

CALCULATING THE POTENTIAL FOR REPOSITORY INTRUSION AT WIPP: SURVEILLANCE OF PETROLEUM ACTIVITIES IN THE DELAWARE BASIN

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ABSTRACT

Prior to receiving approval to open, the U.S. Department of Energy (DOE) was required to demonstrate that the Waste Isolation Pilot Plant (WIPP) repository would not release radioactivity in excess of the prescribed regulatory standards under two sets of conditions. The first is the case in which the repository remains undisturbed from human activity or catastrophic acts of Mother Nature. The second is a significant event that disrupts the containment of the repository. The U.S. Environmental Protection Agency (EPA) requires that DOE analyze the risk of each case and provide documentation of the results. Documentation responsive to this requirement was provided in 1996, which helped facilitate the approval to open WIPP ([1](#)).

Now, after five years of operation, DOE must renew the documentation and update the analysis that will either confirm or revise the previous analysis. This paper summarizes the program established by DOE to track and trend the activities of the petroleum industry in the region surrounding WIPP. It also provides insight on how this information is considered in assessing the long-term performance of the repository.

DISCUSSION

The WIPP is a geologic repository, mined in the Salado Formation salt beds at a depth of about 2,150 feet, that is located about 26 miles east of Carlsbad, New Mexico. The Delaware Basin Drilling Surveillance Program (DBDSP) is designed to monitor drilling activities in the vicinity of the WIPP. This program is based on EPA requirements, including the standards for the management and disposal of transuranic radioactive wastes codified in Title 40 Code of Federal Regulations (CFR), Part 191 ([2](#)). Subparts B and C of 40 CFR Part 191 address the long-term aspects of disposing radioactive waste. Subpart B requires the DOE to demonstrate the expected performance of the disposal system using a probabilistic risk assessment or performance assessment (PA). This assessment must include the consideration of inadvertent drilling into the repository at some future time. To model drilling activities in a representative manner requires the collection of information on various aspects of drilling a well. The collected information is used in the various computer models required to do a PA of the repository.

Definition of the Delaware Basin

In Title 40 CFR, Part 194 (3), the EPA defined the geographical area for the evaluation of the historical rate of drilling for resources, as the Delaware Basin. This same area is to be used for monitoring drilling and drilling-related activities. The definition of the Delaware Basin in Title 40 CFR Part 194.2 is:

“Delaware Basin means those surface and subsurface features which lie inside the boundary formed to the north, east and west of the [WIPP] disposal system, by the innermost edge of the Capitan Reef, and formed, to the south, by a straight line drawn from the southeastern point of the Davis Mountains to the most southwestern point of the Glass Mountains.”

The Delaware Basin, Figure 1, covers 23,102 square kilometers (8,920 square miles). It includes all or part of Brewster, Culberson, Jeff Davis, Loving, Pecos, Reeves, Ward, and Winkler counties in west Texas, and portions of Eddy and Lea counties in southeastern New Mexico. Most of the monitoring activities are observed in this defined area. However, there are some activities being monitored that occur outside of the Delaware Basin. The size of the total monitoring area, depicted in Figure 1, is 96,273 square kilometers (37,171 square miles).

Activities Observed and Tracked

General Drilling Activities

General drilling activities monitored through the DBDSP include the following:

- Total number of deep wells (boreholes equal to or greater than the repository in depth)
- Total number of shallow wells
- Well location
- Total depth of each well
- Type of each well (status)
- Ownership of minerals and hydrocarbon leases in the nine township area

Borehole Drilling Characteristics

In the event that a borehole intercepts waste within the repository at some future time, the characteristics of the drilling activity may influence the magnitude of a potential release of radioactive materials to the environment. These characteristics of the drilling activity are factored into PA computer models. Those that are monitored by the DBDSP include:

- Drill bit diameter
- Drill collar diameter
- Surface casing diameter
- Drill pipe diameter
- Speed of drill string rotation
- Penetration rate through the Salado Formation
- Type and characteristics of drilling mud
- Amounts of drilling fluid used

