GPU NUCLEAR

CALCULATION COVER SHEET

Subject:	Calculation No.	Revision Number
SNEC Facility DCGL Values for Volumetric Contamination	6900-02-008	1

DESCRIPTION OF REVISION

	Signature	Date
Originator	B. Brosey/ B. Brosey	9/16/02
Reviewer	J.P. Donnachie/ J.P. Donnachie	9/17/02
Additional Reviewer		
Additional Reviewer		
Additional Reviewer		
Management Approval	AF Payne	9/18/02

GPU NUCLEAR

Calculation Sheet

Subject	Calculation No.	Rev. No.	Sheet No.
SNEC Facility DCGL Values for Volumetric Contamination	6900-02-008	1	1 of 25
Originator Barry H. Brosey	**Date** September 16, 2002	**Reviewed by** Pat Donnachie	**Date** 9/17/02

1.0 PROBLEM STATEMENT

The purpose of this calculation is to determine SNEC Facility Derived Concentration Guideline Levels (DCGLs) for volumetric contamination and their associated Area Factors (AF). These calculated DCGL values are determined using the dose modeling computer code RESRAD, version 6.1. The code offers a probabilistic calculation option which was used as a step to develop input to a deterministic analysis. These values were developed using a surface model that applies to the upper 1 meter of surface materials at the site.

This calculation supercedes revision 0 of the previous calculation with the same number.

2.0 SUMMARY OF RESULTS

2.1 Table 1 presents a summary of the DCGL values.

Table 1 - SNEC Site DCGLw Values for Surface Materials

SNEC Upper 1 Meter of Soil - DCGL's				
			Limits in pCi/g for:	
Radionuclide	Peak Dose per pCi/g @ Time t (in years)		25 mrem/y TEDE	4 mrem/y DW
Am-241	9.70E-01	mrem/yr @t= 0	25.7	
Am-241 DW	1.93E-02	mrem/yr @t= 1062 ±2		207
C-14	9.30E-01	mrem/yr @t= 0	26.8	
C-14 DW	8.87E-03	mrem/yr @t= 1.504 ±0.003		450
Co-60	7.13E+00	mrem/yr @t= 0	3.5	
Co-60 DW	5.62E-11	mrem/yr @t= 114.8 ±0.2		7.1E+10
Cs-137	3.74E+00	mrem/yr @t= 0	6.6	
Cs-137 DW	2.32E-17	mrem/yr @t= 1189 ±2		1.7E+17
Eu-152	2.46E+00	mrem/yr @t= 0	10.1	
Eu-152 DW	2.18E-15	mrem/yr @t= 1037 ±2		1.8E+15
H-3	3.87E-02	mrem/yr @t= 0	645	
H-3 DW	1.43E-02	mrem/yr @t= 0.913 ±0.002		279
Ni-63	3.34E-02	mrem/yr @t= 0	747	
Ni-63 DW	2.07E-08	mrem/yr @t= 661 ±1		1.9E+08
Pu-238	8.28E-01	mrem/yr @t= 0	30.1	
Pu-238 DW	1.70E-01	mrem/yr @t= 200.4 ±0.4		23.5
Pu-239	3.63E+00	mrem/yr @t= 642 ±1	6.8	
Pu-239 DW	2.83E+00	mrem/yr @t= 556 ±1		1.4
Pu-241	2.89E-02	mrem/yr @t= 54.9 ±0.1	866	
Pu-241 DW	8.33E-04	mrem/yr @t= 950 ±2		4803
Sr-90	2.05E+01	mrem/yr @t= 0	1.2	
Sr-90 DW	5.03E-01	mrem/yr @t= 36.49 ±0.07		7.9

NOTE: Specific Activity Limit (SAL) for Cs & Eu is 8.70E+13 pCi/g & 1.75E+14 pCi/g respectively.

2.2 **Attachment 1-1** presents a summary of the Area Factors developed for the above listed DCGL values.

3.0 REFERENCES

3.1 SNEC Site Characterization Report, GPU Nuclear, 1996.

3.2 "Summary for RESRAD Parameter Inputs (Revision 1), Dated October 18, 2001, from Haley & Aldrich, Incorporated of 150 Mineral Spring Drive, Dover, New Jersey (Underground Engineering & Environmental Solutions), 07801-1635 to J. Patrick Donnachie of GPU Nuclear.

3.3 ANL/EAIS-8, "Data Collection handbook to Support Modeling the Impacts of Radioactive Material in Soil", Environmental Assessment and Information Sciences Division, Argonne National Laboratory, US DOE, April 1993.

3.4 Argonne National Laboratory Report, "K_d Study of Site Soils and Construction Debris from the SNEC Decommissioning Project", February 2002.

3.5 URS Corporation, "Sub-Surface DCGLs for the Saxton Nuclear Experimental Corporation Site – Calculation Package", 756 East Winchester Street, Suite 400, Salt Lake City, UT 84107.

3.6 Microsoft Excel 97, Microsoft Corporation Inc., SR-2, 1985-1997.

4.0 ASSUMPTIONS AND BASIC DATA

4.1 While Cs-137 is the predominant radionuclide present at the SNEC Facility produced during plant operation, other radionuclides of lower concentration have been detected. This calculation determines applicable guideline levels (DCGL) for the eleven (11) radionuclides shown in the following Table.

TABLE 2 - Radionuclides Present at the SNEC Facility

Am-241	C-14	Co-60	Cs-137	Eu-152	H-3
Ni-63	Pu-238	Pu-239	Pu-241	Sr-90	

NOTE: Table 2 radionuclides have been positively detected in samples from the SNEC Facility as reported in the SNEC "Site Characterization Report"(Reference 3.1)

4.2 Input for the RESRAD dose modeling computer code requires numerous groundwater hydrology and geological parameters. Many of these parameters have been determined by Haley & Aldrich, Inc., (Reference 3.2). The summary report from Haley & Aldrich includes the latest groundwater hydrology and geological information for the SNEC site. This information has been used as input to the RESRAD code. The Haley & Aldrich summary report is **Attachment 2-1** of this calculation.

4.3 Argonne National Laboratories (ANL) was contracted by GPU Nuclear to determine distribution coefficients (K_d) for soils and construction debris from the SNEC Facility site. K_d values are the ratio of the mass of the solute species absorbed or precipitated on the solids per unit of dry mass of the soil, S, to the solute concentration in the liquids, C (Reference 3.3). The values ANL has provided were for a group of sample types including construction debris and flyash as well as soils and bedrock from the site. The analysis results of the ANL study of SNEC site materials is shown in **Attachment 3-1.**

4.4 For purposes of this calculation only one set of K_d values were input into the RESRAD computer code. The K_d values selected were the lowest values determined for all data provided by ANL (Reference 3.4). for each element type (or representative element), regardless of the sample from which they came. The reason for the selection of the lowest reported K_d value was to allow GPU Nuclear to calculate DCGLs for each radionuclide that could then be used for any surface site location. Subsurface volumetric DCGL values were developed separately through a GPU contractor and are reported in Reference 3.5.

4.5 This calculation models SNEC site surface materials located within the upper 1 meter of soil layer. The model was assumed to be a 1 meter thick contaminated zone without cover. A basic 10,000 square meter contaminated area is assumed for the base site surface model. Basic RESRAD input parameters are included in **Attachment 4-1** through **4-3.**

4.6 Area factors are developed from the surface modeling parameters. In the base case model the contaminated fraction of plant, meat and milk products is assumed to be equal to one (1) using the resident farmer scenario. Default values of –1 are substituted for these three variables for area sizes less than 10,000 square meters. The three default parameters (-1) appropriately size the contaminated fractions of plants, meat and milk obtained from the site when smaller and smaller area sizes are input into the REARAD computer code.

4.7 The most sensitive RESRAD input parameters have been determined using the probabilistic analysis feature of the RESRAD computer code. These parameters are listed on a per nuclide basis, in the accompanying data book titled, "Upper 1 Meter Surface Material DCGLs" (**Attachment 6-1**). In addition, all RESRAD reports and the computer files are included on the computer file storage CD provided with the data book.

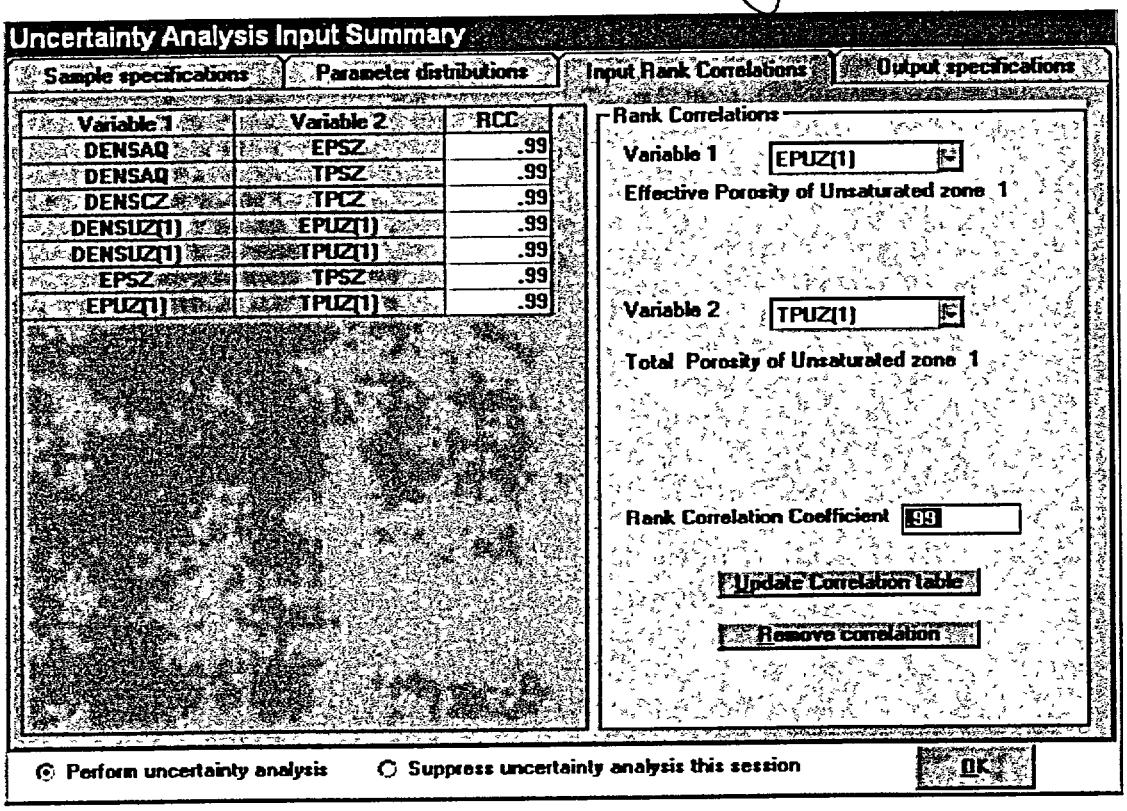
4.8 The logic flow for the RESRAD input parameters is included in **Attachment 5-1** and **5-2.**

