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Dear Dr. Miller:

As a part of this letter, I have included my review of the SRS Dose Reconstruction Report. Aside from a general assessment of the document, I was asked to address the following three questions:

1. Was the methodology appropriate?
2. Can an independent reviewer reproduce the results?
3. Are there significant errors or omissions which could significantly alter the final calculations?

These following paragraphs will address my response to the questions as well as present my overall assessment.

Preface to Review

As expressed many times in the document, there are gaps in data that must be filled in by reasonable methods. This is true of all dose reconstructions. Field measurements of environmental parameters in a given region often vary several orders of magnitude. So the assessor must select values from a range of values more often than not. In many cases there is not a "right way" to fill in the gaps of missing data and select environmental parameters. As a consequence I will restrain from disagreeing with approaches of filling in gaps, etc. if they appear to be reasonable and what I would consider to be in the realm of standard practice. As an engineer, my definition of reasonable includes the producing a result within the constraint of time available to carry out the dose assessment. By that I mean if one had 20 years to produce the dose assessment, the parameters and modeling could be fine tuned *ad infinitum* and there are things we would still not know such as the exact behavior of human receptors. It is my opinion it is unlikely that additional modeling would produce significantly different values for the dose ranges reported in the present document.

My conclusion is that the dose reconstruction used standard methodologies and generally made good uses of the available data. Although there are a few shortcomings in the presentation of the environmental parameters and other values used in the assessment, they can be found in the report and one can construct the base input as well as the receptor behavior input for the GENII code. However, one would need the preprocessor and postprocessor which the authors of the dose reconstruction had available to actual reproduce the assessment doses in any reasonable period of time. I did not find any significant errors that would impact the range of doses obtained in the present work.

Executive Summary

The summary is good. However, serious thought must be given to the difficulty with the difference between the point-estimates and the medians and means for the dose uncertainty analyses (page xix). I think this confuses even the well-educated lay reader because they would assume that "representative" doses were either mean or median doses and not lower then both of them.

The "point estimate dose" on page viii and other locations in the text might be better called the "hypothetical receptors dose" or something else. Does a "point estimate" refer to the use of discrete exposure locations or a single computed value rather than a distribution from an uncertainty analysis as Section 4.2.3 indicates. I guess the latter. Or does it refer to something else?

On page viii, it would be good to put in a discussion of the naturally occurring cancer rates to place the radiation cancer risks in perspective.

Figure 3 will beg the question from the lay reader why the Child Born in 1955 does not have as large of a dose from fish ingestion – they will not bother to read the ordinate and some will not understand the ordinate. Same is true for Figures 5 and 7.

Chapter 2 Background

This chapter largely consists of background, so there are no comments. It is interesting that on page 2-4, the authors take great detail in explaining what heavy water is. Chapter 2 is one of the few chapters in which footnotes are used to address the needs of a knowledgeable, non-technical lay reader.

In Table 2-4, how is it that Cs-137 was released to air and Cs-134 was not? I will discuss this more later.

Chapter 3 Scenario descriptions

In Table 3-1, the "TBD" data were obviously determined before the dose assessment was carried out, as per Table 3-2. I did not review the exposure scenarios and locations as it was my understanding that the CDC, SRSHES, and the dose assessor agreed to them in advance. The representative scenarios seem reasonable and often conservative in their assumptions. For example, the assumption that only locally acquired milk was consumed is largely a conservative assumption. It would be my gut instincts to believe that in the 1970's and 1980's there would be a shift away from family (backyard) cows. The birth years chosen for the children are conservative assumptions in terms of exposing the child born in 1954 to the large radioactive release years as an infant.

Chapter 4 Statement of Goals and Constraints

On page 4-1 is the sentence "The behaviors of the hypothetical receptors were designed to represent a range of plausible activities for the population living near SRS, but these projections were in some sense bounding without being unrealistic". If they are in some "sense bounding", why are they so far below the medians and the upper bounds of the uncertainty analyses? Or were the authors addressing the lower bounds of the dose estimates. That aside, I agree that the point estimate doses for the receptors may be closer to reality than the uncertainty analysis means, modes or upper bounds.

The overall modeling approach for air releases shown if Figure 4-2 is fairly standard approach for a dose assessment with the defined scenarios of Chapter 3. Although cited in the recommendations chapter as a possibility for future work, it appears that air deposition of radionuclides onto ponds should be at least looked at in a scoping calculation. At least anecdotally, I understand that ponds stocked with fish are sufficiently common that they cannot be dismissed without some quantitative reason. In Figure 4-2, is the line connecting "Surface Deposition" and "Plant Uptake" supposed to have an arrow(s) on it? For instance, air deposition onto plants is not represented?

The overall modeling approach for liquid releases shown in Figure 4-3 is again a rather standard approach given the defined exposure scenarios. Should there be a line from "Water Concentration" to "Incidental Water Ingestion"?

Page 4-9, 4.3.1: The use of annual releases rather than releases on a shorter time interval (acute releases) tends to reduce the dose to people who may have been in locations where concentrations were higher for a brief period of time than the yearly average concentrations are. On the other hand, the approach drives up the doses to people who were not in such locations. These cases are more than bounded by the uncertainty analyses.

Page 4-9, line 40-42: In Chapter 6, we find out that the meteorological data is the average of four 5-year averages. I guess it works out to be the same.

Page 4-11, line 18-19: What is the argument that made dermal contact considered not important?

Chapter 5 Release of Radionuclides to Air

Section 5.1.3: The partitioning of radionuclides into separate isotopes for construction of the Phase III source leads to a more appropriate dose analysis.

Page 5-5, line 1: I don't believe that U-234 is made in nuclear reactors to any large extent, if at all. It is part of the U-238 decay chain.

Although the amount of Pu-240 could be 6-7% if the plutonium was weapons grade. The impact of modeling it as Pu-239 should not be great.

The treatment of unidentified alpha emitters as Pu-239 is a conservative assumption. The treatment of alpha-gamma emitters as Sr-90 is an acceptable approach for the internal dose assessments as it is conservative for ingestion and inhalation doses, but it is not conservative for external dose assessments.

Section 5.1.6: The 15 major release points were mapped onto four virtual sources. The stated reason was for efficiency in terms of the analyses to be carried out. This is understandable considering the change in the time scale available to conclude the dose reconstruction project. However, I don't see with my limited knowledge of the GENII code why inputting 15 sources into a run rather than 4 is a large problem, especially since a preprocessor and postprocessor was available. Or is it related to the problem with GENII centering a polar coordinate system about each source so that a given receptor position shifts between wind sectors?

