RAI Volume 2, Chapter 2.1.1.4, Eighth Set, Number 4:

> Provide technical basis for evaluating event sequences separately on the basis of 1) individual waste forms, and 2) operational steps (SAR Section 1.7.4). For example, the event sequences, related to direct exposure resulting from failure to close the port gate during canister transfer operations in the CRCF (CRCF-ESD-18), appear to be predominately initiated by operator error, regardless of the waste form. Explain why the frequencies are not added.
>
> In Section SAR Section 1.7.4, DOE provides the rationale for segregating event sequences by waste form. In response to a staff request for additional information for RAI 2.2.1.1.3-3-014, DOE explained that event sequences are categorized one at a time, based on a waste form type, because of differences between specific event sequences. DOE attributes these differences to facility configuration, operations, waste forms robustness, throughputs, and potential dose consequences. However, DOE does not explain why these differences are relevant for purposes of categorization. Many of these different event sequences share important common operations that are independent of the waste forms. However, NRC staff did not find any discussions of the significance of similarity between different event sequences and how that may affect compliance with the performance objectives specified at 10 CFR 63.111.

1. RESPONSE

Evaluating event sequence frequency separately on the basis of specific waste forms and operational steps in the preclosure safety analysis (PCSA) rather than aggregating for purpose of categorization is based on a methodology that is consistent with regulatory guidance and industry practice. This response also demonstrates that the conservatism in the PCSA and its throughput estimates for the various waste forms produces categorizations that would not change (e.g., from Category 2 to Category 1) even if aggregated across waste forms or hypothetical combinations of event sequences across operations with common or similar steps.

Event sequences are categorized one event sequence at a time. For each Category 2 event sequence, consequences are established. The PCSA is performed using probabilistic safety assessment techniques, consistent with industry practice and regulatory guidance, as described in Attachment I, to establish a level of detail sufficient to define event sequences that best represent the design and operations of the facility and its risks. This approach is described in SAR Section 1.7.4 and the response to RAI 2.2.1.1.3-3-014. It is further explained in Attachment II with regard to the method of event sequence development, which segregates specific waste forms and major operational steps. Such segregation is needed to identify unambiguous initiating and pivotal events, clearly defined initiating and pivotal event probabilities/frequencies, and to provide accurate assignment of bounding consequences.

Once the necessary level of detail (i.e., segregation) is established to achieve an accurate risk model, event sequence probabilities/frequencies are summed. Attachment II provides the justification for segregating event sequences on the basis of major operational steps (i.e., big bubbles), which sum the event sequences arising from constituent individual challenges (i.e., small bubbles) and on the basis of specific waste forms. Categorization is based on big bubble event sequences. Attachment I discusses the practice in nuclear power plant probabilistic safety assessments of segregating event sequences into bins (such as plant damage states and release categories) in order to accurately develop consequences. Attachment I also discusses that the method used in the PCSA is analogous to that used in assessments for power plants, along with relevant guidance provided in 66 FR 55741 regarding 10 CFR Part 63. In nuclear power plant probabilistic safety assessments, all event sequence frequencies leading to core damage are summed to obtain a total core damage frequency. Because all event sequences are summed in such studies, the level of detail of each event sequence is not an issue for purposes of establishing the total core damage frequency. Attachments I and II and the response to RAI 2.2.1.1.3-3-014 conclude, in part, that: a) similar operations involving different waste forms lead to different initiating and pivotal event frequencies/probabilities, different end states, and different consequences, and, therefore, categorization based on similar operations would not be consistent with good modeling practice; b) sharing common operations does not obviate the need to analyze different waste forms as separate event sequences for purposes of categorization because different waste forms are handled differently even when using the same major piece of equipment (e.g., grapples and associated human actions), and categorization on the basis of common operations would be inconsistent with industry practice; and c) although the PCSA-derived event sequences may be summed using different criteria (e.g., human actions, operations, waste forms), the results would be a hypothetical combination of different event sequences, which do not provide the representation needed for meaningful analysis of the facilities and operations.

As discussed in SAR Section 1.6, the PCSA and engineered design are developed iteratively and interactively using risk information. The PCSA event sequences from this process were developed to the level of detail necessary to accurately reflect design and operations of the facilities. From this process, nuclear safety design bases requirements and procedural safety controls were established that results in the design and operations providing the reliability necessary to maintain the event sequence categorization presented in SAR Section 1.7. The process resulted in no Category 1 event sequences. Category 2 event sequences are shown to have consequences well within the regulatory performance objectives. The SAR presents a design which meets the nuclear safety design bases and includes the procedural safety controls as presented in SAR Section 1.9. This is done on the basis of the PCSA presented in SAR Sections 1.6, 1.7, and 1.8. As detailed design progresses, the nuclear safety design bases will be maintained through either adaptation of the design or through appropriate design basis requirement change processes (e.g., 10 CFR 63.44, license amendment). The risk-informed design process includes the potential for design and operational modifications to achieve and maintain desired event sequence categorizations.

Having established that the PCSA event sequence level of detail, which analyzes waste forms and major operations separately, is required for representational accuracy and for discerning among different consequences, combining on the basis of commonality of waste forms or operations would be equivalent to summing multiple event sequences. Event sequence CRCF-ESD-18 involves operations common to a number of different waste forms and is related to direct exposure resulting from failure to close the port slide gate during canister transfer operations in the Canister Receipt and Closure Facility (CRCF). Although CRCF-ESD-18 may be predominately initiated by operator error regardless of the waste form, the information of importance is not that operator errors contribute but how much an operator error contributes to a given event sequence. The PCSA approach for CRCF-ES-18 is to perform end-state binning based on waste form because the exposure consequence depends on the waste form direct radiation characteristics. This binning approach provides a basis for consequence comparison to the preclosure performance objective on a per event sequence basis. However, as shown in Table 1, which summarizes the event sequence end-state frequencies from *Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis* (BSC 2009a, Table 6.8-3), the frequency of a hypothetical event sequence that merges waste forms is their sum, 5×10^{-1}, which would not lead to a change in categorization from a Category 2 to a Category 1 event sequence.

Table 1. CRCF-ESD-18 Event Sequence End-State Frequencies and Categorization

CRCF CTM Event Sequence	Waste Form Canister	End-state Frequency over the Preclosure Period (Mean)	End-state Categorization
ESD18-DSTD-SEQ2	DOE Standard	3×10^{-1}	Category 2
ESD18-DPC-SEQ2	DPC	3×10^{-3}	Category 2
ESD18-HLW-SEQ2	HLW	8×10^{-2}	Category 2
ESD18-MCO-SEQ2	MCO	4×10^{-3}	Category 2
ESD18-TAD-SEQ2	TAD Canister	1×10^{-1}	Category 2
Sum		5×10^{-1}	

NOTE: CTM = Canister Transfer Machine; DPC = dual-purpose canister; HLW = high-level radioactive waste; MCO = multicanister overpack; TAD = transportation, aging, and disposal.

Similar comparisons are provided across waste forms (Attachment III) and operations (Attachment IV) to demonstrate that the hypothetical merged event sequence categorizations would not change by either summations over waste form or summations over operations. Specifically, the hypothetical summations that include Category 2 event sequences would not result in a Category 1 event sequence, hypothetical summations that include both Category 2 and beyond Category 2 event sequences would not result in a Category 1 event sequence, and hypothetical summations that include only beyond Category 2 summations would not result in a Category 1 event sequence.

