WPO 41470

EEG-55

IMPLICATIONS OF THE PRESENCE OF PETROLEUM RESOURCES ON THE INTEGRITY OF THE WIPP

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Environmental Evaluation Group
New Mexico

June 1994

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Environmental Evaluation Group Reports

EEG-1 Goad, Donna, A Compilation of Site Selection Criteria Considerations and Concerns Appearing in the Literature on the Deep Disposal of Radioactive Wastes, June 1979.

EEG-2 Review Comments on Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico SAND 78-1596, Volume I and II, December 1978.

EEG-3 Neill, Robert H., et al., (eds.) Radiological Health Review of the Draft Environmental Impact Statement (DOE/EIS-0026-D) Waste Isolation Pilot Plant, U.S. Department of Energy, August 1979.

EEG-4 Little, Marshall S., Review Comments on the Report of the Steering Committee on Waste Acceptance Criteria for the Waste Isolation Pilot Plant, February 1980.

EEG-5 Channell, James K., Calculated Radiation Doses From Deposition of Material Released in Hypothetical Transportation Accidents Involving WIPP-Related Radioactive Wastes, October 1980.

EEG-6 Geotechnical Considerations for Radiological Hazard Assessment of WIPP. A Report of a Meeting Held on January 17-18, 1980, April 1980.

EEG-7 Chaturvedi, Lokesh, WIPP Site and Vicinity Geological Field Trip. A Report of a Field Trip to the Proposed Waste Isolation Pilot Plant Project in Southeastern New Mexico, June 16 to 18, 1980, October 1980.

EEG-8 Wofsy, Carla, The Significance of Certain Rustler Aquifer Parameters for Predicting Long-Term Radiation Doses from WIPP, September 1980.

EEG-9 Spiegler, Peter, An Approach to Calculating Upper Bounds on Maximum Individual Doses From the Use of Contaminated Well Water Following a WIPP Repository Breach, September 1981.

EEG-10 Radiological Health Review of the Final Environmental Impact Statement (DOE/EIS-0026) Waste Isolation Pilot Plant, U. S. Department of Energy, January 1981.

EEG-11 Channell, James K., Calculated Radiation Doses From Radionuclides Brought to the Surface if Future Drilling Intercepts the WIPP Repository and Pressurized Brine, January 1982.

EEG-12 Little, Marshall S., Potential Release Scenario and Radiological Consequence Evaluation of Mineral Resources at WIPP, May 1982.

EEG-13 Spiegler, Peter, Analysis of the Potential Formation of a Breccia Chimney Beneath the WIPP Repository, May, 1982.

EEG-14 Not published.

EEG-15 Bard, Stephen T., Estimated Radiation Doses Resulting if an Exploratory Borehole Penetrates a Pressurized Brine Reservoir Assumed to Exist Below the WIPP Repository Horizon - A Single Hole Scenario, March 1982.

EEG-16 Radionuclide Release, Transport and Consequence Modeling for WIPP. A Report of a Workshop Held on September 16-17, 1981, February 1982.

EEG-17 Spiegler, Peter, Hydrologic Analyses of Two Brine Encounters in the Vicinity of the Waste Isolation Pilot Plant (WIPP) Site, December 1982.

EEG-18 Spiegler, Peter and Dave Updegraff, Origin of the Brines Near WIPP from the Drill Holes ERDA-6 and WIPP-12 Based on Stable Isotope Concentration of Hydrogen and Oxygen, March 1983.

EEG-19 Channell, James K., Review Comments on Environmental Analysis Cost Reduction Proposals (WIPP/DOE-136) July 1982, November 1982.

EEG-20 Baca, Thomas E., An Evaluation of the Non-Radiological Environmental Problems Relating to the WIPP, February 1983.

EEG-21 Faith, Stuart, et al., The Geochemistry of Two Pressurized Brines From the Castile Formation in the Vicinity of the Waste Isolation Pilot Plant (WIPP) Site, April 1983.

EEG-22 EEG Review Comments on the Geotechnical Reports Provided by DOE to EEG Under the Stipulated Agreement Through March 1, 1983, April 1983.

EEG-23 Neill, Robert H., et al., Evaluation of the Suitability of the WIPP Site, May 1983.

EEG-24 Neill, Robert H. and James K. Channell, Potential Problems From Shipment of High-Curie Content Contact-Handled Transuranic (CH-TRU) Waste to WIPP, August 1983.

EEG-25 Chaturvedi, Lokesh, Occurrence of Gases in the Salado Formation, March 1984.

EEG-26 Spiegler, Peter, Proposed Preoperational Environmental Monitoring Program for WIPP, November 1984.

EEG-27 Rehfeldt, Kenneth, Sensitivity Analysis of Solute Transport in Fractures and Determination of Anisotropy Within the Culebra Dolomite, September 1984.

EEG-28 Knowles, H. B., Radiation Shielding in the Hot Cell Facility at the Waste Isolation Pilot Plant: A Review, November 1984.

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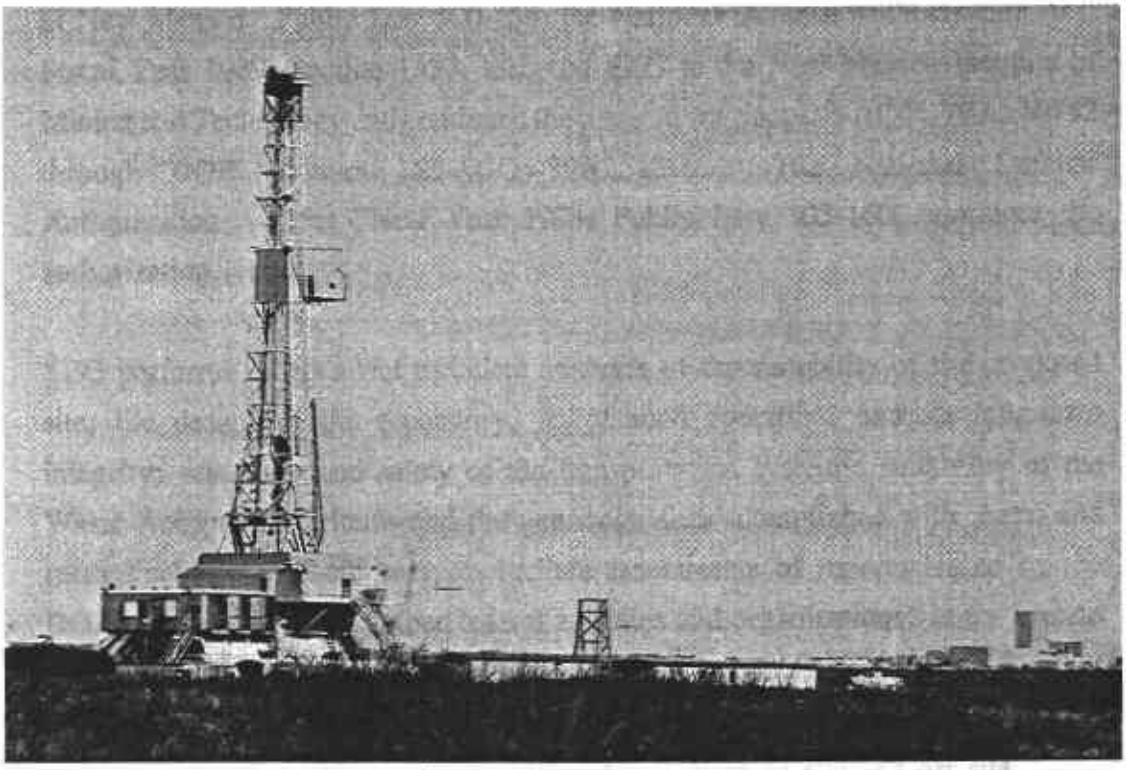
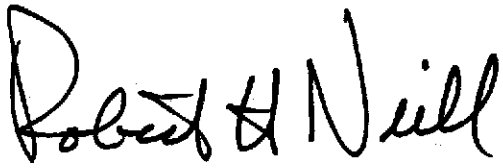


Inset. Oil and gas drilling rig (left) with WIPP waste handling building in the background (right). James Ranch Unit Well #18, January 1993.

FOREWORD

The purpose of the New Mexico Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the Waste Isolation Pilot Plant (WIPP) Project to ensure the protection of the public health and safety and the environment. The WIPP Project, located in southeastern New Mexico, is being constructed as a repository for the disposal of transuranic (TRU) radioactive wastes generated by the national defense programs. The EEG was established in 1978 with funds provided by the U.S. Department of Energy (DOE) to the State of New Mexico. Public Law 100-456, the National Defense Authorization Act, Fiscal Year 1989, Section 1433, assigned EEG to the New Mexico Institute of Mining and Technology and continued the original contract DE-AC04-79AL10752 through DOE contract DE-ACO4-89AL58309. The National Defense Authorization Act for Fiscal Year 1994, Public Law 103-160, continues the authorization.

EEG performs independent technical analyses of the suitability of the proposed site; the design of the repository, its planned operation, and its long-term integrity; suitability and safety of the transportation systems; suitability of the Waste Acceptance Criteria and the generator sites' compliance with them; and related subjects. These analyses include assessments of reports issued by the DOE and its contractors, other federal agencies and organizations, as they relate to the potential health, safety and environmental impacts from WIPP. Another important function of EEG is the independent environmental monitoring of background radioactivity in air, water, and soil, both on-site and off-site.



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EXECUTIVE SUMMARY

The Waste Isolation Pilot Plant (WIPP) is a facility of the U.S. Department of Energy (DOE), designed and constructed for the permanent disposal of transuranic (TRU) defense waste. The WIPP is surrounded by reserves of potash, crude oil, and natural gas. These are attractive targets for exploratory drilling which could disrupt the integrity of the transuranic waste repository. To proceed with disposal, the U.S. Environmental Protection Agency (EPA) Administrator must certify that the probabilities and fraction of the repository's release of radionuclides to the biosphere over the next 10,000 years will be less than those allowed by the EPA standards (U.S. EPA, 1993). The performance assessment calculations published to date have identified future drilling for oil and gas reserves as an event that may disrupt the repository and may release radionuclides in excess of the standards (SNL, 1992, vol. 1, Section 4.1.2). Therefore, the probability of inadvertent human intrusion into the repository by drilling and its impact on the integrity of the repository must be carefully assessed.

While the DOE funded a number of studies and reviews on the possibility of oil and gas reserves in the vicinity of the WIPP, the recent production of crude oil in the WIPP vicinity indicates that the 1974 study by Foster was correct. However, the DOE decided to rely on the reports which indicated or strongly suggested that crude oil was not considered economically recoverable.

The 1974 New Mexico Bureau of Mines and Mineral Resources (Foster, 1974) estimated crude oil reserves would range from 550,000 to 1,200,000 barrels per section in the vicinity of the WIPP Site. The Environmental Evaluation Group (Neill et al., 1983, p. 98) agreed with the Geologic Characterization Report (Powers et al., 1978) and commented that "since Foster's study used a regional statistical approach, there may be considerably more or less than the average quantity of hydrocarbons if the site were actually drilled." But the Environmental Evaluation Group also concluded that "it is possible that significant reserves of oil also exist within the site." The New Mexico Energy and Minerals Department

(NMEMD, 1984) Task Force on natural resources relied on Foster's (1974) estimates of petroleum reserves.

However, four other studies and several reviews commissioned and used by the DOE stated or suggested that there were little or no economically recoverable crude oil reserves in the immediate vicinity of the WIPP. These include the studies of Netherland et al. (1974) and Keesey (1976, 1977, 1979) and the reviews of Griswold (1977), Powers et al. (1978), the DOE WIPP Final Environmental Impact Statement (U.S. DOE, 1980), Brausch et al. (1982), Weart (1983), and Weart et al. (1991).

The Department of Energy acknowledged that the statistical study of the New Mexico Bureau of Mines and Mineral Resources indicated the presence of crude oil, but the DOE decided that later studies had discounted the existence of economically attractive quantities at the site. (McGough, 1983a, p. 4). With respect to the impact of secondary recovery methods on the integrity of the repository, Brausch et al (1982) did not evaluate such production methods because they argued that there was a minimal amount crude oil likely to exist within the WIPP Site. The report of Brausch et al. (1982) served as the basis for the major decision to relinquish control of a one mile buffer zone (Weart, 1983; McGough, 1983b) initially intended to provide DOE control of natural resource production methods (U.S. DOE, 1980). Less than ten years later, the WIPP area was confirmed by the oil and gas industry to be "extremely high in oil and gas reserves...." (Nibert, 1992).

The DOE position of minimal or no crude oil reserves persists in guiding assumptions on other major issues including demonstration of compliance with EPA disposal standards. For example, participants in two expert elicitation exercises conducted by Sandia National Laboratories (SNL) were asked to provide information with which to estimate oil and gas drilling rates in the WIPP vicinity over the next 10,000 years (Hora, 1992). Participants in the first elicitation were asked to identify the activities of future societies that would disrupt the integrity of the repository and to assign probabilities to events such as exploratory drilling.

Participants in the second elicitation were asked to design a marker that would discourage human intrusion and to evaluate the effectiveness of the markers they recommended. However, the participants in both exercises were provided outdated and incorrect information on the two issues that were most important to their discussions — the actual drilling intensity and the crude oil reserves in the immediate vicinity of the WIPP Site. The effective drilling intensities, inferred from the elicitations, were consistently and substantially less than the EPA recommended maximum value of 30 boreholes per km² over 10,000 years (Hora, 1992).

The WIPP Project's experience indicates that allowing credit for institutional control in the performance assessment calculations may be difficult to justify. Experts from each of the four teams in the future societies elicitation exercise expressed reservations about the ability of the project to maintain active control for even a very short period of time (Hora et al., 1991). Two active oil and gas leases within the WIPP Site Boundary and a producing gas well were overlooked in several important DOE documents (Silva and Channell, 1992). Records indicate that DOE and the Department of Interior's Bureau of Land Management (DOI/BLM) did not implement required review, comment, and approval procedures in twenty-two of the twenty-five (88%) drilling applications filed during the first two years a Memorandum of Understanding was in effect and while the WIPP facility was in a state of full readiness to receive waste. The DOE review of the interface with the BLM failed to detect the problem. There is no plan nor commitment by DOE to active institutional control. The DOE intends to negotiate the extent of active institutional control with the State of New Mexico just prior to decommissioning of the facility or approximately 30 years after having taken full credit for active institutional control in the performance assessment calculations. Some components of passive institutional control, such as government ownership of the site, public records, and markers, failed to communicate the existence and location of oil and gas wells, a salt water disposal well, and a pipeline crossover in the WIPP area to WIPP project employees.