Page 5-8, lines 11-13: Sentence is somewhat confusing?

Page 5-12, Line 9-10: Depending on what is meant by U-234 contributing "much of the activity of natural or slightly enriched uranium", U-234 should be in secular equilibrium with U-238 activity in natural uranium. Chemical separation of U-238 from ore would carry the U-234 with it.

Page 5-12, Line 14: I don't know that the argument about fractional activity of Pu-240 should be used. The conservatism of assuming the Pu to be Pu-239 is the better reason. Based on Table C-12 (Appendix C), if activity really was a principal consideration in the isotope selection process, then the very small amount by mass of Pu-241 in the weapons grade plutonium would make it the isotope of choice.

See the comments in Appendix C about Cs-134 and Cs-137. I am not sure that Cs-134 can be dismissed.

Page 5-22, Figure 5-5: Ar-41 releases should directly follow reactor operating time in each year, unless there were changes over the years in the holdup of Ar-41 effluent from the reactors. This could be used in the analysis of fission products inventories in a relative manner.

Chapter 6 Transport of Radionuclides Through the Air to An Exposure Location

Section 6.4.2: There is a discussion of the meteorological data available for SRS. There are no onsite data for the first 20 years of the site's operation. Since recent data from nearby weather stations do not correspond well with onsite data for those years, the dose assessors decided to use the onsite data for the available four five-year averages. This is an acceptable approach given the available data since yearly averages of releases are being used. The only question that comes to mind is that rainfall events may have occurred during peak release times.

Where can one find the joint frequency distribution in the report? It is discussed several times in addition to in Chapter 6 and Appendix A but the data are not presented. Maybe an Excel file was not distributed with my copy of the report. There is a wind rose in Figure D-4 on page D-25, but there is no tabulation of the joint frequency distribution. All the data needed to run the assessment are available somewhere in the report except this information.

Chapter 7 Release of Radionuclides to Water …

The discussion of the adjustment factors is often confusing. Does "facility" refer to the "site" or a facility on the site? To me it is somewhat confusing, but it may not be to other readers.

Page 7-5, Savannah River Steps: Why not merge the measured concentrations, at least for those nuclide concentrations in excess of the detection limits (page 7-10), in the Savannah River with the model estimates for the years in which no measured values are available? The fact that the model fairly consistently underpredicts the measured concentrations does not build a lot of confidence in the River concentrations.

It seems inconsistent to model Cs-134 and Cs-137 as separate isotopes in the Phase III source term (page 7-7, numbered item 1.b.) when all the cesium activity was assigned to Cs-137 for the air exposure pathways. But then Table 7-3 indicates that it was all assigned to Cs-137 for the water pathway as well.

See the comments on both Cs-134/Cs-137 and Zr-95/Nb-95 in the discussion which follows later in the review on Appendix C.

The presentation of the simple model in the main Text (section 7.3) of Chapter 7 serves to confuse what was really done. Since it was not used, perhaps any discussion of it should only be in the Appendix.

The creation of adjustment factors using the K_d values for isotopes not considered in the Phase II modeling of the surface water release to the Savannah River is a reasonable approach given available data. A potential difficulty here is the large difference between the K_d values of cesium and strontium reported in Table 7-6 from site data versus those used as median range values in the Phase II modeling. The Phase II modeling values were used to group the isotopes for release scaling. Shouldn't the Phase III K_d values have been used, especially for Cs? Doing so would have placed Cs in a different grouping.

The decision not to construct a physically-based model to compute all the nuclide concentrations in the Lower Three Runs Creek seems to be driven by expediency. The use of the existing data for H-3, Sr-90 and Cs-137 were handled in a reasonable manner. In Chapter 11, the Delivery Family point dose estimates indicate that P-32 plays a role in the dominant dose pathway, consumption of fish. So failing to provide estimates of other isotopes such as P-32 may not be negligible.

Why did you only show the plots of the model concentrations versus measured concentrations for the Savannah River results in Appendix C? Is it because the model prediction is often less than the measured values?

Chapter 8 Food Chain Transport

This chapter discusses the modeling of radionuclide transport modeling in the food chain.

Section 8.2.1: Fish might also be stocked in ponds. Given the bioaccumulation factor for some radionuclides in fish, the modeling of a pond or at least the discussion of why it is a negligible pathway might be warranted.

Page 8-3, lines 28-29: It is assumed to be constantly rain throughout the year. This is not the best approach, but assessments are often done in a similar manner. I have more commonly used codes which have it rain during certain atmospheric stability classes. How would this affect the results presented here?

Page 8-3, lines 35-40: Were only single year average soil concentrations used for all pathways requiring a soil concentration? The buildup of long-lived isotopes which have relatively large K_d values will build up over time. It does not seem that it would take a major modification to the code to do this. From the reading on page 8-3, one is lead to assume that only the average concentration from the current year's emissions is used. In the Appendix, it is not clear that the same thing was done—although I have now persuaded myself that it was done. Please clarify that $C_{si}(T_{yr})$ set to zero in the equation at the start of D.3.3.2 and in the equation for $C_{ci}(T_{yr})$ on page D-36 for the ingestion of food crops? My suspicion is that since the GENII code was run on the order of 39 times per individual in a scenario, that one cannot input an existing soil concentration in the input file. If one can input a soil composition into a GENII run, why not handle this in the preprocessor. I have included a short computation of the differences in Cs-137 activity in soil if one assumes buildup or uses single-year emission soil concentrations averages.

<u>Soil Buildup</u>

For the dose reconstruction, a comparison was performed for Cs-137 releases by air. Since the Cs-137 deposition rates were not available in the report, the analysis was performed in a relative manner. Since the same wind data were used for each of the 39 years in the report, the deposition rate on the soil, R_{ait} on page D-32 is the product of the source term for Cs-137 and set of factors which are the same year after year, i.e. $R_{ai\,t} \cong F \times$

Q where Q is the yearly release rate. Using a variation on the notation used on pages D-31 and D-32, the average soil concentration during the N^{th} year of emissions is given by

$$C_{esi}(T_N) = \left[C_{si}(T_N) + \frac{R_{ait}}{(\lambda_i + \lambda_{si})(1year)} \left[1year - \left(\frac{1 - e^{-(\lambda_i + \lambda_{si})(1year)}}{1year} \right) \right] \right].$$

From my reading I understand that $C_{si}(T_N)$, the average concentration for the concentration at the start of the N^{th} year due to emission in previous years, was set to zero. This approach ignores the buildup of the radioactive material concentration in the soil over the years and just uses the average amount due to only emissions in the current year. λ_i and λ_{si} are the rate constants for radioactive decay and leaching from the 15-cm depth of soil of interest in the dose reconstruction, respectively.