In summary, the method for event sequence development followed by the PCSA is consistent with regulatory guidance, industry practice, and the modeling required to achieve accuracy in representation of the facility, accuracy in development of probabilities/frequencies, and accuracy in consequence analysis. The method used in the PCSA led to event sequence categorization that is insensitive to changes in segregation methods. The impacts of future design activities on event sequence categorization and nuclear safety design bases will be managed through appropriate design control and approval processes.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

ANSI/ANS-58.21-2007. *American National Standard, External-Events PRA Methodology*. La Grange Park, Illinois: American Nuclear Society. TIC: 259266

ASME RA-Sb-2005. Addenda to ASME RA-S-2002, *Standard for Probabalistic Risk Assessment for Nuclear Power Plant Applications*. New York, New York: American Society of Mechanical Engineers. TIC: 258909.

BSC (Bechtel SAIC Company) 2009a. *Canister Receipt and Closure Facility Reliability and Event Sequence Categorization Analysis*. 060-PSA-CR00-00200-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20090112.0004.

BSC 2009b. *Initial Handling Facility Reliability and Event Sequence Categorization Analysis*. 51A-PSA-IH00-00200-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20090112.0007.

BSC 2009c. *Receipt Facility Reliability and Event Sequence Categorization Analysis*. 200-PSA-RF00-00200-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20090112.0010.

BSC 2009d. *Wet Handling Facility Reliability and Event Sequence Categorization Analysis*. 050-PSA-WH00-00200-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20090112.0006

BSC 2009e. *Intra-Site Operations and BOP Reliability and Event Sequence Categorization Analysis*. 000-PSA-MGR0-00900-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20090112.0008.

BSC 2009f. *Subsurface Operations Reliability and Event Sequence Categorization Analysis*. 000-PSA-MGR0-00500-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20090112.0009.

NRC (U.S. Nuclear Regulatory Commission) 1983. *PRA Procedures Guide, A Guide to the Performance of Probabilistic Risk Assessments for Nuclear Power Plants*. NUREG/CR-2300. Two volumes. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 205084.

Attachment I

Consistency with Regulatory Guidance and Industry Practice

DOE applied accepted industry guidance for the development and binning of event sequences (e.g., *PRA Procedures Guide, A Guide to the Performance of Probabilistic Risk Assessments for Nuclear Power Plants*, NUREG/CR-2300, NRC 1983; ANSI/ANS-58.21-2007; ASME RA-Sb-2005) as well as available NRC guidance (e.g. Federal Register Notice 66 FR 55741 regarding Preclosure Safety Analyses, Issue 2; Division of High-Level Waste Repository Safety Interim Staff Guidance; *Yucca Mountain Review Plan*, NUREG-1804).

Although NUREG/CR-2300, *PRA Procedures Guide, A Guide to the Performance of Probabilistic Risk Assessments for Nuclear Power Plants* (NRC 1983, p. 3-106) was developed for nuclear power plant probabilistic risk assessments (PRAs), a similar methodology was used for developing event sequence binning for the PCSA. In particular, Chapters 3.8 and 7.5 provide a general approach to defining and binning event sequences for initiating events with potential for radiological consequences. The general approach to the overall modeling process can be summarized as follows: accident-initiating events are postulated, the response of the plant to each type of initiating event is evaluated, and plant-level models are developed to identify the various sequences of events that terminate in an identified plant state. Sequences that have the potential for offsite consequences are referred to as “plant-damage states” and are grouped in plant-damage bins. This grouping is performed in conjunction with the analysis of physical processes. The individual event-tree headings are evaluated by system-modeling techniques to allow the quantification of accident sequences that result in plant-damage states. The results of accident-sequence definition and system-modeling are a group of accident-sequence logic models that can be quantitatively or qualitatively evaluated.

In the task of “Selection of Initiating Events,” NUREG/CR-2300 states that “Accident-initiating events must be identified and grouped according to similarity of plant responses,” and that “The identified events are grouped by the safety function that is threatened and the effects of each group of initiators” (p. 3-108 and 3-109). NUREG/CR-2300, Section 7.5, describes approaches to grouping event sequences. The analyst develops groups of “plant event-sequence categories” identified by the characteristics that affect the release of radionuclides to the environment. All of the sequences’ end-states within a group are assigned the same radionuclide release categories. Furthermore, event sequences of different release categories may involve the same or similar operations. For example, different station blackout event sequences that lead to different release categories would involve an attempt by the operator to open power operated relief valves. Release categories for high pressure reactor vessel failure (failure to open these relief valves) would differ from the release categories for low pressure reactor vessel failure (successful opening of relief valves). Therefore, categorization based on similar human operations has been shown to lead to different end states and consequences and would not be consistent with good modeling practice.

Event sequence end-state characteristics that affect the release of radionuclides and/or direct radiation exposure are waste-form dependent. Therefore, sharing common operations does not obviate the need to analyze different waste forms as separate event sequences for purposes of categorization, and categorization on the basis of common operations would be inconsistent with industry practice.

Consistent with this practice, the PCSA includes initiating events, pivotal events representing facility response, end states, and consequence binning. Initiating events are grouped by similarity in facility response, and event trees are developed that represent this response using fault trees developed to the level at which reliability data are available. Similar to the binning process employing “plant-damage states” and segregation based on characteristics that affect radionuclide release, the PCSA uses “bounding events” as a binning technique. These “bounding events,” as described in SAR Section 1.8.2.4, were developed to envelope the potential consequences of Category 2 event sequences with radionuclide releases. The appropriate bounding event envelops the end-state conditions and material-at-risk of event sequences within its bin. The bounding events are defined for waste forms potentially involved in a Category 2 event sequence, including high-level radioactive waste; transportation, aging, and disposal canisters; dual purpose canisters; and commercial spent fuel assemblies. The bounding events are differentiated by their end-state conditions that affect radionuclide release or reactivity, such as waste form physical characteristics, release into an air or pool water environment, and containment leak path factors provided by canisters or casks.

The probability of the entire event sequence, including initiating events and the associated combinations of repository system or component failures, is considered (Federal Register Notice 66 FR 55741 promulgating 10 CFR Part 63 in response to Comment 2.1 *Preclosure Safety Analyses, Issue 2*). For example, the probability is based on the entire event sequence, which includes the initiating events and associated combinations of repository system or component failures, release of radioactive material, and exposure of an individual. The event sequences developed in the PCSA include one or more initiating events, associated combinations of repository system or component failures specific to the design features analyzed in response to the initiating event (which are called pivotal events), and end states. The end states are directly associated with release of radioactive material and exposure to radiation via bounding consequence categories (SAR Section 1.8).

As described in the response to RAI 2.2.1.1.3-3-014, the potential release and direct radiation characteristics that define an end state (e.g., radionuclide inventory, damage fraction, self-shielding, partitioning and release fractions) are dependent on the waste form involved and its configuration and robustness (e.g., canister or cask confinement). Therefore, the event sequence development and quantification must explicitly consider waste form dependence. Waste form physical and radiological characteristics and their cask/canister configurations provide different potential release, direct radiation, and reactivity characteristics that result in different end states and are thus unique event sequences even for common operational steps.

The approach to evaluating event sequences separately on the basis of individual waste forms in the PCSA is consistent with guidance and industry practice and provides an accurate representation of event sequences that accounts for fundamental differences in initiating events and their frequencies/probabilities, pivotal events and their probabilities, end states, and consequences.

Attachment II

Event Sequence Segregation Approach Background

Event sequences are categorized individually, based on a specific waste form type, because of differences between individual event sequences that can be attributed to differences in facility configuration, operations, waste form robustness, throughputs, and potential dose consequences. The importance of these differences for purposes of categorization is derived from an understanding of the process used to identify and categorize those occurrences resulting from the operation of the repository that could result in exposures to workers or the public and to demonstrate that the consequences of these occurrences are within the category-based regulatory performance objectives. This is accomplished by using a structured, logical approach to establish the levels of segregation required to create meaningful event sequences that accurately represent the design and operation of the facility.

