OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT ANALYSIS/MODEL COVER SHEET

1. QA: QA

Page: 1 of: 38

Complete Only Applicable Items

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	☐ Performance Assessment		☐ Model Documentation
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Initial Issue

Revisions 00A and 00C of this analysis used the definitions of DBE categories and dose criteria from the DOE Interim Guidance, dated June 18, 1999, and the Revised DOE Interim Guidance (Dyer 1999), dated September 3, 1999, respectively. Revision 00B of this analysis used the same data from the proposed rule 10 CFR 63 (64 FR 8640), Sections 2 and 111, pending the issuance of Dyer (1999). A review and evaluation of the the definitions of DBE categories and dose criteria in these three documents was conducted and it was concluded that using Dyer (1999) in Revision 00C of this analysis has no impact on the analysis results or conclusion.

**OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL REVISION RECORD**

1. Page: 2 of: 38

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1.0 PURPOSE

The purpose of this document is to perform a preliminary design basis event (DBE) analysis of the immobilized plutonium (can-in-canister) waste form to be referred to in this analysis as high level waste/plutonium (HLW/Pu). The objective of the analysis is to determine any preclosure safety impacts of the waste form on the Monitored Geologic Repository (MGR). The scope of this analysis is to determine the offsite dose consequences and associated frequencies of selected DBEs for systems handling disposable canisters that bound all surface and subsurface off-normal events, and to compare these results against regulatory limits. The results of this work are preliminary and are intended to be used to establish a set of preliminary MGR and waste form requirements, to identify mitigation or prevention options that may be required to meet regulatory limits, and to provide input to the Site Recommendation (SR) report. This document is prepared in accordance with the associated development plan (Civilian Radioactive Waste Management System Management and Operating Contractor [CRWMS M&O] 1999e).

2.0 QUALITY ASSURANCE

The Quality Assurance (QA) program applies to this analysis. The work reported in this document is part of the analysis of MGR DBEs. The work done for this analysis was evaluated according to QAP-2-0, *Conduct of Activities* (CRWMS M&O 1998a). This Activity Evaluation determined that such activities are subject to the requirements of *Quality Assurance Requirements and Description* (QARD) (DOE 1998a).

This analysis is quality affecting because the results may be used to support analyses of MGR structures, systems, and components (SSCs) in accordance with QAP-2-3, *Classification of Permanent Items* (CRWMS M&O 1999g).

Inputs and their sources are identified and documented in accordance with AP-3.15Q, *Managing Technical Product Inputs* (CRWMS M&O 1999f).

3.0 COMPUTER SOFTWARE AND MODEL USAGE

3.1 Scientific and Engineering Software

Not applicable, since no software, routines, macros or models subject to the QARD were produced to support this analysis. This analysis relied solely on Excel 97 spreadsheets for all dose and frequency calculations.

3.2 Computational Support Software

Excel 97 for Windows

All dose calculations performed to support this analysis were generated with Excel 97 spreadsheets and run on Pentium personal computers. A spreadsheet was used to calculate doses for the DBE scenarios analyzed. The methodology used to perform the dose and frequency calculations is described in Sections 6.4 and 6.5. Results were verified by visual inspection and/or hand calculations.

4.0 INPUTS

Design inputs apply to the preliminary design. These design inputs will require subsequent qualification before the analysis can be used to support procurement, fabrication, or construction activities. Unverified inputs are tracked in accordance with AP-3.15Q, *Managing Technical Product Inputs* (CRWMS M&O 1999f).

4.1 Data and Parameters

4.1.1 Canister Related DBEs

A complete list of canister related DBEs was obtained from the *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a, Table 7).

4.1.2 Bounding Plutonium Inventory

The bounding HLW/Pu canister inventory shown in Attachment III was obtained from the *Plutonium/High Level Vitrified Waste - DBE Offsite Dose Calculation* (CRWMS M&O 1999d, Table 5-1).

4.1.3 Bounding Dose Consequences

The bounding doses to the maximum exposed offsite individual on a per canister basis of HLW and HLW/Pu, including total effective dose equivalent (TEDE), highest committed dose equivalent plus deep dose equivalent (CDE+DDE), skin dose, and dose to lenses of the eye, are shown in Table 4.1-1 (CRWMS M&O 1999c, Attachment VII; CRWMS M&O 1999d, Table 6-1):

Table 4.1-1: Bounding Dose Consequences to Maximum Exposed Off-Site Individual per Canister

Waste Form	HEPA Filter Mitigation	Dose per Canister (rem/canister)			
		TEDE	Highest CDE + DDE	Skin	Lens of the Eye
HLW/Pu ⁽¹⁾	No	$3.4 \times 10^{+1}$	$6.1 \times 10^{+2}$	4.6×10^{-5}	0.0
HLW/Pu ⁽¹⁾	Yes	1.0×10^{-2}	1.8×10^{-1}	1.4×10^{-8}	0.0
HLW ⁽²⁾	No	6.4×10^{-1}	$1.1 \times 10^{+1}$	5.1×10^{-5}	0.0
HLW ⁽³⁾	Yes	1.9×10^{-4}	3.3×10^{-3}	1.5×10^{-8}	0.0

- (1) Data taken from CRWMS M&O 1999d. Fraction of HLW displaced by Pu is 0.12.
- (2) Data taken from CRWMS M&O 1999c.
- (3) Numbers in this row were obtained by multiplying the unmitigated HLW data in the third row by the High-Efficiency Particulate Air (HEPA) filter mitigation factor of 3.0E-04.

4.1.4 Frequency Data

All frequency related data were obtained from the *MGR Event Tree Analysis for Cask, Canister and Container Drop Events* (CRWMS M&O 1999b).

4.2 Criteria

The primary criteria applicable to this analysis are the regulatory dose limits for radiation protection of the public as specified in the *Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations for Yucca Mountain, Nevada* (Dyer 1999) and in Title 10 of the Code of Federal Regulations Part 20 (10 CFR 20), Section 1301. This analysis compares the regulatory criteria against calculated doses at assumed boundary distances for the preclosure boundary area to determine if the MGR can be operated without exceeding the regulatory dose limits. The applicable dose criteria are listed in Table 4.2-1.

Table 4.2-1: Dose Criteria for MGR DBEs

DBE Type	Dose Type	Dose Criteria
Category 1	Cumulative Dose from all pathways and all Category 1 DBEs	25 mrem/yr
Category 2	TEDE	5 rem/event
Category 2	CDE + DDE	50 rem/event
Category 2	Lens of the Eye	15 rem/event
Category 2	Skin & Extremities	50 rem/event

In Table 4.2-1, TEDE is equivalent to the committed effective dose equivalent (CEDE) plus DDE where CEDE is based on the "effective" inhalation dose conversion factors (DCFs) and DDE is based on the air submersion dose conversion factor (DCF). The CDE is based on the inhalation DCFs for the lungs, breast, gonads, red marrow, bone surface, thyroid, and remainder. The dose to the lens of the eye is based on the presence of Kr-83m, which is the only radioisotope to have a DCF for the eye. The dose to the skin and extremities is solely based on air submersion DCFs. No ingestion dose was considered for Category 2 events.

4.3 Codes and Standards

- 4.3.1 10 CFR 20. *Standards for Protection Against Radiation*, U.S. Nuclear Regulatory Commission, Washington, DC, January 1, 1999.
- 4.3.2 Dyer 1999. *Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations for Yucca Mountain, Nevada*, Letter from J. Russell Dyer (DOE) to D. R. Wilkins (YMP), U.S. Department of Energy, North Las Vegas, Nevada, September 9, 1999.

5.0 ASSUMPTIONS

- 5.1 Only those surface and subsurface events identified in Table 6.2-1 have the potential to result in a radioactive material release. *Basis: Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a, Table 7). *Usage: Used in Section 6.2, "Selection of Bounding DBEs."*
- 5.2 There are no credible events that can cause a cart tipover or the shipping cask (SC) to breach as a result of a cart tipover. *Basis: TBV-3122. Usage: Used in Section 6.2, "Selection of Bounding DBEs."*
- 5.3 Facility controls are employed to ensure that the drop of any handling equipment cannot cause an SC, canister, or disposal container (DC) to breach. *Basis: TBV-3123. Usage: Used in Section 6.2, "Selection of Bounding DBEs."*
- 5.4 There are no credible events that can cause the lag storage rack to fail resulting in a canister breach. *Basis: TBV-3124. Usage: Used in Section 6.2, "Selection of Bounding DBEs."*
- 5.5 Facility controls are employed to ensure that the collision of a canister with another canister cannot cause either canister to breach. *Basis: TBV-3125. Usage: Used in Section 6.2, "Selection of Bounding DBEs."*
- 5.6 There are no credible events that can cause a cart tipover or the DC to breach as a result of a cart tipover. *Basis: TBV-3126. Usage: Used in Section 6.2, "Selection of Bounding DBEs."*
- 5.7 A Waste Package (WP) is designed to not breach if dropped from normal handling heights, and a WP is not certified to withstand a drop from the two-block height associated with the Disposal Container Handling System crane (TBV-1342). *Basis: MGR Event Tree Analysis for Cask, Canister and Container Drop Events* (CRWMS M&O 1999b). *Usage: Used in Section 6.2, "Selection of Bounding DBEs."*
- 5.8 SCs and DCs will contain up to five canisters of HLW and HLW/Pu in any combination with a minimum of one HLW/Pu canister (TBV-3113). *Basis: Report on Intact and Degraded Criticality for Selected Plutonium Waste Forms in a Geologic Repository, Volume II: Immobilized in Ceramic* (CRWMS M&O 1998f). *Usage: Used in Section 6.4, "Consequence Analysis."*
- 5.9 Varying the distance from 5,000 m to 10,000 m, the atmospheric dispersion factor, χ/Q , decreases by a factor of 2 (TBV-3114). *Basis: Preliminary χ/Q Concentration Estimates Using NRC Regulatory Guide 1.145 as Implemented by the XQ145 Software*

Routine (CRWMS M&O 1998g). *Usage*: Used in Section 6.8.1, "Additional Consequence Analysis Option."

- 5.10 The preclosure period is assumed to be 100 years (TBV-690). *Basis*: *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a). *Usage*: Used in Section 6.5.1, "DBE Category Definitions."
- 5.11 It is assumed that the airborne release fraction for the plutonium ceramic in the can-in-canister waste form is equal to 1.6×10^{-3} (TBV-3115). *Basis*: *Plutonium/High Level Vitrified Waste - DBE Offsite Dose Calculation* (CRWMS M&O 1999d). *Usage*: Used in Section 6.4, "Consequence Analysis"
- 5.12 A breathing rate of 20 l/min for the volume intake of air for "light activity" is assumed (TBV-3102). *Basis*: *Report of the Task Group on Reference Man. ICRP Publication 23* (ICRP 1974). *Usage*: Used in Section 6.4, "Consequence Analysis"
- 5.13 The MGR is designed to withstand the following subsurface DBEs: an uncontrolled transporter decent, WP horizontal drop onto sharp object, and fuel rod rupture/internal pressurization (TBV-245). *Basis*: *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a). *Usage*: Used in Section 6.2.1, "Bounding DBE Determination."
- 5.14 It is assumed that rockfall exceeding WP design basis is a Beyond Design Basis Event (TBV-684). *Basis*: *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a). *Usage*: Used in Section 6.2.1, "Bounding DBE Determination."
- 5.15 It is assumed that a fire in subsurface facilities is a Beyond Design Basis Event (TBV-688). *Basis*: *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a). *Usage*: Used in Section 6.2.1, "Bounding DBE Determination."
- 5.16 It is assumed that the frequency of preclosure early failure of a WP is very low and the consequences associated with the event are negligible (TBV-3116). *Basis*: *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a). *Usage*: Used in Section 6.2.1, "Bounding DBE Determination."

6.0 ANALYSIS

The purpose of this section is to document the preliminary DBE analysis of the immobilized HLW/Pu waste form. The objective of the analysis is to determine any preclosure safety impacts of the waste form on the MGR.

The DBE analysis includes identification of the Bounding DBEs, calculation of the associated frequencies and consequences, comparison of the results to criteria, and identification of facility and waste form requirements. Figure 1 provides a flowchart of the DBE analysis process, and Figure 2 provides a flowchart of the supporting documents.

6.1 Overview of Canister Handling Operations

This section presents an overview of the MGR canister handling operations.

Figure 1: DBE Analysis Process Flowchart

Figure 2: Calculational Interfaces for Pu Waste Form DBE Analysis Documentation

6.1.1 Carrier/Cask Transport System

Canisters are transported to the MGR inside a SC on a carrier (e.g., a rail car) and are received by the Carrier/Cask Transport System. The site prime mover is attached to the carrier, and the SC and carrier are transported to the Carrier Preparation Building (CPB). The personnel barrier and impact limiters are not removed from the SC during this operation. These operations are based on the mechanical flow diagram (MFD) for the Carrier/Cask Transport System (CRWMS M&O 1997a).

6.1.2 Carrier Preparation Building

In the CPB, the personnel barrier and impact limiters are removed from the SC while the SC remains on the carrier. The SC and carrier are then transported to the carrier bay of the Waste Handling Building (WHB). These operations are based on the MFD for the CPB material handling system (CRWMS M&O 1997b).

6.1.3 Carrier/Cask Handling System

In the carrier bay, the SC is upended on the carrier by the Carrier/Cask Handling System (CHS) bridge crane and transferred from the carrier to a transfer cart. The SC on the transfer cart is then transported to the Canister Transfer System (CTS). These operations are based on the MFD for the CHS (CRWMS M&O 1997c).