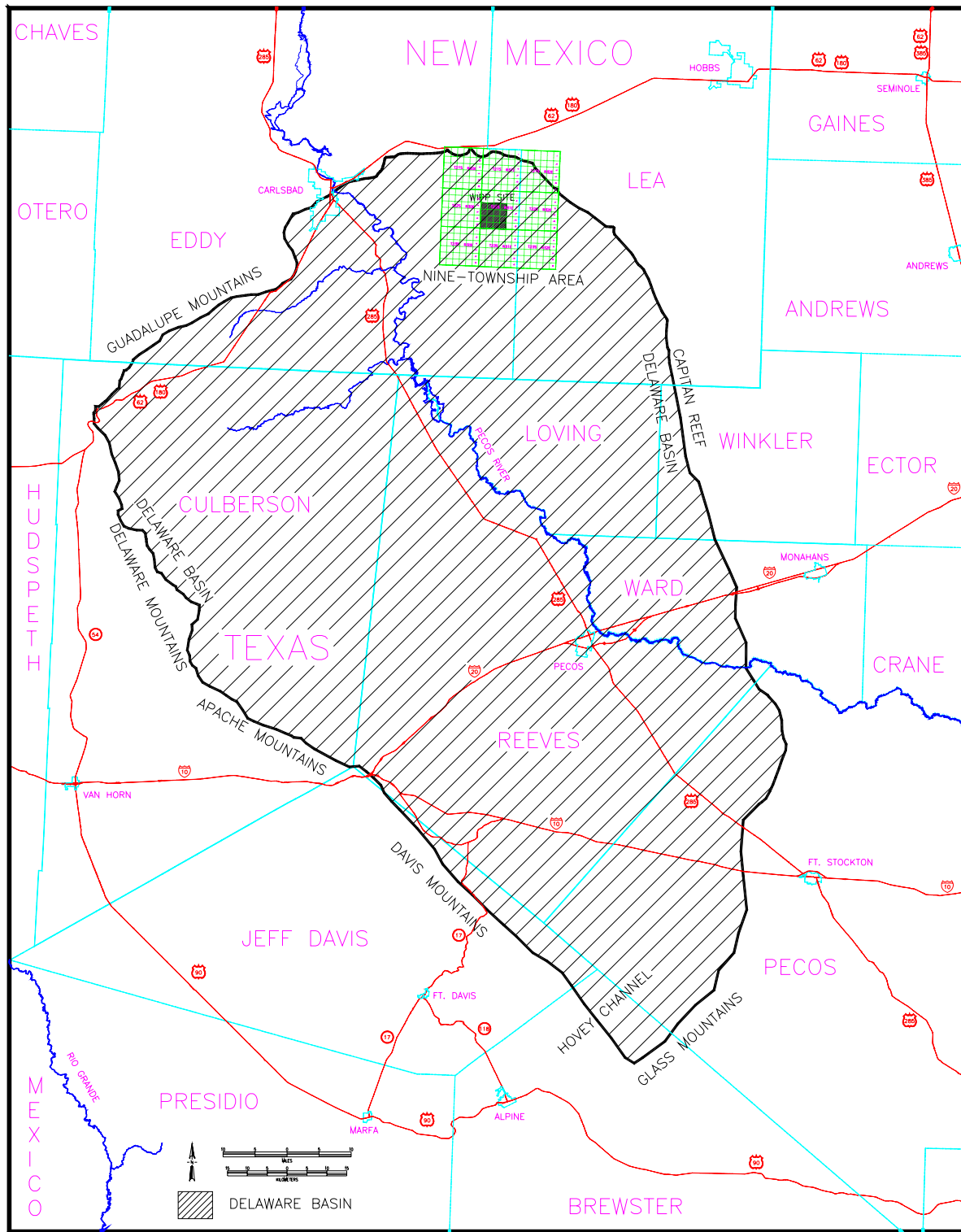


Fig. 1. WIPP Site, Delaware Basin, and Surrounding Area.

Castile Brine Reservoirs

Scenarios evaluated in the PA process include the connection of the repository with an underlying pressurized brine pocket in the Castile Formation by one or more intruding boreholes. Assessment of these scenarios requires information on the characteristics of Castile brine pockets. The following parameters are monitored by the DBDSP to support related PA analyses:

- Number of encounters of pressurized brine within the Castile Formation
- Castile brine reservoir pressure
- Castile brine reservoir volume
- Shortest time till shut-in
- Longest time till shut-in

In addition, information regarding pressurized brine encounters is sought using questionnaires and interviews with drillers operating in the Delaware Basin.

