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MAXDOSE-SR AND POPDOSE-SR: ROUTINE-RELEASE ATMOSPHERIC DOSE MODELS USED AT SRS

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EXECUTIVE SUMMARY

MAXDOSE-SR and POPDOSE-SR are used to calculate dose to the offsite Reference Person and to the surrounding Savannah River Site (SRS) population respectively following routine releases of atmospheric radioactivity. These models are currently accessed through the Dose Model Version 2014 graphical user interface (GUI).

MAXDOSE-SR and POPDOSE-SR are personal computer (PC) versions of MAXIGASP and POPGASP, which both resided on the SRS IBM Mainframe. These two codes follow U.S. Nuclear Regulatory Commission (USNRC) Regulatory Guides 1.109 and 1.111 (1977a, 1977b). The basis for MAXDOSE-SR and POPDOSE-SR are USNRC developed codes XOQDOQ (Sagendorf et. al 1982) and GASPAR (Eckerman et. al 1980). Both of these codes have previously been verified for use at SRS (Simpkins 1999 and 2000).

The revisions incorporated into MAXDOSE-SR and POPDOSE-SR Version 2014 (hereafter referred to as MAXDOSE-SR and POPDOSE-SR unless otherwise noted) were made per Computer Program Modification Tracker (CPMT) number Q-CMT-A-00016 (Appendix D). Version 2014 was verified for use at SRS in Dixon (2014).

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LIST OF ABBREVIATIONS

χ/Q	Average relative air concentration
CPMT	Computer Program Modification Tracker
D/Q	Relative deposition rate
EDAM	Environmental Dose Assessment Manual
GUI	Graphical User Interface
NOAA	National Oceanic and Atmospheric Administration
ORNL	Oakridge National Laboratory
PC	Personal Computer
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
USDOE	United States Department of Energy
USNRC	United States Nuclear Regulatory Commission

1.0 Introduction

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2.0 CODE DESCRIPTION

The significant modules in the FORTRAN code for MAXDOSE-SR and POPDOSE-SR are listed in Table 1.

2.1 MODULES

Table 1. MAXDOSE-SR and POPDOSE-SR Modules

MAXDOSE-SR	POPDOSE-SR	DESCRIPTION
MGPROTEM	PGPROTEM	Input template is read, printed, and written to a file.
MGPREXOQ	PGPROTEM	Reads in data pertaining to boundary coordinates, terrain, and meteorology.
XOQDOQ	XOQDOQ	Calculates the relative air concentrations (χ/Qs) and relative deposition rates (D/Qs) for each of the boundary points (MAXDOSE-SR) and for radial rings out to 50 miles (POPDOSE-SR).
N/A	PGPOP90	Calculates the 50 mile offsite population in a radial arc format centered on user entered coordinates.
MGPREGAS	PGPRGAS	MAXDOSE-SR reads site specific data mostly concerning usage parameters in the input file created by MGPROTEM and writes the output file MGPREGAS.DAT. POPDOSE-SR reads site information and agricultural data for use in the population dose calculations from PGPROTEM and PGPOP90, the output file PGPREGAS.DAT is written by PGPRGAS.
RGASPAR	RGASPAR	Calculates pathway and organ specific doses and writes the unformatted data to an output file.
FOPEN	FOPEN	This subroutine opens the files needed by the MGPROTEM or PGPROTEM subroutines, the output word doc file is also opened. This program was added for the Mainframe to PC conversion project.

2.2 XOQDOQ

The main modules (XOQDOQ and GASPAR) will be discussed in detail. It is important to note that XOQDOQ and GASPAR were originally written as two different programs and were not designed to work together. As a result, some of the calculations performed in GASPAR are to reformat results from XOQDOQ so that they may be used correctly to calculate dose.

2.2.1 Code History

The XOQDOQ computer program was developed for use by the USNRC to evaluate atmospheric releases from commercial nuclear power operations. The calculations performed by XOQDOQ are those established in USNRC (1977b) for the release of an effluent from a stack or vent under conditions of constant wind direction. A straight line Gaussian plume model is used, and the plume is assumed to be depleted by dry deposition and radioactive decay.

XOQDOQ was originally developed by J. Sagendorf, National Oceanic and Atmospheric Administration (NOAA) and J. Gnoll, USNRC. XOQDOQ was modified by W. Pillinger in 1983 and 1984 for use at SRS (Pillinger and Huang 1986). The changes were primarily associated with expanding arrays and changing read/write statements to make it possible for XOQDOQ to calculate relative concentrations (1) at specific points along the SRS boundary for "reference" and "typical" individuals, and (2) within compass sector regions for population dose assessments (used in a population dose program). In addition, an option was invoked which constrains sector-arc average relative air concentrations (χ/Qs) to values less than plume centerline χ/Qs.

Additional modifications were made by Bauer (1990). The subroutines called by XOQDOQ to calculate χ/Qs from short-term releases were removed from the code. XOQDOQ is not the best available code for estimating χ/Qs from purges or process upsets. This step prevented the unauthorized use of XOQDOQ for such calculations.

2.2.2 Description of Input Data Files

All of the data files called upon by XOQDOQ are identified in Appendix A. The three types of data calls made by XOQDOQ include the following:

1) SRS Boundary Data
2) Regional Terrain Data
3) SRS Meteorological Data

2.2.1.1 SRS Boundary Data

The current boundaries of the SRS are recognized by XOQDOQ as 875 pairs of SRS Easting and Northing coordinates, which is the local coordinate system used at SRS. These coordinates have been reviewed for accuracy and approved for use (Bauer 1990). The perimeter of the site, as drawn by the boundary file SRSBNDRY.DAT, is shown in Figure 1. The file starts with a point under the 'nose' on the west side of the site and proceeds clockwise around the boundary.

Within XOQDOQ, the minimum distance from the release point to the site boundary is determined for each of the sixteen sectors. First, the 875 pairs of boundary coordinates are reduced to 320 equally spaced points along the perimeter. The point in a given sector that is closest to the release point is selected based on the smallest distance to one of the following:

1) Any of the boundary points
2) Any of the line segments connecting the boundary points
3) The two intersections of the compass sector with the perimeter

This distance is then used to calculate the maximally exposed individual dose for each sector.

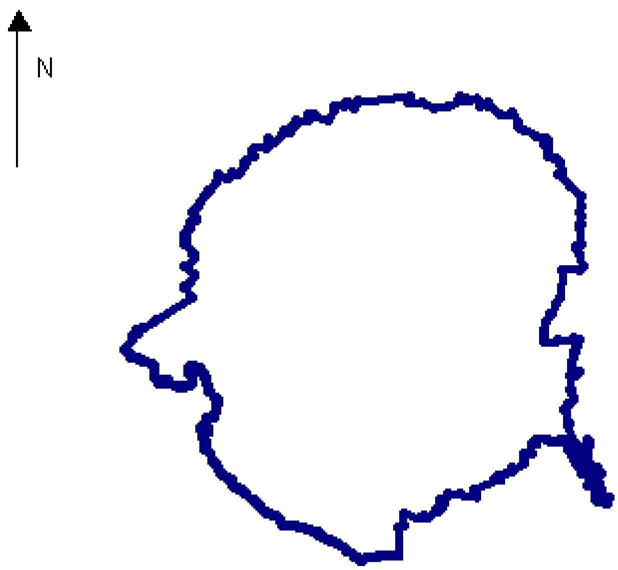

Figure 1. Current Boundary File, SRSBNDRY

2.2.2.2 Regional Terrain data

The height of the plume as it travels from the release point may be adjusted to account for changes in terrain. The terrain file is a binary file called 'TPGY100.bin'. This terrain database is a product of Oak Ridge National Laboratory (ORNL) and contains elevations above mean sea level referenced by coordinates of latitude and longitude. These data are used to develop an array of maximum changes in elevation, relative to the release point's elevations. This array is then called to determine the reduction in plume height required for a specific compass sector and downwind location. The plume height is reduced to account for the fact that if the plume is traveling in a straight line and a receptor is standing on elevated ground, they are closer to the plume.

2.2.2.3 SRS Meteorological data

XOQDOQ has the ability to access wind speed, wind direction, and atmospheric stability data collected from one of seven onsite meteorological towers. The towers are instrumented at 61 meters above ground level, which is the height of the primary reactor and separations areas stacks. The towers are equipped with cup anemometers to measure wind speed, and with bivanes to measure the horizontal and vertical components of wind direction. Previously, XOQDOQ accessed data files representing meteorological data that was hard coded, now the user may specify which files to use in an input file. SRNL Atmospheric Technologies Group (ATG) has updated the five-year metrological datasets used by MAXDOSE-SR and POPDOSE-SR. The new datasets cover the period 2007-2011 (Viner 2013 and 2014). The meteorological datasets initially did not include the appropriate wind speed modification to stability class calculation and were used for revision 0. The modification has been applied and ATG has supplied updated meteorological datasets (Dixon 2014). The meteorological monitoring program in use at the SRS has been described in more detail in SRNS (2012). The collection and quality assurance of these data are the responsibility of the Atmospheric Technologies Group at the Savannah River National Laboratory (SRNL).

XOQDOQ uses meteorological data in the form of joint frequency distributions of wind direction, wind speed range, and atmospheric stability class for each of the sixteen 22.5 degree compass sectors. The turbulence typing scheme used is the Pasquill-Gifford stability classification system.

The USNRC recommends the collection of mixing height data (USNRC 1977b). Mixing, sometimes called inversion, height is the distance above the ground in which the plume is essentially trapped due to temperature inversion. Vertical diffusion is typically limited to the value of the mixing height within XOQDOQ. Mixing height is not routinely measured onsite and is not a user-specified variable in XOQDOQ. The maximum vertical plume dispersion allowed by the code is 1000 meters. However, regional compiled data show that monthly average mixing heights are generally greater than this value except during the months of December and January (Garrett 1981). Although the averages for these winter months were found to be lower than 1000 meters, this is not believed to impact significantly the calculation of annual average χ/Qs.

2.2.3 XOQDOQ Code Structure

The structure of XOQDOQ is shown in

Figure 2 for all of the main subroutines. The calculations performed by major subroutines are described in the following sections. More detailed discussions of XOQDOQs treatment of depletion, deposition, and plume rise also follow.

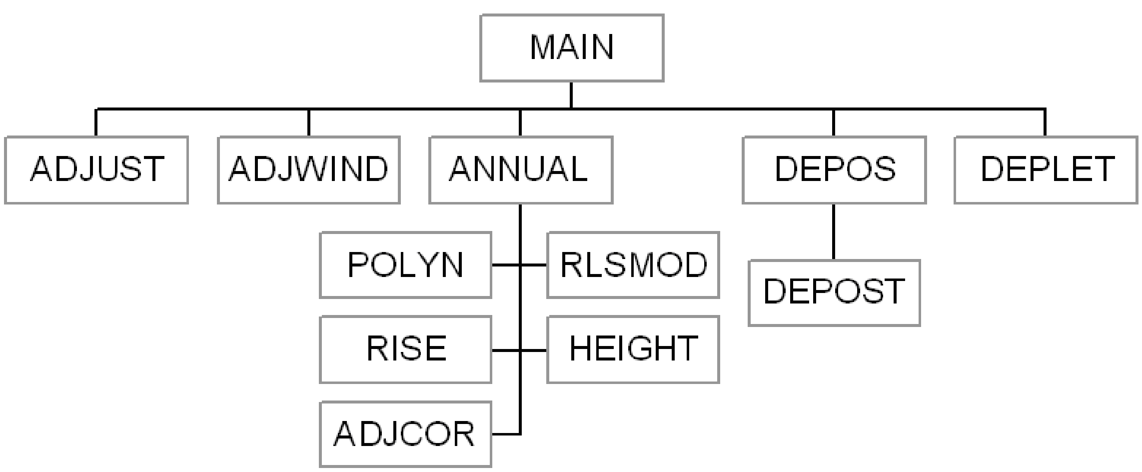

Figure 2. XOQDOQ Code Structure

2.2.3.1 XOQDOQ Subroutine Descriptions and Methodology

ADJUST -Adjusts effective plume height to correct for terrain changes using the terrain file that was discussed above. Such modifications are required to establish which series of depletion/deposition curves are to be read at a given downwind location.

ADJWIND - Provides a wind speed correction factor, CORR, when the release height does not equal the height at which the wind speed is measured. The correction factor is defined below:

$$\mathrm{CORR} = \left(\frac{\mathrm{SL}}{\mathrm{PL}}\right)^{\mathrm{EX}} \tag{1}$$

where,

SL	desired wind height, m
PL	measured wind height, 61 m
EX	0.25 (stability classes A, B, C, D)
	0.50 (stability classes E, F, G)

ANNUAL - Calculates annual-average ground level and elevated relative air concentrations (χ/Qs) and deposition concentrations (D/Qs) for a uniform distribution of effluent across the compass sector. For an elevated release, the χ/Q values are calculated as follows:

$$\frac{\chi}{Q}(x,k) = 2.032 \sum_{ij} \frac{\mathrm{JFD}_{ijk}\,\mathrm{DEC}_i(x)\,\mathrm{DEPL}_{ij}(x,k)}{u_i(x)\,\sigma_{z_j}(x)\,x}\, e^{-0.5\left(\frac{h_e}{\sigma_{z_j}(x)}\right)^2} \tag{2}$$

where,

$\chi/Q(x,k)$ relative air concentration at x meters in the k^{th} 22.5 degree compass sector, s/m^3

i wind speed class (1-6) corresponding to the ranges shown in Table 2

j atmospheric stability class (1-7) corresponding to Pasquill-Gifford stability classes A-G

A, B, C	Unstable
D	Neutral
E, F, G	Stable

$u_i(x)$ midpoint of the ith wind speed class (see Table 1), m/s

$\sigma_{zj}(x)$ vertical plume spread due to ambient free-stream turbulence as determined by subroutine POLYN, m

JFD_{ijk} joint frequency distribution of wind speed and atmospheric stability observations – percent of time over five year period that stability class j and wind speed range i occur in sector k

$DEPL_{ij}(x,k)$ plume depletion factor as determined by subroutine DEPLET

h_e effective plume height as defined by subroutines RISE and HEIGHT, m

$DEC_i(x)$ radioactive decay, $e^{-(0.693t/T)}$

t travel time=$x/(86400*u_i)$, days

T half-life of the radioactive material, days

x downwind or travel distance, m

A correction for recirculation and stagnation is available for Equation 2, but has been excluded since the factor is set to unity for SRS calculations.