6.1.4 Canister Transfer System

The CTS receives the SC on the transfer cart from the CHS. The CTS consists of a cask preparation and decontamination area and a canister handling area. The cask preparation and decontamination area consists of a cask preparation station and a cask decontamination station. In the cask preparation operation, flexible hoses are attached to the cask; the cask is sampled, vented, and purged; and the lid bolts are de-tensioned and removed. The lid handler is positioned above the cask, and the cask lid is unbolted. The cask is then decontaminated and moved to the canister handling area by the transfer cart.

The canister handling area consists of a delid/transfer station and a DC loading station. The cask lid lifting fixture is moved into position over the cask in the delid/transfer station, lifting bolt holes in the cask lid are engaged, and the lid is lifted off the cask. The canister bridge crane remotely attaches the lifting fixture, mates with the canister, and transfers a HLW/Pu canister to the canister staging rack or directly into the DC on a transfer cart. After all the canisters are loaded into a DC, the transfer cart and loaded DC are then transported to the Disposal Container Handling System (DCHS). These operations are based on the MFDs for the CTS (CRWMS M&O 1997d; CRWMS M&O 1997e).

6.1.5 Disposal Container Handling System

The DC is transferred from the transfer cart to the welding station turntable for final closure operations. After final closure operations, the DC, now called a WP, is transferred to a tilting fixture for loading onto a horizontal transfer cart. The WP is then transferred horizontally from the transfer cart to the WP transporter. The WP transporter is then transported through the

transfer corridor to the emplacement ramp and then to the underground emplacement area. These operations are based on the MFDs for the DCHS (CRWMS M&O 1997f).

6.2 Selection of Bounding DBEs

This section identifies and defines in detail the applicable bounding DBEs for each system that directly or indirectly handles disposable canisters. This section performs steps 1 and 2 of Figure 1.

6.2.1 Bounding DBE Determination

The bounding DBEs were determined from the *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a, Tables 6, 7, 9, and 10). MGR DBEs are identified in that analysis without regard to the waste form. It identifies four categories of events: Preliminary External DBEs, Internal Events with Potential Releases, Internal Events with No Release, and Beyond Design Basis Events. These event categories were reviewed to determine the bounding DBEs to be analyzed in Sections 6.4 through 6.7.

The first category of events reviewed in the *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a, Table 6) includes Preliminary External DBEs. External MGR DBEs are initiated by an external event such as an earthquake. All applicable External DBEs were removed from the list of DBEs requiring further analysis because all externally induced canister related DBEs are prevented by design (CRWMS M&O 1999a). For example, an earthquake could cause the WHB to collapse, resulting in damage to the casks and canisters contained within it. However, the WHB is designed to not collapse during a design basis earthquake. Therefore, this event (building collapse due to an earthquake) is prevented by design, and the associated DBE does not require further evaluation in this analysis.

The second category of events reviewed in the *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a, Table 7) and shown in Table 6.2-1 are Internal Events with Potential Releases. Internal events are caused by events within the MGR such as an equipment malfunction or an operator error. Only those surface and subsurface events identified in Table 6.2-1 have the potential to result in a radioactive material release (Assumption 5.1). These events were reviewed and three events were identified as requiring further evaluation in this analysis as Bounding DBEs. These Bounding DBEs are as follows:

- Shipping Cask Drop (no impact limiters)
- Canister Drop onto Floor
- Unsealed DC Drop and Slapdown

The reasons for not further evaluating other events are provided in Table 6.2-1.

The third category of events listed in the *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a, Table 9) includes Internal Events with No Release. Similar to the External DBEs, these internal events were removed from the list of DBEs requiring further evaluation in this analysis because they are prevented by design from resulting in a radiological release.

The fourth category of events listed in the *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a, Table 10) are Beyond Design Basis Events. Beyond Design Basis Events are those events that are expected to occur with a frequency of less than one time in a

million years. Based on the event definitions provided in the *Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations for Yucca Mountain, Nevada* (Dyer 1999), consequence analysis of Beyond Design Basis Events is not required. Section 6.5 of this analysis provides more information related to the event definitions. Thus, all of the events in this category except the two-block events and the Unsealed DC Drop (from normal handling height) were removed from the list of events requiring further evaluation in this analysis. Discussion of the two-block event is provided below.

In the *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a), an assumption was made that SSCs could be incorporated into the MGR design and operation to ensure that the two-block event is a Beyond Design Basis Event. While this may be possible, it may place unnecessary requirements on the MGR design and operations. Thus, this analysis did not take credit for that assumption and conservatively considered a two-block event to be credible and included it as another initiator of a shipping cask, canister, or DC drop event.

Additionally, the assumption that a two-block event is a Beyond Design Basis Event in the *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a) resulted in removing the waste package drop event from the list of events with potential releases. Since this analysis did not take credit for this assumption and considers that a two-block event is credible, and also assumes that a waste package is not certified to withstand a drop from the two-block height associated with the DCHS crane (TBV-1342), a waste package drop event is further evaluated. Thus, a waste package drop was included as part of the DC Drop Analysis.

Note that the first, second, third, and fourth categories of events listed in the *Preliminary Selection of MGR Design Basis Events* (CRWMS M&O 1999a) also include subsurface events. All subsurface events involve waste packages. The first category of events that could involve subsurface facilities includes loss-of-offsite power to MGR, earthquake, and flood. As stated above these events are prevented by design from resulting in breach of a WP. The second category of events includes a subsurface event, i.e., preclosure early failure of a WP (TBV-3116). Table 6.2-1 provides the rationale for excluding this event from further evaluation in this analysis. The third category of events has three subsurface events, i.e., an uncontrolled transporter descent (TBV-245), WP horizontal drop onto sharp object (TBV-245), and fuel rod rupture/internal pressurization (TBV-245). These three events were removed from the list of DBEs requiring further analysis because they are prevented by design from resulting in breach of a WP. The fourth category of events has two subsurface events, i.e., a fire in subsurface facilities (TBV-688) and rockfall exceeding WP design basis (TBV-684). These two events were removed from the list of DBEs requiring further analysis because they are Beyond Design Basis Events. Therefore, no subsurface events are evaluated in this analysis.

Thus, the bounding DBEs are as follows:

- Carrier/Cask Transport System – None (Shipping Cask with impact limiters ensures no breach can occur)
- Cask Preparation Building – None
- Carrier/Cask Handling System – Shipping Cask Drop (no impact limiters)
- Canister Transfer System – Canister Drop onto Floor
- Disposal Container Handling System – Unsealed DC Drop and Slapdown, and Two-Block DC/WP Drop

Table 6.2-1: Internal Events-DBE Screening Analysis

#	DBE Description	Location	Screened Out	Reason for Screening
1	Shipping Cask Drop (no impact limiters)	Carrier Bay	No	Not screened. Analyzed as a DBE
2	Shipping Cask Tipover/Slapdown (no impact limiters)	Carrier Bay	Yes	Event caused by earthquake. Cart design to not tipover during earthquake (TBV-3122). Therefore, this event is design for.
3	Shipping Cask Drop into Cask Preparation Pit	Cask Prep Pit	Yes	Not part of disposable canister handling systems.
4	Shipping Cask Drop into Cask Unloading Pool	ATS Pool	Yes	Not part of disposable canister handling systems.
5	SFA Drop onto Pool Floor	ATS Pool	Yes	Not part of disposable canister handling systems.
6	SFA Drop onto Another SFA in Pool Staging Rack	ATS Pool	Yes	Not part of disposable canister handling systems.
7	SFA Collision	ATS Pool or ATS Hot Cell	Yes	Not part of disposable canister handling systems.
8	Handling Equipment Drops onto SFA	ATS Pool or ATS Hot Cell	Yes	Not part of disposable canister handling systems.
9	SFA Drop onto Hot Cell Floor	ATS Hot Cell	Yes	Not part of disposable canister handling systems.
10	SFA Drop into Empty DC	ATS Hot Cell	Yes	Not part of disposable canister handling systems.
11	SFA Drop onto Another SFA in DC or Dryer	ATS Hot Cell	Yes	Not part of disposable canister handling systems.
12	SFA Basket Drop onto Pool Floor	ATS Pool	Yes	Not part of disposable canister handling systems.
13	SFA Basket Collision	ATS Pool or Hot Cell	Yes	Not part of disposable canister handling systems.
14	Uncontrolled Descent of Loaded Incline Basket Transfer Cart	ATS Pool	Yes	Not part of disposable canister handling systems.
15	SFA Basket Drop onto Hot Cell Floor	ATS Hot Cell	Yes	Not part of disposable canister handling systems.
16	Handling Equipment Drops onto SFA Basket	ATS Pool or ATS Hot Cell	Yes	Not part of disposable canister handling systems.

Table 6.2-1: Internal Events-DBE Screening Analysis

#	DBE Description	Location	Screened Out	Reason for Screening
17	SFA Basket Drop onto Another SFA Basket in Dryer	ATS Hot Cell	Yes	Not part of disposable canister handling systems.
18	Canister Drop onto Floor	CTS Hot Cell	No	Not Screened. Analyzed as a DBE.
19	Handling Equipment Drop onto Canister	CTS Hot Cell	Yes	Canister does not breach. Analysis and facility controls employed to ensure no breach (TBV-3123).
20	Canister Tipover/Slapdown	CTS Hot Cell	Yes	Event caused by earthquake. Rack designed for earthquake (TBV-3124). Therefore, this event is designed against.
21	Canister Drop onto Sharp Object	CTS Hot Cell	Yes	Subset of Canister Drop onto floor event (#18). Frequency of all drops included in event #18 without regard to orientation of drop and without regard to impacted surface. Consequence bounded by event #18 as that event uses conservative release fraction that covers drops onto other objects.
22	Canister Drop onto DC	CTS Hot Cell	Yes	Subset of Canister Drop onto floor event (#18). Frequency of all drops included in event #18 without regard to orientation of drop and without regard to impacted surface. Consequence bounded by event #18 as that event uses conservative release fraction that covers drops onto other object.
23	Canister Collision	CTS Hot Cell	Yes	Canister does not breach. Analysis and facility controls employed to ensure no breach (TBV-3125).

Table 6.2-1: Internal Events-DBE Screening Analysis

#	DBE Description	Location	Screened Out	Reason for Screening
24	Small Canister Drop onto Another Small Canister	CTS Hot Cell	Yes	Subset of Canister Drop onto floor event (#18). Frequency of all drops included in event #18 without regard to orientation of drop and without regard to impacted surface. Consequence bounded by event #18 as that event uses conservative release fraction that covers drops onto other objects. In addition, material at risk included in #18 consequence calculation includes the material at risk of two canisters.
25	Unsealed DC Drop and Slapdown	DC Hot Cell	No	Not screened. Analyzed as a DBE.
26	Handling Equipment Drop onto Unsealed DC	DC Hot Cell	Yes	Canister does not breach. Analysis and facility controls employed to ensure no breach (TBV-3123).
27	Unsealed DC Tipover/Slapdown	DC Hot Cell	Yes	Event caused by earthquake. Cart designed to not tipover during earthquake (TBV-3126). Therefore, this event is designed against.
28	Preclosure "Early Failure" of a WP	Subsurface	Yes	Early failure of a WP has a very low frequency because multiple barriers must be corroded/damaged before a release can occur and only gases and volatile elements could be released, resulting in negligible consequences (TBV-3116). Thus, further evaluation of this event in this analysis is not required.

The specific inputs and assumptions made for this screening analysis to determine the Bounding DBEs are listed in Sections 4 and 5.

6.2.2 Bounding DBE Descriptions

This section provides a detailed description of the Bounding DBEs that involve HLW/Pu canisters.

6.2.2.1 CHS - Shipping Cask Drop (No Impact Limiters)

In the CHS, an SC without impact limiters has a potential to be dropped from the bridge crane while it is being lifted off the carrier and lowered onto a transfer cart. The SC is loaded with five canisters of which one to five are HLW/Pu canisters. The drop may occur as a result of operator error or mechanical failure of the crane (e.g., hoist failure). The normal lifting height required to remove this SC from the carrier and place it on the transfer cart is 80 inches above the CHS floor (CRWMS M&O 1999b). The maximum abnormal lift height is 333 inches above the floor (CRWMS M&O 1999b). There are two scenarios considered for this drop event:

- 80-inch drop onto the CHS floor - this drop is from the normal handling height (CRWMS M&O 1999b)
- 333-inch drop onto the CHS floor - this drop is from the two-block hook height crane position, which is based on Carrier Bay floor to the maximum height of the crane hook (552 inches), plus the two-block margin of 24 inches plus the 12-inch trunnion height, less the 150-inch length of the SC, and less the 105-inch length of the handling fixture (CRWMS M&O 1999b)

These two scenarios are considered to bound the potential drop heights of the SC in the CHS. SC drops may occur from less than 80 inches during normal handling operations. No SC drops will occur from heights greater than 333 inches. In addition, drops onto the CHS floor will bound drops onto the carrier or transfer cart, which would provide some drop-force dampening to SCs, as well as reduce the height of the drop. All impact orientations of the SC are considered in this analysis.

