
**Title 40 CFR Part 191
Subparts B and C
Compliance Recertification Application 2014
for the
Waste Isolation Pilot Plant**

**Results of Compliance Assessments
(40 CFR § 194.55)**



**United States Department of Energy
Waste Isolation Pilot Plant**

**Carlsbad Field Office
Carlsbad, New Mexico**

Compliance Recertification Application 2014
Results of Compliance Assessments
(40 CFR § 194.55)

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Acronyms and Abbreviations

CARD	Compliance Application Review Document
CCA	Compliance Certification Application
CFR	Code of Federal Regulations
CRA	Compliance Recertification Application
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
LHS	Latin hypercube sampling
mrem	millirem
PA	performance assessment
PAVT	Performance Assessment Verification Test
pCi/L	picocuries per liter
USDW	underground source of drinking water
WIPP	Waste Isolation Pilot Plant

Elements and Chemical Compounds

Am	americium
Pu	plutonium
Ra	radium
Rn	radon
Th	thorium
U	uranium

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1 **55.0 Results of Compliance Assessments (40 CFR § 194.55)**

2 **55.1 Requirements**

§ 194.55 Results of Compliance Assessments

(a) Compliance assessments shall consider and document uncertainty in the performance of the disposal system.

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

(c) Computational techniques which draw random samples from across the entire range of values of each probability distribution developed pursuant to paragraph (b) of this section shall be used to generate a range of:

(1) Estimated committed effective doses received from all pathways pursuant to § 194.51 and § 194.52;

(2) Estimated radionuclide concentrations in USDWs pursuant to § 194.53; and

(3) Estimated dose equivalent received from USDWs pursuant to § 194.52 and § 194.53.

(d) The number of estimates generated pursuant to paragraph (c) of this section shall be large enough such that the maximum estimates of doses and concentrations generated exceed the 99th percentile of the population of estimates with at least a 0.95 probability.

(e) Any compliance application shall display:

(1) The full range of estimated radiation doses; and

(2) The full range of estimated radionuclide concentrations.

(f) Any compliance application shall document that there is at least a 95 percent level of statistical confidence that the mean and the median of the range of estimated radiation doses and the range of estimated radionuclide concentrations meet the requirements of § 191.15 and part 191, subpart C of this chapter, respectively.

3

4 **55.2 Background**

5 The individual and groundwater protection requirements of 40 CFR § 191.15 and 40 CFR Part
6 191 Subpart C (U.S. EPA 1993) place limitations on both the potential radiation exposure of
7 individuals and the possible levels of radioactive contamination of groundwater caused by
8 disposal of waste in the Waste Isolation Pilot Plant (WIPP). The criteria for compliance are
9 provided in 40 CFR §§ 194.51 through 194.55 (U.S. EPA 1996). The individual protection
10 requirement focuses on the annual radiation dose of a maximally exposed person living on the
11 surface just outside the Land Withdrawal Act boundary. In particular, section 191.15 requires
12 that the WIPP be constructed in such a manner as to provide a reasonable expectation that, for
13 10,000 years after disposal, undisturbed performance of the disposal system will not cause the
14 annual committed effective dose equivalent (hereafter called “dose”) to exceed 15 millirems
15 (mrem) (150 microsieverts) to any member of the public in the accessible environment. Part 191
16 Subpart C also requires that underground sources of drinking water (USDWs) be protected at
17 least to the extent prescribed by the Safe Drinking Water Act regulations at 40 CFR Part 141 as
18 they existed on January 19, 1994 (per 40 CFR § 191.24(a)(1)).

19 **55.3 1998 Certification Decision**

20 **55.3.1 40 CFR § 194.55(a)**

21 In the Compliance Certification Application (CCA) (U.S. DOE 1996), the U.S. Environmental
22 Protection Agency (EPA) found that the U.S. Department of Energy (DOE) considered
23 uncertainty in two ways: (1) by assigning probability distributions to 57 of the key parameters
24 that describe the repository, and sampling from those distributions to carry out the performance

1 assessment (PA) (see the CCA, Chapter 6.0, pp. 6-21 to 6-23 and 6-173 to 6-199; and Appendix
2 PAR), and (2) by translating from groundwater contaminant level to doses by means of the
3 bounding analysis (see the CCA, Chapter 8.0, and Dials 1997).