Table 2. Wind Speed Classes and Ranges

Wind Speed Class	Wind Speed Range (m/s)	Wind Speed Range Midpoint – u (m/s)
1	$0 \le u \le 2$	1.0
2	$2 < u \le 4$	3.0
3	$4 < u \le 6$	5.0
4	$6 < u \le 8$	7.0
5	$8 < u \le 12$	9.0
6	$12 < u \le 14.1$	13.05

For the ground level releases, the larger value from the following two equations is used for specific downwind locations.

$$\frac{\chi}{Q}(x,k) = \frac{2.032}{x} \sum_{ijk} \frac{JFD_{ijk} DEC_i(x) DEPL_{ij}(x,k)}{u_i(x)\sqrt{3}\sigma_{zj}(x)} \qquad (3)$$

$$\frac{\chi}{Q}(x,k) = \frac{2.032}{x}\sum_{ijk}\frac{JFD_{ijk}DEC(x)DEPL_{ij}(x,k)}{u_i(x)\sqrt{\sigma_{zj}^2(x) + cD^2/\pi}} \qquad (4)$$

where,

c defined constant, 0.5 (USNRC 1977b)

D building height used to evaluate dispersion due to building wake effects

Subroutine ANNUAL also calculates relative concentrations and deposition for ten downwind segments in each of the 16 compass sectors which is needed for the population dose calculations. The computed value represents an average value for the downwind directional sector bounded by the range of the region. The method used by ANNUAL to calculate a segment average χ/Q is shown in Equation 5. A similar equation is also used to calculate segment average D/Qs.

$$\frac{\overline{\chi}}{Q}seg(k) = \frac{R_1\frac{\chi}{Q}(R_1,k) + R_2\frac{\chi}{Q}(R_2,k) + R_3\frac{\chi}{Q}(R_3,k)}{R_1 + R_2 + R_3} \qquad (5)$$

where,

$\frac{\overline{\chi}}{Q}seg(k)$ average χ/Q for the segment in compass sector k, s/m^3

$\frac{\overline{\chi}}{Q}(R_n,k)$ χ/Q at downwind distance R_n for compass sector k, s/m^3

$R_{1,3}$ downwind distance of the segment boundaries, m

R_2 downwind distance of the midpoint, m

These segment average values are used to calculate population doses for a given region.

DEPOS - This subroutine calculates D/Qs (relative deposition per unit area). DEPOS uses the same distance information as ANNUAL.

$$\frac{D}{Q}(x,k) = \frac{RF(x,k)\sum_{ij}D_{ij}f_{ij}(k)}{(2\pi/16)x} \qquad (6)$$

where,

$\frac{D}{Q}(x,k)$ average relative deposition per unit area at a downwind distance x and direction k, m^{-2}

D_{ij} relative deposition rate from Figures 7 through 10 of the USNRC 1977b for the ith wind speed class and the jth stability class, m^{-1}

$f_{ij}(k)$ joint probability of the ith wind speed class, jth stability class, and kth wind direction sector

x downwind distance, m

RF(x,k) correction factor for air recirculation and stagnation at distance x and kth wind direction.

DEPOST – This subroutine solves the polynomial regression equations for the deposition curves of USNRC 1977b in order to define a value to D_{ij} defined above.

POLYN – This subroutine calculates values of vertical and horizontal plume spread as a function of downwind distance. Vertical plume spread is calculated using the following equation:

$$\sigma_{z_j}(x) = ax^b + c \qquad (7)$$

where,

a,b,c coefficients, derived by Eimutis and Konicek (1972), which are functions of stability class and distance - values are shown in Table 3.

x downwind distance, m

Table 3. Values used to Calculate Vertical Diffusion Coefficients (Eq 7)

Pasquill Category	Valid Range (m)								
	< 100 m			100 - 1000 m			> 1000 m		
	a	b	c	a	b	c	a	b	c
A	0.192	0.936	0	0.00066	1.941	9.27	0.00024	2.094	-9.6
B	0.156	0.922	0	0.0382	1.149	3.3	0.055	1.098	2.0
C	0.116	0.905	0	0.113	0.911	0.0	0.113	0.911	0.0
D	0.079	0.881	0	0.222	0.725	-1.7	1.26	0.516	-13
E	0.063	0.871	0	0.211	0.678	-1.3	6.73	0.305	-34
F	0.053	0.814	0	0.086	0.74	-.035	18.05	0.18	-48.6

The horizontal plume spread is calculated using the following equation

$$\sigma_{y_j}(x) = Ax^{0.9031} \qquad (8)$$

Where A is represented by the values that are shown in Table 4 as a function of Pasquill's atmospheric stability categories and x is the downwind distance in meters (Eimutis and Konicek 1972).

Table 4. Values of A for Horizontal Diffusion Coefficients

Pasquill Category	A
A	0.3658
B	0.2751
C	0.2089
D	0.1471
E	0.1046
F	0.0722

The vertical and horizontal diffusion coefficients for stability class G are determined using the following equation:

$$\sigma_z(G) = 2A\log_{10}(F) - A\log_{10}(E) \qquad (9)$$

where, E and F are the horizontal diffusion coefficient values for stability classes E and F, respectively.

RLSMOD - Invoked for mixed-mode releases. RLSMOD evaluates the need for an entrainment factor, E, by computing the ratio of the plume exit velocity to the wind speed. If a mixed-mode release is indicated, the proportion of the plume considered to be elevated and the proportion considered to be ground level are determined by the following relationships:

$$\begin{aligned} E_t &= 1.0 && \text{for } w/u < 1.0 \\ E_t &= 2.58 - 1.58(\text{w/u}) && \text{for } 1.0 \le w/u \le 1.5 \\ E_t &= 0.3 - 0.06(\text{w/u}) && \text{for } 1.5 < w/u < 5.0 \\ E_t &= 0.0 && \text{for } w/u \ge 5.0 \end{aligned} \qquad (10)$$

where,

E_t fraction of the time the release is ground level

w plume exit velocity, m/s

u average wind speed at vent height, m/s

RISE - Plume rise, h_{pr}, is calculated using the formula of Briggs (1969). Plume rise due to momentum and buoyancy is considered. At SRS, atmospheric releases are considered to be ambient temperature plumes, and therefore, plume rise may be considered to be exclusively a function of momentum.

The formulae of Briggs (1969) are based on the effective stack height method in which plume rise is artificially decoupled from dispersion. The principal site-specific parameters upon which plume rise depends are effluent exit velocity, wind speed, stack diameter, and stack height.

The specific empirical relationships recognized by RISE for h_{pr} as a function of momentum are:

For stability classes A, B, C, D, the smaller value from the following two equations is used:

$$h_{pr} = 1.44\left(\frac{w}{u}\right)^{2/3}\left(\frac{x}{d}\right)^{1/3} d \tag{11}$$

$$h_{pr} = 3\left(\frac{w \bullet d}{u}\right) \tag{12}$$

where,

w	effluent exit velocity, m/s
u	wind speed at release height, m/s
x	downwind distance, m
d	stack diameter, m

If the effluent velocity is less than 1.5*wind speed, then plume rise height is further corrected as follows

$$h_{pr} = h_{pr} - 3(1.5 - w/u) \bullet d \tag{13}$$

For stability classes E, F, G, the smallest value from the following equations is used:

$$h_{pr} = 1.44\left(\frac{w}{u}\right)^{2/3}\left(\frac{x}{d}\right)^{1/3} d \tag{14}$$

$$h_{pr} = 3\left(\frac{w \bullet d}{u}\right) \tag{15}$$

$$h_{pr} = 4\left(\frac{F_m}{s}\right)^{0.25} \tag{16}$$

$$h_{pr} = 1.5\left(\frac{F_m}{u}\right)^{1/3} s^{-1/6} \tag{17}$$

where, F_m is the momentum flux parameter, m^4/s^2

$$F_m = \left(\frac{w \bullet d}{2}\right)^2 \tag{18}$$

s	acceleration per unit vertical displacement for adiabatic motion in the atmosphere, by stability class - see below, s^{-2}

Stability Class	Value for s (s^{-2})
E	8.75E-04
F	1.75E-03
G	2.45E-03

If the effluent velocity is less than 1.5*wind speed, then plume rise height is further corrected as follows

$$h_{pr} = h_{pr} - 3(1.5 - w/u) \bullet d \tag{19}$$

HEIGHT - An effective plume height, h_e is calculated by XOQDOQ using Equation 20. HEIGHT linearly interpolates an h_t for a given downwind distance x, based on the highest elevation between the source and the given downwind distance.

$$h_e = h_s + h_{pr} - h_t \quad (h_e \geq 0) \tag{20}$$

where,

h_e	effective plume height, m
h_s	physical stack height, m
h_{pr}	plume rise, m
h_t	terrain height, m

ADJCOR - Keeps track of the cross-over heights (discussed in next section) which each plume passes for each direction, wind-speed class, and stability category. This subroutine determines which depletion and deposition adjustment factors derived in ADJUST should be used. XOQDOQ's treatment of depletion and depositions are described more fully in a subsection below.

2.2.3.2 Depletion

Plume depletion by XOQDOQ is automatic whenever 8 day decayed χ/Qs are calculated. Plume depletion via ground surface absorption is assumed by Markee (1967) to be a function of eddy diffusivity and wind velocity. By establishing vertical profiles of these variables, Markee (1967) was able to estimate vertical plume concentration profiles for a variety of release conditions. The results of studies were used by the USNRC to develop depletion factors for general use. Depletion curves for release heights of 0, 30, 60, and 100 meters, expressed as a function of atmospheric stability class were published in USNRC (1977b).

XOQDOQ decreases the total mass in the plume at progressive downwind distances by solving the polynomial regression equations of the depletion curves described above. Because depletion factors are a function of plume height, XOQDOQ uses subroutines ADJCOR and ADJUST to track the plume and modify the depletion factors as terrain features (and therefore, effective plume heights) change with increasing distance. This often dictates that more than one set of depletion curves be used. The downwind distances at which it is necessary to change from one set of curves to another are referred to in XOQDOQ as cross-over points.

XOQDOQ's treatment of depletion is shown in Figure 3 for a 60 meter release. The depletion factors of USNRC (1977b) would be adjusted by XOQDOQ as shown in Figure 3.

2.2.3.3 Deposition

Relative deposition is calculated in XOQDOQ based on deposition velocities (v_d) measured by Pelletier and Zimbrick (1970) as a function of wind speed. The data collected are specific to the vegetation, wind velocity, temperature, and humidity profiles of the northwest desert.

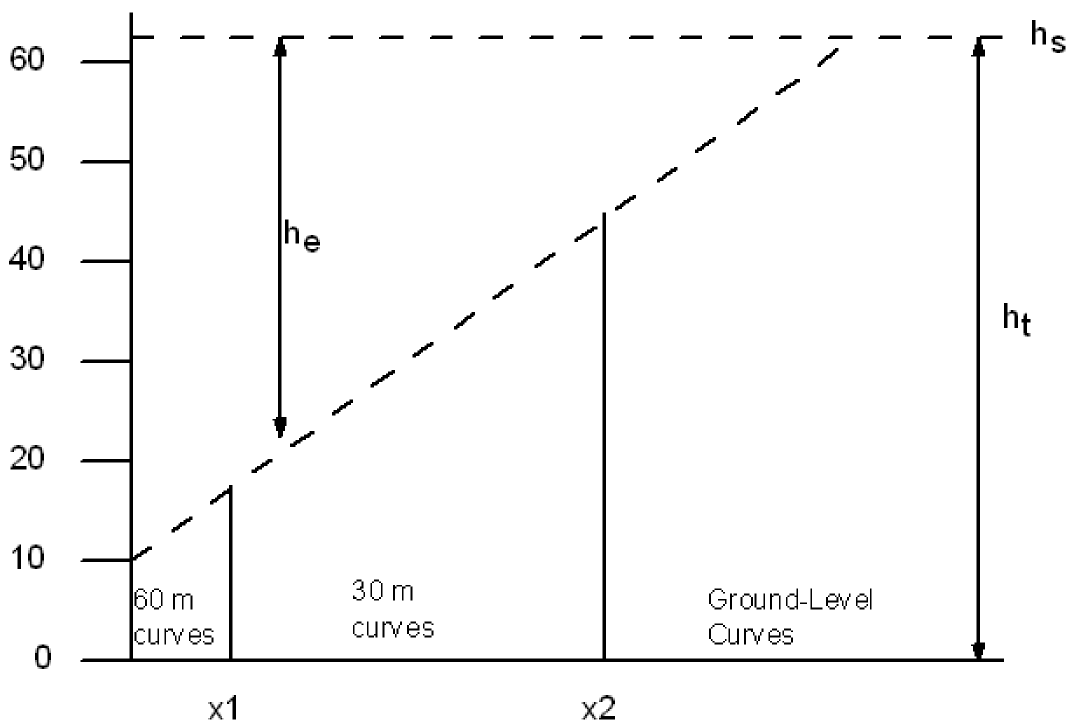

Figure 3. XOQDOQ Treatment of Cross-Over Points (Bauer 1991)

$x < x_1$ Stability-class-specific depletion factors taken from their respective 60 meter curves. No adjustment necessary.

$x_1 \leq x \leq x_2$ Once the plume passes a cross-over point, depletion factor adjustments are required. Depletion factors for distances in this range are adjusted by adding to them the difference between the 60 and 30 meter depletion factors evaluated at the cross-over point, x_1.

$x \geq x_2$ At this point, the depletion factors are adjusted by adding to them the difference in the 60 and 30 meter curves at x_1 as well as the difference between the 30 meter and ground level curves at x_2.

The deposition curves developed by the USNRC from the Pelletier and Zimbrick data have not shown to be equally applicable to all sites. Also, the USNRC position does not address the roles of such parameters as particle size distribution, solubility, roughness length for particulates or surface area, surface moisture, and stoma openings for gases. However, to follow USNRC Guidance these curves are used.

XOQDOQ uses the deposition curves of the USNRC (1977b) to determine relative deposition rates. Deposition rates are considered to be functions of the distance from the source, release height and atmospheric stability. XOQDOQ estimates relative deposition per unit area by multiplying the relative deposition rate by the fraction of the release transported into the sector. This value must then be divided by the arc length of the sector at the distance of interest.

As required for the depletion factors, XOQDOQ makes adjustments in the deposition factors to account for changes in plume height. The adjustments made at the cross-over points can be categorized by looking at Figure 3.

2.2.4 XOQDOQ Results

The results of the subprogram XOQDOQ include the following for each radial arc:

$\frac{\chi}{Q}$	relative air concentration (s/m^3)
$\left(\frac{\chi}{Q}\right)_D$	relative air concentration decayed by 2.26 days (s/m^3). This is a holdover from USNRC (1977b) when all noble gases were conservatively assumed to have a half life of 2.26 days.
$\left(\frac{\chi}{Q}\right)_{DD}$	relative air concentration decayed for 8.0 days and corrected for depletion using the curves discussed above (s/m^3). This is a holdover from USNRC 1977b when all radioiodines were assumed to have a half-life of 8.0 days. When this concentration is used in conjunction with the real half-life of the radionuclide, the 8.0 day decay is removed.
$\frac{D}{Q}$	relative deposition per unit area (m^{-2})

These results of XOQDOQ are written to a file for later use by GASPAR to calculate the individual dose for MAXDOSE-SR ver. 2013 and the population dose for POPDOSE-SR ver. 2013.

2.3 GASPAR

The GASPAR code (Eckerman et. al. 1980) was written in 1977 by Oak Ridge National Laboratory for the USNRC. The models in GASPAR calculate radionuclide-specific atmospheric concentrations, deposition rates, concentrations in foodstuffs, and radiation dose to individuals and populations resulting from chronic releases of radionuclides to the atmosphere (USNRC 1977a). For use at SRS GASPAR is called GASPAR within POPDOSE. The atmospheric transport models that feed GASPAR are contained in XOQDOQ (USNRC 1977b and Sagendorf et. al 1982).

2.3.1 Description of Input Files for GASPAR

The data files used by GASPAR (AGRIMMV.DAT and DOSEFACT.DAT) are described in Appendix A.