6.2.2.2 CTS - Canister Drop onto Floor

The HLW/Pu canister has the potential to be dropped by the CTS bridge crane when it is lifted out of the SC, transferred to either the lag storage rack or directly to the DC, lowered into either the lag storage rack or the DC, lifted from the lag storage rack, or transferred to the DC from the lag storage rack. These drops may occur as a result of operator error or mechanical failure of the crane (e.g., hoist failure). The normal lifting height required to remove the HLW/Pu canister from the SC is 264 inches above the CTS floor (CRWMS M&O 1999b). This handling height is enough to clear the height of the lag storage rack as well as the DC and SC and thus, is considered the normal handling height. The maximum abnormal lift height is 448 inches above the floor (CRWMS M&O 1999b). There are two scenarios considered for this drop event:

- 264-inch drop onto the CTS floor - this drop is from the normal handling height (CRWMS M&O 1999b)
- 448-inch drop onto the CTS floor - this drop is from the two-block hook height crane position, which is based on Canister Handling Area floor to the maximum crane hook height of 564 inches, plus the two-block margin of 24 inches, less the 118-inch length of the

HLW/Pu canister, and less the 22-inch length of the handling fixture (CRWMS M&O 1999b). The HLW/Pu canister is not equipped with trunnions; hence, the trunnion height is 0 inches.

These two scenarios are considered to bound the potential drop heights of the HLW/Pu canister in the CTS. HLW/Pu canister drops may occur from less than 264 inches during normal handling operations. No HLW/Pu canister drops will occur from heights greater than 448 inches. In addition, drops onto the CTS floor will bound drops into an SC or DC or onto an empty lag storage rack, which would provide some drop-force dampening for the HLW/Pu canisters through either rack plastic deformation or through a piston-like effect in SCs/DCs. All impact orientations of the HLW/Pu canister are considered in this analysis. For HLW/Pu canister drops onto a canister located in the lag storage rack, the potential of breaching two canisters is considered.

6.2.2.3 DCHS - Unsealed Disposal Container/Waste Package Drop

The DCHS handles both DCs and WPs; thus, this event considers a drop of either one. The unsealed DC drop could occur while the DC is being lifted off the transfer cart and transferred to the welding station turntable. The WP drop could occur as it is moved from the welding station to the tilting station. All other WP drops are prevented by design since the maximum lift height is below the WP certified height (CRWMS M&O 1999a) (Assumption 5.7). The DC and the WP contain five canisters with one to five HLW/Pu canisters. The drop may occur as a result of operator error or mechanical failure of the crane (e.g., hoist failure). The normal lifting height required to move the DC or the WP is 60 inches above the DCHS floor (CRWMS M&O 1999b). The maximum abnormal lift height is 254 inches above the floor (CRWMS M&O 1999b). There are two scenarios considered for this drop event:

- 60-inch drop of the DC onto the DCHS floor - this drop is from the normal handling height (CRWMS M&O 1999b). This event involves only the DC, because the WP (with a welded lid) is designed to not breach when dropped from the normal handling height (CRWMS M&O 1999a).
- 254-inch drop of the DC or the WP onto the DCHS floor - this drop is from the two-block hook height crane position, which is based on Disposal Container Handling Area floor to the maximum crane hook height of 468 inches, plus the two-block margin of 24 inches, plus the 10-inch trunnion height, less the 149.2-inch length of the DC/WP containing HLW/Pu canisters and HLW canisters, and less the 99-inch length of the handling fixture (CRWMS M&O 1999b).

These two scenarios are considered to bound the potential drop heights of the DC/WP containing HLW/Pu canisters and HLW canisters in the DCHS. The DC drops may occur from less than 60 inches during normal handling operations. None of the DC or WP drops will occur from heights greater than 254 inches. In addition, drops onto the DCHS floor will bound the drops onto the transfer cart, the staging fixture, the welding station, or the tilting fixture, which would provide some drop-force dampening for the DC/WP, as well as reduce the drop heights. All impact orientations of the DC/WP are considered in this analysis.

6.3 Source Terms

The HLW/Pu source term and waste form characteristics are described in Attachments III and IV. This information comes from the *Plutonium/High Level Vitrified Waste - DBE Offsite Dose Calculation* (CRWMS M&O 1999d). This section is part of step 3 in Figure 1.

6.4 Consequence Analysis

This section presents the HLW/Pu consequence analysis. The analysis is based on the consequence analyses performed for the *DOE High - Level Vitrified Waste Dose Calculation* and the *Plutonium/High Level Vitrified Waste - DBE Offsite Dose Calculation* (CRWMS M&O 1999c; CRWMS M&O 1999d). In those analyses, consequence analyses are performed on a per-canister basis. This section provides the results of unmitigated (i.e., no credit for HEPA filters) and mitigated (i.e., credit for HEPA filters) consequence analysis. This section completes step 3 of Figure 1.

6.4.1 Unmitigated Dose Consequence Analysis

Unmitigated dose consequence analysis is performed for each DBE using the single-canister results from the *DOE High - Level Vitrified Waste Dose Calculation* and the *Plutonium/High Level Vitrified Waste - DBE Offsite Dose Calculation* (CRWMS M&O 1999c; CRWMS M&O 1999d). No credit is taken for any high-efficiency particulate air (HEPA) filters that may be present at the MGR.

The consequence methodology is described in the *Plutonium/High Level Vitrified Waste - DBE Offsite Dose Calculation* (CRWMS M&O 1999d). In general, the consequence analyses calculate the dose to the maximum exposed individual at the site boundary. The calculations are based on conservative assumptions for the amount of material released from the WHB, for the projected wind dispersion, for the location and the breathing rate of the exposed individual, and for the amount of time the individual is exposed. The amount of material released from the WHB is based on conservative values for the amount of material impacted by the DBE, the amount of material made airborne and respirable, and the amount of material that escapes all containers and exits the WHB. The specific input values used in these calculations are shown in Attachments III and IV.

Consequences from the single-canister analysis, based on the maximum drop height case, are used, because the HLW dose increases with increasing drop height (CRWMS M&O 1999c). Thus, use of the maximum height produces bounding results shown in Table 4.1-1. The following DBE calculations using Table 4.1-1 were made:

- Shipping Cask Drop Event

The SC contains five total canisters with any combination of HLW/Pu and HLW canisters (one HLW/Pu canister minimum) [Assumption 5.8]. The doses for this event are established by performing the following steps:

1. The single HLW/Pu canister and HLW canister doses in Table 4.1-1 are multiplied by the number of canisters of each type, respectively.
2. The HLW/Pu canister doses are added to the HLW canister doses to produce the total SC doses.

- Canister Drop Event

Two calculations are made for this drop event. The first calculation involves the drop and breach of a single HLW/Pu canister. The second calculation involves the drop of a HLW/Pu canister onto another HLW/Pu canister in the lag storage rack. In this case, the

calculated doses are conservatively multiplied by two for the two canisters involved in the event.

- DC/WP Drop Event

The calculations associated with the DC/WP are the same as those associated with the SC event.

Table 6.4-1 summarizes the results of the calculations described above.

6.4-1: Unmitigated Dose Consequences for Drop DBEs Involving HLW/Pu Canisters

DBE	Number of Canisters	Dose at 5,000 m (rem)			
		TEDE	Highest CDE + DDE	Skin	Lens of the Eye
HLW/Pu Shipping Cask Drop or DC/WP Drop	1 Pu and 4 HLW	$3.6 \times 10^{+1}$	$6.6 \times 10^{+2}$	2.5×10^{-4}	0.0
	2 Pu and 3 HLW	$7.0 \times 10^{+1}$	$1.3 \times 10^{+3}$	2.5×10^{-4}	0.0
	3 Pu and 2 HLW	$1.0 \times 10^{+2}$	$1.9 \times 10^{+3}$	2.4×10^{-4}	0.0
	4 Pu and 1 HLW	$1.4 \times 10^{+2}$	$2.5 \times 10^{+3}$	2.4×10^{-4}	0.0
	5 Pu and 0 HLW	$1.7 \times 10^{+2}$	$3.1 \times 10^{+3}$	2.3×10^{-4}	0.0
Canister Drop	1 Pu	$3.4 \times 10^{+1}$	$6.1 \times 10^{+2}$	4.6×10^{-5}	0.0
Canister Drop	2 Pu	$6.8 \times 10^{+1}$	$1.2 \times 10^{+3}$	9.2×10^{-5}	0.0

6.4.2 Mitigated Analysis

In this section, mitigated dose consequences were calculated identically to the unmitigated analysis, except the effect of HEPA filters was included (CRWMS M&O 1999c; CRWMS M&O 1999d). The effect of HEPA filters is to reduce the doses in Table 6.4-1 by a factor of 3E-04 (CRWMS M&O 1999d), which is the HEPA filter efficiency. The results are presented in Table 6.4-2.

6.4-2: Mitigated Dose Consequences for Drop DBEs Involving HLW/Pu Canisters (HEPA Filtration Included)

DBE	Number of Canisters	Dose at 5,000 m (rem)			
		TEDE	Highest CDE + DDE	Skin	Lens of the Eye
HLW/Pu Shipping Cask Drop or DC/WP Drop	1 Pu and 4 HLW	1.1×10^{-2}	1.9×10^{-1}	7.4×10^{-8}	0.0
	2 Pu and 3 HLW	2.1×10^{-2}	3.7×10^{-1}	7.3×10^{-8}	0.0
	3 Pu and 2 HLW	3.0×10^{-2}	5.5×10^{-1}	7.2×10^{-8}	0.0
	4 Pu and 1 HLW	4.0×10^{-2}	7.2×10^{-1}	7.1×10^{-8}	0.0
	5 Pu and 0 HLW	5.0×10^{-2}	9.0×10^{-1}	7.0×10^{-8}	0.0
Canister Drop	1 Pu	1.0×10^{-2}	1.8×10^{-1}	1.4×10^{-8}	0.0
Canister Drop	2 Pu	2.0×10^{-2}	3.6×10^{-1}	2.8×10^{-8}	0.0

6.5 Design Basis Event Categories

This section defines the DBE category for each Bounding DBE. The DBE category is based on the frequency of the DBE and is used to determine the dose criteria applicable to each DBE. The DBE category definitions, DBE category frequency analysis method, and DBE category frequency analysis results are presented. This section performs steps 4, 5, and 6 of Figure 1.

6.5.1 DBE Category Definitions

The DBE category definitions are based on the definitions provided in the document titled *Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations for Yucca Mountain, Nevada* (Dyer 1999) as follows:

Category 1 events - Those natural and human-induced events that are expected to occur one or more times before permanent closure of the MGR operations area.

Category 2 events - Other natural and human-induced events that have at least one chance in 10,000 of occurring before permanent closure of the MGR.

The MGR operations area is expected to be operational for up to 40 years. However, the performance requirement for retrieval requires 100 years to lapse from the time of initial fuel receipt until permanent closure of the repository (CRWMS M&O 1999a). Therefore, 100 years is used as the duration for the operations area prior to permanent closure. Thus, the DBE categories applicable to the MGR are defined as follows:

Category 1 events - Those natural and human-induced events that are expected to occur one or more times in 100 years.

Category 2 events - Other natural and human-induced events that are expected to occur one or more times in 1,000,000 years and less than one time in 100 years.

For the MGR, those DBEs that occur with a frequency of less than one in 1,000,000 years are identified as Beyond Design Basis Events.

6.5.2 DBE Category Frequency Analysis Method

Specific DBE frequencies for the three Bounding DBEs are calculated in the *MGR Event Tree Analysis for Cask, Canister and Container Drop Events* (CRWMS M&O 1999b). Frequency calculations included estimating the frequency of the initiating event, the frequency of having any radioactive material release, and the frequency of having a radioactive material release which results in the maximally exposed offsite individual receiving a dose exceeding regulatory limits.

The *Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations for Yucca Mountain, Nevada* (Dyer 1999), defines the Category 1 and 2 frequency limits. Since these frequencies are defined as event sequence frequencies instead of initiating event frequencies for human-induced events such as drop events, the appropriate calculation is the frequency of having any radioactive material release as a result of a specific Bounding DBE. This calculation includes grouping all event sequences, with or without releases, that originate from the same initiating event (without regard to the cause of that initiating event or waste form) and includes all events in each event sequence from the initiating event, through prevention and mitigation features (if desired or necessary), to radioactive material release. This method ensures that the appropriate frequency is calculated for comparison to the category definition.

Thus, to determine the category definition frequency, event trees for each initiating event were developed in *MGR Event Tree Analysis for Cask, Canister and Container Drop Events* (CRWMS M&O 1999b) to represent identified event sequences. The frequency of each event sequence was calculated by multiplying the frequency of the initiating event by the probability of each event in that event sequence. Then, all event sequences that resulted in a radioactive material release without regard to waste form were summed to determine the overall DBE frequency of having a release.

The SC Drop event tree analysis can be used as an example. First, the initiating event (i.e., SC drop) could be caused by an operator or equipment error. The estimated initiating event frequency includes both of these errors. Second, the number of cask lifts includes all casks handled. The number of cranes used and the contents of the casks are not relevant to the calculation (i.e., using five cranes instead of one would not change the overall probability of a cask drop). Third, the drop could come from any height, including heights above the normal

handling heights. The probability of having a drop from above or below the normal handling heights is included. This number only makes a difference in the final frequency if the casks or canisters contained therein are certified to the normal lift heights of the CHS. Fourth, the probability that the cask breaches is included. For each event sequence that resulted in a radioactive material release, the numbers associated with each event in that scenario are multiplied together, summed by scenario, and summed by fuel type (i.e., Department of Energy Spent Nuclear Fuel [DOE SNF], commercial SNF, Naval Fuel, HLW, and HLW/Pu).

