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Atmospheric Data Package for the 2004 Composite Analysis

B. A. Napier
J. V. Ramsdell, Jr.

April 2004

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Richland, Washington 99352

Summary

A composite analysis is required by U.S. Department of Energy (DOE) Order 435.1 to ensure public safety through the management of active and planned low-level radioactive waste disposal facilities associated with the Hanford Site. The original Hanford Site Composite Analysis of 1998 must be revised and submitted to DOE Headquarters (DOE-HQ) in 2004 because of revisions to waste site information in the 100, 200, and 300 Areas, updated performance assessments and environmental impact statements (EIS), changes in inventory estimates for key sites and constituents, and a change in the definition of offsite receptors.

Beginning in fiscal year (FY) 2003, the DOE Richland Operations Office (DOE-RL) initiated activities, including the development of data packages, to support the 2004 Composite Analysis. This report describes the data compiled in FY2003 to support atmospheric modeling for the 2004 Composite Analysis. This work was conducted as part of the Characterization of Systems Task of the Groundwater Remediation Project (formerly the Groundwater Protection Program) managed by Fluor Hanford, Inc., Richland, Washington.

The purpose of this data package is to summarize our conceptual understanding of atmospheric transport and deposition, describe how this understanding will be simplified for numerical simulation as part of the 2004 Composite Analysis (i.e., implementation model), and finally to provide the input parameters needed for the simulations.

Contents

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1.0   Introduction

A composite analysis is required by U.S. Department of Energy (DOE) Order 435.1 to ensure public safety through the management of active and planned low-level radioactive waste disposal facilities associated with the Hanford Site (DOE M 435.1-1). The original Composite Analysis detailed in Kincaid et al. (1998) must be revised and submitted to DOE Headquarters (DOE-HQ) in 2004 because of revisions to waste site information in the 100, 200, and 300 Areas, updated performance assessments and environmental impact statements (EIS), changes in inventory estimates for key sites and constituents, and a change in the definition of offsite receptors.

Kincaid, Bryce, and Buck (2004) describe the technical scope of the 2004 Composite Analysis for the Hanford Site and the approach to perform this analysis. It will be a site-wide analysis, considering final remedial actions for the Columbia River corridor and the Central Plateau, and will be a companion site-wide assessment to waste-specific and site-specific assessments. The 2004 Composite Analysis also will provide supporting information on a regional or site-wide basis for use in important Hanford assessments and decisions such as the CERCLA 5-year review in 2005, tank closure decisions, decisions on final groundwater remedies for the 200 Areas, decisions on final groundwater remedies for the 100 Areas, and the Columbia River corridor final record of decision.

Beginning in fiscal year (FY) 2003, the DOE Richland Operations Office (DOE-RL) initiated activities, including the development of data packages, to support the 2004 Composite Analysis. This report describes the data compiled in FY2003 to support atmospheric modeling for the 2004 Composite Analysis. This work was conducted as part of the Characterization of Systems Task of the Groundwater Remediation Project (formerly the Groundwater Protection Program) managed by Fluor Hanford, Inc., Richland, Washington.

The purpose of this data package is to summarize our conceptual understanding of atmospheric transport and deposition, describe how this understanding will be simplified for numerical simulation as part of the 2004 Composite Analysis (i.e., implementation model), and finally to provide the input parameters needed for the simulations.

The general approach for this work was to extract data and interpreted information from existing documents and databases. Every attempt was made to provide traceability back to the original source(s) of the data or interpretations.

2.0   Background

The atmospheric transport and deposition model selected for implementation in the System Assessment Capability (SAC Rev. 1) is named RATCHET (Ramsdell et al. 1994). An adaptation of RATCHET, named RATCHET2, was prepared.