From page D-31, the rate constant for leaching is defined by

$$\lambda_{si} = \frac{(P + I - E)}{d_s \theta_s \left(1 + \frac{\rho_s}{\theta_s} K_{ds} \right)}$$

The values for the variables from the report are in the worksheets in the EXCEL Workbook *soil_buildup_Cs.xls* where the leach rate was computed for K_{ds} = 59 and 1000 for Cs-137. If the buildup of isotopes in the soil were to be included, the $C_{is}(T_N)$ term has the following value if the soil concentration were averaged over the current year.

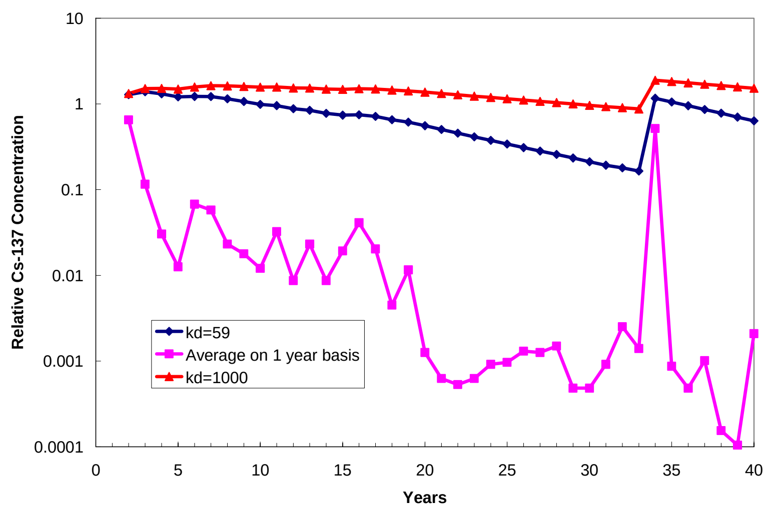
$$C_{is}(T_N) = \frac{\int_0^{1year} C_{is}^*(T_{N-1}) e^{-\lambda_{eff} t} dt}{\int_0^{1year} dt} = \frac{C_{is}^*(T_{N-1})}{\lambda_{eff}(1year)} \left(1 - e^{-\lambda_{eff}(1year)} \right)$$

$C_{is}^*(T_{N-1})$ is the concentration of radioactivity at the start of the year due to buildup from previous years. It would be the summation of the concentrations at the ends of all the previous years properly decayed to the start of the current year, T_N. This is mathematically given by

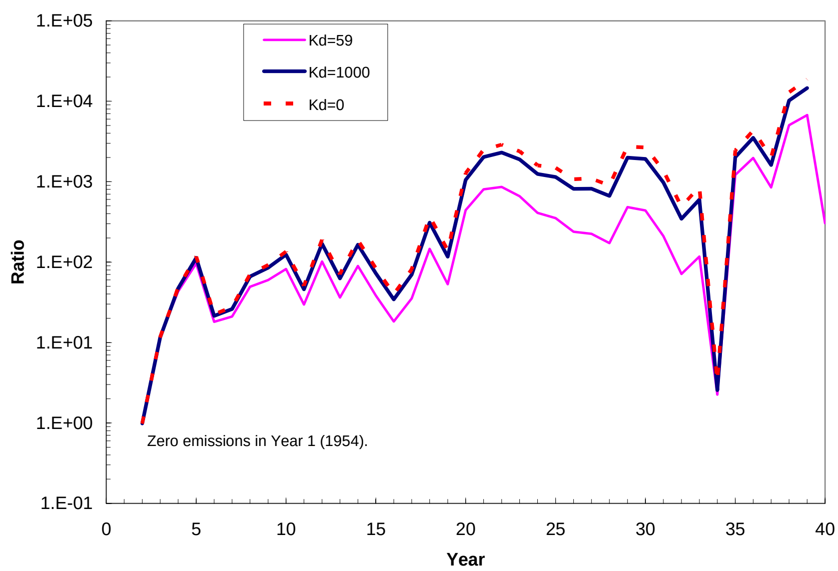
$$\mathrm{C}_{is}^*(\mathrm{T}_{N-1}) = \sum_{n=1}^{N-1} \frac{\mathrm{Q}_n \left(1 - e^{-\lambda_{eff}(1year)} \right)}{\lambda_{eff}} e^{-\lambda_{eff}(T_{n-1} - 1year)}$$

where Q_n is the emission rate in year T_n. Using these equations and the Cs-137 emissions data from Table B-2, the ratio of the average soil concentrations with buildup included to the one-year average values, like the ones that were used in the reconstruction, was computed. The computations are in the *soil_concentration_Cs.xls* spreadsheets. The relative Cs-137 soil concentrations are plotted below since the deposition rate was not known.

The ratio of the average of the averages of the soil concentration with buildup considered over all 39 years divided by the average of the one-year average concentrations is approximately a factor of 15 for the K_d=59 case. This obviously would increase the ground surface external to individuals by a factor of 15. However, those doses are so low that even such an increase would not change significantly any of the total doses in the report. This would not necessarily have to be true for other isotopes delivering dose through other pathways which have the soil concentrations in them. A few scoping computations could be carried out by the authors of the report since they have deposition rates and other intermediate data that are necessary to do so.



The ratios between the relative concentrations with buildup and one-year averages are plotted below.



I now return to the report. The main text says that leaching was considered for the agriculture pathways. This seems not to be the case in Appendix D unless the λ_i in Section D3.4.1.1 should be λsi.

Page 8-3, line 43: The bulk soil density was set to1.6 g/cm^3. Reference [4] verifies that value. It is more defensible than the nominal value argument.

Page 8.5, lines 1-4: Is the transfer rate constant for the Columbia River valid for the Savannah River? Don't we know the shoreline sediment density for the Savannah River? It does not seem like it would be too hard to attempt to create a site-specific value. Or maybe it is known that the nominal value is good at just about any location.

Section 8.4: Ponds are ignored as a pathway. They may yield higher concentrations than the Savannah River release concentrations since ponds may have much lower dilution effect on deposited radionuclides since the turnover rate can be low. The stocking of ponds with fish may be something that needs to be considered.

