, Reston, VA. November 13.

Takeshita K., 1972. "Residual radiation from the atomic bomb at Hiroshima." In: *Proceedings of Hiroshima University–RINMB 13*. pp 1-8 (in Japanese).

Takeshita K., 1975. "Dose estimation from residual and fallout radioactive—1. Areal surveys." In: "Review of Thirty Years Study of Hiroshima and Nagasaki Atomic Bomb Survivors." *Journal of Radiation Research,* 16(Suppl. 1):24–31.

VA (Department of Veterans Affairs), 2015. "38CFR3.309 - Disease subject to presumptive service connection," *Code of Federal Regulations*, National Archives and Records Administration's Office of the Federal Register and the Government Printing Office, Washington DC. July 1.

Appendix A.

Weathering Effects of Rainfall on Fallout Exposure Rates

A-1. Introduction

Weathering is defined for this analysis as natural phenomena that act to reduce the amount of radioactive contaminants in a specific area over time. These phenomena can include processes such as wind, rainfall runoff and infiltration, and flooding. Although soil samples taken in the area of Nishiyama Reservoir in 1970 suggested that fission-product contamination in undisturbed soil had not been significantly altered by weathering (McRaney and McGahan, 1980), weathering effects have been postulated to account for inconsistencies found in measurements of soil samples from the Nishiyama Reservoir (Kerr et al., 2015). There are no known documented weathering effects on exposure rates from fixed soil activation products at either Hiroshima or Nagasaki. Because of uncertainties and the likely lower magnitude of potential effects on exposure rates from fixed soil activation products, consideration of weathering effects in this report is limited to surface-deposited fallout.

The NTPR dose assessment methods and procedures, including those for H&N RDAs, do not include explicit consideration of weathering effects (DTRA, 2010). However, the H&N EPG exposure scenarios include two key features not typically found in other NTPR dose assessments: unique scenario timing, and significant rainfall. H&N EPG exposure scenarios begin at times from about 1 month (for the Nagasaki EPG) to 2.5 months (for the POW EPG) prior to the dates of relevant measurements, which is much longer than for most NTPR exposure scenarios. Because the exposure scenarios begin well before the relevant measurements, the measured exposure rates must be back-calculated to obtain the initial exposure rate at the beginning of each exposure scenario. In combination with timing considerations, a large amount of rainfall occurred in southern Japan during the period from the time fallout was deposited to the dates of the relevant measurements. The significant amounts of rainfall that occurred prior to the measurements could have resulted in removal of surface-deposited fallout through runoff or infiltration, thereby reducing the measured exposure rates more than they would be reduced by radioactive decay alone. By accounting for this potential weathering reduction, higher initial exposure rates are obtained when the measured exposure rates are back-calculated to the start times of the H&N EPG scenarios. Because consideration of weathering prior to the relevant measurements would result in higher doses for some H&N EPG scenarios, the weathering effects of rainfall on fallout exposure rates are conservatively incorporated into the H&N EPG dose assessments.

A-2. Weathering Model and Rainfall Data

The possible effect of rainfall on fallout exposure rates at Hiroshima and Nagasaki has been discussed by Takeshita (1972; 1975) and also more recently in Kerr et al. (2015). Based on an evaluation of measured exposure rates, a rainfall weathering constant was derived (Takeshita, 1975) that can be used with the rainfall amounts to estimate the degree of reduction in exposure rates due to weathering. This is accomplished using the equation described in Takeshita (1975) and Kerr et al. (2015) and shown below.

$$I_m = I_{dep} \times \left(\frac{t_m}{t_{dep}}\right)^{-1.2} \times e^{-kQ_m} \quad \text{(A-1)}$$

where,

I_m = Exposure rate at the time of measurement (R h^{-1})
I_{dep} = Exposure rate at the time of fallout deposition (R h^{-1})
t_m = Post-detonation time of measurement (h)
t_{dep} = Post-detonation time of fallout deposition (h)
k = Rainfall weathering constant (= 0.001 mm^{-1})
Q_m = Rainfall for entire period of interest (amount [mm] occurring between t_{dep} and t_m)

This function can be expressed more generally using the measured exposure rate and applicable rainfall amount to back-calculate the estimated exposure rate at any time *t* as follows:

$$I_t = I_m \times \left(\frac{t_m}{t}\right)^{1.2} \times e^{k(Q_m - Q_t)} \quad \text{(A-2)}$$

where,

I_t = Exposure rate at time *t* (R h^{-1})
Q_t = Rainfall occurring from t_{dep} to time *t* (mm)
$(Q_m - Q_t)$ = Rainfall occurring from time *t* to the time of measurement t_m (mm)

The rainfall occurring at Hiroshima and Nagasaki for the three months after the bombings is shown in Figure A-1. To simplify the rainfall weathering calculations for this assessment, rainfall amounts at Hiroshima (for the Hiroshima EPG), and at Nagasaki (for the Nagasaki and POW EPGs) was apportioned into four periods as shown in Table A-1.