RATCHET2 is a Lagrangian trajectory, Gaussian puff atmospheric dispersion model that includes deposition and depletion. The code was originally developed for the Hanford Environmental Dose Reconstruction Project (HEDR). For HEDR, it used hourly meteorological and iodine-131 release data to estimate daily exposures (time-integrated concentrations) and surface contamination over an area of approximately 195,000 km^2 (75,000 mi^2) in eastern Washington, eastern Oregon, and northern Idaho. For SAC, RATCHET2 has been modified to estimate normalized annual exposures and surface contamination over an area of approximately 9,100 km^2 (3,500 mi^2) that includes the Hanford Site and adjacent land. Meteorological data for the SAC Rev. 1 calculations consist of hourly observations made at 28 stations from 1983 through 2003. These data, which typically include wind direction and speed, temperature, precipitation, and an indicator of atmospheric stability, are used to derive the spatially and temporally varying meteorological fields needed by RATCHET2. Ground-level and elevated release points can be placed at appropriate locations on the Hanford Site, and exposures and surface contamination are estimated at more than 2100 locations on a 41 x 53 Cartesian grid that has 2 km spacing.

Gaussian models are used to describe the atmospheric dispersion of radioactive and chemical effluents from nuclear facilities. These models have frequently been used in licensing and emergency response calculations [e.g., PAVAN (Bander 1982), XOQDOQ (Sagendorf et al. 1982), MESORAD (Scherpelz et al.1986; Ramsdell et al. 1988), and RASCAL Version 2.0 (Athey et al. 1993; McGuire et al. 2003)], because they quickly provide reasonable estimates of atmospheric concentrations, deposition, and doses given relatively limited information on topography and meteorology. A Lagrangian-trajectory Gaussian puff model is used where temporal or spatial variations in meteorological conditions or depletion of the plume due to dry deposition may be significant.

3.0   Theoretical Bases for Gaussian Models

The derivation of the Gaussian models used to describe atmospheric dispersion is discussed in many texts. Various texts including Slade (1968), Csanady (1973), Randerson (1984), and Seinfeld (1986) provide the bases for the following discussion. They may be consulted where additional detail is desired.

Atmospheric dispersion is governed, in part, by a differential equation called the diffusion equation. With a set of assumptions that can reasonably be applied to atmospheric processes, the diffusion equation has a specific, closed-form algebraic solution that is Gaussian. In one dimension, the solution is

$$\chi(x)/Q = \frac{1}{(2\pi)^{1/2}\sigma} \exp\left[-\frac{1}{2}\left(\frac{x-x_o}{\sigma}\right)^2\right] \tag{3.1}$$

where $\chi(x)$ = concentration at a distance x from the center of the concentration distribution, x_o
   Q = amount of material released
   σ = dispersion parameter

Atmospheric dispersion parameters are functions of either distance from the release point or time since release. They may also be functions of atmospheric stability and surface roughness. Numerous atmospheric dispersion experiments have been conducted to evaluate dispersion parameters and to develop methods to predict dispersion-parameter values from readily available data. A number of these experiments are described by Draxler (1984).

The one-dimensional solution of the diffusion equation can be expanded to three dimensions using the principle of superposition to get the basic Gaussian puff model. In a Cartesian coordinate system with x and y axes in a horizontal plane and z in the vertical, the normalized concentration in the vicinity of the puff is

$$\chi(x,y,z)/Q = \frac{1}{(2\pi)^{3/2}\sigma_x\sigma_y\sigma_2} \exp\left[-\frac{1}{2}\left(\frac{x-x_o}{\sigma_2}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{y-y_o}{\sigma_y}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{z-z_o}{\sigma_z}\right)^2\right] \tag{3.2}$$

This equation, when combined with a transport mechanism to move the center of the puff (x_o, y_o, z_o), is a simplified version of the puff model in RATCHET2. The dispersion parameters are shown as functions of direction from the puff center. However, in most implementations of the puff model, the puff is assumed to be symmetrical in the x and y directions. Hence, x and y may be replaced by the horizontal distance r from the center of the puff.

The form of Eq. (3.1) shown is appropriate if the height of the center of the puff is such that vertical dispersion proceeds unimpeded either by the ground or by an elevated layer of the atmosphere. Unimpeded vertical dispersion is generally not the case. Typically, the earth's surface and the top of the atmospheric mixing layer are assumed to be reflective surfaces. When these assumptions are made, the vertical exponential term

$$\exp\left[-\frac{1}{2}\left(\frac{z-z_o}{\sigma_z}\right)^2\right]$$ (3.3)

is replaced by a sum of exponential terms that account for reflection. This sum is

$$\sum_{n=-\infty}^{\infty}\left\{\exp\left[-\frac{1}{2}\left(\frac{2nH-h-z}{\sigma_2}\right)\right]^2+\exp\left[-\frac{1}{2}\left(\frac{2nH+h-z}{\sigma_2}\right)\right]^2\right\}$$ (3.4)

where   H = the height of the top of the mixing layer
        h = the release height