The WIPP facility will be subjected to the actual exploration, production, and abandonment practices of the petroleum industry on adjacent properties. The potential problems due to secondary recovery have not yet been addressed because the project assumed that there were minimal crude oil reserves. Primary production of crude oil immediately adjacent to the WIPP is underway. The feasibility of secondary recovery or tertiary recovery for adjacent oil fields needs to be investigated. Of particular concern is the potential migration of injected water from adjacent properties through the Salado Formation (Ramey, 1976; Bailey, 1990, LaVenue, 1991; Hartman, 1993).

The leakage of existing and future oil, gas, and salt water injection wells appears to have a potential impact on the regional hydrology. In addition to faulty cement emplacement, leakage can result from rapid corrosion of well casings in the highly corrosive saline environment (LaVenue, 1991). There are several salt water disposal wells operating in the vicinity of the WIPP Site.

The performance assessment effort needs to address the problems associated with inadequate borehole sealing and abandonment practices on Bureau of Land Management properties (U.S. DOI, 1989, U.S. DOI, 1990, Baier, 1990). "The Bureau of Land Management's (BLM) existing guidelines on well completions, workovers and abandonments have never been formalized and published" (U.S. DOI, 1991, p. 20568). The potential impact of abandoned wells on the regional hydrology and on the performance of the repository has yet to be determined.

1. STATEMENT OF PROBLEM

The Waste Isolation Pilot Plant (WIPP) is intended to serve as a repository for the safe disposal of transuranic waste generated by the defense activities of the United States Government. The anticipated inventory includes 176,000 cubic meters (6.2 million cubic feet or 850,000 drum equivalents) of contact-handled transuranic (CH-TRU) waste and about 7,100 cubic meters (250,000 cubic feet or 8000 canisters) of remote-handled transuranic (RH-TRU) waste. The CH-TRU waste is estimated to contain 9 million curies of activity. The activity of the RH-TRU waste is limited to 5.1 million curies.

The Waste Isolation Pilot Plant is located in a resource rich area in southeastern New Mexico. Natural resources in the immediate vicinity of the WIPP Site include economically attractive reserves of potash, crude oil, and natural gas. The 1985 EPA Standards (U.S. EPA, 1985) for the disposal of transuranic waste specifically cautioned against siting a repository in an area with resource potential "unless the favorable characteristics of such places compensate for their greater likelihood of being disturbed in the future." (U.S. EPA, 1985, p. 38081). This provision has been retained in the repromulgated standards (U.S. EPA, 1993).

The site has been selected and much of the facility has been constructed. To proceed with disposal, the EPA Administrator must certify (Waste Isolation Pilot Plant Land Withdrawal Act, 1992) analyses which demonstrate that the repository's release of radionuclides to the biosphere over the next 10,000 years will be less than that allowed by the EPA standards (U.S. EPA, 1985; U.S. EPA, 1993). The EPA decision will rely heavily on performance assessment calculations. The performance assessment calculations published to date have identified future drilling for oil and gas reserves as an event that may disrupt the repository and release radionuclides in excess of the standards (SNL, 1992, Section 4.1.2).

This report evaluates:

- the studies funded by the DOE to examine the crude oil potential in the immediate vicinity of the WIPP
- the use of an elicitation exercise to predict future drilling rates for use in the calculation of the repository performance.
- the observed limitations of institutional controls

Because the WIPP Site is in an area rich in oil and gas resources, the integrity of the repository is inherently subject to the drilling, production, and abandonment practices of the oil and gas industry. The decision by the EPA to approve the facility for disposal depends on a realistic assessment of oil and gas resources and actual industry practices. The practices of other industries, such as mining, may be important but are not considered in this report. This report identifies the following issues that remain to be resolved:

- the limited performance of blowout preventers after drilling into high pressure zones immediately adjacent to the WIPP Site Boundary.
- reported problems with waterflooding operations in southeastern New Mexico.
- reported water level rises in several wells completed in the Rustler Formation, south of the WIPP Site, possibly due to oil and gas wells or leaking injection wells.
- reports of inadequate well abandonment practices on BLM leases and the continued absence of enforceable regulations.

2. INTRODUCTION

The repository is located 25 miles (40 kilometers) east of the city of Carlsbad at a depth of 2150 feet (655 meters) in the lower part of a 1970-foot (600 meters) thick salt formation. The area of land that lies within the WIPP Site Boundary is a square four miles (6.44 kilometers) on a side. It contains 10,240 acres (16mi^2; 4,144 hectares) including Sections 15, 16, 17, 18, 19, 20, 21, 22, 27, 28, 29, 30, 31, 32, 33, and 34 in T22S, R31E, NMPM in southeastern New Mexico (U.S. DOE, 1990a, Section 2.1.1.1)

Figure 1 illustrates the WIPP boundary and the areas of Zone I and Zone II. Zone I contains the WIPP facility surface structures, is surrounded by a chain link fence, and covers about 35 acres (14 hectares) in Sections 20 and 21. Zone II defines the maximum extent of the area for underground development. Originally, the intent was to select a repository site such that the distance to any deep borehole would be at least 2 miles. When this was found not to be feasible, a one mile buffer was accepted (Powers et al., 1978). The WIPP Site Boundary provides a minimum one mile (1.6 kilometers) buffer from pre-existing (non-WIPP) boreholes around Zone II (U.S. DOE, 1990a, Section 2.1.1.1).

Although the designations of Zone III and Zone IV are no longer used, they merit a description because many of the studies and reviews refer to these zones. The location of Zones III and IV are shown in Figure 2.

Zone III essentially provided a one-mile (1.6 kilometer) buffer around Zone II. In Zone III, all mining, other than for the repository, and deep drill holes penetrating through the evaporites would have been prohibited (U.S. DOE, 1980, p. 8-4).

Zone IV provided a one-mile (1.6 kilometer) buffer around Zone III. Within Zone IV, conventional potash mining would have been permitted but solution mining would have been prohibited. Deep drill holes would also be allowed

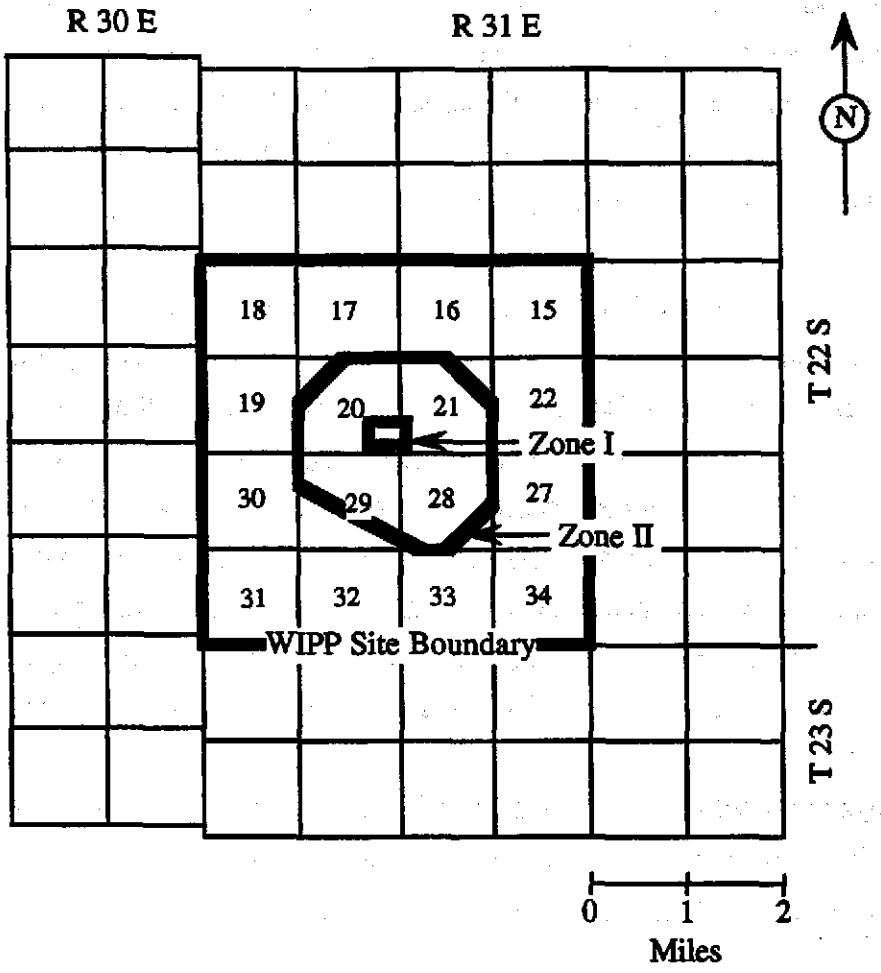

Figure 1. 1983 Zone I, Zone II, and WIPP Site Boundary.
(WIPP FSAR, U.S. DOE, 1990a.)

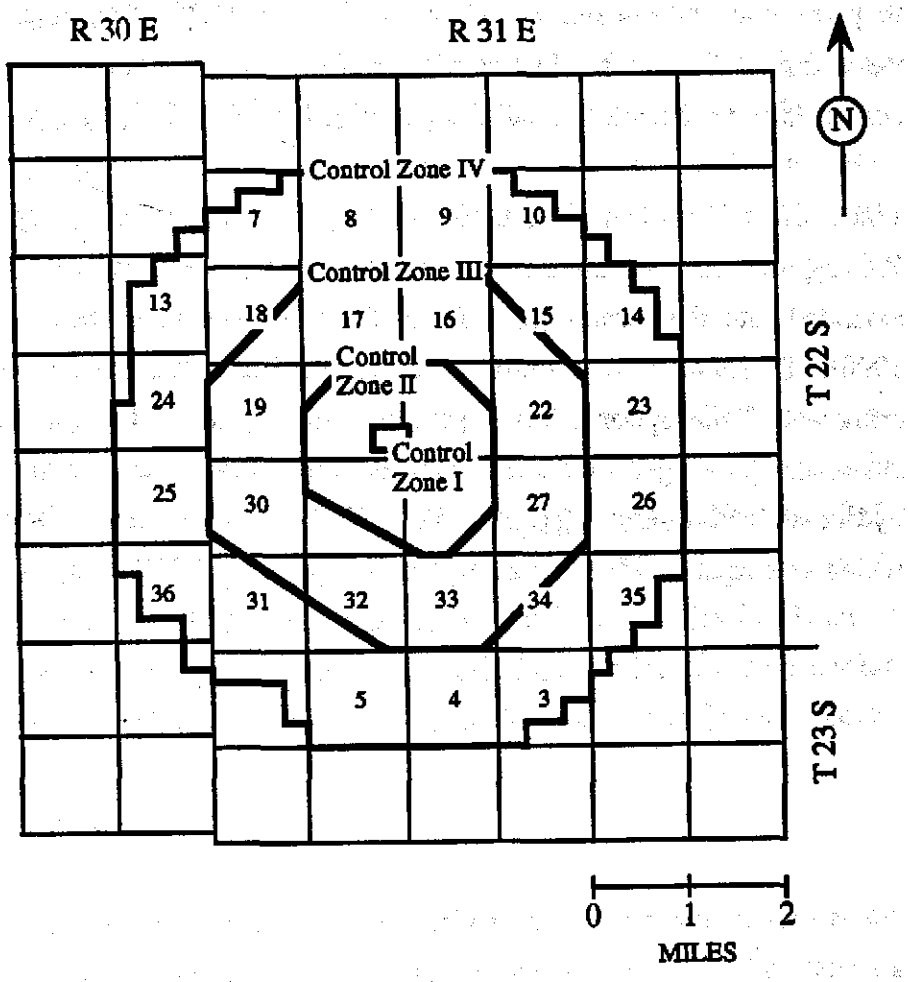

Figure 2. 1980 Control Zones at the WIPP Site.
(FSEIS, U.S. DOE, 1990c)

but water flooding and massive hydrofracture for hydrocarbon recovery would not be permitted (U.S. DOE, 1980, p. 8-4). The Final Environmental Impact Statement also noted existing oil and gas wells producing in this zone would have been permitted to continue through their useful lives. To protect the repository, they would have been sealed as prescribed by the DOE when abandoned. New wells for oil and gas production were to be drilled in conformance with DOE standards to facilitate eventual plugging (U.S. DOE, 1980, p. 8-4).

When Zone IV was relinquished by DOE as being unnecessary (McGough, 1983b), the Zone III boundary was "squared off" and the new site boundary extended into the former Zone IV at the four corners (Weart, 1983; Weart, 1990). By relinquishing control over the remainder of Zone IV, the DOE also relinquished the opportunity to prescribe drilling and plugging practices and abandoned the right to restrict waterflooding and massive hydrofracture for hydrocarbon recovery in the one mile buffer around the former Control Zone III which was squared off to form the 4 mile by 4 mile WIPP Site.

3. STUDIES AND REVIEWS OF OIL AND GAS POTENTIAL

In evaluating the crude oil potential of the site, one early study and two reviews appear to have been most nearly correct. The New Mexico Bureau of Mines and Mineral Resources (Foster, 1974) estimated crude oil reserves would range from 550,000 to 1,200,000 barrels per section in the vicinity of the WIPP Site. The Environmental Evaluation Group (Neill et al., 1983, p. 98) concluded that "it is possible that significant reserves of oil also exist within the site." The 1984 report by the New Mexico Energy and Minerals Department Task Force (NMEMD, 1984) used Foster's (1974) estimates to calculate the loss of revenues to the state.

Four studies and several reviews stated or suggested that there were no economically recoverable crude oil reserves in the immediate vicinity of the WIPP. These include the studies of Netherland et al.[1] (1974) and Keesey (1976, 1977, 1979) and the WIPP project reports by Griswold (1977), Powers et al. (1978), the DOE WIPP Final Environmental Impact Statement (1980), Brausch et al. (1982), Weart (1983), and Weart et al. (1991). The following discussion is organized chronologically according to the publication dates of these reports.

3.1 Netherland et al., 1974

Netherland et al. (1974) studied a site originally selected but abandoned after the borehole ERDA-6 encountered pressurized brine in 1975. The report's conclusions are wrong. The report states:

> As a result of this study, ***we conclude that no economically recoverable oil and gas***[2] exist within the limits of the ORNL Study Area or under the acreage immediately adjoining the Study Area. Comprehensive analyses

---

[1]ORNL Study Area Northwest of the WIPP. See Figure 3.