4.9 K_d values were included in the RESRAD probabilistic analysis. H-3 and C-14 K_d values were included in the probabilistic analysis. However, since ANL determined that the most likely values for these K_ds were near 1 in either case, a limiting range for these K_ds was assigned. This range was postulated to be 0 to 0.5 for ^{3}H and 0 to 5 for ^{14}C. The results of the deterministic analysis are conservatively bounded by the use of these K_d value ranges.

4.10 Area Factor development was performed using the deterministic RESRAD option. As discussed previously, a default value of –1 was substituted for the contamination fractions for Plant, Meat & Milk food. This was done so that RESRAD could scale smaller contaminated areas (10,000 m^2, 2,500 m^2, 400 m^2, 100 m^2, 25 m^2 and 1 m^2).

4.11 In addition to computer runs for Area Factors and the 25 mrem/y dose limit, a drinking water RESRAD run was also performed for each radionuclide using only the drinking water option from the pathways options listing. However, a probabilistic analysis was performed for each drinking water analysis prior to running the deterministic analysis in order to determine the sensitive parameters. Once the sensitive parameters were developed, these values were inserted into the deterministic cases for each radionuclide.

4.12 Correlated values for each probabilistic run are shown in the following graphic file.



4.13 The individual computer file names provided in the included CD are listed below for Am-241. All other radionuclide files have the same format:

- NEW AM241.RAD = 25 mrem/y TEDE, 10,000 m^2 area dose
- NEW AM241 DW.RAD = 4 mrem/y drinking water, 10,000 m^2 area dose
- NEW AM241A.RAD = 25 mrem/y TEDE, 2500 m^2 area dose
- NEW AM241B.RAD = 25 mrem/y TEDE, 400 m^2 area dose
- NEW AM241C.RAD = 25 mrem/y TEDE, 100 m^2 area dose
- NEW AM241D.RAD = 25 mrem/y TEDE, 25 m^2 area dose
- NEW AM241E.RAD = 25 mrem/y TEDE, 1 m^2 area dose

4.14 The complete probabilistic output files for all radionuclides are contained in the included CD computer disk.

4.15 The complete deterministic output files for all radionuclides are contained in the included CD computer disk.

5.0 CALCULATIONS

5.1 All calculations are performed using an Excel spreadsheet or are internal to the RESRAD 6.1 computer code. A "Read Only" CD ROM is provided with this calculation containing all RESRAD computer generated input & output files (see **Attachment 6-1**).

6.0 LIST OF ATTACHMENTS

6.1 Attachment 1-1, Summary Table of RESRAD Area Factor output results.

6.2 Attachment 2- to 2-13, Haley & Aldrich communication (Reference 3.2).

6.3 Attachments 3-1, Summary Table of ANL provided K_d values (Reference 3.3).

6.4 Attachment 4-1 and 4-3, RESRAD input values for probabilistic & deterministic analysis.

6.5 Attachment 5-1 and 5-2, Logic chart for developing the dose modeling DCGL values.

6.6 Attachment 6-1, addendum entitled "Upper 1 Meter Surface Material DCGLs", in a loose leaf binder that includes the RESRAD computer files on a CD.

Table 5-15

Area Factors (AF) For Open Land Areas

Based on 25 mrem/y TEDE and Upper 1 Meter Volumetric Surface Modeling

File Names ⇒	NEW XXXXX.RAD*		NEW XXXXXA.RAD		NEW XXXXXB.RAD		NEW XXXXXC.RAD		NEW XXXXXD.RAD		NEW XXXXXE.RAD	
AREA ⇒	10000 m^2		2500 m^2		400 m^2		100 m^2		25 m^2		1 m^2	
Radionuclides	Base DCGL	AF	Implied DCGL EMC	AF	Implied DCGL EMC	AF	Implied DCGL EMC	AF	Implied DCGL EMC	AF	Implied DCGL EMC	AF
Am-241	25.7	1.0	47.7	1.9	110.1	4.3	321.7	12.5	699.1	27.2	3005	116.9
C-14	26.8	1.0	151.1	5.6	984.8	36.7	2.69E+03	100.2	7206	268.9	1.79E+05	6682.8
Co-60	3.5	1.0	4.4	1.3	4.9	1.4	5.4	1.6	7.0	2.0	43.4	12.4
Cs-137	6.6	1.0	14.9	2.3	19.9	3.0	23.8	3.6	31.1	4.7	189.3	28.7
Eu-152	10.1	1.0	10.5	1.0	11.1	1.1	12.1	1.2	15.5	1.5	94.3	9.3
H-3	645	1.0	1.47E+03	2.3	3.23E+03	5.0	7.87E+03	12.2	1.78E+04	27.6	3.55E+05	550.2
Ni-63	747	1.0	3.66E+03	4.9	1.29E+04	17.2	5.14E+04	68.8	2.05E+05	275	5.07E+06	6789.8
Pu-238	30.1	1.0	57.7	1.9	142.9	4.7	408.2	13.6	694.4	23.1	1.08E+04	358.8
Pu-239	6.8	1.0	11.9	1.7	26.9	4.0	56.4	8.3	114.8	16.9	1374	202.1
Pu-241	866	1.0	1607	1.9	3713	4.3	1.09E+04	12.6	2.39E+04	27.6	1.02E+05	118.1
Sr-90	1.2	1.0	3.6	3.0	9.8	8.1	38.5	32.1	146.7	122.3	2826	2355

* Where "XXXXX" is the radionuclide computer file name, as an example "Am241".

NOTE 1: Base case DCGLs (in pCi/g) are for 10,000 square meter surface model only.

NOTE 2: The above set of DCGL values are used only to determine the Area Factors (AF) that will then be applied to the values listed in Table 5-1 (surface materials only).

NOTE 3: When AF values are calculated in the RESRAD computer code, the settings for contaminated fractions for plant food, meat and milk must be re-set to their default condition (-1) in order to allow the computer code to scale the food supply for the size of the areas appropriately.

ATTACHMENT 1.1

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18 October 2001
File No. 74683-000

GPU Nuclear, Inc.
Route 441 South
Post Office Box 480
Middletown, PA 17057-0480

Attention: Mr. J. Patrick Donnachie

Subject: Summary for RESRAD Parameters Inputs (Revision 1)

Dear Mr. Donnachie:

As we discussed, the attached document presents the summary for an updated version of RESRAD (Revision 1) containing revised inputs which were identified in our 12 September 2001 report.

The primary reason for the revisions is that recent supplemental field investigations provided site-specific information. These recent reports which were a follow-up to these field investigations are noted in Section I of the attachment while the recommended inputs for RESRAD are incorporated into Section II.

Figure 1, which accompanied our 12 September 2001 is also attached and replaces Figure 1 that was included with the initial RESRAD parameter inputs.

Figure 1 provides a generalized sketch of subsurface conditions. In the center column, subsurface materials are identified (labeled geologic), while hydrogeologic and RESRAD considerations are presented in the left and right columns respectively. Regarding specific inputs to RESRAD, in some instances revisions were made to total porosity, effective porosity, field capacity, hydraulic gradient, hydraulic conductivity and other related parameters.

In Figure 1, under the geologic heading, three subsurface materials are noted: Fill (A), Boulder layer (overburden) unit B and the Siltstone bedrock (C). The interface between the base of the boulder layer and the bedrock (B/C) is also characterized in our 12 September 2001 report.

Based on our 12 September 2001 report we recommended the following considerations for RESRAD. The Fill (A) unit is unsaturated throughout most of the hydrologic year and contains the contaminated zone. The Boulder layer (overburden) unit (B) a feature associated with the rivers depositional processes, is saturated, however, due to its low

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permeability serves as a hydraulic barrier to flow between the Fill and the underlying Siltstone bedrock. Regarding the saturated interface (B/C) between the Boulder layer (B) and the underlying saturated Siltstone bedrock (C) we recommend using inputs for the bedrock, since the aquifer testing results for hydraulic conductivity for both units are similar (the same order of magnitude). The saturated thickness of the bedrock is much thicker than the interface layer.

If you have any questions regarding Revision 1, please contact us.

Sincerely yours,
HALEY & ALDRICH, INC.