   In practice, only a small number of terms need be considered. In RATCHET2, as in MESORAD (Scherpelz et al. 1986; Ramsdell et al. 1988) and RASCAL (McGuire et al. 2003), the summation is carried out from n = -2 to 2. This term can be simplified if one or more of H, h, or z equals zero. For example if H is large compared to σ_z and z is zero, the summation may be replaced by

$$2\exp\left[-\frac{1}{2}\left(\frac{h}{\sigma_2}\right)^2\right]$$ (3.5)

   At long down-wind distances where the vertical dispersion parameter is the same magnitude as the mixing layer thickness, the puff model can be further simplified by assuming that material is uniformly distributed in the vertical. With this last assumption, the puff model becomes

$$\chi(r)/Q=\frac{1}{2\pi\sigma_r^2 H}\exp\left[-\frac{1}{2}\left(\frac{r}{\sigma_r}\right)^2\right]$$ (3.6)

where H is the mixing layer thickness. RATCHET2 switches to the uniformly mixed model when $\sigma_z >$ 1.05H.

   The Gaussian puff model behaves well in calm winds. If the dispersion parameters are a function of time, as they are in many models, the material in the puff continues to disperse even though it isn't moving. If, as in RATCHET2, the dispersion parameters are calculated as the function of travel distance, dispersion ceases during calm winds, and the material distribution remains unchanged as long as the wind is calm. In either case, deposition, depletion, exposures, and doses are calculated just as they are during windy conditions.

   The calculational domain consists of a square Cartesian grid with receptor nodes uniformly spaced throughout the domain.

RATCHET2 explicitly accounts for transit time in all calculations because the model tracks the movement of individual puffs and calculates concentrations and doses based on puff positions. Decay and ingrowth of radionuclides and depletion of the puffs as a result of wet and dry deposition are calculated at 5-minute intervals.

Neither the wind data nor the wind fields are modified to force the centers of puffs to pass directly over the receptor nodes. As time goes by and atmospheric conditions (wind direction, wind speed, stability, mixing layer thickness, and precipitation) change, Gaussian puff models will give realistic concentration and dose patterns. In addition, puff models will give more realistic concentration and dose patterns than plume models when topography modifies the winds because the wind fields may be modified to account for topography.

The movement of puffs is controlled by the wind at the center of the puff as it moves through the model domain. The spatial variation of winds is represented by two-dimensional fields of vectors that give the direction and speed of puff movement. These fields are prepared by the meteorological model and are updated at 15-minute intervals based on the available wind data.

Calculation of puff movement is a six-step process. In sequence, the steps are

1. Make an initial estimate of the direction and speed of the puff movement given the current puff position and height above ground using bilinear interpolation (Press et al. 1986) of the vectors at the nearest nodes of the field.

2. Make an initial estimate of the puff position at the end of the period using the initial estimates of direction and speed.

3. Make a second estimate of the direction and speed of puff movement using the estimated puff position at the end of the period.

4. Make a second estimate of the puff position at the end of the period using the estimate of direction and speed from Step 3.

5. Average the end points calculated in Steps 2 and 4.

6. Calculate the final estimate of direction and speed of puff movement using the puff's initial position and the average end point calculated in Step 5.

The actual puff movement for the period may take place in one or several steps. The step size is adjusted to ensure adequate accuracy in the integration of concentrations that takes place at receptors. Errors in the integration should be less than 5% at typical wind speeds.

The vector fields prepared by the meteorological program are for a height of 10 m above ground. These vectors are used for puffs that represent ground-level releases. If the actual release height is greater than 12 m, a wind-speed profile is used to adjust the transport speed from 10 m to the puff transport height. The profile used to adjust the wind speed considers both surface friction and atmospheric stability (see Panofsky and Dutton 1984, Sections 6.4 and 6.6).