2.3.2 GASPAR Code Structure

The GASPAR program diagram in shows the interactions between modules relative to data transfer for all of the main subroutines. GASPAR is arranged so that it operates in either MAXDOSE-SR ver. 2013 or POPDOSE-SR ver. 2013 to calculate radiation doses to humans resulting from atmospheric releases of radionuclides.

2.3.3 *GASPAR Subroutine Descriptions and Methodology*

BLKDAT reads in various data that are needed for dose calculations - most of which is element specific (i.e. stable element transfer factors for milk and meat).
REDDF reads in dose factor libraries. For version 2011, the dose factors are based on USEPA (1993) and on International Commission of Radiological Protection Publication 72 (ICRP, 1996), which are for external and internal exposures, respectively. The updated dose factors are presented in Appendix B along with a comparison to the previous dose factors.
REDSIT used to read in array data for meat, milk, and agricultural productivity that could be used for population runs.
PRINTM prints meteorological and site data.
AGPROD calculates agricultural productivities for a 50 mile array.
SOURCE checks source term to ensure dose factor is available for all radionuclides that are included.
REDMET reads in meteorological data, relative air concentrations, and deposition rates as calculated by XOQDOQ.
DOSIT subroutine where, the bulk of the calculations are performed. Calls the following subroutines that calculate dose based on which radionuclide is being considered.
TRITON calculates tritium dose.
CARBON calculates carbon dose.
NOBLE calculates dose from noble gases.
PART calculates dose from particulates.

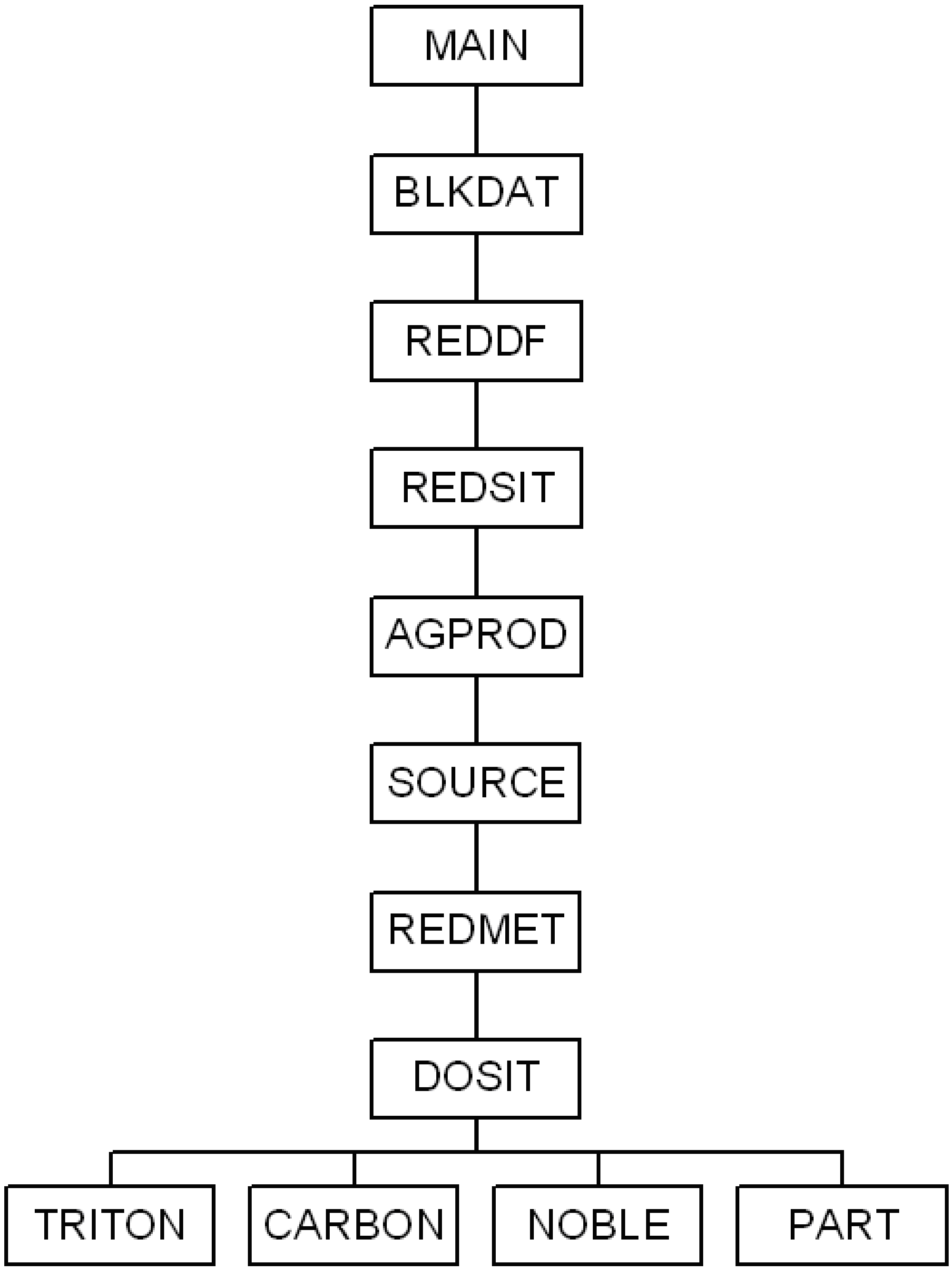

Figure 4. GASPAR Code Layout

Following the dose calculations there are a series of subroutines that store the output. For radionuclide transport at the SRS, actual radioactive decay is calculated for each nuclide released to the atmosphere. GASPAR accepts only four outputs from the XOQDOQ computer code listed below. The nondecayed χ /Q and the 2.26 day decayed χ_D/Q are used to calculate the travel time from the source to the receptor (see section on 2.2.3.3 **Deposition**).

1) Sector arc relative air concentration, χ/Q
2) Sector arc relative air concentration decayed by 2.26 days, χ_D/Q
3) Sector arc relative air concentration decayed and depleted for 8 days, χ_{DD}/Q
4) Sector arc relative deposition, D/Q

2.3.4 Nuclide Concentrations In The Atmosphere

2.3.4.1 Tritium and Carbon-14

Downwind atmospheric concentrations, χ_i, of tritium and carbon-14 are estimated using

$$\chi_i = \frac{\chi}{Q}\left(\frac{s}{m^3}\right) \bullet Q_i\left(\frac{Ci}{yr}\right) \bullet 10^{12}\left(\frac{pCi}{Ci}\right) \bullet 3.17x10^{-8}\left(\frac{yr}{s}\right) \qquad (21)$$

where,

χ_i	air concentration, μCi/m^3
χ/Q	relative air concentration from XOQDOQ, s/m^3
Q_i	release amount by radionuclide, Ci/yr
3.17E-08	conversion factor, yr/s
1.0E06	conversion factor, μCi/Ci

Since both tritium and carbon-14 have relatively long half-lives, radiological decay is not taken into account when estimating downwind concentration for these nuclides.

2.3.4.2 Noble Gases

Air concentrations of noble gases are estimated by,

$$\chi_i = \frac{\chi}{Q} \bullet Q_i \bullet 1.0E06 \bullet 3.17E-08 \bullet e^{-\lambda_i t} \qquad (22)$$

where,

λ	radioactive decay constant, s^{-1}
t	decay time during transit, s

Where, the exponential accounts for radioactive decay during transit to the receptor. The value of t is determined in the same manner later in the calculation of the deposition rate (Equation 27).

2.3.4.3 Radioiodines

Radioiodine concentrations in the atmosphere are determined using,

$$\chi_i = \left\{ \frac{\chi}{Q} \bullet (1 - F_I) + \frac{\chi_{DD}}{Q} \bullet F_I \bullet e^{31.62t} \right\} \bullet Q_i \bullet e^{-\lambda_i t} \quad (23)$$

where,

χ_{DD}/Q decayed and depleted concentration taken from XOQDOQ, s/m^3

F_I fraction of iodine that is elemental, unitless

The factor in brackets calculates a weighted relative air concentration accounting for the deposition of the elemental fraction. The positive rate coefficient (31. 62 yr^{-1}) negates decay from the generic 8 day half-life that was already applied to the χ/Q within XOQDOQ. An exponential term is also included in this equation to account for the actual radioactive decay during plume transit.

2.3.4.4 Other Nuclides

Air concentrations of the remaining nuclides (those not considered above), are calculated using,

$$\chi_i = \frac{\chi_{DD}}{Q} \bullet Q_i \bullet 1.0E06 \bullet 3.17E-08 \bullet e^{(31.62-\lambda_i)t} \quad (24)$$

where, all terms have been defined previously. Again, the positive rate coefficient in the exponential term (31.62 yr^{-1}) negates the decay from the 8 day half-life that was already applied to the χ/Q within XOQDOQ.

2.3.5 Deposition

Deposition of iodines and particulates can occur by several mechanisms. The primary removal mechanism of atmospheric material is gravitational settling or contact with the ground, vegetation, or other ground cover such as buildings (dry deposition). Wet deposition occurs whereby gases and particulates are removed from an atmospheric plume by precipitive scavenging (rain, sleet, and snow). For long-term averages, such as those calculated in POPDOSE-SR ver. 2013, dose calculations considering only dry deposition usually are not changed significantly by the consideration of wet deposition (USNRC 1977b). Wet deposition should be considered at sites that have a well-defined rainy season corresponding to the grazing season (USNRC 1977b).

Average monthly rainfall rates from 1978 to 2008 range between 2.97 and 5.55 inches per month (Kabela 2009). The SRS does not have a rainy season; however, the months of November and December typically have less rain than other months. Since there is not a well-defined rainy season, wet deposition would be insignificant at the SRS for long-term averages and, therefore, is not considered in POPDOSE-SR ver. 2013.

Dry deposition of tritium, carbon-14 and the noble gases is not considered. Specific activity models for tritium and carbon-14 utilize atmospheric concentrations to estimate vegetation concentrations.

2.3.5.1 Radioiodine

Deposition rates, d_i, of iodine radioisotopes are estimated using,

$$d_i = \frac{D}{Q} \bullet Q_i \bullet F_I \bullet 1.0E6 \bullet e^{-\lambda_i t} \tag{25}$$

where,

D/Q	relative deposition value from XOQDOQ, m^{-2}
Q_i	radionuclide release rate, Ci/yr
F_I	fraction of iodine assumed to be elemental, unitless
λ_i	nuclide-specific decay constant, yr^{-1}
t	plume travel time from the source to the receptor, yr

The parameter t is the average time required for the effluent to reach the receptor (site boundary for maximum individual). The XOQDOQ subroutine calculates a decayed and a non-decayed χ/Q. The decayed χ /Q is obtained by assuming the effluent is radioactive with a half-life of 2.26 days (USNRC 1977b). The value of t is found by solving the radioactive decay equation used in XOQDOQ to calculate a 2.26 day decayed relative air concentration,

$$\frac{\chi_D}{Q} = \frac{\chi}{Q} e^{-(112 yr^{-1})t} \tag{26}$$

where, the value 112 yr^{-1} is the decay constant for a 2.26 day half-life. The plume travel time (in years) is then,

$$t = \frac{\ln\left(\frac{\chi_D / Q}{\chi / Q}\right)}{\left(\frac{\ln 2 \bullet 365d}{2.26d \bullet 1yr}\right)} \tag{27}$$

The plume travel time is used in subsequent equations to account for radioactive decay, ground deposition, and plume depletion.

2.3.5.2 Other Nuclides.

Deposition rates for all remaining nuclides are determined using

$$d_i = \frac{D}{Q} \bullet Q_i \bullet 1.0E6 \bullet e^{(31.62-\lambda_i)t} \qquad (28)$$

where, all parameters have been previously defined. The deposition equilibrium coefficient for iodine (31.62 yr^{-1}) is applied to all other nuclides as well. Deposition is modeled for all radionuclides, except for tritium, carbon-14 and noble gases.

2.3.6 Nuclide Concentration In Vegetation

2.3.6.1 Tritium

A specific activity model describes the uptake of tritium in vegetation. Tritium concentrations in vegetation are determined directly from the concentrations of tritium in atmospheric moisture. Equilibrium is assumed to be achieved in a short time relative to an annual release. The concentration of tritium in vegetation, C_T^V , is determined by

$$C_T^V = \frac{\chi_T \bullet 0.75 \bullet 0.5}{H} \qquad (29)$$

where,

C^V_T	concentration in vegetation, μCi/g
χ_T	atmospheric concentration, μCi/m^3
0.75	fraction of plant mass that is water (USNRC 1977a), unitless
0.5	concentration ratio of plant tritium to atmospheric tritium (Hamby and Bauer 1994), unitless
H	annual average absolute humidity (12.9 g/m^3 for SRS) (Kabela 2011)

Studies (Bauer and Hamby 1991, Hamby 1993) have shown that dose estimates for the vegetation consumption pathway are sensitive to the parameters in this model. Therefore, a site-specific value was determined for the plant-tritium-to-atmospheric-tritium model (Hamby and Bauer 1994).

2.3.6.2 Carbon 14

The carbon-14 model for vegetation concentrations is similar to the tritium model. The following equation is used to estimate the concentration:

$$C_C^V = \frac{\chi_c \bullet F_t \bullet 0.11}{0.00016} \qquad (30)$$

where,

χ_c	atmospheric concentration, μCi/m^3

F_t	0.5 - ratio of the total annual release time to the total annual time during which photosynthesis occurs (taken to be 4380 hrs) (USNRC 1977a), unitless
0.11	fraction of total plant mass that is natural carbon (USNRC 1977a), unitless
0.00016	concentration of natural carbon in the atmosphere (USNRC 1977a), unitless

2.3.6.3 Other Nuclides

The concentration of other nuclides in vegetation is determined using

$$C_i^V = d_i \bullet \left[\frac{r_i(1-e^{-\lambda_i^w t_e})}{Y_V \lambda_i^w} + \frac{B_i^v(1-e^{-\lambda_i t_b})}{P \bullet \lambda_i} \right] \bullet e^{-\lambda_i t_h} \quad (31)$$

where,

d_i	deposition rate-determined earlier, mCi/m^{3}yr
r_i	fraction of the nuclide deposited that remains on the surface of the plant (Jannik et al. 2017), unitless
λ_i^w	represents both weathering and radioactive loses (USNRC 1977a), yr^{-1}
t_e	crop exposure time (Jannik et al. 2017), yr
Y_v	crop productivity (Jannik et al. 2017), kg/m^2
B_i^v	element-specific soil/plant uptake ratio (Jannik et al. 2017), unitless
λ_i	radioactive decay constant, yr^{-1}
t_b	time over which the buildup of radionuclides occurs (user entered), yr
P	surface soil density (USNRC 1977a), kg/m^2
t_h	hold-up time after harvest (allowing decay before consumption) (Jannik et al. 2017), yr

The two expressions in the brackets account for contamination via foliar deposition and root uptake, respectively. All particulate nuclides are assume to be 20% retained on vegetation (r=0.2) while 100% of the iodines are retained (r=1.0) (USNRC 1977a). The loss constant, λ_i^w accounts for losses through physical weathering (14 day half-life) and radioactive decay. Values of Y_v, t_e, and t_h vary depending on the type of crop and whether the vegetation is for human consumption or is to be used as fodder (Jannik et al. 2017).

