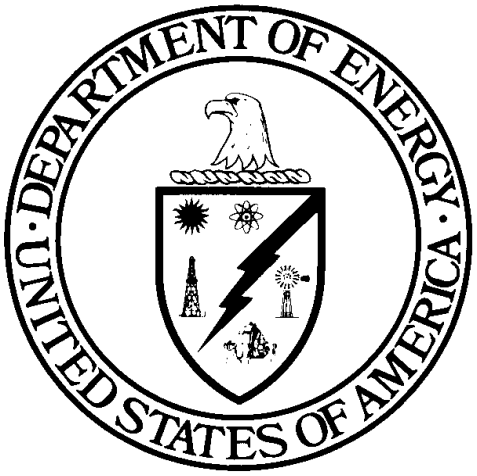
Title 40 CFR Part 191
Subparts B and C
Compliance Recertification
Application
for the
Waste Isolation Pilot Plant

Results of Performance Assessments
(40 CFR § 194.34)



United States Department of Energy
Waste Isolation Pilot Plant

Carlsbad Field Office
Carlsbad, New Mexico

Results of Performance Assessments
(40 CFR § 194.34)

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Acronyms and Abbreviations

CARD	Compliance Application Review Document
CCA	Compliance Certification Application
CCDF	complementary cumulative distribution function
CPR	cellulose, plastic, and rubber
CRA	Compliance Recertification Application
DBR	direct brine release
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
LHS	Latin hypercube sampling
PA	performance assessment
PABC	Performance Assessment Baseline Calculation
PAVT	Performance Assessment Verification Test
WIPP	Waste Isolation Pilot Plant

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34.0 Results of Performance Assessments (40 CFR § 194.34)

34.1 Requirements

§ 194.34 Results of Performance Assessments

(a) The results of performance assessments shall be assembled into complementary, cumulative distribution functions (CCDFs) that represent the probability of exceeding various levels of cumulative release caused by all significant processes and events.

(b) Probability distributions for uncertain disposal system parameter values used in performance assessments shall be developed and documented in any compliance application.

(c) Computational techniques, which draw random samples from across the entire range of the probability distributions developed pursuant to paragraph (b) of this section, shall be used in generating CCDFs and shall be documented in any compliance application.

(d) The number of CCDFs generated shall be large enough such that, at cumulative releases of 1 and 10, the maximum CCDF generated exceeds the 99th percentile of the population of CCDFs with at least a 0.95 probability. Values of cumulative release shall be calculated according to Note 6 of Table 1, Appendix A of Part 191 of this chapter.

(e) Any compliance application shall display the full range of CCDFs generated.

(f) Any compliance application shall provide information which demonstrates that there is at least a 95 percent level of statistical confidence that the mean of the population of CCDFs meets the containment requirements of 40 CFR 191.13.

34.2 40 CFR § 194.34(a)

34.2.1 Background

The radioactive waste disposal regulations of 40 CFR Part 191 Subparts B and C (U.S. Environmental Protection Agency 1993) include containment requirements for radionuclides. The containment requirements of 40 CFR § 191.13 specify that releases from a disposal system to the accessible environment must not exceed the release limits set forth in Part 191 Appendix A, Table 1. Assessment of the likelihood that the Waste Isolation Pilot Plant (WIPP) will meet the release limits is conducted through a process known as a performance assessment (PA). The WIPP PA consists of a series of computer simulations that model the physical attributes of the repository (site, geology, waste forms and quantities, engineered features) in a manner that captures the expected behaviors and interactions among its various components over the 10,000-year regulatory time frame.

The PA must consider all significant processes and events that may affect the disposal system (see Section 32 of this application), and it must be structured and conducted in a way that (1) demonstrates an adequate understanding of the physical conditions at the disposal system and its surroundings and (2) shows that the future performance of the system can be predicted with reasonable assurance. In addition, it must include simulations for both undisturbed conditions and human intrusion scenarios. The results of the PA are used to demonstrate compliance with the containment requirements of section 191.13.