6.5.3 DBE Category Frequency Analysis Results

The initial calculations in *MGR Event Tree Analysis for Cask, Canister and Container Drop Events* (CRWMS M&O 1999b) to determine the frequency of an unfiltered release are based on the input parameters described in Attachment V and identified as the Initial Case. The frequency results for the Initial Case are compared to the DBE Category 1 and 2 frequency limits in Table 6.5-1. The table shows that all Initial Case DBEs are classified as Category 1 DBEs.

In anticipation that combined releases from all waste forms would exceed Category 1 dose limits, additional calculations were made in CRWMS M&O 1999b using a variety of inputs and assumptions to determine the necessary requirements to ensure that each Bounding DBE is classified as a Category 2 DBE. Based on these calculations, a set of refined inputs and assumptions (Figure 1, step 6) was selected and labeled the Baseline Case as identified in Attachment V. Changes from the Initial Case to the Baseline Case include: (1) reducing the two-block probability from 24% to 1%; (2) certifying the commercial fuel SC to the normal lift height of the CHS; and (3) certifying the HLW, DOE SNF, and HLW/Pu canisters, including Multicanister Overpacks (MCOs), to the normal lift heights of the CTS. Certification means that the SC or canister is designed to not breach when dropped from up to the certified height. Note that for certified SCs or canisters, potential flaws in the manufacturing or final welding process are considered. This analysis considers the likelihood of manufacturing flaws that will cause a certified cask or canister to breach when dropped from any height. The refined inputs and assumptions used in the Baseline Case, as taken from the *MGR Event Tree Analysis for Cask, Canister and Container Drop Events* (CRWMS M&O 1999b), are described in Attachment V.

The Bounding DBE frequency results for the Baseline Case and a comparison of the Baseline Case event frequencies to the DBE Category 1 and 2 frequency limits are shown in Table 6.5-1. The table demonstrates that all three Baseline Case DBEs are classified as Category 2 DBEs.

6.6 Licensing Basis Dose Limits

This section identifies the applicable regulatory dose criteria. This section performs step 7 of Figure 1.

The primary criteria applicable to this analysis are the regulatory dose limits for radiation protection of the public as specified in the *Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations for Yucca Mountain, Nevada* (Dyer 1999) and 10 CFR 20.1301. This analysis compares the regulatory criteria against calculated doses at assumed boundary distances for the preclosure controlled area to determine the preventive or mitigative features that may be needed. The applicable dose criteria are listed in Table 4.2-1.

Table 6.5-1: DBE Category Frequency Analysis Results and Comparison to Limits for the Initial and Baseline Cases

Case	DBE	Frequency (drops resulting in an unfiltered release per year)	Category 1 Low Limit (events per year)	Category 2 Low Limit (events per year)	DBE Category Designation
Initial	Cask Drop	1.2×10^{-2}	1.0×10^{-2}	1.0×10^{-6}	Category 1
Initial	Canister Drop	2.8×10^{-2}	1.0×10^{-2}	1.0×10^{-6}	Category 1
Initial	DC/WP Drop	1.2×10^{-2}	1.0×10^{-2}	1.0×10^{-6}	Category 1
Baseline	Cask Drop	4.2×10^{-4}	1.0×10^{-2}	1.0×10^{-6}	Category 2
Baseline	Canister Drop	5.0×10^{-3}	1.0×10^{-2}	1.0×10^{-6}	Category 2
Baseline	DC/WP Drop	5.8×10^{-3}	1.0×10^{-2}	1.0×10^{-6}	Category 2

6.7 Safety Margins and DBE Frequency Analysis

Safety margins reflect the difference between the potential dose consequence of a DBE and the regulatory limit. Doses given in Table 6.4-2 are divided by their respective Category 2 dose limits, i.e., 5-rem TEDE, 50-rem CDE+DDE, 50-rem skin dose, and 15-rem lenses of the eye dose. The results are given in Table 6.7-1. Table 6.7-1 compares the results from the HLW/Pu DBE consequence analysis and the Category 2 dose limits. The Category 2 dose limits are used for comparison because the bounding DBEs for the Baseline Case are determined to be Category 2 events (see Table 6.5-1).

As shown in Table 6.7-1, the unmitigated consequences of all three HLW/Pu DBEs exceed two of the four dose criteria for Category 2 events. Thus, no safety margin is identified. Furthermore, since there is no safety margin, the response to Figure 1, step 8 is "no" and a re-evaluation of the event frequencies to see whether they are below $1.0\text{E-}6$ events/year must be performed (Figure 1, step 10). A re-evaluation of frequencies is necessary, because all frequencies given in Table 6.5-1 are based on all drop events with radioactive material releases, regardless of the magnitude of dose consequences. In Figure 1, step 10, we need to calculate frequencies based on only drop events that result in dose consequences exceeding the Category 2 dose criteria. To obtain these new frequencies, a new case called "DBE Baseline Case" was analyzed by changing only one input parameter used in the Baseline Case. The input parameter called "Dose Consequences" was modified to include only those DBEs whose dose consequences exceed Category 2 dose criteria. This input parameter requires users to specify whether the dose consequence from a particular waste form is "Above" or "Below" the dose criteria. In the Baseline Case, the dose consequence input for each waste form is "Above" the Category 2 dose criteria, resulting in a summation of all frequencies resulting from all waste forms. In the DBE Baseline Case, CSNF, Navy, and HLW in Canister are "Below" the Category 2 dose criteria (CRWMS M&O 1999b) and therefore their respective frequencies are not included in frequency calculations, resulting in a lower DBE frequency.

Table 6.7-1: Comparison of HLW/Pu Unmitigated Dose Consequences versus the Dose Criteria

DBE	Number of Canisters	Dose/Category 2 Dose Limit			
		TEDE	Highest CDE + DDE	Skin	Lens of the Eye
HLW/Pu Shipping Cask Drop or DC/WP Drop	1 Pu and 4 HLW	7	13	<<1	0.0
	2 Pu and 3 HLW	14	26	<<1	0.0
	3 Pu and 2 HLW	20	38	<<1	0.0
	4 Pu and 1 HLW	28	50	<<1	0.0
	5 Pu and 0 HLW	34	62	<<1	0.0
Canister Drop	1 Pu	7	12	<<1	0.0
Canister Drop	2 Pu	14	24	<<1	0.0

The frequencies used for the Figure 1, step 10 frequency re-evaluation are obtained from the DBE Baseline Case and inputs and assumptions are shown in Attachment VII. The calculated frequencies for the DBE Baseline Case, which are taken from the "Baseline* Case" (CRWMS M&O 1999b, Table 6.2-2), are shown in Table 6.7-2.

The results of the DBE Baseline Case indicate that the frequencies associated with all three DBEs are greater than 1.0×10^{-6} events per year. Therefore, the response to Figure 1, step 10 is "no" and the identification of additional consequence and frequency analysis options (Figure 1, step 11) is performed in Section 6.8.

In summary, the results of the consequence and frequency analyses and comparison to the Category 2 dose criteria indicate that the potential unmitigated dose consequences of all three Bounding HLW/Pu DBEs could exceed the offsite dose criteria for Category 2 events. Therefore, additional analysis is necessary to reduce either the dose consequences below the dose limit, or to ensure that the frequency of each event with consequences exceeding the dose criteria is less than 1×10^{-6} events per year.

Table 6.7-2: Frequencies for the DBE Baseline Case

Case	DBE	Frequency (drops resulting in doses exceeding Category 2 dose criteria per year)	Is it a credible event?
DBE Baseline	Cask Drop	9.7×10^{-5}	yes
DBE Baseline	Canister Drop	4.6×10^{-4}	yes
DBE Baseline	DC/WP Drop	8.3×10^{-5}	yes

6.8 Additional Consequence and Frequency Analysis Options

This section summarizes the evaluation of potential design and analysis options and their expected impact on the consequence and frequency analyses. This section performs step 11 of Figure 1.

6.8.1 Additional Consequence Analysis Options

The inputs and assumptions associated with the existing consequence analysis were evaluated. As described in Section 6.4, the consequence analysis calculations are based on assumptions for the amount of radioactive material released from the Waste Handling Building (WHB), for the projected wind dispersion, and for the breathing rate of the exposed individual. The specific input parameters used in the consequence calculations are shown in Attachments III and IV. This section describes the impact of variations in these parameters.

The amount of material released from the WHB is the largest variable in the consequence analysis and is based on the amount of material impacted by the DBE, the amount of material made airborne and respirable, and the amount of material that escapes all containers and exits the WHB.

The amount of material impacted by the DBE is based on the material at risk (MAR), which is the total amount of material in the HLW/Pu canister, and the damage ratio (DR), which is the fraction of that material impacted by the event. The MAR in a HLW/Pu canister is based on the *Plutonium/High Level Vitrified Waste - DBE Offsite Dose Calculation* (CRWMS M&O 1999d). Any variation in this parameter within a canister will directly impact the consequence analysis results since the offsite dose results are directly proportional to this parameter.

Additionally, the MAR within a SC or DC/WP is up to five HLW/Pu canisters (CRWMS M&O 1998f). Certification of the HLW/Pu canister to the normal handling height reduces the material at risk for non-two-block drop events to one canister since it is a credible event for a

manufacturing flaw to cause one canister to breach, but not two or more. Thus, certification of the HLW/Pu canister to the normal handling height ensures that the Bounding DBEs involve at most one HLW/Pu canister for drops from normal handling heights. Note that if the certified height of the canister is higher than the CHS and DCHS two block heights, the MAR for all events including two-block events is one HLW/Pu canister. Table 6.8-1 summarizes the impact of SC and canister certification on the DBE consequence analysis. Note that the consequence analysis performed in Section 6.4 does not take the certification credit (i.e., reduced number of failed canisters following a DBE) as shown in Table 6.8-1, column No. 5. Additional analyses are required to validate the assumptions used to establish this credit. If the certification credit can be established, the consequence analysis results would be decreased by a factor of 5.

The current DBE analysis conservatively assumes that the DR in the drop event is 100% of the canister contents. Thus, the analysis assumes that all 28 internal Pu cans are equally damaged and breached during the DBEs. Additional analysis of the DBE may show that seven or less (the bottom row) of the internal Pu cans are damaged during the DBE or no Pu can fails if a more robust Pu can is used. This additional analysis will have a large impact on the results, since the results of the analysis are directly proportional to this parameter. Thus, if it can be shown that the damage ratio is 25% of the total canister contents, the consequence analysis results would be decreased by a factor of 4.

The amount of material made airborne is based on the airborne release fraction (ARF) and respirable fraction (RF) associated with the event being analyzed. For the drop event, a conservative value for both parameters was selected (CRWMS M&O 1999d) due to a lack of experimental data on the plutonium ceramic. It is estimated that the combined value is conservative by factor of 3 to 100. This combined value has a large impact on the results since the results of the consequence analysis are directly proportional to this parameter. Thus, if it can be shown that a more accurate but still conservative combined ARF/RF is 25% of the value currently used, the consequence analysis results would be decreased by a factor of 4.

The current DBE analysis conservatively assumes that the leak path factor (the amount of material that escapes all containers and the building) following a DBE is 100% of the airborne and respirable material. Thus, the analysis assumes that 100% of the airborne and respirable material escapes the internal cans; the surrounding glass; the HLW/Pu canister; the SC, DC, or WP (for those events); and the building. In reality, a fraction of airborne and respirable material would deposit on the surfaces of these structures due to a variety of physical processes. While this result is intuitive, it is difficult to prove by calculation. However, additional analysis may be able to determine a more realistic yet still bounding value (i.e., 50%) for this parameter. The results of the consequence analysis are directly proportional to this parameter and therefore would be decreased by a factor of 2.

The projected wind dispersion is based on site meteorological conditions and the distance from the location of the event to the nearest site boundary. The site meteorological conditions are based on a conservative analysis of historically measured data. This is standard consequence methodology, and no variations in these data or method are analyzed or proposed.

The consequence analysis assumes that the nearest site boundary is 5,000 meters from the DBE location. Based on information from (CRWMS M&O 1998g), increasing the distance to the site boundary to 10,000 meters would reduce the dose consequences by approximately a factor of 2.

The breathing rate of the exposed individual is based on standard consequence methodology (ICRP 1974). Thus, no variations in this parameter are analyzed or proposed.

It should be noted that the unmitigated dose consequence calculations do not take credit for HEPA filtration. The mitigation factor associated with HEPA filtration is 3.0×10^{-4} (CRWMS

M&O 1999d). Thus, if HEPA filtration is credited for event sequences with operable HEPA filters, the dose consequences for the bounding DBEs would be below the dose criteria with no further analysis required. However, any event sequence evaluation will need to consider HEPA filter failures following a drop event.

In summary, the results of the current consequence analysis indicate that the potential consequences of a bounding DBE could exceed the dose criteria by a factor of approximately 60 as shown in Table 6.7-1. Additional consequence analysis based on more realistic but still bounding inputs and assumptions will result in lower DBE consequences, perhaps below the dose criteria. The parameters recommended for further analysis (Figure 1, step 12) are summarized in Attachment VI. Based on current estimates, additional analysis using the options listed above could result in a reduction of the dose consequences by a factor of 100 or more. A reduction of the dose consequences by a factor of 100 would result in unmitigated dose consequences in Table 6.7-1 being below Category 2 dose limits.