4 The DOE's method of evaluation of uncertainty in the amounts of contaminants transported
5 underground was essentially the same as that for the 300 scenarios involving human intrusion in
6 the PA, as presented in the CCA, Chapter 6.0, Section 6.1.2, except that those uncertainties
7 introduced by the borehole drilling process can be ignored. The EPA found this aspect of the
8 treatment of uncertainties to be satisfactory.

9 The EPA reviewed the bounding calculation as presented in the CCA, Chapter 8.0 and
10 supplementary information regarding models and computer codes, parameter values, dose
11 calculations and related topics (Dials 1997) and reported the results of that evaluation in
12 Compliance Application Review Document (CARD) 51/52 (U.S. EPA 1998a). The EPA
13 determined that the DOE's conceptual model and the use of the GENII-A computer code to
14 calculate radiation doses were appropriate. The EPA found this bounding calculation to be
15 acceptable in lieu of further uncertainty analysis (CARD 55, U.S. EPA 1998b).

16 **55.3.2 40 CFR § 194.55(b)**

17 The probability distributions for uncertain disposal system parameter values used for
18 demonstrating compliance with the individual dose and groundwater criteria of section 194.55
19 are identical to those used for the containment requirements in 40 CFR § 194.34 (U.S. EPA
20 1996). The EPA concluded that the DOE provided general information in the CCA on
21 probability distributions, data sources for parameter distribution, forms of distributions, bounds,
22 and importance of parameters to releases.

23 The EPA initially raised concerns about the completeness of the list of PA parameters in the
24 CCA, the descriptions and justifications that support the development of some code input
25 parameters, and the traceability of data reduction and analysis of parameter records. The DOE
26 improved the documentation regarding the basis of parameters, and also developed better
27 "roadmaps" that link parameter documentation and parameter development. Upon subsequent
28 review of records, the EPA determined that the DOE adequately provided the required
29 information for probability distributions of code input parameters (CARD 55, U.S. EPA 1998b).

30 **55.3.3 40 CFR § 194.55(c)**

31 The EPA examined the DOE's use of the Latin hypercube sampling (LHS) procedure and found
32 that the LHS technique draws samples from the entire range of each sampled parameter, was
33 appropriate for use in assessing the concentrations of radionuclides in groundwater, and was
34 implemented correctly by the DOE.

35 The DOE's evaluation of individual doses and groundwater radionuclide contamination and
36 assessment of USDWs were described in the CCA, Chapter 8.0. The EPA evaluated the
37 conceptual model that the DOE used to estimate a maximum individual exposure in its bounding
38 calculation. The EPA determined that the DOE's conceptual model and the use of the GENII-A
39 computer code to calculate the radiation doses were appropriate (CARD 55, U.S. EPA 1998b).

1 55.3.4 40 CFR § 194.55(d)

2 Compliance with 40 CFR § 194.55(d) is described in detail in Appendix IGP-2009, Section IGP-
3 2.4. A summary is provided here.

4 The number of estimates generated must be large enough that the probability is at least 0.95 that
5 the maximum estimate exceeds the 99th percentile of the population of estimates. If the 300
6 realizations were statistically independent, then the probability that the maximum estimate
7 exceeded the 99th percentile of the population of estimates would equal $1 - (0.99)^{300} = 0.951$, and
8 the section 194.55(d) criterion would be satisfied. On that basis, the probability that the
9 maximum estimate exceeds the 99th percentile of the population of estimates exceeded 0.95, and
10 the section 194.55(d) criterion was satisfied.

11 The determination of the groundwater concentration and individual dose was based on the PA
12 analysis of releases to the Salado Formation interbeds. Therefore, the number of estimates of
13 concentrations and doses caused by releases to the interbeds was the same as the number in the
14 PA and was dependent on the same calculations. The EPA concluded that the assessment of 300
15 realizations of the modeling system meets the requirements of section 194.55(d) (CARD 55, U.S.
16 EPA 1998b).