The containment requirements place limits on the likelihood of radionuclide releases from a disposal system. A radionuclide release to the accessible environment is defined in terms of the location of the release and its magnitude. Any release of radionuclides to the ground surface,

atmosphere, or surface water is considered a release to the accessible environment. In addition, any subsurface transport of radionuclides beyond the boundary of the WIPP controlled area is also considered a release to the accessible environment.

The results of the WIPP PA are required to be expressed as complementary cumulative distribution functions (CCDFs). A CCDF indicates the probability of exceeding various levels of cumulative release. The CCDFs must be generated using random sampling techniques that draw upon the full range of values established for each uncertain parameter.

34.2.2 1998 Certification Decision

To meet the requirements of 40 CFR § 194.34(a) (U.S. Environmental Protection Agency 1996), the U.S. Environmental Protection Agency (EPA) expected the U.S. Department of Energy (DOE) to demonstrate that

1. The results of the PA were assembled into CCDFs.

2. The CCDFs represent the probability of exceeding various levels of cumulative release caused by all significant processes and events.

3. All significant processes and events that may affect the repository during the 10,000-year period after closure have been incorporated into the CCDFs presented.

The EPA reviewed the features, events, and processes for WIPP and the construction of the CCDFs for the Compliance Certification Application (CCA) (U.S. Department of Energy 1996). The EPA concluded that the DOE appropriately captured the significant processes and events that could occur during the regulatory period in the CCDFs and thus complied with the requirements of section 194.34(a).

A complete description of the EPA's 1998 Certification Decision for section 194.34(a) can be obtained from Compliance Application Review Document (CARD) 34, Section 34.A.6 (U.S. Environmental Protection Agency 1998a).

34.2.3 Changes in the CRA-2004

The DOE developed CCDFs for the 2004 Compliance Recertification Application (CRA-2004) (U.S. Department of Energy 2004) using the same methodology as used for the CCA and the CCA Performance Assessment Verification Test (PAVT); the only changes were in the values of some parameters and modeling assumptions. See the CRA-2004, Chapter 6.0, Table 6-1.

The DOE used selected computer codes and input parameters to generate estimates of radionuclides for a large number of scenarios. In total, 300 CCDFs (100 for each of the 3 replicates) were constructed and presented in the CRA-2004 Performance Assessment Baseline Calculation (PABC) Report (Leigh et al. 2005) for total normalized releases. Three hundred realizations were needed to satisfy the criteria of 40 CFR § 194.34(d). Normalized release results for 10,000 simulations of possible futures were used to calculate each of the 300 CCDF curves. In addition, the DOE provided CCDFs for individual pathways.

34.2.4 EPA's Evaluation of Compliance for the 2004 Recertification

The EPA's analysis concluded that the DOE adequately presented the PA results in CCDFs, which show the probability of exceeding various levels of cumulative releases (U.S. Environmental Protection Agency 2006a, Section 12.0).

Based on a review and evaluation of the CRA-2004 and supplemental information provided by the DOE, the EPA determined that the DOE continued to comply with the requirements for section 194.34(a) (see CARD 34, Section Recertification Decision [194.34(a)], U.S. Environmental Protection Agency 2006b).

34.2.5 Changes or New Information Since the 2004 Recertification

There are changes in the CRA-2009 related to parameter updates, error corrections, and code improvements made since the CRA-2004 decision (see Appendix PA-2009, Section PA-2.1.1 for more details). The DOE developed CCDFs for the CRA-2009 using the same sampling process and CCDF computational technique as in the CCA and the CRA-2004 (see the CCA, Chapter 6.0, Section 6.1).

In total, 300 CCDFs (100 for each of the 3 replicates) for total normalized releases were constructed and presented in Appendix PA-2009 (Figure 34-1). All of the 300 CCDFs lie below the limit of cumulative releases as defined in the containment requirements of section 191.13. Thus, the DOE continues to demonstrate compliance with the provisions of section 194.34(a).