3.3

4.0   Dispersion Parameters

The horizontal dispersion parameters (σ_y and σ_r) used in the dispersion model are based on the results of a large number of dispersion experiments conducted in the 1950s and 1960s. The experiments, which were conducted over relatively flat terrain, typically involved tracer releases ranging from about 10 minutes to 1 hour in duration with ground-level concentration measurements at distances ranging from 100 m to several kilometers. Only a few direct measurements of vertical dispersion parameters (σ_z) were made. Consequently, vertical dispersion parameters have been estimated with dispersion models using measured values of the horizontal dispersion parameter and measured concentrations. Dispersion parameters have been summarized in many forms. Perhaps the best known summary is the set of dispersion parameter curves called the Pasquill and Gifford curves (Gifford 1976).

Regulatory guidance published by the U.S. Nuclear Regulatory Commission (NRC) includes graphic depiction of these curves, and numerical approximations to the curves are included in many computer codes used by the NRC. In RATCHET2, dispersion parameters are estimated using the same basic algorithms that were used in RASCAL (McGuire et al. 2003) and are used in other NRC codes including PAVAN (Bander 1982) and XOQDOQ (Sagendorf et al. 1982). These parameterizations have generally been attributed to Eimutis and Konicek (1972). However, the σ_y parameterization is properly attributed to Tadmor and Gur (1969), and the σ_z parameterization is properly attributed to Martin and Tikvart (1968).

The basic dispersion parameter relationships are

$$\sigma_y(x) = a_y x^{0.9031} \tag{4.1}$$

and

$$\sigma_z(x) = a_z(x) \cdot x^{b_z(x)} + c_z(x) \tag{4.2}$$

where   x = the distance from the release point, in meters
                a_y = a function of stability class
a_z, b_z, and c_z = functions of stability class and distance

Table 4.1 gives values for a_y, a_z, b_z, and c_z. Note that 0.9031, a_y, a_z, b_z and c_z are empirical constants evaluated by fitting curves. Of these constants, 0.9031 and b_z are dimensionless; c_z has dimensions of meters; and a_y and a_z have dimensions of $m^{(1.0-0.9031)}$ and $m^{(1-b_x)}$, respectively.

The mixing layer thickness is included in all dispersion calculations. The thickness is passed to the atmospheric dispersion program in the meteorological data files. The thickness may be estimated from meteorological data and surface roughness; it may be estimated from climatological data; or it may be entered directly.

Table 4.1.   **Constant Values for Calculation of Atmospheric Dispersion Parameters**

	Distance Range (m)	Stability Class						
		A	B	C	D	E	F	G
a_y	all x	0.3658	0.2751	0.2089	0.1471	0.1046	0.0722	0.0481
a_z	x < 100 m	0.192	0.156	0.116	0.079	0.063	0.053	0.032
	100 m < x < 1000 m	0.00066	0.0382	0.113	0.222	0.211	0.086	0.052
	1000 m < x	0.00024	0.055	0.113	1.26	6.73	18.05	10.83
b_z	x < 100 m	0.936	0.922	0.905	0.881	0.871	0.814	0.814
	100 m < x < 1000 m	1.941	1.149	0.911	0.725	0.678	0.74	0.74
	1000 m < x	2.094	1.098	0.911	0.516	0.305	0.18	0.18
c_z	x < 100 m	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	100 m < x <1000 m	9.27	3.3	0.0	-1.7	-1.3	-0.35	-0.21
	1000 m < x	-9.6	2.0	0.0	-13.0	-34.0	-48.6	-29.2

4.1   Deposition

RATCHET2 calculates deposition for iodine and particles using the dry and wet deposition models used in MESORAD (Scherpelz et al. 1986; Ramsdell et al. 1988) and RASCAL (McGuire et al. 2003). The activity deposited each time step is the product of the total deposition rate and the time-step duration. At any time, the surface contamination (activity/m^2) is the sum of the activity deposited in the current time step plus previously deposited activity.