The ingestion of soil was not "considered" to be a significant pathway for animal product contamination. In reference [5] the quantity of soil eaten by beef cattle and dairy cattle are 0.4 kg/day and 1.6 kg/day. So it may be an additional intake of concern that was not addressed.

Section 8.5: Although maybe not applicable for flowing water, reference [6] reported bioaccumulation factors of 750 liter/kg, 8,500 liter/kg, and 1,200 liter/kg for strontium, cesium and plutonium for fish in Pond B at SRS.   These values are different from those in Table 8-7. The bioaccumulation factors for these elements in the table are at least in part selected from another source of Savannah River Site data.

All in all the parameters reported in this chapter for the food pathway modeling are acceptable values. Many could be more site-specific. The authors seemed to have relied on default values in many cases when in all likelihood SRS staff modelers probably have site-specific values. Most of the parameters needed to perform the dose reconstruction are in Appendices D-F. One must still do a fair amount of skipping around the text to obtain all the values. It might be useful to append a couple of input files.

Chapter 9 Exposure Routes and Pathways

This chapter covers the ways in which the receptors receive a radiation dose from SRS releases by coming in contact with contaminated media. The methodology is fairly standard in approach. It conservatively uses the same indoor air concentrations as outdoor concentrations.   Many of the exposure times are based on regional data as opposed to a nominal set of national data.

In terms of inadvertent soil ingestion, is 50 milligrams per day per adult high enough for a farmer who might be a smoker? Given the magnitude of the soil ingestion doses for the rural family scenarios, this is probably not a concern.

The shielding factors for contaminated soil and shoreline were selected to be conservative.

The food ingestion rates come from standard sources and incorporate regional data as available. Of course one could argue with some of the values, but reasonable judgment has been used to pick representative values.

Chapter 10 Dose and Risk Calculations

Unlike most of the other chapters, Chapter 10 seems to try and address the knowledgeable lay reader.

Federal Guidance Reports 11, 12 and 13U are comprehensive documents and largely represent the state-of-the art in dose and risk assessment. The authors conclude that the error in using external dose conversion coefficients for adults to compute the doses for all age groups results in “small” errors, usually <30%. If one looks at the available literature on the computation of external dose conversion coefficients [9], they will find that the organ equivalent doses computed by different people using similar anthropomorphic models and different computer codes may vary by this percentage for many different organs. However, it seems somewhat cavalier for the author to dismiss this error by saying it is negligible compared to the errors associated with the simplified geometry in which the conversion factors were computed. The dose conversion coefficients used for external exposure are likely conservative.

Section 10.2.3: Are the authors mixing ICRP Publication 60 and 26 names? Are the Federal Guidance Reports using effective dose equivalent and organ dose equivalent (ICRP 26) or effective dose and organ equivalent dose (ICRP 60)? Sometimes in this chapter one sees effective dose equivalent and other times effective dose. Which one is it? On page 10-9, this is stated--- I think?

Chapter 11 Point Estimate Results

Page 11-1, line 31: So effective dose was computed?

The organ and effective doses are computed for the exposure scenarios and the exposure locations. The doses are reported for each scenario in a variety of formats. The chapter is a rather straightforward presentation of the doses to individuals. The Delivery Person Family receives a large fraction of their total dose from the water pathways as does the Outdoors Person Family and the Near Water Family. The big doses with exception of child born in 1955, came from eating fish.

The chapter uses “point dose estimates” to obtain a sense of the important pathways for each individual in each scenario.

The conversion to risk is straightforward and is a standard approach to doing so.

There is nothing that appears to be grossly disparate in the doses and risks reported.

Chapter 12 Uncertainty Analysis and Results

The dose assessors used a standard approach to the uncertainty analysis and sensitivity analyses for the scenarios and individuals considered in the scenarios. They reduced the dimensionality of the study using accepted practices. They use a standard tool, Latin Hypercube Sampling, to perform the study. The probability distributions they assume are standard assumptions for environmental parameters.

I am disappointed that the point-estimate results are below the median values for the uncertainty analysis. That makes the point estimates difficult to call “representative doses” in a public meeting. However, maybe they are more realistic doses than those from the uncertainty analysis. My concern with the results in Chapter 12 is what values will be used to talk to the public. Many in the public will not understand the uncertainty results or the explanation of the median dose being larger in all cases then the representative doses for the scenarios (point-estimates).

The authors selected mid-range values for most parameters in their point estimate computations. They do a reasonable job of explaining the results given the complex nature of the model.

Page 12-9: The receptor behaviors are assumed to be fixed. There are regional data which give a range of values for such behaviors. For example, see the milk consumption data in Reference [9] which gives an average and a maximum. Similar values are in that report for other consumption behaviors.

The upper limit doses for the uncertainty analyses give an extreme upper limit of approximately 6 rem. Over 39 years, this is of very little concern, especially when compared to other risks. Of course I have abused the statistical nature of the uncertainty results by only citing one number. Perhaps these points to another concern with using the dose reconstruction in a straightforward manner in public: “What is the answer if you are not a statistician?”

Chapter 13 Conclusions and Recommendations

I concur in general with the conclusions.
Some of the recommendations made in the report for future work are listed below with my comments:

- Look at large, acute releases to see if the pattern of doses would be changed significantly.

  This would really require at least hourly wind data. I do not think it will yield any significant changes. It seems that the dose bounds from the uncertainty analysis would envelope any changes from this analysis.

- Examine the buildup of long-lived radionuclides in soil to determine if terrestrial doses change significantly.

  I scoped numbers for Cs-137. It could make a difference, but I feel that the statements made about the authors about its minimal impact is likely correct.

- Model contamination in reservoirs to see if it causes significant doses.

  It would be good to look at this effect with a scoping calculation from a spreadsheet to see if it would lead to significant changes. One should include runoff from the soil in the watershed in the scoping study. One might as an alternative look at a stocked fish pond. I am told that this is common in the area; however, it may be rather recent phenomena.

- Compare modeled concentrations in foodstuffs (fruit, vegetables, grain, beef, deer, etc.) with monitoring data for model validation.

  Of course this would better validate the modeling, but given the large uncertainty in environmental parameters and pathway modeling it would probably prove to be an unproductive avenue to embark upon. In addition, it would be a time-intensive activity.

- Perform an auxiliary analysis to determine if the breast-feeding of infants changes dose substantially.