In order to establish the levels of segregation, it is necessary to understand each activity contributing to the overall waste handling process and how it is to be accomplished. Once this is understood, it is then necessary to identify how deviations from the normal process might occur. This is accomplished through both deductive and inductive methods documented in each facility event sequence development analysis. These methods (i.e., master logic diagrams and hazard and operability evaluations) resulted in numerous event sequence initiators that could be grouped, as described in NUREG/CR-2300, based on similar system/facility responses.

The first two levels of segregation for initiating events are by facility and by major waste handling process because in order to understand and manage risks, it is necessary to know where the risk is occurring. These are natural levels of segregation, as the equipment and activities associated with each major process area are different and must be modeled separately despite some similarities in equipment and human actions. The equipment, operations, and primary confinement barriers are different in each of the facility areas, and small differences in waste form handling leads to differences in human failure event modeling. Furthermore, development of event sequences without including such important differences would result in a significant loss of risk information that is used in the development of the design. The CRCFs, however, are conservatively analyzed as if all throughput associated with three CRCFs flowed through a single CRCF.

The third level of segregation is associated with the equipment for waste handling activities. It is not sufficient to know that "something was dropped" when trying to develop and quantify event sequences and consequences. A level of segregation is established in a manner that allows the characteristics of each failure mode of each piece of equipment and human action to be included for an accurate representation of event sequences, frequencies/probabilities, and consequences. For example, quantification of event sequences and consequences for handling waste in the form of a vitrified glass log is significantly different from that for handling irradiated spent nuclear fuel. On the other hand segregation beyond the level necessary to characterize waste forms, equipment, and human actions is not needed to fully analyze the facility hazards.

The fourth level of segregation is associated with the failure modes or specific challenges posed by each piece of equipment to radionuclide containment, personnel exposure, or nuclear reactivity increase. The fourth level of segregation is necessary because, although each of these event sequences is represented using the same pivotal events, the probabilities of each small bubble and associated pivotal events are different.

Having segregated potential event sequences for the purpose of accurate modeling, aggregation for purposes of categorization is represented by the "big bubble, small bubble" concept presented in SAR Section 1.7. The individual initiators of the fourth level of segregation are represented as small bubbles and are grouped into an aggregated initiator called a big bubble. Categorization is performed on the basis of the big bubble using the summation process described in SAR Section 1.7.

The end state of each event sequence is a natural outcome determined by the system response to the initiator. The system response is represented by a series of pivotal event successes and failures along a path terminating in a unique end state on an event sequence diagram or event tree. An event sequence for purposes of categorization is, therefore, the big bubble initiating event, the series of success and failures of pivotal events, and an associated end state. Each event sequence is associated with a consequence. Summation over different big bubbles, while mathematically possible, does not provide insights into the frequency of each event sequence and does not provide the additional insight into the risk associated with design and operations. Such a summation is simply a summation over different event sequences.

Quantification of event sequences is accomplished for each individual small bubble initiating event using fault trees. These fault trees may contain similar types of basic events (e.g., human errors). Each event sequence, therefore, is represented by event sequence cut sets, and the event sequence frequency/probability is the sum of the associated cut set frequencies/probabilities. Combining event sequences on the basis of a top-level perception of similarity in human actions does not provide a sufficient basis for categorization because the human failure events are different from one operation to another and from one waste form to another. For example, the grapple arrangement for lifting different waste forms is different resulting in different human error probabilities. Summation of event sequences on the basis of similarity in top-level human actions, while possible, provides little useful insight into end states, equipment malfunctions, and event sequence consequences. In other words, such a combination is not an individual event sequence.

The PCSA-derived event sequences can be mathematically summed using different criteria (e.g., operations, human actions, waste forms). The results would be a hypothetical combination of different event sequences, which have no relationship to the representation needed for meaningful analysis of the facilities and operation.

Attachment III

Hypothetical Summation of Event Sequences across Waste Forms

If a hypothetical merged event sequence were based on a single common operation with multiple waste forms, the hypothetical merged frequency leading to all end-states independent of waste form would be the sum of the individual single waste form event sequence frequencies. This is only significant if a different overall categorization would be obtained due to the hypothetical aggregation. The difference between the magnitude of hypothetical merged event sequence frequencies and individual waste form frequencies can be estimated from the throughputs of the individual waste forms used to determine their end-state frequencies. Table III-1, developed from SAR Table 1.7-5, provides the ratio of summed throughputs for all waste forms to the highest single waste form throughput for each waste form configuration in the various facilities. For example, in the Initial Handling Facility operations involving canisters in a transportation cask, the throughputs are 600 high-level radioactive waste (HLW) canisters and 400 naval canisters with a sum of 1,000 canisters. The ratio of sum to highest single is 1.7. Therefore, a hypothetical merged frequency for a common operation involving both HLW and naval canisters would be 1.7 times the HLW canister only end-state frequency. Table III-1 shows the largest ratio is 2.2 for CRCF common operations with canisters not contained in a cask, aging overpack, or waste package. No event sequence frequency, as provided in SAR Table 1.7-11 for the CRCF, is within that ratio of a categorization boundary. Therefore, a hypothetical merger across waste forms would not affect CRCF event sequence categorization. The same conclusion applies to the other facility specific ratios in Table III-1 when operating on their event sequence frequencies. No hypothetical merged event sequence would be a Category 1 event sequence.

Table III-1. Throughput Ratios by Facility and Waste Form Configuration

Facility	Configuration During Operation	Waste Form	Throughput	Sum/Max. Throughput
IHF	In transportation cask	HLW canister	600	1.7
		Naval canister	400	
	In waste package	HLW canister	200	
		Naval canister	400	1.5
	Not contained	HLW canister	1,000	1.4
		Naval canister	400	
WHF	In transportation cask	Uncanistered Commercial SNF	3,775	1.1
		DPC	346	
	In aging overpack or not contained	TAD canister	1,165	1.3
		DPC	346	
RF	In transportation cask	TAD canister	6978	1.1
	In aging overpack	DPC	346	
CRCF	In transportation cask	HLW canister	1,960	
		DOE standard canister	385	
		MCO canister	113	
		DPC	346	
		TAD canister	6,978	1.4
	In aging overpack	TAD canister	8,143	1.0
		DPC	346	
	not contained	HLW canister	11,760	
		DOE standard canister	6,215	
		MCO canister	451	
		DPC	346	
		TAD canister	15,121	2.2
	In waste package	1 DOE standard/5 HLWs	3,300	
		2 MCOs/2 HLWs	225	
		TAD canister	8,143	1.4
Intra-site	In transportation cask	HLW canister	2,360	
		DOE std canister	385	
		MCO canister	113	
		Naval canister	400	
		Uncanistered Commercial SNF	3,775	
		DPC	346	
		TAD canister	6,978	2.1
	In aging overpack	TAD canister	8,143	1.0
		DPC	346	

NOTE: DPC = dual-purpose canister; HLW = high-level radioactive waste; IHF = Initial Handling Facility; MCO = multicanister overpack; RF = Receipt Facility; SNF = spent nuclear fuel; TAD = transportation, aging, and disposal; WHF = Wet Handling Facility

Source: Based on SAR Table 1.7-5.

Attachment IV

Hypothetical Summation of Event Sequences across Operations

If a hypothetical merged event sequence were based on multiple operations, the hypothetical merged event sequence frequency leading to all end-states independent of operation would be the sum of the individual operations event sequence frequencies. Frequencies for the event sequences leading to an end-state of radionuclide release from event sequence categorization analyses are summarized for each facility in Tables IV-1 to IV-6.