17 55.3.5 40 CFR § 194.55(e)

18 40 CFR § 194.55(e) requires the DOE to display the full ranges of estimated doses and
19 concentrations. The EPA found that:

- 20 • The estimated doses caused by ingesting water from the USDW were reported in the CCA,
21 Chapter 8.0, Table 8-2. The maximum estimated dose rate from the other relevant pathways
22 (0.46 mrem per year) was reported in the DOE response document (Dials 1997). The all-
23 pathway individual doses were obtained by adding 0.46 mrem per year to those values. The
24 maximum annual dose obtained in this fashion was less than 1 mrem per year (0.93 mrem per
25 year).
- 26 • The CCA, Chapter 8.0, Section 8.2.3, pp. 8-15 and 8-16, states that the maximum estimated
27 radium (Ra) concentration across the nine nonzero realizations was 2.0 picocuries per liter
28 (pCi/L).
- 29 • The CCA, Chapter 8.0, Table 8-1 contains the 300 estimated concentrations for the 5
30 radionuclides: americium-241 (²⁴¹Am), plutonium-239 (²³⁹Pu), plutonium-238 (²³⁸Pu),
31 uranium-234 (²³⁴U), and thorium-230 (²³⁰Th), of which only nine were above the selection
32 criteria. The nine radium-226 (²²⁶Ra) concentrations were not separately recorded, but the
33 maximum gross alpha-particle concentration, including Ra and excluding radon (Rn) and
34 uranium (U), was reported as 7.81 pCi/L. The confidence interval analysis described below
35 under 40 CFR § 194.55(f) used a more conservative approach that added the total Ra
36 concentration bound (2.0 pCi/L) to the total of the five radionuclide concentrations, including
37 U.
- 38 • The USDW dose estimates were reported in the CCA, Chapter 8.0, Table 8-2.

1 The EPA found the DOE's calculations to be conservative and therefore acceptable (CARD 55,
2 U.S. EPA 1998b).

3 **55.3.6 40 CFR § 194.55(f)**

4 As part of the CCA certification process, the EPA required the DOE to perform an additional PA
5 termed the Performance Assessment Verification Test (PAVT; EPA 1998c) using modifications
6 to the parameters and codes used in the CCA PA. Since WIPP compliance assessments are
7 based on PA results, the DOE performed additional compliance assessment calculations of
8 individual dose and radioactivity concentration as part of the CCA PAVT. The mean dose
9 calculated in the CCA PAVT from all pathways was an order of magnitude below the limit of
10 section 191.15. Because all radionuclides contributing to the dose were alpha-emitting, the CCA
11 PAVT also demonstrated compliance with the annual dose equivalent to the total body or any
12 internal organ from beta particle and photon radioactivity in USDWs. The mean radionuclide
13 concentrations calculated in the CCA PAVT for alpha-emitting radionuclides (including Ra but
14 excluding Rn and U) and for ^{226}Ra and ^{228}Ra were below the limits of 40 CFR Part 191 Subpart
15 C (U.S. DOE 1997a).

16 The DOE was required to demonstrate that there was at least a 95% level of statistical confidence
17 that the mean and the median of the range of estimated radiation doses were less than 15 mrem
18 per year, and that the range of estimated radionuclide concentrations was compatible (after
19 dilution, as discussed above) with the regulations developed under the Safe Drinking Water Act.
20 The DOE's bounding analysis indirectly verified these requirements by showing that the
21 maximum estimated dose or concentration was always lower than the maximum allowable value.