  I don’t have a comment on this recommendation as it is far beyond my area of expertise.

- Perform an auxiliary analysis to determine how in-utero doses change total dose and cancer risk.

  This seems like a difficulty undertaking that would be wrought with many uncertainties. It may open more modeling questions than it answers SRS dose reconstruction questions.

- Model consumption of venison more carefully to see if the result changes.

This would be an interesting avenue to explore, but it probably will not yields tremendous increases in doses. Based on the Attachment J in Appendix T, I would not pursue it except for the science involved.

- Model dose from the consumption of drinking water taken from the Savannah River for municipal water supplies some distance downstream from the SRS (i.e., the municipal water intakes at Port Wentworth, Georgia, and Hardeeville, South Carolina, for Beaufort and Jasper Counties).
-

This does not seem like a profitable undertaking.

- Obtain technical peer review of the study by publishing papers on the methods and results in peer-reviewed journals.

This is a very good idea but probably a little too late. It would have been a method of obtaining independent reviews of the work by publishing individual parts of the assessment which would have been reviewed by experts in a specific field and by more than one expert. It seems that if this were to be done, one would want to publish pieces of the reconstruction prior to assembling it into the final dose reconstruction document.

Appendix A Merging Air Release Sources

This appendix addresses the use of four virtual used to represent the approximately 15 major sources of air emissions from the SRS. The virtual sources were used to reduce the volume of data that had to be processed and handled. On page A-7, the way in which the GENII code handles multiple source locations is to shift the coordinate grid to the sources. So the sectors in which the air concentrations are calculated are centered about the source location to which the grid center is shifted. As a consequence the exposure from two nearby sources can change substantially because of this methodology. This can lead to a nonphysical change in the concentrations at a given location. This problem was avoided by slightly shifting the coordinates of two of the locations of interest. This is acceptable since sector averaged concentrations are being used.

The dilution factors between actual and virtual sources are presented in the appendix as percent differences to illustrate the impact of using four virtual sources rather than the 15 major sources. The comparison demonstrated that the virtual source in each of the four locations represented the combined effect of all the real sources, if they were of nearly equal magnitude, in a group better than a single real source in that group.

As I previously mentioned, except for time, it seems rather straightforward to program the preprocessor and postprocessor to do the 15 source computations.

Appendix B Radionuclide Source Terms Used for Phase III Analysis

I have no comment as it is a listing of the source terms.

Related Matters from Appendix C

Section C.2.2: Equal amounts by mass or atoms of Zr-95 and Nb-95 atoms are created only if the fissions occur at a single instant in time. During irradiation in a reactor, the isotopes build up according to the following equations.

$$N_{Zr} = \frac{\dot{F}y_{Zr}}{\lambda_{Zr}}\left(1-e^{-\lambda_{Zr}t}\right)$$

$$N_{Nb} = \lambda_{Zr}\dot{F}y_{Zr}\left[\frac{\left(1-e^{-\lambda_{Zr}t}\right)}{\lambda_{Zr}\left(\lambda_{Nb}-\lambda_{Zr}\right)}+\frac{\left(1-e^{-\lambda_{Nb}t}\right)}{\lambda_{Nb}\left(\lambda_{Zr}-\lambda_{Nb}\right)}\right]+\frac{\dot{F}y_{Nb}}{\lambda_{Nb}}\left(1-e^{-\lambda_{Nb}t}\right)$$

Where $\dot{F}$ = the fission rate,

y_{Zr} = cumulative fission yield of Zr-95

y_{Nb} = independent fission yield of Nb-95

λ_{Zr} = decay constant for Zr-95

λ_{Nb} = decay constant for Nb-95

N_{Zr} = Number of atoms of Zr-95after time *t*

N_{Nb} = Number of atoms of Nb-95 after time *t*

t = time irradiated in the reactor

At the end of irradiation time *t*, the activities of Zr-95 and Nb-95 are:

$$A_{Zr} = \frac{\dot{F}y_{Zr}}{\lambda_{Zr}}\left(1-e^{-\lambda_{Zr}t}\right)$$

$$A_{Nb} = \lambda_{Nb}\lambda_{Zr}\dot{F}y_{Zr}\left[\frac{\left(1-e^{-\lambda_{Zr}t}\right)}{\lambda_{Zr}\left(\lambda_{Nb}-\lambda_{Zr}\right)}+\frac{\left(1-e^{-\lambda_{Nb}t}\right)}{\lambda_{Nb}\left(\lambda_{Zr}-\lambda_{Nb}\right)}\right]+\dot{F}y_{Nb}\left(1-e^{-\lambda_{Nb}t}\right)$$

The fission yield data from England and Rider [7] for mass number 95 are given on the next page per 100 fissions. Since all precursors to Zr-95 have very short half-lives, it can be assumed that the cumulative yield for Zr-95 (6.5%) can be used for the y_{zr} value. The direct yield of Nb-95 from fission is so low that it can be assumed that all the Nb-95 comes from the decay of Zr-95, i.e.

$$A_{Nb} \cong \lambda_{Nb}\lambda_{Zr}\dot{F}y_{Zr}\left[\frac{\left(1-e^{-\lambda_{Zr}t}\right)}{\lambda_{Zr}\left(\lambda_{Nb}-\lambda_{Zr}\right)}+\frac{\left(1-e^{-\lambda_{Nb}t}\right)}{\lambda_{Nb}\left(\lambda_{Zr}-\lambda_{Nb}\right)}\right]$$