Charles R. Butts, P.G.

Enclosures

c: Mr. Art Paynter
Mr. Barry Brosey

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HALEY & ALDRICH

ATTACHMENT 2 - 2

The preceding cover letter dated October 18, 2001 provides a brief introduction and overview to this attachment (referred to as Revision 1). This revision contains some new inputs to RESRAD for the SNEC facility, based on the results of supplemental subsurface information from recent site investigations. Revisions have been made in some cases to total porosity, effective porosity, field capacity, hydraulic gradient and hydraulic conductivity and other related parameters.

RESRAD Input Parameters:

R013 Cover depth (m)
R013 Density of cover material (g/cm^3)
R013 Cover depth erosion rate (m/yr)
R013 Density of contaminated zone (g/cm^3)
R013 Contaminated zone erosion rate (m/yr)
R013 Contaminated zone total porosity
R013 Contaminated zone effective porosity
R013 Contaminated zone hydraulic conductivity (m/yr)
R013 Contaminated zone b parameter
R013 Average annual wind speed (m/sec)
R013 Humidity in air (g/m^3)
R013 Evapotranspiration coefficient
R013 Precipitation (m/yr)
R013 Irrigation (m/yr)
R013 Irrigation mode
R013 Runoff coefficient
R013 Watershed area for nearby stream or pond (m^2)

R014 Density of saturated zone (g/cm^3)
R014 Saturated zone total porosity
R014 Saturated zone effective porosity
R014 Saturated zone hydraulic conductivity (m/yr)
R014 Saturated zone hydraulic gradient
R014 Saturated zone b parameter
R014 Water table drop rate (m/yr)
R014 Well pump intake depth (m below water table)
R014 Model: nondispersion (ND) or Mass-balance (MB)
R014 Well pumping rate (m^3/yr)

R015 Number of unsaturated zone strata
R015 Unsaturated zone 1, thickness (m)
R015 Unsaturated zone 1, soil density (g/cm^3)
R015 Unsaturated zone 1, total porosity
R015 Unsaturated zone 1, effective porosity
R015 Unsaturated zone 1, soil-specific b parameter
R015 Unsaturated zone 1, hydraulic conductivity (m/yr)

- Contaminated Zone Thickness (m)
- Field Capacity

Section I - Background Information and Objectives for Site Investigations

Several investigations concerning subsurface conditions at the site have been undertaken since 1981. The following section provides a brief summary of the scope, objectives and results for these investigations that formed the basis for the initial RESRAD inputs. However, three additional Haley & Aldrich investigations (one geotechnical and two hydrogeologic reports dated May 1999, March 2001 and August 2001 respectively) provide additional site-specific information which is the basis for this revision (Revision 1). Revisions that were noted in the Haley & Aldrich 12 September 2001 report have been incorporated into Section II.

Groundwater Technology's, Inc. investigation (1981) provided the basic hydrogeologic framework for the site, serving as a guide for future groundwater monitoring. Monitoring well installations have occurred, since the initial investigation in 1981, in a staged approach, first by GEO Engineering (1992, and 1994) and by Haley & Aldrich (1998). Depending on the purpose for monitoring, wells were installed at several locations typically adjacent to site structures of interest. Monitoring wells were installed in both soil and bedrock.

The Preliminary Hydrological Investigation, Saxton Nuclear Station, Saxton, Pennsylvania. 1981 by GROUNDWATER TECHNOLOGY, INC. reviewed information obtained from the Pennsylvania State Geologist and the United States Geological Survey (Water Resource Branch). In conjunction with geologic reconnaissance, this provided the initial geologic interpretation for the Saxton site. Test borings located near the containment vessel (CV) and the radioactive waste disposal facility (RWDF) were installed to characterize the soils and bedrock and the groundwater in each media.

Results of investigation lead to following conclusions:

- The result of this investigation identified three distinct subsurface materials: fill, a boulder layer with silty clay matrix and bedrock (occurring in this order from ground surface when present).
- Field permeability tests were conducted in boreholes and soil laboratory mechanical analysis was performed on construction fill materials. Based on the field permeability testing, the highest permeability is at the boulder layer/bedrock interface.
- The boulder layer appears to act as a barrier to the flow of groundwater between the construction fill and the bedrock.
- Preliminary groundwater level observations in test borings indicate a hydraulic gradient of 10 to 15 feet of a distance of 600-800 feet from the site to the river.
- The combination of hydraulic gradient, bedrock permeability, and bedrock structure (bedding and fracture patterns) indicates that the groundwater has a potential to flow from the site to the river.

The main objective of the Phase I Report of Findings-Groundwater Investigation Saxton Nuclear Experimental Station, Saxton, Pennsylvania, 1992 GEO Engineering was the installation of 8 monitoring wells at locations near the CV and RWDF. The wells were screened (and sanded) across the top bedrock and boulder layer contact. This was an area identified in the 1981 investigation as an area of relatively higher permeability compared to its immediate surroundings. Other pertinent information follows:

- A relative elevation survey of each well using an arbitrary datum of 100.00 feet at GEO-1 was completed. Water level information from these eight wells was used to produce computer-generated contour maps of the groundwater surface. The resultant direction of

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groundwater flow (groundwater flowing perpendicular from locations with higher contour to those with lower elevations) is in a westerly direction towards the Raystown Branch of Juniata River.

- For the purpose of monitoring radionuclide contamination in groundwater, several wells were installed hydraulically downgradient of the CV and several other upgradient of this structure.
- The investigation confirmed the orientation of potential groundwater pathways in the bedrock (fractures and bedding)
- A recommendation was proposed for the installation of two groundwater monitoring wells in bedrock adjacent to the CV.

In 1994, two gas-actuated monitoring wells devices were installed into the bedrock near the CV as reported in GEO Engineering's, Summary of Field Work, 1994. These two devices were installed into the bedrock to a depth similar to the base of the CV. The devices were installed west and northwest of the CV, at approximately 25 degree angles, to facilitate the interception of groundwater flowing in the bedrock.

During this field activity a 50-foot observation well (GEO-9) was installed in bedrock making it possible to obtain water level elevation data from the bedrock unit. As part of this field activity, monitoring wells GEO-1 to GEO-8 were retrofitted with gas actuated samplers.

In The Report of Field Work by Haley & Aldrich (1998) two additional gas actuated groundwater monitoring devices were installed adjacent to the RWDF (to the depth of the sump) to investigate the potential presence of tritium in groundwater. Also, GEO-10 was installed at the bedrock /soil interface to supplement the existing monitoring wells. It was situated downgradient of GEO-5 to evaluate trace amounts of tritium detected in the groundwater at GEO-5.

Section II - Summary of Descriptions and Justifications for Individual Parameters

R013 Cover depth (m) – Physical Parameter
Based on information provided by GPU Nuclear, cover will not be placed over the area for which the modeling applies, and therefore, the cover depth was input as 0.0 meters.

R013 Density of cover material (g/cm^3) – Physical Parameter
Since the above-described parameter (cover depth) is input as 0.0, density of the cover material is not applicable and therefore not input into the RESRAD model.

R013 Cover depth erosion rate (m/yr) – Physical Parameter
Since the above-described parameter (cover depth) is input as 0.0, density of the cover material is not applicable and therefore not input into the RESRAD model.

R013 Density of contaminated zone (g/cm^3) – Physical Parameter
Based on information provided by GPU Nuclear regarding locations and depths of sampling points with radionuclide concentrations above background, the contaminated zone is located between approximately 0 and 1.0 meters, as shown on Figure 1. Based on subsurface investigations as described in Section I, the geologic stratigraphy at this depth is described as mixed soils, sandy or silty clay to well graded sand and gravel with rock fragments. Based on the May 1982 Department of Navy Naval Facilities Engineering Command (NAVFAC) DM-7.1 Manual, dry weight density for this type of material is in the range of 80 to 120 lb./ft^3 (or 1.28 to 1.92 g/cm^3). The range for dry weight as opposed to wet, or submerged

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weight, was used as the depth of soil contamination is unsaturated. The value input into the RESRAD model was 1.60 g/cm^3, the average of the above-stated range.

R013 Contaminated zone erosion rate (m/yr) - Physical Parameter
Based on the Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil (C. Yu, C. Loureiro, J. J. Cheng, L.G. Jones, Y.Y Wang, Y.P Chia, and E. Faillace, Environmental Assessment Division Argonne National Laboratory - www.ead.anl.gov) and assuming future use scenario as row-crop agriculture with an approximate 2% slope, the range of $9x10^{-5}$ to $6x10^{-4}$ to m/yr was used. The value input into the RESRAD model was $3.45x10^{-4}$ m/yr, the average of the above-stated range.

R013 Contaminated zone total porosity - Physical Parameter
Based on subsurface investigations as described in Section I, the geologic stratigraphy of the contaminated zone is described as mixed soils, sandy or silty clay to well graded sand and gravel with rock fragments. Referencing Maidment, Handbook of Hydrology (pp. 5.14), 1993, these soil types correspond to total porosity ranges of between 0.35 and 0.56. Total porosity is defined as the part of the soil volume that is void space. The recommended value input into the RESRAD model is 0.46, the average of the above-stated range.

R013 Contaminated zone effective porosity - Physical Parameter
The effective porosity range for the site was based on the soil types. Referencing Maidment, Handbook of Hydrology (pp. 5.14), 1993 expressed the effective porosity range of 0.28 to 0.54 based on the soil types found at the site. Effective porosity is defined as the percentage of inter-connected void space, and is applied to characterize soil. The recommended value input into the RESRAD model is 0.41, the average of the above-stated range. This value is not used by RESRAD 6.0.