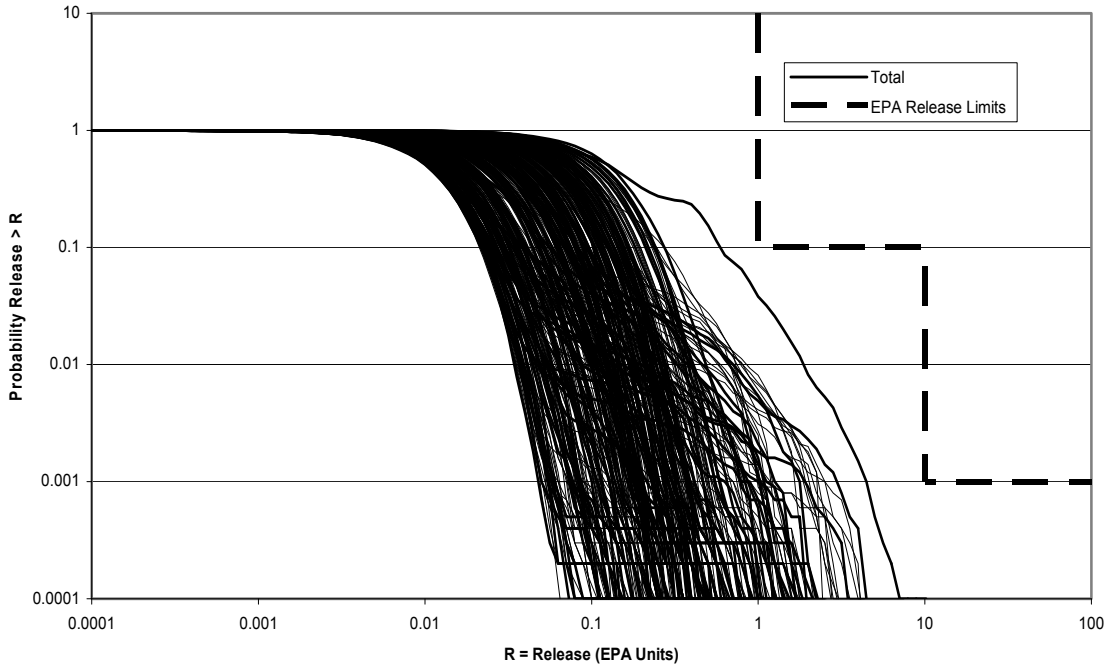

Figure 34-1. 300 CCDFs for Total Normalized Releases: CRA-2009 PA (from Figure 6-6 in Clayton et al. [2008])

34.3 40 CFR § 194.34(b)

34.3.1 Background

There is uncertainty associated with many of the parameters used in PA. 40 CFR § 194.34(b) addresses the need for the uncertain parameters to be sampled from a probability distribution (e.g., uniform, normal, etc.) that has been appropriately documented and justified.

34.3.2 1998 Certification Decision

To meet the criteria in section 194.34(b), the EPA expected the DOE to

1. Discuss the sources used and the methods by which each of the probability distributions was developed (e.g., experimental data, field data, etc.)

2. Identify the functional form of the probability distribution (e.g., uniform, lognormal) used for the sampled parameters

3. Describe the statistics of each probability distribution, including the values for lower and upper ranges, mean (geometric mean when appropriate), and median

4. Identify the importance of the sampled parameters to the final releases

5. Demonstrate that the data used to develop the input parameter probability distribution were qualified and controlled in accordance with 40 CFR § 194.22

Upon reviewing the DOE's parameters, the EPA found that the DOE adequately documented the probability distributions in the CCA, Appendix PAR. In addition, the DOE discussed the data and method used to create the probability distribution of each of the 57 sampled variables. The DOE provided general information on probability distributions, data sources for parameter distribution, forms of distributions, bounds, and importance of parameters to releases. The EPA identified inconsistencies with some of the parameter values and probability distributions, but these were resolved for the CCA PAVT the EPA required the DOE to conduct (U.S. Environmental Protection Agency 1998b, Section 5.0).

A complete description of the EPA's 1998 Certification Decision for section 194.34(b) can be obtained from the CARD 34, Section 34.B.5 (U.S. Environmental Protection Agency 1998a).

34.3.3 Changes in the CRA-2004

There were some changes in parameter values and probability distributions in the CRA-2004 PA from the CCA PAVT. Many of these changes are related to inventory changes, but some are related to modeling assumption changes (see Leigh et al. 2005, Section 2.0). However, the basic process the DOE used to develop the parameter information and sample the parameters did not change from the CCA methodology.