[2]Emphasis added.

of the available geological and engineering data have been made for the upper portion of the Delaware Basin in which the Study Area is located, and the thorough study and analysis of these data lead us ***firmly***[3] to this conclusion (Netherland et al., 1974).

That repository site (ORNL Study Area, Figure 3) was abandoned and the site was reopened for oil and gas exploration. Figure 4 shows oil wells on forty acre spacing throughout much of the original WIPP Site (ORNL Study Area). The firm conclusion of Netherland et al. (1974) was wrong.

3.2 Foster, 1974

Foster (1974) provided an updated geologic description of the repository area and a preliminary evaluation of the petroleum potential of the proposed waste disposal site. Site selection criteria precluded deep drill boreholes. It was difficult to assess hydrocarbon reserves under the site because there was no production data. Furthermore, there was limited oil and gas exploration in the four township contract area referred to as the "Pilot area" (Figure 5).[4] In fact, of the 144 sections in the Pilot area, 117 sections had not yet been drilled to explore for oil and gas. Thus, Foster found it necessary to expand the investigation to a larger area to properly evaluate the oil and gas potential. The study was expanded to include 42 townships as shown in Figure 5. These were defined as the "Study Area" and included T20S R's 30 to 35E and T's 21 to 26S, R's 29 to 34 E. Foster estimated the oil and gas reserves based on geological and statistical evaluations of each part of the geologic section known to contain *commercial* accumulations of petroleum. The geologic evaluation considered:

1) the occurrence and number of suitable reservoir and source rocks;

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[3]Emphasis added.

[4]The present 4 mile x 4 mile WIPP Site is located in the southwestern corner of Foster's "Pilot Area." See Figure 5.

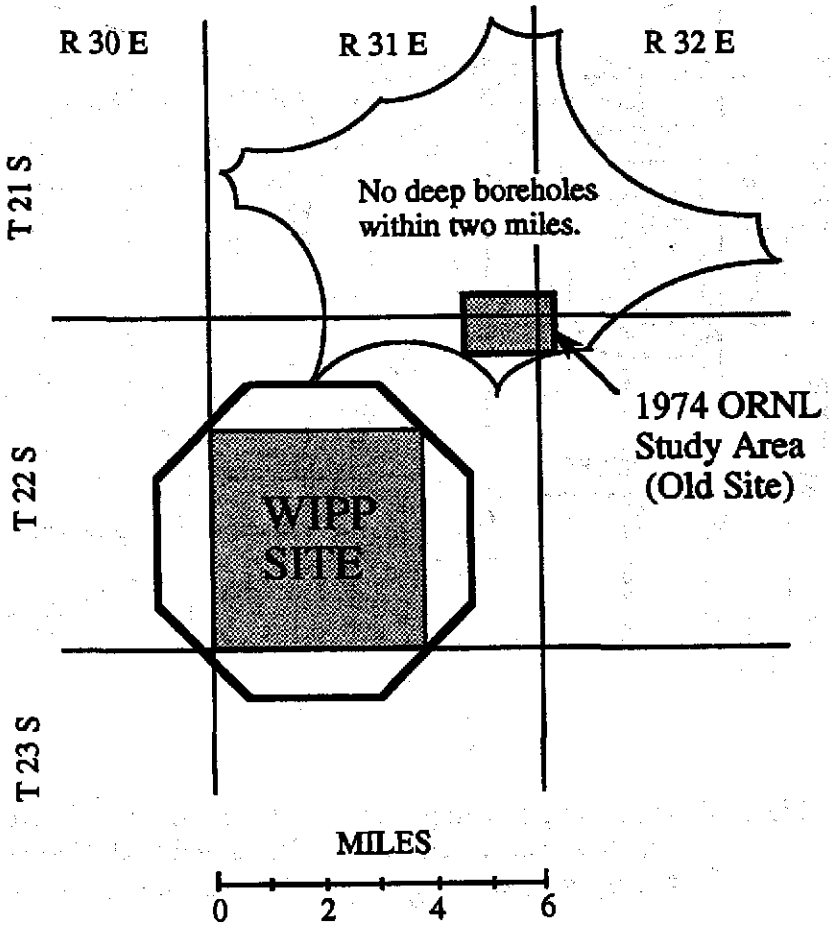

Figure 3. 1974 ORNL Study Area. (Griswold, 1977)

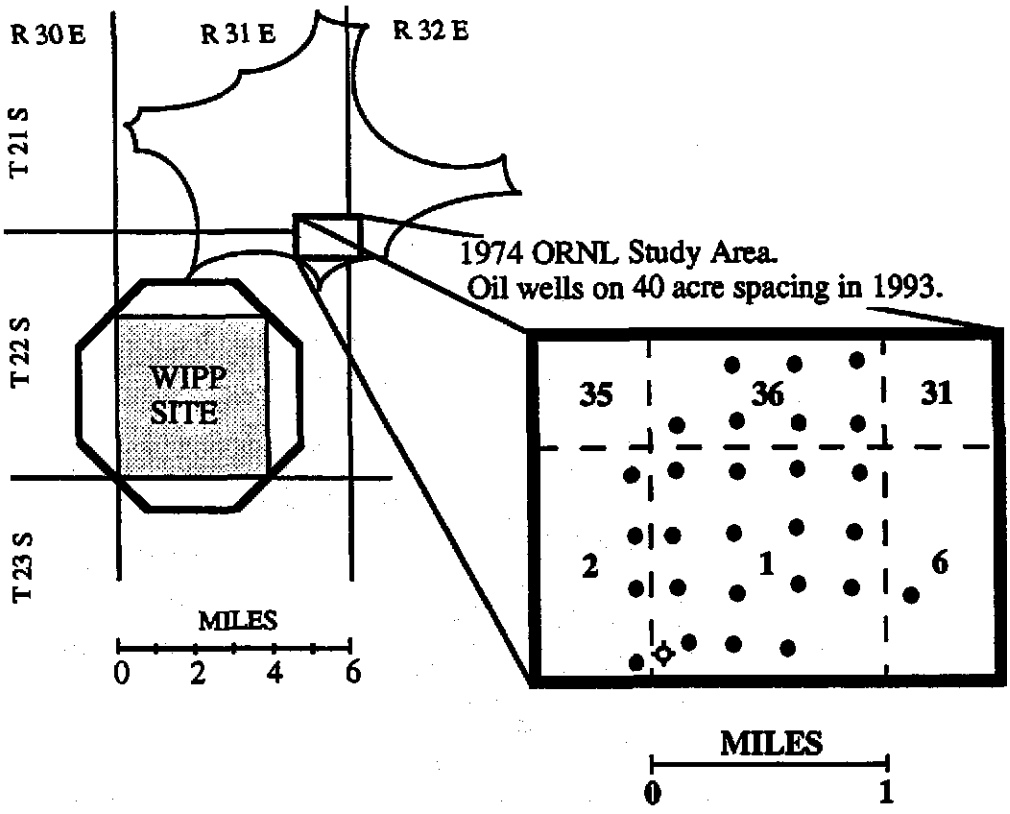

Figure 4. Producing oil and gas wells in the abandoned ORNL Study Area which was characterized by Netherland et al. (1974) as not having economically recoverable oil and gas reserves.

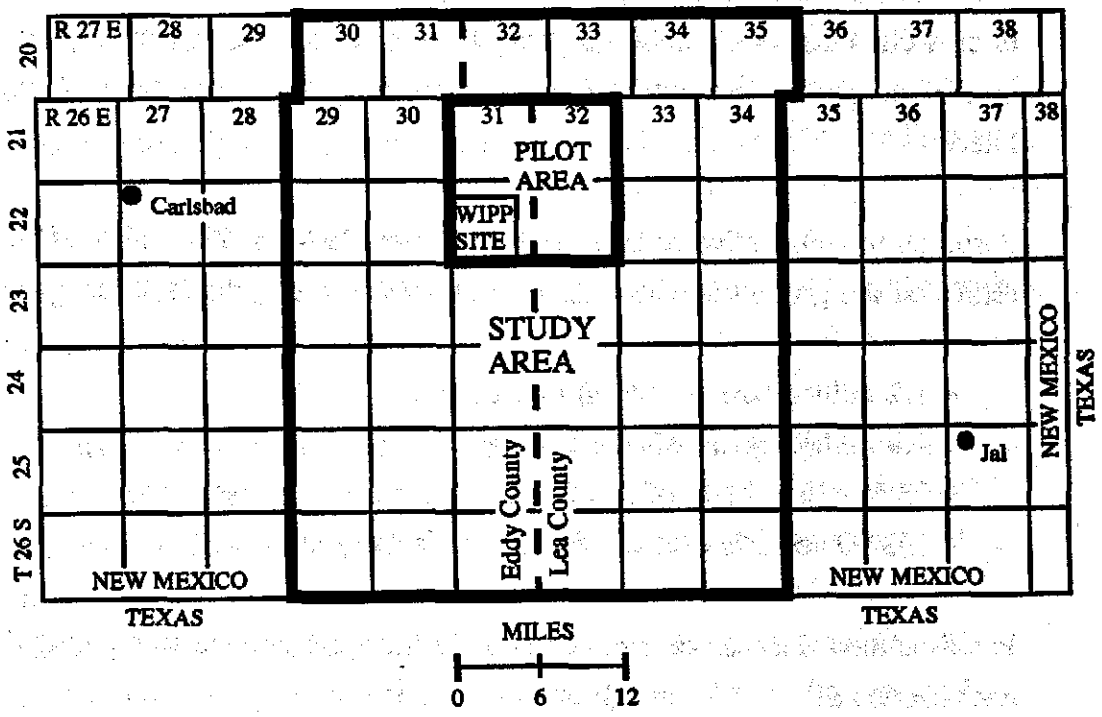

Figure 5. Pilot Area and Study Area. (Foster, 1974).

2) the type of trap most commonly associated with accumulations in a specific part of a section;
3) the potential presence of such a trap in the "Pilot area";
4) the distribution of known occurrences of oil and/or gas primarily within the "Study area."

The statistical evaluations were based ***primarily on productive acreage*** compared with total acreage tested and wildcat success ratios. The evaluation also considered the occurrence of petroleum, whether commercial or not; the number of oil wells versus the number of gas wells completed for each interval; average production per well; and oil/associated gas and gas/distillate ratios for each interval.

Based on the productive acreage method, Foster (1974, p. 282 and p. 287-288) estimated the production potential for *each section* within the "Pilot area" as;

- 1.2 million barrels (BBLs) of crude oil
- 2.9 million MCF[5] of associated gas
- 13.5 million MCF of natural gas
- 193,000 barrels of distillate (gas condensate)

Based on the wildcat success ratios, Foster estimated the production potential for *each section* as

- 550,000 BBLs of crude oil
- 2.2 million MCF of associated gas
- 12.5 million MCF of natural gas
- 170,000 barrels of distillate (gas condensate)

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[5]An MCF is equal to one thousand standard cubic feet (28.32 cubic meters) of gas. A BBL is equal to one barrel (0.159 cubic meters) of oil or condensate.

It appears that Foster's estimates for crude oil reserves were correct. Recent production data for wells recently drilled in former Control Zone IV suggest an ultimate primary recovery of 1.1 million barrels of crude oil for Section 23 and 673,000 barrels of crude oil for Section 26 (T22S, R31E) assuming full development of each section with oil wells on 40 acre spacings. Section 3.11 of this report discusses the recent estimates.

3.3 Keesey, 1976, 1977, 1979

Keesey's 1976 study was intended to guide Sandia National Laboratories in deciding the suitability of the site and to establish the potential monetary value of the hydrocarbon rights. Emphasis was placed on deliverability and *proven* reserves.

Like Foster (1974), Keesey found that the area was largely unexplored. Hence, Keesey cautioned:

> Extensive deep drilling has not been undertaken in the New Mexico portion of the Delaware Basin, and only 10 to 15 percent of the available acreage has been tested. This low development percentage does not mean that the Delaware Basin has no potential. ***On the contrary, the Delaware Basin has been, and still is, an area that is considered to have major oil and gas potential, particularly in the Delaware and Pennsylvanian series.***[6] The lack of extensive drilling in the northern portion of the Delaware Basin is believed to be related to: (1) a historically low controlled price for gas, (2) a somewhat higher risk of finding sufficient quantities of reserves as a result of the varying depositional environment, and (3) lack of readily available pipelines for the transportation of reserves to market during earlier periods. In the immediate vicinity of the "site area", the existence of potash mines has

[6]Emphasis added.

also deterred or prevented drilling for hydrocarbon reserves (Keesey, 1976, p. 4).

Keesey expanded the review from the site area of 32 square miles (83 km^2) to 400 square miles (1036 km^2), centered on the new WIPP Site, to accommodate the lack of hydrocarbon tests in the site area.

Keesey classified the hydrocarbon production potential as 1) proved producing reserves, 2) proved non-producing reserves, 3) proved undeveloped reserves, 4) probable reserves, and 5) possible reserves. Keesey found insufficient engineering and geological data to evaluate "possible reserves" (Keesey, 1976, p. 24) and could not assign any reserve potential to 11,360 acres (4,600 hectares) within the site area. Keesey focused on the "proven" potential for the economic production of natural gas and distillate for the remaining area. Within these constraints, Keesey concluded there was too much economic risk in the WIPP Site Area for crude oil exploration.

Keesey's 1977 analysis was limited to the production of natural gas and gas condensate from the deeper formations. The study was an appraisal of the fair market value of the hydrocarbon reserves underlying the four control zones of the WIPP Site. Although Keesey commented that multiple zones of oil and gas production could exist from the Delaware zone at 4,200 feet (1280 meters)to the Devonian zone at 15,800 feet (4618 meters), Keesey maintained that the primary target would be the deeper natural gas producing formations rather than the shallower oil producing formations.

Keesey's 1979 study also did not consider crude oil potential. Keesey estimated the potential hydrocarbon reserves underlying the WIPP Site Area, the percentage of these reserves recoverable through the use of known drilling technology, the value of the hydrocarbon reserves, the cost to recover these reserves, and the potential loss of future revenue to the State of New Mexico if the reserves could not be recovered due to the existence of the WIPP Site Area. Again, only the

natural gas and condensate potential for the deeper formations were considered.