Table A-1. Rainfall periods and amounts used in weathering calculations

EPG	Period #1*	Period #2	Period #3	Period #4	Total†
Hiroshima EPG	Aug 6–Sep 5 190 mm	Sep 6–Sep 17 280 mm	Sep 18–Sep 25 140 mm	Sep 26–Oct 10 300 mm	Aug 6–Nov 1 910 mm
Nagasaki and POW EPGs	Aug 9–Sep 1 550 mm	Sep 2–Sep 17 275 mm	Sep 18–Oct 2 150 mm	Oct 3–Oct 18 225 mm	Aug 9–Oct 21 1,200 mm

* The dates of the period (all 1945) and the amount of accumulated rainfall during the period (millimeter [mm]) is shown for each period. For calculation purposes the rainfall accumulated during each period is all assumed to occur on the last day of the period.

† The dates and rainfall for "Total" are for the entire period from fallout deposition to the date of the relevant measurement for each detonation and EPG.

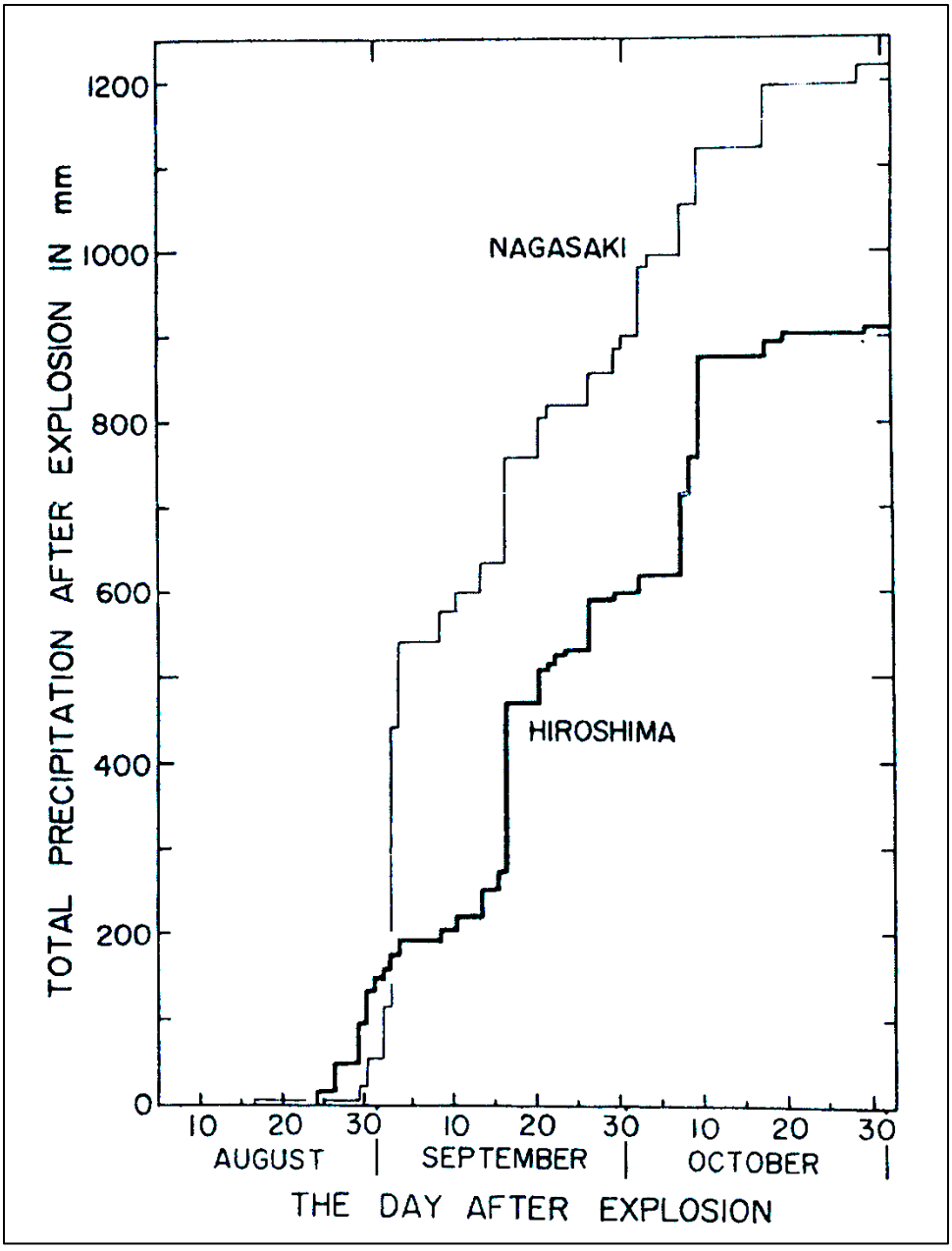

Figure A-1. Daily and total rainfall at Hiroshima and Nagasaki during the three months following the bombings

(Takeshita, 1972; Kerr et al., 2015)

A-3. Effects of Weathering on Exposure Rates

Using Equation A-2 and the rainfall amounts in Table A-1, the peak fallout exposure rates prior to weathering were calculated. For the POW EPG, the peak exposure rate at Kumamoto POW camp (as measured on the Shimabara Peninsula – see main text of this report) occurred at H+8, which is the assumed end of fallout deposition. For the Hiroshima and Nagasaki EPGs, deposition times are not relevant to this assessment because occupation forces

were not present at early times after the detonations, so the peak fallout exposure rates at Koi/Takasu (Hiroshima EPG) and Nishiyama Reservoir (Nagasaki EPG) are arbitrarily assumed to have occurred occur at H+1. The peak rates calculated with weathering are larger by factors of about 2.5 (Hiroshima EPG) and 3.3 (Nagasaki and POW EPGs) than when calculated using only radioactive decay. These factors were calculated using the total rainfall amounts shown in Table A-1. For example, for Hiroshima the peak rate is increased by a factor of $exp(0.001 \times 910) = 2.5$. The factors are applicable for all times from the time of the peak exposure rate to the date of the first modeled rainfall for each EPG.