These tables provide frequencies and associated event sequence categorization based on summing over all operational steps for each waste form configuration. These tables also identify those event sequences that are currently classified as Category 2. All other event sequences are currently classified as beyond Category 2. In all cases, the summation of all the event sequence frequencies/probabilities across all operations for each waste form would produce the same categorization as the current highest categorization. The nuclear safety design bases and procedural safety controls were developed for the event sequence that led to the highest categorization. Therefore, neither changes in these requirements nor the design would be needed on the basis of this hypothetical combination. Finally, no hypothetical merged event sequence would be a Category 1 event sequence.

Table IV-1. Initial Handling Facility—Frequencies of Waste Form Handling Event Sequences Leading to Radionuclide Release

		Naval Canister Configurations				**HLW Canister Configurations**			
IHF Operation	**Event Sequence**	**Naval Canister in Cask**	**Naval Canister in Unbolted Cask**	**Naval Canister**	**Naval Canister in Waste Package**	**5 HLW Canisters in Cask**	**5 HLW Canisters in Unbolted Cask**	**2 HLW Canisters**	**5 HLW Canisters in Waste Package**
1	IHF-ESD-01	7×10^{-7}				3×10^{-8}			
2	IHF-ESD-02	1×10^{-7}				1×10^{-6}			
3	IHF-ESD-03					8×10^{-7}			
4	IHF-ESD-04	6×10^{-7}							
5	IHF-ESD-05	4×10^{-6}				6×10^{-6}			
6	IHF-ESD-06		1×10^{-10}				2×10^{-10}		
7	IHF-ESD-07			4×10^{-6}				7×10^{-3} [a]	
8	IHF-ESD-08				1×10^{-7}				6×10^{-8}
9	IHF-ESD-09				1×10^{-6}				0
10	IHF-ESD-10				1×10^{-5}				7×10^{-9}
11	IHF-ESD-11				4×10^{-6}				2×10^{-6}
Summed frequencies		5×10^{-6}	1×10^{-10}	4×10^{-6}	2×10^{-5}	8×10^{-6}	2×10^{-10}	7×10^{-3}	2×10^{-6}
Summed categorization		BC2	BC2	BC2	BC2	BC2	BC2	Category 2	BC2

NOTE: [a] Event sequence currently classified as Category 2.

BC2 = beyond Category 2; HLW = high-level radioactive waste; IHF = Initial Handling Facility.

Source: BSC 2009b, Attachment A and Table G-2.

Table IV-2 Receipt Facility – Frequencies of Waste Form Handling Event Sequences Leading to Radionuclide Release

		DPC Configurations		TAD Canister Configurations	
RF Operation	**Event Sequence**	**DPC in Cask**	**DPC Unconfined or in Aging Overpack**	**TAD Canister in Cask**	**TAD Canister Unconfined or in Aging Overpack**
1	RF-ESD-01	2×10^{-8}		3×10^{-7}	
2	RF-ESD-02	2×10^{-6}		2×10^{-5}	
3	RF-ESD-03	7×10^{-7}		9×10^{-6}	
4	RF-ESD-04	3×10^{-9}		7×10^{-8}	
5	RF-ESD-05	1×10^{-11}		2×10^{-10}	
6	RF-ESD-06		2×10^{-6}		4×10^{-5}
7	RF-ESD-07		4×10^{-7}		9×10^{-6}
8	RF-ESD-08		2×10^{-8}		5×10^{-7}
9	RF-ESD-09		2×10^{-8}		
Summed frequencies		3×10^{-6}	2×10^{-6}	3×10^{-5}	5×10^{-5}
Summed categorization		BC2	BC2	BC2	BC2

NOTE: BC2 = beyond Category 2; DPC = dual-purpose canister; RF = Receipt Facility; TAD = transportation, aging, and disposal.

Source: BSC 2009c, Attachment A and Table G-2.

Table IV-3 CRCF—Frequencies of Waste Form Handling Event Sequences Leading to Radionuclide Release

		DPC Configurations		DOE Standard Canisters		HLW Canisters		TAD Canister Configurations			DOE Canisters	
CRCF Operations	**Event Sequence**	**DPC in Cask**	**DPC Unconfined, in Aging Overpack or unbolted Cask**	**DOE Standard Canister in Cask**	**DOE Standard Canister Unconfined or in unbolted Cask**	**HLW Canister in Cask**	**HLW Canister Unconfined or in unbolted Cask**	**TAD Canister in Cask**	**TAD Canister Unconfined, in Aging Overpack, unbolted Cask, or Unsealed Waste Package**	**TAD Canister in Waste Package**	**DOE Standard + HLW in Unsealed Waste Package**	**DOE Standard + HLW in Waste Package**
1	CRCF-ESD-01	2×10^{-8}		2×10^{-8}		1×10^{-7}		3×10^{-7}				
2	CRCF-ESD-02								6×10^{-7}			
3	CRCF-ESD-03	2×10^{-6}		9×10^{-7}		4×10^{-6}		2×10^{-5}				
4	CRCF-ESD-04		7×10^{-7}		5×10^{-7}		3×10^{-6}		1×10^{-5}			
5	CRCF-ESD-05								9×10^{-6}			
6	CRCF-ESD-06		3×10^{-9}		4×10^{-9}		2×10^{-8}		4×10^{-7}			
7	CRCF-ESD-07		1×10^{-11}		1×10^{-11}		6×10^{-11}		3×10^{-10}	3×10^{-10}	1×10^{-10}	
8	CRCF-ESD-08		1×10^{-10}		2×10^{-9}		3×10^{-9}		5×10^{-9}			
9	CRCF-ESD-09		2×10^{-6}		5×10^{-5}		1×10^{-2} [a]		1×10^{-4} [a]			
10	CRCF-ESD-10								2×10^{-7}		1×10^{-7}	
11	CRCF-ESD-11								2×10^{-5}		1×10^{-5}	
12	CRCF-ESD-12		4×10^{-7}						7×10^{-6}			
13	CRCF-ESD-13									3×10^{-7}		1×10^{-7}
14	CRCF-ESD-14		2×10^{-8}						3×10^{-7}			
15	CRCF-ESD-15									1×10^{-5}		5×10^{-6}
16	CRCF-ESD-16		2×10^{-8}						3×10^{-7}			
Summed frequencies		2×10^{-6}	3×10^{-6}	9×10^{-7}	5×10^{-5}	4×10^{-6}	1×10^{-2}	2×10^{-5}	1×10^{-4}	1×10^{-5}	1×10^{-5}	5×10^{-6}
Summed categorization		BC2	BC2	BC2	BC2	BC2	Category 2	BC2	Category 2	BC2	BC2	BC2

NOTE: [a]Event sequence currently classified as Category 2.

BC2 = beyond Category 2; DPC = dual-purpose canister; HLW = high-level radioactive waste; TAD = transportation, aging, and disposal.

Source: BSC 2009a, Attachment A and Table G-2.