Borehole Plugging

PA scenarios involving interconnections between the repository and an underlying pressurized brine pocket in the Castile Formation are influenced by the manner in which boreholes may be plugged. Information regarding the method of plugging, including plug materials and mixtures, plug dimensions, the steel alloy used in well casings, and plugging patterns is used to evaluate the process of borehole plug degradation and to estimate the expected permeability of plugged holes. The following parameters related to borehole plugging are monitored by the DBDSP:

- Method of plugging
- Pattern of plugs
- Plug materials
- Plug length
- Total number, location, and depth of abandoned boreholes
- Well casing type of steel alloy

Injection Well Activities

Analyses of features, events, and processes (FEP)s that may impact the performance of the repository include assessments of the potential impacts of injection well activities in the vicinity of the project. It has been suggested that the injection of fluids at high pressures could create a pathway for the movement of the fluids into the repository. FEPs screening analyses have shown that this is unlikely and, accordingly, the influence of fluid injection has not been modeled in the WIPP PA. However, the following information is monitored by the DBDSP to support continuing assessments of injection well influences:

- Total number, location, and depth of injection wells for fluid disposal
- Total number, location, and depth of injection wells for secondary recovery
- Total number of injection well failures

Mining in the Delaware Basin

The likelihood and potential consequences of mining in the vicinity of the repository are assessed by FEP screening analyses. The following information is monitored by the DBDSP to support these analyses:

- Location of potash leasing and mining activity
- Total number and location of potash and salt solution mining activity

Incidences of Non-Compliance

The results of the FEPs screening analyses pertaining to interconnections between the repository and Castile brine pockets and injection well influences are based, in part, on assessments of the effectiveness of relevant regulatory provisions. The total number and type of incidences of non-compliance with Bureau of Land Management and New Mexico Oil Conservation Division rules are tracked by the DBDSP. Incidence reports are only collected on wells within the nine-township area immediately surrounding the WIPP Site.

Earthquake Activity

Seismic activity could potentially affect the repository and is assessed in FEPs screening evaluations. On a quarterly basis, the New Mexico Institute of Mining and Technology reviews and reports on earthquake activity in the New Mexico and Texas portions of the Delaware Basin. These reports are maintained on file by the DBDSP and seismic epicenters are recorded on maps maintained by the DBDSP.

Pipeline Construction

The construction of natural gas pipelines in the vicinity of the WIPP Site could enhance the economic viability of natural gas production from wells located near the WIPP. This, in turn, could influence the total number of natural gas wells in the area, potentially influencing PA analyses.

In addition, potential influences upon the repository from CO₂ flooding (to enhance oil and gas recovery) have been assessed through FEPs screening. The application of enhanced oil and gas recovery methods using CO₂ injection in the WIPP area would require construction of a pipeline to deliver the CO₂ to the enhanced recovery project. To support continuing evaluations, natural gas and CO₂ pipeline construction activity near the WIPP is monitored by the DBDSP.

Other General Monitoring Activities

In addition to the specific parameters described in the sections above, more general factors are monitored through the DBDSP. This monitoring is performed to track trends and developments that may potentially influence PA parameter values, FEPs screening arguments, or conceptual models. Monitoring of this type includes:

- **Current drilling practices in the Delaware Basin** - The potential application of alternative drilling practices (such as the use of air to circulate drill cuttings instead of brine) may influence the compliance evaluations. Accordingly, the DBDSP includes the monitoring of general trends in drilling practices in the basin to track any emerging developments.

- **Injection practices** - General injection practices in the basin, including the application of new and emerging technologies, are monitored to provide a basis for updating relevant assumptions in the PA. Various aspects of injection practices, such as injection depths, bottom hole injection pressures, and injection pressure gradients, may be important to future compliance evaluations.
- **Mineral exploration** – Mineral exploration activities are also tracked on a routine basis.
- **Potash mining technology** - Information related to the development and application of new potash mining technologies, including solution mining, is collected to help ensure the continuing adequacy of PA assumptions.

Reporting to EPA

The current status of hydrocarbon development and potash mining within the Delaware Basin is provided in quarterly reports. These reports detail drilling practices, fluid injection (including CO₂ injection) practices, pipelines, plugging practices, and mining (including solution mining) technologies. The reports also address new drilling efforts in the Basin and list the changes to the status of current drilling activities that occurred during the reporting period.

The quarterly reports are developed by the WIPP Managing and Operating Contractor. The DOE and the WIPP Scientific Advisor formally review the reports to determine whether changes have occurred that may impact assumptions made in the PA. When appropriate, feedback is provided to the monitoring program.