Concentrations in four types of vegetation are calculated in GASPAR. These four types along with their associated parameter values are given in Table 5. Noble gases are assumed not to concentrate or deposit on vegetation.

Table 5. Parameters for Vegetation Concentrations

Parameter	Other Vegetables	Leafy Vegetables	Pasture Grass	Stored Feed	Reference
r (iodines)	1.0	same	same	same	USNRC 1977a
r (particulates)	0.2	same	same	same	USNRC 1977a
λ_w (yr^{-1})	$18.07+\lambda_i$	same	same	same	USNRC 1977a
t_e (yr)	0.192	0.192	0.0822	0.192	Jannik et al. 2017
Y_v (kg/m^2)	2.2	2.2	0.7	0.7	Jannik et al. 2017
B_i	element specific	same	same	same	Jannik et al. 2017
λ_ι (yr^{-1})	nuclide specific	same	same	same	USNRC 1977a
t_b (yr)	scenario specific	same	same	same	Usually (current year – 1954)
P (kg/m^2)	240	same	same	same	USNRC 1977a
t_h (yr)	0.0164	0.00274	0	0.247	Jannik et al. 2017
d_i (mCi/m^3yr	nuclide specific	same	same	same	from XOQDOQ

2.3.7 Nuclide Concentrations In Meat And Milk

Concentrations of radionuclides in meat and milk are determined from feed concentrations, fodder intake rates, and element-specific feed-to-meat/feed-to-milk transfer factors. The equations for meat and milk concentration estimates are essentially identical with the exception of feed transfer coefficient. Concentrations are estimated using,

$$C_i^{meat} = C_i^{fodder} \bullet F_i^b \bullet Q_F \bullet e^{-\lambda_i t_s} \qquad (32)$$

$$C_i^{milk} = C_i^{fodder} \bullet F_i^m \bullet Q_F \bullet e^{-\lambda_i t_f} \qquad (33)$$

where,

C_i^{fodder} nuclide concentration in cattle feed (determined below), Ci/kg

F_i^b and F_i^m feed transfer coefficients for beef cow and milk cow, respectively (Jannik et al. 2017), (d/kg or d/L)

Q_F cattle feed rate, kg/d

t_s and t_f transport time for meat and milk, respectively, s

Values for these parameters are listed in Table 6.

Table 6. GASPAR Parameters for Meat and Milk Ingestion (Jannik et al. 2017)

Parameter	Meat	Milk (cow)	Milk (goat)
Feed consumption rate (kg/d)	44[a]	44[a]	6
Milking/Slaughter to consumption (d)	6	3	2
Fraction of year on pasture	1.00	1.00	0.79
Fraction intake from pasture[b]	0.75	0.56	0.85
[a]Average of beef-cow and milk-cow consumption rates [b]while on pasture			

The nuclide concentration in fodder is estimated based on the fraction of time cattle spend on pasture and the fraction of that time that is spent consuming fresh pasture grass. The next equation calculates fodder concentration by weighting the concentration of pasture grass and stored feed.

$$C_i^{fodder} = f_p f_s C_i^p + \left[f_p (1 - f_s) + (1 - f_p) \right] C_i^s \qquad (34)$$

where,

C_i^p concentration in pasture grass, Ci/kg

C_i^s concentration in stored feed, Ci/kg

f_p fraction of time cattle spend on pasture (Jannik et al. 2017), unitless

f_s fraction of time that cattle eat fresh grass while on pasture (Jannik et al. 2017), unitless

2.3.8 MAXDOSE-SR Dose Calculations

DOE Order 458.1 (2013) states that compliance with the DOE annual dose limit of 100 mrem (1 mSv), for a member of the public, may be demonstrated by calculating dose to the maximally exposed individual (MEI) or to a representative person. Prior to 2012, SRS used the MEI concept for dose compliance using adult dose coefficients and adult male usage parameters. Beginning in 2012, SRS now uses the representative person concept for dose compliance.

DOE (2013) defines the representative person as an individual receiving a dose that is representative of the more highly exposed individuals in the population. This term is equivalent of and replaces the "average member of the critical group." However, in the *International Commission on Radiological Protection* (ICRP) *Report 101*, the definition is extended to include the average value for the more highly exposed group or the 95th percentile of appropriate national or regional data. At SRS, the reference person who is at the 95th percentile of national usage data is now used as a replacement for the MEI.

2.3.8.1 Plume Shine Dose

Dose to the Representative Person from plume shine is estimated in GASPAR only for noble gases. The gamma dose from a particular noble gas in the atmospheric plume is calculated by

$$D_i^p = \chi_i \bullet SF \bullet DF_i^p \bullet 1yr \tag{35}$$

where,

χ_i atmospheric concentration

SF shielding factor accounting for the fraction of time spent indoors (0.7 for individuals)

DF_i^p nuclide specific plume-shine dose factor (Stone and Jannik 2013), mrem m^3/yr µCi

2.3.8.2 Ground Shine Dose

Ground-shine doses are calculated for all particulate, gamma emitting nuclides. The dose accounts for buildup over the plant lifetime and is given by,

$$D_i^g = d_i \bullet SF \bullet DF_i^g \bullet \frac{1-e^{-\lambda_i t_b}}{\lambda_i} \bullet 1yr \tag{36}$$

where,

DF_i^g nuclide-specific ground shine dose factor (Stone and Jannik 2013)

2.3.8.3 Inhalation Dose

Inhalation dose is determined for the Representative Person by assuming a constant breathing rate and a constant air concentration throughout the year of exposure. The nuclide-specific dose is estimated by,

$$D_h^{inh} = \chi_i \bullet BR \bullet DF_i^{inh} \bullet 1000 \left[\frac{mrem}{rem}\right] \bullet 1yr \tag{37}$$

where,

χ_i atmospheric concentration

BR breathing rate, 6400 m^3/yr (Stone and Jannik 2013)

DF_i^{inh} nuclide specific dose conversion factor (Stone and Jannik 2013), rem/µCi

2.3.8.4 Food Ingestion Dose

Dose to the Representative Person is estimated for ingestion of foodstuffs including vegetables, meat, and milk. Radionuclide intakes through the vegetation consumption pathway consider vegetables as being classified as either "leafy" or "other." The "other" category includes fruits, grains, produce, and below ground vegetables. The dose via vegetable consumption for a one year period is calculated using,

$$D_i^{veg} = \left[C_i^v U^v f_v + C_i^l U^l f_l\right] \bullet DF_i^{ing} \bullet 1000 \frac{\text{mrem}}{\text{rem}} \bullet 1\text{yr} \quad (38)$$

where,

C_i	radionuclide concentrations in leafy or other vegetables
U	consumption rates of the two vegetable classifications (see Table 7)
f	fraction of two vegetable classifications that are home grown
DF_i^{ing}	nuclide specific ingestion dose conversion factor (Stone and Jannik 2013), rem/μCi

Individual dose from meat and milk consumption is calculated in the same manner, using the equations

$$D_i^{meat} = C_i^{meat} \bullet U^f \bullet DF_i^{ing} \bullet 1000 \frac{\text{mrem}}{\text{rem}} \bullet 1\text{yr} \quad (39)$$

$$D_i^{milk} = C_i^{milk} \bullet U^m \bullet DF_i^{ing} \bullet 1000 \frac{\text{mrem}}{\text{rem}} \bullet 1\text{yr} \quad (40)$$

The dose conversion factor for ingestion is nuclide specific and is the same value for water, vegetable, meat and milk consumption. Usage factors for vegetables, meat, and milk are shown in Table 7 for reference and typical individuals.

Table 7. Consumption Parameters (Stone and Jannik 2013)

	Consumption Rate (kg/yr)	
Parameter	**Reference Person**	**Typical Person**
Vegetables	289	89
Meat	81	32
Milk	260	69

2.3.9 POPDOSE-SR Dose Calculations

SRS has developed reference usage parameters at the 50th percentile to calculate dose to a "typical" person for determining collective (population) doses (Stone and Jannik 2013).

2.3.9.1 Plume Shine Dose

Population dose is estimated using average plume concentrations in each of 160 sector/annulus segments; 16 sectors and 10 annuli with distance ranges of 0-1, 1-2, 2-3, 3-4, 4-5, 5-10, 10-20, 20-30, 30-40, and 40-50 miles. Population dose from plume shine is calculated using the following equation:

$$D_i^p = SF \bullet DF_i^p \bullet 1yr \bullet \sum_{k=1}^{160} \left(\chi_{ik} \bullet N_k \right) \tag{41}$$

where,

SF	shielding factor accounting for the fraction of time spent indoors (0.5 for population)
χ_{ik}	atmospheric concentration of nuclide I in area-segment k (Ci/m^3)
N_k	number of people (all ages) residing in segment k (Koffman 2011)

2.3.9.2 Ground Shine Dose

Ground-shine doses are calculated for all particulate, gamma-emitting nuclides. The population dose accounts for buildup over the plant lifetime and is given by,

$$D_i^g = SF \bullet DF_i^g \bullet \frac{1 - e^{-\lambda_i t_b}}{\lambda_i} \bullet 1yr \sum_{k=1}^{160} \left(d_{ik} \bullet N_k \right) \tag{42}$$

where,

d_{ik}	deposition rate of nuclide I in segment k, m^{-2}

All other terms are previously defined. The exponential term accounts for the ground surface buildup and subsequent radiological decay. Nuclide specific doses are summed for the total dose.

2.3.9.3 Inhalation Dose

Inhalation dose is determined for the population assuming a constant breathing rate and a constant concentration throughout the year of exposure. The nuclide specific population dose is estimated by,

$$D_h^{inh} = BR \bullet DF_i^{inh} \bullet 1000 \left[\frac{mrem}{rem} \right] \bullet 1yr \sum_{k=1}^{160} \left(\chi_{ik} \bullet N_k \right) \tag{43}$$

where, all terms are previously defined.

2.3.9.4 Food Ingestion Dose

Dose to the population is estimated for ingestion of foodstuffs including vegetables, meat, and milk. Radionuclide intake through the vegetation consumption pathway considers vegetables as being classified as either “leafy” or “other.” The “other” category includes fruits, grains, produce, and below ground vegetables.

ALARA population dose is calculated by GASPAR based on the assumption that the food consumed by the population within 50 miles of the SRS center is produced in the 50 mile region. If production rates exceed consumption needs, food is exported from the region (consumption of which is included in the NEPA dose estimate). Equations for the estimation of population dose via consumption of vegetables, meat, and milk are given below.

$$D_{ip}^{veg} = DF_{ip}^{ing} \bullet 1yr \bullet U_p^v \bullet N \bullet \sum_{k=1}^{160} \left[C_{ik}^{veg} \bullet \frac{VEG_k}{VEGT} \right] \quad (44)$$

$$D_{ip}^{meat} = DF_{ip}^{ing} \bullet 1yr \bullet U_p^f \bullet N \bullet \sum_{k=1}^{160} \left[C_{ik}^{meat} \bullet \frac{MET_k}{METT} \right] \quad (45)$$

$$D_{ip}^{milk} = DF_{ip}^{ing} \bullet 1yr \bullet U_p^m \bullet N \bullet \sum_{k=1}^{160} \left[C_{ik}^{milk} \bullet \frac{MLK_k}{MLKT} \right] \quad (46)$$

where,

U_p consumption rates of the various media (Stone and Jannik 2013), kg

N number of persons served by the total production within an 80 km radius of the site (Jannik et al. 2017)

C_{ik} average concentration of nuclide I in vegetation, meat, or milk within area-segment k (calculated from XOQDOQ output), Ci/kg

VEG_k mass of vegetables produced in that sector arc (Jannik et al. 2017), kg

VEGT total mass of vegetables produced (Jannik et al. 2017), kg

MET_k mass of beef produced in that sector arc (Jannik et al. 2017), kg

METT total mass of beef produced (Jannik et al. 2017), kg

MLK_k mass of milk produced in that sector arc (Jannik et al. 2017), liters

MLKT total mass of milk produced (Jannik et al. 2017), liters

The consumption of homegrown leafy vegetables is not considered when calculating population dose.

Table 8 has the typical person consumption rates and other population parameters used for estimating vegetable, meat, and milk population dose. The expressions that follow the summation symbols in Equations 38-40 provide a weighted nuclide concentration for estimating the average nuclide concentrations in foods within the dose assessment region. The dose conversion factor for ingestion is nuclide specific and is the same value for vegetable, meat and milk consumption.

Table 8. Typical Person consumption rates, population served, and production (Jannik et al. 2017)(Stone and Jannik 2013)

Parameter	Units	Vegetable	Meat	Milk
Consumption Rate	kg/yr	89	32	69
Population Served	persons	32,500	177,000	708,000
Total Production	kg	5,300,000	7,600,000	85,000,000

2.3.10 GASPAR Results

The results of GASPAR contain the dose estimates by pathway, organ, and radionuclide. A summary table also shows the total estimated dose. Doses are shown for both ALARA and NEPA methodologies. NEPA population doses are typically higher because they account for the export of food beyond the 50 mile radius. For typical runs, the ALARA output is used rather than the NEPA output.

3.0 VERIFICATION

MAXDOSE-SR and POPDOSE-SR Version 2014 were verified by running the test cases as per the Software Quality Assurance Plan for Environmental Dosimetry (Jannik 2010). The results of the verification process are documented in SRNL-L4321-2011-00051 Dixon (2014). No modifications were done to the formulas in the source code between versions 1.1 and 2011; however, the SRNL Atmospheric Technologies Group (ATG) has updated the five-year meteorological datasets with the appropriate wind speed modification to stability class calculation. This modification was applied for the updated meteorological datasets used by MAXDOSE-SR and POPDOSE-SR to reflect the current values (Dixon 2014). Thus, as expected, results generated by MAXDOSE-SR and POPDOSE-SR Version 2014 differ from previous versions.

In Jannik et al. (2017), a complete comparison was made of MAXDOSE-SR ver. 1.1 and POPDOSE-SR 1.1 with 1) no changes and with 2) these versions updated with the physical and behavior parameters and bioaccumulation factors recommended in that report. That comparison did not include the additional changes made to the dose factors or population that are included in the current MAXDOSE-SR and POPDOSE-SR Version 2013. However, that report did document the expected changes in dose values caused by just the updated physical and behavior parameters and bioaccumulation factors.

In addition to the test cases, MAXDOSE-SR and POPDOSE-SR Version 2014 were used to calculate doses based on the source terms used in the SRS 2011 Annual Site Environmental Report (ASER). The results from these simulations are presented in Appendix C along with a comparison to the Version 2011 results. As expected, individual radionuclide results differed up or down based on the various changes made to the input parameters. However, for the Reference Person, the overall total dose was about 12 percent higher for Version 2013 (0.163 mrem) as compared to Version 2011 (0.146 mrem). This 12 percent increase was caused by an overall increase in the internal dose coefficients. For the population dose, the POPDOSE-SR Version 2013 calculated value (2.03 person-rem) was nearly 3 percent lower than the Version 2011 value (2.09 person-rem). The small change in population dose is caused by the increase in internal dose factors being offset in a general decrease in the typical individual exposure pathway.