The dry deposition rate is calculated using a constant deposition velocity of 0.003 m/s (0.3 cm/s). This deposition velocity is used because data summarized by Sehmel (1984) indicate that it is a reasonable value for iodine assuming that about one-third of the iodine in the atmosphere is associated with particles, another one-third is in the from of reactive gases (e.g., I$_2$ or HI) and the remaining one-third is in the form of nonreactive gases (e.g., CH$_3$I). A deposition velocity of 0.003 m/s is slightly high for 1 µm particles. The dry deposition rate is given by

$$\omega'_d = -v_d \chi \tag{4.3}$$

where ω'_d = the deposition rate in (activity/m^2)/s
         v_d = the dry deposition velocity

The wet deposition rate is calculated using a washout model. In the washout model, the wet deposition rate is

$$\omega'_w = -\lambda_p \int_0^\infty \chi \, dz \tag{4.4}$$

where λ_p is a washout coefficient that is a function of the precipitation type. The washout coefficients are listed in Table 4.2. These coefficients are based on analyses of experimental data by Engelmann (1968). The units for the washout coefficients are converted to s^{-1} for use in the model. Hanna et al. (1982) and Slinn (1984) point out that the washout model is appropriate only for monodisperse aerosols and highly reactive gases.

The total deposition rate at any point is the sum of the dry and wet deposition rates at that point. The total deposition rate is a function of position only because the concentration in the plume is a function of position. The total deposition rate is a function of position because the concentration varies in space and meteorological conditions may vary in space. The total deposition rate is a function of time at a point because both the concentration and precipitation may change with time.

RATCHET2 calculates and stores deposition by radionuclide for all radionuclides except noble gases. Noble gases are assumed not to deposit.

Table 4.2.   Wash-out Coefficients[a]

Precipitation Type	Wash-out Coefficient (h^{-1})
1 (light rain)	0.79
2 (moderate rain)	2.2
3 (heavy rain)	4.0
4 (light snow)	0.36
5 (moderate snow)	1.2
6 (heavy snow)	2.3
(a) Source - Engelmann 1968.	

4.2   Depletion

RATCHET2 maintains a mass balance. Material deposited on the surface by wet and dry deposition is removed from the puff by decreasing the total mass of the puff. The approach used is a variation of the source-depletion model described in Hanna et al. (1982). The mass removed from each puff is determined by analytical integration of the deposition flux over the area of the puff and the computational interval. During periods of precipitation, the additional rate of mass loss from a puff by washout of particles is determined by integrating the washout rate over the area covered by the puff, which is equal to the product of the mass in the puff and the washout coefficient. RATCHET2 computes depletion at the end of each time step.

4.3   Meteorological Data

The following information is needed for each meteorological station:

- A station identification. The station identification can be any 10 letter character; the release site identification (ID) is appropriate for the first station in the station list; Federal Aviation Administration (FAA) or International Civil Aviation Organization (ICAO) location indicators are appropriate for national weather service or other stations that have them.

- The latitude (positive north of the equator and negative south of the equator) and longitude (positive east of the prime meridian and negative west of the prime meridian) of the station in decimal degrees.

- The elevation of the station (m). The elevation should be the height of the station above mean sea level.

- The surface roughness for the station (m). Meteorological texts such as Panofsky and Dutton (1984) and Stull (1988) provide guidance on estimating surface roughness. If no other information is available, a surface roughness of 0.2 m may be used.

- The height at which the wind measurements are made (m). The instrument height should be height above ground level.

Station meteorological data are entered for specific dates and times. The data may be actual observations (measurements) or they may be taken from meteorological forecasts. If available, the following data should be entered for each station:

- Surface-level wind direction and speed

- Estimated atmospheric stability

- Precipitation class

- Estimated mixing height

All of these data are used in the transport, diffusion, and deposition calculations. In addition, the following data should be entered for the first station (center of the grid):

- Ambient air temperature

- Pressure (station)

- Humidity measurement (dew point temperature, relatively humidity, or wet bulb temperature)

The air temperature is used in plume rise calculations.

4.4   Calculating Spatially Varying Meteorological Conditions

RATCHET2 takes into account both spatial and temporal variations in the atmospheric conditions. The following subsections describe the preparation of the fields from the station data.

Winds. RATCHET2 uses wind fields to calculate movement of puffs. These are fields of U (east-west) and V (north-south) components of the wind vector. The wind fields are created from station wind data using a $1/r^2$ interpolation scheme, where r is the distance from the grid point to the station. This interpolation scheme, which was used in earlier NRC codes such as MESOI (Ramsdell et al. 1983) and MESORAD (Scherpelz et al. 1986; Ramsdell et al. 1988), is common in spatial interpolation of the wind fields (Hanna et al. 1982).

