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U.S. Nuclear Regulatory Commission
ATTN: Mr. Michael L. Fuller
Division of Waste Management and Environmental Protection
Two White Flint North
11545 Rockville Pike
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Washington, DC 20555

Subject: Transmittal of Description of Methodology for Biosphere Dose Model BDOSE™ and Comment Responses Deliverable 14003.01.006.220, Final Revision 1

Dear Mr. Fuller:

The purpose of this letter is to transmit the subject deliverable. The final copy of the model/code and documentation was prepared to describe the results of activities under Task 6 [Enhancements to the Biosphere Model (BDOSE) and Related Work]. This version of the model/code and documentation includes addressing additional comments by the U.S. Nuclear Regulatory Commission (NRC) that were received on September 30, 2008. For clarity, we have also documented our responses to those comments separately. We appreciate the careful evaluation of the documentation and model by NRC staff. Their comments have led to some additional improvements in the model and documentation.

As a result of the comments, the input for drinking water ingestion in the generic input dataset should be changed to a normal distribution with a mean of 337 L/yr and standard deviation of 100 L/yr. Please ensure all users are notified of this.

If you have any questions regarding this report, please contact me at (210) 522-6260.

Sincerely,

Ali Simpkins

Ali Simpkins
Assistant Director
Environmental Science and
Environmental Engineering

AS/ls
Enclosures
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COMMENTS ON BDOSE V. 2.0

Generic

1. List the changes that were made to BDose from V. 1.0 to 2.0 in this comment response. Describe any benchmarking activities comparing the two versions of BDose and any other codes. Explain any differences observed between BDose, earlier version, and other codes. If benchmarking was not performed, explain how the model was checked for accuracy.

Response: These changes are documented within a series of Software Change Reports. Validation testing was performed for each software change report. Validation testing includes checking to see if the model produces desired results. This was primarily done by benchmarking with BDOSE Version 1.0. A brief summary of the changes is listed below as taken from the Software Change Reports.

- Input parameters are scattered throughout the graphical interface in BDOSE. To enhance transparency and improve quality control capabilities these parameters have been consolidated into a single container, "BDOSE_Inputs."

- Implemented a stochastic model for soil K_ds.

- Moved the fluid element "BDOSE_soil" to the physical soil submodel to ease BDOSE installation into existing models.

- Concentration limits were implemented for radionuclides in submodels where the intruder source calculations occur.

- Result summaries for receptors were edited to only include those pathways selected.

- Created and implemented a dynamically-linked library that calculates peak of the mean values for the receptors, and creates a file for all realization values at the time step of the peak of the mean.

- Soil K_d values in BDOSE were updated from Table A–4 of the methodology description report to correct data entry errors for Se, Ra, and Am.

- Default input values were changed for the following parameters with the new values shown.

  — Drinking water consumption: Normal Distribution: Mean 337 L/yr, Standard Deviation 100 L/yr. Note: This change will need to be made in the current generic input file used by NRC, not in the SRS input file.

  — Transfer Factor for Leafy Vegetables for Uranium: changed to 8.3e-03 to correct a data entry error.

Methodology Documentation

2. Figure 2-1, The Figure implies that the groundwater concentration extracted from the well for drinking water is different than the concentration of groundwater used for an irrigation well; that the irrigation well is drawn from the groundwater; and the drinking water well is used for animals and the irrigation well is used for crops. In fact, the irrigation well can come from groundwater, surface water or pond water, and the crop and animals can draw irrigation water from all three sources as well. The figure should be updated to correct this inconsistency.

Response: Figure revised.

3. Page 13, The intruder scenarios are described in Section 2.3. For the intruder scenarios, BDose provides the user with the option of selecting non-contaminated water or water defined by resident scenario in the user inputs ("Triggers, Switches, and Controls"). It is not clear if the groundwater concentrations input for the resident scenario are used to calculate the drinking water doses and if the contaminated groundwater is also used to irrigate the crops and for animal ingestion when this option is selected. It is also not clear if the various soil models that account for radionuclide build-up in soil would be considered for the case where contaminated groundwater is applied. Please clarify in the methodology document and within BDose itself.

Response: Sentences added in first paragraph of 2.3.

4. Equation 2-1, Because the concentration in groundwater is a function of time, Eq. 2-1 and corresponding variable definitions should be changed to indicate the time dependency of the irrigation deposition rate and groundwater concentration.

Response: Equation modified.

5. Equation 2-2, Because the soil concentration is a function of time, the term in Eq. 2-2 should indicate the variable is a function of time consistent with the $C_{soil,i}$ variable definition below the equation.

Response: Equation modified.

6. Equation 2-3, Specify if the leaching loss rate is constant. The leaching constant is expressed as a first order decay constant based on the penetration depth of the radionuclide in relation to the thickness of soil contamination. Because the depth of contamination could theoretically change over time as the source is depleted (as is done in other codes), it is not clear if the rate is constant. This also pertains to the erosion constant.