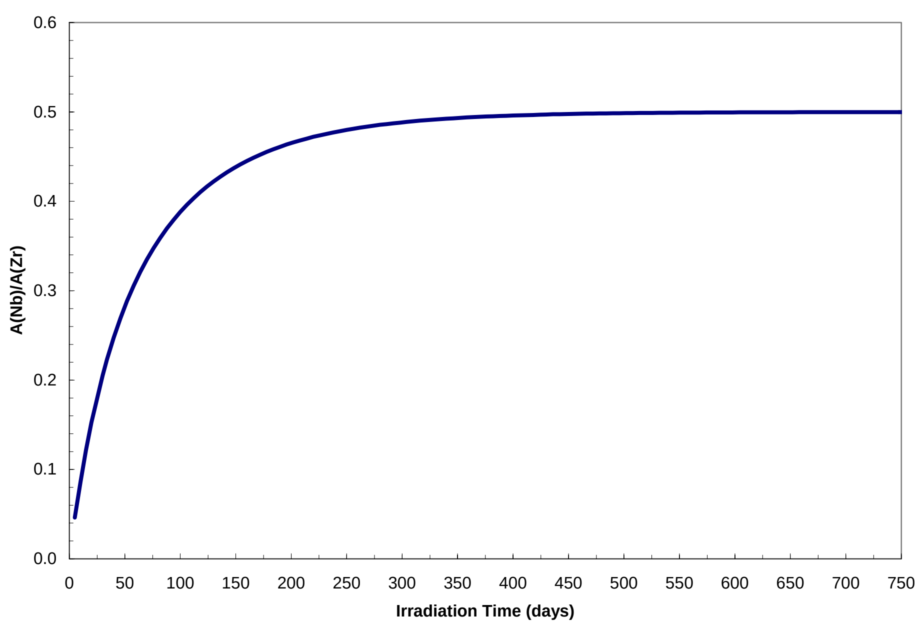
If one solves this equation (analysis in Excel Workbook *fp_yield.xls*) and plots the ratio of the resulting Nb-95 activity to the Zr-95 activity, the ratio approaches 0.5. The plot is shown on the next page. This means that the total activity should be apportioned equally

(50%-50%) between Nb-95 and Zr-95 and not in a 65%-35% split as stated on page C-12 for the reactor areas. Furthermore, equation C2-5 is not the correct equation for computing the time of maximum Nb-95 activity after removal from the reactor. The reason is that the maximum Nb-95 activity is present when the material is removed from the reactor for any reasonably long irradiation time. The equation used in the Appendix would be correct if there were no Nb-95 activity upon removal from the reactor.

Fission Yields of Mass Number 95 per 100 Thermal Neutron Induced Fissions in U-235 [7]

Nuclide	$t_{1/2}$	Independent Yield	Cumulative Yield
^{95}Kr	0.78 s	7.19E-03	7.19E-03
^{95}Rb	0.377s	7.64E-01	7.70E-01
^{95}Sr	25.1s	4.54E+00	5.27E+00
^{95}Y	10.3 m	1.11E+00	6.38E+00
^{95}Zr	**64.02d**	**1.27E-01**	**6.50E+00**
^{95m}Nb	3.61 d	2.48E-05	6.51E-02
^{95}Nb	**34.97d**	**1.06E-04**	6.50E+00
^{95}Mo	stable	4.94E-10	6.50E+00

.



In addition, the appendix then states that after the time computed in equation C2-4, Nb-95 is in transient equilibrium with Zr-95. This is not true. It takes about 500 days for the ratio of the Nb-95 activity to reach the factor of 2.2 times the activity of the Zr-95. At 67 days the activity ratio is approximately 1.0 and increases to 2.12 at a year (see plot *Nb to Zr activity ratio after* in the *fp_yields* workbook).

Apparently the authors found the referencing of unnamed documents in some set of class notes from NE 301 in 1988 at some undisclosed location to document their transient equilibrium assumption, namely Reference 8 on page C-46. Just about any health physics book or handbook could be referenced here, so why reference class notes that we all do not have available to us.

All of the above may have no real impact on the doses computed as the Nb-95 contributions are very low, but it makes one wonder about the other techniques which rely on more convoluted manipulation of data to carry out the dose reconstruction.

Table C-9 is in question. Eisenbud [1] reports that a nuclear reactor produces an activity ratio of Cs-134 to Cs-137 which ranges between 0.4-0.6. Faw and Shultis [2] report data from a 1988 UN study that yields a ratio of Cs-134 to Cs-137 activity in the vicinity of 0.5 – 0.55 when discussing liquid effluent releases from BWR's and PWR's. Table 8.1 in reference [3] for discharged fuel for a 1000 MW_e reactor and three-year fuel irradiation that 6.7 MCi/y and 2.94 MCi/y for Cs-134 and Cs-137, respectively. In Table 8.1 of the same reference, the fission yields for Cs-133, Cs-134 and Cs-137 are reported to be 5.37%, 0.694% (or maybe almost zero based on other sources) and 6.02%, respectively.

As stated in the report, most Cs-134 is produced by neutron capture in Cs-133 (158 barns effective cross section at thermal energy) and Cs-134 also has large capture cross section (129 barns effective cross section at thermal energy). So the accumulated yields in Table C-9 for Cs-134 are not based on the conversion of Cs-133 to Cs-134 in the reactor. In the dose assessment, all the Cs was assumed to be Cs-137 since they assumed that very little Cs-134 was present. However, this may not be the case based on the cited information above. Cs-134 does have larger inhalation, ingestion and ground surface dose coefficients than Cs-137 and therefore could impact some of the reference scenario results. It would require detailed reactor operating histories to compute Cs-134 and Cs-137 activities as irradiation time of the fissioning material dictates the relative ratio. However, the present assumptions in the report seem to not make any attempt to address the conversion of the stable fission product Cs-133 to Cs-134. The KAERI data cited must not include the activation of Cs-133 to yield Cs-134 in its accumulated yield values.

Table C-10: If the uranium is truly "natural uranium", there is no U-236 present. If the depleted uranium is not the tails from the enrichment of reprocessed uranium, there should be no U-236 present in it either. So these entries in the table are zeroes and not "No Data Available." If there is U-236 present in the enriched uranium, it is more than just enriched it has also been reprocessed. It would also be a straightforward calculation to estimate the U-234 in the depleted uranium, although it would be of no practical significance in the current dose computations.

It is disappointing that the modeled concentration for H-3 in the Savannah River (Figure C-3) underpredicted the measured values for most of the years for which measured data existed. Why not piece together the model results and the measured data when it is available?

Appendix D Transport, Pathway and Dose Assessment

This appendix summarizes the GENII code mathematical relationships.

Page D-36 – Is the second equation supposed to come from the differential equation above it? It is the same as the contaminated soil concentration less division by the mass on page D-32. I understand that leaching was not considered in the external dose soil concentration but was it for the agricultural soil concentrations (chapter 8). The differential equation is for areal concentration on the surface of the soil. I guess this would be used for a surface source treatment of the deposited radionuclides. It would be difficult to reference any equations in Appendix D as they are not numbered.

Page D-32: The equation for C_{esi} is incorrect. The value $C_{Si}(T_{yr})$ is the average concentration for the concentration present in the soil at the start of the current year. It is set to zero, is it not?

Appendix E Receptor Activities and Usage Rates

The seven exposure scenarios are described in detail along with the derivations of the data which depends on human patterns of activity. By and large this section is complete as will be discussed in the section on the data check for running GENII.