Table IV-4 Wet Handling Facility – Frequencies of Waste Form Handling Event Sequences Leading to Radionuclide Release

		DPC Configurations			Commercial SNF Configurations			TAD Canister Configurations		
WHF Operations	Event Sequence	DPC in Cask or STC in Air	DPC in STC in Pool	DPC Unconfined or in Aging Overpack	Commercial SNF in Cask in Air	Commercial SNF in Cask in Pool	Commercial SNF in Pool	TAD Canister in STC in Air	TAD Canister in STC in Pool	TAD Canister Unconfined or in Aging Overpack
1	WHF-ESD-01				2×10^{-7}					
2	WHF-ESD-02	2×10^{-8}								
3	WHF-ESD-03			0						
4	WHF-ESD-04	2×10^{-8}								
5	WHF-ESD-05				7×10^{-6}					
6	WHF-ESD-06	1×10^{-6}								
7	WHF-ESD-07	1×10^{-6}								
8	WHF-ESD-08				1×10^{-6}					
9	WHF-ESD-09	7×10^{-7}								
10	WHF-ESD-10			3×10^{-9}						
11	WHF-ESD-11			3×10^{-7}						9×10^{-7}
12	WHF-ESD-12			4×10^{-12}						1×10^{-11}
13	WHF-ESD-13			2×10^{-6}						8×10^{-6}
14	WHF-ESD-14	3×10^{-9}								
15	WHF-ESD-15	7×10^{-7}								
16	WHF-ESD-16				1×10^{-1} [a]					
17	WHF-ESD-17			9×10^{-3} [a]						
18	WHF-ESD-18			2×10^{-2} [a]						
19	WHF-ESD-19	6×10^{-6}	7×10^{-5}							
20	WHF-ESD-20				7×10^{-5} [a]	7×10^{-4} [a]				
21	WHF-ESD-21		2×10^{-5}			2×10^{-4} [a]			7×10^{-5} [a]	
22	WHF-ESD-22						3×10^{-1} [a]			
24	WHF-ESD-24							7×10^{-6}	5×10^{-4} [a]	
25	WHF-ESD-25									2×10^{-6}
26	WHF-ESD-26									0
27	WHF-ESD-27									2×10^{-3} [a]
28	WHF-ESD-28							3×10^{-6}		

		DPC Configurations			**Commercial SNF Configurations**			**TAD Canister Configurations**		
WHF Operations	**Event Sequence**	**DPC in Cask or STC in Air**	**DPC in STC in Pool**	**DPC Unconfined or in Aging Overpack**	**Commercial SNF in Cask in Air**	**Commercial SNF in Cask in Pool**	**Commercial SNF in Pool**	**TAD Canister in STC in Air**	**TAD Canister in STC in Pool**	**TAD Canister Unconfined or in Aging Overpack**
Summed frequencies		9×10^{-6}	9×10^{-5}	3×10^{-2}	1×10^{-1}	9×10^{-4}	3×10^{-1}	1×10^{-5}	6×10^{-4}	2×10^{-3}
Summed categorization		BC2	BC2	Category 2	Category 2	Category 2	Category 2	BC2	Category 2	Category 2

NOTE: [a]Currently classified as Category 2.

Event sequence WHF-ESD-23 is low-level liquid waste only and excluded.

BC2 = beyond Category 2; DPC = dual-purpose canister; SNF = spent nuclear fuel; STC = shielded transfer cask; TAD = transportation, aging, and disposal; WHF = Wet Handling Facility.

Source: BSC 2009d, Attachment A and Table G-2.

Table IV-5 Intra-Site Operations—Frequencies of Waste Form Handling Event Sequences Leading to Radionuclide Release

		Waste Form Configurations							
		DPC Waste Forms		**DOE Std**	**HLW**	**Naval**	**Commercial SNF**	**TAD Canisters**	
Intra-Site Operations	**Event Sequence**	**DPC in Cask**	**DPC Canister in Aging Overpack**	**DOE Standard Canister in Cask**	**HLW Canister in Cask**	**Naval Canister in Cask**	**Commercial SNF in Cask**	**TAD Canister in Cask**	**TAD Canister in Aging Overpack**
1	ISO-ESD-01	3×10^{-7}	–	3×10^{-7}	2×10^{-6}	3×10^{-7}	2×10^{-6}	6×10^{-6}	–
2	ISO-ESD-02	–	3×10^{-8}	–	–	–	–	–	8×10^{-7}
3	ISO-ESD-03	2×10^{-5}	–	–	–	–	–	–	–
4	ISO-ESD-04	7×10^{-6}	–	–	–	–	–	–	–
Summed frequencies		3×10^{-5}	3×10^{-8}	3×10^{-7}	2×10^{-6}	3×10^{-7}	2×10^{-6}	6×10^{-6}	8×10^{-7}
Summed categorization		BC2	BC2	BC2	BC2	BC2	BC2	BC2	BC2

NOTE: Other Intra-site operations event sequences not applicable to radionuclide release.

BC2 = beyond Category 2; DPC = dual-purpose canister; HLW = high-level radioactive waste; SNF = spent nuclear fuel; TAD = transportation, aging, and disposal.

Source: BSC 2009e, Attachment A and Table G-2.

Table IV-6 Subsurface Operations—Frequencies of Waste Form Handling Event Sequences Leading to Radionuclide Release

		Waste Package Configurations		
Subsurface Operations	**Event Sequence**	**Waste Package in CRCF[a]**	**Waste Package in IHF**	**Waste Package**
1	SSO-ESD-01	1×10^{-5}	1×10^{-6}	
2	SSO-ESD-02			5×10^{-8}
3	SSO-ESD-03			7×10^{-7}
Summed frequencies		1×10^{-5}	1×10^{-6}	8×10^{-7}
Summed categorization		BC2	BC2	BC2

NOTE: [a]Release occurs within the CRCF.
Other subsurface event sequences not applicable to radionuclide release.

BC2 = beyond Category 2; IHF = Initial Handling Facility.

Source: BSC 2009f, Attachment A and Table G-2.

RAI Volume 2, Chapter 2.1.1.4, Eighth Set, Number 8:

Provide an analysis of potential event sequences related to failure of cut or fill slopes near the aging pads or on transportation routes to and from the aging pads, or explain how these event sequences will be prevented or mitigated.

SAR Figure 1.1-129 and information on the terraced layout of the aging pads in DOE's response to a previous RAI (RAI: 2.2.1.1.7-3-001) on this subject suggests that excavation and fill for aging pad foundations could expose the alluvium in cut and fill slopes of up to approximately 9 to10 m [29 to 32 ft] high. Failure of the cut slope could result in the failed material depositing on the Aging Facility located in the vicinity of the toe of the slope. This material could block the vents of the Aging casks and potentially impact the Aging cask complying with the thermal limit requirement for the fuel being aged at the facility. Failure of a fill slope, where the Aging facility is located on top of the slope, has the potential for the Aging Casks to be in the failure zone and be unstable. Also, transportation routes that link the aging pads to other surface-facility structures (SAR figure 1.2.7-2) could involve cut or fill slopes. DOE has not provided an assessment of the stability of the slopes for static and applicable seismic loading conditions and did not identify potential event sequences resulting from failure of the slopes. This information is needed to determine compliance with 10 CFR 63.21(c)(5) and 63.112(b).

1. RESPONSE

Any potential event sequences due to the initiating event of failure of cut and fill slopes near the aging pads or on transportation routes near the aging pads will be mitigated by engineering design to ensure that such cut and fill slopes remain stable at ground motions up to those of the design basis ground motion 2 (DBGM-2) earthquake (2,000-year return period). As stated in the response to RAI 2.2.1.1.1-002, preliminary calculations indicate these slopes do not fail at the DBGM-2 earthquake ground motions, and that grading of the slopes near the aging pads and the access road to the aging pads and the associated analysis of the slopes for stability will be determined during detailed design. The permanent slopes, as indicated in SAR Section 1.1.5.3.2.1, will be no steeper than 2H:1V. The discussion below addresses the potential consequences of slope collapse as a result of greater than DBGM-2 earthquake ground motion.

1.1 SLOPE FAILURE

The *Geologic Repository Operations Area Aging Pad Site Plan* (BSC 2008a) shows the general layout of the aging pads, the relative proximity of the aging pads to the various surface facilities of the repository, security fencing surrounding the aging facility, access roads, and the designation for each of the two aging pads (17P and 17R). The aging pad site plan also provides the topography and preliminary cut and fill information for the aging facility slopes. Further perspective on the topography and preliminary cut and fill information are shown on Figures 1, 2, and 3.