The DOE documented its selection of parameters and probability distributions for the key parameters in the CRA-2004, Chapter 6.0 and Appendix PA, Attachment PAR; the CRA-2004

PABC report (Leigh et al. 2005); and associated references. The CRA-2004 PABC sampled 56 parameters whose values were obtained through random sampling in the PA (Kirchner 2005). There were changes to several of the parameters from the CRA-2004 PA for the CRA-2004 PABC (Leigh et al. 2005). The ultimate goal of parameter sampling was to capture uncertainties in the parameters and show their effects on the CCDFs, which the DOE discussed in the CRA-2004, Chapter 6.0, Sections 6.4 and 6.5 and in the CRA-2004 PABC report (see Leigh et al. 2005, Section 2.9).

34.3.4 EPA's Evaluation of Compliance for the 2004 Recertification

The EPA reviewed the DOE's parameter selection and probability distributions in several technical support documents related to computer codes (U.S. Environmental Protection Agency 2006c and 2006d), parameters (U.S. Environmental Protection Agency 2006e, 2006f, and 2006g), and chemistry (U.S. Environmental Protection Agency 2006a, 2006f, and 2006g). The EPA found that the DOE adequately documented the probability distributions. In addition, the DOE discussed the data and method used to create the probability distribution of each sampled variable.

Based on a review and evaluation of the CRA-2004 and supplemental information provided by the DOE, the EPA determined that the DOE continued to comply with the requirements for section 194.34(b) (see CARD 34, Section Recertification Decision [194.34(b)]; U.S. Environmental Protection Agency 2006b).

34.3.5 Changes or New Information Since the 2004 Recertification

Although 15 parameters were modified and 90 were added (Fox 2008, Table 6), the process that the DOE used to develop the parameter information and sample the parameters did not change from the EPA-approved CCA methodology (see Fox 2008 for parameter sample distribution information). Thus, the DOE continues to demonstrate compliance with provision of section 194.34(b).

34.4 40 CFR § 194.34(c)

34.4.1 Background

The intent of 40 CFR § 194.34(c) is to ensure that the sampled parameters were appropriately selected for use in PA.

34.4.2 1998 Certification Decision

To demonstrate compliance with section 194.34(c), the EPA expected the DOE to do the following:

1. Discuss the computational techniques used for random sampling

2. Demonstrate that sampling occurred across the entire range of each parameter

The EPA agreed it was appropriate to use the Latin hypercube sampling (LHS) method for the 57 sampled parameters described in the CCA, Appendix PAR. The CCDFGF code also sampled stochastic variables with Monte Carlo sampling for each realization. The EPA concluded that the DOE adequately discussed the computational techniques and sampling ranges.

A complete description of the EPA's 1998 Certification Decision for section 194.34(c) can be obtained from CARD 34, Section 34.C.5; (U.S. Environmental Protection Agency 1998a).

34.4.3 Changes in the CRA-2004

In the CRA-2004, the DOE used the same LHS methodology for sampling uncertain parameters as in the CCA. There was no change in the methodology.

34.4.4 EPA's Evaluation of Compliance for the 2004 Recertification

The EPA determined during the CCA review that the LHS method ensures parameter values will be selected from the entire range of the probability distributions because LHS stratifies the probability distributions into a number (100, in this case) of equal-probability regions and then samples one value from each region. The EPA noted that the LHS method is appropriate for generating random samples (CARD 34, Section 34.C.5; U.S. Environmental Protection Agency 1998a). The DOE used the same approach in the CRA-2004.

Based on a review and evaluation of the CRA-2004 and supplemental information provided by the DOE, the EPA determined that the DOE continued to comply with the criteria for section 194.34(c) (see CARD 34, Section Recertification Decision [194.34(c)]; U.S. Environmental Protection Agency 2006b).

34.4.5 Changes or New Information Since the 2004 Recertification

In the CRA-2009, the DOE uses the same LHS methodology for sampling uncertain parameters as in the CCA and CRA-2004. There is no change in the methodology. Thus, the DOE continues to demonstrate compliance with provisions of section 194.34(c).