Response: Text added to clarify.

7. Page 6, Eq. 2-2 contains terms to account for radioactive decay of radionuclides assuming a constant application rate; however, it is not clear how build-up of concentrations in soil due to in-growth of parent constituents is considered in calculating the soil concentrations of daughter products, if at all. As a GoldSim cell element is needed to account for radioactive in-growth and decay, explain how the stylized

calculation used for Soil Model 4 differs from the concentrations in Soil Models 5 and 6 which account for in-growth.

Response: Several modifications have been made to the text for Soil Models 4, 5 and 6. Paragraph also added prior to the individual soil model discussions to clarify how GoldSim works.

8. Explain how the explicit consideration of radioactive decay in Eq. 2-2 to calculate the soil concentrations over time prevents double counting of decay removal mechanisms, as it is not clear that only Eq. 2-2 and not GoldSim which also accounts for radioactive decay is removing mass from the soil column (e.g., how is decay treated differently in Soil Models 1–4 versus Soil Models 5 and 6). If necessary, provide a warning to the user regarding this potential problem.

Response: There is no double counting of decay removal based on how GoldSim tracks materials. Text added prior to discussion of different soil models to address how GoldSim tracks materials.

9. Page 7, The soil depth in Eqs. 2-3 and 2-4 is supposed to correspond to the root zone. Indicate what root zone depth is the default in BDOSE. Specify what parameter in Table A-1 corresponds to the soil depth (it appears to be the soil plow depth in BDOSE). In general, the parameter names used in these equations should be used in the BDOSE model itself or a cross-walk provided so the user knows what the parameter values are and how they are used in the BDOSE model. Otherwise, it is left for the user to try and figure out how the parameter values described in the methodology documentation are used in the model.

Response: Parameter name has been changed in the equations to those used in BDOSE.

10. Page 7, The text states that for Soil Model 1, a constant value is calculated over time. Because the groundwater concentration is a function of time, unless the groundwater concentrations were held constant, the soil concentration would not be constant over time. Please clarify this in the text. This comment also applies for other soil models (e.g., Soil Models 2 and 3).

Response: Text added to Soil Models 1, 2 and 3.

11. Page 7 and 8, In describing Soil Model 3, a statement is made that the soil concentration is constant over time for each radionuclide and considerably higher than Soil Model 2 because of the longer equilibrium time. This statement is only true if none of the first order degradation rates accounting for erosion, leaching, and radioactive decay are very large (in which case the equilibrium time would be very long). If any of the radioactive decay constants are relatively large, then the equilibrium time would be low (or fast), in which case the soil concentration would be reach equilibrium before 1 year (would be the same as Soil Model 2). Suggest providing additional text regarding the range of equilibrium times for the radionuclides evaluated in BDOSE. Suggest also providing additional details regarding the problem with approaching equilibrium when time-varying groundwater concentrations are used in BDOSE.

Response: Text added to Soil Models 1, 2 and 3.

12. Page 8, The text describing Soil Model 4 states that removal mechanisms are considered for the time period up to the year in which the concentration is being estimated and that the equilibrium time used in Eq. 2-2 is equal to the time in which the calculation is being performed. It is not clear what year the concentration is being estimated and the calculation is being performed. Is the author referring to the time steps established in the run simulations or some other time period? Explicitly state when the soil concentrations are being calculated by these various different soil models and how the run simulations do or do not affect the calculations and results. As dose is usually calculated for one year time intervals, and the run simulations are set up to have 10- or 50-year time step intervals by default, explain how the simulation settings would affect the results in the case where groundwater concentrations are assumed to change every year.

Response: Text added to refer to the timesteps within BDOSE.

13. Page 8, The text describing Soil Model 4 states that the model will overestimate build-up of only C-14 because it does not track carbon gaseous emission losses. However, no information is tracked on how carbon gaseous emissions are lost in describing how the soil concentrations are calculated for Eq. 2-2. Explicitly state this additional removal information in this section or reference another section of the document where carbon emissions are described. Clarify here or elsewhere whether these carbon emissions from the irrigation deposition are considered through the groundwater to air pathway (or if the mass is just lost through the soil pathway). If dose from carbon emissions is calculated consider adding a pathway from irrigation water well to air in Figure 2-1 or footnote the table to indicate this pathway for C-14.

Response: Carbon emission losses are not part of the air pathway. Text added in Section 2.2.2 to clarify this.