The general arrangements for aging pads 17P and 17R are detailed in SAR Figures 1.2.7-3 and 1.2.7-4 and shown in *Geologic Repository Operations Area Aging Pad Site Plan* (BSC 2008a). The aging pads are reinforced concrete mats, nominally 3 ft thick, that are supported on the natural alluvium at the site, and compacted fill where needed. The aging pad slabs are reinforced to resist forces determined for potential design load combinations (BSC 2007a, Section 7). The natural alluvium has been determined to be adequate to support the loaded aging pads for potential design load combinations.

The compacted aggregate aging pad periphery typically extends 75 ft. beyond the concrete mat, such that vertical aging cask would be no closer than 89 ft to the upslope hillside from the toe of the engineered cut that will be no steeper than 2H:1V. As shown in Figure 1, a slope failure of an engineered slope 29 to 32 ft high would not result in soil sliding onto the aging pads and contacting an aging cask. The distance of the aging pads and vertical aging casks from up-slope hillsides precludes soil from sliding onto the concrete aging pads and contacting the aging casks (BSC 2007a, p. A-4). The layouts for aging pads 17P and 17R also illustrate that the engineered design recognizes and mitigates the potential failure of cut and fill slopes. The highest engineered slope (approximately 32 ft) is located in the northeast corner of aging pad 17P (BSC 2008a and Figures 1 and 2).

1.2 PRECLOSURE EVENT SEQUENCES

The preclosure safety analysis event sequence analysis focuses on end states associated with the release of radioactive material. The end state under consideration in this RAI is whether the probability of loss of integrity of the containment provided by the aging cask/canister combination is greater than 1 in 10,000 during the preclosure period, and if so, the nature of the resulting release of radioactive material and potential public exposure. Radiation exposure at the site boundary due to shine from degraded aging casks/canisters is not a concern because the dose would be diminished by approximately 13 orders of magnitude to insignificant levels due to the intervening distance (BSC 2007b).

Event sequences associated with the failure of cut and fill slopes, based on the qualitative and quantitative considerations discussed below, that would result in radioactivity exposure that exceeds regulatory limits would have a probability of occurrence less than 1 in 10,000 during the preclosure period (beyond Category 2) with significant margin.

Event sequences related to failure of cut and fill slopes near aging pads or on transportation routes near the aging pads that could result in exposures at the site boundary would be initiated by seismic events and involve pivotal events associated with:

1. Collapse of the roadway or aging pad due to loss of structural support with resultant tipover impact loads on the canister within vertical aging cask and potential loss of containment due to canister failure; or

2. Heat up of the canister due to blocking of the convective ventilation ports on a vertical aging cask by debris from collapse of slopes at elevations higher than the aging pad.

Both types of pivotal events are discussed in *Intra-Site Operations and BOP Reliability and Event Sequence Categorization Analysis* (BSC 2009, Attachment D).

1.2.1 Potential Roadway Collapse

No event trees were developed for site transporter tipover as a result of roadway displacement associated with cut and fill slope collapse based on the tipover of the site transporter not being considered credible. The site transporter is a crawler-type vehicle with four tank-type treads designed with a broad footprint and low center of gravity intended to preclude tipover. The size and weight of a loaded site transporter, along with the low center of gravity, preclude tipover if hit by a general service vehicle, the forces for which would be enveloped by the seismic spectrum described in the sliding/rocking calculation (BSC 2008b). The routes defined in *Geologic Repository Operations Area North Portal Site Plan* (BSC 2008c) and *Geologic Repository Operations Area Aging Pad Site Plan* (BSC 2008a) are evenly graded across gentle terrain and are paved or compacted aggregate. Consequently, cut and fill slopes associated with the roadway are not expected to be of sufficient height that their failure would have any significant impact on roadway structural support and, therefore, the slopes are not considered contributors to tipover events. Employing standard construction practices ensures that any culverts required along the transportation paths are barricaded to prevent vehicles from driving off at those points and the culverts are, therefore, not considered contributors to tipover events.

Notwithstanding the above qualitative considerations, the following simplified and conservative probability calculation demonstrates that an event sequence related to seismically initiated failure of cut and fill slopes on transportation routes to and from the aging pads that could result in exposures at the site boundary is well below Category 2. Such an event sequence would be initiated by an earthquake with ground motion greater than the DBGM-2 earthquake (2,000-year return period) occurring at a time when the site transporter is moving an aging cask containing a transportation, aging, and disposal canister or dual-purpose canister to or from an aging pad (only one site transporter will be on the roadway at a time). It is assumed for purposes of this response that all cut and fill slopes fail at ground motions greater than the DBGM-2 earthquake, and their failure results in roadway displacement sufficient to cause a tipover of the site transporter. A conservative estimate of the frequency of such an event sequence is obtained by multiplying the frequency of an earthquake greater than DBGM-2 by the length of the preclosure period in years and the conditional probability of failure of a canister as a result of the slapdown forces associated with the tipover of the site transporter. The exceedance frequency of the DBGM-2 earthquake is 5.0×10^{-4}/year. The length of time the aging pads are in use during the preclosure period is 50 years. The conditional probability of canister failure as a result of slapdown is 1.0×10^{-5} (BSC 2009, Attachment D).

The frequency of this tipover and canister failure event sequence over the preclosure period would be 2.5×10^{-7}, well below the Category 2 threshold. Therefore, tipover of a site transporter is not analyzed further for categorization.

1.2.2 Potential Aging Pad Displacement

No event trees were developed for vertical aging cask tipover[1] as a result of aging pad displacement associated with cut and fill slope collapse, because the toe of these slopes is located at least 75 ft from the concrete pads and their failure is not expected to result in loss of structural support of the aging pads. The following simplified, conservative probability calculation demonstrates that event sequences related to seismically initiated failure of cut and fill slopes surrounding the aging pads that could result in exposures at the site boundary would be well below Category 2.

Such an event sequence would be initiated by an earthquake with ground motion greater than the DBGM-2 earthquake. It is assumed that all cut and fill slopes fail at ground motions greater than DBGM-2, and their failure results in displacement of the aging pad sufficient to cause a tipover of vertical aging casks located in proximity to the failed slope. A conservative estimate of the frequency of such an event sequence is obtained by multiplying the number of aging casks at risk by the frequency of an earthquake greater than DBGM-2, the length of time the aging pads would be in use, and by the conditional probability of failure of a canister as a result of the slapdown forces associated with the tipover of the aging cask.

Aging pad displacement as a result of slope failure does not affect the horizontal aging modules because they are even further removed from the toe of the fill slopes and are not susceptible to tipover because they are positioned horizontally a few feet above the aging pad. Therefore, they are not considered to be at risk from this potential initiating event.

Because of the offset of the toe of the engineered cut slopes from the first row of vertical aging casks, it is improbable that failure of even the highest elevation slopes would result in undercut of the concrete of the aging pads sufficient to cause a structural failure of the pad and sufficient pad displacement to cause tipover of any aging casks. Notwithstanding the improbable nature of pad displacement due to slope failure, those vertical aging casks that are located in the outer row of the aging pads adjacent to a fill slope are included in the model. Based on *Geologic Repository Operations Area Aging Pad Site Plan* (BSC 2008a) and SAR Figures 1.2.7-3 and 1.2.7-4, the number of vertical aging casks in the outer row of the fully loaded aging pads adjacent to a fill slope would be 76. The exceedance frequency of the DBGM-2 earthquake is

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[1] The vertical aging cask is a concrete and steel cylindrical container with a base a maximum of 12 ft in diameter, and a height a maximum of 22 ft, with a maximum weight (loaded) of 250 tons (BSC 2008d). For potential tipover, the design requirement for the aging cask is that the aging cask shall remain upright and free standing during and after a seismic event characterized by the horizontal and vertical peak ground accelerations of 96.52 ft/s^2 (3 g) (BSC 2008b). From *Seismic Event Sequence Quantification and Categorization Analysis*, (BSC 2008b, Attachment E), sequence ISO-IE-S-MAIN 06 represents either tipover or sliding impact of the aging casks, including the potential for tipover caused by vertical displacement of the aging pad foundation due to seismic excitation, resulting in canister breach and an unfiltered radionuclide release. This sequence is beyond Category 2 with a probability of about 1×10^{-5} over the preclosure period.