6.8.2 Additional Frequency Analysis Options

Exploratory event tree frequency analyses were performed to evaluate various options and to determine the frequency of the DBEs with potential dose consequences exceeding the dose criteria. The additional frequency analyses were performed in the *MGR Event Tree Analysis for Cask, Canister and Container Drop Events* (CRWMS M&O 1999b) calculation. The method used is described in Section 6.5.

Numerous additional combinations of inputs and assumptions for MGR features that impact DBE frequency were evaluated. The parameters evaluated include the following: SC, canister, and DC/WP throughput; frequency of the initiating event; two-block frequency; certification requirements; manufacturing flaw probability; and the dose consequences associated with each waste form. In order to obtain frequencies below 1.0×10^{-6} events/year, the DBE frequencies as shown in Table 6.7-2 need to be reduced by at least a factor of 463 (i.e., canister drop frequency of 4.63×10^{-4} events/year is divided by 463 to obtain 1.0×10^{-6} events/year). The analysis of each parameter is summarized below.

The DBE Baseline Case assumes bounding throughputs (CRWMS M&O 1999b). The frequency results are directly proportional to the throughput. Thus, reducing the throughput of the waste forms that have potential consequences exceeding the dose criteria would reduce the overall DBE frequency.

The DBE Baseline Case is based on an initiating event frequency of 1.4×10^{-5} drops per lift. This value is based on data from cranes with unknown safety features and procedures. Additional analysis may result in a value of 1.0×10^{-5} to 1.0×10^{-6} drops per lift for this parameter. This value has a large impact on the results since the results of the frequency analysis are directly proportional to this value. Thus, if it can be shown that the initiating event frequency is 25% of the value currently used, the frequency analysis results would be decreased by a factor of 4.

The DBE Baseline Case input for the two-block frequency is 1% of all drop events (i.e., 0.01 two-block drop/drop from any height). This value is based on a conservative estimate of current industry data. Additional modeling of expected crane safety features and commercial nuclear power plant data should result in a probability of 1.0×10^{-3} to 1.0×10^{-6} drops per lift for this parameter. Use of this low value may require specific crane safety features.

Table 6.8-1: Impact of Certified SCs and Canisters on the Dose Consequence Analysis for Drops From Normal Handling Heights

Drop Event	Number of Canisters	Shipping Cask Certified	Canisters Certified	Maximum Number of Failed Canisters Following DBE	Impact on Dose Consequences
HLW/Pu Shipping Cask Drop	5 Pu and 0 HLW	No	No	5	Bounding unmitigated case, consequences shown in Table 6.4-1.
HLW/Pu Shipping Cask Drop	5 Pu and 0 HLW	Yes	No	0 to 5	Five canisters fail, however, no release since shipping cask is certified. Failure of the shipping cask is possible due to a manufacturing flaw.
HLW/Pu Shipping Cask Drop	5 Pu and 0 HLW	No	Yes	0 or 1	One canister may fail due to a manufacturing defect in the canister. Failure of more than one canister due to a manufacturing flaw is calculated to be a BDBE.
HLW/Pu Shipping Cask Drop	5 Pu and 0 HLW	Yes	Yes	0 or 1	One canister may fail due to a manufacturing defect. However no release is postulated since failure of a canister and the SC is expected to be an incredible event.
Canister Drop	1 Pu	N/A	No	1	Bounding unmitigated case, consequences shown in Table 6.4-1.
Canister Drop	1 Pu	N/A	Yes	0 or 1	One canister may fail due to a manufacturing defect in the canister.
Canister Drop	2 Pu	N/A	No	2	Bounding unmitigated case, consequences shown in Table 6.4-1.
Canister Drop	2 Pu	N/A	Yes	0 or 1	One canister may fail due to a manufacturing defect in the canister. Failure of more than one canister due to a manufacturing flaw during the event is calculated to be an incredible event.

Note: If the certified height of the canister is higher than the CHS and DCHS two-block heights, the MAR for all events including two-block events is a maximum of one HLW/Pu canister.

The DBE Baseline Case assumes that the commercial SNF SC and the DOE SNF, HLW, and HLW/Pu canisters are certified to the normal handling heights. In order to obtain a DBE frequency of less than 1.0×10^{-6} events per year, as a minimum, canisters containing waste forms that produce DBE consequences exceeding the dose criteria will need to be certified to their normal handling heights or higher. In addition, other parameters, such as drop frequency, two-block frequency, and manufacturing flaw probability, must be equal to or reduced below the values used in the DBE Baseline Case (see Attachment VIII, Scopes 52, 56, 57, and 58). These certification requirements may require cask vendor, canister vendor, and MGR design changes.

The DBE Baseline Case assumes that the probability of a manufacturing flaw is 1.06×10^{-3} . Depending on the changes made to other parameters, this value may have to be reduced below 1.0×10^{-4} in order to obtain a DBE frequency of less than 1.0×10^{-6} events exceeding the dose criteria per year. This value will require the cask and canister vendors to demonstrate that their manufacturing process meets this requirement.

The DBE Baseline Case assumes that the consequences associated with the HLW/Pu waste form exceed the dose criteria for all DBEs (CRWMS M&O 1999b). If the consequence can be shown to be below the dose criteria, the frequency of all HLW/Pu related events will be removed from the overall DBE frequency analysis. Note that if the dose consequences for all waste forms can be shown to be below the dose criteria, the frequency of the DBE analyses would be zero events exceeding the dose criteria per year, and no additional frequency analysis and resulting requirements would be necessary.

In summary, the results of the current frequency analysis indicate that the frequencies associated with the bounding DBEs are greater than 1×10^{-6} events exceeding the dose criteria per year. Additional frequency analysis based on more realistic but still bounding inputs and assumptions will result in lower DBE frequencies, perhaps below 1×10^{-6} events exceeding the dose criteria per year. Attachment VIII summarizes some alternate inputs and assumptions for cases that result in DBE frequencies below 1.0×10^{-6} events exceeding the dose criteria per year. However, use of these alternate inputs and assumptions could result in additional waste form and facility requirements.

6.9 MGR Waste Form and Facility Requirements

MGR waste form and facility requirements are necessary to ensure compliance with all analysis assumptions. These requirements are placed on the waste form, the waste form packages, the facility, and/or the facility operations. The derivation of the waste form and facility requirements is described below, and the requirements to reduce event sequence frequencies to Category 2 are listed in Attachment IX. This section supports the performance of step 9 on Figure 1. Note that step 9 cannot be completed until the options suggested in Section 6.8 are chosen to complete Figure 1, step 12 and remaining steps (i.e., steps 13 through 16), if required.

Since the DBE analysis is not complete, the requirements identified are preliminary and are subject to change pending preparation of additional analyses and determination of the final design. Final requirements may be more or less restrictive than those identified at this time.

6.9.1 Requirements Derived from the Selection of Bounding DBEs

Requirements are derived from the selection of Bounding DBEs described in Section 6.2. Section 5 lists assumptions used in this analysis. All of these assumptions are proposed as waste form or facility requirements in Attachment IX, Section 1.

6.9.2 Requirements Derived from Bounding Inventory

Requirements defined in Attachment IX, Section 2 are derived from the bounding inventory described in Section 6.3. The assumption in this analysis that requires waste form requirements is that the fuels identified in Attachment III will result in the bounding consequences to the maximum exposed offsite individual for each fuel group.

6.9.3 Requirements Derived from the Consequence Analysis

Requirements are derived from the consequence analysis described in Section 6.4. Attachment IV lists assumptions used in the consequence analysis. Only one (i.e., distance to the site boundary) of these assumptions is proposed as a requirement in Attachment IX. The others are physical properties, such as breathing rate and do not require waste form or facility requirements. Future consequence analysis with options discussed in Section 6.8.1 may result in additional requirements.

6.9.4 Requirements Derived from the Category Determination Analysis and DBE Baseline Case Frequency Analysis

Requirements are derived from the category determination analysis described in Section 6.5. Attachment V lists assumptions used in the category determination analysis. These assumptions are proposed as requirements in Attachment IX, Section 4.

Requirements in Attachment IX, Section 4 are also derived from the inputs and assumptions described in Attachment VII associated with the DBE Baseline Case frequency analysis.

6.9.5 Requirements Derived from the Additional Analysis

The additional analyses proposed in Section 6.8 include both consequence and frequency analyses. No requirements are derived from the proposed additional analyses.

If additional frequency analysis is performed to reduce the DBE frequency below 1×10^{-6} events exceeding the dose criteria per year, additional requirements may be required based on the final selection of inputs and assumptions. For example, the current Category Determination Analysis requires that the two-block probability to be less than or equal to 1×10^{-2} . Additional frequency analysis may require a lower two-block probability in order to obtain DBE frequencies below 1.0×10^{-6} events exceeding the dose criteria per year.

7.0 CONCLUSIONS

7.1 General Conclusions

This analysis identified and evaluated the bounding DBEs for the Pu can-in-canister canister handling systems at the MGR. This analysis supported the DBE process through step 11 of Figure 1. The analysis is based on the VA design.

The bounding DBEs were identified as follows:

- Carrier/Cask Transport System – None (Shipping Cask with impact limiters ensures all events are BDBE)
- Cask Preparation Building – None
- Carrier/Cask Handling System – Shipping Cask Drop (no impact limiters)
- Canister Transfer System – Canister Drop onto the Floor
- Disposal Container Handling System – DC/WP Drop

The Initial Case frequency assessment associated with each DBE resulted in a Category 1 classification. Further analysis (Baseline Case) based on refined waste form and facility assumptions resulted in a DBE classification of Category 2. Thus, specific waste form and facility requirements are necessary to ensure that the bounding DBEs are classified as Category 2.

Consequence analysis for each bounding DBE was performed. It was determined that the unmitigated bounding consequences associated with each bounding DBE could exceed the offsite dose criteria. As a result, frequency analysis was performed to determine if the associated DBE frequency is less than 1.0×10^{-6} events exceeding the dose criteria per year. The analysis (DBE Baseline Case) based on current design assumptions resulted in DBE frequencies associated with all three bounding HLW/Pu canister DBEs greater than 1.0×10^{-6} events exceeding the dose criteria per year. Therefore, additional consequence analysis and frequency analysis options were identified. Additional consequence or frequency analysis is required to demonstrate that the consequences are below the dose limit, or that the DBE frequency is less than 1.0×10^{-6} events exceeding the dose criteria per year.

The current consequence analysis is based on a conservative set of bounding assumptions. Individually, the conservative assumptions were selected because they are easily defensible. Collectively, these conservative assumptions have produced large consequences and may result in some unnecessary waste form and facility requirements. A more accurate evaluation of these assumptions should significantly reduce the associated offsite consequences, perhaps below the dose criteria. Evaluation options were presented in Section 6.8.1.

DBE frequency scoping analysis was performed in Section 6.8.2 to identify potential design changes that would ensure a DBE frequency of less than 1.0×10^{-6} events exceeding the dose criteria per year. While some of the cases (see Attachment VIII, Scopes 52, 56, 57, and 58) yielded DBE frequencies below 1.0×10^{-6} events exceeding the dose criteria per year, the analyses may be hard to license and may require very restrictive facility and waste form requirements.

Therefore, it is recommended that additional consequence analysis be performed to demonstrate that the potential consequences are below the dose criteria for the Bounding DBEs. The additional consequence analysis should initially focus on removing unnecessary conservatism from the inputs and assumptions through performance of additional analysis. If necessary, additional test data for HLW/Pu should be obtained as appropriate. This may result in additional waste form requirements.

If the DBE dose consequences still exceed the dose limit, additional frequency analysis should be performed. The additional frequency analysis should initially focus on removing unnecessary conservatism from the inputs and assumptions through performance of additional study and analysis. This should include trade studies on the selection of feasible options.

If the additional DBE frequency assessment yields frequencies greater than 1.0×10^{-6} events exceeding the dose criteria per year, modifications to the facility design and operations should be considered and evaluated.

The results of this analysis also include the development of preliminary facility and waste form requirements. The requirements ensure that inputs and assumptions in the analysis are assured. However, these requirements are preliminary and subject to change upon completion of the DBE analysis. Final requirements may be more or less restrictive than those identified at this time.

The analysis of other waste forms has not been issued at this time and a quantitative comparison was not made because of the uncertainties in very conservative parameter values. However, work to date on the other waste forms indicates that the Can-in-Canister Plutonium waste form will not be bounded by commercial spent nuclear fuel but will be bounded by some DOE spent fuels.

The issue of bounding relates to requirements. Assuming canister certification will not impact its design, none of the waste form related requirements defined in Section 6.9 will impact the current Can-in-Canister design. Additional requirements may be derived from the recommended additional consequence analyses. However, the only options that can affect the Can-in-Canister design are to reduce the plutonium inventory in a canister and/or to make the plutonium cans more robust. These options are not proposed at this time and would only be considered if all analysis options recommended in Section 6.8 fail.

7.2 TBV/TBD Impact on Analysis and Conclusions

This section discusses the impact of TBVs on this analysis. Information on where and how TBVs are generated is given in Attachment I- Document Input Reference Sheets (DIRS).

TBV-3107: MFD - Carrier/Cask Transport System (DIRS, Item No. 1).

Dimensions and distances taken from this drawing are considered as unqualified data. These data are used in the DBE frequency analysis to determine the normal and two-block drop heights. Any change in these values would directly impact the results of the frequency analysis.

TBV-3108: MFD - CPB Material Handling System (DIRS, Item No. 2).

Dimensions and distances taken from this drawing are considered as unqualified data. These data are used in the DBE frequency analysis to determine the normal and two-block drop heights. Any change in these values would directly impact the results of the frequency analysis.