R013 Contaminated zone hydraulic conductivity (m/yr) - Physical Parameter
Hydraulic conductivity values are based on the results of field tests, soil characterization, empirical relationships, published values and the experience of our expert consultant. Packer tests (rock pressure tests) were performed during the 1981 Preliminary Hydrogeologic Investigation in order to estimate the range in values for hydraulic conductivity of the bedrock below the site. The packer test involves pumping water under pressure into selected sections of an open borehole isolated using pneumatic packers. Packer tests indicated hydraulic conductivity of the bedrock to range between $1x10^{-3}$ cm/s to negligible flow.

In addition to packer testing for the 1981 report, sieve analyses were conducted on samples of the silty sand fill and ash fill. Initial estimates of hydraulic conductivity suggested a high of $1x10^{-6}$ cm/s for the fill.

Based on recent analyses for the purpose of the RESRAD modeling, data from the grain size distributions of the fill collected from the 1981 investigation were entered into several empirical relationships in order to refine the estimates of hydraulic conductivity. These empirical relationships relate median effective grain diameter (typically, the grain diameter which represents the 10% finer by weight on a grain size distribution) as well as other properties including sorting and porosity to hydraulic conductivity. The empirical relationships used have been shown to correspond well with field measured hydraulic conductivity (Vukovic, Milan and Soro, Andjelko, Determination of Hydraulic Conductivity of Porous Media from Grain-Size Composition, 1992).

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4
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The following presents one of the empirical equations as taken from Vukovic, Milan and Soro, Andjelko, Determination of Hydraulic Conductivity of Porous Media from Grain-Size Composition, 1992:

Slichter:

$$K = {}^{g}/_{v} * C_s * n^{3.287} * d_{10}^2$$

Where: K = hydraulic conductivity (cm/sec)
g = acceleration due to gravity: 980 cm/sec^2
v = kinematic viscosity of water [at 20 deg C]: 1.125×10^{-2}
C_s = constant: 1.0×10^{-2}
n = porosity
d_{10} = effective grain diameter

Hydraulic conductivity values for the fill generated through the empirical relationships using grain size data were somewhat higher than the estimates initially suggested in the 1981 Preliminary Hydrogeologic Investigation report. Specifically, the original report suggested hydraulic conductivity values ranging from 1×10^{-6} to 1×10^{-5} to cm/s (0.315 to 3.15 m/yr). However, recent evaluations of grain size data (soil samples S-1, S-2 from the 1981 Ground/Water Technology investigation and TB-1, similar to TB-3 from the Haley&Aldrich geotechnical investigation 1999) suggest hydraulic conductivity values ranging from 1×10^{-6} to 8×10^{-2} cm/s (3.62×10^{-1} to 2.54×10^{4} to m/yr), which is the range used in the RESRAD modeling. The recommended value input into the RESRAD model is 32.3 m/yr (1×10^{-4} cm/sec), the geometric mean of the above-stated range.

In addition to methods described above, hydraulic conductivity was qualitatively assessed given the experience of our expert consultant and based on their visual observation during installation of the soil borings and soil sample characterization. The values given above also correspond with published values for silts, sandy silts, and clayey sands (Applied Hydrogeology, Fetter, C.W., 1988).

R013 Contaminated zone b parameter - Physical Parameter

As described in the Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil (C. Yu, C. Loureiro, J.-J. Cheng, L.G. Jones, Y.Y Wang, Y.P Chia, and E. Faillace, Environmental Assessment Division Argonne National Laboratory - www.ead.anl.gov) the soil-specific exponential b parameter is an empirical and dimensionless parameter that is used to evaluate the saturation ratio (or the volumetric water saturation) of the soil. Published data based on laboratory testing indicate a range of the exponential b parameter is between 4.05 and 7.12. The RESRAD input for this parameter was based on the values corresponding from sand to loam in Table 13.1 of the Data Collection Handbook. The recommended value input into the RESRAD model is 5.6, the average of the above-stated range.

R013 Average annual wind speed (m/sec) - Physical Parameter

The input value for this parameter were based on data provided from the National Climatic Data Center (1999 Annual Summary Local Climatological Data for Pittsburgh, Pennsylvania). The RESRAD input reflects the minimum monthly mean wind speed (3.13 m/sec or 7.0 mph) and maximum monthly mean wind speed (4.83 m/sec or 10.8 mph) over a

42 year span. The value input into the RESRAD model is the annual mean wind speed based on 42 years of data of 4.07 m/sec (9.1 mph).

R013 Humidity in air (g/m^3) – Physical Parameter
The default value of 8.0 g/m^3 was used in the RESRAD model.

R013 Evapotranspiration coefficient – Physical Parameter
The value range for this input parameter was based primarily on guidance in the Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil, and was estimated through an iterative solution with other parameter values including precipitation, irrigation and runoff coefficient. The range was based on a runoff coefficient (C_r) range of 0.3 to 0.4; a precipitation range (P_r) of 0.688 to 1.327 m/yr; and an irrigation value (IR_r) of 0.2 (refer to individual parameter justifications, as described below). Using these values, an evapotranspiration rate (ET_r) was estimated (this value is not used implicitly in RESRAD, but is an intermediate step in calculating the evapotranspiration coefficient). Based on the Evaporation Atlas of the United States (NOAA, 1982), evaporation is estimated to be approximately half of the total (annual) precipitation for the Saxton, PA area. Given this, the evapotranspiration coefficient was estimated as follows:

$$C_e = \frac{ET_r}{(1 - C_r) * P_r + IR_r}$$

Calculated Range of C_e = 0.50 to 0.67 m/yr

The value input into the RESRAD model was 0.59, the average of the above-stated range.

R013 Precipitation (m/yr) – Physical Parameter
The input values for this parameter were based on data provided from the National Weather Service (1999 Annual Summary Local Climatological Data for Pittsburgh, Pennsylvania). The RESRAD input range reflects the 30 year minimum (0.688 m/yr or 27.09 inches/yr) and maximum (1.327 m/yr or 52.24 inches/yr) annual precipitation amounts. The value input into the RESRAD model was 0.936 m/yr (36.85 inches/yr), which is the 30 year annual precipitation average.

R013 Irrigation (m/yr) – Physical Parameter
Based on the agricultural use scenario, the default value for irrigation (0.2 m/yr) was input into the RESRAD model.

R013 Irrigation mode – Physical Parameter
It was assumed that the irrigation would be distributed overhead.

R013 Runoff coefficient – Physical Parameter
The input values for this parameter were based on data provided from two sources: U.S. Geological Survey Hydrologic Investigation Atlas HA-710 – Average Annual Runoff in the United States, 1951-1980; and Table 10.1 of the Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil. The RESRAD input range represents coefficient values corresponding to an agricultural environment comprised of flat to rolling land (slopes of 0.3 to 6.1 m/mi). The corresponding range for runoff coefficient is 0.3 to 0.4. The value input into the RESRAD model was 0.35, the average of the above-stated range.

R013 Watershed area for nearby stream or pond (m^2) – Physical Parameter
Based on the topographic quadrangles for Saxton, PA and Hopewell, PA, the watershed area surrounding the facility was estimated as the total area of land bounded by the Juniata River and surrounding topographic high areas. The value input in the RESRAD model was $5x10^6$ m^2.

R014 Density of saturated zone (g/cm^3) – Physical Parameter
Based on information provided by GPU Nuclear regarding water levels in the vicinity of the site, the saturated zone begins at between 0.7 and 2.3 meters below ground surface. Based on subsurface investigations as described in Section I, the geologic stratigraphy at this depth and below, is described as mixed soils and bedrock. Based on the May 1982 Department of Navy Naval Facilities Engineering Command (NAVFAC) DM-7.1 Manual, density for this type of material is in the range of 80 to 120 lb./ft^3 (or 1.28 to 1.92 g/cm^3). The range for wet weight was used as this pertains to saturated soil/rock. The value input into the RESRAD model was 1.60 g/cm^3, the average of the above-stated range.

R014 Saturated zone total porosity – Physical Parameter
Based on subsurface investigations as described in Section I, the geologic stratigraphy of the saturated zone is described as mixed soils and bedrock. As denoted in Figure 1, units B, B/C and C are considered saturated and only units B/C and C subject to any appreciable flow of groundwater. Further, based on the thicker saturated thickness of unit C in relationship to unit B/C and other pertinent information we recommended combining the interface and bedrock units (B/C and C) and using values for the siltstone bedrock for the RESRAD inputs.

Referencing Domenico and Schwartz, Physical and Chemical Hydrogeology (1990, p. 29) the siltstone bedrock's total porosity ranges between 0.31 and 0.41. Total porosity in bedrock is related to fracture porosity, which for this rock type, provides the majority of the void space. The recommended value input into the RESRAD model is 0.36, the average of the above-stated range.

R014 Saturated zone effective porosity – Physical Parameter
The effective porosity range is based on bedrock. Referencing Domenico and Schwartz, Physical and Chemical Hydrogeology (1990, p.29) expressed the effective porosity range of 0.005 to 0.05 based on shale bedrock. The recommended value input into the RESRAD model is 0.028, the average of the above-stated range.

R014 Saturated zone hydraulic conductivity (m/yr) – Physical Parameter

The hydraulic conductivity for the bedrock based on testing of bedrock wells OW-3R, OW-4R, OW-5R and OW-7R is 67.91 m/yr, the geometric mean of these four test results, (value reported in Haley & Aldrich's August 2001 report) in the saturated zone. The recommended value input into the RESRAD model is 67.91 m/yr.

