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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
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Subject: Final Software Validation Test Plan and Report for SIBERIA Version 8.33 and EAMS Version 2.09 (Deliverable 14003.01.007.330)

Dear Mr. Fuller:

This letter transmits deliverable 14003.01.007.330 Final SIBERIA Validation Report.

This report includes the software validation test plan and documentation of validation activities for SIBERIA Version 8.33 and EAMS Version 2.09. This validation was conducted using the Center for Nuclear Waste Regulatory Analyses (CNWRA®) Technical Operating Procedure (TOP)–18. This suite of landscape evolution software simulates long-term erosion processes responsible for the evolution of natural and artificial landscapes. This final version of the report includes changes made in response to NRC staff comments on an earlier version of the report. Responses to specific comments are included with this transmittal.

As discussed with NRC staff, the subject validation is limited. Consistent with TOP–18 requirements, selected functions of the codes were tested. Full validation of the codes would require data not presently available from physical models against which to evaluate the performance of the codes.

Please do not hesitate to contact me (210.522.6260) or Dr. Cynthia Dinwiddie (210.522.6085) with any questions about the subject report or software.

Sincerely,

Ali Simpkins
Assistant Director
Environmental Science and
Environmental Engineering

EP/AS/ls-enclosures

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Review of the

Software Validation Test Plan and Report for EAMS Version 2.09 and SIBERIA Version 8.33

[Intermediate Milestone 14003.01.007.240 (new: 14003.01.007.330)]

October 8, 2008

Response (in Italics): October 17, 2008

General Comments/Questions

(1) No mention is given in this report of the Geosciences and Engineering Division Technical Operating Procedure (TOP–018), Development and Control of Scientific and Engineering Software. How do these procedures work and how do the results of this report fit in with TOP–018? What is the final status of this code based on TOP–018?

The report conforms to the software validation requirements of Technical Operating Procedure 18 (TOP–018)—Development and Control of Scientific and Engineering Software. Software is validated to gain confidence that software successfully implements underlying theory and algorithms. Software validation test plans describe test cases that will provide evidence supporting the correct and successful implementation of software functions. (See page 1.)

(2) The report should include an introductory section that discusses the basic features of the code and its capabilities relevant to the types of processes at NDAA sites, and a crosswalk should be provided between the test case examples and these basic processes [see new VADOSE draft report].

SIBERIA was recommended to the U.S. Nuclear Regulatory Commission (NRC) staff (Walter and Dubreuilh, 2007) as a potentially useful erosion code based on a review of codes that could simulate erosion-related processes for engineered closure caps installed over radioactive waste processing tanks that are planned for in-place closure under provisions of the National Defense Authorization Act (NDAA) of Fiscal Year 2005. SIBERIA can simulate changes in cover topography and provide information about the potential for localized channel development in a cover. SIBERIA may be used to indicate the susceptibility of engineered closure caps to long-term erosion and the style of resulting erosion features and thus should be useful for evaluating the long-term integrity of engineered closure caps. The NRC staff interest in SIBERIA is mainly from the standpoint of simulating the landscape evolution of engineered waste disposal covers and surrounding terrain over a period on the order of thousands of years. Based on consideration of possible cover designs that might be proposed for in-place tank closures, the environmental processes affecting the performance of such covers, and the information likely to be available for assessing the performance of these covers, the following features are desirable for erosion assessment codes under as-built and future conditions:

- *Physics-based models and database representation of erosion processes appropriate for future cover properties and climate*
- *Ability to simulate changes in cover topography due to short- and long-term processes*

Major physical processes SIBERIA can model include fluvial sediment transport, diffusive sediment transport (e.g., soil creep, rainsplash, and rockslide), vegetation cover effects, and the topographic and erosional effects of tectonic uplift. (See page 1.)