The use of adjustment factors (Section E.4.2) is somewhat confusing without multiple readings. These factors are used to adjust GENII exposures and particularly to correct for the fact that GENII does not include mechanisms to correct food grown imported from outside the assessment area. It is not clear to me if the factorsy are applied in the postprocessor or after postprocessing. This impacts the ability of a practitioner to

Appendix F Site Specific Parameter Values Used for Base Case

This section includes most of the parameters used in the GENII code that do not depend on the behavior of the receptors. When I tried to create a GENII run, I found that some values requested by the code are not in this Appendix, like the diameter of the stack. I used the defaults in the code. I presume that the preprocessor supplies those values to the code.

Appendix G System Implementation

As stated the input files are huge and the use of a preprocessor/postprocessor was a good approach. I did not have the preprocessor or the postprocessor available to me. The CDC may want to provide access to them as well as the input files in an electronic format.

Appendix H Selection of GENII, Version II, For Assessment of Doses and Risks for the SRS Dose Reconstruction Project

I have no comments on this section.

Appendices I-T

Appendices I-K are spreadsheets showing the component doses for the representative hypothetical receptors.

Appendices L-M discusses the data and methods for the uncertainty analysis.

Appendix R is almost a duplicate of Appendix C. Maybe it is not needed. Was it a white paper along the way.

Appendix T has a set of decision data.

Parameter Availability and Adequacy to Perform GENII/FRAMES Runs with the Data Used in the Report

The objective was to determine if all the data needed to run the FRAMES/GENII code package were available in the SRS dose reconstruction report submitted to the CDC. The preprocessor written by the authors of the dose reconstruction report was not available and this leads to the need to assume some input that was probably hardwired into the preprocessor. In addition the postprocessor uses adjustment factors from Appendix E to adjust the GENII results for its inability to completely model the detail proposed in the report, e.g. the food fraction imported from outside the assessment area. So only an attempt to create GENII input for one of the hypothetical receptors was attempted. Several limitations and difficulties were encountered.

The first problems arose from the difficulty of installing and running the FRAMES/GENII code package which was received electronically from the CDC. The installation directory and default parameters as transmitted were not adequate to get the code to run on the PC. Even after following the additional help files enclosed with the code, the program still would not run correctly. The code worked after several modifications were made to the installation file creations and directories. Since the present discussion is not a review of the FRAMES/GENII code package, the problems with installing it will not be enumerated here.

In terms of data input for a GENII run, no meteorological data file was provided with the report. A table should be added to the report listing the joint frequency distribution for wind speed, stability class and direction. The accompanying STAR file for Columbia, SC, was attempted to be used as input to the code, but the code would not run with it. One possibility is that I did not make all the installation corrections needed. In the end a file of MET data obtained from the internet was used in order to move beyond this portion of input to see if other data could be input.

After review of the data provided in the report, the preprocessor and postprocessor for the radionuclide sources should be provided if a true check of the modeling is desired. Some variables that the code asks for are not listed Appendix F like stack exit temperature, velocity and exit area; it is assumed that the default in the codes were used. However, without the preprocessor, it is difficult to say for certain.

In some cases, one had to peruse large portions of the document to supplement or fully understand the information in the tables in Appendices E and F. As an example, the variables associated with beef and dairy cattle consuming hay are somewhat confusing. In the report it is mentioned that Bermuda grass can be grown and cut often for hay. It is mentioned that cattle forage year round but also states that they do eat hay. Similarly the table in Appendix F says that the consumption ratio of grain by beef cattle is zero; however, the code requires a minimum value of 0.001 kg/d for the CONSUM variable.

Similarly on page F-32, the default value for the Translocation for animal feed – poultry feed was set to 0.1. The table states that the default average value is 0.1 in the code. However, when working through the GENII input, the default value is listed as 1.0, not 0.1 as shown in the table. Is this a typographical error in the table or does the preprocessor set it to 0.1? This item is rather a mute point as one can input 0.1, but did the authors mean to use the default of 1.0?

Another problem encountered is that the GENII/FRAMES code asked for values of several variables which had to be inferred or defaults selected from the GENII code. Some of these choices involved more sophisticated treatment of parameters which I assume were not used. Other variables such as chemical formula molecular weight solubility in water have to be taken to be either the default value or left blank due to the lack of data. Again most of these are probably hardwired in the preprocessor so were not reported in the report. The assumption is that no one would try to run the reconstruction directly inputting the information into GENII.

Lastly, several values usually cited as default values, that were listed in the tables in Appendices E and F were not accepted by the GENII code package. Examples of this include the average daily rain rate which is 11.4 mm/d in the report; however, the code only allows a maximum of 10 mm/day to be input.

Some mis-typed values were encountered. On page F-53 the value $10x10^{-7}$ is really $1.0x10^{-7}$. On page F-52 the word "adsorption" is used in the table but the code requests a value meant to be absorption. I assume that the adsorption value is to be input at that point.

All in all, the majority of the data required to run the SRS scenarios, albeit requiring some minor assumptions and often discussed in a somewhat muddled manner, are available in the report. I have attached the not and output decks which I created for the average adult male rural family member for a one year release in the checking. It is rather large and can be submitted if you so desire. Keep in mind that I did not reproduce the values because I did not have the joint frequency wind distribution that was used in the dose reconstruction report. The input file was created so that I was able to try and input parameters one-by-one and make sure they were available in the report.

One must have the preprocessor and postprocessor to use the defaults the assessors used without explanation and to adjust the GENII output for its deficiencies in certain areas such as the imported food example I previously measured. With these processors and the report plus the wind data in hand, I am confident that one can perform the dose reconstruction computations with GENII. A more profitable check of the results would be to run a different assessment code using the scenarios and their associated data from the report.

Please contact me if you have additional questions about my comments or the report.

Sincerely,

Nolan E. Hertel, Ph.D., P.E.

Click here to download the supporting files.

Of An Editorial Nature

data ….was" occurs too often to enumerate them all.

"et al" should be "et al." - many times usually in connection with reference to Cummins.

Many of the Tables have more significant digits than the data warrant.

The term now used internationally is dose conversion coefficient and not dose conversion factor. I do not care which is used, it is just an observation.

Executive Summary

Page i: "HES" should be spelled out the first time it is referenced.

Page ii: "(2.)" should be (2).

Page viii, 1st paragraph of 2.1, second line: "Born" should not be capitalized.