22 As with the CCA, the CCA PAVT involved groundwater modeling simulations for the
23 undisturbed repository. The results of this modeling projected nonzero groundwater
24 concentrations for 13 of the 300 modeling simulations (as opposed to 9 in the CCA, Appendix
25 PA). The projected groundwater concentrations from the CCA PAVT are found in *Summary of*
26 *EPA-Mandated Performance Assessment Verification Test (Replicate 1) and Comparison with*
27 *the Compliance Certification Application Calculations* (U.S. DOE 1997b), and *Supplemental*
28 *Summary of EPA-Mandated Performance Assessment Verification Test (All Replicates) and*
29 *Comparison with the Compliance Certification Application Calculations* (U.S. DOE 1997c).
30 The EPA found that the mean and median radionuclide concentrations in groundwater calculated
31 in the CCA PAVT complied with the requirements of Part 191, Subpart C both for gross alpha
32 particle radioactivity (including Ra but excluding Rn and U) and for radioactivity concentration
33 for ^{226}Ra and ^{228}Ra (U.S. EPA 1998a).

34 Drinking-water and all-pathways doses corresponding to projected groundwater concentrations
35 in the CCA PAVT were estimated using the modeling methodology established for the CCA.
36 The DOE initially submitted results for the drinking-water pathway only, where the largest dose
37 value was 3.2×10^{-2} mrem per year (U.S. DOE 1997a, Table 3). Later, in its *Summary of the*
38 *EPA-Mandated Performance Assessment Verification Test Results for Individual Protection*
39 *Requirements*, the DOE calculated 3.1×10^{-2} mrem per year for all other pathways combined
40 (U.S. DOE 1997d, Table 5). This calculation again resulted in a value two orders of magnitude
41 less than the 15 mrem per year requirement. The EPA's calculation of the total body dose from

1 the DOE's concentrations for the 13 nonzero realizations yielded a maximum value of 3.1×10^{-1}
2 mrem per year (U.S. EPA 1998d).

3 The DOE's PAVT analysis of beta, electron, and photon doses to the whole body and to
4 individual internal organs is shown in its *Summary of the EPA Mandated Performance*
5 *Assessment Verification Test Results for Individual Protection Requirements* (U.S. DOE 1997d,
6 Table 3). The DOE demonstrated that the largest organ dose is 2.9×10^{-4} mrem per year on the
7 bone surface. The analysis also showed that the maximum effective dose from beta, electron,
8 and photon emissions is 1.5×10^{-5} mrem per year.

9 Results of the CCA PAVT thus showed that the mean dose contributions from both alpha-
10 emitting radionuclides and from photon- and beta-emitting radionuclides were below the limits
11 in section 191.15 and Part 191 Subpart C.

12 Based on its review of the material provided by the DOE in the CCA and additional information
13 from the CCA PAVT, the EPA concluded that the DOE demonstrated compliance with the
14 requirements of section 194.55. A complete description of the EPA's 1998 Certification
15 Decision for section 194.55 is found in U.S. EPA 1998e.

16 **55.4 Changes in the CRA-2004**

17 The DOE's methodology for demonstrating compliance with section 194.55 did not change since
18 the CCA. The CRA-2004, Chapter 8.0 described the DOE's compliance with the individual and
19 groundwater protection requirements (U.S. DOE 2004). The DOE considered and documented
20 uncertainty as required by 40 CFR § 194.55(a), in the CRA-2004, Section 6.1.2. As noted in the
21 CRA-2004, Chapter 8.0, Section 8.1.5, parameter uncertainty was discussed in Appendix PA-
22 2004, Attachment PAR to verify compliance with 40 CFR § 194.55(b). The CRA-2004, Chapter
23 8.0 describes how the DOE calculated the effective dose and dose equivalent as required by
24 section 194.55(c). The CRA-2004, Chapter 8.0, Section 8.1.4 also noted that the DOE's
25 selection of more than 298 sampled vectors fulfilled the requirements of 40 CFR § 194.55(d).
26 The DOE also noted in the CRA-2004, Chapter 8.0, Section 8.1.4 that their bounding analysis
27 adequately fulfilled the requirements of section 194.55(f). The CRA-2004, Chapter 8.0, Section
28 8.1 showed how the DOE considered the full range of estimated radiation doses and radionuclide
29 concentrations as required by section 194.55(e).