(3) The report is lacking summary, conclusion, final software validation status, relative usefulness of the code for NDAA-site covers, and possible recommendations. A conclusion section should be added to the report that provides an overall evaluation of the capability of the code to model cap degradation and performance for radioactive waste disposal performance assessments, or a recommendations section should be added to identify additional software validation exercises that may need to be conducted to ensure SIBERIA would be able to simulate coupled processes important to cover degradation and performance. (See pages 20 and 22.)

The final status of SIBERIA as a result of this software validation is that its functionalities addressed in Test Cases 1–3 have undergone limited validation, consistent with TOP–18. Not every functionality of SIBERIA was tested herein. Additional test cases would be required, for example, for limited validation of the tectonic uplift and diffusive sediment transport capabilities of SIBERIA.

Were laboratory-scale physical analog models of landscape evolution available, they might provide an avenue for direct comparison of model results with the characteristics of a well-controlled landscape developed on a relatively short time interval. Full validation could be enabled by such comparisons.

Additional capabilities for SIBERIA under development include a soils model, a layers model, and a detachment model. The layers model will allow for up to 5 layers for erosion and deposition, and the detachment model can only be used in combination with the layers model. The soils model cannot be used in combination with the layers model. These extended models are poorly documented in the user manual. Researching relevant peer-reviewed literature to understand virtually undocumented, transitional (i.e., in non-final form) capabilities of SIBERIA was deemed beyond the scope of this software validation report. Reviewing the peer-reviewed literature concerning use of SIBERIA, however, is a logical and important next step in the process of understanding the utility of this code for specific application to NDAA sites. (See pages 20 and 22.)

(4) p. 5, Sec. 1, last paragraph:
Why do the three software validation test case exercises indicate that the SIBERIA code produces physically realistic and expected landform characteristics? (Why were these three test cases selected to verify model correctness?)

Because benchmark test cases for landscape evolution codes are unknown, this report describes a "limited validation" of SIBERIA. The scope of this software validation is limited to confirmation that the software represents physically realistic and expected landscape evolution when applied to several stylized problems. The selected test cases were selected because they were easily implementable, consistent with budgetary constraints, and because they test fundamental and long-standing aspects of the process model. More recently developed functions not yet in their final form and not fully documented were not selected for validation. Full validation of various features could potentially be enabled through replication of results from appropriately posed laboratory-scale physical analog models of landscape evolution. (See page 3.)

(5) p. 5, Sec. 1, last paragraph:
Why is the software validation associated with SIBERIA (not CHILD) considered to be a "limited validation?"

The software validation for both codes is considered "limited validation," as stated in each report. This is because benchmark test cases for landscape evolution codes are unknown, thus, there are no published studies against which our results can be quantitatively compared. (See page 3 and original CHILD report.)

Specific Comments/Questions

(6) If possible, use the term "software validation" in the report instead of just "validation."

Accomplished. (Throughout)

(7) Can Section 4 "Prerequisites" be removed?

Accomplished. (See page 4.)

(8) p. 6, Sec. 5, first paragraph:
If possible, expand on the reasons why SIBERIA cannot simulate mass transport mechanisms (one or two sentences).

SIBERIA can simulate some mass transport mechanisms, as demonstrated in the report. But, as stated in the report, SIBERIA cannot simulate mass transport mechanisms that require knowledge of regolith or soil depth to be modeled, such as plastic transport. Soil depth is variable in space and time and is a function of the geomorphology, geochemistry, and biology of and the climate acting on the catchment, and is considered beyond the scope of reliable modeling according to the SIBERIA author. (Pages 4 and 5.)

(9) p. 8, Sec. 5, 2nd last paragraph:
If bedrock channel erosion is not well modeled, can such NDAA cover layers such as lateral drain layers (gravel) or erosion resistant layers (stone and rocks) be well modeled?