Exposure rates calculated for the dates of the beginning of the EPG exposure scenarios are also of interest. These exposure rates are larger by factors of about 1.5 (Nagasaki EPG), 2.0 (Hiroshima EPG), and 3.3 (POW EPG). These factors are based on the amount of rainfall occurring from the start of each exposure scenario to the measurement date (see main text of this report for the beginning dates of the H&N EPG exposure scenarios). The POW EPG exposure scenario started on the day of the Nagasaki detonation, so the factor reflects the total amount of rainfall shown in Table A-1 for the POW EPG (1,200 mm). The Nagasaki factor is the lowest of the three factors because the amount of rainfall that occurred from the beginning of the Nagasaki exposure scenario to the measurement date is the lowest of the three EPGs (375 mm between September 24 and October 21, 1945).

To illustrate the effect of weathering on the exposure rate functions, comparisons of the exposure rate functions for each EPG as modeled with and without weathering are shown in Figure A-2, Figure A-3, and Figure A-4. The increased peak exposure rates are evident in these figures. Also evident in these figures are the marked decreases in exposure rates at the end of each of the rainfall periods described in Table A-1.

A-4. Impacts of Weathering on EPG Doses

Several factors affect the magnitude of the weathering assumptions on estimated EPG organ and skin doses. These factors include: rainfall amounts occurring between scenario start dates and measurement dates; exposure scenario timing, including whether any portion of the exposure scenario occurs after the measurement date; the assumed location(s) of individuals in the scenario (GZ or fallout location); and radiological half-lives of radionuclides contributing to internal organ doses.

Organ and skin doses calculated with the weathering exposure rate functions are generally higher by a factor of about 3.2 for the POW EPG as compared to doses calculated assuming no weathering. Organ and skin doses calculated for the Hiroshima and Nagasaki EPGs are affected much less than the POW EPG doses, with increases ranging from zero to increases of 1–25 percent.