An annual report is prepared (4) and included with other environmental data that are made available to the EPA. The annual report consists of information and maps developed from the quarterly reports. Supplemental information included in the annual report is the status of mining in the Carlsbad Mining District (R-111-P area), any new mineral exploration (coreholes) within the Basin, the status of potash and hydrocarbon leases in the nine-township area, earthquake activity, pipeline activity, and updates of reports concerning drilling practices, fluid injection (including CO₂ injection practices), pipelines, plugging practices, and mining (including solution mining technologies).

Every five years, information from the annual reports is summarized and re-evaluated for input into the recertification process as defined in 40 CFR, Section 194.15 (3).

Consideration of the Intrusion Scenario

Regulatory Context

The regulatory documentation that must be submitted to the EPA is in the form of a compliance application, the contents of which are specified in §194.14. The first application was known as the Compliance Certification Application (CCA), and was submitted by DOE in 1996 (1). The CCA was required to include information on the presence and characteristics of potential

pathways for transport of waste from the disposal system to the accessible environment including, but not limited to, existing boreholes and other potentially permeable features.

The Part 194 rule clarifies, for the purposes of certification, the definition of performance assessments by stating that the DOE considers both natural processes and anthropogenic activities, such as mining, deep drilling, and shallow drilling, that may affect the disposal system during the regulatory time frame (10,000 years). Deep drilling is defined as drilling events in the Delaware Basin that reach or exceed a depth of 655 meters (2,150 feet) (the WIPP disposal horizon) while shallow drilling refers to drilling depths of less than 655 meters (2,150 feet). The following process and assumptions, specified in §194.33, are to be used in assessing the likelihood and consequences of drilling events. (2, 3)

- Assume that inadvertent and intermittent drilling for resources is the most severe (worst case) human intrusion scenario.
- In the performance assessment, assume that drilling for resources occurs at random intervals in time and space over the 10,000-year time frame.
- Calculate the deep drilling frequency by identifying the drilling that has occurred for each resource in the Delaware Basin over the past 100 years. The total drilling rate is to be derived by summing the drilling rates for each resource.
- Calculate the shallow drilling frequency by identifying the drilling that has occurred for each resource in the Delaware Basin over the past 100 years, considering only the resources of similar type and quality to those in the controlled area. The total drilling rate is to be derived by summing the drilling rates for each resource.

The analysis of the frequency and the consequences of resource-related drilling events over a 10,000-year period is dependent on future state assumptions. To foreclose speculation, the EPA requires that compliance applications assume that future practices remain what they are at the time of the compliance application. This assumption applies to human activities and societal conditions and not to geologic, hydrologic, or climatic changes. This means that, for purposes of the Part 194 compliance evaluation, the DOE can assume drilling technologies, drilling practices, and regulatory requirements will remain consistent with current practices in the Delaware Basin (§194.33[c][1]). The assumed future drilling practices include, but are not limited to: types and amounts of drilling fluids; borehole depths, diameters, and seals (plugs); and the fraction of boreholes sealed (plugged) by humans. Although assumptions concerning drilling and plugging regulations are not specified by the EPA, it is apparent future drilling practices and technologies are in part dependent on and interrelate with federal and state regulations. Regulations are a societal condition and are, therefore, assumed to remain the same.

Shallow Drilling Events

One of the requirements of Title 40 CFR Part 194 is that any compliance application must adequately and accurately characterize the frequency of shallow drilling within the Delaware Basin, as well as, support the assumptions and determinations, particularly those that limit consideration of shallow drilling events based on the presence of resources of similar type and

quantity found in the controlled area. The DOE concluded in Appendix SCR of the CCA that shallow drilling could be removed from PA consideration based on low consequence. As a result, the DOE did not include shallow drilling in its PA drilling rate calculations and did not include any reduction in shallow drilling rates during the active and passive institutional control periods. In the EPA's Compliance Application Review Document, Number 32, the EPA accepted the DOE's finding that shallow drilling would not be of consequence to repository performance and need not be included in the PA (5).

Although the EPA has agreed shallow drilling can be eliminated from PA and need not be tracked, the DBDSP collects data on all wells drilled within the boundaries of the Delaware Basin. The program makes no distinctions between shallow and deep drilling events except when calculating the intrusion rate for deep drilling. Information on all wells drilled is vital for trending future activities.