3.4 Griswold, 1977

Griswold (1977) characterized the crude oil potential from the Delaware and Bone Springs Formations as of "minor importance." Griswold also maintained that experience elsewhere in this part of the Delaware Basin indicated a low probability of striking commercial reservoirs. This is in contrast to Keesey's initial observation:

> On the contrary, the Delaware Basin has been, and still is, an area that is considered to have major oil and gas potential, particularly in the Delaware[7] and Pennsylvanian series. (Keesey, 1976, p. 4).

Griswold (1977) maintained that the Delaware, Bone Springs, and Atoka Formations would be tested by any well going through to the deeper Morrow Formation. However, Foster cautioned that if the exploration target is a deep pay zone, then the shallower, potentially productive intervals are commonly not tested or may not even be carefully examined through the use of logs or samples (Foster, 1974, p. 103).

3.5 Powers et al., 1978

The Geologic Characterization Report (Powers et al., 1978) characterized the reserve estimates of the New Mexico Bureau of Mines and Mineral Resources (Foster, 1974, Section 8.4.8 and Table 8-13) as resources that may be in place without considering the economics associated with their extraction.[8] However, Foster's "statistical evaluations were based on productive acreage compared with total acreage tested, and wildcat success ratios in the Delaware Basin" (Foster,

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[7]Emphasis added.

[8]As noted in the preface of the GCR, Chapter 8 of the GCR was prepared by George Griswold.

1974, p. 279). The "productive acreage" indicates economical attractiveness. It is unclear why the Geologic Characterization Report (GCR) tabulated Foster's production estimates as "in place resources" in contrast with Keesey's estimates which were characterized as "economic resources." Foster's own table of "calculated reserves" characterized the petroleum potential as "production estimate" or "adjusted production estimate" and not as "in place" resources. The GCR acknowledged "a reasonable possibility that Foster's estimated resources could exist under the site" and commented that this probably represents the upper bound of exploitable reserves.

On the issue of avoiding existing oil fields, the Geologic Characterization Report (Powers et al., 1978) makes a strong statement.

> Regarding possible conflict with hydrocarbon reserves, the avoidance of deep drill holes automatically insures that a potential site would not be located over an existing oil or gas field. To minimize the possibility of siting over areas having favorable potential for discovery of additional hydrocarbon reserves, oil and gas trends in the subsurface beneath a possible site location would be considered in siting the repository. The locations of such trends are shown in Figure 2-7 (Powers et al., 1978, Section 2.3.5).

However, the avoidance of deep drill holes does not automatically insure that a potential repository site would not be located over an existing oil or gas reservoir. Avoidance of deep drill holes simply insures that any existing oil and gas reservoirs under the repository site were not yet discovered and/or developed. In this case the area was largely unexplored.

Two of the production trends cited by the Geologic Characterization Report (GCR) are shown in Figure 6. The GCR argues that known oil and gas trends "minimize the possibility of siting over areas having favorable potential for discovery of additional hydrocarbon reserves." However, in a largely unexplored

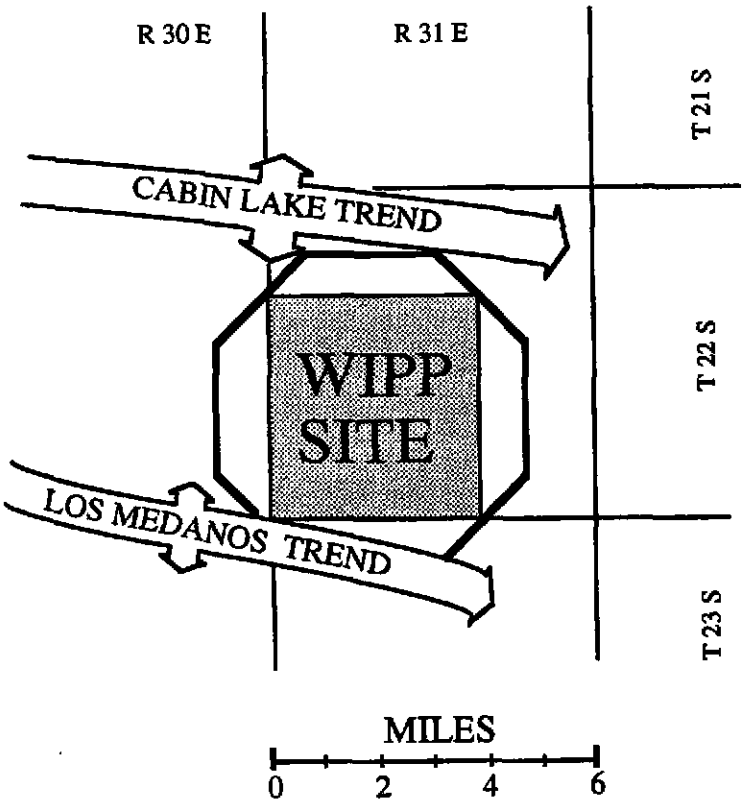

Figure 6. Production Trends. (Griswold, 1977)

area, production trends alone do not establish petroleum reservoir boundaries. As noted by Foster in describing the Pennsylvanian Formation, the geographical limits of petroleum production in the vicinity of the WIPP had not yet been identified.

> ....Production trends without intervening dry holes and the multiple producing zones support a conclusion that production from the Pennsylvanian may eventually cover a considerable part of this area. Significant as far as the Pilot area is concerned is the Paduca - Poker Lake - Sand Dunes - Los Medaños trend and potential for extension toward Hat Mesa. Drilling to date has not defined the horizontal or vertical limits of petroleum accumulations for any part of this area. (Foster, 1974, p. 116).

3.6 Final Environmental Impact Statement, 1980

The WIPP Final Environmental Impact Statement (U.S. DOE, 1980, Table 9-14) characterized the crude oil reserves at the WIPP Site as "nil." Foster's crude oil reserve estimates of 1.2 million barrels per section were described by the WIPP Final Environmental Impact Statement (FEIS) as resources rather than reserves (Table 9-14).[9] It is not clear why the DOE WIPP FEIS characterized the New Mexico Bureau of Mines and Mineral Resources estimate of petroleum production potential as resources rather than reserves. Foster specifically identified the estimates as "calculated reserves" (Foster, 1974, Table 46, p. 282). Furthermore, Foster's estimates were based on productive acreage which was presumably being produced because it was economically attractive with existing technology. Foster's characterization would be consistent with the WIPP FEIS definition for reserves.

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[9]The FEIS defined resources as minerals that are currently or potentially of economic value and reserves as resources that are economic at today's market prices and with existing technology (DOE FEIS, 1980, Section 9.2.3.1).

> Reserves are the portion of resources that are economic at today's market prices and with existing technology (p. 9-18, U.S. DOE, 1980).

It is also unclear why the map published in the WIPP FEIS (U.S. DOE, 1980, Figure 8.6) and shown in Figure 7 disclosed six abandoned drill holes, including two abandoned drill holes outside Control Zone IV, but failed to show four other abandoned drill holes and the eight producing oil and gas wells identified by Griswold (1977).

3.7 Brausch et al., 1982

As part of the Stipulated Agreement between the DOE and the State of New Mexico to resolve the State Attorney General's lawsuit against the DOE in 1981, the DOE agreed to prepare the Natural Resources Study Final Report (Brausch et al., 1982). Brausch et al. dismissed the crude oil reserves determined by Foster for the four control zones with the comment "not considered an economic reserve" (Brausch et al., 1982, Table 1). Brausch et al. further stated:

> crude oil resources are not considered reasonably extractable, but significant quantities of natural gas are likely to be present at the site (Brausch et al., p. 13).

Citing the economic analysis of Keesey (1976, 1979, 1980) Brausch et al. commented:

> only a single zone, the Morrow Formation, is worthy of exploration risk. **Gas production from the Atoka Formation is not large enough to justify exploration of this unit,**[10] although some production ancillary to Morrow production may be possible.

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[10]Emphasis added.

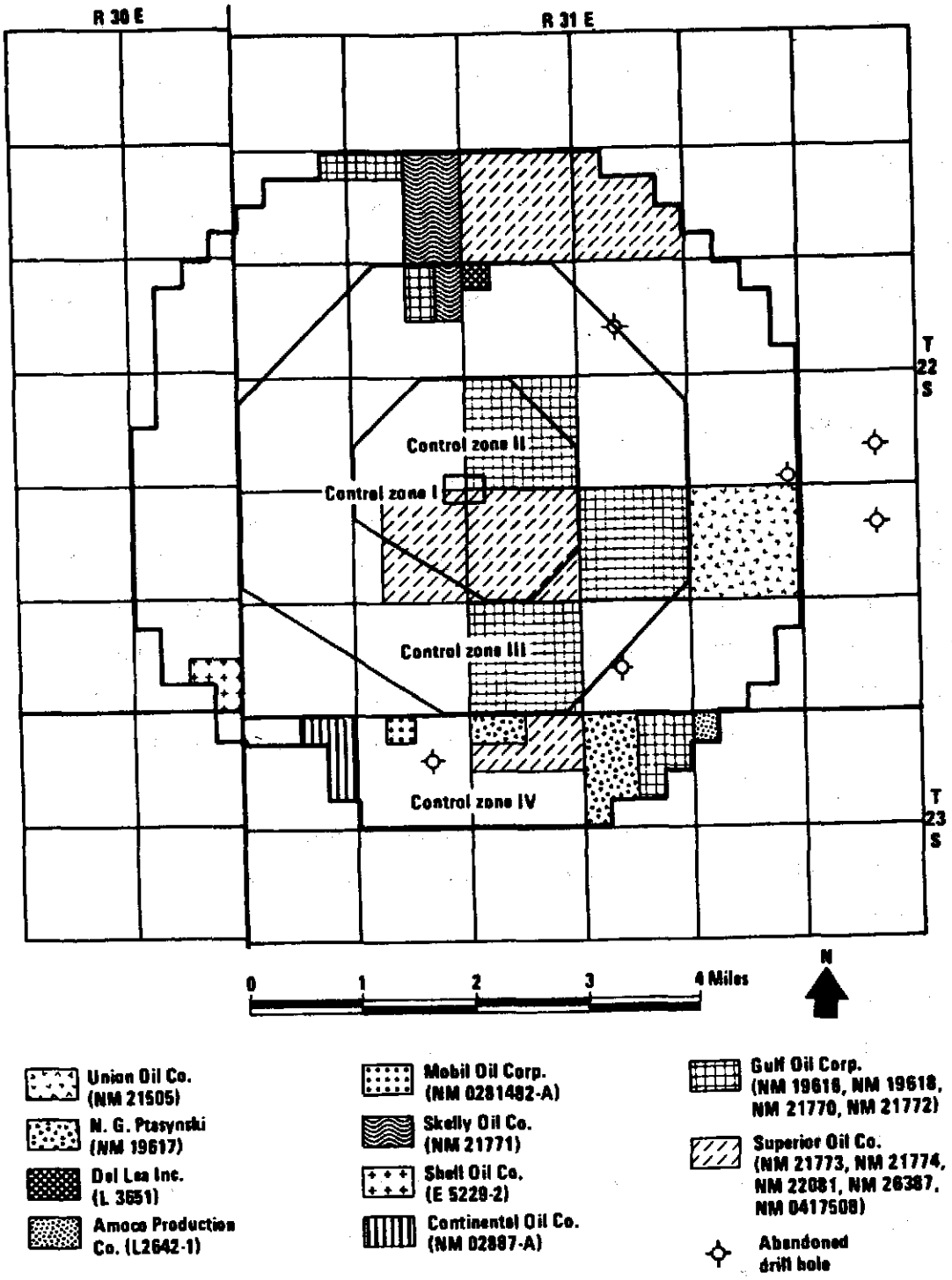

Figure 7. Oil and gas leases within the WIPP Site according to the DOE FEIS (U.S. DOE, 1980, Figure 8-6, reproduced with permission).

In 1980, the DOE had intended to maintain control of exploration, production, and abandonment activities in former control zone IV.

> Existing producing oil and gas holes in this zone will be permitted to continue through their useful lives; to protect the repository, they will be sealed as prescribed by the DOE when they are abandoned. New wells for oil and gas production may be drilled in conformance with DOE standards to facilitate eventual plugging; recovery methods such as flooding or hydrofracturing will not be permitted (U.S. DOE, 1980, p. 8-4).

However, based on the report of Brausch et al. (1982), the DOE relinquished jurisdiction over former control zone IV (McGough, 1983b; Weart, 1983). With respect to the impact of secondary recovery of crude oil on the integrity of the repository, Brausch et al. (1982) stated:

> Secondary recovery methods are commonly employed in portions of the Delaware Basin that contain practical quantities of crude oil. Such production methods are ***not***[11] evaluated in detail in this report, however, because of the minimal amount of crude oil likely to exist within the WIPP site (Brausch et al., 1982, p. 30).

The position was adopted by the DOE. The DOE Revised Interim Policy Statement on Resource Recovery at the WIPP Site stated:

> Secondary recovery methods .... and tertiary recovery methods ... may also be employed but, ***because the crude oil resources at the site are not reasonable or economically extractable,***[12] these techniques are not

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[11]Emphasis added.

[12]Emphasis added.

> expected to be useful unless significant technological advances and adaptation are made (McGough, 1982).

The DOE relinquished both the opportunity to prescribe drilling and plugging practices and the right to restrict waterflooding and massive hydrofracture for hydrocarbon recovery in former control zone IV.

Based on the report of Brausch et al., the DOE concluded that control of zone IV was no longer required to protect the long term integrity of the site and the DOE chose to rely on other agencies for institutional control of resource recovery activities in former control zone IV.

> As you know, the DOE revised Interim Policy Statement on Resource Recovery at the WIPP Site is based on the Natural Resource Study [Brausch et al., 1982] which concludes that resource recovery outside the Site boundary (Zone III) using current technology, will not compromise the integrity of the WIPP underground facility. Accordingly, the DOE does not plan to exercise any control over resource recovery activities outside the Site boundary and will rely, primarily, on other Federal and State regulatory agencies to assure that the WIPP boundaries are not violated. As an additional protection measure, the BLM will notify the DOE of any requests for resource recovery permits within one mile of the WIPP Site boundary so that the DOE will be aware of resource recovery activities near the Site (McGough, 1983b).

When control zone IV was relinquished by DOE, it was opened for petroleum exploration. Crude oil is now being produced from former control zone IV and has been recently characterized as "extremely high in oil and gas reserves and it is no exaggeration to state that the Livingston Ridge Delaware Pool underlying the WIPP Area is one of the most significant proven oil and gas developments in the State of New Mexico...." (Nibert, 1992).