34.5 40 CFR § 194.34(d)

34.5.1 Background

The intent of 40 CFR § 194.34(d) is to ensure that PA modeling appropriately sampled uncertain parameters and that future scenarios were appropriately used in PA.

34.5.2 1998 Certification Decision

To demonstrate compliance with section 194.34(d), the EPA expected the DOE to do the following:

1. Identify the number of CCDFs generated

2. Discuss how the DOE determined the number of CCDFs to be generated

3. List the probabilities of exceeding cumulative releases of 1 and 10 for each CCDF generated

4. Demonstrate that the maximum CCDF generated, at cumulative normalized releases of 1 and 10, exceeds the 99th percentile with at least a 0.95 probability, including examples of calculations

The EPA found the analysis presented in the CCA, Chapter 8.0, sufficient to show that 298 CCDF curves would satisfy the statistical criterion. The EPA's independent analysis also verified that the 300 CCDF curves computed and presented in the CCA were sufficient (CARD 34, Section 34.D.5; U.S. Environmental Protection Agency 1998a). The DOE correctly interpreted the definition of the 99th percentile value, and applied standard mathematical expressions for deriving the probability of an outcome of multiple events (i.e., the generation of multiple CCDF curves). The probabilistic analysis was found to be appropriate for sampling with the LHS method, which achieves better coverage than nonstratified random sampling of parameter ranges.

A complete description of the EPA's 1998 Certification Decision for section 194.34(d) can be obtained from the CARD 34, Section 34.D.5 (U.S. Environmental Protection Agency 1998a).

34.5.3 Changes in the CRA-2004

In the CRA-2004, the DOE used the same methodology as in the CCA to generate 300 CCDFs in three sets (replicates) of 100. There was no change in the methodology.

34.5.4 EPA's Evaluation of Compliance for the 2004 Recertification

The EPA noted that the DOE generated 3 sets of 100 CCDFs each and discussed the statistical confidence levels based on the entire set of CCDFs. Based on the analysis in the CCA and the fact that the DOE used the same approach in the CRA-2004, the EPA concurred with the DOE's CRA-2004 analyses.

Based on a review and evaluation of the CRA-2004 and supplemental information provided by the DOE, the EPA determined that the DOE continued to comply with the requirements for section 194.34(d) (see CARD 34, Section Recertification Decision [194.34(d)]; U.S. Environmental Protection Agency 2006b).

34.5.5 Changes or New Information Since the 2004 Recertification

In the CRA-2009, the DOE is using the same methodology as in the CCA and CRA-2004 to generate 300 CCDFs in 3 sets (replicates) of 100. There is no change in the methodology. Thus, the DOE continues to demonstrate compliance with provisions of section 194.34(d).

34.6 40 CFR § 194.34(e)

34.6.1 Background

The intent of 40 CFR § 194.34(e) is to show the full range of CCDFs in order to provide an indication of the nature of the releases.

34.6.2 1998 Certification Decision

To demonstrate compliance with section 194.34(e), the EPA expected the DOE to do the following:

1. Display the full range of CCDFs generated

2. Present appropriate information to allow the EPA to confirm the DOE's PA analysis, including the steps used to arrive at the result and the data values that are represented by the CCDFs

3. Include descriptive statistics such as the range, mean, median, etc., for the estimated CCDFs at cumulative releases of 1 and 10

The DOE employed LHS to create 3 independent replicates of 100 realizations each, yielding 300 CCDF curves. The DOE concluded that the requirement of section 194.34(e) was met. The EPA concurred with this conclusion.

A complete description of the EPA's 1998 Certification Decision for section 194.34(e) can be obtained from CARD 34, Section 34.E.5 (U.S. Environmental Protection Agency 1998a).

34.6.3 Changes in the CRA-2004

There were no changes to the approach used by the DOE with regards to section 194.34(e) in the CRA-2004. The DOE presented and discussed the results of the PA analysis in the CRA-2004, Chapter 6.0 and the CRA-2004 PABC report (see Chapter 6 in Leigh et al. 2005), which display the full range of CCDFs generated. Furthermore, appropriate information needed to confirm the analysis and descriptive statistics for the estimated CCDFs were shown.