Deep Drilling Events

Only the drilling of a deep well could result in inadvertent human intrusion into the WIPP repository. The only known wells that can be classified as deep are oil and gas wells and several exploratory holes (potash and sulfur). The DOE used the historical record of deep drilling for resources below 2,150 feet that has occurred over the past 100 years in the Delaware Basin. This was chosen because it is the depth of the repository, and the repository can not be directly breached by boreholes less than this depth. In the past 100 years, deep drilling occurred for oil, gas, potash, and sulfur. These drilling events were used in calculating a rate for deep drilling for PA. The period used for calculation was 1896 through June 1995. Historical drilling for purposes other than resource exploration and recovery (such as WIPP Site investigation) was excluded from the calculation in accordance with EPA's criteria (§194.33).

The EPA provided a formula for calculating the current drilling rate or intrusion rate when 40 CFR Part 194 was promulgated. The formula is as follows: number of holes times 10,000 years divided by the area of the Delaware Basin (23,102 sq. km.) divided by 100 years (1897-1996, the year the CCA was submitted). This formula is used to calculate both shallow and deep drilling rates for each resource. Since shallow drilling events are of no consequence, only deep drilling events are applied to the formula. The DBDSP uses all deep drilling events of any resource (potash, oil, gas, water, etc.) to calculate the drilling or intrusion rate.

PA is required by regulation to consider disturbed case scenarios that include intrusions into the repository by inadvertent and intermittent drilling for resources. The probability of these intrusions is based on a future drilling rate of 46.8 boreholes per square kilometer per 10,000 years. This rate is based on consideration of the past record of drilling events in the Delaware Basin.

The drilling rates since 1996 (the year the CCA was submitted to EPA) are shown in Table I. The large increase between 1996 and 1997 is the result of updating the databases with information from June 1995 through August 1997. Also, the 100-year window is considered a sliding window, in which 100 years worth of data is used each time the calculation is performed. As each new year's data is added, the oldest year's data is dropped. For example, the drilling

rate was calculated in 1999 by using the data from 1900 through 1999. In 2000, the data from 1901 through 2000 was used to calculate the drilling rate.

Table I Past Drilling Rates for the Delaware Basin

Year	Number of Deep Holes	Drilling Rate
1996	10,804 Holes Deeper Than 2,150 Ft	46.8
1997	11,444 Holes Deeper Than 2,150 Ft	49.5
1998	11,616 Holes Deeper Than 2,150 Ft	50.3
1999	11,684 Holes Deeper Than 2,150 Ft	50.6
2000	11,828 Holes Deeper Than 2,150 Ft	51.2
2001	12,056 Holes Deeper Than 2,150 Ft	52.2
2001	12,139 Holes Deeper Than 2,150 Ft	52.5
2003	12,316 Holes Deeper Than 2,150 Ft	53.3

In using the sliding window formula as discussed earlier, 100 years of drilling data is used. As new wells are added, old wells are dropped from the count. The original data was collected from 1896 through 1995, but the first oil well deeper than 2,150 feet. was not drilled until 1911. The next well to meet the criteria was drilled in 1914. In 1920, three wells met the criteria. By 1925, only 26 wells had been drilled deeper than 2,150 feet. Therefore, the drilling rates, as presently calculated, will continue to increase for many years.

CONCLUSION

The Delaware Basin Drilling Surveillance Program, as implemented by the DOE, is a robust monitoring program that continues to monitor resource activities occurring within the Delaware Basin where the WIPP Site is located. In accordance with the criteria established in Title 40 CFR Part 194 this will continue until the DOE and the EPA mutually agree no further benefit can be gained from continued surveillance. At each five-year recertification period, the results of the ongoing surveillance will be used to determine if a significant change has occurred that would affect the performance of the disposal system.

REFERENCES

- 1 U.S. Department of Energy, 1996. Compliance Certification Application. DOE/CAO 1996-2184. Carlsbad Area Office, October 29, 1996.
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- 3 U.S. Environmental Protection Agency, 1996. Title 40 CFR, Part 194. *Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance With the 40 CFR Part 191 Disposal Regulations*. 61 FR 5224, February 9, 1996
- 4 U.S. Department of Energy, 2003. Delaware Basin Monitoring Annual Report. DOE/WIPP-99-2308, Rev. 4. U.S. Department of Energy, Carlsbad Field Office.

- 5 U.S. Environmental Protection Agency, 1998. Compliance Application Review Documents for the Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations: Proposed Certification Decision; CARD 33. Office of Radiation and Indoor Air, Washington, D.C. 20460