Prior to version 1.0, the model ran on the mainframe. The mainframe versions are titled MAXIGASP and POPGASP respectively. Additional test cases were ran when MAXIGASP and POPGASP were migrated to the PC. The first PC version was titled version 1.0 however in the previous manual it is referred to as MAXDOSE-SR and POPDOSE-SR with no version number specified. Refer to the previous manual for verification between mainframe and the 1.0 PC versions (Simpkins 1999 and Simpkins 2000). The 2011 version of the dose models was compiled using the Portland Group, Inc. Visual Fortran Compiler. Previous PC based versions were compiled in Compaq Visual Fortran which is no longer supported.

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4.0 USER'S MANUAL

MAXDOSE-SR and POPDOSE-SR Version 2014 are FORTRAN codes compiled using the Portland Group FORTRAN compiler as part of Microsoft Visual Studio 2008. These codes are subsequently referred to as MAXDOSE-SR and POPDOSE-SR with the understanding that this report refers to Version 2014 unless otherwise noted. To operate properly, these codes require formatted input files that can be tedious to produce. A graphical user interface (GUI) front end has been developed in Microsoft Excel 2010 that implements Visual Basic coding to generate the required formatted input files based on user supplied input. Although it is possible to independently create the formatted input files and successfully execute MAXDOSE-SR and POPDOSE-SR, using the EXCEL based GUI greatly simplifies the process and is strongly recommended.

4.1 INSTALLATION INSTRUCTIONS

MAXDOSE-SR and POPDOSE-SR may be obtained on CD from Environmental Dosimetry Group (EDG) personnel. To use the programs, simply copy the directory structure on the CD to the local C drive. For the program to operate correctly, it is necessary to maintain the directory structure and file naming conventions as provided on the CD. An Excel workbook provides the GUI to the programs. The workbook consists of spreadsheets for input of user data and macros for executing the MAXDOSE-SR and POPDOSE-SR codes. The macros read the user input from the spreadsheet, create the formatted input files required by the codes, initiate execution of the codes, and optionally open the resulting output in Excel.

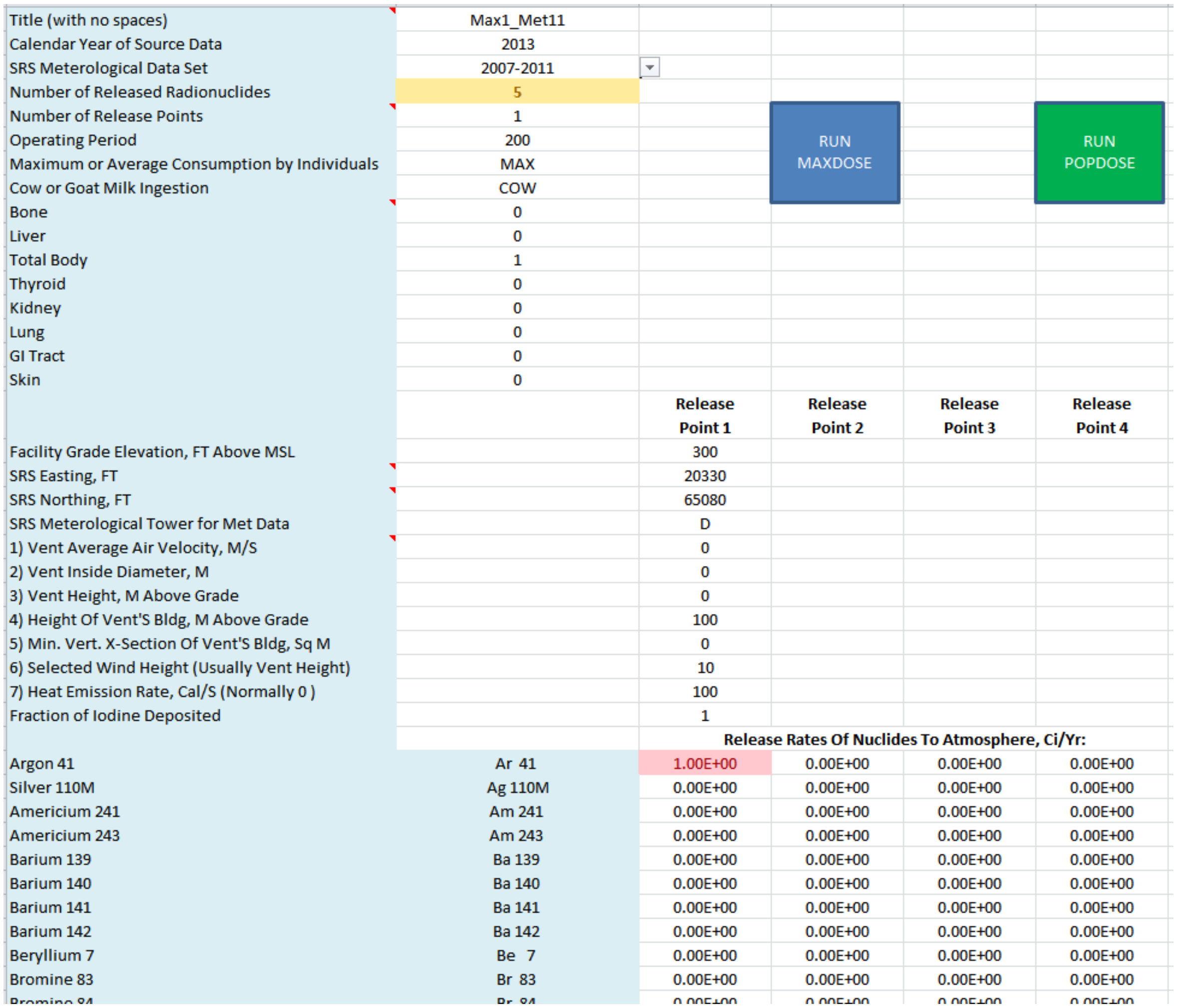
Clicking the "MAXDOSE" or "POPDOSE" macro button will cause Excel to initiate the series of macros that reads the user input, creates the necessary program input files, and executes the MAXDOSE-SR and POPDOSE-SR codes. Once the programs have competed operation, the user is prompted to view the results in Excel. A text file containing the results can also be viewed in Microsoft Word (runtitle.doc).

4.2 METEORLOGICAL DATA

There are currently five meteorological data sets, 1)1987-1991, 2)1992-1996, 3)1997-2001, 4)2002-2006, and 5)2007-2011. The user may select the desired dataset from the drop down menu provided in the Excel GUI. The required meteorological input file for MAXDOSE-SR POPDOSE-SR is created upon execution of the "MAXDOSE" or "POPDOSE" macro (metlist.txt).

4.3 INPUT INSTRUCTIONS

The user can provide input for MAXDOSE-SR and POPDOSE-SR using the Excel GUI. Each of the inputs is discussed below in detail. Once all of the inputs have been entered, the user clicks on either of the "MAXDOSE" or "POPDOSE" button to execute the appropriate code. Figure 5 shows a portion of the GUI.



Title (with no spaces)	Max1_Met11				
Calendar Year of Source Data	2013				
SRS Meterological Data Set	2007-2011				
Number of Released Radionuclides	5				
Number of Release Points	1				
Operating Period	200		RUN MAXDOSE		RUN POPDOSE
Maximum or Average Consumption by Individuals	MAX				
Cow or Goat Milk Ingestion	COW				
Bone	0				
Liver	0				
Total Body	1				
Thyroid	0				
Kidney	0				
Lung	0				
GI Tract	0				
Skin	0				
		Release Point 1	Release Point 2	Release Point 3	Release Point 4
Facility Grade Elevation, FT Above MSL		300			
SRS Easting, FT		20330			
SRS Northing, FT		65080			
SRS Meterological Tower for Met Data		D			
1) Vent Average Air Velocity, M/S		0			
2) Vent Inside Diameter, M		0			
3) Vent Height, M Above Grade		0			
4) Height Of Vent'S Bldg, M Above Grade		100			
5) Min. Vert. X-Section Of Vent'S Bldg, Sq M		0			
6) Selected Wind Height (Usually Vent Height)		10			
7) Heat Emission Rate, Cal/S (Normally 0)		100			
Fraction of Iodine Deposited		1			
		Release Rates Of Nuclides To Atmosphere, Ci/Yr:			
Argon 41	Ar 41	1.00E+00	0.00E+00	0.00E+00	0.00E+00
Silver 110M	Ag 110M	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Americium 241	Am 241	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Americium 243	Am 243	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Barium 139	Ba 139	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Barium 140	Ba 140	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Barium 141	Ba 141	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Barium 142	Ba 142	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Beryllium 7	Be 7	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bromine 83	Br 83	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Bromine 84	Br 84	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Figure 5. MAXDOSE-SR and POPDOSE-SR Graphical User Interface (GUI)

A detailed discussion of each of the input parameters is below.

TITLE:

The user can enter a descriptive title for the run in the space provided up to 40 characters in length. MAXDOSE-SR and POPDOSE-SR will not accept run titles with spaces. Therefore, any spaces in the run title will be automatically replaced with an underscore ("_") upon execution of the program. The run title will appear at the top of most of the output pages and it will be used as the name for the input and output folders created by execution of the code. An example path is "C:\dosemodels\maxdose\runtitle\output".

NUMBER OF RELEASE POINTS:

This input is only used for MAXDOSE-SR which can simulate up to four release points. POPDOSE-SR only simulates one release point.

OPERATING PERIOD (YEARS):

Enter the operating period in years. This is the length of time that the facility has been operating. Per USNRC (1977a), deposition buildup is assumed to occur for half of this period. If the user is not concerned with USNRC (1977a) and would like to model deposition buildup for the entire operating period then the user should double the time period.

CONSUMPTION BY INDIVIDUALS:

Previous versions of MAXDOSE-SR and POPDOSE-SR used maximum and average consumption rates. Consumption rates have been updated to reflect the "reference" and "typical" person (Stone and Jannik, 2013). However, MAXDOSE-SR is hard coded to accept only "MAX" and "AVG" to denote consumption rates in the input decks. As such, the Excel GUI continues to use this terminology. The Excel GUI user should note that reference person consumption rates may be selected by choosing "MAX" in and typical person consumption rates may be selected by choosing "AVG". POPDOSE-SR does not read this value and uses typical person consumption rates; it therefore has no effect on the output. For MAXDOSE-SR, 'MAX' should be used for estimating annual doses as this will select reference person consumption rates. These values can be found in the current Environmental Dose Assessment Manual (EDAM).

MILK INGESTION:

This is used for MAXDOSE-SR and has no effect on POPDOSE-SR output. Cow milk ingestion is assumed for POPDOSE-SR. MAXDOSE-SR will evaluate doses for cow or goat milk ingestion. These values can be found in the current EDAM.

SELECT RADIONUCLIDES:

The current dose factor library file (DOSEFACT.DAT) contains 881 radionuclides (Dixon 2013b). MAXDOSE-SR and POPDOSE-SR ver. 2014 have the capability to simulate up to 1000 radionuclides per run. Therefore, it is possible to simulate every radionuclide in the dose factor library file per simulation. In order to minimize the size of the Excel input spreadsheet, the default GUI contains 144 of the 881 radionuclides in the dose factor library file. The user can add any of the radionuclides in the dose factor library to the spreadsheet as needed for specific simulations. Likewise, the default radionuclides in the spreadsheet may be deleted in favor of the radionuclides of interest for a specific simulation. The release rate (Ci/yr) of each radionuclide is entered directly into the spreadsheet in the column corresponding to the appropriate release point. For POPDOSE-SR, release rates should be entered into the column corresponding to release point one. When a release rate is entered, the cell is automatically highlighted to allow the user to easily scan the spreadsheet and check for data entry errors. The spreadsheet also automatically tracks the total number of radionuclides released based on the input provided by the user.

Facility Grade Elevation: (0 for Unknown; 1000 for Flat Terrain)

Enter the facility grade elevation in feet above sea level. If '1000' is selected, the terrain database will not be accessed to adjust for release height as the plume travels downwind.

Release SRS-Grid Coordinates: Easting =

Northing =

Enter the release coordinates in the site conventional system of Easting and Northing with units of feet. Refer to Karapatakis (2008) for the coordinates of the major facilities onsite,

SRS Area Meteorological Tower for Met Data:

Use the pull down menu to select the meteorological tower that you wish to be accessed. Ideally, pick the one that is closest and has similar terrain. The order of the pull down menu references the list in the 'metlist.txt' file. This information is updated every five years and provided by the Atmospheric Technologies Group as documented in Kabela (2009).

Vent Average Air Velocity:

Enter the stack exit velocity in m/s. This will be used to calculate plume rise due to momentum of the plume. This parameter is typically set equal to '0' for conservatism.

Vent Inside Diameter:

Enter the inside diameter of the stack/vent. This parameter will also be used to calculate plume rise effects.

Vent Height:

Enter the height of the release in meters above grade. If the release is 100% elevated, use a negative sign in front of the number.

Height of Vent's Building:

Enter the height of building. This number is used in Equation 4 to determine if the building effects plume dispersion.

Minimum Vertical X-Section of Vent's Building:

Enter the vertical cross-section of the building in square meters.

Selected Wind Height: (Usually Vent Height)

Enter the height to which the wind speed will be adjusted. This is usually the release height, unless the release is from ground level and then a wind speed height of 10 meters is usually assumed. Wind measurements at SRS are taken at 61 meters and a correction factor is applied (See Equation 1) to adjust the wind speed according to the appropriate height.

Heat Emission Rate: (Normally 0)

Enter heat emission rate, if known, in cal/s. This parameter is used for plume rise due to buoyancy effects.

Fraction of Radioiodine elemental:

Enter the fraction of radioiodine that is elemental, if known. This is used in Equations 23 and 25 to calculate the deposition rates and atmospheric concentrations of radioiodine. Note, this value cannot be set to zero, if a value of zero is desired, 0.01 should be entered instead.

4.4 INPUT AND OUTPUT FILES GENERATED

For each MAXDOSE-SR or POPDOSE-SR run, input and output files are saved in folders corresponding to the run title provided by the user. An example path is "C:\dosemodels\maxdose\runtitle\input" or "C:\dosemodels\popdose\runtitle\output" where "runtitle" is substituted with the actual run title. If the folders already exist, the program will prompt the user with a warning that existing files will be overwritten.

4.4.1MICROSOFT WORD OUTPUT FILE

Historically this file was titled maxdose.doc or popdose.doc. This version takes the name from the 'Title' input field. For example, if the 'Title' input field is populated with "Test_1" then a file entitled "Test_1.doc" will be generated in the output directory of the model that was run. This file contains all the input and output that a user would need to verify a run. Once the file is opened, change the page layout to landscape and reduce font size to 8 for ease in viewing. Most of the output is self-explanatory, but a brief discussion follows.

1) Input template is echoed.
2) Meteorological joint frequency distribution with averages and summaries.
3) Terrain height as a function of distance from the release location and sector.
4) Annual average χ/Qs with three different categories: no decay, undepleted (2.26 day decay and 8.0 day decay), and depleted.
5) Relative deposition as a function of distance and sector.
6) Relative air concentrations and relative depositions for each of the 320 equally spaced boundary locations.
7) Stable element transfer factors.
8) Maximum and average radionuclide air concentrations at the boundary for each of the radionuclides. (MAXDOSE-SR only)
9) Population data along with population consumption factors. (POPDOSE-SR only)
10) Committed Effective Dose Equivalents (CEDEs).
    a. Dose broken down by radionuclide.

  b. Dose broken down by Organ for the following pathways: plume shine, ground shine, vegetable consumption, meat consumption, milk consumption (cow or goat), and inhalation.