3.8 Weart, 1983

Weart (1983; U.S. DOE, 1983) evaluated the WIPP site suitability, citing factors listed in the Geological Characterization Report and in the Final Environmental Impact Statement. Weart's discussion on natural resources recognized that virtually any sedimentary basin would be the target for oil and gas exploration. Weart noted that the WIPP project could never rule out the possibility of human intrusion.

In discussing crude oil potential, Weart did not cite Foster's adjusted production estimates of 550,000 to 1,200,000 barrels crude oil per section. Citing only the DOE Final Environmental Impact Statement (1980) and the report of Brausch et al. (1982), Weart stated:

> Prospects for oil in this immediate area are not promising. (Weart, 1983, p. 24)

3.9 Neill et al., 1983

Neill et al., (1983) acknowledged the limitations and the merit's of Foster's regional statistical approach. Echoing the caution given by Powers et al. (1978) in the Geological Characterization Report, Neill et al, commented:

> Of course, since Foster's study used a regional statistical approach, there may be considerably more or less than the average quantity of hydrocarbons if the site were actually drilled (Neill et al, 1983, p. 98).

However, Neill et al. concluded:

> Therefore, it is possible that significant reserves of oil also exist within the site. (Neill et al., 1983, p. 98)

3.10 Weart et al., 1991

Weart et al., (1991) presented the following conclusion as background information to the expert panels on inadvertent intrusion into the Waste Isolation Pilot Plant:

> Crude oil will not be a target for exploration unless the price of oil rises to levels substantially higher than the price during the past energy crises. Natural gas in the Morrow Formation will remain the main and perhaps only hydrocarbon of potential economic importance (Weart et al., 1991, p. VI-12).

3.11 Estimated Crude Oil Potential Based on Current Production

Evaluation of recent production decline data for wells recently drilled in former Control Zone IV suggest an ultimate primary recovery of 1.1 million barrels of crude oil for Section 23 and 673,000 barrels of crude oil for Section 26 (T22S, R31E)[13] thus suggesting that the New Mexico Bureau of Mines and Mineral Resources report (Foster, 1974) was correct in its assessment of crude oil reserves.

The estimates are not intended to represent the complete crude oil potential of these sections. The estimates are inherently limited. The wells have been in production for only a few months. The production data do not include formation potential behind casing that has not yet been perforated. Each section has not been entirely drilled because of the presence of potash. Potential crude oil production due to future secondary recovery, tertiary recovery, or infill drilling is not yet known.

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[13]The extrapolation assumes that the sections would have been developed with wells on 40 acre spacings which was not allowed due to the presence of potash.

Table 1. Estimated ultimate crude oil recovery by primary production. (Babyak, 1994)

Sec, Tnsp, Rnge	Well #	First Production	Ultimate Crude Oil Recovery (BBLs)
23, T22S, R31E	1	Aug 90	73,066
23, T22S, R31E	2	Apr 92	24,690
23, T22S, R31E	3	Aug 91	69,798
23, T22S, R31E	5	Apr 91	106,286
26, T22S, R31E	1	Jul 90	65,186
26, T22S, R31E	2	Apr 91	28,325
26, T22S, R31E	3	Sep 91	75,228
26, T22S, R31E	4	Dec 91	29,101
26, T22S, R31E	5	Jan 91	28,174
26, T22S, R31E	6	Apr 92	28,339
26, T22S, R31E	7	May 92	39,937

3.12 Summary

The DOE funded a number of studies and reviews on the possibility of oil and gas reserves in the vicinity of the WIPP. Recent production of crude oil in the WIPP vicinity indicates that the 1974 study by the New Mexico Bureau of Mines and Mineral Resources (Foster, 1974) was correct. However, the Department of Energy rejected the findings of the New Mexico Bureau of Mines and Mineral Resources.

> Although the New Mexico Bureau of Mines and Mineral Resources (NMBM&MR) study shows that minor deposits of crude oil are statistically probable at the WIPP Site, later studies have discounted the existence of economically attractive quantities of crude oil at the site (McGough, 1983a, p.4).

Yet, in less than ten years, the WIPP area has been found by the oil and gas industry to be:

> extremely high in oil and gas reserves and it is no exaggeration to state that the Livingston Ridge Delaware Pool underlying the WIPP Area is one of the most significant proven oil and gas developments in the State of New Mexico in what is otherwise a generally dismal exploration and development climate (Nibert, 1992).

The industry observation and actual crude oil production raises questions about the DOE decision making process. Brausch et al. (1982) chose not to evaluate the possible impact of secondary recovery on the integrity of the repository because of the "minimal amount of crude oil likely to exist within the WIPP Site." Based on the report of Brausch et al. (1982), the DOE decided to relinquish control zone IV. In 1980, the DOE intended to maintain control of exploration, production, and abandonment activities in this zone. However, the DOE relinquished both the opportunity to prescribe drilling and plugging practices and the right to restrict waterflooding and massive hydrofracture for hydrocarbon recovery in former control zone IV.

The position of minimal crude oil reserves persists in guiding DOE assumptions on other major issues including the demonstration of compliance with the EPA disposal regulations. Participants in two elicitation exercises were asked to provide information with which to estimate oil and gas drilling rates in the WIPP vicinity over the next 10,000 years (Hora, 1992). Unfortunately, the participants were told that crude oil would not be a target for exploration unless the price of oil substantially exceeded the price during the past energy crises and were further

told that natural gas from the Morrow Formation will remain the main and perhaps only hydrocarbon of potential economic importance in the area (Weart et al., 1991). Hence, the elicitation exercise generated future drilling rates far lower than the observed drilling rates.

4. DRILLING RATES AND EXPERT JUDGEMENT

Predicting the drilling rate over the next 10,000 years represents a major uncertainty in calculating the performance of the repository. The performance assessment calculations are highly sensitive to the assumed drilling rates (SNL, 1992, vol. 3, Table 5.2). The postulated drilling rates used in the 1992 effort are low and account for a very important factor in the calculated repository performance as shown in Figure 8 (SNL, 1992, vol 1, Figure 5-1).

4.1 Expert Judgment

The 1992 performance assessment calculations included very low drilling rates inferred from two elicitation exercises cited as "expert judgment" by Hora et al. (1991). The elicitation exercises were intended to estimate drilling rates for oil and gas resources over the next 10,000 years. Participants in the first elicitation were asked to identify the activities of future societies that would disrupt the integrity of the repository. They were also asked to assign probabilities to events such as exploratory[14] drilling. Participants in the second elicitation were asked to design a marker that would discourage human intrusion. As an additional task they were asked to evaluate the effectiveness of the markers they recommended. The participants in both exercises were provided outdated and incorrect information on the two issues that were most important to their discussions — the actual drilling intensity and the crude oil reserves in the immediate vicinity of the WIPP Site. This report questions the low drilling rates inferred from these elicitations and used in the WIPP performance assessment, and examines some very poor near future predictions.

Participants in the future societies elicitation exercise were assembled in the summer of 1990. The elicitation consisted of four teams with four members on

[14]The various definitions for exploratory drilling are discussed in Section 4.6. This evaluation considers all drilling activity as potentially intrusive.

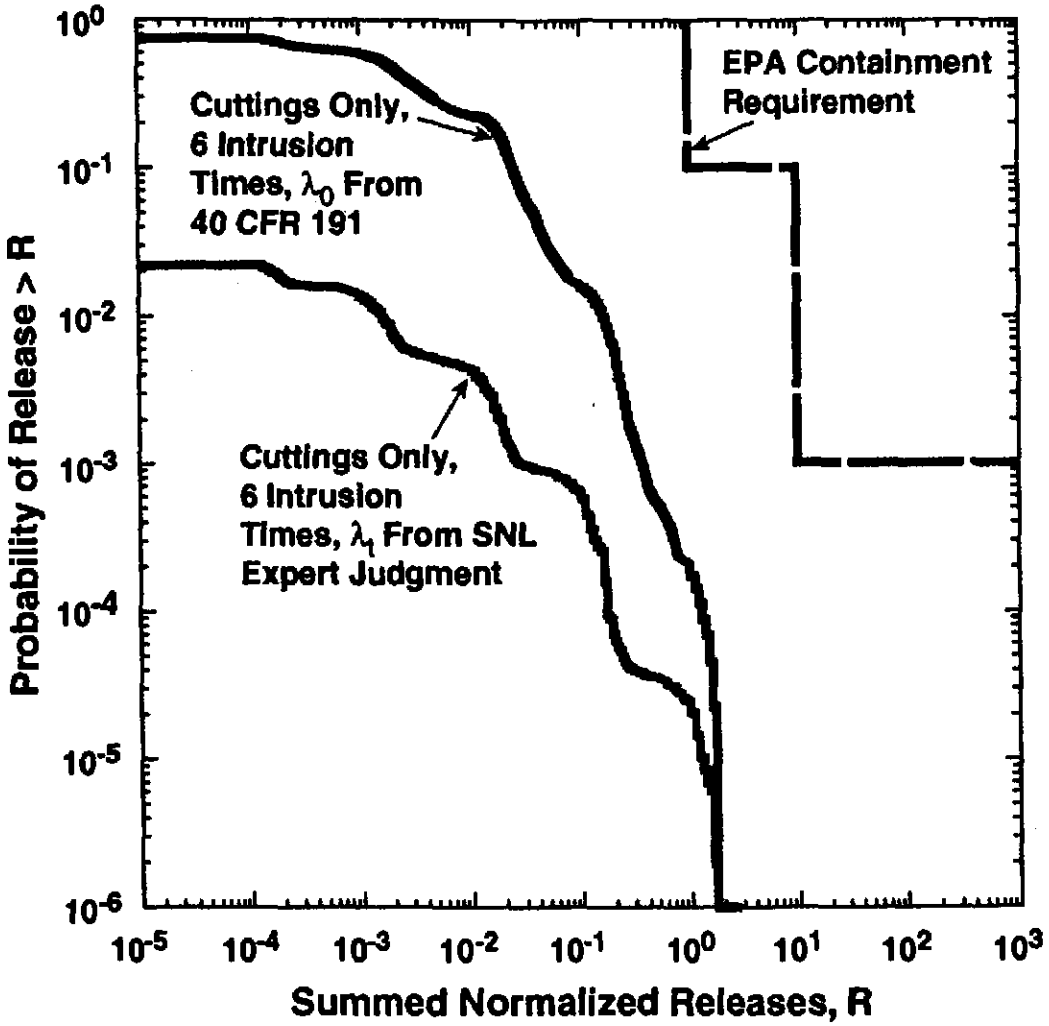

Figure 8. Mean CCDF's calculated for cuttings releases only for six intrusion times. (SNL, 1992)

each team. Their team reports were completed at different times from October 1990 through January 1991. The analysis was published by Hora et al. (1991) in December 1991. The Washington A Team consisted of a resource economist, a political scientist, an environmental attorney, and a nuclear physicist (Chapman, Ferkiss, Reicher and Taylor, 1991, p. E-5). The Washington B Team consisted of a risk analyst, a futurist, a climatologist, and a historian (Glickman, Singer, Rosenberg and Vinovskis, 1991[15], p. F-3). Members of the Boston Team held credentials in futures research, law, sociology, and physics (Gordon, Baram, Bell and Cohen, 1991, p. C-3). The Southwest Team characterized itself as "an astrophysicist who also writes science fiction, a decision analyst, a physical scientist turned social scientist, and a geographer" (Benford, Kirkwood, Otway, and Pasqualetti, 1991, p. D-6). The extractive minerals industries and the petroleum industry were not represented by membership on any of the teams.

The participants were told:

> Crude oil will not be a target for exploration unless the price of oil rises to levels substantially higher than the price during the past energy crises. Natural gas in the Morrow Formation will remain the main and perhaps only hydrocarbon of potential economic importance (Weart et al., 1991, p. VI-12).

4.2 Washington A Team

The Washington A Team appears to have assumed that all 1029 exploration and development wells drilled in the region from 1919 through 1987 were for the production of natural gas and none were for the production of crude oil.

> Natural gas exists in commercial quantities in the region at depths below the 2100 foot WIPP level. Production is current, and 1029 exploration

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[15]The report was undated but was included as an appendix to the 1991 report by Hora et al. 1991.

and development wells were drilled in the 69 years commencing in 1919 (Chapman et al., 1991, p. E-21).

From this assumption the Washington A Team developed probabilities of inadvertent intrusion for the near future[16], 1990 to 2190, and specifically identified the prediction as the "natural gas case study" (Chapman et al., 1991, p. E-23) as shown in Figure 9.

There is a plausible explanation for the Washington A Team to consider only natural gas and not crude oil potential. The team relied on information documented in a report by Weart et al., (1991) and the information they received at the August 13-15, 1990 meeting in Albuquerque. At the meeting, one overhead referred to the report of Brausch et al., (1982) and characterized crude oil with the comment "not a reserve." Only potash and natural gas were quantified as reserves. Another overhead referred to the report of Powers et al. (1978) and maintained that only potash and natural gas had potential as significant exploitable deposits. The presentations strongly suggested that there was no crude oil potential. The Washington A Team did not consider crude oil in their analyses.

4.3 Washington B Team

The Washington B Team concluded:

> Drilling for other resources is also possible in the area. But the area is so poor in other resources that are not at least equally available elsewhere that gas seems to be a more likely objective than all other potential resources put together (Glickman et al., 1991, p. F-27).

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[16]Hora et al. (1991, p. V-7) incorrectly state "the Washington A Team used the first 200 years after the lapse of active controls."