34.6.4 EPA's Evaluation of Compliance for the 2004 Recertification

Based on a review and evaluation of the CRA-2004 and supplemental information provided by the DOE, the EPA determined that the DOE continued to comply with the requirements for section 194.34(e) (see CARD 34, Section Recertification Decision [194.34(e)]; U.S. Environmental Protection Agency 2006b).

34.6.5 Changes or New Information Since the 2004 Recertification

There are no changes to the approach used by the DOE with regards to section 194.34(e) in the CRA-2009. The full range of CCDFs generated for the CRA-2009 PA is shown in Figure 34-1. Thus, the DOE continues to demonstrate compliance with provisions of section 194.34(e).

34.7 40 CFR § 194.34(f)

34.7.1 Background

Because of the unique nature of the WIPP, the EPA wanted to ensure that the PA results could be used to adequately support a certification decision. To this end, the EPA required the DOE to demonstrate compliance with a high statistical confidence. For 40 CFR § 194.34(f), the DOE must show, in effect, that the mean of its 300 CCDF curves, and the 95th percentile upper confidence limit of the population mean, meet the containment requirements of section 191.13 for the cumulative releases at 1 and 10 times the quantities in Part 191 Appendix A, Table 1.

34.7.2 1998 Certification Decision

To demonstrate compliance with section 194.34(f), the EPA expected the DOE to do the following:

1. Present appropriate information, including steps used to arrive at the result and the data used in the analysis, allowing the EPA to confirm that the mean of the CCDF population meets the containment requirements of section 191.13 with a 95% statistical confidence level

2. Identify the mean of the sample of CCDFs generated for the cumulative releases at 1 and 10 times the quantities in Part 191 Appendix A, Table 1

3. Identify the CCDF values associated with a 95% statistical confidence level of the population mean for the cumulative releases at 1 and 10 times the quantities in Part 191 Appendix A, Table 1

Upon analysis of the CCA PA, the EPA identified inconsistencies with some of the parameter values and probability distributions, and so the EPA required the DOE to conduct the CCA PAVT, which resolved the issues (U.S. Environmental Protection Agency 1998b, Section 5.0). The Certification Decision was based on the CCA PAVT results. The CCA PAVT results demonstrated that the mean of the CCDFs met the section 191.13 containment requirements and that the level of statistical confidence is significantly greater than 95%. Therefore, the EPA concluded that the final result of the CCA PAVT was in compliance with the containment requirements of section 191.13 and that the results were presented in accordance with section 194.34(f) (see CARD 34, Section 34.F.5, U.S. Environmental Protection Agency 1998a).

34.7.3 Changes in the CRA-2004

In the CRA-2004, the DOE used the same general approach for calculating the statistical confidence for release limits as was used in the CCA. The DOE provided the CCDFs and uncertainty information in the CRA-2004 documentation.

34.7.4 EPA's Evaluation of Compliance for the 2004 Recertification

The EPA's and the DOE's review of the CRA-2004 identified several errors that may have affected the CRA-2004 PA's compliance with section 194.34(f) (Cotsworth 2005). Incorrect LHS transfer files were used as input to PRECCDFGF for Replicates 2 and 3; thus, some of the same parameter inputs were used multiple times instead of being appropriately sampled for each replicate. A spallings release calculation for the volume fraction of contact-handled transuranic waste was omitted from CCDFGF, and an error in the input control file for the computer code SUMMARIZE affected spallings results. Finally, only 50 vectors for DRSPALL calculations were run for the CRA-2004 PA, instead of a full set of 100 vectors for each of the three replicates, thus potentially reducing the range of spallings releases.

Because of these problems, the EPA required the DOE to run a full set of DRSPALL vectors and correct the problem with LHS transfer files in the CRA-2004 PABC. The results of the CRA-2004 PABC are provided in the DOE's CRA-2004 PABC report (Leigh et al. 2005). In its review of the CRA-2004 PABC, the EPA concurred that the errors were corrected (CARD 34, U.S. Environmental Protection Agency 2006b).