R014 Saturated zone hydraulic gradient – Physical Parameter

The hydraulic gradient in the bedrock based on water level information recorded on January 11, 2001 ranges between 0.02 and 0.03 (gradient between the tunnel and the river and the site to the discharge tunnel respectively). A review of water level information on June 13, 2001 indicated a decrease in the hydraulic gradient from the tunnel to the river (0.013) while the value from the site to the tunnel remained the same as that calculated for the January water

level information. The recommended value input into the RESRAD model is 0.02, the average of the lower value of the tunnel to the river and the value of the site to the tunnel.

R014 Saturated zone b parameter – Physical Parameter
Refer to the discussion of the zone b parameter for the contaminated zone, presented above. The recommended value input in the RESRAD model is 5.6.

R014 Water table drop rate (m/yr) – Physical Parameter
Annual variation of the groundwater elevation at the SNEC facility is approximately 0.5 meters in the fill deposits and approximately 1.6 meters in the bedrock unit. This information is based on water level measurements collected over the period March 1999 to April 2001 by GPU Nuclear personnel. Although seasonal variation is up to approximately 1.6 meters, and possibly could be higher, a decline in long term groundwater elevations is expected to be significantly less, if any, since water table conditions are moderated by the strong hydrogeologic influence of the Juniata River, including existing river elevation controls. In addition, there is no unusually high consumptive use of groundwater locally. Based on this, a value of 0 m was input into the RESRAD model.

R014 Well pump intake depth (m below water table) – Physical Parameter
Based on recommended well pump intake depths (Driscoll, Fletcher, Groundwater and Wells, Second Edition, 1986) and the subsurface conditions as described in Section I, the range for the well pump intake depth was input as 10 to 50 meters below the water table. Actual pump intake depths may vary based on the actual depth of the well, in addition to actual well yield and usage requirements. The value input into the RESRAD model was 30 m, the average of the above-stated range.

R014 Model: nondispersion (ND) or Mass-balance (MB) – Physical Parameter
Guidelines from Appendix C – Rev 0 of the NMSS Decommissioning SRP indicate that the nondispersion approach should be acceptable when the area of contamination is known to be larger than the assumed capture area of a hypothetical well. The guidance provides a calculation to estimate the capture area of a hypothetical well, however the calculation assumes a flat water table, which, based on subsurface investigations decried in Section I, is not the case at the SNEC facility. The gradient based on data from monitoring wells collected as part of the 18 November 1992 report entitled Phase I Report of Findings - Groundwater Investigation, ranges from 0.02 to 0.04. Given static hydraulic gradient, hydraulic conductivity, and saturated thickness of the geologic strata, potential capture zone of a hypothetical well can be estimated as follows:

- **Downgradient flow boundary (null point):*

$$X_l = Q/(2\pi * K * b * i) \qquad X_l = 286.2/(2\pi * 67.91 * 50 * 0.02) \qquad X_l = 0.67m$$

- **Transverse boundary (width of capture):*

$$Y_l = Q/(K * b * i) \qquad Y_l = 286.2/(67.91 * 50 * 0.02) \qquad Y_l = 4.21m$$

Where,

Q = average pumping rate of RESRAD input range (m^3/yr)
K = average hydraulic conductivity of RESRAD input range (m/yr)
b = saturated thickness of the aquifer (m)
i = average hydraulic gradient of RESRAD input range (m/m)

- Equation taken from Wellhead Protection Strategies, US Geological Society, 1991.
- Since the transverse boundary is equivalent to a linear distance (width of capture zone), to extrapolate to a total capture area, the transverse boundary is multiplied times pi.

$A_c = Y_l * \pi$ $\quad$ $A_c = 13.23m^2$

Based on information provided by GPU Nuclear, the area of contamination ranges from 182.4 to 1,161 m^2. Based on the above equations, an estimate of capture zone for a hypothetical well at the SNEC facility is approximately 13.23 m^2. Based on this, the area of the contamination is greater than the capture area of a hypothetical well, and therefore the non-dispersion mode was applied for the RESRAD modeling.

R014 Well pumping rate (m^3/yr) – Physical Parameter
Based on data collected in the American Water Works Association Research Foundation's Residential End Use Study, 1998, the typical usage volume for a single domestic well varies from approximately 207.3 m^3/yr to 365 m^3/yr. The value input into the RESRAD model was 286.2 m^3/yr, the average of the above-stated range.

R015 Number of unsaturated zone strata – Physical Parameter
As noted earlier, the contaminated zone is present to 1.0 m below ground surface for the modeled area (Figure 1). The saturated zone begins at approximately 1.5 m below ground surface, and given the seasonal variation of the water table, the unsaturated zone exists (and varies) from 1 to 1.5 m below ground surface. During a period of one to two months in the spring water levels may be higher than throughout most of the hydrologic year resulting in a period of transient saturation. Therefore, 1 was input for the number of unsaturated zone strata.

R015 Unsaturated zone 1, thickness (m) – Physical Parameter
As noted above, the unsaturated zone exists (and varies) from 1 to 1.5 m below ground surface. Therefore, the unsaturated zone thickness ranges from 0 to 0.5 m (see Figure 1). The value input into the RESRAD model was 0.25 m, the average of the above-stated range.

R015 Unsaturated zone 1, soil density (g/cm^3) – Physical Parameter
Based on subsurface investigations as described in Section I, the geologic stratigraphy at this depth is described as mixed soils, sandy or silty clay to well graded sand and gravel with rock fragments. Based on the May 1982 Department of Navy Naval Facilities Engineering Command (NAVFAC) DM-7.1 Manual, dry weight density for this type of material is in the range of 80 to 120 lb./ft^3 (or 1.28 to 1.92 g/cm^3). The range for dry weight as opposed to wet, or submerged weight, was used as the depth of soil contamination is unsaturated. The value input into the RESRAD model was 1.60 g/cm^3, the average of the above-stated range.

R015 Unsaturated zone 1, total porosity – Physical Parameter
The total porosity range for the site in the unsaturated zone is based in three soil types (fill materials). Specifically, soil samples S-1 and S-2 from the 1981 Ground/Water Technology

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investigation and TB-1, similar to TB-3 from the Haley & Aldrich geotechnical investigation 1999 were selected. Referencing Maidment, Handbook of Hydrology (pp. 5.14), 1993, the on-site soil types correspond to a range in total porosity between 0.35 and 0.56. Total porosity is defined as the part of the soil volume that is void space. The recommended value input into the RESRAD model is 0.46, the average of the above-stated range.

R015 Unsaturated zone 1, effective porosity – Physical Parameter
The effective porosity range for the site was based on the soil types. Referencing Maidment, Handbook of Hydrology (pp. 5.14), 1993, the range of 0.28 to 0.54 for effective porosity is the recommended as the appropriate parameter input based on the soil types found at the site. The recommended value input into the RESRAD model is 0.41, the average of the above-stated range.

R015 Unsaturated zone 1, soil-specific b parameter – Physical Parameter
Refer to the discussion of the zone b parameter for the contaminated zone, presented above. The recommended value input into the RESRAD model is 5.6.

R015 Unsaturated zone 1, hydraulic conductivity (m/yr) – Physical Parameter
Refer to the discussion of hydraulic conductivity for the contaminated zone, presented above. As the geologic profile does not change significantly with regard to hydraulic conductivity, the input range for the contaminated zone hydraulic conductivity was used again as the range for the unsaturated zone hydraulic conductivity. The recommended value input into the RESRAD model is 32.3 m/yr (1 x 10^{-4} cm/sec), the geometric mean of three site soil types.

- Contaminated Zone Thickness (m) – Physical Parameter

  Based on information provided by GPU Nuclear and for the specific application of the RESRAD modeling, the contaminated zone is considered to be the upper 1 meter throughout the modeled area (Figure 1). The value input into the RESRAD model was therefore 1 meter.

- Field Capacity – Physical Parameter (All Zones)

  Based on information provided by GPU Nuclear and RESRAD developers at Argonne National Laboratory, field capacity, a value included in the RESRAD 6.0 code, refers to specific retention as it applies to unsaturated soil. Based on published values for field capacity for soil materials classified as similar to on-site soil (Brady, The Nature & Property of Soils, 1974) field capacity ranges from 0.079 to 0.192. The recommended value input into the RESRAD model is 0.136, the average of the minimum and maximum estimated values.

Endnote:

Anthony Bonasera originally compiled the list of RESRAD input parameters and references supporting the values. The equations presented in the text were hand checked by Daniel G. Eurich of Haley & Aldrich, Inc in March 2001. The June 2001 updated version includes revisions to the evapotranspiration and model parameter equations due to changes in the input parameters. The 12 June 2001 version includes edits to the evapotranspiration, precipitation values (increased precipitation decimal places, field capacity, hydraulic conductivity, effective porosity and model parameter equations. Nancy van Dyke & Charlie Butts of Haley & Aldrich, Inc checked the June 2001 equation revisions. As you requested, Haley & Aldrich, Inc. created a file of citations for this document, this file is being maintained and updated for GPU's future reference.