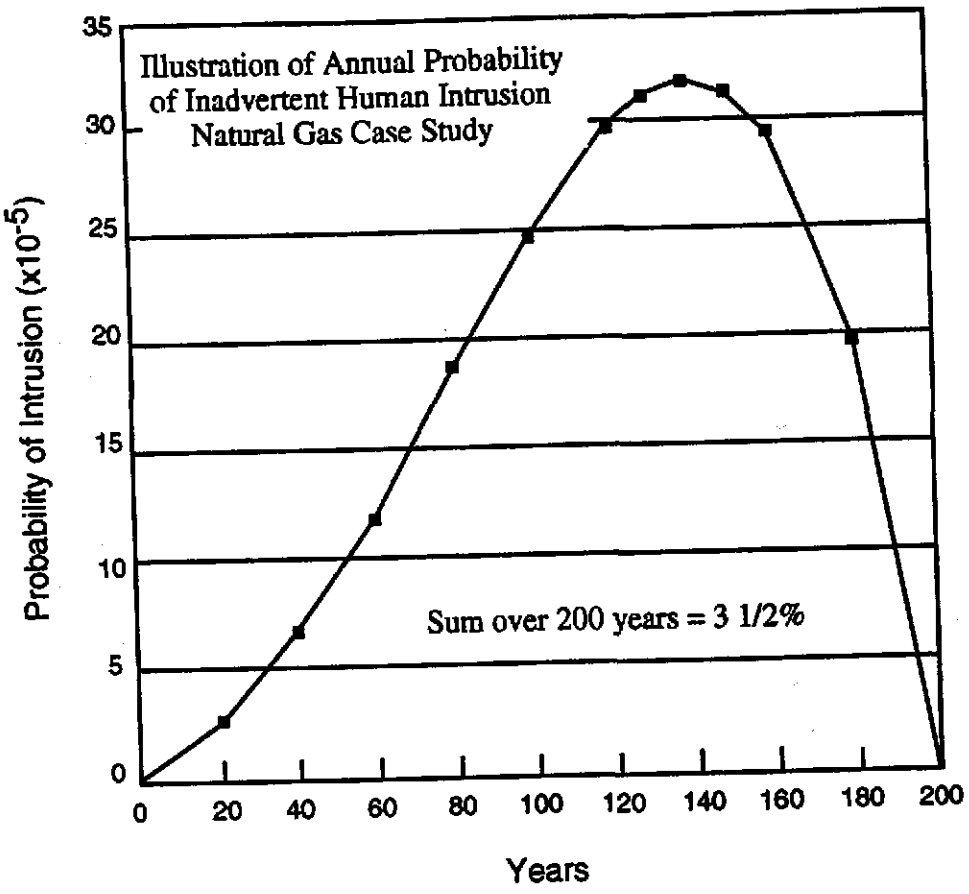

Figure 9. Washington A Team annual probability of inadvertent intrusion. (Chapman et al., 1991, p. E-24)

The Washington B Team then predicted exploration and production activity for the near future[17]

> The exploration and extraction of resources in the near future is limited to drilling, primarily drilling for natural gas. Other resources are 0.2 to 0.1 times as likely to be exploited, and thus gas exploration dominates the near future.

However, it is crude oil, and not natural gas, that has dominated recent drilling activity in the immediate vicinity of WIPP. Table 2 shows the number of oil and gas wells drilled from 1987 through 1992 in a 124 km² area (2 mile band) immediately adjacent to the WIPP Site Boundary. From 1987 through 1989, just prior to the elicitation, there were no new gas wells drilled within two miles of the WIPP Site Boundary, yet nine new oil wells had been drilled. In 1990, the year of the elicitation exercise, thirteen oil wells were drilled, but not a single gas well was drilled. In 1991 and 1992, sixty new oil wells were drilled compared with only two new gas wells. Yet the Washington B Team identified natural gas as the resource for near term exploration and extraction activity.

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[17]The Washington B Team defined the near future as 0-200 years after closure (Glickman, Singer, Rosenberg & Vinovskis, pp. F-4, F-27; Hora et al., p. IV-55).

Table 2. Oil and gas wells drilled immediately adjacent to the WIPP.

Year	New Gas Wells	New Oil Wells
1987	0	4
1988	0	2
1989	0	3
1990	0	13
1991	1	37
1992	1	23

4.4 Non-use of Public Records

The exercise raises questions about the effectiveness of public records to convey information, which is a key component of passive institutional control. The elicitor, the panel members, and the presenters were well educated and their services were retained to find facts about a project in progress. There had been no changes in language, culture or government. Yet it appears that not a single person consulted the public records of the U.S. Department of Interior nor the public records of the New Mexico Oil Conservation Division. Otherwise, they would have found that it was crude oil, and not natural gas, that had dominated recent resource exploration and production in the immediate vicinity of the WIPP. This exercise, conducted to use the current state of knowledge to predict the future, produced a disturbing snapshot of the failure of well educated individuals to learn from ***current*** public records and facts on the ground. What confidence can society have in public records to provide knowledge in the future and to prevent drilling into the repository?

The low drilling rates inferred from the elicitation exercise reflects the outdated information provided to the participants. In tabulating the number of exploration

and development wells and the location of oil and gas fields, Weart et al. (1991) referenced a 1987 map published by Midland Map Company and two 1977 maps published by the Roswell Geological Society. It is widely recognized in the petroleum industry that drilling information from Midland Map Company and other such commercial services is revised ***continuously*** to reflect the current activity in the area. Further, the BLM also maintains up-to-date maps and records of petroleum exploration and production on its properties. Why did Weart et al. (1991) use maps that were fourteen years and four years old? There is no discernible reason to base decisions or predictions on maps that are so seriously out of date. It appears that the commercially available maps and the current BLM maps were not consulted.

There is another well known industry practice that tends to contradict the predictions of the expert panels. Drilling for natural gas in New Mexico, as well as other states, is often accomplished with wells drilled on 320 acre spacings, although exceptions are not uncommon. Drilling for oil is generally accomplished on 40 acre spacings or less. On a square mile the economic production of oil would usually require sixteen wells compared with only two wells typically drilled for gas production. Contrary to the discussions and predictions of the expert panels, the drilling rate for gas is generally one-eighth the drilling rate for oil. The guidelines for these practices are also a matter of public record and can be obtained from the New Mexico Energy, Minerals, and Natural Resources Department's Oil Conservation Division (1993).

There is further economic incentive for a higher drilling rate for crude oil than there is for natural gas. Infill drilling can be used in developed fields to increase or accelerate oil recovery. New wells are drilled between existing wells to reduce the average spacing. Infill drilling increases the production rate and recent studies also indicate that infill drilling increases ultimate recovery, converting previously unrecovered mobile oil into proven producible reserves (U.S. DOE, 1989).

4.5 Inferred Drilling Rates

Figure 10 (a and b) compares the drilling rates suggested by EPA (1985, 1993) and those proposed by Hora (1992). The EPA Standards (U.S. EPA, 1985) for the disposal of transuranic waste specify a maximum drilling rate of 30 boreholes per square kilometer over 10,000 years (U.S. EPA, 1985, p. 38089). The raw drilling intensities shown in Figures 10 (a and b) reflect drilling rates inferred from elicitation of the "futures" panel. The effective drilling intensity reflects drilling rates inferred from elicitation of the "markers" panel. The drilling rates estimated by Hora are consistently and substantially lower than the EPA maximum for sedimentary geologic formations. Hora (1992, p. 88) reported the *largest* time integrated drilling intensity from among 1,000 vectors for the entire regulatory period to be only 1.11 boreholes per km^2 over 10,000 years. For the 1,000 to 10,000 year period after closure, or 90% of the regulatory period, Hora (1992) estimated the raw drilling intensity as 0.3 boreholes per square kilometer over 10,000 years or 2 orders of magnitude less than the EPA maximum of 30 boreholes per square kilometer over 10,000 years.

Figure 11 shows the number of oil and gas wells in the immediate vicinity of WIPP in 1977. The map includes a two mile (3.2 km) border encompassing the 124 km^2 area surrounding the WIPP Site Boundary. Until 1977, 15 oil and gas wells (including dry holes) had been drilled within this 3.2 km border region. If the EPA maximum drilling rate of 30 boreholes per km^2 per 10,000 years had been sustained following 1977, an additional 8 wells would have been drilled by 1993. However, Figure 12 shows an additional 99 oil and gas wells[18] drilled from 1978-1993 in the region. If averaged over 15 years, that yields a drilling rate of 530 boreholes per km^2 per 10,000 years. Table 3 lists the drilling rates extrapolated from yearly data for the area immediately surrounding WIPP. In 1991, the drilling rate peaked at 3057 well bores per km^2 per 10,000 years.

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[18]The map does not differentiate between wildcat wells and field and pool wells. Locations of notice of stakings and pending, approved, denied, or canceled applications to drill are also shown because they indicate the level of industry interest.

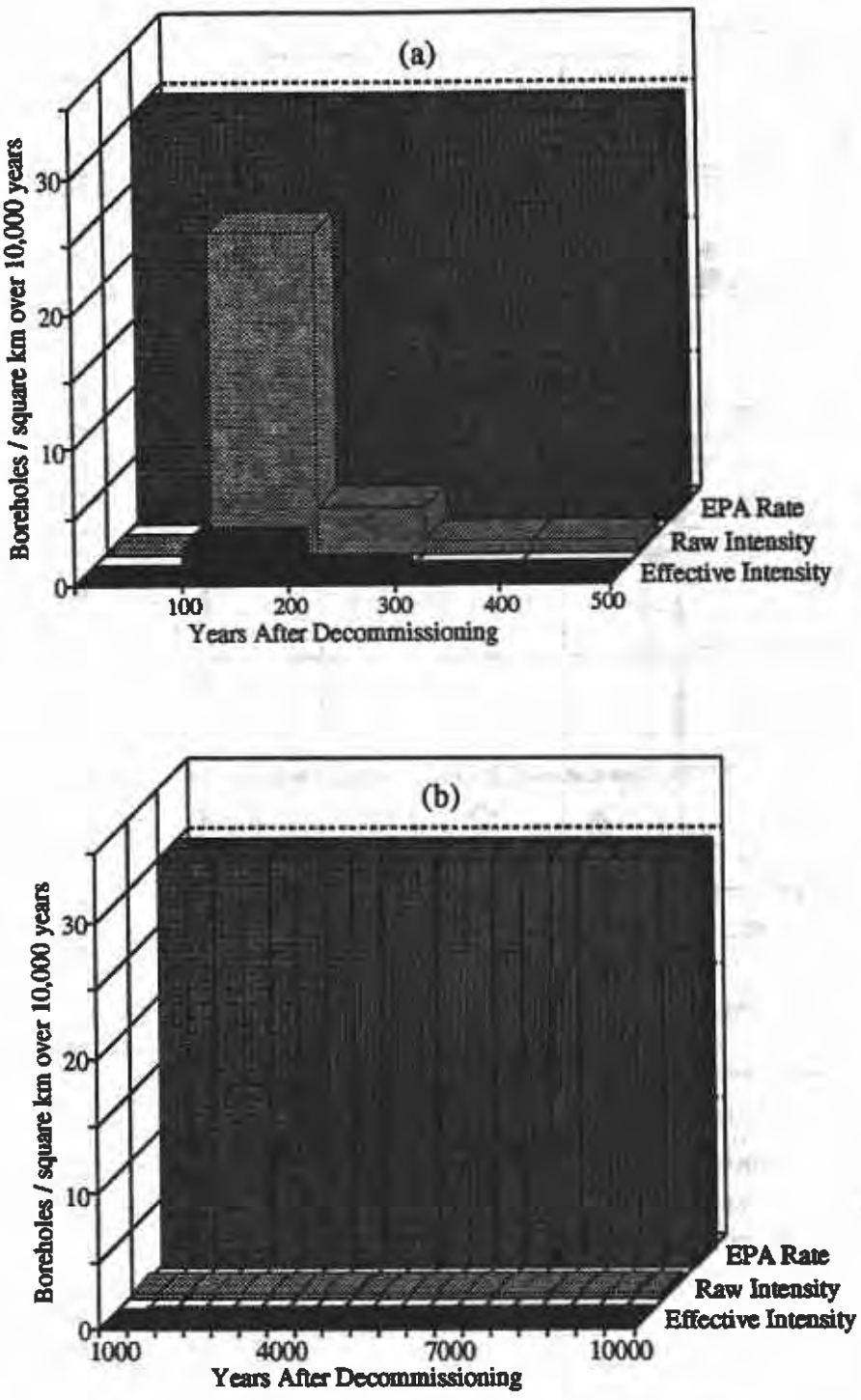

Figure 10. Mean drilling intensities inferred from elicitation of expert judgment. Plot includes full credit for 100 years of active institutional control.

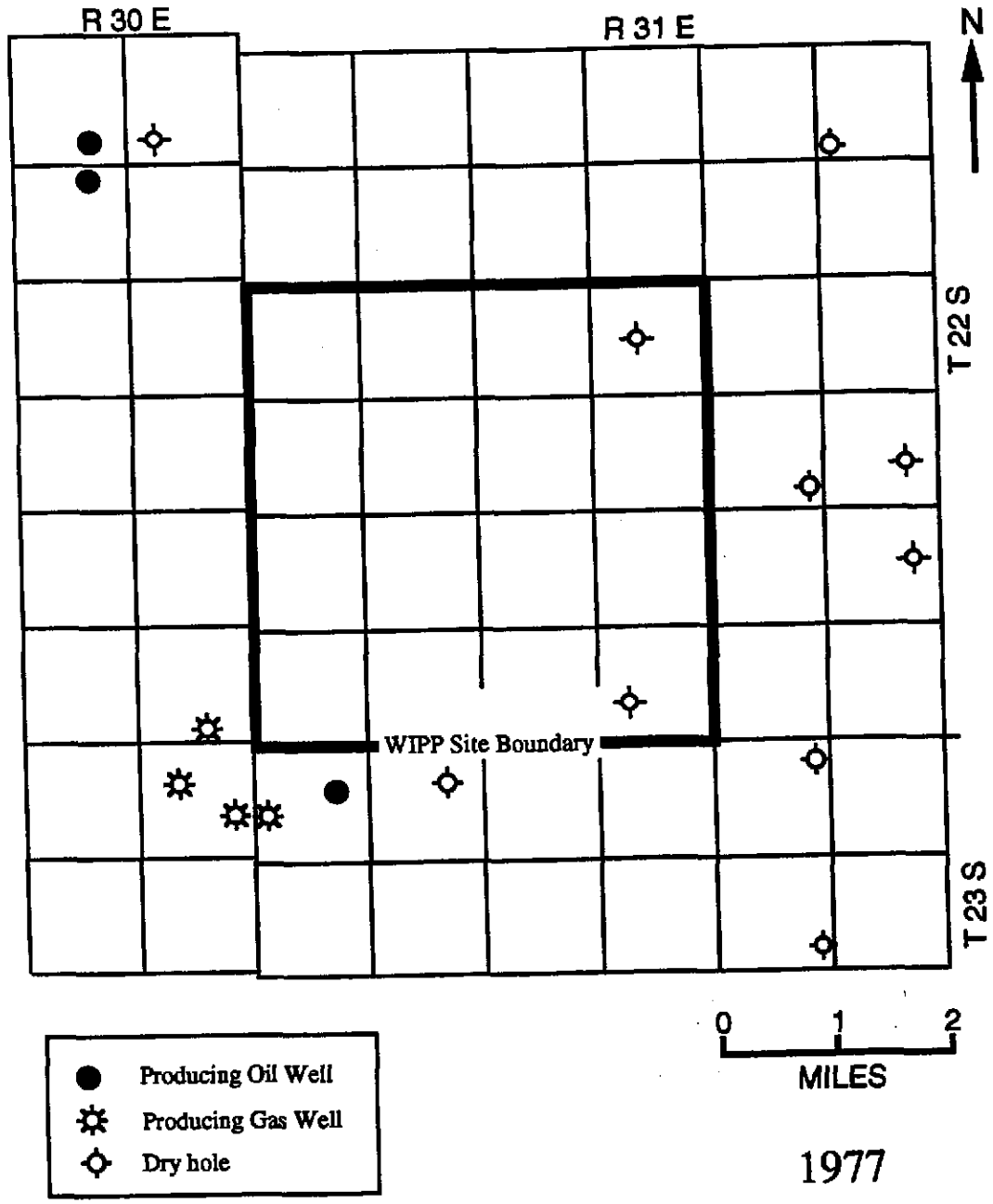

Figure 11. Oil and gas exploration and production in the immediate vicinity of the WIPP until 1977.