As described above, weathering by rainfall is considered in the H&N EPG calculations for rainfall occurring over the time periods from fallout deposition to the times of the relevant measurements. Consideration of the rainfall occurring after the measurements could also reduce the calculated doses for members of the Hiroshima and Nagasaki EPGs by further weathering the deposited fallout. However, this potential reduction in doses is not accounted for in this analysis consistent with NTPR SOP methods (DTRA, 2010).

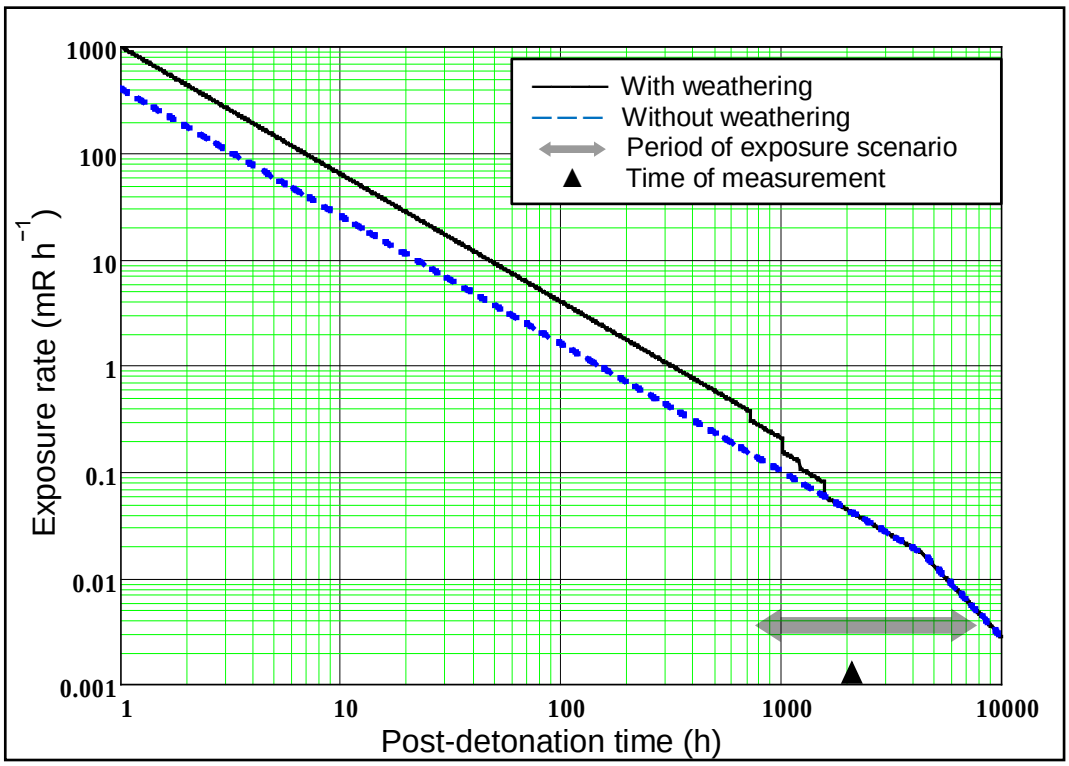

Figure A-2. Comparison of modeled fallout exposure rates for the Hiroshima EPG

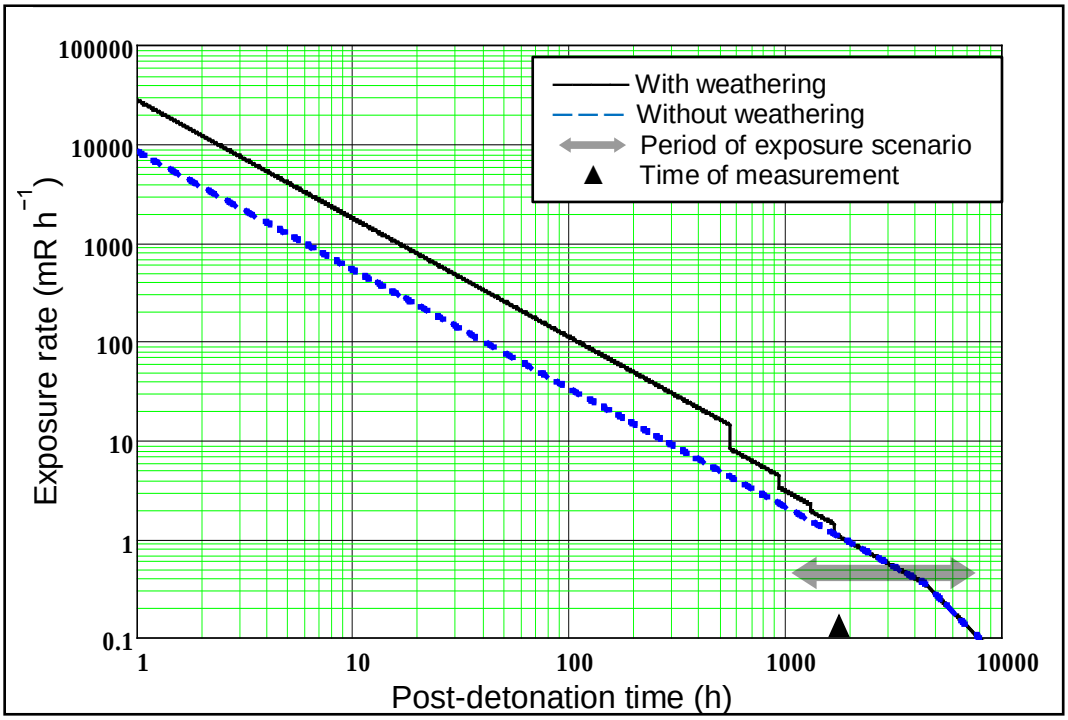

Figure A-3. Comparison of modeled fallout exposure rates for the Nagasaki EPG

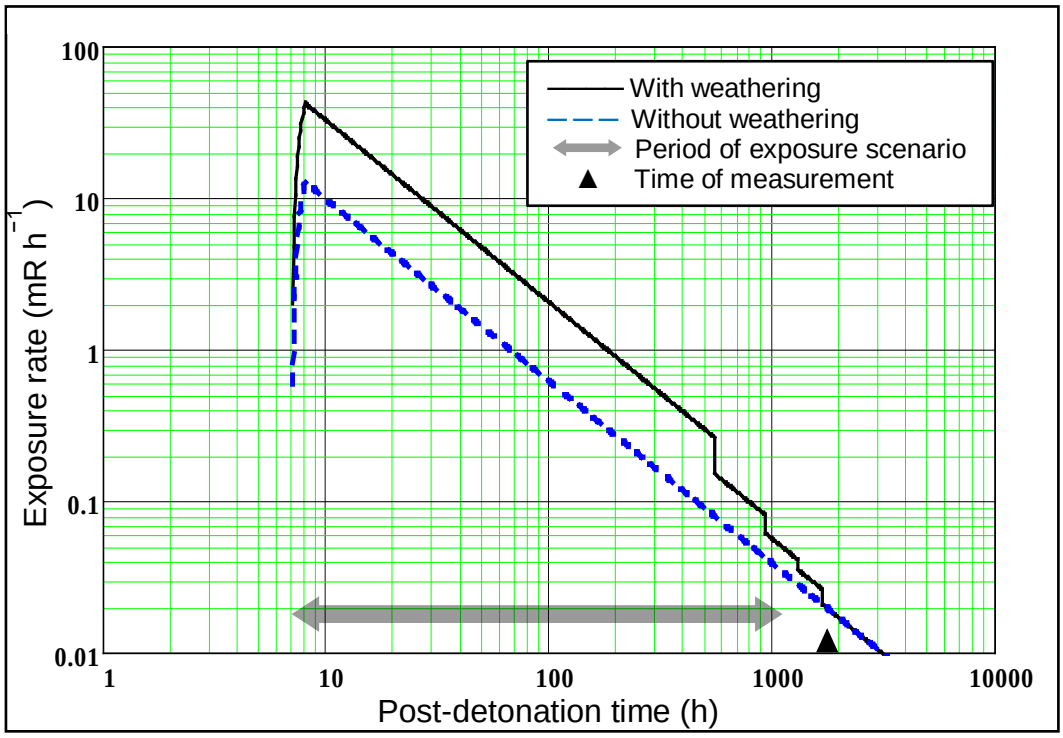

Figure A-4. Comparison of modeled fallout exposure rates for the POW EPG

Appendix B.

Parameter Values for H&N EPG Skin Dose Assessments

The methodology and assumptions used for H&N skin dose assessments are based on information contained primarily in NTPR standard methods (DTRA, 2008; DTRA, 2010). Some assumptions are based on standard methods that have been revised since the establishment of the default H&N assumptions. In addition, skin dose calculations for covered skin sites for Hiroshima and Nagasaki occupation forces are not included in the default RDA analyses for H&N RDAs. Therefore, this Appendix augments the listing of key assumptions in the main text of this report by documenting additional key assumptions used in the skin dose calculations for the H&N EPGs.