TBV-3109: MFD - Carrier/Cask Handling System (DIRS, Item No. 3).

Dimensions and distances taken from this drawing are considered as unqualified data. These data are used in the DBE frequency analysis to determine the normal and two-block drop heights. Any change in these values would directly impact the results of the frequency analysis.

TBV-3110: MFD - Canister Transfer System (Large Canister) (DIRS, Item No. 4).

Dimensions and distances taken from this drawing are considered as unqualified data. These data are used in the DBE frequency analysis to determine the normal and two-block drop heights. Any change in these values would directly impact the results of the frequency analysis.

TBV-3111: MFD - Canister Transfer System (Small Canister) (DIRS, Item No. 5).

Dimensions and distances taken from this drawing are considered as unqualified data. These data are used in the DBE frequency analysis to determine the normal and two-block drop heights. Any change in these values would directly impact the results of the frequency analysis.

TBV-3112: MFD - DC Handling System (Welding and Staging) (DIRS, Item No. 6).

Dimensions and distances taken from this drawing are considered as unqualified data. These data are used in the DBE frequency analysis to determine the normal and two-block drop heights. Any change in these values would directly impact the results of the frequency analysis.

TBV-3113: SCs and DCs will contain up to five canisters of HLW and HLW/Pu in any combination with a minimum of one HLW/Pu canister (DIRS, Item No. 8).

This assumption is used in the Consequence Analysis. Any change in this value would directly impact the results of the consequence analysis.

TBV-3114: Varying the distance from 5,000 m to 10,000 m, the atmospheric dispersion factor, χ/Q , decreases by a factor of 2 (DIRS, Item No. 9).

This assumption is used in the Consequence Analysis. Any change in this value would directly impact the results of the consequence analysis.

TBV-690: The preclosure period is assumed to be 100 years (DIRS, Item No. 10).

This assumption is used in the DBE Category Determination. Any change in this value would impact the frequency criteria used to evaluate the results with.

TBV-245: The MGR is designed to withstand the following subsurface DBEs: an uncontrolled transporter decent, WP horizontal drop onto sharp object, and fuel rod rupture/internal pressurization (DIRS, Item No. 10).

This TBV encompasses a set of unconfirmed technical data used in the design to withstand DBEs in the category of DBEs with no release. This TBV is used in Section 6.2.1. Any change in these values would directly impact the determination of bounding DBEs.

TBV-684: It is assumed that rockfall exceeding WP design basis is a Beyond Design Basis Event (DIRS, Item No. 10).

This assumption is used in Section 6.2.1. Any change in this assumption would directly impact the determination of bounding DBEs.

TBV-688: It is assumed that a fire in subsurface facilities is a Beyond Design Basis Event (DIRS, Item No. 10).

This assumption is used in Section 6.2.1. Any change in this assumption would directly impact the determination of bounding DBEs.

TBV-3116: It is assumed that the frequency of preclosure early failure of a WP is very low and the consequences associated with the event are negligible (DIRS, Item No. 10).

This assumption is used in Section 6.2.1. Any change in this assumption would directly impact

the determination of bounding DBEs. If this assumption is false, the frequency of the early failure event would need to be included in the frequency analysis and accounted for in the DBE category determination since the DBE category determination is based on the frequency of all events that could result in an unfiltered release. The frequency of this event has not been determined, but if frequent enough, it could require the DBEs to be classified as Category 1, or result in additional facility or waste form requirements.

TBV-1342: This assumption is used to justify a WP being certified to drop from normal handling heights in the DCHS, and not certified from the two-block height (DIRS, Item No. 11).

This assumption is used in the DBE Category Determination and the additional frequency analysis. If the WP were not certified, the frequency of a DC/WP drop resulting in a breach would increase. This increased frequency could impact the DBE Category Determination and the additional frequency analysis and result in a Category 1 classification or additional facility and waste form requirements.

TBV-3115: An airborne release fraction of 1.6×10^{-3} is used for the plutonium ceramic in the can-in-canister waste form (DIRS, Item No. 13).

This assumption is used in the Consequence Analysis. Any change in this value would directly impact the results of the consequence analysis. The value currently used is extremely conservative. Potential reductions in this value could impact the requirements and conclusions developed in this analysis. This value should be further analyzed to determine if lower values are defensible.

TBV-3102: A breathing rate of 20 l/min for the volume intake of air for "light activity" is assumed (ICRP Publication 23) (DIRS, Item No. 18).

This assumption is used in the Consequence Analysis. Any change in this value would directly impact the results of the consequence analysis.

TBV-3122: There are no credible events that can cause a cart tipover or the shipping cask to breach as a result of a cart tipover (DIRS, Item No. 21).

This assumption is used in the Bounding DBE Determination and the DBE Category Determination. If this assumption is false, the results of the Bounding DBE Determination would not change since the Bounding DBE Determination is based on potential consequences, and the consequences associated with the current Bounding DBEs are larger than the consequences associated with the cart tipover event. This is due to the fact that the current bounding DBEs are based on drops from larger heights than the heights involved in the cart tipover event. However, the frequency of the cart tipover event would need to be included in the frequency analysis and accounted for in the DBE Category Determination since the DBE Category Determination is based on the frequency of all events that could result in an unfiltered release. The frequency of this event has not been determined, but if frequent enough, it could require this DBE to be classified as Category 1, or result in additional facility or waste form requirements.

TBV-3123: Facility controls are employed to ensure that the drop of any handling equipment cannot cause a SC, canister, or disposal container (DC) to breach (DIRS, Item No. 22).

See discussion for TBV-3122.

TBV-3124: There are no credible events that can cause the lag storage rack to fail resulting in a canister breach (DIRS, Item No. 23).

See discussion for TBV-3122.

TBV-3125: Facility controls are employed to ensure that the collision of a canister with another canister cannot cause either canister to breach (DIRS, Item No. 24).

See discussion for TBV-3122.

TBV-3126: There are no credible events that can cause a cart tipover or the DC to breach as a result of a cart tipover (DIRS, Item No. 25).

See discussion for TBV-3122.

8.0 ATTACHMENTS

Attachment I	Document Input Reference Sheets
Attachment II	Acronyms
Attachment III	Plutonium Bounding Inventory
Attachment IV	Bounding Parameters Used in the HLW/Pu Consequence Analysis
Attachment V	Parameters Used in the Initial Case and the Baseline Case
Attachment VI	DBE Consequence Analysis Parameters Requiring Further Analysis
Attachment VII	Parameters Used in the DBE Baseline Case
Attachment VIII	Additional Requirement Options to Ensure the DBE Frequencies Are Less than 10^{-6} Per Year
Attachment IX	Waste Form and Facility Requirements

Attachment I: Document Input Reference Sheets

Document Identifier No./Rev.: ANL-WPS-SE-000002 REV 00			Change: N/A	Title: Plutonium Can-In-Canister - Design Basis Event Analysis					
Input Document							TBV Due To		
No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used In	Input Description	TBV/ TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
1	CRWMS M&O 1997a. MFD - Carrier/Cask Transport System. Repository Surface Design. BCBD00000-01717-2700-67001, Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971029.0595. Initial Use.	Entire	TBV-3107	6.1.1	System operation	2	X	N/A	N/A
2	CRWMS M&O 1997b. MFD - CPB Material Handling System. Repository Surface Design. BCBD00000-01717-2700-67002, Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971113.0074. Initial Use.	Entire	TBV-3108	6.1.2	System operation	2 7	X	N/A	N/A
3	CRWMS M&O 1997c. MFD - Carrier/Cask Handling System. Repository Surface Design. BCBD00000-01717-2700-67003, Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980408.0618. Initial Use.	Entire	TBV-3109	6.1.3	System operation	2	X	N/A	N/A
4	CRWMS M&O 1997d. MFD - Canister Transfer System (Large Canister). Repository Surface Design. BCBD00000-01717-2700- 67009, Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971029.0603. Initial Use.	Entire	TBV-3110	6.1.4	System operation	2	X	N/A	N/A

Document Identifier No./Rev.: ANL-WPS-SE-000002 REV 00			Change: N/A	Title: Plutonium Can-In-Canister - Design Basis Event Analysis					
Input Document							TBV Due To		
No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used In	Input Description	TBV/TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
5	CRWMS M&O 1997e. MFD - Canister Transfer System (Small Canister). Repository Surface Design. BCBD00000-01717-2700-67010, Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971029.0604. Initial Use.	Entire	TBV-3111	6.1.4	System operation	2	X	N/A	N/A
6	CRWMS M&O 1997f. MFD - DC Handling System (Welding and Staging). Repository Surface Design. BCBD00000-01717-2700-67011, Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971029.0605. Initial Use.	Entire	TBV-3112	6.1.5	System operation	2	X	N/A	N/A
7	CRWMS M&O 1998a. Conduct of Activities. QAP-2-0, Rev. 05. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980826.0209	Entire	N/A	2.0	General Reference	N/A	N/A	N/A	N/A
8	CRWMS M&O 1998f. Report on Intact and Degraded Criticality for Selected Plutonium Waste Forms in a Geologic Repository, Volume II: Immobilized in Ceramic. BBA000000-01717-5705-00020, Rev. 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981217.0112. Initial Use.	2.4	TBV-3113	5.8, 6.8.1	SCs and DCs will contain up to five canisters of HLW and HLW/Pu in any combination with a minimum of one HLW/Pu canister.	2	X	X	N/A
9	CRWMS M&O 1998g. Preliminary x/Q Concentration Estimates Using NRC Regulatory Guide 1.145 as Implemented by the XQ145 Software Routine. Interoffice Memorandum from W. Schalk and D. Landwehr to K. Montague. LV.EAP.WWS.12/98-004. Las Vegas, Nevada. CRWMS M&O. ACC: MOL.19990222.0117. Initial Use.	Table 2	TBV-3114	5.9,6.8.1	Varying the distance from 5,000 m to 10,000 m, the atmospheric dispersion factor, x/Q, decreases by a factor of 2.	2	X	X	N/A

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Input Document							TBV Due To		
No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used In	Input Description	TBV/ TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
10	CRWMS M&O 1999a. Preliminary Selection of MGR Design Basis Events. ANL-WHS-SE-000003, Rev 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990720.0406. [pre-assigned].	Entire	N/A	4.1.1, 5.1	List of Canister related DBEs		N/A	N/A	
		Entire	N/A	6.2.1	Source of external, internal, and no release DBEs, and Beyond Design Basis Events.				
		Entire	N/A	6.2.2.3	Waste Package DBEs				
		5.2	TBV-690	5.10, 6.5.1	The preclosure period is assumed to be 100 years.	2			X
		Table 9	TBV-245	5.13, 6.2.1	Uncontrolled transporter decent, WP horizontal drop onto sharp object, and fuel rod rupture/internal pressurization	2			X
		Table 10	TBV-684	5.14, 6.2.1	Rockfall exceeding WP design basis	2			X
		Table 10	TBV-688	5.15, 6.2.1	Fire in subsurface facilities	2			X
	Initial Use.	Table 7	TBV-3116	5.16, 6.2.1	Preclosure early failure of a WP	2			X

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Input Document							TBV Due To		
No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used In	Input Description	TBV/ TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
11	CRWMS M&O 1999b. MGR Event Tree Analysis for Cask, Canister and Container Drop Events. CAL-WPS-SE-000003, Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990720.0401. [pre-assigned].	Entire	N/A	4.1.4, 6.5.2 6.5.3 6.7 6.8.2	Source for all freq. related data		N/A	N/A	
		Table 6.2-2	N/A	6.7	Source for frequency data In Table 6.7-2				
		Table-5.2-6	N/A	6.2.2.1	SC Lift Heights				
		Table-5.2-7	N/A	6.2.2.2	Canister Lift Heights				
		Table-5.2-8	N/A	6.2.2.3	DC Lift Heights				
		Entire	N/A	Att. V, VII & VIII	Inputs and Assumptions for reference analysis				
		3.3.1.1	TBV-1342	5.7, 6.2.1	Used to justify a WP being certified to drop from normal handling heights in the DCHS, and not certified from the two-block height.	2			X
12	CRWMS M&O 1999c. DOE High-Level Vitrified Waste Dose Calculation. CAL-WPS-SE-000002 Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL. 19990720.0403. [pre-assigned].	6.0	N/A	4.1.3, 6.4.1	Bounding dose consequences	N/A	N/A	N/A	N/A
		Entire	N/A	6.4 6.4.2	General Reference				

Document Identifier No./Rev.: ANL-WPS-SE-000002 REV 00			Change: N/A	Title: Plutonium Can-In-Canister - Design Basis Event Analysis					
Input Document							TBV Due To		
No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used In	Input Description	TBV/ TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
13	CRWMS M&O 1999d. Plutonium/High Level Vitriified Waste - DBE Offsite Dose Calculation. CAL-WPS-SE-000001, REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL. 19990720.0404. [pre-assigned]. Initial Use.	5.2.1	N/A	4.1.2	Plutonium Bounding Inventory	N/A	N/A	N/A	N/A
		5.2.2	N/A	Att. III	PU Waste Form Mass Data				
		3.0	N/A	Att. III, IV VI	HLW/PU Bounding Parameters for Consequence Analysis				
		6.0	N/A	4.1.3, 6.4.1	Bounding Dose Consequences				
		2.0	N/A	6.4.1	Consequence Methodology				
		Entire	N/A	6.4	General Reference				
		5.2.2	N/A	6.8.1	MAR in HLW/PU				
		3.7, 3.8	TBV-3115	5.11, 6.8.1	An ARF of 1.6×10^{-3} for the Pu ceramic in the Can- in-Canister Waste Form	2			X
		5.2.1, & 5.2.2	N/A	6.3	HLW/Pu Source Term & Waste Form Characteristics				
		5.2.7	N/A	6.4.2, 6.8.1	HEPA Filter Mitigation Factor				
14	CRWMS M&O 1999e. AP-3.10Q Analysis Work Direction for Preliminary DBE Analysis of Immobilized Plutonium Waste Form. Interoffice Memorandum from D.W. Gwyn to T.D. Dunn. LV.SA.RPM.5/99-061. Las Vegas, Nevada. CRWMS M&O. ACC: MOL.19990602.0167. MOL.19990602.0168 (Attachment)	Entire	N/A	1.0	General Reference	N/A	N/A	N/A	N/A