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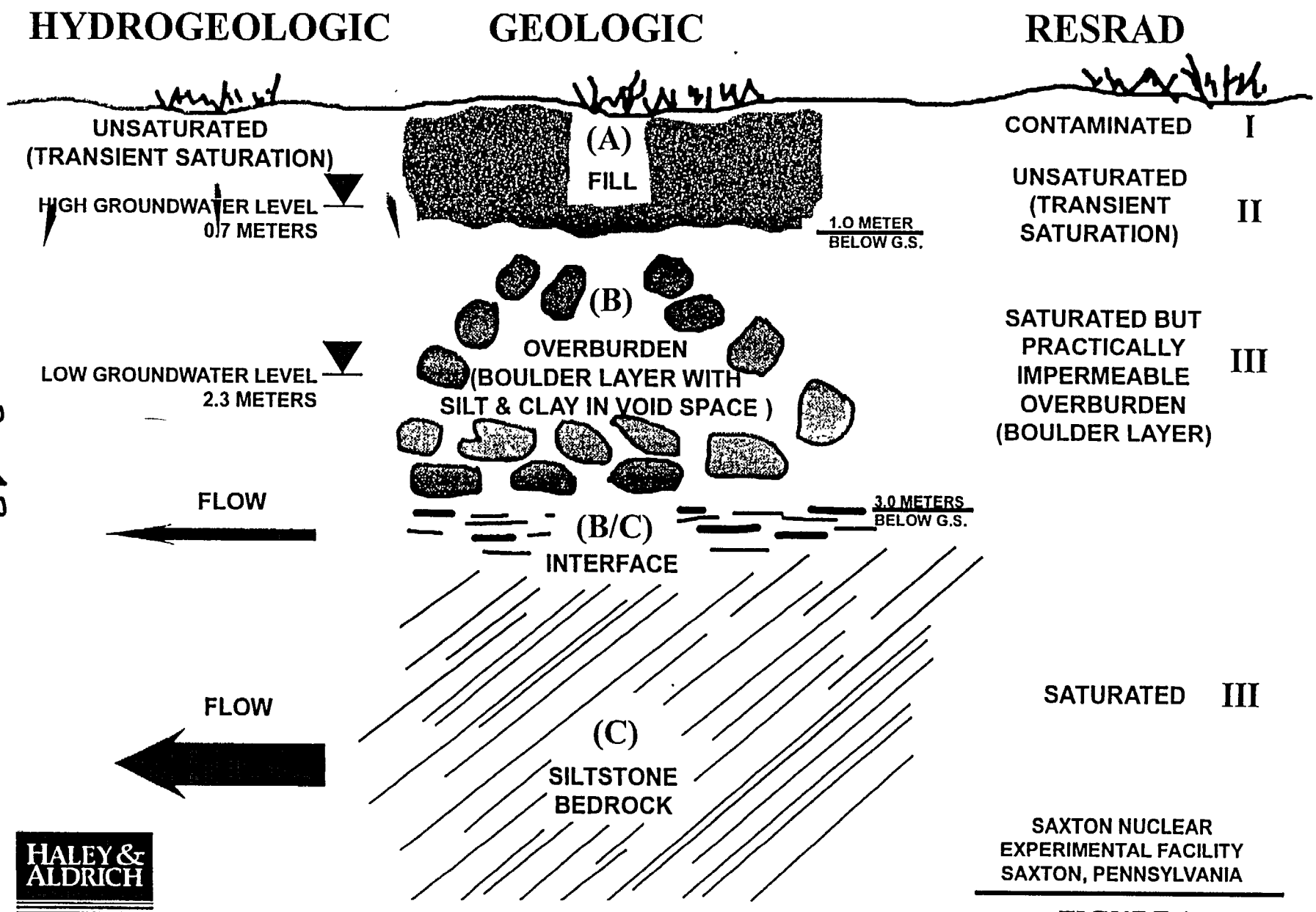
SKETCH OF UNDERGROUND MATERIALS



SAXTON NUCLEAR
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SAXTON, PENNSYLVANIA

FIGURE 1
REVISION 1

HALEY & ALDRICH

SNEC SAMPLES ASSAYED FOR Kd VALUES AT ANL														
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8						
Location	River (composite) Sediment Sample	SSGS SE Sump	South of Warehouse by Old Access Road	CV Area	CV Area, Near Switchyard	CV Area	CV Area	CV Area						
Material Type	Sediment	Construction Debris	Fly Ash & Cinders	Back-Fill Materials	Fill Soil	Clay Material	Weathered Bedrock	Unweathered Bedrock (crushed)						
Reference Grid No & Coordinates	Bank Above Bridge & Off Tip Of Island	AV-133	AJ-131, 21' N by 2' W	AZ-129, 14' W by 10' N	BA-129, 1' N	BA-129, 1' N by 2' W	AZ-128, 13' N	AZ-129, 15' N by 12 to 18' E						
Depth (Grade=811' El)	0' - 1' Below Sediment Surface	~787' El	~811'	~795'	~810 8'	~809 12'	~800'	~800'	Lowest Value	Highest Value				
Elements											AVERAGE	SIGMA	Sigma as a %	
H	~1	~1	~1	~1	~1	~1	~1	~1	1	1	1	0	0 0%	H
C	~1	~1	~1	~1	~1	~1	~1	~1	1	1	1	0	0 0%	C
Ni	10000	10000	4000	10000	10000	10000	1300	1500	1300	10000	7100	4082	57 5%	Ni
Zr, Nb	600	80	500	500	500	500	500	500	80	600	460	157	34 2%	Zr, Nb
Tc	8.1	54	54	8.6	1.4	1.6	1.3	1.3	1.3	54	18	23	144 1%	Tc
U	37	16	5200	17	34	106	5200	226	16	5200	1355	2375	175 3%	U
Pu	600	160	600	400	400	400	600	400	160	600	445	152	34 1%	Pu
Ce, Eu	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	0	0 0%	Ce, Eu
Co	1000	1000	200	1000	1000	1000	1000	1000	200	1000	900	283	31 4%	Co
Cs	2340	2433	2131	14149	13618	2884	9746	28341	2131	28341	9453	9205	97.4%	Cs
Fe	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	0	0 0%	Fe
Am, Cm	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	0	0 0%	Am, Cm
Sr	60	25	475	28	11	24	114	60	11	475	100	155	155 7%	Sr
Sb	1100	153	5200	2070	1100	1800	5000	1900	153	5200	2291	1838	80 2%	Sb
Pb	46000	1.60E+05	58000	81000	31000	98000	9700	26000	9700	160000	63713	48553	76 2%	Pb

ATTACHMENT 3 - 1

B. Brosey, 2/5/02 ; P. Donnachie, 2/5/02

RESRAD INPUT FOR SNEC SURFACE MODEL

Menu	Class	PARAMETERS	Basic RESRAD Input	SNEC Range of Values Min.	SNEC Range of Values Max.	Assigned Distribution	Default Distribution
C14	P	Thickness of Soil Evasion Layer of C-14 in Soil (m)	0.3	0.2	0.6	Triangular	
D-5	P	Bioaccumulation Factors, Fresh Water	Default Values	Varies	Varies	Lognormal	
D-34	P	Food Transfer Factors	Default Values	Varies	Varies	Lognormal	
N/A	P	Contaminated Zone Effective Porosity	Not Used	0.28	0.54	N/A	
RO11	P	Area of Contaminated Zone (m^2)	10000	N/A	N/A	N/A	
RO11	NRC	Basic Radiation Dose Limit (mrem/y) (NRC)	25	N/A	N/A	N/A	
RO11	P	Length Parallel to Aquifer Flow (m)	112.8	N/A	N/A	N/A	
RO11	P	Thickness of Contaminated Zone 1 (m)	1	N/A	N/A	N/A	
RO11	P	Time Since Placement of Materials (yr)	0	N/A	N/A	N/A	
RO11	P	Times for Calculations (yr)	1	N/A	N/A	N/A	
RO11	P	Times for Calculations (yr)	3	N/A	N/A	N/A	
RO11	P	Times for Calculations (yr)	10	N/A	N/A	N/A	
RO11	P	Times for Calculations (yr)	35	N/A	N/A	N/A	
RO11	P	Times for Calculations (yr)	150	N/A	N/A	N/A	
RO11	P	Times for Calculations (yr)	300	N/A	N/A	N/A	
RO11	P	Times for Calculations (yr)	1000	N/A	N/A	N/A	
RO11	P	Times for Calculations (yr)	10000	N/A	N/A	N/A	
RO13	P	Average Annual Wind Speed (m/sec)	4.07	3.13	4.83	Uniform	Bounded Lognormal-N (1.4 - 13)
RO13	P	Contaminated Zone Field Capacity	0.136	0.079	0.192	Uniform	None Assigned
RO13	P	Contaminated Zone b Parameter	5.6	4.05	7.12	Uniform	Bounded Lognormal-N (0 5 - 30)
RO13	P, B	Contaminated Zone Erosion Rate (m/yr)	0.000345	0.00009	0.0006	Loguniform	Continuous Logarithmic (5E-08 - 0.2)
RO13	P	Contaminated Zone Hydraulic Conductivity (m/yr)	32.3	0.362	25400	Loguniform	Bounded Lognormal-N (0 004 - 9250)
RO13	P	Contaminated Zone Total Porosity	0.46	0.35	0.56	Uniform	Truncated Normal, (0.157 - 0 693)
RO13	P	Cover Depth (m)	0	N/A	N/A	N/A	
RO13	P, B	Cover Depth Erosion Rate (m/yr)	Not Used	N/A	N/A	N/A	
RO13	P	Density of Contaminated Zone (g/cc)	1.6	1.28	1.92	Uniform	Truncated Normal (0.809 - 2.23)
RO13	P	Density of Cover Material (g/cc)	Not Used	N/A	N/A	N/A	
RO13	P	Evapotranspiration Coefficient (m/yr)	0.59	0.5	0.67	Uniform	Uniform (0.5 - 0.75)
RO13	P	Humidity in Air (g/m^3)	8	2.58E+00	2.03E+01	Truncated Lognormal-N	
RO13	B	Irrigation (m/yr)	0.2	---	---	None Assigned	
RO13	B	Irrigation Mode (Overhead)	Overhead	N/A	N/A	N/A	
RO13	P	Precipitation (m/y)	0.936	0.688	1.327	Uniform	None Assigned
RO13	P	Runoff Coefficient	0.35	0.3	0.4	Uniform	Uniform (0.1 - 0 8)
RO13	P	Watershed Area for Nearby Stream or Pond (m^2)	5.00E+06	---	---	None Assigned	None Assigned
RO14	P	Density of Saturated Zone (g/cc)	1.6	1.28	1.92	Uniform	Truncated Normal (0 809 - 2.23)
RO14	P	Model: Non-dispersion (ND) or Mass-Balance (MB)	Non-Dispersion	N/A	N/A	N/A	
RO14	P	Saturated Zone b Parameter	Not Used	N/A	N/A	N/A	
RO14	P	Saturated Zone Effective Porosity	0.028	0.005	0.05	Loguniform	Truncated Normal (0.075 - 0.635)
RO14	P	Saturated Zone Hydraulic Conductivity (m/yr)	67.91	15.59	909.53	Uniform	Bounded Lognormal-N (0 004 - 9250)
RO14	P	Saturated Zone Hydraulic Gradient	0.02	0.013	0.03	Uniform	Bounded Lognormal-N (0.00007 - 0.5)
RO14	P	Saturated Zone Total Porosity	0.36	0.31	0.41	Uniform	Truncated Normal, (0.157 - 0.693)
RO14	P	Water Table Drop Rate (m/yr)	0	---	---	None Assigned	None Assigned
RO14	P	Well Pump Intake Depth (m)	30	10	50	Uniform	Triangular (6 -30)
RO14	B, P	Well Pumping Rate (m^3/yr)	286.2	207.3	365	Uniform	None Assigned
RO14	P	Saturated Zone Field Capacity	0.136	0.079	0.192	Uniform	None Assigned
RO15	P	Density of Unsaturated Zone 1 (g/cc)	1.6	1.28	1.92	Uniform	Truncated Normal (0 809 - 2.23)
RO15	P	Effective Porosity of Unsaturated Zone 1	0.41	0.28	0.54	Uniform	Truncated Normal (0.075 - 0.635)
RO15	P	Hydraulic Conductivity of Unsaturated Zone 1 (m/yr)	32.3	0.362	25400	Loguniform	Bounded Lognormal-N (0.004 - 9250)
RO15	P	Number of Unsaturated Zone Strata	1	N/A	N/A	N/A	N/A
RO15	P	Thickness of Unsaturated Zone 1 (m)	0.25	0	0.5	Uniform	Bounded Lognormal-N (0.18 - 320)