11) Total dose for all pathways summed together by radionuclide and organ, air, and ground concentrations for each of the sectors.
12) Distance to the Reference Person in each sector. (MAXDOSE-SR only)
13) Population dose values (POPDOSE-SR only) are shown for ALARA methodologies and then using NEPA methodologies. NEPA population doses are typically higher because they account for the export of food beyond the 50 mile radius and the dose to the U.S. population as a result of this. For typical runs, the ALARA output should be used since the NEPA assumptions are overly conservative.

4.4.2 OTHER OUTPUT FILES

Intermediate files generated when running MAXDOSE-SR and POPDOSE-SR are stored in the output directory. They can be used to ensure the code is executing properly.

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6.0 Appendix A. MAXDOSE-SR AND POPDOSE-SR INPUT FILES

6.1 MAXDOSE-SR VER. 2014 DATA FILES

The following contains brief descriptions of the data files used by MAXDOSE-SR ver. 2014.

AGRIMMV.DAT

This file contains agricultural parameters for all sectors onsite. This information is used for population dose calculations. Milk, meat, and vegetable production are included for each sector and for 10 arcs which are bracketed by the following distances (in miles) from the center of the site: 0.5-1, 1-2, 2-3, 3-4, 4-5, 5-10, 10-20, 20-30, 30-40, and 40-50. This data is taken from Jannik et al. (2010).

DOSEFACT.DAT

This file contains the dose conversion factors used to calculate dose to the maximally exposed offsite individual. The first several entries are for the noble gases whose dose conversion factors have been modified to include contribution from the daughters as per Hamby (Jannik et al. 2010). Dose conversion factors for all other radionuclides are shown next.

MGPREGAS.DAT

This file contains a variety of site specific information that is used to perform the dose calculations. Parameters for reference and typical individual are shown separately.

SITEINFO.DAT

This data file contains a small amount of site specific information.

SRSBNDRY.DAT

The SRS boundary file contains 875 pairs of site coordinates which make up the site boundary. Section 2.1.2.1 discusses this file in greater detail. The first point corresponds to about the '9:00' position on the site boundary which is under the 'nose' on the west side.

METEOROLOGICAL DATA Files

Meteorological data files exist for each of the seven towers onsite. They are in the form of a joint frequency distribution by wind speed and stability class. Average wind speeds are also included in the files although they are not used by MAXDOSE-SR ver. 2013.

METLIST.TXT

The ‘metlist.txt’ can be modified when new meteorological data files become available. This file must be located in “C:\dosemodels\maxdose”.

6.2 POPDOSE-SR VER. 2014 DATA FILES

The following contains brief descriptions of the data files used by POPDOSE-SR ver. 2014.

AGRIMMV.DAT

This file contains agricultural parameters for all sectors onsite. This information is used for population dose calculations. Milk, meat, and vegetable production are included for each sector and for 10 arcs which are bracketed by the following distances (in miles) from the center of the site: 0.5-1, 1-2, 2-3, 3-4, 4-5, 5-10, 10-20, 20-30, 30-40, and 40-50. This data is taken from Jannik et al., (2010).

DOSEFACT.DAT

This file contains the dose conversion factors used to calculate dose to the maximally exposed offsite individual. The first several entries are for the noble gases whose dose conversion factors have been modified to include contribution from the daughters as per Jannik et al., (2017). Dose conversion factors for all other radionuclides are shown next.

SITEINFO.DAT

This data file contains a small amount of site specific information like relative humidity, soil density and fractions of foods home produced.

METEOROLOGICAL DATA Files

Meteorological data files exist for each of the seven towers onsite. They are in the form of a joint frequency distribution by wind speed and stability class. Average wind speeds are also included in the files although they are not used by POPDOSE-SR ver. 2013.

METLIST.TXT

The ‘metlist.txt’ can be modified when new meteorological data files become available. This file must be located in “C:\dosemodels\popdose”.

GRIDTOT.DAT

GRIDTOT.DAT is a population file that contains a grid of 120x120 starting at 82.625 32.251 with incremental distances corresponding to 0.0166667. This file is used in the PGPOP90 subroutine to determine a radial arc distribution of population centered on the release point of interest. The population data is based on 2010 census data (Koffman 2011).

7.0 Appendix B. DOSE Coefficients

Table B.1. Comparison of dose factors between version 2013 and 2014 for MAXDOSE-SR and POPDOSE-SR.

Atomic Number	Nuclide	Version 2013 Decay (1/s)	Version 2014 Decay (1/s)	% Diff	Version 2013 Ingestion Dose Coefficient (mrem/pCi)	Version 2014 Ingestion Dose Coefficient (mrem/pCi)	% Diff	Version 2013 Inhalation Dose Coefficient (mrem/pCi)	Version 2014 Inhalation Dose Coefficient (mrem/pCi)	% Diff	Version 2013 External Dose Coefficient (mrem-m^2/pCi-h)	Version 2014 External Dose Coefficient (mrem-m^2/pCi-h)	Percent Change
1	H-3	1.78E-09	1.78E-09	0	7.77E-08	7.77E-08	0	1.07E-07	1.07E-07	0	0.00E+00	0.00E+00	0
4	Be-7	1.51E-07	1.51E-07	0	1.29E-07	1.29E-07	0	2.37E-07	2.37E-07	0	6.34E-10	6.34E-10	0
6	C-14	3.85E-12	3.85E-12	0	2.34E-06	2.34E-06	0	2.48E-08	2.48E-08	0	1.70E-13	1.70E-13	0
11	Na-24	1.29E-05	1.29E-05	0	2.02E-06	2.02E-06	0	2.16E-06	2.16E-06	0	4.78E-08	4.78E-08	0
15	P-32	5.62E-07	5.62E-07	0	1.25E-05	1.25E-05	0	1.62E-05	1.62E-05	0	1.13E-09	1.13E-09	0
16	S-35	9.17E-08	9.17E-08	0	6.44E-07	6.44E-07	0	5.77E-06	5.77E-06	0	1.77E-13	1.77E-13	0
24	Cr-51	2.90E-07	2.90E-07	0	1.86E-07	1.86E-07	0	1.61E-07	1.61E-07	0	3.98E-10	3.98E-10	0
25	Mn-54	2.57E-08	2.57E-08	0	3.29E-06	3.29E-06	0	1.33E-05	1.33E-05	0	1.05E-08	1.05E-08	0
25	Mn-56	7.47E-05	7.47E-05	0	1.26E-06	1.26E-06	0	5.70E-07	5.70E-07	0	2.16E-08	2.16E-08	0
26	Fe-55	8.03E-09	8.03E-09	0	2.04E-06	2.04E-06	0	1.62E-06	1.62E-06	0	1.93E-18	1.93E-18	0
26	Fe-59	1.80E-07	1.80E-07	0	1.01E-05	1.01E-05	0	1.52E-05	1.52E-05	0	1.47E-08	1.47E-08	0
27	Co-57	2.95E-08	2.95E-08	0	1.16E-06	1.16E-06	0	2.29E-06	2.29E-06	0	1.45E-09	1.45E-09	0
27	Co-58	1.13E-07	1.13E-07	0	3.74E-06	3.74E-06	0	6.59E-06	6.59E-06	0	1.23E-08	1.23E-08	0
27	Co-60	4.17E-09	4.17E-09	0	2.03E-05	2.03E-05	0	4.14E-05	4.14E-05	0	3.06E-08	3.06E-08	0
28	Ni-59	2.17E-13	2.17E-13	0	2.95E-07	2.95E-07	0	5.48E-07	5.48E-07	0	1.97E-13	1.97E-13	0
28	Ni-63	2.19E-10	2.19E-10	0	7.33E-07	7.33E-07	0	2.01E-06	2.01E-06	0	0.00E+00	0.00E+00	0
28	Ni-65	7.65E-05	7.65E-05	0	9.10E-07	9.10E-07	0	3.74E-07	3.74E-07	0	7.69E-09	7.69E-09	0
30	Zn-65	3.29E-08	3.29E-08	0	1.76E-05	1.76E-05	0	6.66E-06	6.66E-06	0	7.15E-09	7.15E-09	0
34	Se-75	6.70E-08	6.70E-08	0	1.24E-05	1.24E-05	0	4.59E-06	4.59E-06	0	4.74E-09	4.74E-09	0

Atomic Number	Nuclide	Version 2013 Decay (1/s)	Version 2014 Decay (1/s)	% Diff	Version 2013 Ingestion Dose Coefficient (mrem/pCi)	Version 2014 Ingestion Dose Coefficient (mrem/pCi)	% Diff	Version 2013 Inhalation Dose Coefficient (mrem/pCi)	Version 2014 Inhalation Dose Coefficient (mrem/pCi)	% Diff	Version 2013 External Dose Coefficient (mrem-m^2/pCi-h)	Version 2014 External Dose Coefficient (mrem-m^2/pCi-h)	% Diff
34	Se-79	7.45E-14	7.45E-14	0	1.73E-05	1.73E-05	0	6.22E-06	6.22E-06	0	1.93E-13	1.93E-13	0
35	Br-83	8.02E-05	8.02E-05	0	2.21E-07	2.21E-07	0	2.23E-07	2.23E-07	0	3.84E-10	3.84E-10	0
35	Br-84	3.63E-04	3.63E-04	0	4.37E-07	4.37E-07	0	1.71E-07	1.71E-07	0	2.20E-08	2.20E-08	0
37	Rb-86	4.30E-07	4.30E-07	0	1.41E-05	1.41E-05	0	1.95E-05	1.95E-05	0	2.20E-09	2.20E-09	0
37	Rb-87	4.46E-19	4.46E-19	0	7.59E-06	7.59E-06	0	6.22E-05	6.22E-05	0	1.05E-12	1.05E-12	0
37	Rb-88	6.50E-04	6.50E-04	0	4.51E-07	4.51E-07	0	1.23E-07	1.23E-07	0	9.96E-09	9.96E-09	0
37	Rb-89	7.63E-04	7.63E-04	0	2.20E-07	2.20E-07	0	9.77E-08	9.77E-08	0	2.82E-08	2.82E-08	0
38	Sr-89	1.59E-07	1.59E-07	0	1.34E-05	1.34E-05	0	2.53E-05	2.53E-05	0	9.16E-10	9.16E-10	0
38	Sr-90	7.63E-10	7.63E-10	0	1.33E-04	1.33E-04	0	1.45E-04	1.45E-04	0	2.18E-11	2.18E-11	0
38	Sr-91	2.00E-05	2.00E-05	0	3.13E-06	3.13E-06	0	1.64E-06	1.64E-06	0	9.79E-09	9.79E-09	0
38	Sr-92	7.24E-05	7.24E-05	0	2.01E-06	2.01E-06	0	9.25E-07	9.25E-07	0	1.63E-08	1.63E-08	0
39	Y-90	3.00E-06	3.00E-06	0	1.37E-05	1.37E-05	0	6.55E-06	6.55E-06	0	1.47E-09	1.47E-09	0
39	Y-91	1.37E-07	1.37E-07	0	1.21E-05	1.21E-05	0	3.67E-05	3.67E-05	0	9.90E-10	9.90E-10	0
39	Y-91m	2.32E-04	2.32E-04	0	5.40E-08	5.40E-08	0	4.92E-08	4.92E-08	0	6.77E-09	6.77E-09	0
39	Y-92	5.44E-05	5.44E-05	0	2.51E-06	2.51E-06	0	7.96E-07	7.96E-07	0	5.10E-09	5.10E-09	0
39	Y-93	1.89E-05	1.89E-05	0	5.92E-06	5.92E-06	0	1.92E-06	1.92E-06	0	2.89E-09	2.89E-09	0
40	Zr-93	1.44E-14	1.44E-14	0	3.70E-06	3.70E-06	0	3.34E-05	3.34E-05	0	0.00E+00	0.00E+00	0
40	Zr-95	1.25E-07	1.25E-07	0	4.66E-06	4.66E-06	0	1.96E-05	1.96E-05	0	9.27E-09	9.27E-09	0
40	Zr-97	1.15E-05	1.15E-05	0	1.04E-05	1.04E-05	0	4.07E-06	4.07E-06	0	1.22E-08	1.22E-08	0
41	Nb-95	2.29E-07	2.29E-07	0	2.78E-06	2.78E-06	0	6.07E-06	6.07E-06	0	9.67E-09	9.67E-09	0
41	Nb-97	1.60E-04	1.60E-04	0	3.40E-07	3.40E-07	0	1.87E-07	1.87E-07	0	9.08E-09	9.08E-09	0
42	Mo-99	2.92E-06	2.92E-06	0	2.86E-06	2.86E-06	0	3.81E-06	3.81E-06	0	2.36E-09	2.36E-09	0
43	Tc-99m	3.20E-05	3.20E-05	0	1.08E-07	1.08E-07	0	8.29E-08	8.29E-08	0	1.52E-09	1.52E-09	0
43	Tc-99	1.04E-13	1.04E-13	0	3.33E-06	3.33E-06	0	1.64E-05	1.64E-05	0	8.72E-13	8.72E-13	0