B-1. Parameters used in Contaminated Soil Groundshine Pathway

Beta-to-gamma dose ratios are used to calculate the beta skin dose skin from contaminated soil for each H&N EPG. Beta-to-gamma dose ratios applicable to bare skin exposure of an individual standing upright in an infinite planar field of fission product deposition are shown in Table B-1 (DTRA, 2010, SM ED03). These ratios were derived for the PPG, and are judged to be appropriate for the similar environment of Japan. In deriving the ratios, it was assumed that body self-shielding reduced both 1) the beta dose at any target site on the body by a factor of 0.5 from its free-field value, and 2) the gamma dose recorded on a properly worn film badge to a value of 0.7 times its free-field value. Beta-to-gamma dose ratios for the 11 representative body location skin sites for applicable times from Table B-1 are used for each EPG: those from approximately 6 hours to 1 month for the POW EPG, and approximately 1 month to 1 year for the Hiroshima and Nagasaki EPGs.

As a conservative simplification, constant beta-to-gamma dose ratios for exposure to radiations from *in situ* neutron-induced soil radionuclides are used for all body sites, regardless of the post-shot time and distance from the soil: 0.2 for the POW EPG; 0.02 for the Nagasaki EPG, and 0.03 for the Hiroshima EPG (DTRA, 2008, Appendix A-1).

Multiplicative modification factors that reduce the beta groundshine dose to account for the presence of clothing over the skin are shown in Table B-2 (DTRA, 2010, ED03). The factors were derived assuming that the individual is standing upright on an infinite plane of deposited fission products, wearing a single layer of clothing that is 28 mg cm^{-2} in density-thickness. This density thickness is representative of "coverall" material. For H&N skin dose analyses for deposited fission products, values for 1 month after fission are used as default values (shaded in table below). As a conservative simplification, clothing modification factors are not used in the assessment of beta skin doses for exposure to *in situ* neutron-induced soil contaminants because these skin doses are typically very small (much smaller than exposure to deposited fission products).

Table B-1. Beta-to-gamma dose ratios for bare skin exposures to mixed fission products at the Pacific Proving Ground

Time after Fission	Distance from source plane (cm)							
	1	20	40	80	100	120	160	200
0.5 hour	36.4	24.2	17.7	11.9	10.4	9.1	7.0	5.4
1 hour	32.5	21.4	15.5	10.3	8.9	7.8	5.9	4.5
2 hours	32.0	20.8	15.0	9.9	8.5	7.4	5.5	4.2
4 hours	40.3	25.9	18.5	12.0	10.3	8.9	6.7	5.0
6 hours	51.1	32.6	23.1	14.9	12.7	11.0	8.2	6.2
12 hours	65.6	41.0	28.6	17.8	15.0	12.8	9.3	6.8
1 day	65.1	38.7	25.8	14.9	12.2	10.0	6.8	4.7
2 days	64.4	35.2	22.1	11.8	9.3	7.4	4.7	2.9
3 days	62.8	32.2	19.3	9.8	7.6	6.0	3.6	2.1
1 week	62.3	29.0	16.3	7.7	5.8	4.5	2.5	1.4
2 weeks	65.5	30.5	17.1	8.1	6.2	4.7	2.7	1.6
1 month	72.4	34.7	19.9	9.8	7.6	6.0	3.7	2.2
2 months	85.7	39.8	22.8	11.8	9.5	7.8	5.1	3.3
4 months	90.7	40.4	23.0	12.5	10.5	9.0	6.4	4.4
6 months	94.6	42.5	24.5	13.9	11.9	10.4	7.7	5.5
9 months	116.7	54.5	32.5	19.6	17.2	15.4	11.8	8.8
1 year	166.1	81.2	50.3	31.7	28.2	25.6	20.1	15.2
2 years	494.2	251.9	160.5	104.2	93.6	85.3	68.0	52.3