Bedrock is not a component of any engineered closure cap. Intact bedrock behaves differently under erosional forces than do rocks, stones, and boulders that might be used to form erosion resistant layers. Additional capabilities under development for SIBERIA include a soils model, a layers model, and a detachment model. The layers model will allow for up to 5 layers for erosion and deposition, and the detachment model can only be used in combination with the layers model. The soils model cannot be used in combination with the layers model. These extended models are poorly documented in the user manual. For more information on the soils model, the SIBERIA user manual, dated 2005, pointed to a then-pending peer reviewed paper that has since been published (Saco, et al., 2006). Reading this and other papers to understand virtually undocumented, transitional (i.e., in non-final form) capabilities of SIBERIA was deemed beyond the scope of the software validation report. Reading the peer-reviewed literature concerning use of SIBERIA is a logical and important next step in the process of

understanding the utility of the code for specific application to NDAA sites. (See page 22.)

Reference: Saco, P.M., G.R. Willgoose, and G.R. Hancock. "Spatial Organization of Soil Depths Using a Landform Evolution Model." *Journal of Geophysical Research. Vol. 111, No. F02016. doi:10.1029/2005JF000351. 2005.*

(10) p. 10, Sec. 6.1.2, bullet 6:
Define "landscape evolution characteristics" in more detail. Provide the units in Fig. 4.

Definitions for and units of each landscape evolution characteristic are provided in the existing legend for Figure 4. No change is required. (See pages 8 and 12.)

(11) p. 13, Fig. 3:
Based on Fig. 4 and Sec. 6.1.3, why is the "Residual slope and channels after 10,000 yrs" in Fig. 3 so much lower than the "Residual slope and channels after 10,000 yrs" in Fig. 2?

To explore its viewer capabilities and limitations, we elected to display all landform results directly from SIBERIA, rather than export results to more sophisticated, third party software. To correctly interpret these figures, the reader must realize the color stretch used by EAMS-Viewer stretches twice as much for an initially 6-m-high slope than for an initially 3-m-high slope. As such, the lower elevation residual slope in Figure 2 shows both red and green tones, whereas, the slightly more elevated residual slope in Figure 3 appears nearly entirely red-toned. This outcome does not imply that the residual slope of Figure 3 is at a lower elevation than the residual slope of Figure 2; in fact, the opposite is true. The lack of axes and a color bar are additional limitations of EAMS Viewer. (See pages 10 and 11.)

(12) p. 13, Fig. 3:
Why are the boundaries on three sides of the model in the "Residual slope and channels after 10,000 yrs" in Fig. 3 of such relatively high elevation?

For algorithmic purposes, the SIBERIA author automatically adds bounding nodes that are outside the domain of the actively degrading DEM. For a one-dimensional slope, these bounding points are displayed in EAMS-Viewer as having the initial elevation of the DEM. The output does not suggest that a thin boundary around the DEM remains in place in perpetuity, rather, this boundary can serve as a visual cue for extent of landscape erosion. One can debate the merits of displaying this extra information; however, these figures illustrate how SIBERIA is coded. (see pages 10, 11, and 21.)

(13) p. 17, Fig. 7:
Why are no erosional channels forming at the four corners of the figure 7 model similar to the channels formed at lower elevations in Fig. 8 (irrespective if multi- or unidirectional)?

The unidirectional channels of Figure 7 are thought to initiate because of numerical instabilities that occur precisely at locations of abrupt slope change between the flat top and angled sides of the perfectly smooth-sided mound. Once a numerical instability initiates channel development, the channel continues to incise and grow with the

passage of time. This interpretation is supported by the observation that unidirectional channels did not form in the corner areas of the degraded landscape of Figure 7. The corner areas, while subject to an interface between two side slopes, are not subject to the same numerical instabilities that may occur only at an interface between a horizontal surface and a side slope. When a SIBERIA model of a perfectly smooth, one-dimensional side slope (in the absence of abrupt interfaces between surfaces) is run, channels do not form at all—only uniform (non-channelized) downhill erosion takes place, as would be expected for an ideal slope exhibiting no roughness. Even though perfectly smooth surfaces do not occur in nature, SIBERIA tends to produce sensible, interpretable output. *(See page 15.)*