Atomic Number	Nuclide	Version 2013 Decay (1/s)	Version 2014 Decay (1/s)	% Diff	Version 2013 Ingestion Dose Coefficient (mrem/pCi)	Version 2014 Ingestion Dose Coefficient (mrem/pCi)	% Diff	Version 2013 Inhalation Dose Coefficient (mrem/pCi)	Version 2014 Inhalation Dose Coefficient (mrem/pCi)	% Diff	Version 2013 External Dose Coefficient (mrem-m^2/pCi-h)	Version 2014 External Dose Coefficient (mrem-m^2/pCi-h)	% Diff
43	Tc-101	8.14E-04	8.14E-04	0	9.25E-08	9.25E-08	0	5.18E-08	5.18E-08	0	4.88E-09	4.88E-09	0
44	Ru-103	2.04E-07	2.04E-07	0	3.48E-06	3.48E-06	0	9.66E-06	9.66E-06	0	6.31E-09	6.31E-09	0
44	Ru-105	4.34E-05	4.34E-05	0	1.39E-06	1.39E-06	0	8.07E-07	8.07E-07	0	9.96E-09	9.96E-09	0
44	Ru-106	2.15E-08	2.15E-08	0	3.55E-05	3.55E-05	0	1.15E-04	1.15E-04	0	0.00E+00	0.00E+00	0
45	Rh-105	5.45E-06	5.45E-06	0	1.86E-06	1.86E-06	0	1.49E-06	1.49E-06	0	9.83E-10	9.83E-10	0
45	Rh-106m	8.82E-05	8.82E-05	0	8.07E-07	8.07E-07	0	4.88E-07	4.88E-07	0	3.58E-08	3.58E-08	0
46	Pd-109	1.41E-05	1.41E-05	0	2.85E-06	2.85E-06	0	1.63E-06	1.63E-06	0	4.96E-10	4.96E-10	0
47	Ag-110m	3.21E-08	3.21E-08	0	1.31E-05	1.31E-05	0	3.21E-05	3.21E-05	0	3.45E-08	3.45E-08	0
50	Sn-123	6.21E-08	6.21E-08	0	1.08E-05	1.08E-05	0	5.25E-05	5.25E-05	0	8.72E-10	8.72E-10	0
50	Sn-126	9.55E-14	9.55E-14	0	2.36E-05	2.36E-05	0	6.14E-04	6.14E-04	0	6.42E-10	6.42E-10	0
51	Sb-122	2.95E-06	2.95E-06	0	8.55E-06	8.55E-06	0	4.51E-06	4.51E-06	0	6.50E-09	6.50E-09	0
51	Sb-124	1.33E-07	1.33E-07	0	1.25E-05	1.25E-05	0	2.65E-05	2.65E-05	0	2.30E-08	2.30E-08	0
51	Sb-125	7.96E-09	7.96E-09	0	5.44E-06	5.44E-06	0	1.97E-05	1.97E-05	0	5.51E-09	5.51E-09	0
51	Sb-126m	6.03E-04	6.03E-04	0	1.85E-07	1.85E-07	0	8.51E-08	8.51E-08	0	2.06E-08	2.06E-08	0
51	Sb-126	6.50E-07	6.50E-07	0	1.29E-05	1.29E-05	0	1.31E-05	1.31E-05	0	3.53E-08	3.53E-08	0
52	Te-125m	1.40E-07	1.40E-07	0	4.51E-06	4.51E-06	0	1.37E-05	1.37E-05	0	3.57E-10	3.57E-10	0
52	Te-127m	7.36E-08	7.36E-08	0	1.26E-05	1.26E-05	0	3.05E-05	3.05E-05	0	1.14E-10	1.14E-10	0
52	Te-127	2.06E-05	2.06E-05	0	8.51E-07	8.51E-07	0	5.59E-07	5.59E-07	0	1.40E-10	1.40E-10	0
52	Te-129m	2.39E-07	2.39E-07	0	1.57E-05	1.57E-05	0	2.69E-05	2.69E-05	0	7.77E-10	7.77E-10	0
52	Te-129	1.66E-04	1.66E-04	0	3.15E-07	3.15E-07	0	1.61E-07	1.61E-07	0	1.55E-09	1.55E-09	0
52	Te-131m	6.42E-06	6.42E-06	0	9.95E-06	9.95E-06	0	4.63E-06	4.63E-06	0	1.81E-08	1.81E-08	0
52	Te-131	4.62E-04	4.62E-04	0	4.48E-07	4.48E-07	0	1.25E-07	1.25E-07	0	6.29E-09	6.29E-09	0
52	Te-132	2.50E-06	2.50E-06	0	1.98E-05	1.98E-05	0	9.18E-06	9.18E-06	0	2.84E-09	2.84E-09	0
52	Te-134	2.76E-04	2.76E-04	0	4.92E-07	4.92E-07	0	2.80E-07	2.80E-07	0	1.10E-08	1.10E-08	0

Atomic Number	Nuclide	Version 2013 Decay (1/s)	Version 2014 Decay (1/s)	% Diff	Version 2013 Ingestion Dose Coefficient (mrem/pCi)	Version 2014 Ingestion Dose Coefficient (mrem/pCi)	% Diff	Version 2013 Inhalation Dose Coefficient (mrem/pCi)	Version 2014 Inhalation Dose Coefficient (mrem/pCi)	% Diff	Version 2013 External Dose Coefficient (mrem-m^2/pCi-h)	Version 2014 External Dose Coefficient (mrem-m^2/pCi-h)	% Diff
53	I-129	1.40E-15	1.40E-15	0	4.48E-04	4.48E-04	0	4.00E-04	4.00E-04	0	2.65E-10	2.65E-10	0
53	I-131	1.00E-06	1.00E-06	0	1.16E-04	1.16E-04	0	9.66E-05	9.66E-05	0	4.86E-09	4.86E-09	0
53	I-132	8.39E-05	8.39E-05	0	1.50E-06	1.50E-06	0	1.43E-06	1.43E-06	0	2.90E-08	2.90E-08	0
53	I-133	9.26E-06	9.26E-06	0	2.44E-05	2.44E-05	0	2.03E-05	2.03E-05	0	8.29E-09	8.29E-09	0
53	I-134	2.20E-04	2.20E-04	0	5.07E-07	5.07E-07	0	5.99E-07	5.99E-07	0	3.32E-08	3.32E-08	0
53	I-135	2.93E-05	2.93E-05	0	4.85E-06	4.85E-06	0	4.29E-06	4.29E-06	0	1.96E-08	1.96E-08	0
55	Cs-134	1.06E-08	1.06E-08	0	6.92E-05	6.92E-05	0	2.43E-05	2.43E-05	0	1.97E-08	1.97E-08	0
55	Cs-135	9.55E-15	9.55E-15	0	9.77E-06	9.77E-06	0	3.38E-06	3.38E-06	0	6.74E-13	6.74E-13	0
55	Cs-137	7.28E-10	7.28E-10	0	4.92E-05	4.92E-05	0	1.70E-05	1.70E-05	0	4.17E-11	4.17E-11	0
55	Cs-138	3.46E-04	3.46E-04	0	4.74E-07	4.74E-07	0	1.16E-07	1.16E-07	0	3.01E-08	3.01E-08	0
56	Ba-139	1.39E-04	1.39E-04	0	6.07E-07	6.07E-07	0	2.48E-07	2.48E-07	0	1.98E-09	1.98E-09	0
56	Ba-140	6.29E-07	6.29E-07	0	1.34E-05	1.34E-05	0	2.11E-05	2.11E-05	0	2.54E-09	2.54E-09	0
56	Ba-141	6.32E-04	6.32E-04	0	3.64E-07	3.64E-07	0	1.47E-07	1.47E-07	0	1.29E-08	1.29E-08	0
56	Ba-142	1.09E-03	1.09E-03	0	1.65E-07	1.65E-07	0	9.07E-08	9.07E-08	0	1.35E-08	1.35E-08	0
57	La-140	4.78E-06	4.78E-06	0	9.88E-06	9.88E-06	0	5.00E-06	5.00E-06	0	2.86E-08	2.86E-08	0
57	La-141	4.91E-05	4.91E-05	0	1.89E-06	1.89E-06	0	7.14E-07	7.14E-07	0	1.86E-09	1.86E-09	0
57	La-142	1.27E-04	1.27E-04	0	8.55E-07	8.55E-07	0	3.96E-07	3.96E-07	0	2.88E-08	2.88E-08	0
58	Ce-141	2.47E-07	2.47E-07	0	3.62E-06	3.62E-06	0	1.31E-05	1.31E-05	0	9.28E-10	9.28E-10	0
58	Ce-143	5.83E-06	5.83E-06	0	5.70E-06	5.70E-06	0	3.27E-06	3.27E-06	0	3.98E-09	3.98E-09	0
58	Ce-144	2.82E-08	2.82E-08	0	2.68E-05	2.68E-05	0	1.50E-04	1.50E-04	0	2.30E-10	2.30E-10	0
59	Pr-144	6.69E-04	6.69E-04	0	2.52E-07	2.52E-07	0	8.07E-08	8.07E-08	0	2.14E-09	2.14E-09	0
61	Pm-147	8.37E-09	8.37E-09	0	1.34E-06	1.34E-06	0	2.95E-05	2.95E-05	0	3.74E-13	3.74E-13	0
61	Pm-148	1.49E-06	1.49E-06	0	1.36E-05	1.36E-05	0	9.29E-06	9.29E-06	0	8.14E-09	8.14E-09	0
61	Pm-151	6.78E-06	6.78E-06	0	3.69E-06	3.69E-06	0	2.05E-06	2.05E-06	0	4.33E-09	4.33E-09	0

Atomic Number	Nuclide	Version 2011 Decay (1/s)	Version 2013 Decay (1/s)	% Diff	Version 2011 Ingestion Dose Coefficient (mrem/pCi)	Version 2013 Ingestion Dose Coefficient (mrem/pCi)	% Diff	Version 2011 Inhalation Dose Coefficient (mrem/pCi)	Version 2013 Inhalation Dose Coefficient (mrem/pCi)	% Diff	Version 2011 External Dose Coefficient (mrem-m^2/pCi-h)	Version 2013 External Dose Coefficient (mrem-m^2/pCi-h)	% Diff
62	Sm-151	2.44E-10	2.44E-10	0	5.00E-07	5.00E-07	0	3.64E-05	3.64E-05	0	5.07E-14	5.07E-14	0
63	Eu-152	1.62E-09	1.62E-09	0	6.44E-06	6.44E-06	0	3.67E-04	3.67E-04	0	1.45E-08	1.45E-08	0
63	Eu-154	2.56E-09	2.56E-09	0	9.66E-06	9.66E-06	0	4.26E-04	4.26E-04	0	1.56E-08	1.56E-08	0
63	Eu-155	4.61E-09	4.61E-09	0	1.67E-06	1.67E-06	0	5.11E-05	5.11E-05	0	7.18E-10	7.18E-10	0
72	Hf-181	1.89E-07	1.89E-07	0	5.55E-06	5.55E-06	0	2.41E-05	2.41E-05	0	6.69E-09	6.69E-09	0
74	W-187	8.12E-06	8.12E-06	0	2.95E-06	2.95E-06	0	1.79E-06	1.79E-06	0	5.87E-09	5.87E-09	0
76	Os-185	8.57E-08	8.57E-08	0	2.35E-06	2.35E-06	0	6.40E-06	6.40E-06	0	8.71E-09	8.71E-09	0
88	Ra-224	2.19E-06	2.19E-06	0	4.66E-04	4.66E-04	0	1.19E-02	1.19E-02	0	1.28E-10	1.28E-10	0
88	Ra-228	3.82E-09	3.82E-09	0	5.92E-03	5.92E-03	0	1.14E-02	1.14E-02	0	9.78E-12	9.78E-12	0
90	Th-228	1.15E-08	1.15E-08	0	4.29E-04	4.29E-04	0	1.61E-01	1.61E-01	0	2.88E-11	2.88E-11	0
90	Th-230	2.91E-13	2.91E-13	0	9.36E-04	9.36E-04	0	5.44E-02	5.44E-02	0	8.54E-12	8.54E-12	0
90	Th-232	1.56E-18	1.56E-18	0	1.03E-03	1.03E-03	0	9.47E-02	9.47E-02	0	6.03E-12	6.03E-12	0
90	Th-234	3.33E-07	3.33E-07	0	1.73E-05	1.73E-05	0	3.18E-05	3.18E-05	0	1.09E-10	1.09E-10	0
91	Pa-233	2.97E-07	2.97E-07	0	4.88E-06	4.88E-06	0	1.69E-05	1.69E-05	0	2.69E-09	2.69E-09	0
92	U-232	3.19E-10	3.19E-10	0	1.49E-03	1.49E-03	0	3.19E-02	3.19E-02	0	9.72E-12	9.72E-12	0
92	U-233	1.38E-13	1.38E-13	0	2.23E-04	2.23E-04	0	1.44E-02	1.44E-02	0	6.34E-12	6.34E-12	0
92	U-234	8.93E-14	8.93E-14	0	2.15E-04	2.15E-04	0	1.41E-02	1.41E-02	0	7.73E-12	7.73E-12	0
92	U-235	3.12E-17	3.12E-17	0	2.03E-04	2.03E-04	0	1.25E-02	1.25E-02	0	1.98E-09	1.98E-09	0
92	U-236	9.39E-16	9.39E-16	0	2.02E-04	2.02E-04	0	1.29E-02	1.29E-02	0	6.42E-12	6.42E-12	0
92	U-237	1.19E-06	1.19E-06	0	3.92E-06	3.92E-06	0	6.81E-06	6.81E-06	0	1.64E-09	1.64E-09	0
92	U-238	4.91E-18	4.91E-18	0	1.94E-04	1.94E-04	0	1.16E-02	1.16E-02	0	5.21E-12	5.21E-12	0
93	Np-237	1.03E-14	1.03E-14	0	4.63E-04	4.63E-04	0	8.51E-02	8.51E-02	0	3.25E-10	3.25E-10	0
93	Np-238	3.79E-06	3.79E-06	0	4.44E-06	4.44E-06	0	8.29E-06	8.29E-06	0	7.50E-09	7.50E-09	0
93	Np-239	3.40E-06	3.40E-06	0	4.11E-06	4.11E-06	0	4.00E-06	4.00E-06	0	2.16E-09	2.16E-09	0

Atomic Number	Nuclide	Version 2011 Decay (1/s)	Version 2013 Decay (1/s)	% Diff	Version 2013 Ingestion Dose Coefficient (mrem/pCi)	Version 2014 Ingestion Dose Coefficient (mrem/pCi)	% Diff	Version 2011 Inhalation Dose Coefficient (mrem/pCi)	Version 2013 Inhalation Dose Coefficient (mrem/pCi)	% Diff	Version 2011 External Dose Coefficient (mrem-m^2/pCi-h)	Version 2013 External Dose Coefficient (mrem-m^2/pCi-h)	% Diff
94	Pu-238	2.50E-10	2.50E-10	0	9.73E-04	9.73E-04	0	1.72E-01	1.72E-01	0	7.98E-12	7.98E-12	0
94	Pu-239	9.11E-13	9.11E-13	0	1.07E-03	1.07E-03	0	1.86E-01	1.86E-01	0	4.08E-12	4.08E-12	0
94	Pu-240	3.35E-12	3.35E-12	0	1.07E-03	1.07E-03	0	1.86E-01	1.86E-01	0	7.57E-12	7.57E-12	0
94	Pu-241	1.53E-09	1.53E-09	0	1.93E-05	1.93E-05	0	3.31E-03	3.31E-03	0	1.90E-14	1.90E-14	0
94	Pu-242	5.86E-14	5.86E-14	0	1.01E-03	1.01E-03	0	1.77E-01	1.77E-01	0	7.41E-12	7.41E-12	0
95	Am-241	5.08E-11	5.08E-11	0	8.81E-04	8.81E-04	0	1.56E-01	1.56E-01	0	2.90E-10	2.90E-10	0
95	Am-243	2.98E-12	2.98E-12	0	8.73E-04	8.73E-04	0	1.54E-01	1.54E-01	0	6.61E-10	6.61E-10	0
96	Cm-242	4.93E-08	4.93E-08	0	7.10E-05	7.10E-05	0	2.12E-02	2.12E-02	0	8.90E-12	8.90E-12	0
96	Cm-243	7.55E-10	7.55E-10	0	6.66E-04	6.66E-04	0	1.20E-01	1.20E-01	0	1.57E-09	1.57E-09	0
96	Cm-244	1.21E-09	1.21E-09	0	5.59E-04	5.59E-04	0	1.01E-01	1.01E-01	0	7.79E-12	7.79E-12	0
96	Cm-246	4.61E-12	4.61E-12	0	8.92E-04	8.92E-04	0	1.58E-01	1.58E-01	0	5.15E-11	5.15E-11	0
96	Cm-248	6.31E-14	6.31E-14	0	3.34E-03	3.34E-03	0	5.55E-01	5.55E-01	0	1.67E-08	1.67E-08	0
98	Cf-252	8.30E-09	8.30E-09	0	5.59E-04	5.59E-04	0	8.33E-02	8.33E-02	0	5.75E-09	5.75E-09	0

Table B.2. Comparison of noble gas dose factors between version 2013 and 2014 for MAXDOSE-SR and POPDOSE-SR.