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RO15	P	Total porosity of Unsaturated Zone 1	0.46	0.35	0.56	Uniform	Truncated Normal, (0.157 - 0.693)
RO15	P	Unsaturated Zone 1 b Parameter	5.6	4.05	7.12	Uniform	Bounded Lognormal-N (0.5 - 30)
RO15	P	Unsaturated Zone Field Capacity	0.136	0.079	0.192	Uniform	None Assigned
RO17	P	External Gamma Shielding Factor	0.7	4.400E-02	1	Bounded Lognormal-N	
RO17	P, B	Indoor Dust Filtration Factor	0.4	0.15	0.95	Uniform	
RO17	B	Indoor Time Fraction	0.66	0	1	Continuos Linear	
RO17	M, P	Inhalation Rate (m^3/yr)	8400	4380	13100	Triangular	
RO17	P, B	Mass Loading for Inhalation (g/m^3)	0.0001	0	0.0001	Continuos Linear	
RO17	B	Fraction of Time Spent Outdoors	0.12	—	—	None Assigned	
RO18	B, P	Contaminated Fraction of Aquatic Food	1	0	1	Triangular	
RO18	B, P	Contaminated Fraction of Drinking Water	1	—	—	None Assigned	
RO18	B, P	Contaminated Fraction of Household Water	Not Used	N/A	N/A	N/A	
RO18	B, P	Contaminated Fraction of Irrigation Water	1	—	—	None Assigned	
RO18	B, P	Contaminated Fraction of Livestock Water	1	—	—	None Assigned	
RO18	B, P	Contaminated Fraction of Meat	1	—	—	None Assigned	
RO18	B, P	Contaminated Fraction of Milk	1	—	—	None Assigned	
RO18	B, P	Contaminated Fraction of Plant Food	1	—	—	None Assigned	
RO18	M, B	Drinking Water Intake (L/yr)	478.6	90.4	1860	Truncated Lognormal-N	
RO18	M, B	Fish Consumption (kg/yr)	20.6	—	—	None Assigned	
RO18	M, B	Fruit, Vegetable, and Grain Consumption (kg/yr)	111.8	135	318	Triangular	
RO18	M, B	Leafy Vegetable Consumption (kg/yr)	21.4	—	—	None Assigned	
RO18	M, B	Meat and Poultry Consumption (kg/yr)	67	—	—	None Assigned	
RO18	M, B	Milk Consumption	233	60	200	Triangular	
RO18	M, B	Other Seafood Consumption (kg/yr)	0.9	—	—	None Assigned	
RO18	M, B	Soil Ingestion Rate (g/yr)	18.3	0	36.5	Triangular	
RO19	M, B	Livestock Water Intake for Milk	60	—	—	None Assigned	
RO19	M, B	Depth of Roots (m)	0.9	0.3	1	Uniform	
RO19	M, B	Depth of Soil Mixing Layer (m)	0.15	0	0.6	Triangular	
RO19B	M, B	Weathering Removal Constant of all Vegetation	20	5.1	84	Triangular	
RO19B	M, B	Wet Crop Yield for Fodder (kg/m^2)	1.1	—	—	None Assigned	
RO19B	M, B	Wet Crop Yield for Leafy (kg/m^2)	1.5	—	—	None Assigned	
RO19B	M, B	Wet Crop Yield for Non-Leafy (kg/m^2)	0.7	0.397	7.72	Truncated Lognormal-N	
RO19B	M, B	Wet Foliar Inception Fraction of Leafy Vegetables	0.25	0.06	0.95	Triangular	
STOR	B	Storage Times for Livestock Fodder	0	—	—	None Assigned	