5.0×10^{-4}/ year. The length of time the aging pads are in use during the preclosure period is 50 years. The conditional probability of canister failure as a result of slapdown is 1.0×10^{-5}. The frequency of the event sequence over the preclosure period would be 1.9×10^{-5}, below the Category 2 threshold. Therefore, this event sequence is not analyzed further for categorization.

1.2.3 Potential Blocked Vents

No event trees were developed for blocked vents on vertical aging casks or horizontal aging modules resulting from any event initiator because the consequences of the resultant overheating would not include loss of canister containment. NUREG-1864 analyzed the maximum canister temperature that would result from blockage of all storage overpack vents. That analysis shows that vent blockage results in a maximum canister shell temperature of 283°C (542°F). That temperature is hundreds of degrees below the temperature (mean 1203K (930°C) with a standard deviation of 22.85° or a range of approximately 1124K to 1250K (851°C to 977°C)) at which the canister would fail (BSC 2009, Attachment D, Section D2). The failure analyses show that even after 20 years of vent blockage and 50% fuel failure, no multipurpose canister failures are expected (NUREG-1864). The storage overpack and canister configuration analyzed in NUREG-1864 are similar to the transportation, aging, and disposal canister and aging cask configuration, so these results can be applied in the preclosure safety analysis. Due to design differences, complete blockage of horizontal aging module vents is less likely to occur than in vertical aging casks. If such a blockage were to occur, the large thermal capacity of the surrounding concrete would result in a similarly low maximum canister temperature and low canister failure probability. Therefore, canister overheat that leads to breach due to blocked vents is not analyzed further for categorization.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

4. REFERENCES

BSC (Bechtel SAIC Company) 2007a. *Aging Facility (AP) Foundation Design*. 170-DBC-AP00-00100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071031.0008; ENG.20080306.0011.

BSC 2007b. *GROA External Dose Rate Calculation*. 000-PSA-MGR0-01300-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071023.0003.

BSC 2007c. *Aging Facility General Arrangement Aging Pad 17P Plan*. 170-P10-AP00-00102-000-00C. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071126.0019.

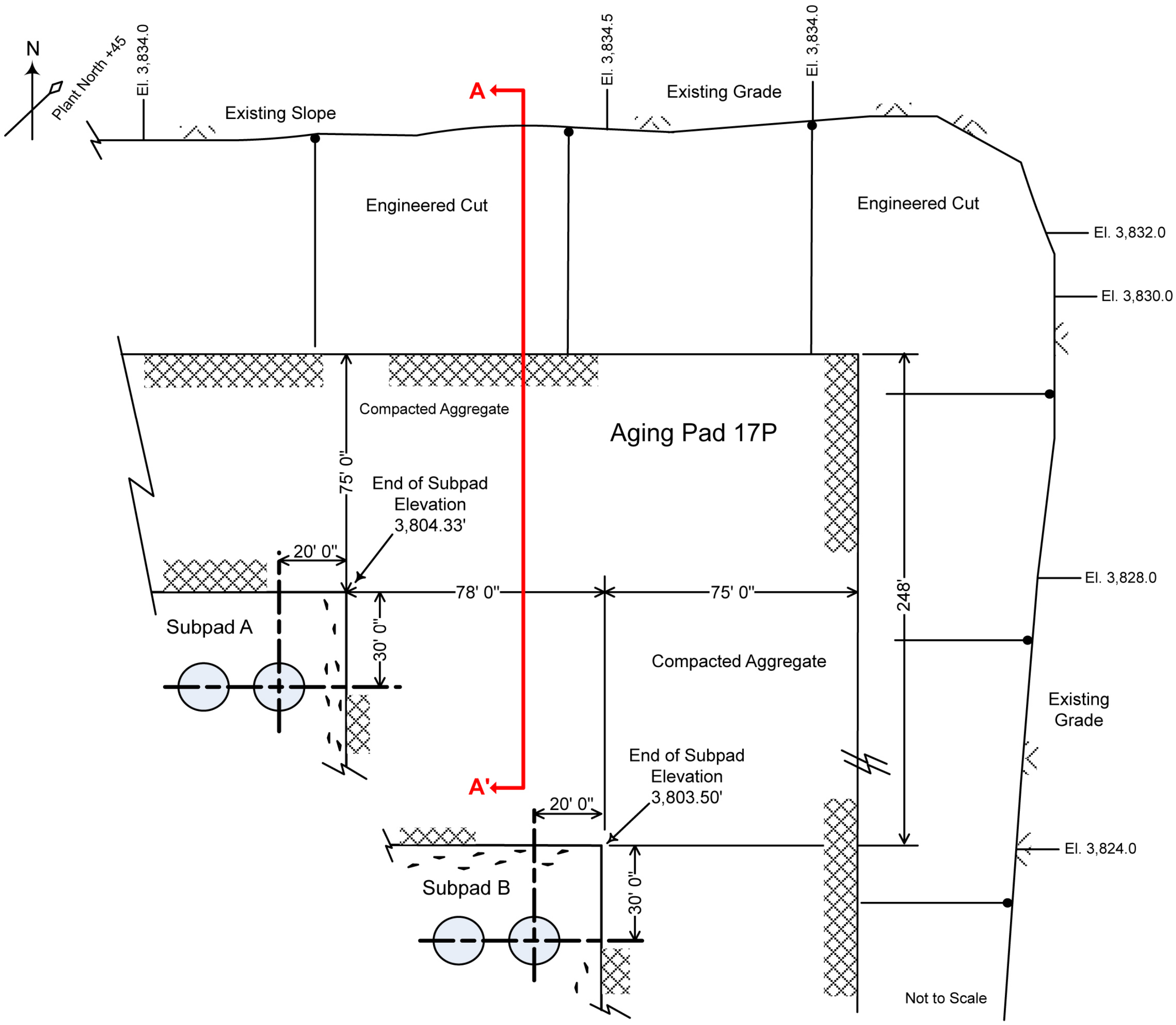
BSC 2008a. *Geologic Repository Operations Area Aging Pad Site Plan*. 170-C00-AP00-00101-000-00C. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080129.0005.

BSC 2008b. *Seismic Event Sequence Quantification and Categorization Analysis*. 000-PSA-MGR0-01100-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20090112.0013.

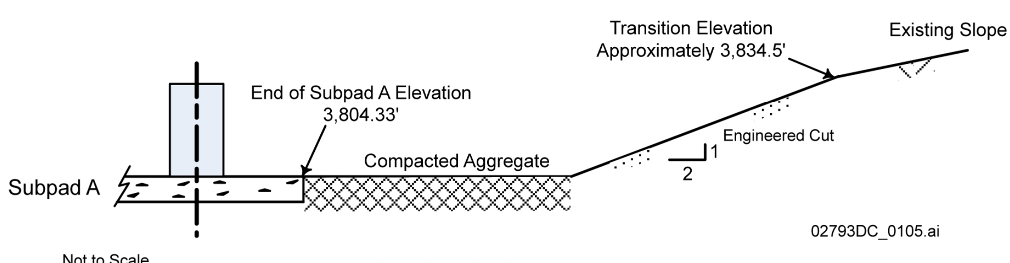
BSC 2008c. *Geologic Repository Operations Area North Portal Site Plan*. 100-C00-MGR0-00501-000-00F. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080125.0007.