Table B-2. Modification factors for light clothing

Time after fission	Distance from source plane (cm)							
	1	20	40	80	100	120	160	200
1 hour	0.59	0.74	0.80	0.83	0.84	0.86	0.87	0.87
2 hours	0.59	0.73	0.79	0.84	0.84	0.85	0.87	0.87
6 hours	0.57	0.72	0.78	0.83	0.84	0.85	0.86	0.87
1 day	0.52	0.67	0.73	0.78	0.80	0.81	0.82	0.83
1 week	0.40	0.54	0.66	0.71	0.72	0.74	0.74	0.78
2 weeks	0.40	0.55	0.66	0.71	0.72	0.73	0.77	0.74
1 month	0.41	0.56	0.67	0.73	0.74	0.75	0.78	0.77
1 year	0.42	0.62	0.78	0.86	0.87	0.87	0.88	0.88

To illustrate the use of the beta-to-gamma dose ratios applicable to bare skin exposure and the clothing modification factors for covered skin sites, values of these parameters applicable to the representative skin sites for the "standard height" individual assumed for H&N EPG skin dose assessments are shown in Table B-3. The skin site heights listed are based on an individual's height of 172.7 cm (68 inches). (DTRA, 2010, SM ED03)

Table B-3. Standard heights and corresponding parameter values

Skin Site	Standard Heights (cm)		Beta-to-gamma Dose Ratio*	Clothing Modification Factor†
	Standing	Sitting (ground)		
foot or ankle	1.0	5.1	72.4	0.410
calf or shin	20.3	15.2	34.5	0.562
knee	40.6	15.2	19.7	0.671
hand or mid-thigh	71.1	15.2	12.0	0.717
waist	99.1	14.0	7.7	0.740
forearm	99.1	20.3	7.7	0.740
lower back or stomach	119.4	34.3	6.0	0.750
upper back, upper arm, or mid-chest	139.7	54.6	4.9	0.765
neck	149.9	64.8	4.3	0.772
face, nose, ear, or head	160.0	74.9	3.7	0.780
top of head	172.7	87.6	3.2	0.777

* Beta-to-gamma dose ratios listed are fission product values applicable to the standard standing heights, for a post-detonation time of 1 month.

† Clothing modification factors shown are applicable to the standard standing heights, for a post-shot detonation time of 1 month. A single layer of clothing with density thickness of 28 mg cm^{-2} was assumed.

B-2. Parameters Used in Dermal Contamination Pathway

Skin doses from dermal contamination are included in the skin dose assessment for the POW EPG. In addition to the assumptions listed in Section 3.3, other key assumptions are described in the following sections. (DTRA, 2010, SM ED04)

B-2.1. Parameters for Dermal Contamination by Resuspended Contaminants

An effective interception and retention fraction is defined for the fraction of resuspended contaminants that is intercepted and retained on skin. The effective interception and retention fraction for resuspended contaminants (F_{res}) is calculated as follows:

$$F_{res_i} = \frac{IRF_i}{IRF_{fa}} \times CE \times PS_{res} \times EM_{res} \times EF \quad \text{(B-1)}$$

where:

F_{res_i} = Effective interception and retention fraction for resuspended contaminants at skin site *i* (unitless)
IRF_i = Interception and retention fraction for skin site *i* (unitless)
IRF_{fa} = Reference interception and retention fraction for forearm (unitless)
CE = Collection efficiency (unitless)
PS_{res} = Particle size factor for resuspended contaminants (unitless)
EM_{res} = Moisture factor for resuspended contaminants (unitless)
EF = Enrichment factor (unitless)

Values used for parameters in Equation B-1 are listed in Table B-4. The values and a discussion of each of these factors are provided in SM ED04 of DTRA (2010).

Table B-4. Summary of factors in the calculation of the effective retention fraction for resuspended contaminants

Parameter	Value
Collection Efficiency (CE)	0.02
Interception and retention fraction (IRF_i)	See values in Table B-6
Particle Size Factor (PS_{res})	1.0
Moisture Factor for high humidity areas (EM_{res})	3.0
Enrichment Factor (EF)	1.0

B-2.2. Parameters for Dermal Contamination by Descending Fallout

The effective interception and retention fraction for descending fallout (F_{des}) for the POW EPG skin dose assessment is calculated as follows:

$$F_{des_i} = IRF_i \times PS_{des} \times EM_{des} \times EF \quad \text{(B-2)}$$

where:

F_{des_i} = Effective interception and retention fraction for descending fallout at skin site *i* (unitless)
IRF_i = Interception and retention fraction for skin site *i* (unitless)
PS_{des} = Particle size factor for descending fallout (unitless)
EM_{des} = Moisture factor for descending fallout (unitless)
EF = Enrichment factor (unitless)

Values used for parameters in Equation B-2 are listed in Table B-5. These values are based on information in SM ED04 of DTRA (2007). Discussions of the values and factors are provided in DTRA (2007), DTRA (2010), and Apostoaei and Kocher (2010).