Adjustment of Wind Fields for Topography. If the meteorological stations reporting data are well placed with respect to major topographic features, the wind fields developed by interpolation will give reasonable puff trajectories. However, with one meteorological station or a small number of stations, the wind fields may not properly reflect the effects of topography.

Stability and Precipitation. The stability class and precipitation fields (precipitation class and precipitation rate) are based on data for the closest meteorological station. Fields created in this manner include stability class, inverse Monin-Obukhov length, precipitation class, and precipitation rate. This procedure avoids averaging that would minimize the effects of extreme stability or instability. It also provides maximum detail in treating isolated precipitation events.

Mixing Height. Estimates of station mixing height are not considered particularly reliable. Therefore, the spatial variation of the mixing height is modeled using two steps. The initial step is to create a mixing height field using the mixing height for the closest station for each point in the field. If there is only one station the process is terminated after this step. The second step is taken when there are two or more stations. In this step, the mixing height at each point in the field is replaced by an average of the initial mixing height and the mixing heights at 24 surrounding points. This second step smooths the mixing height field.

4.5   Data Requirements

The files used in the Atmospheric Transport Module are listed in Table 4.3. The individual components of each type of file are discussed in the following subsections.

Table 4.3.   Atmospheric Transport Module Files

File	Contents	Notes
met.file	File containing one year of Hanford meteorological data	Data file created by RATCHET2 user – used for all simulations
station.file	File containing meteorological station data	Data file created by RATCHET2 user – used for all simulations
sfc_roughness.file	File containing surface roughness data	Data file created by RATCHET2 user – used for all simulations

Meteorological Files. The meteorological data include hourly measurements of:

- Surface-level wind direction and speed

- Estimated atmospheric stability

- Precipitation class

- Estimated mixing height

All of these data are used in the transport, diffusion, and deposition calculations. In addition, the following data are entered for the first station:

- Ambient air temperature

- Pressure (station)

- Humidity measurement (dew point temperature, relatively humidity, or wet bulb temperature)

All of these data were retrieved from the database at the Hanford Meteorological Station. Data were assembled from the database of the Hanford Meteorological Station and the surrounding grid of the Hanford reporting network for the years 1983 through 2002. These hourly data were formatted for the RACHET2 input requirements, and the completeness and acceptability of each year's data file was tested and verified.

Station Files. The locations of the meteorological data sources, and their dates of operation are listed in Table 4.4. In Table 4.4, the station at Wahluke moved to Beverly in 1991 and the station at Sage moved to the 200 West Area Plutonium Finishing Plant in 1992. The data in this table is essentially that of the station file.

Surface Roughness. The surface roughness length is associated with small-scale topographic features. It arises as a constant of integration in the derivation of the wind profile equations and is used in several boundary-layer relationships. Texts on atmospheric diffusion, air pollution and boundary-layer meteorology (Panofsky and Dutton 1984; Stull 1988) contain tables that give approximate relationships between surface roughness and land use, vegetation type, and topographic roughness. For SAC Rev. 1, a data file was adapted from the HEDR application.