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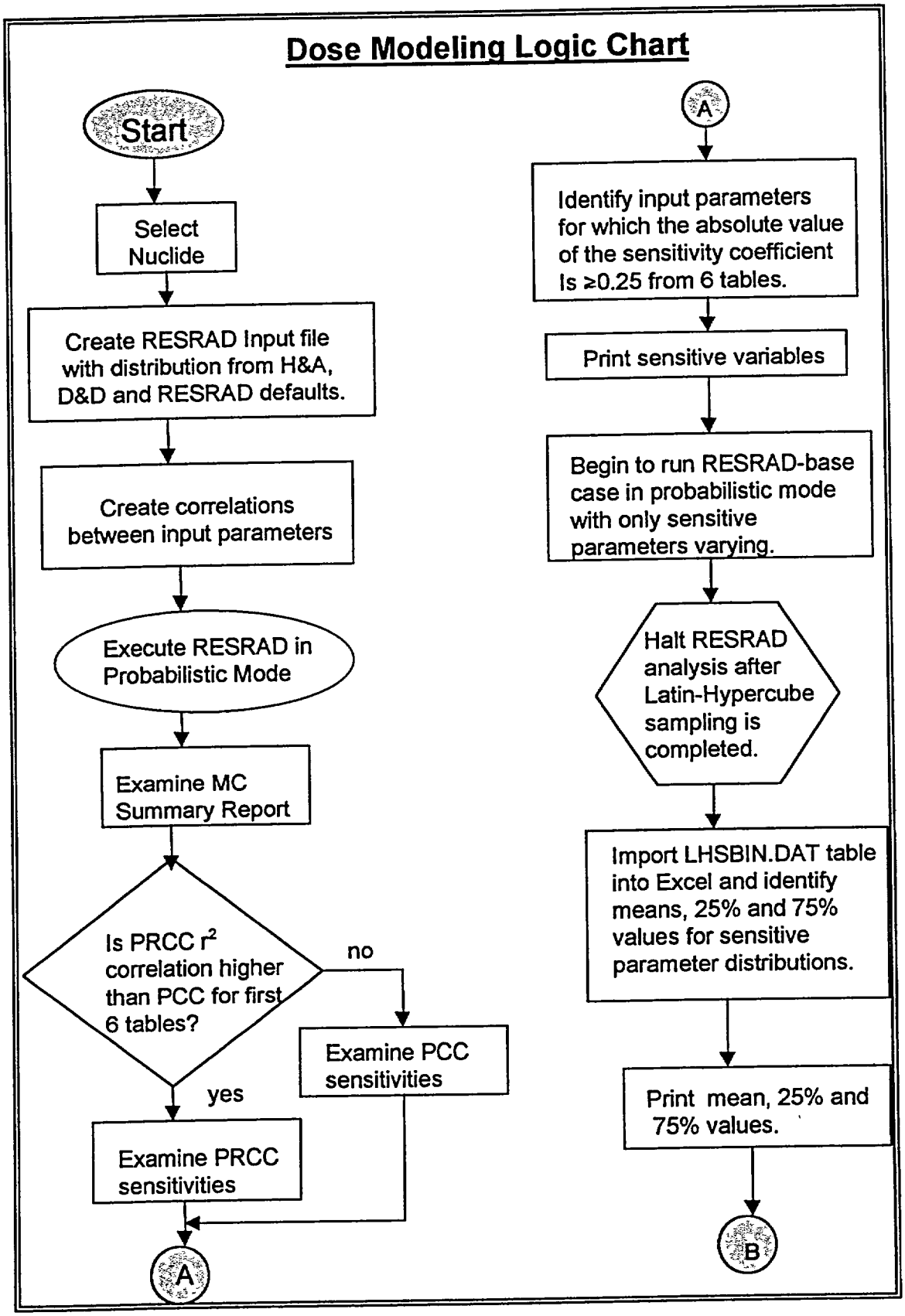
		Distribution Coefficient for Americium & Curium	Value Used	ANL Min.	ANL Max.	Distribution Type	
R16	P	1. Contaminated Zone (cm^3/g)	1000	1000	5000	RESRAD Default	
R16	P	2. Unsaturated Zone (cm^3/g)	1000	1000	5000	RESRAD Default	
R16	P	3. Saturated Zone (cm^3/g)	1000	1000	5000	RESRAD Default	
		Distribution Coefficient for Carbon	ANL Value	GPU Min.	GPU Max.	Distribution Type	
R16	P	1. Contaminated Zone (cm^3/g)	~1	0	5	Uniform	
R16	P	2. Unsaturated Zone (cm^3/g)	~1	0	5	Uniform	
R16	P	3. Saturated Zone (cm^3/g)	~1	0	5	Uniform	
		Distribution Coefficient for Cesium	Value Used	ANL Min.	ANL Max.	Distribution Type	
R16	P	1. Contaminated Zone (cm^3/g)	2131	2131	28341	RESRAD Default	
R16	P	2. Unsaturated Zone (cm^3/g)	2131	2131	28341	RESRAD Default	
R16	P	3. Saturated Zone (cm^3/g)	2131	2131	28341	RESRAD Default	
		Distribution Coefficient for Cobalt	Value Used	ANL Min.	ANL Max.	Distribution Type	
R16	P	1. Contaminated Zone (cm^3/g)	200	200	1000	RESRAD Default	
R16	P	2. Unsaturated Zone (cm^3/g)	200	200	1000	RESRAD Default	
R16	P	3. Saturated Zone (cm^3/g)	200	200	1000	RESRAD Default	
		Distribution Coefficient for Europium	Value Used	ANL Min.	ANL Max.	Distribution Type	
R16	P	1. Contaminated Zone (cm^3/g)	1000	1000	5000	RESRAD Default	
R16	P	2. Unsaturated Zone (cm^3/g)	1000	1000	5000	RESRAD Default	
R16	P	3. Saturated Zone (cm^3/g)	1000	1000	5000	RESRAD Default	
		Distribution Coefficient for Hydrogen	ANL Value (GPU)	GPU Min.	GPU Max.	Distribution Type	
R16	P	1. Contaminated Zone (cm^3/g)	~1 (0.25)	0	0.5	Uniform	
R16	P	2. Unsaturated Zone (cm^3/g)	~1 (0.25)	0	0.5	Uniform	
R16	P	3. Saturated Zone (cm^3/g)	~1 (0.25)	0	0.5	Uniform	
		Distribution Coefficient for Iron	Value Used	GPU Min.	GPU Max.	Distribution Type	
R16	P	1. Contaminated Zone (cm^3/g)	10000	10000	50000	RESRAD Default	
R16	P	2. Unsaturated Zone (cm^3/g)	10000	10000	50000	RESRAD Default	
R16	P	3. Saturated Zone (cm^3/g)	10000	10000	50000	RESRAD Default	
		Distribution Coefficient for Lead	Value Used	ANL Min.	ANL Max.	Distribution Type	
R16	P	1. Contaminated Zone (cm^3/g)	9700	9700	160000	RESRAD Default	
R16	P	2. Unsaturated Zone (cm^3/g)	9700	9700	160000	RESRAD Default	
R16	P	3. Saturated Zone (cm^3/g)	9700	9700	160000	RESRAD Default	
		Distribution Coefficient for Nickel	Value Used	ANL Min.	ANL Max.	Distribution Type	
R16	P	1. Contaminated Zone (cm^3/g)	1300	1300	10000	RESRAD Default	
R16	P	2. Unsaturated Zone (cm^3/g)	1300	1300	10000	RESRAD Default	
R16	P	3. Saturated Zone (cm^3/g)	1300	1300	10000	RESRAD Default	
		Distribution Coefficient for Plutonium	Value Used	ANL Min.	ANL Max.	Distribution Type	
R16	P	1. Contaminated Zone (cm^3/g)	160	160	600	RESRAD Default	
R16	P	2. Unsaturated Zone (cm^3/g)	160	160	600	RESRAD Default	
R16	P	3. Saturated Zone (cm^3/g)	160	160	600	RESRAD Default	
		Distribution Coefficient for Strontium	Value Used	ANL Min.	ANL Max.	Distribution Type	
R16	P	1. Contaminated Zone (cm^3/g)	11	11	475	RESRAD Default	
R16	P	2. Unsaturated Zone (cm^3/g)	11	11	475	RESRAD Default	
R16	P	3. Saturated Zone (cm^3/g)	11	11	475	RESRAD Default	
		Distribution Coefficient for Uranium	Value Used	ANL Min.	ANL Max.	Distribution Type	
R16	P	1. Contaminated Zone (cm^3/g)	16	16	5200	RESRAD Default	
R16	P	2. Unsaturated Zone (cm^3/g)	16	16	5200	RESRAD Default	
R16	P	3. Saturated Zone (cm^3/g)	16	16	5200	RESRAD Default	

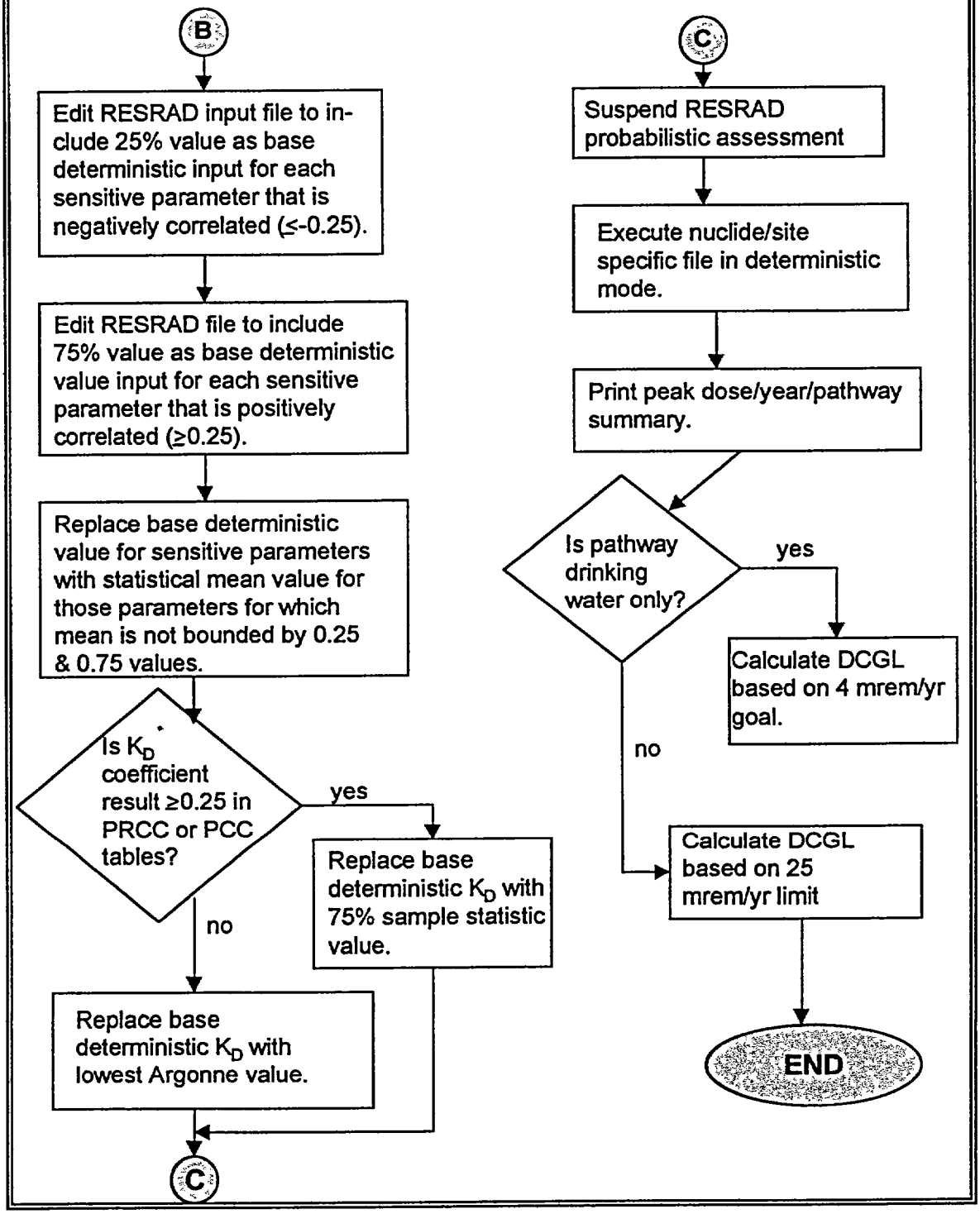
NOTE: ANL Kd values may be "greater than" values. The ANL Min. value is the lowest reported value for this element and the ANL Max. value is the highest reported value.
NOTE: Items in RED type face are SNEC input values.
NOTE: Items with BLUE background are D & D default values, while items with a background are RESRAD default values. Unlisted parameters are RESRAD defaults.

Figure 6-1
(Resident Farmer Scenario)



ATTACHMENT 5.1

Dose Modeling Logic Chart (cont.)



ATTACHMENT 5.2