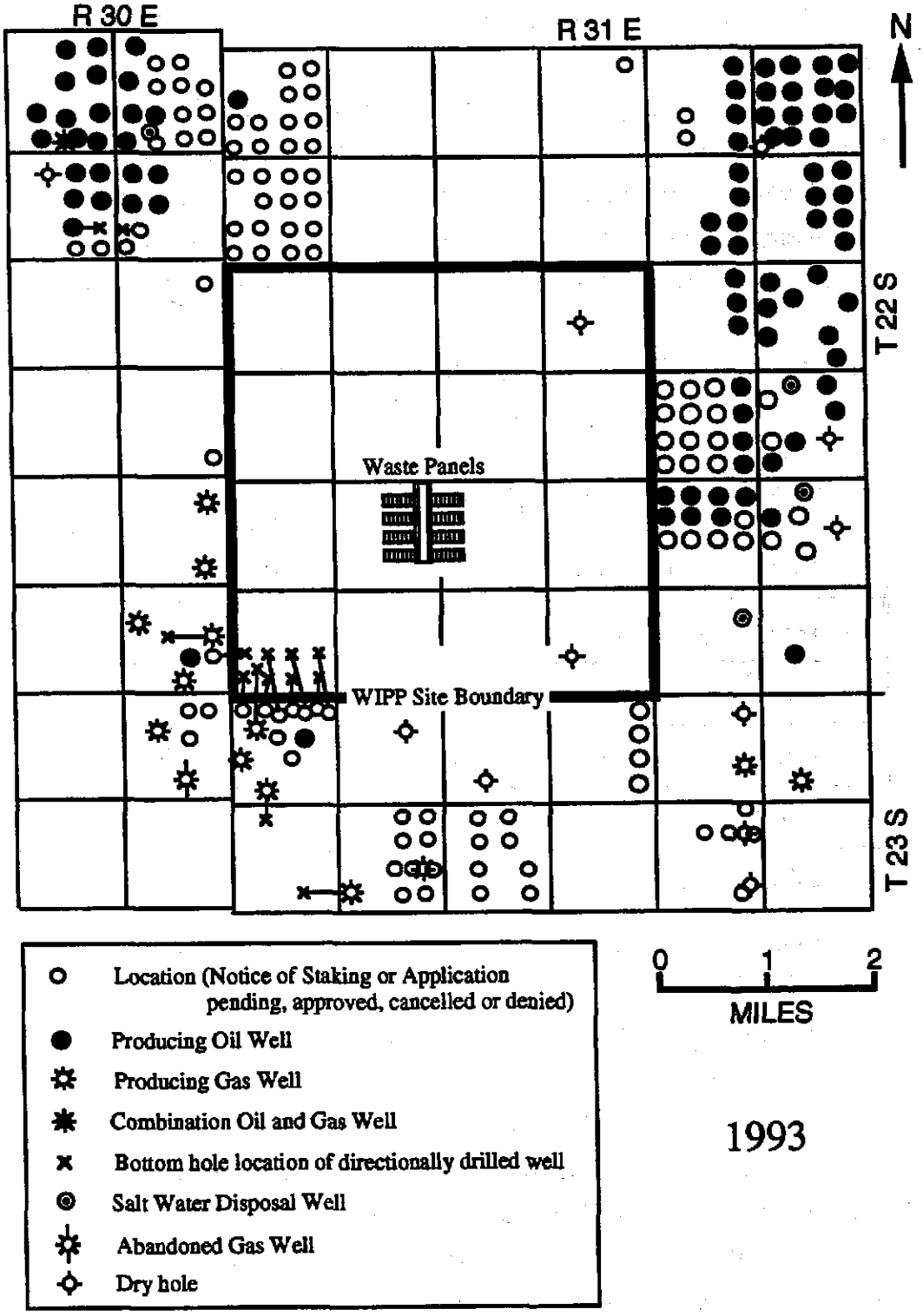

Figure 12. Oil and gas exploration and production in the immediate vicinity of the WIPP until October,1993.

The drilling rates listed in Table 3 must be viewed with caution. This report certainly does not advocate that this level of drilling will be sustained for any length of time nor does it advocate that the drilling rate is constant. However, this report does identify the most recent period of time in which the drilling rate in the immediate vicinity of the WIPP exceeded 3000 boreholes per km^2 per 10,000 years or was more than 2 orders of magnitude higher than the EPA maximum of 30 boreholes per km^2 over 10,000 years and 4 orders of magnitude higher than the Hora (1992) estimate of 0.3 boreholes/km/10,000 years.

Table 3. Drilling rate extrapolated from yearly data for a 124 km^2 area immediately surrounding the WIPP.

Year	Gas Wells	Oil Wells	Extrapolated Drilling Rate (Wells/km^2/10,000 years)
1987	0	4	322
1988	0	2	161
1989	0	3	241
1990	0	13	1046
1991	1	37	3057
1992	1	23	1930

The actual drilling rate in the vicinity of WIPP might have been much higher had it not been for potash reserves. The objectives of the two industries are inherently incompatible. For safety reasons, potash mining avoids an oil or gas wellbore (Baier, 1990). If an oil or gas well is drilled through the potash, the potash surrounding the wellbore can not be mined and the potash resource is lost. Hence, the BLM often denies oil and gas drilling applications until after the potash reserves are removed. The guidelines for the approval or denial of oil and gas drilling applications within the potash enclave are described in the Secretarial

Order of 1986 (U.S. DOI, 1986). The active potash leases immediately surrounding the WIPP Site are shown in Figure 13.

4.6 Need for Clarification of EPA Terminology

Use of the terminology "inadvertent exploratory drilling" in the EPA Standards creates uncertainty. Exploratory drilling is not the only kind of drilling that may be inadvertent, in other words drilling without knowledge of the repository. Any kind of drilling activity, including a production well, should be considered as inadvertent as long as the drillers do not have knowledge of the repository.

Further, the term exploratory is not clearly defined in regulation. On applications for permit to drill (APD), the Bureau of Land Management and the New Mexico Oil Conservation Division do not use the term "exploratory." Oil and gas wells are classified as either "field and pool" or "wildcat." The Rules and Regulations of the New Mexico Oil Conservation Division (1993, Rule 104) defines "wildcat" wells and "development" wells but does not appear to use the term exploratory.

In the information provided to the expert panels, Weart et al. (1991, p. VI-12) suggested, by parenthetical reference, that the term "exploratory" was synonymous with "wildcat" and other wells were "developmental." However, it is not clear that this interpretation is consistent with the intent of the EPA Standards (U.S. EPA, 1985; U.S. EPA, 1993) or with industry definitions.

Apparently exploratory wells are not limited only to wildcat wells. Bates and Jackson (1980) define an exploratory well as a well drilled to an unexplored depth or in unproven territory, either in search of a new pool of oil or gas *or* with the expectation of greatly extending the known limits of a field already partly developed. Whitehead (1976) defines an exploration well as a borehole drilled in the search for a new source of hydrocarbons. An exploration well may be a new field wildcat, or a probe for a new production formation in an existing field. In this sense a delineation well is also an exploration well. A delineation well is an exploration well drilled as part of a carefully planned program with the object

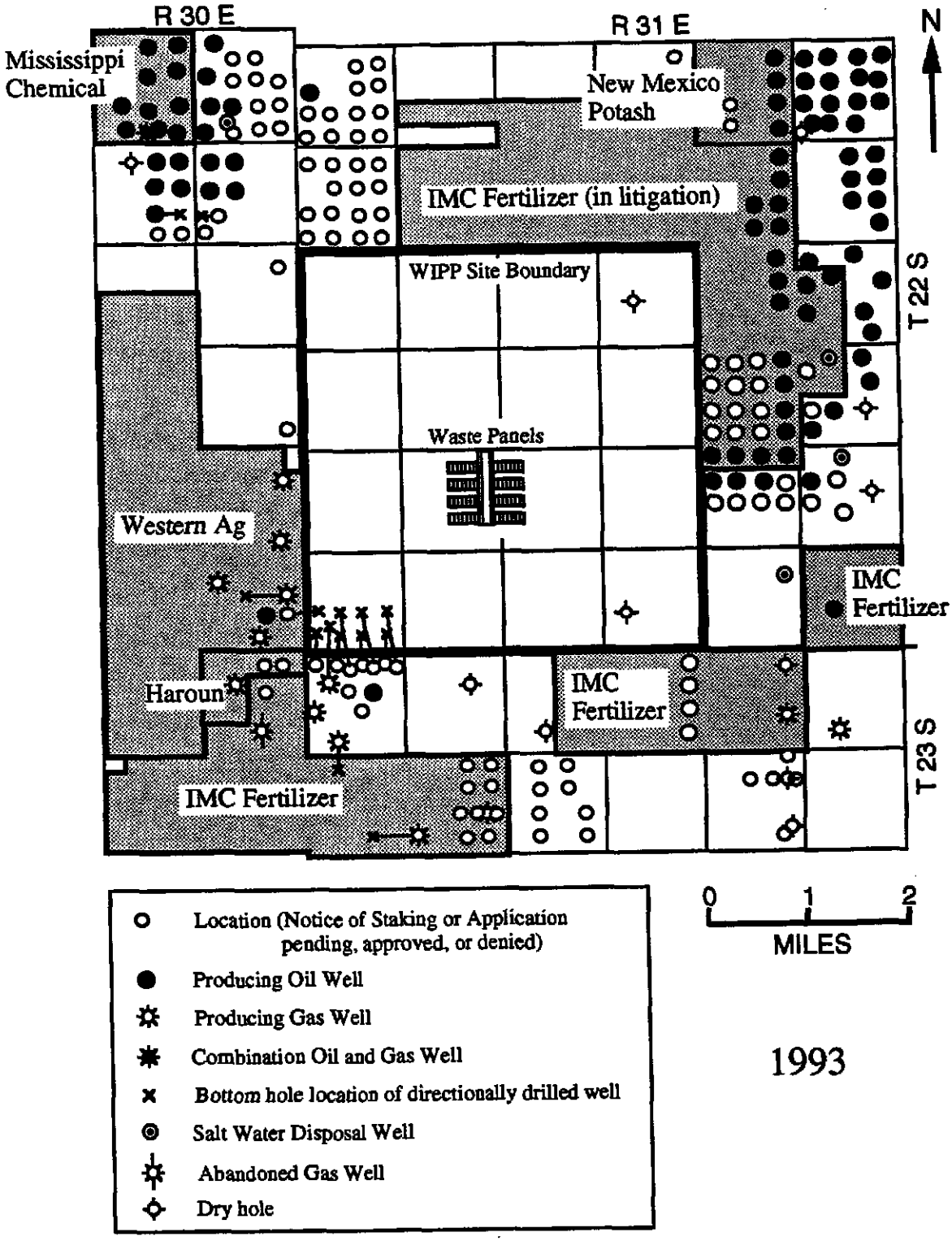

Figure 13. Active potash leases in the immediate vicinity of the WIPP.

of appraising the value of an oil or gas discovery. Delineation wells, or step-out wells, are drilled so that the probable outline of the oil- or gas-field may be delineated (Whitehead, 1976).

The use of the term exploratory well in the EPA Standards (U.S. EPA, 1985; U.S. EPA, 1993) is open to broad interpretation which is not desirable given the sensitivity of the performance assessment calculations to well-drilling rates. All drilling should be considered to be "inadvertent" as long as the drillers are unaware of the existence of the repository.

4.7 Summary of the Drilling Rates Issue

The performance assessment calculations are very sensitive to the assumed drilling rates. The 1992 performance assessment calculations include very low drilling rates inferred from two expert elicitation exercises. The participants in both exercises were provided outdated and incorrect information on the two issues that were most important to their discussions — the actual drilling intensity and the estimated crude oil reserves in the immediate vicinity of the WIPP Site. Hora subsequently (1992, p. 88) reported the *largest* time integrated drilling intensity from among 1,000 vectors for the entire regulatory period to be only 1.11 boreholes per km^2 over 10,000 years. For the last 9000 years (1000 years after closure to 10,000 years after closure), or 90%, of the regulatory period, the effective drilling intensity inferred from the "expert" elicitation exercise, is about 0.15 boreholes per km^2 over 10,000 years or more than 2 orders of magnitude less than the EPA recommended value of 30 boreholes per km^2 over 10,000 years. The low inferred drilling rates probably reflect the limited, outdated and incorrect information provided to the panel members.

The use of the term exploratory well in the EPA Standards (U.S. EPA, 1985; U.S. EPA, 1993) is open to broad interpretation which is not desirable given the sensitivity of the performance assessment calculations well-drilling rates. All drilling should be considered to be "inadvertent" as long as the drillers are unaware of the existence of the repository.