Document Identifier No./Rev.: ANL-WPS-SE-000002 REV 00			Change: N/A	Title: Plutonium Can-In-Canister - Design Basis Event Analysis					
Input Document							TBV Due To		
No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used In	Input Description	TBV/ TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
15	CRWMS M&O 1999f. Managing Technical Product Inputs. AP-3.15Q, Rev. 0, ICN 0. Las Vegas, Nevada: CRWMS M&O. ACC: MOL. 19990702.0315.	Entire	N/A	2.0, 4.0	General Reference	N/A	N/A	N/A	N/A
16	CRWMS M&O 1999g. Classification of Permanent Items. QAP-2-3, Rev. 10. Las Vegas, Nevada: CRWMS M&O. ACC: MOL. 19990316.0006.	Entire	N/A	2.0	General Reference	N/A	N/A	N/A	N/A
17	Dyer 1999. Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations for Yucca Mountain, Nevada. Letter from J. Russell Dyer (DOE) to D. R. Wilkins (YMP), September 3, 1999. ACC: MOL. 19990910.0079. [pre-assigned]	111 2	N/A	4.2, 4.3 6.5.2 6.6 6.2.1, 6.5.1	Dose criteria DBE categories	N/A	N/A	N/A	N/A
18	International Commission on Radiological Protection (ICRP) 1974. Report of the Task Group on Reference Man. ICRP Publication 23. Oxford, England: Pergamon Press. TIC: 237218.	pg 346	TBV-3102 Form from APSIII.2Q submitted	5.12, 6.8.1	20 l/min breathing rate for the volume intake of air for "light activity"	2	N/A	N/A	X
19	DOE 1998a. Quality Assurance Requirements and Description for the Civilian Radioactive Waste Management Program (QARD). DOE/RW/0333P Rev. 08. Vienna, Virginia: CRWMS M&O. ACC: MOL. 19980601.0022.	Entire	N/A	2.0	General Reference	N/A	N/A	N/A	N/A
20	10 CFR 20 (Title 10 Code of Federal Regulations Part 20). Standards for Protection Against Radiation, U.S. Nuclear Regulatory Commission, Washington, DC, January 1, 1999. TIC: 238505.	1301	N/A	4.2, 4.3 6.6	Regulatory dose limits for radiation protection of the public	N/A	N/A	N/A	N/A
21	There are no credible events that can cause a cart tipover or the Shipping Cask (SC) to breach as a result of a cart tipover. Initial Use.	N/A	TBV-3122	5.2, Table 6.2-1	There are no credible events that can cause a cart tipover or the Shipping Cask (SC) to breach as a result of a cart tipover.	2	X	N/A	N/A

Document Identifier No./Rev.: ANL-WPS-SE-000002 REV 00			Change: N/A	Title: Plutonium Can-In-Canister - Design Basis Event Analysis					
Input Document							TBV Due To		
No.	Technical Product Input Source Title & Identifiers with Version	Section	Input Status	Section Used In	Input Description	TBV/TBD Priority	Unqual.	From Uncontrolled Source	Unconfirmed
22	Facility controls are employed to ensure that the drop of any handling equipment cannot cause an SC, canister, or disposal container (DC) to breach. Initial Use.	N/A	TBV-3123	5.3, Table 6.2-1	Facility controls are employed to ensure that the drop of any handling equipment cannot cause an SC, canister, or disposal container (DC) to breach.	2	X	N/A	N/A
23	There are no credible events that can cause the lag storage rack to fail resulting in a canister breach. Initial Use.	N/A	TBV-3124	5.4, Table 6.2-1	There are no credible events that can cause the lag storage rack to fail resulting in a canister breach.	2	X	N/A	N/A
24	Facility controls are employed to ensure that the collision of a canister with another canister cannot cause either canister to breach. Initial Use.	N/A	TBV-3125	5.5, Table 6.2-1	Facility controls are employed to ensure that the collision of a canister with another canister cannot cause either canister to breach.	2	X	N/A	N/A
25	There are no credible events that can cause a cart tipover or the DC to breach as a result of a cart tipover. Initial Use.	N/A	TBV-3126	5.6, Table 6.2-1	There are no credible events that can cause a cart tipover or the DC to breach as a result of a cart tipover.	2	X	N/A	N/A
26	64 FR 8640. Disposal Of High-Level Radioactive Waste in a Proposed Geologic Repository at Yucca Mountain, Nevada, U.S. Nuclear Regulatory Commission, Washington, DC. Proposed Rule 10CFR63. TIC: 240509.	Entire	N/A	Page 1	General Reference	N/A	N/A	N/A	N/A

Attachment II: Acronyms

ARF	Airborne Release Fraction
ATS	Assembly Transfer System
BDBE	Beyond Design Basis Event
CDE	Committed Dose Equivalent
CEDE	Committed Effective Dose Equivalent
CFR	Code of Federal Regulations
CHS	Carrier/Cask Handling System
CPB	Carrier Preparation Building
CRWMS	Civilian Radioactive Waste Management System
CSNF	Commercial Spent Nuclear Fuel
CTS	Canister Transfer System
DBE	Design Basis Event
DC	Disposal Container
DCF	Dose Conversion Factor
DCHS	Disposal Container Handling System
DDE	Deep Dose Equivalent
DIRS	Document Input Reference Sheets
DSNF	DOE Spent Nuclear Fuel
DOE	Department of Energy
DPC	Dual-Purpose Canisters
DR	Damage Ratio
HEPA	High-Efficiency Particulate Air
HLW	High Level Waste
HLW/Pu	Pu Can-in-Canister
ICRP	International Commission on Radiological Protection
LA	License Application
MAR	Material At Risk
MCO	Multicanister Overpack
M&O	Management and Operating Contractor
MFD	Mechanical Flow Diagram
MGR	Monitored Geologic Repository
MPC	Multi-Purpose Canister
NRC	Nuclear Regulatory Commission
QA	Quality Assurance

RF	Respirable Fraction
SC	Shipping Cask
SFA	Spent Fuel Assembly
SNF	Spent Nuclear Fuel
SSC	Structure, System, and Component
TBD	To Be Determined
TBV	To Be Verified
TEDE	Total Effective Dose Equivalent
VA	Viability Assessment
WHB	Waste Handling Building
WP	Waste Package

Attachment III: Plutonium Bounding Inventory

(Data taken from CRWMS M&O 1999d)

Curies per Kilogram of Total Plutonium Plus Americium

Isotope	Activity (Ci per kg of Pu + Am)	
	18-Metric Ton Case*	50-Metric Ton Case
²³⁸ Pu	4.2	2.1
²³⁹ Pu	56.3	57.7
²⁴⁰ Pu	19.2	15.0
²⁴¹ Pu	165.0	99.3
²⁴¹ Am	25.0	15.1
²⁴² Pu	0.0034	0.00161

*Bounding Case

Plutonium Waste Form Mass Data

Property	Value
Disks per can	20
Cans per tube	4
Tubes per Pu can-in-canister canister	7
Ceramic mass per can	9.755 kg
Maximum Pu per can-in-canister canister	28.68 kg
Maximum fraction of HLW displaced by Pu in a canister	0.12

Attachment IV: Bounding Parameters Used in the HLW/Pu Consequence Analysis

(Data taken from CRWMS M&O 1999d)

The site boundary is assumed to be 5,000 meters from the location of the WHB.

The radioactive material release occurs during a two-hour period.

The adult breathing rate is assumed to be 3.33×10^{-4} cubic meters per second.

The atmospheric dispersion factors are based on 99.5% meteorological data.

The airborne release fraction times the respirable fraction for the plutonium ceramic material is 1.6×10^{-3} .

The leak path factor is conservatively assumed to be 1.0.

The damage ratio is conservatively assumed to be 1.0.

All internal Pu cans are conservatively assumed to breach.

The inhalation dose associated with the HLW canister is conservatively based on the maximum drop height.

The dose associated with HLW is bounded by the data in Table 4.1-1 of this document.

Attachment V: Parameters Used in the Initial Case and the Baseline Case

(Data taken from CRWMS M&O 1999b)

The values of the parameters given in this Attachment are applicable to both cases, unless indicated otherwise.

1. Bounding Throughputs

The yearly throughputs for each waste form and package type are as follows:

Waste Form*	SCs	Canisters	DCs
Totals	865	1,154	570
Total Commercial	664	300	381
CSNF Bare	364	N/A	81
CSNF DPCs	0	N/A	N/A
CSNF MPC	300	300	300
Total DSNF**	101	354	89
DSNF Separate Disposal	41	195	69
Navy Fuel	15	15	15
DSNF MCO	5	20	5
DSNF with HLW	40	124	65 [†]
Total HLW	100	500	100
HLW	65	430	65
HLW/Pu	35	70	35

*Waste Forms Abbreviations-
CSNF - commercial spent nuclear fuel
bare - bare fuel (i.e., uncanistered)
DPC - dual-purpose canister
MPC - multi-purpose canister
DSNF - DOE spent nuclear fuel
MCO - multi-canister overpack
HLW - high level waste
HLW/Pu - Pu Can-in-Canister

** Total DSNF includes fuel from all six DOE SNF Fuel Groups. There are no restrictions on specific quantities for each DOE SNF Fuel Group.

[†] This value for co-disposal DCs is not included in the total DSNF DCs.

N/A - not applicable

2. Drop Frequencies

This analysis assumed the following event probabilities:

- CHS Bridge Crane 1.4×10^{-5} drops/lift
- CTS Bridge Crane 1.4×10^{-5} drops/lift

- DCHS Bridge Crane 1.4×10^{-5} drops/lift
- probability of a two-block 24% of all drops (Initial Case)
- probability of a two-block 1% of all drops (Baseline Case)

3. Number of Lifts

This analysis assumed that the number of lifts for each package at the MGR are as follows:

- one lift per SC
- two lifts per small canister
- one lift per large canister
- one lift per DC
- two lifts per WP

Note that a fully loaded DC will contain only one large canister or more than one small canister.

4. HEPA Filter Efficiency and Availability

None assumed.

5. Certification Requirements

5a. Initial Case

No certification for SC, canister, or DC.

5b. Baseline Case

Certification requirements identify the height at which the SC, canister, or DC must survive a drop with no breach. The certification requirements assumed in this analysis are as follows:

Waste Form	SC	Canister	DC
CSNF	Normal	None	None
DSNF	None	Normal	None
HLW	None	Normal	None
HLW/Pu	None	Normal	None
Naval	None	None	None

Notes:

Normal - Normal Handling Heights
 Max - Maximum Possible Handling Heights
 None - No certification required

6. Manufacturing Flaws

A manufacturing flaw in a certified SC, canister, or DC will enable a drop from below the certified height to cause a breach.

For this analysis, the probability of a manufacturing flaw in a SC, canister, or DC is assumed to be 1.06×10^{-3} .

7. Dose Consequences

This value identifies whether or not a release of a specific waste form would result in dose consequences that exceed the applicable criteria. Since the purpose of this calculation is to determine the frequency of a DBE with consequences exceeding the limit, the frequencies of DBE scenarios involving waste forms in packages that produce consequences below the criteria do not contribute to the overall DBE frequency.

For this analysis, the applicable criteria are any unmitigated releases. Thus, a release involving any waste form is assumed to exceed the limit.

8. SC, Canister, and DC Handling Times

There are no restrictions on SC, canister, or DC handling times.

Attachment VI: DBE Consequence Analysis Parameters Requiring Further Analysis

Parameter	Value Used*	Possible Value	Comment
Damage Ratio	100%	0% to 50%	The value used for the Baseline Case assumes that all of the material in a canister is subject to the same maximum forces. In reality, the impact energy would vary throughout the canister. For example, the analysis assumes that all 28 Pu cans breach during the DBE. An evaluation may show that the bottom row of cans (seven) or less breach.
Airborne Release Fractions times the Respirable Fraction	1.6×10^{-3}	5×10^{-5} to 1×10^{-4}	The value used is similar to the value appropriate for a powder material. Additional analysis or testing should result in a lower, but still bounding, value.
Leak Path Factor	1.0	1% to 50%	The value used takes no credit for any package retaining any of the airborne material. For example, no credit is taken for the Pu can, the glass waste, the canister, the shipping cask, or the building to reduce the amount of material released out of the building. Additional analysis may identify a more realistic, but still bounding, value.

* Values are taken from CRWMS M&O (1999d).