Based on a review and evaluation of the CRA-2004 and supplemental information provided by the DOE, the EPA determined that the DOE continued to comply with the requirements for section 194.34(f) (CARD 34, Section Recertification Decision [194.34(f)], U.S. Environmental Protection Agency 2006b).

34.7.5 Changes or New Information Since the 2004 Recertification

For the CRA-2009, the DOE is using the same approach to calculate the statistical confidence for evaluation against the release limits. The mean of the 300 CCDFs, along with the 95% confidence levels about the overall mean for the total normalized releases of the CRA-2009 PA, are shown in Figure 34-2. Table 34-1 lists the overall mean total normalized release CCDF values of the CRA-2009 PA at the compliance probabilities of 0.1 and 0.001, along with the values of the upper and lower 95% confidence limit CCDFs at the same probabilities. More details on the normalized release results of the CRA-2009 PA are discussed in Appendix PA-2009, Section PA-9.0. As seen in Figure 34-2 and Table 34-1, the results of the PA demonstrate a greater than 95% level of statistical confidence that the overall mean of the population of CCDFs is in compliance with the containment requirements of section 191.13, and thus the DOE continues to comply with provisions of section 194.34(f).

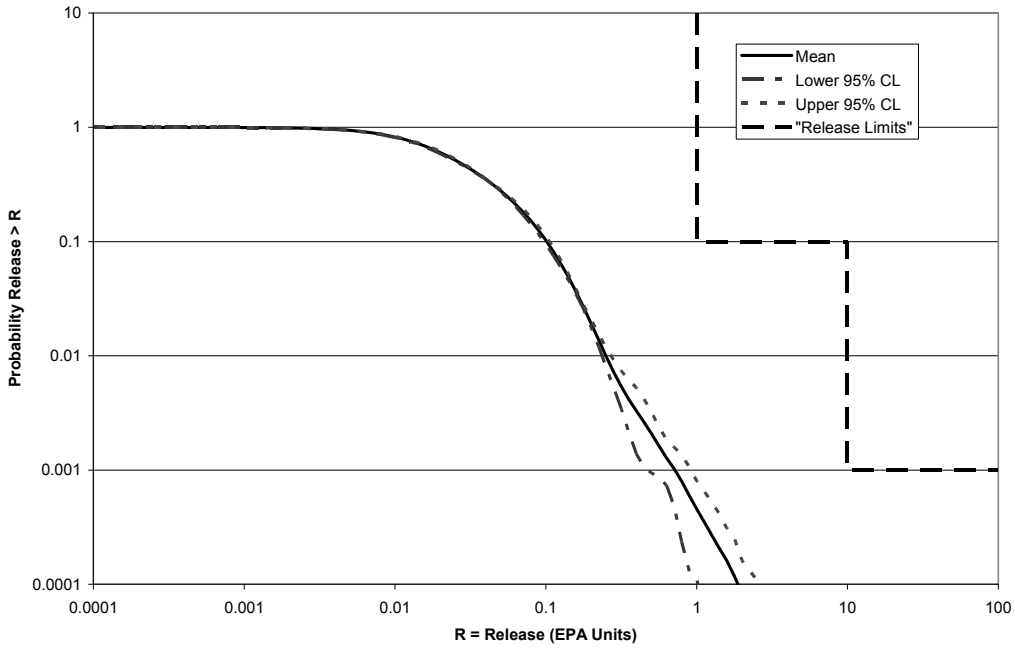

Figure 34-2. Mean and Confidence Interval CCDFs for Total Normalized Releases: CRA-2009 PA (from Figure 6-7 in Clayton et al. [2008])

Table 34-1. CRA-2009 PA Statistics on the Overall Mean for Total Normalized Releases at Probabilities of 0.1 and 0.001, All Replicates Pooled Compared with Release Limits (from Table 6-1 in Clayton et al. [2008])

Probability	Mean Total Release	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Regulatory[a] Limit
0.1	0.10	0.10	0.11	1
0.001	0.72	0.48	0.92	10

[a] Releases divided by the release limits in Part 191 Appendix A, Table 1.

The DOE believes that the information presented in this section and additional information in Appendix PA-2009 demonstrates continued compliance with section 194.34.

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