30 **55.5 EPA's Evaluation of Compliance for the 2004 Recertification**

31 The EPA reviewed the DOE's CRA-2004 documents, in particular Chapter 8.0. The EPA found
32 that little had changed since the original certification decision. The EPA did not receive any
33 public comments on the DOE's continued compliance with the compliance assessment
34 requirements of section 194.55. The EPA concluded that the DOE continued to demonstrate
35 compliance with the requirements of section 194.55 (CARD 55, U.S. EPA 2006).

1 **55.6 Changes or New Information Between the CRA-2004 and the CRA-2009**
2 **(Previously: Changes or New Information Since the 2004 Recertification)**

3 The DOE's methodology for demonstrating compliance with section 194.55 was not changed in
4 the CRA-2009 from the methodology in the CRA-2004 or the CCA. Appendix IGP-2009 was an
5 updated version of the CCA, Chapter 8.0 and the CRA-2004, Chapter 8.0. It documented the
6 DOE's continued compliance with the individual and groundwater protection requirements.
7 Compliance with the various subsections of section 194.55 was demonstrated in 2009 as follows:

- 8 • As indicated in Appendix IGP-2009, Section IGP-2.1, parameter uncertainty was discussed
9 in Fox 2008, which demonstrated compliance with section 194.55(b).
- 10 • Appendix IGP-2009, Section IGP-2.2 described how the DOE calculated the effective dose
11 and dose equivalent as required by 40 CFR § 194.55(c).
- 12 • Appendix IGP-2009, Section IGP-2.4 also explained that the DOE's selection of more than
13 298 sampled vectors fulfilled the requirements of section 194.55(d).
- 14 • Appendix IGP-2009, Sections IGP-2.1 and 2.2 demonstrated that the DOE considered the
15 full range of estimated radionuclide concentrations and radiation doses as required by section
16 194.55(e).
- 17 • Appendix IGP-2009, Section IGP-2.4 demonstrated that the DOE's bounding analysis
18 approach meet the requirements of section 194.55(f).

19 Based on this information, the DOE believed that continued compliance with the provisions of
20 section 194.55 was demonstrated at that time.

21 **55.7 EPA's Evaluation of Compliance for the 2009 Recertification**

22 The EPA reviewed the DOE's CRA-2009 documents and found that little had changed since the
23 original certification decision. The EPA did not receive any public comments on the DOE's
24 continued compliance with the requirements of section 194.55. The EPA concluded that the
25 DOE continued to demonstrate compliance with the requirements of section 194.55 (CARD 55,
26 U.S. EPA 2010).

27 **55.8 Changes or New Information Since the CRA-2009**

28 The DOE's methodology for demonstrating compliance with section 194.55 has not changed
29 since the CCA. Appendix IGP-2014 is an updated version of the CCA, Chapter 8.0 and the
30 CRA-2004, Chapter 8.0. It documents the DOE's continued compliance with the individual and
31 groundwater protection requirements. Compliance with the various subsections of section
32 194.55 is demonstrated as follows:

- 33 • As indicated in Appendix IGP-2014, Section IGP-2.1, parameter uncertainty is discussed in
34 Kicker and Herrick 2013, which demonstrates compliance with section 194.55(b).

- 1 • Appendix IGP-2014, Section IGP-2.2 describes how the DOE calculates the effective dose
2 and dose equivalent as required by 40 CFR § 194.55(c).
- 3 • Appendix IGP-2014, Section IGP-2.4 also explains that the DOE's selection of more than
4 298 sampled vectors fulfills the requirements of section 194.55(d).
- 5 • Appendix IGP-2014, Sections IGP-2.1 and 2.2 demonstrate that the DOE considered the full
6 range of estimated radionuclide concentrations and radiation doses as required by section
7 194.55(e).
- 8 • Appendix IGP-2014, Section IGP-2.4 demonstrates that the DOE's bounding analysis
9 approach meets the requirements of section 194.55(f).

10 Based on this information, the DOE believes that continued compliance with the provisions of
11 section 194.55 is demonstrated.

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