BSC 2008d. *Basis of Design for the TAD Canister-Based Repository Design Concept*. 000-3DR-MGR0-00300-000-003. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20081006.0001.

BSC 2009. *Intra-Site Operations and BOP Reliability and Event Sequence Categorization Analysis*. 000-PSA-MGR0-00900-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20090112.0008.



Plan
17P Aging Pad Northeast End



Section A-A'
17P Aging Pad Northeast End

Figure 1. Aging Pad 17P Partial Plan and Section Showing Cut Slopes, Northeast Corner

Source: BSC 2007c.

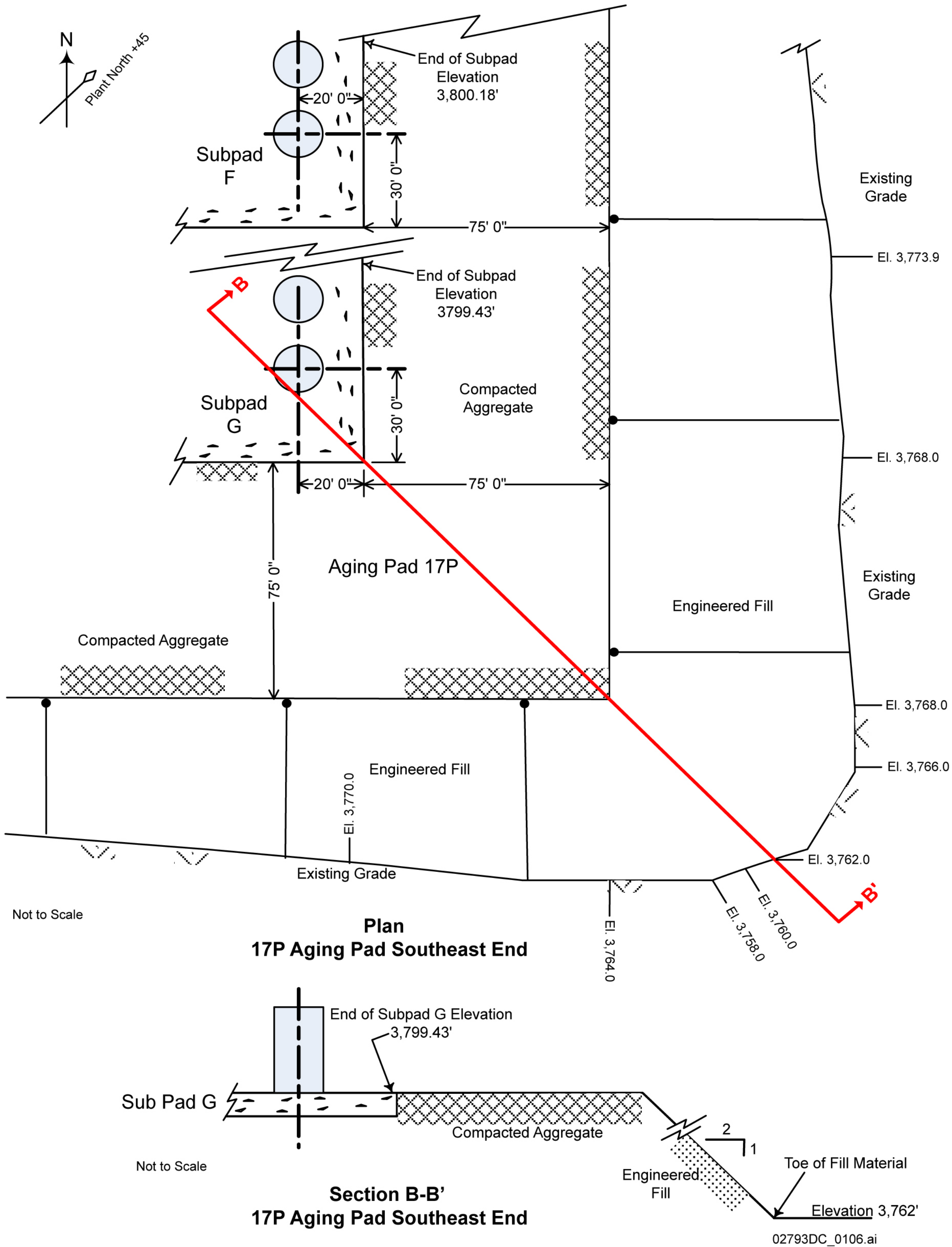


Figure 2. Aging Pad Partial Plan and Section Showing Fill Slopes, Southeast Corner

Source: BSC 2007c.

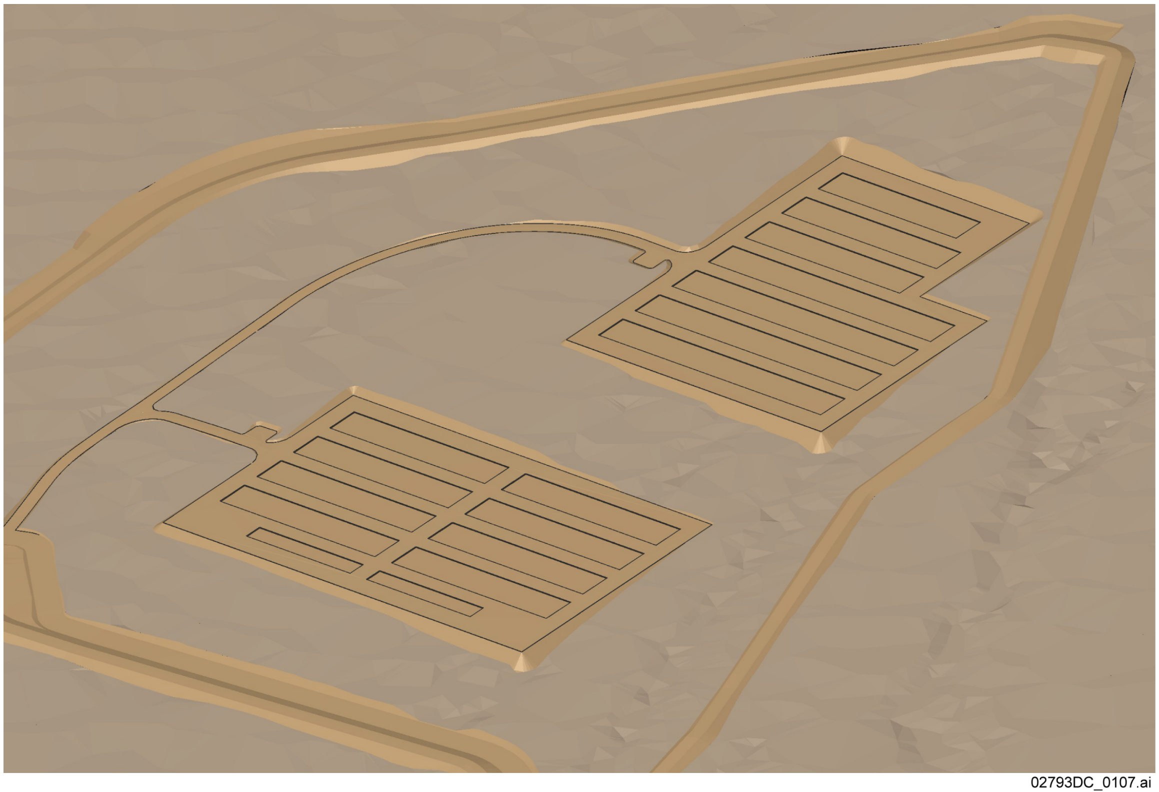


Figure 3. 3D Layout of Aging Pad Sites Showing Surrounding Roadways