Page xv, last complete line on the page. It should read SRSHES. I assume that this is the SRSHES. So two different acronyms are used for it?

Page xvii, second line in #2, "release of to water" to "release to water"

Page xx, "Till JE should be Till, J.E. to be consistent.

Chapter 1

Page -4, Line 33: should "Technical Challenges" be at the start of that line?

Page 1-5, Line 20 "Savanna"

Page 1-10: The references in Chapter one deviate from those in the Executive Summary in that periods are not placed after the initials of the authors. The references are never in quite the same format for a given Chapter.

Chapter 2

Page 2-17, Lines 18-19 "highest levels …in winter and spring and the lowest levels occur in fall and winter" ---- Winter is true in both cases?

Chapter 3

Page 3-13, line 16 "Times" → "Time"?

Chapter 4

Page 4-12, lines 44-45: “Seivert” should be “sievert”.

Page 4-16, Ref.3: period is missing after “E”

Chapter 5

Page 5-5, line 28: “III” should be after “Phase”?

Page 5-10, line 1: “SRS.2” should be “SRS.(2)”?

Chapter 6

Page 6-8: It looks like the authors of this chapter intended to use the “Authors, Year” approach to referencing then switched to numbering the references. So there is no need for “Till and Meyer, 1983” in Reference 1, etc.

Lots of was’s instead of were’s when “data” is the subject of the sentences in this chapter.

Reference #5: “Meterological” should be “Meteorological”.

Chapter 7

Page 7-5, step S-4: “.Phase the II model” ??
0
Page 7-16, footnotes to Table 7-6. The references are not at the end of the Chapter.

Page 7-20: Should Figure 7-5 be 7-7? A ”) ” is missing in this caption.

Page 7-21, Last paragraph, 1^{st} line: Figure 7-8?

Chapter 7 General Comment: The chapter could be more to the point. The simple model could be dismissed with a sentence saying it was tried and did not work. Things are somewhat confusing on the first and even the second reading. Maybe a technical editor should be asked to read it.

Same comment on Chapter 7 references as for Chapter 6 ones.

Chapter 8

In Table 8-1, the K_d for Sr is 3041. It is 3040 in Table 7-6. A typo? Not that it impacts anything.

Chapter 9

Page 9-9, line 21: “Variables (3), (4), and (5)” is confusing as the key variables are not numbered in the text.

Chapter 11

Table 11-5: the value for dose to the adult female from soil ingestion is split on two lines, i.e. the exponent of -7 is on a different line than the remainder of the number. Similarly in Table 11-8.

Table 11-10 has it last line on page 11-27 rather than with the rest of the table. There is also a stray “1” on the top of page 11-26.

Table 11-11 is split between two pages. Maybe it was my printer?

In fact many tables are split between two pages.

Page C-11, equation C.2-2: If N_o is the number produced per fission event, then the activities are also per fission event.

Page C-28, Table C-18: On Tc-99 line, “Hydrogent” should be “Hydrogen”

Page C-46: Bad indention on Reference 5.

Page C-46: Reference 8 – unlikely a reader would know what this is or where to find it.

Page D-31 – equation for soil removal rate constant should be (P+I-E) in the numerator and not (P+1-E)

Page D-22, 6th paragraph – respectively needs to be set off by commas

Page D-24, 2nd to last line: “prepareres” should be “preparers”.

Page D-32, after equation, “Where” is on the wrong line. Also on Page D-33 after second equation on page. Also after second equation on page D-34. A “cut and past” propagation.

Page D-35: There are 2 periods after the last sentence on the page

Page D-36 a space is needed after “Where” after the second equation.

Page D-38: after 2nd equation the misplaced “where” occurs again.

Page D-39: What does “*Need better words”* in the first paragraph of D.3.4.1.7

Page D-39: “where” misaligned

Page D-45: heading D.3.4.2.4 “radioactive” needs to be capitalized.

Page D-51: should it be “radiation weighting factor” instead of “weighting factor”? If using ICRP 60 terminology. Throughout the remainder of the chapter this interchange of terminology occurs as well.

Page D19: “Swim-ming” does not need to be hyphenated – Table D-13

Page D-31: footnote #12 , should the word be “cited” rather than “sited”?

Page D-32: The equation for C_{esi} is incorrect. The value $C_{Si}(T_{yr})$, if it is really the average concentration for the soil at the start of the current year needs to be corrected for decay and leaching during the year under consideration.

Page D-33: The variable on the left hand side of the equation should be C_{sai} and not C_{esi}

Page G-1: 2nd paragraph, line 3: is it “GENII-V3”? or is that at typo. Same line, delete the “was” at the end of the line.

Page 13-5: Table 13-4 has the same heading as does Table 13-3.

References

1. M. Eisenbud, Environmental Radioactivity From Natural, Industrial, and Military Sources," 3rd edition, Academic Press, Inc., New York, 1987.
2. R. E. Faw and J. K. Shultis, Radiological Assessment Sources and Doses, American Nuclear Society, 1999.
3. M. Benedict, T. H. Pigford, and H. W. Levi, Nuclear Chemical Engineering, McGraw-Hill, Boston, 1981.
4. B. B. Looney, M. M. Grant, and C. M King, Estimating of Geochemical Parameters for Assessing Subsurface Transport at the Savannah River Plant: Environmental Information Document, DPST-85-904, March 1987.
5. U.S. Environmental Protection Agency, EPA Draft Guidance for Performing Screening Level Risk Analysis at Combustion Facilities Burning Hazardous Waste, Office of Emergency and Remedial Response, Office of Solid Waste, April 15, 1994.
6. F. W. Whicker, J. E. Pinder, J. W. Bowling, J. J. Alberts, and I. L. Brisbin, "Distribution of long-lived Radionuclides in an Abandoned Reactor Cooling Reservoir," Ecological Monographs 60, 471-496 (1990).
7. T.R. England and B.F. Rider, "Fission Product Yields per 100 Fissions for ^{235}U Thermal Neutron Induced Fission Decay, LA-UR-94-3106, ENDF-349.
8. Chase and Rabinowitz,
9. International Commission on Radiation Protection and Measurements "ICRP Publication 74: Conversion Coefficients for use in Radiological Protection against External Radiation" Annals of the ICRP **26**(3) (1996).
10. D. M. Hamby, "Land and Water Use Characteristics in the Vicinity of Savannah River Site (U), WSRC-RP-91-17, March 1991.