Table 4.4.   Details of Meteorological Stations Supplied to the Station File

Station Number	Site Name	Station Code	Latitude	Longitude	Height	Period of Operation
1	Hanford Meteorology Station	hms	46.563	119.599	15.2	01/82 - present
2	FFTF	fftf	46.43	119.36	9.1	01/82 - present
3	300 Area	300a	46.364	119.2856	9.1	01/82 - present
4	100-N Area	100n	46.689	119.551	9.1	01/82 - present
5	Prosser Barricade	Prosser	46.392	119.412	9.1	01/82 - present
6	EOC	eoc	46.392	119.537	9.1	01/82 - present
7	Army Loop Road	army	46.489	119.551	9.1	01/82 - present
8	Rattlesnake Springs	rspg	46.506	119.7	9.1	01/82 - present
9	Edna rail siding	edna	46.587	119.397	9.1	01/82 - present
10	200 East Area	200e	46.556	119.521	9.1	01/82 - present
11	200 West Area	200w	46.543	119.663	9.1	01/82 - present
12	Beverly	beverly	46.752	119.944	9.1	Wahluke thru 7/91, Beverly 8/91 - present
13	Yakima Barricade	yak	46.578	119.726	9.1	01/82 - present
14	Wye Barricade	wyeb	46.482	119.391	9.1	01/82 - present
15	Energy Northwest	wnp2	46.47	119.345	9.1	01/82 - present
16	Franklin County	franklin	46.417	119.238	9.1	01/82 - present
17	Ringold	ringold	46.545	119.238	9.1	01/82 - present
18	Richland Airport	richland a	46.301	119.301	9.1	01/82 - present
19	Plutonium Finishing Plant	200W PFP	46.545	119.633	9.1	Sage thru 1994, PFP 3/94 - present
20	Tri-Cities Airport	pasco air	46.257	119.114	9.1	10/87 - present
21	Gable West	gable west	46.612	119.558	9.1	3/86 - present
22	100-F Area	100f	46.635	119.452	9.1	3/86 - present
23	Vernita Bridge	vernita	46.641	119.728	9.1	2/88 - present
24	Benton City	benton city	46.29	119.608	9.1	2/95 - present
25	Vista	Vista.	46.218	119.201	9.1	2/91 - present
26	Roosevelt, Washington	Roosevelt	45.744	120.218	9.1	9/94 - present
27	100-K Area	100k	46.657	119.578	9.1	3/96 - present
28	HAMMER	hammer	46.356	119.326	9.1	1/98 - present
19	Sage	sage	46.735	119.836	9.1	01/82 – 12/92
12	Wahluke	wahluke	46.656	119.299	9.1	01/82 – 7/91

5.0 History Matching/Validation with Krypton-85 Monitoring Data

Processing of reactor fuel is accompanied by the release of noble gas fission products, including krypton-85. The last processing of reactor fuel at Hanford occurred in the PUREX Plant in the 200 East Area intermittently from December 1983 through November 1987. Annual krypton-85 releases at Hanford for this period were reported in annual environmental reports. The total release for PUREX for the period was approximately 1.7 MCi. Krypton-85 activity released from other locations was signify-cantly lower (~47 kCi) than the PUREX releases. The 1984 through 1987 krypton-85 releases were chosen for use in evaluation of RATCHET2, because the PUREX Plant was the dominant source during this period and the Surface Environmental Surveillance Project measured krypton-85 concentrations at a number of locations on and near the Hanford Site. Krypton data for 1983 were not included because the releases were not distributed through-out the year. For RATCHET2 evaluation for SAC Rev 1, the releases were assumed to take place at a constant release rate from a 61-m stack in a nominal flow of about 9.4 m^3/s at a temperature of about 25°C.

The Surface Environmental Surveillance Project collected air samples at a number of locations on site, near the boundary of the Hanford site, and off site during the period of interest. Twelve of the locations were within, or sufficiently close to, the RATCHET2 domain to provide measured concentration for comparison with model estimates. Of these locations, three were within 3 km of the PUREX stack, five were between 18 and 25 km from the stack, and the remaining four locations were between 38 and 45 km from the stack. One location at 25 km occasionally had two monitors running simultaneously. The air samples typically covered 28 day periods, with a range from 14 days to 42 days. Average concentrations for each period were determined by counting the activity in the samples; typical counting errors were 10 to 15 percent. However, the monitoring was not continuous at any location. Consequently, annual average concentrations were estimated using a weighted average of the available data for comparison with concentrations predicted by RATCHET2. Ultimately, there were 41 usable estimates of annual concentrations at the 12 locations.

RATCHET2 generally predicts the annual concentrations well ($r^2 = 0.81$), although the model has a bias to slightly over-predict concentrations (geometric mean ratio between the predicted and measured concentrations = 1.26 with a geometric standard deviation of 1.7). Model errors were greatest for the 3 monitoring locations near PUREX, where the concentrations and concentration gradients are highest. Farther from PUREX, RATCHET2 predicted 28 of 33 concentrations within a factor of 2 and all 33 concentrations within a factor of 3. Neither the krypton-85 releases nor the monitoring were continuous. Thus, estimation of annual concentrations from the monitoring data is a source of uncertainty. However, it does not appear to have contributed to the differences between concentrations predicted by RATCHET2 and those estimated from monitoring data in a systematic manner.

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