Atomic Number	Nuclide	Version 2013 mrem-m3/pCi y	Version 2014 mrem-m3/pCi y	% diff
18	Ar-41	7.18E-03	7.18E-03	0
36	Kr-83m	1.28E-07	1.28E-07	0
36	Kr-85m	8.00E-04	8.00E-04	0
36	Kr-85	2.81E-05	2.81E-05	0
36	Kr-87	4.64E-03	4.64E-03	0
36	Kr-88	1.13E-02	1.13E-02	0
36	Kr-89	1.12E-02	1.12E-02	0
54	Xe-131m	4.17E-05	4.17E-05	0
54	Xe-133m	1.51E-04	1.51E-04	0
54	Xe-133	1.60E-04	1.60E-04	0
54	Xe-135m	2.21E-03	2.21E-03	0
54	Xe-135	1.28E-03	1.28E-03	0
54	Xe-137	1.21E-03	1.21E-03	0
54	Xe-138	6.39E-03	6.39E-03	0

8.0 Appendix C. COMPARISON TO SER 2014 RESULTS

Table C.1. Comparison of total effective dose using the 2011 Site Environmental Report Source Terms for MAXDOSE-SR Versions 2013 and 2014

NUCLIDE	Version 2013 TED	Version 2014 TED	% diff	NUCLIDE	Version 2013 TED	Version 2014 TED	% diff
Ag-110M	1.01E-12	9.15E-01		Pu-241	1.80E-05	6.64E-01	
Am-241	7.00E-05	3.19E+01		Pu-242	5.83E-06	3.55E+01	
Am-243	1.22E-06	3.25E+01		Ra-228	6.67E-07	3.54E+01	
C-14	2.63E-06	2.49E-02		Ru-103	2.55E-07	3.26E-02	
Ce-141	1.14E-07	9.88E-03		Ru-106	5.63E-06	1.91E-01	
Ce-144	3.90E-06	1.44E-01		Sb-124	9.51E-07	1.71E-01	
Cm-244	1.93E-06	2.01E+01		Sb-125	9.48E-06	5.73E-01	
Co-60	1.50E-04	5.88E+00		Se-79	9.12E-11	3.48E-01	
Cs-134	6.85E-08	2.14E+00		Sm-151	1.95E-09	9.42E-03	
Cs-137	6.18E-03	8.07E+00		Sn-123	8.54E-14	1.73E-01	
Eu-152	8.70E-05	7.08E+00		Sn-126	6.59E-13	2.15E+00	
Eu-154	2.40E-04	4.90E+00		Sr-89	1.32E-12	4.32E-02	
Eu-155	8.90E-08	1.39E-01		Sr-90	2.73E-02	4.90E+00	
H-3	1.24E-01	5.46E-05		Tc-99	7.38E-04	2.97E+01	
I-129	2.02E-03	2.23E+01		Te-127	7.05E-17	1.00E-04	
I-131	6.77E-06	6.73E-01		Te-129	1.04E-18	2.55E-05	
Mn-54	2.22E-07	9.28E-03		Th-230	6.85E-11	1.42E+01	
Nb-95	7.19E-12	3.38E-01		U-232	3.87E-09	1.69E+01	
Ni-59	1.54E-08	3.81E-02		U-233	1.15E-06	4.46E+00	
Ni-63	2.47E-09	5.42E-03		U-234	8.29E-06	4.34E+00	
Np-237	4.09E-06	1.03E-02		U-235	9.58E-05	8.84E+00	
Np-239	3.54E-08	1.86E+01		U-236	8.21E-09	4.01E+00	
Pa-233	1.61E-09	1.47E-03		U-238	2.97E-06	3.72E+00	
Pm-147	2.54E-09	1.52E-02		Y-91	2.40E-12	4.05E-02	
Pr-144	5.18E-16	1.19E-02		Zn-65	9.29E-09	6.87E-01	
Pu-238	4.65E-04	4.54E-06		Zr-95	1.24E-09	7.27E-02	
Pu-239	2.77E-04	3.44E+01		Alpha	7.38E-05	3.73E+01	
Pu-240	7.58E-05	3.73E+01		Beta	1.61E-03	3.53E+00	
				Total	**1.63E-01**	**4.35E+02**	**192.67**

Table C.2. Comparison of effective dose equivalents using the 2011 Site Environmental Report Source Terms for POPDOSE-SR Versions 2013 and 2014

NUCLIDE	Version 2013 TED	Version 2014 TED	% diff	NUCLIDE	Version 2013 TED	Version 2014 TED	% diff
Ag110M	1.70E-11	1.63E+00		Pu241	3.12E-04	2.73E+00	
Am241	1.22E-03	1.30E+02		Pu242	1.01E-04	1.46E+02	
Am243	2.11E-05	1.30E+02		Ra228	1.65E-06	1.28E+01	
C 14	1.21E-05	2.07E-02		Ru103	3.80E-06	5.47E-02	
Ce141	1.26E-06	1.70E-02		Ru106	1.90E-05	1.13E-01	
Ce144	2.07E-05	1.45E-01		Sb124	1.44E-05	2.82E-01	
Cm244	3.36E-05	8.34E+01		Sb125	1.63E-04	1.05E+00	
Co 60	2.65E-03	1.10E+01		Se 79	2.86E-10	7.46E-02	
Cs134	9.23E-07	2.95E+00		Sm151	2.76E-08	3.04E-02	
Cs137	1.03E-01	1.44E+01		Sn123	4.64E-13	1.04E-01	
Eu152	1.56E-03	1.35E+01		Sn126	8.87E-12	3.63E+00	
Eu154	4.29E-03	9.42E+00		Sr 89	8.31E-12	3.63E-02	
Eu155	1.53E-06	2.75E-01		Sr 90	1.70E-01	3.16E+00	
H 3	1.72E+00	1.87E-04		Tc 99	1.40E-03	3.88E+00	
I 129	7.74E-03	6.56E+00		Te127	7.75E-16	1.82E-04	
I 131	4.72E-05	3.60E-01		Te129	4.80E-18	1.22E-06	
Mn 54	3.83E-06	6.20E-01		Th230	9.37E-10	4.52E+01	
Nb 95	1.18E-10	6.78E-02		U 232	3.19E-08	2.78E+01	
Ni 59	5.14E-08	1.95E-03		U 233	1.48E-05	1.21E+01	
Ni 63	6.39E-09	2.86E-03		U 234	1.08E-04	1.19E+01	
Np237	6.98E-05	7.19E+01		U 235	1.42E-03	1.98E+01	
Np239	5.05E-07	3.63E-03		U 236	1.05E-07	1.09E+01	
Pa233	2.11E-08	2.81E-02		U 238	3.73E-05	9.80E+00	
Pm147	2.34E-08	2.49E-02		Y 91	1.67E-11	4.46E-02	
Pr144	2.03E-14	2.77E-08		Zn 65	6.94E-08	4.73E-01	
Pu238	8.10E-03	1.42E+02		Zr 95	1.93E-08	1.27E-01	
Pu239	4.81E-03	1.54E+02		Alpha	1.28E-03	1.54E+02	
Pu240	1.32E-03	1.54E+02		Beta/Gamma	3.07E-03	5.50E-01	
				Total	**2.03E+00**	**1.39E+03**	**172.89**

9.0 Appendix D. MAXDOSE and POPDOSE Test Cases

Table D.1. Comparison of test cases for MAXDOSE-SR Version 2013 and 2014

MAXDOSE Test Case 1			
Pathway	**Version 2013 mrem/y**	**Version 2014 mrem/y**	**% Difference**
Plume	7.13E-05	1.26E-04	76.72
Ground	7.70E+00	7.50E+00	-2.60
Inhalation	1.05E+00	2.00E+00	90.48
Vegetation	1.85E+00	1.80E+00	-2.70
Cow Milk	3.06E-01	2.98E-01	-2.61
Meat	1.98E-01	1.93E-01	-2.53
Total	1.11E+01	1.18E+01	6.19
MAXDOSE Test Case 2			
Plume	5.93E-06	5.35E-06	-9.78
Ground	3.05E-01	2.34E-01	-23.28
Inhalation	1.09E-01	1.66E-01	52.29
Vegetation	2.30E-02	1.76E-02	-23.48
Cow Milk	3.22E-03	2.47E-03	-23.29
Meat	3.10E-03	2.38E-03	-23.23
Total	4.43E-01	4.22E-01	-4.71
MAXDOSE Test Case 3			
Plume	3.97E-06	6.09E-06	53.40
Ground	2.03E-01	2.04E-01	0.49
Inhalation	6.13E-02	1.28E-01	108.81
Vegetation	2.39E-02	2.39E-02	0.00
Cow Milk	1.46E-02	1.46E-02	0.00
Meat	4.01E-03	4.02E-03	0.25
Total	3.07E-01	3.75E-01	22.07
MAXDOSE Test Case 4			
Plume	1.58E-06	2.24E-06	41.77
Ground	3.19E-03	3.50E-03	9.72
Inhalation	3.45E-02	6.29E-02	82.32
Vegetation	1.26E-02	1.38E-02	9.52
Cow Milk	8.28E-03	9.11E-03	10.02
Meat	2.27E-03	2.50E-03	10.13
Total	6.08E-02	9.18E-02	50.90
MAXDOSE Test Case 5			
Plume	6.24E-04	1.09E-03	74.68
Ground	3.37E-01	3.10E-01	-8.01
Inhalation	7.13E+00	1.29E+01	80.93
Vegetation	1.33E+00	1.23E+00	-7.52
Cow Milk	8.75E-01	8.07E-01	-7.77
Meat	2.41E-01	2.22E-01	-7.88
Total	9.91E+00	1.55E+01	56.05

MAXDOSE Test Case 6			
Pathway	**Version 2013 mrem/y**	**Version 2014 mrem/y**	**% Difference**
Plume	5.15E-06	5.78E-06	12.23
Ground	4.79E-01	3.01E-01	-37.16
Inhalation	9.85E-02	1.09E-01	10.66
Vegetation	1.27E-01	7.99E-02	-37.09
Cow Milk	2.27E-02	1.43E-02	-37.00
Meat	1.58E-02	9.90E-03	-37.34
Total	7.43E-01	5.14E-01	-30.81
MAXDOSE Test Case 7			
Plume	1.92E-06	2.41E-06	25.52
Ground	2.70E-01	1.11E-01	-58.89
Inhalation	5.51E-02	7.47E-02	35.57
Vegetation	2.25E-02	9.27E-03	-58.80
Cow Milk	3.42E-03	1.41E-03	-58.77
Meat	3.51E-03	1.44E-03	-58.97
Total	3.55E-01	1.98E-01	-44.20
MAXDOSE Test Case 8			
Plume	5.58E-06	6.56E-06	17.56
Ground	2.73E-01	2.00E-01	-26.74
Inhalation	1.16E-01	1.78E-01	53.45
Vegetation	1.02E-01	7.49E-02	-26.57
Cow Milk	7.40E-02	5.43E-02	-26.62
Meat	1.36E-02	9.99E-03	-26.54
Total	5.79E-01	5.17E-01	-10.61
MAXDOSE Test Case 9			
Plume	3.36E-06	4.88E-06	45.24
Ground	1.06E+00	1.10E+00	3.77
Inhalation	2.20E-01	4.52E-01	105.45
Vegetation	3.08E-01	3.19E-01	3.57
Cow Milk	4.88E-02	5.05E-02	3.48
Meat	2.78E-02	2.88E-02	3.60
Total	1.66E+00	1.95E+00	17.16

Table D.2. Comparison of test cases for POPDOSE-SR Version 2013 and 2014

POPDOSE Test Case 1			
Pathway	**Version 2013 mrem/y**	**Version 2014 mrem/y**	**% Difference**
Plume	3.82E-05	3.39E-05	-11.26
Ground	1.91E-01	1.72E-01	-9.95
Inhalation	6.03E+00	1.32E+01	118.91
Vegetation	9.96E-02	8.64E-02	-13.25
Cow Milk	1.72E-01	1.34E-01	-22.09
Meat	5.19E-02	4.31E-02	-16.96
Total	6.54E+00	1.36E+01	108.35
POPDOSE Test Case 2			
Plume	4.22E-05	3.71E-05	-12.09
Ground	6.56E+00	6.60E+00	0.61
Inhalation	3.95E+00	7.04E+00	78.23
Vegetation	1.03E-01	1.07E-01	3.88
Cow Milk	1.73E-01	1.70E-01	-1.73
Meat	5.43E-02	5.48E-02	0.92
Total	1.08E+01	1.40E+01	28.89
POPDOSE Test Case 3			
Plume	3.48E-05	3.37E-05	-3.16
Ground	1.10E+01	1.11E+01	0.91
Inhalation	4.03E+00	7.27E+00	80.40
Vegetation	1.13E-01	1.18E-01	4.42
Cow Milk	1.86E-01	1.83E-01	-1.61
Meat	5.61E-02	5.65E-02	0.71
Total	1.54E+01	1.87E+01	21.72
POPDOSE Test Case 4			
Plume	2.56E-05	2.44E-05	-4.69
Ground	1.07E+01	1.08E+01	0.93
Inhalation	3.36E+00	6.66E+00	98.21
Vegetation	1.38E-01	1.42E-01	2.90
Cow Milk	2.05E-01	2.02E-01	-1.46
Meat	5.84E-02	5.88E-02	0.68
Total	1.45E+01	1.79E+01	23.52
POPDOSE Test Case 5			
Plume	1.94E-05	1.30E-05	-32.99
Ground	6.43E+00	6.45E+00	0.31
Inhalation	5.11E+00	9.63E+00	88.45
Vegetation	1.03E-01	1.08E-01	4.85
Cow Milk	1.73E-01	1.72E-01	-0.58
Meat	5.50E-02	5.57E-02	1.27
Total	1.19E+01	1.64E+01	38.28

POPDOSE Test Case 6			
Pathway	**Version 2013 mrem/y**	**Version 2014 mrem/y**	**% Difference**
Plume	2.37E-05	1.67E-05	-29.54
Ground	1.15E+01	8.76E+00	-23.83
Inhalation	5.47E+00	1.06E+01	93.78
Vegetation	1.37E-01	1.11E-01	-18.98
Cow Milk	1.86E-01	1.41E-01	-24.19
Meat	5.60E-02	4.38E-02	-21.79
Total	1.73E+01	1.97E+01	13.30
POPDOSE Test Case 7			
Plume	1.14E-04	1.69E-04	48.25
Ground	2.52E-01	1.83E-01	-27.38
Inhalation	4.59E+00	9.25E+00	101.53
Vegetation	8.97E-02	6.38E-02	-28.87
Cow Milk	1.59E-01	1.09E-01	-31.45
Meat	4.79E-02	3.34E-02	-30.27
Total	5.14E+00	9.64E+00	87.58
POPDOSE Test Case 8			
Plume	2.54E-05	2.44E-05	-3.94
Ground	1.06E+01	1.08E+01	1.89
Inhalation	4.69E+00	1.03E+01	119.62
Vegetation	1.11E-01	1.15E-01	3.60
Cow Milk	1.57E-01	1.54E-01	-1.91
Meat	5.66E-02	5.73E-02	1.24
Total	1.56E+01	2.14E+01	37.22

MAXDOSE-SR AND POPDOSE-SR: ROUTINE-RELEASE ATMOSPHERIC DOSE MODELS USED AT SRS

Distribution List

G. R. Whitney, 730–B
G. T. Jannik, 999-W
K. L. Dixon, 773-42A
J. J. Mayer, 999-W
EDG Records, 999-W