Attachment VII: Parameters Used in the DBE Baseline Case

(Data taken from CRWMS M&O 1999b)

1. Bounding Throughputs

The yearly throughputs for each waste form and package type are as follows:

Waste Form*	SCs	Canisters	DCs
Totals	865	1,154	570
Total Commercial	664	300	381
CSNF Bare	364	N/A	81
CSNF DPCs	0	N/A	N/A
CSNF MPC	300	300	300
Total DSNF**	101	354	89
DSNF Separate Disposal	41	195	69
Navy Fuel	15	15	15
DSNF MCO	5	20	5
DSNF with HLW	40	124	65 [†]
Total HLW	100	500	100
HLW	65	430	65
HLW/Pu	35	70	35

*Waste Forms Abbreviations-
CSNF - commercial spent nuclear fuel
bare - bare fuel (i.e., uncanistered)
DPC - dual-purpose canister
MPC - multi-purpose canister
DSNF - DOE spent nuclear fuel
MCO - multi-canister overpack
HLW - high level waste
HLW/Pu - Pu Can-in-Canister

** Total DSNF includes fuel from all six DOE SNF Fuel Groups. There are no restrictions on specific quantities for each DOE SNF Fuel Group.

[†] This value for co-disposal DCs is not included in the total DSNF DCs.

N/A - not applicable

2. Drop Frequencies

This analysis assumed the following event probabilities:

- CHS Bridge Crane No change from the Baseline Case.
- CTS Bridge Crane No change from the Baseline Case.
- DCHS Bridge Crane No change from the Baseline Case.
- Probability of a two-block No change from the Baseline Case.

3. Number of Lifts

No change from the Baseline Case.

4. HEPA Filter Efficiency and Availability

No change from the Baseline Case.

5. Certification Requirements

No change from the Baseline Case.

6. Manufacturing Flaws

No change from the Baseline Case.

7. Dose Consequences

This input parameter identifies whether a specific waste form release results in dose consequences that exceed the applicable dose criteria. This input parameter has two input values for each waste form: "above" or "below". "Above" means the calculated dose is expected to be above the dose criteria and "below" means the calculated dose is expected to be below the dose criteria. Since the purpose of this calculation is to determine the frequency of a DBE with consequences exceeding the limit, the frequencies of DBE scenarios involving waste forms in packages that produce consequences below the dose criteria do not contribute to the overall DBE frequency.

For the Category 2 DBE frequency analysis, the dose criteria are described in Table 4.2-1 (i.e., 5 rem TEDE to the maximum exposed offsite individual). The table below provides a comparison of the unmitigated doses to the dose criteria:

Waste Form	SC	Canister	DC
CSNF	Below	Below	Below
DSNF	Above	Above	Above
HLW	Above	Below	Above
HLW/Pu	Above	Above	Above
Naval	Below	Below	Below

As shown on the table, this analysis assumes that events involving all commercial SNF and Naval Fuel packages, and HLW canisters produce consequences below the dose criteria. Thus, the frequency associated with these events does not contribute to the overall frequency calculations.

8. SC, Canister, and DC Handling Times

No change from the Baseline Case.

Attachment VIII: Additional Requirement Options to Ensure the DBE Frequencies Are Less than 10^{-6} Per Year

(Data taken from CRWMS M&O 1999b)

Case*	Throughputs	Drop Freq.	Two-Block Freq.	Certification Requirements (handling height)	Manufacturing Flaw Probability	Dose Consequence	Freq -SC, Canister, DC/WP (Event/yr)
DBE Baseline Case	See Attachment V	1.4×10^{-5} drops/lift	1%	Commercial SNF SC, DOE, HLW, HLW/Pu canisters - normal height	1.06×10^{-3}	See Attachment VII	9.7×10^{-5} 4.6×10^{-4} 8.3×10^{-5}
Scope 52	No change from DBE Baseline	No change from DBE Baseline	0.001%	All SCs -normal height All canisters - normal height	DSNF, HLW/Pu and HLW canister to 1.0×10^{-5}	No change from DBE Baseline	2.7×10^{-8} 6.1×10^{-7} 4.8×10^{-7}
Scope 56	No change from DBE Baseline	1.0×10^{-6} drops/lift	0.001%	All SCs - normal height All canisters - normal height	DSNF, HLW/Pu, HLW canisters and MCO to 1.0×10^{-4}	No change from DBE Baseline	2.0×10^{-9} 1.1×10^{-7} 8.4×10^{-8}
Scope 57	No change from DBE Baseline	1.0×10^{-6} drops/lift	1%	All SCs - normal height All canisters - maximum height	DSNF, HLW/Pu, HLW canisters to 1.0×10^{-5}	No change from DBE Baseline	1.0×10^{-9} 9.9×10^{-8} 7.9×10^{-8}
Scope 58	No change from DBE Baseline	No change from DBE Baseline	1%	All SCs - normal height All canisters - maximum height	DSNF, HLW/Pu, HLW canisters to 1.0×10^{-5}	No change from DBE Baseline	1.4×10^{-9} 1.4×10^{-7} 1.1×10^{-7}

* Case name from *MGR Event Tree Analysis for Cask, Canister, and Container Drop Events* (CRWMS M&O 1999b, Table 6.2-3)

Attachment IX: Waste Form and Facility Requirements

1. Requirements from the DBE Selection Analysis (Section 5)

- Cart Controls

Cart shall be designed to not tip over during a design basis earthquake. This ensures that a SC or an unsealed DC would not tip over during a design basis earthquake.

- Handling Equipment Controls

Controls are required to ensure that the drop of any handling equipment cannot cause a SC, canister, or DC to breach.

- Canister Handling Controls

Controls are required to ensure that the collision of a canister with another canister cannot cause either canister to breach.

- Lag Storage Rack Controls

Controls are required to ensure that a canister cannot breach as a result of failure of the lag storage rack.

2. Requirements from the Selection of Bounding Inventory (Attachment III)

- Waste Types

The inventory listed in Attachment III is bounding with respect to offsite dose consequences to the maximum exposed individual. Facility controls are required to ensure that an inventory that could result in larger dose is not accepted at the MGR.

3. Requirements from the Unmitigated Consequence Analysis (Attachment IV)

- Distance to the Site Boundary

The distance from the WHB to the site boundary is at least 5,000 meters.

4. Requirements from the Category Determination Analysis (Attachment V) and the DBE Baseline Case Frequency Analysis (Attachment VII)

- Bounding Throughputs

The bounding values shown in the following table are established by selecting the minimum throughputs presented in Attachments V and VII. The bounding values are maximum throughputs allowed at the MGR. Note that these values are based on the referenced frequency analysis, and these values are subject to change should that analysis be revised.

Waste Form	Categorization Determination Analysis (Attachment V) (No. of SCs, canisters, or DCs per year)	DBE Baseline Case Frequency Analysis† (Attachment VII) (No. of SCs, canisters, or DCs per year)	Bounding Throughput Requirement (No. of SCs, canisters, or DCs per year)
<i>Total SCs</i>	865	NR ⁽⁶⁾	865
CSNF SCs			
Bare	NR ⁽¹⁾	NR ⁽⁵⁾	NR
DPCs	NR ⁽¹⁾	NR ⁽⁵⁾	NR
MPCs	NR ⁽¹⁾	NR ⁽⁵⁾	NR
Total	664	NR ⁽⁵⁾	664
DSNF SCs			
Separate and Co-Disposal*	NR ⁽²⁾	81 ⁽⁷⁾	81
MCOs	20 less # Naval Fuel SCs ⁽³⁾	5	5
Naval Fuel	20 less # MCO SCs ⁽³⁾	NR ⁽⁵⁾	20 less # MCO SCs
Total	101	NR ⁽⁶⁾	101
HLW SCs			
HLW	NR ⁽⁴⁾	NR ⁽⁵⁾	NR
Pu/HLW	NR ⁽⁴⁾	35	35
Total	100	NR ⁽⁶⁾	100
<i>Total Canisters</i>	1154	NR ⁽⁶⁾	1154
CSNF Canisters			
Bare	N/A	N/A	N/A
DPCs	N/A	N/A	N/A
MPCs	300	NR ⁽⁵⁾	300
Total	300	NR ⁽⁶⁾	300
DSNF Canisters			
Separate and Co-Disposal*	NR ⁽²⁾	319 ⁽⁷⁾	319
MCOs	35 less # Naval Fuel Canisters ⁽³⁾	20	20
Naval Fuel	35 less # MCOs ⁽³⁾	NR ⁽⁵⁾	35 less # MCOs
Total	354	NR ⁽⁶⁾	354
HLW Canisters			
HLW	NR ⁽⁴⁾	NR ⁽⁵⁾	NR
Pu/HLW	NR ⁽⁴⁾	70	70
Total	500	NR ⁽⁶⁾	500

Waste Form	Categorization Determination Analysis (Attachment V) (No. of SCs, canisters, or DCs per year)	DBE Baseline Case Frequency Analysis [†] (Attachment VII) (No. of SCs, canisters, or DCs per year)	Bounding Throughput Requirement (No. of SCs, canisters, or DCs per year)
Total DCs	570	NR ⁽⁶⁾	570
CSNF DCs Bare DPCs MPCs Total	NR ⁽¹⁾ N/A NR ⁽¹⁾ 381	NR ⁽⁵⁾ N/A NR ⁽⁵⁾ NR ⁽⁶⁾	NR N/A NR 381
DSNF DCs Separate and Co-Disposal* MCOs Naval Fuel Total	NR ⁽²⁾ 20 less # Naval Fuel DCs ⁽³⁾ 20 less # MCO DCs ⁽³⁾ 89	69 ⁽⁷⁾ 5 NR ⁽⁵⁾ NR ⁽⁶⁾	69 5 20 less # MCO DCs 89
HLW DCs HLW Pu/HLW Total	NR ⁽⁴⁾ NR ⁽⁴⁾ 100	NR ⁽⁵⁾ 35 NR ⁽⁶⁾	NR 35 100

Notes:

NR - No Restriction
N/A - Not Applicable

[†] As necessary, additional requirements may be derived from this analysis upon its completion.

* DSNF separate disposal and co-disposal waste forms include fuel from all six DOE SNF Fuel Groups. There are no restrictions on specific quantities for each DOE SNF Fuel Group.

(1) - The handling rate of the various SCs and DCs are interchangeable in the DBE Categorization analysis, thus the results are not sensitive to their specific throughput rates. However, the total number of CSNF SCs and DCs must be satisfied.

(2) - The handling rate of the various SCs, canisters, and DCs are interchangeable in the DBE Categorization analysis, thus the results are not sensitive to their specific throughput rates. However, the total number of DSNF SCs, canisters, and DCs must be satisfied.

(3) - The DBE Categorization analysis handles these fuel types in the same manner and analyzes a combined total of 20, 35, and 20 SCs, canisters, and DCs respectively. Thus, any combination of these SCs, canisters, or DCs up to 20, 35, and 20 respectively, is acceptable.

(4) - The handling rate of the various SCs, canisters, and DCs are interchangeable in the DBE Categorization analysis, thus the results are not sensitive to their specific throughput rates. However, the total number of HLW SCs, canisters, and DCs must be satisfied.

(5) - The potential dose consequences of a bounding DBE involving this fuel type is below the dose limit. Thus, the additional frequency analysis is not sensitive to this number because the frequency of having an event with consequences exceeding the dose limit is zero for this fuel type regardless of the number of SCs, canisters, or DCs handled.

(6) - This total number of SCs, canisters, or DCs is not restricted because it includes a fuel type that is not restricted. Note that specific fuel type restrictions that are part of this total must be met where indicated.

(7) The additional frequency analysis handles these fuel types in the same manner and analyzes a combined total of 81, 319, and 69 SCs, canisters, and DCs respectively. Thus, any combination of these SCs, canisters, or DCs up to 81, 319, and 69 respectively, is acceptable.

- Drop Frequencies

The minimum frequencies and probabilities associated with the following events are as follows:

CHS Bridge Crane	1.4×10^{-5} drops/lift
CTS Bridge Crane	1.4×10^{-5} drops/lift
DCHS Bridge Crane	1.4×10^{-5} drops/lift
Probability of a two-block	1.0% of all drops

- Number of Lifts

The maximum number of lifts for each package at the MGR is as follows:

one lift per SC
two lifts per small canister
one lift per large canister
one lift per DC, two lifts per waste package with the DC handling crane

- HEPA Filter Efficiency and Availability

There are no requirements on HEPA filter efficiency or availability.

- Certification Requirements

Certification requirements identify the height at which the SC, canister, or DC must survive a drop with no breach. The minimum certification requirements are as follows:

Waste Form	SC	Canister	DC
CSNF	Normal	None	None
DSNF	None	Normal	None
HLW	None	Normal	None
HLW/Pu	None	Normal	None
Naval	None	None	None

Notes:

Normal - Normal Handling Heights
Max - Maximum Possible Handling Heights
None - No certification required

- Manufacturing Flaws

A manufacturing flaw in a certified SC, canister, or DC will enable a drop from below the certified height to cause a breach.

The minimum probability of a manufacturing flaw in an SC, canister or DC/WP is 1.06×10^{-3} .

- Dose Consequences

The unmitigated dose consequences must be below the Category 2 dose criteria for the DBEs identified as "**Below**" in the following table.

Waste Form	SC	Canister	DC
CSNF	Below	Below	Below
DSNF	Above	Above	Above
HLW	Above	Below	Above
HLW/Pu	Above	Above	Above
Naval	Below	Below	Below

- SC, Canister, and DC Handling Times

There are no restrictions on SC, canister, or DC handling times within the MGR.

5. Additional Requirements from the Additional Consequence and Frequency Analyses

In addition to the requirements already presented, additional requirements as necessary will be derived from the additional consequence and frequency analyses after they are completed.