14. Page 8, It was not clear that Soil Model 5 did not track the removal mechanisms for each individual radionuclide until reading the description of Soil Model 6. Provide specific details on how Soil Model 5 calculates the removal mechanisms—for example, does it se the most conservative radionuclide or does it not track the removal mechanisms separately with individual cell elements? It appears that you could enter radionuclide-specific K_ds in the B_Dose soil fluid element. Clarify the differences between Soil Models 5 and 6. Explain if the assumption regarding use of the minimum sum of the leach and erosion rate of the decay chain for the selected radionuclide is used in just model 6 (because the erosion rate is the same for all radionuclides, it would make sense to just state that the minimum leach rate is used for the entire decay chain). Please clarify.

Response: Soil Model 5 does track removal for each radionuclide individually. Text added.

15. Page 9, Eq. 2-6 provides the calculation for the contaminant concentration in a stream or river. The variable groundwater flux is included in this equation. However, it is not clear how the groundwater flux should be calculated. Because infiltration volume flow rate is the actual input parameter value used in BDOSE, the user should be given additional details on how the flux to the stream or river is calculated. Specify the underlying assumptions inherent in these calculations (e.g., groundwater velocity, aquifer width intersecting the river or stream, width of the contaminated zone, and average

groundwater concentration in aquifer should be used to calculate the infiltration volume flow rate and flux).

Response: Equation 2-6 modified and another equation added to clarify how dilution is handled.

16. Page 14, It is not clear what the concentration in surface soil is used for in Section 2.3.1 versus what the concentration in soil volume is used for in Section 2.3.2. The text states that for the chronic intruder the person farms and grows livestock on the contaminated area in Section 2.3.1, implying that the surface soil concentrations are used. In Section 2.3.2, the text states that for the chronic intruder the contamination is assumed to be plowed in the ground for farming implying that the volumetric soil concentrations are used for the chronic intruder.

Response: Text revised. Surface soil concentrations used for the chronic intruder and these are plowed in as necessary applying Eq. 2-9.

17. Page 17, second paragraph. The text states that BDOSE uses FGR 12 for external dose as ICRP 72 consistent values were not available. The report could look at page 38 of NCRP 129 "Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies," where it discusses a study by Zankl et al. which states that use of FGR 12 results in a less than 10 percent error for most photon sources.

Response: This comment will be considered for future revisions to BDOSE.

18. Page A–2, The well_diameter for the acute intruder is specified in the BDOSE model in the "Source Parameter Group" but is not included under "Source" in Table A–1. The parameter value is listed under "Acute Exposure Input" in Table A–1, while the acute exposure input "source_excavation_volume_acute" is listed under "Soil Model Parameters" in Table A–1. Additionally, The "Soil Model Parameters" section of Table A–1 includes parameters in the "Source Parameter Group" in BDOSE. There are many more examples of where the parameter locations are not consistent between BDOSE and Table A–1. The organization of Table A–1 is very confusing and inconsistent. Table A–1 organization should be consistent with the organization of the input folders in BDOSE to allow the user to more easily identify where the parameter values are located.

Response: Staff performed a complete check of parameters for consistency with BDOSE, which will allow user to search for specific parameters either in model or documentation.

19. Table A–1. Several parameter values are listed incorrectly in Table A–1 (e.g., source_excavation_volume_acute should be source_excavation_vol_acute). The parameter lists should be scrubbed to ensure that the BDose parameter names are correct in Table A–1 to facilitate finding the parameter values in BDOSE.

Response: Each parameter listed in Table A–1 has been verified for consistency with BDOSE and several changes were made.

20. Table A–1. Several parameter values are incorrect in Table A–1 (e.g., RES_water_consumption_**rate**). Table A–1 should be scrubbed to ensure the parameter values are correct.

Response: Each parameter listed in Table A–1 has been verified for consistency with BDOSE and several changes were made.

Model

21. Clarify how the no source decay sources options in the "Controls" section of the model are implemented in GoldSim (e.g., whether the no decay prevents consideration of decay in the soil models that explicitly consider decay in calculating the soil concentrations).

Response: Text has been added to the model to discuss this.

22. Several parameters used in the BDOSE model have the _c after the end of the parameter value. Please explain in the documentation or code what the _c means. The BDOSE model incorrectly refers to the _c as a cloned parameter value when model element is linked to another parameter value (rather than being a cloned parameter value). Please correct any incorrect reference to clones in the BDOSE model and verify that clones are actually used (rather than links) as indicated on page 18 of the methodology document.

Response: Methodology document has been modified to clarify that they are links.

23. It is not always clear what some of the input parameter values are in the portion of the model where the user would provide the information. For example, how are the Soil K_ds input found under the soil input parameters used (it appears to be an option for a user defined soil K_d as explained in the triggers, switches and controls portion of BDose but is not defined where the inputs are entered)? What are radionuclides 1-49? It is difficult to determine which radionuclide each of these K_ds pertains to and for what soil model they would be used for (e.g., Soil Models 2–4 and 6).

Response: Text has been added to the model to discuss this.