Table B-5. Summary of factors in the calculation of the effective interception and retention fraction for descending fallout

Parameter	Value
Interception and retention fraction (IRF_i)	See values in Table B-6
Particle Size Factor (PS_{des})	3.33
Moisture Factor for high humidity areas (EM_{des})	1.0
Enrichment Factor (EF)	1.0

B-2.3. Summary of Interception and Retention Fractions

Using Equation B-1 and the parameter values in Tables B-4 and B-6, the calculation of F_{res} for the POW EPG skin dose assessment is simplified as follows:

$$\begin{aligned} F_{res_i} &= \frac{IRF_i}{0.1} \times 0.02 \times 1.0 \times 3.0 \times 1.0 \\ &= IRF_i \times 0.6 \end{aligned} \quad \text{(B-3)}$$

Likewise, using Equation B-2 and the parameter values in Tables B-5 and B-6, the calculation of F_{des} for the POW EPG skin dose assessment is simplified as follows:

$$\begin{aligned} F_{des_i} &= IRF_i \times 3.33 \times 1.0 \times 1.0 \\ &= IRF_i \times 3.33 \end{aligned} \quad \text{(B-4)}$$

A summary of the interception and retention fractions (IRF), and effective interception and retention fractions (F_{res} and F_{des}) for the list of representative uncovered skin sites for the POW EPG skin dose assessment are shown in Table B-6.

B-3. Parameters Used in Clothing Contamination Pathway

Skin doses due to clothing contamination by fission products are calculated for the POW EPG. In addition to other key assumptions discussed in the main text of this report, the value of IRF assumed for covered skin (all sites) is 0.04, based on information in Apostoaei and Kocher (2010). Using this value and Equations B-3 and B-4, values of 0.024 and 0.133 are calculated for F_{res} and F_{des}, respectively, for all skin sites covered by a layer of clothing.

Table B-6. Interception and retention fractions

Bare Skin Site	Interception and Retention Fraction (*IRF*)	Effective Interception and Retention Fraction	
		Resuspended contaminants (F_{res})	Descending fallout (F_{des})
foot or ankle	1.5*	0.900	5.00
calf or shin	0.1	0.060	0.333
knee	0.1	0.060	0.333
hand or mid-thigh	0.1	0.060	0.333
waist	1.5*	0.900	5.00
forearm	0.1	0.060	0.333
lower back or stomach	0.04	0.024	0.133
upper back, upper arm, or mid-chest	0.04	0.024	0.133
neck	1.5*	0.900	5.00
face, nose, ear, or head	0.015	0.009	0.05
top of head	0.17	0.102	0.567

* The bare foot/ankle, waist, and neck were assumed to represent sites that exhibit enhanced collection and retention of particles.

Abbreviations, Acronyms, and Unit Symbols

BCC	Basal cell carcinoma
Ci	curie
cm	centimeter (= 0.01 m)
d	day
DNA	Defense Nuclear Agency
DTRA	Defense Threat Reduction Agency
EPG	Expedited Processing Group
GZ	Ground Zero
h	hour
H&N	Hiroshima and Nagasaki (locations included in the NTPR program for selected personnel during specified time periods)
L	liter
LD	Limiting Dose
m	meter
mg	milligram (= 0.001 gram)
mi	mile
mm	millimeter (= 0.001 m)
MM	Malignant melanoma
mR	milliroentgen (= 0.001 roentgen, a unit for radiation exposure)
NIOSH-IREP	National Institute of Occupational Safety and Health -Interactive RadioEpidemiological Program
NMRI	Naval Medical Research Institute
NTPR	Nuclear Test Personnel Review
NTS	Nevada Test Site
POW	Prisoner of War
PPG	Pacific Proving Ground
rad	A unit for radiation absorbed dose
RCT	Regimental Combat Team
RDA	Radiation Dose Assessment
rem	Roentgen Equivalent Man (a unit for equivalent and effective dose)
SCC	Squamous cell carcinoma
SM	Standard Method
SOP	Standard Operation Procedure
TOD	Total Organ Dose
VA	U.S. Department of Veterans Affairs
XP	Expedited processing (NTPR process based on the use of two broadly-defined exposure scenarios)