24. The user input for the intruder scenario related to the area that the contaminated waste is spread over (page 14, Section 2.3.1) is not included in the Source Parameter Group folder in BDOSE as would be expected. Likewise, the depth that contaminated waste is mixed into the soil (page 14, Section 2.3.2) is also not listed in the Source Parameter Group folder of BDOSE. Two different dilution scenarios appear to be included in the Source Parameter Group (e.g., dilution in well bore and dilution in excavated volume). However, these scenarios are not congruent with the documentation on pages 14 and 15. Please reconcile the parameter definitions (user inputs), scenarios, and soil concentration calculations between BDOSE V2.0 and the methodology documentation.

Response: Area of contaminated waste parameter has been moved to the source parameter group. Soil depth parameter was not moved as it pertains to other scenarios as well. Text added to Sections 2.3.1 and 2.3.2 to clarify the excavation scenario.

Editorial

25. In the folder \BDOSE\B-DOSE_Input\Controls, the "Soil K_d selector" has a copy and paste error for a descriptor related to the groundwater source switch.

Response: Text has been revised.

26. Page 17, A statement is made that doses can be summed according to the receptors in Table A–1. As Table A–1 contains a listing of parameter values, it is not clear why Table A–1 is being referred to with regard to receptors.

Response: Reference to incorrect table fixed.

27. Page 17, A statement is made that the game transfer factors are the same as the beef transfer factors and are assumed to be representative of deer. Does this statement imply that the beef transfer factors are actually deer transfer factors, that the factors for beef and deer are similar, or are the beef and game transfer factors actually two different values?

Response: Text added in Section 2.5 to clarify the use of transfer factors.

COMMENTS ON BDOSE VERSION 2.0 FINAL

1. Generic comment 1, It is not clear what the bullet "corrected conditions so that nonphysical concentrations of RN in the intruder source calculations occur" is referring to. Concentration limits for the intruder scenario soil concentrations were implemented—please clarify if this is what the bullet is referring to or if it is something else. One of the bullet states that the "soil K_d values were updated from Table 4.1 of user's manual." It is not clear how/why the partition coefficients were changed. It is also not clear why the drinking water consumption rate was changed to a stochastic distribution with an upper limit of only 730 L/yr. The transfer factor for uranium/leafy vegetables was changed by an order of magnitude—clarify the basis for this change (e.g., typographical error).

Response: Changes made to add clarification. Drinking water consumption rate changed. Please note that this change will need to be made in BDOSE Version 2.0.

2. Comment 2, the figure still needs to be revised to reflect the fact that crops can be irrigated with surface (and pond) water. Additionally, surface water can be used for drinking and irrigation water.

Response: Figure revised to link surface water to animal product and ingestion dose.

3. Comment 7, Specifically state that unlike Soil Models 5 and 6, that in-growth is not considered for Soil Models 1–4 in the methodology document. It is also not clear if the user should select the decay option with manual input of groundwater concentrations when Soil Model 5 or 6 is selected which also accounts for decay. If the purpose of the decay option with manual input of groundwater concentration is simply to account for concentrations in a stagnant water body that allows what would otherwise be constant water concentrations to decay over time, then it would be helpful to state why this option is included. For our specific problems, we will always link a time-varying water concentration from the upstream model to BDOSE; therefore, it seems that this option would be inappropriate for our problems. Please clarify in the text of the methodology documentation.

Response: Text added on page 8.

4. Comments 10, 11, 12, Several comments on the soil models were related to linking of time-varying groundwater concentrations to BDOSE and how this affects the soil concentration calculations and time to equilibrium. The text of the methodology document recognizes the case of time varying soil concentrations when decay in the source domain is considered; however, for our problems we will almost always link BDOSE to an upstream model that produces time-varying groundwater concentrations. Because in these cases the groundwater concentrations are always changing, the textual discussion related to the time to equilibrium may be misleading. For example, for Soil Models 1–3, the groundwater concentration and thus, soil concentration can change over time (they are not constant) even when source domain decay is not considered. For Soil Model 4, the equilibrium time selected is the time of the simulation for which

the soil concentration is being calculated so theoretically the soil concentration would eventually reach equilibrium if the source concentration were constant; however, the soil concentration may never reach equilibrium because the linked groundwater concentrations may be continuously changing even when the no decay option is selected for the groundwater concentration in the source domain. Please clarify these considerations in the text.

Response: Text added on pages 8 and 9.

5. Comment 13, Add text to section 2.2.2 that specifically states that although carbon emission is considered as a removal mechanism, emissions do not contribute to the air pathway dose, if this is the case.

Response: Text changed on page 9.

6. Comment 14, Specifically state that the only difference between Soil Models 5 and 6 is that daughters have the same erosion and leach rates as their parents in Soil Model 6, if this is the case.

Response: Text changed on page 9.