5. INSTITUTIONAL CONTROL AT THE WIPP

The actual experience of the WIPP project strongly suggests that the performance assessment calculations should not take much credit for institutional control, even for a short period of time. Silva and Channell (1992) found that two active oil and gas leases and a producing gas well within the WIPP Site Boundary were overlooked in several important DOE documents despite public records and the visible existence of a producing gas wellhead from the south access highway to the WIPP facility. In response to the report, the DOE identified the internal procedures of the BLM as the control crucial to protecting the site from inadvertent human intrusion. The procedures required BLM to obtain and consider DOE's review of each drilling application within one mile of WIPP prior to issuing a permit to drill. However, a review of the actual permitting process indicates that either the BLM or the DOE failed to implement those crucial procedures in 22 out of 25 applications submitted between October 26, 1990 and October 30, 1992.

5.1 Lapse in DOE Records

As reported by Silva and Channell in EEG-50 (1992), the U.S. Department of Energy (DOE) documentation overlooked two active oil and gas leases and a gas well within the WIPP Site Boundary. This informational lapse occurred in spite of lease, drilling, and production records filed by the oil company with the federal government (BLM); a condemnation suit filed in civil court by the federal government in 1977; a Consultation and Cooperation Agreement between the State of New Mexico and the federal government; a Memorandum of Understanding between agencies of the federal government recognizing the existence of these leases; technical reports funded by the federal government on area oil and gas resources; and the visible existence of a producible gas well from the south access highway to the WIPP facility. Several important DOE documents were either incorrect, silent, or inconsistent on the existence of these leases:

1) The Final Environmental Impact Statement (U.S. DOE, 1980, pp. 8-8 to 8-10) identified the oil and gas leases held by ten companies in March 1979, yet the 1952 Conoco and 1959 Bass leases in the southwest corner of the WIPP Site on Section 31 were not mentioned.
2) The WIPP Final Safety Analysis Report (U.S. DOE, 1990a, Section 2.1.1.1), incorrectly stated that there were no active oil and gas leases within the WIPP Site Boundary and failed to chart the intruding well on its map of producible oil and gas wells.
3) The DOE No-Migration Variance Petition to EPA incorrectly stated that the DOE has purchased all oil and gas leases in the area of the WIPP site to prevent any exploration now and in the future (U.S. DOE, 1990b).
4) The Secretary of Energy's Decision Plan monitored the status of an active potash lease until it was purchased by the DOE but remained silent on the active oil and gas lease issue even after an article in the Albuquerque Journal raised the issue (McCutcheon, 1990).
5) The DOE Implementation of the Resource Disincentive document, (U.S. DOE, 1991) was inconsistent on the number of active oil and gas leases within the WIPP Site Boundary and on the production status of the forgotten gas well.

The DOE's loss of institutional knowledge was confirmed in an explanation from the DOE to the EPA.

> The lease on the 80 acres in Section 17 expired on June 30, 1984, (Attachment 14). Thereafter, DOE believed that there were no hydrocarbon leases remaining within the WIPP site (Lytle, 1991).

5.2 Lapse in Institutional Control at DOE and DOI/BLM

There are two components of passive institutional control that have been inherently in place at the WIPP during that period of full operational readiness

to receive waste; 1) government ownership and regulations regarding land or resource use and 2) public records.[19]

In response to the questions raised by Silva and Channell (1992) on institutional control, the DOE maintained:

> None of the documents listed in EEG-50 as being "incorrect, silent, or inconsistent" are part of the institutional control process at the WIPP. Nor are any of the documents critical to the maintenance of the institutional controls at the WIPP. ***The controls that are crucial to protect the site from inadvertent exploration[20] are BLM leasing procedures and lease records and the internal procedures of the BLM which require the DOE's review and comment for any permit application to drill within one mile of the WIPP site.***[21]
>
> Adherence to policies governing resource extraction at the WIPP has been carefully maintained. Review of the BLM's interface with the DOE reveals numerous requests from the BLM for DOE comments regarding requests to drill in the area. (Arthur, 1992)

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[19]"Passive institutional control" means: (1) permanent markers placed at a disposal site, (2) public records and archives, (3) government ownership and regulations regarding land or resource use, and (4) other methods of preserving knowledge about the location, design, and contents of a disposal system. "Active institutional control" means: (1) controlling access to a disposal site by any means other than passive institutional controls, (2) performing maintenance operations or remedial actions at a site, (3) controlling or cleaning up releases from a site, or (4) monitoring parameters related to disposal system performance. (U.S. EPA, 1985, p. 38035)

[20]The term "inadvertent exploration" is used in the DOE response. The term does not make sense because exploration is deliberate. Intrusion is inadvertent.

[21]Emphasis added.

However, it appears that the BLM did not have effective internal operating procedures in place. Procedures should have been developed and implemented by BLM which would allow BLM to approve an application to drill only after receiving DOE's written comments in response to a written request from BLM.

On October 26, 1990, the DOE and the DOI/BLM signed a Memorandum of Understanding (U.S. DOE, U.S. DOI, 1990).[22] With respect to drilling for oil and gas, the MOU specifically required the BLM to notify the DOE of applications for permit to drill for oil and gas within one mile of the WIPP Site Boundary and that "drilling approval will be withheld until comments are received from the DOE" (U.S. DOE, U.S. DOI, 1990). On September 25, 1992, almost two years into the MOU, the BLM reassured the DOE:

> as per the MOU the BLM will notify the DOE of any proposed mineral development within one mile of the WIPP site boundary. The DOE will submit comments to the BLM relative to the allowance of the application and proposal, for BLMs consideration in making the final decision (Cone, 1992).

The MOU was revoked on October 30, 1992 with the passage of the 1992 WIPP Land Withdrawal Act (Section 3 (b)).[23]

How effective was the MOU for that two year period, a period in which the WIPP facility was in full readiness to receive waste? The following example is

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[22]The MOU was an agreement cited as the guiding document to support the of 43 CFR Public Lands Order 6826 (Administrative Land Withdrawal) of January 28, 1991.

[23]The October 26, 1990 MOU was extended by mutual agreement between BLM/DOI and DOE on November 12, 1993 until an MOU to support the 1992 WIPP Land Withdrawal Act could be finalized (L.L. Woodard, 1992).

fairly typical of the overall failure to implement institutional procedures intended to prevent violation of the WIPP Site Boundary.[24]

There was an application to drill a well with a surface location only 330 feet from the east boundary of the WIPP Site. The BLM approved the application to drill Well #4, Section 26, T22S, R31E, on October 15, 1991. On October 17, 1991, two days later, BLM (Manus, 1991) sent a letter to the DOE requesting a review of an "Application for Permit to Drill" within one mile of the WIPP Site Boundary. BLM received a reply from the DOE (Becker, 1991) on October 25, 1991. However, not only had the application already been approved by BLM ten days earlier, but drilling had already commenced with the well having been spudded the day before, October 24, 1991, according to the completion records filed by the oil company with the BLM. Thus, the DOE's review was never considered in the application permitting process, the DOE review was not even solicited until after the drilling had been approved, and the DOE review was not received by BLM until after drilling had started!

The institutional failure rate for the MOU between these two active and neighboring federal agencies was 88% (22/25). Table 4 identifies the twenty-five applications for permit to drill submitted by oil and gas producers to BLM. Table 5 summarizes the lapses in institutional control. In summary, the MOU failed in twenty-two out of twenty-five applications. The observation is of concern because these are "the controls that are crucial to protect the site from inadvertent exploration..." (Arthur, 1992).

[24]There is no indication that the WIPP Site Boundary has actually been violated despite the lapse in institutional procedure.

Table 4. Lapse in institutional control by BLM and DOE in the processing of applications for permit to drill (APD) oil and gas wells from October 26, 1990 to October 30, 1992.

Lease No	Sec,Tnp,Rng	Well	APD rec'd by BLM	DOE review requested by BLM	DOE written review rec'd by BLM	APD appr'd by BLM	Drilling Initiated	Drilling Complete	Lapse in Institutional control
NM 65417	11, 22S, 31E	#2	1-28-91	2-27-91	4-18-91	2-25-91[C]	3-19-91	4-2-91	BLM[C]
NM 65417	11, 22S, 31E	#3	3-14-91	4-15-91	4-22-91	4-23-91	5-6-91	5-26-91	Satisfactory
NM 65417	11, 22S, 31E	#4	3-14-91	4-10-91	No response	4-23-91	9-2-91	9-19-91	DOE[B],BLM[D]
NM 65417	11, 22S, 31E	#5	4-5-91	5-3-91	5-13-91	12-19-91	1-8-92	2-21-92	Satisfactory
NM 65417	11, 22S, 31E	#6	5-20-91	No request	N/A	2-21-92	3-9-92	3-24-92	BLM[A]
NM 65418	14, 22S, 31E	#3	3-14-91	4-10-91	No response	4-23-91	6-1-91	6-21-91	DOE[B],BLM[D]
NM 65418	14, 22S, 31E	#4	3-14-91	4-26-91	No response	Denied*	N/A	N/A	DOE[B]
NM 0479142	12, 22S, 30E	#11	1-23-91	3-4-91	4-18-91	2-26-91[C]	3-20-91	4-1-91	BLM[C]
NM 0479142	12, 22S, 30E	#12	1-26-91	2-19-91	4-18-91	2-20-91	9-14-91	9-26-91	BLM[D]
NM 0479142	12, 22S, 30E	#13	1-29-91	2-19-91	4-18-91	2-20-91	11-3-91	11-20-91	BLM[D]
NM 0479142	12, 22S, 30E	#14	1-29-91	2-19-91	4-18-91	2-19-91	11-22-91	12-10-91	BLM[D]
NM 0479142	12, 22S, 30E	#15	3-25-91	No request	N/A	8-3-92	8-9-93	9-4-93	BLM[A]
NM 62589	23, 22S, 31E	#5	2-11-91	3-13-91	4-18-91	3-13-91	3-19-91	3-31-91	BLM[D]
NM 62589	23, 22S, 31E	#6		6-21-91	7-1-91	Denied*	N/A	N/A	Satisfactory
NM 62590	26, 22S, 31E	#2	1-18-91	2-11-91	4-18-91	2-6-91[C]	2-21-91	4-4-91	BLM[C]
NM 62590	26, 22S, 31E	#3	6-18-91	7-10-91	No response	7-10-91	7-19-91	8-23-91	BLM[D]
NM 62590	26, 22S, 31E	#4	Illegible	10-17-91	10-25-91	10-15-91[C]	10-24-91	11-11-91	BLM[C]
NM 62590	26, 22S, 31E	#5	9-20-91	10-11-91	10-21-91	10-9-91[C]	12-3-91	12-19-91	BLM[C]
NM 62590	26, 22S, 31E	#6	1-7-92	2-13-92	No response	2-6-92[C]	3-29-92	4-10-92	BLM[C],DOE[D]
NM 62590	26, 22S, 31E	#7	1-7-92	2-13-92	No response	2-7-92[C]	4-1-92	4-11-92	BLM[C],DOE[D]
NM 62590	26, 22S, 31E	#8	2-5-92	No Request	N/A	7-2-92	Not yet	N/A	BLM[A]
NM 62590	26, 22S, 31E	#9	2-28-92	4-29-92	No response	7-2-92	Not yet	N/A	DOE[B],BLM[D]
NM 62590	26, 22S, 31E	#10	3-19-92	4-30-92	No response	7-2-92	Not yet	N/A	DOE[B],BLM[D]
NM 62590	26, 22S, 31E	#11	3-25-92	4-30-92	No response	7-2-92	Not yet	N/A	DOE[B],BLM[D]
NM 62590	26, 22S, 31E	#12	3-31-92	4-30-92	No response	7-2-92	Not yet	N/A	DOE[B],BLM[D]

A - BLM fails to request DOE review.

B - DOE fails to responde to BLM request.

C - BLM prematurely approves APD prior to request of DOE written review.

D - BLM prematurely approves APD prior to receipt of DOE written review.

* - Denied to first allow potash production.

Table 5. Lapses in institutional control by DOE and BLM for 25 applications during a two year period.

Satisfactory procedure	3
BLM failed to request DOE review.	3
DOE failed to respond to BLM request.	9
BLM approved permits to drill before requesting DOE review.	5
BLM approved permits to drill before receiving DOE review.	5

EEG notified DOE of this lapse in institutional control in 1993 (Neill, 1993a, p. 6; Neill, 1993b). DOE maintains that DOE and BLM have since improved their record for tracking applications for permit to drill (Hunter, 1994).

5.3 Inadvertent Removal of Active Institutional Control

In the written materials and presentations provided to the elicitation panels on future societies (August 13, 1990, Albuquerque) and on markers (November 4, 1991, Albuquerque), the Second Modification to the Consultation and Cooperation (C&C) Agreement was identified as active institutional control:

> In the Second Modification to the Consultation and Cooperation Agreement, the DOE agreed to prohibit subsurface mining, drilling, slant drilling under the withdrawn area, or resource exploration unrelated to the WIPP Project on the sixteen square miles to be withdrawn [and remain][25] under DOE control (Weart et al., 1991, p. III-2; Bertram-Howery, 1990; Gruebel, 1991).

[25]The words in brackets were included in Weart et al. (1991) but not in the overheads.

Weart et al. (1991) further commented:

> A complication to this conclusion of resource assessibility is that an agreement between the DOE and the State of New Mexico (U.S. DOE and State of New Mexico, 1981, as modified) prohibits directional (slant) drilling beneath the land-withdrawal area for as long as active institutional controls are maintained (Weart et al., 1991, p. VI-10).

It appears that the BLM still can not enforce the DOE agreement with the State of New Mexico. On the subject of the leases under the WIPP Site Boundary, the BLM position is clear:

> The existing oil and gas lease are valid and are in good standing. Therefore, the leaseholders can further develop these leases in compliance with applicable regulations (Woodard, 1993).

The BLM decides on drilling applications including wells that could be directionally drilled into the two active federal oil and gas leases under the WIPP Site.

> Section 4(b)(5)(B) of the 1992 WIPP Land Withdrawal Act states:
>
> Existing rights under Federal Oil and Gas Leases No. NMNM 02953 and No. NMNM 02953C shall not be affected unless the Administrator [of EPA] determines, after consultation with the Secretary [of Energy] and the Secretary of Interior, that the acquisition of such leases is required to comply with the final disposal regulations or with the Solid Waste Disposal Act (42 U.S.C. 6901 et seq.)

In March 1993, Bass Enterprises submitted applications to directionally drill eight additional wells beneath the WIPP Land Withdrawal Area for the production of crude oil from the 320 acre lease (NM 02953C) in the southern half of Section 31, T22S, R31E. The surface locations are shown in Figure 14 as open circles

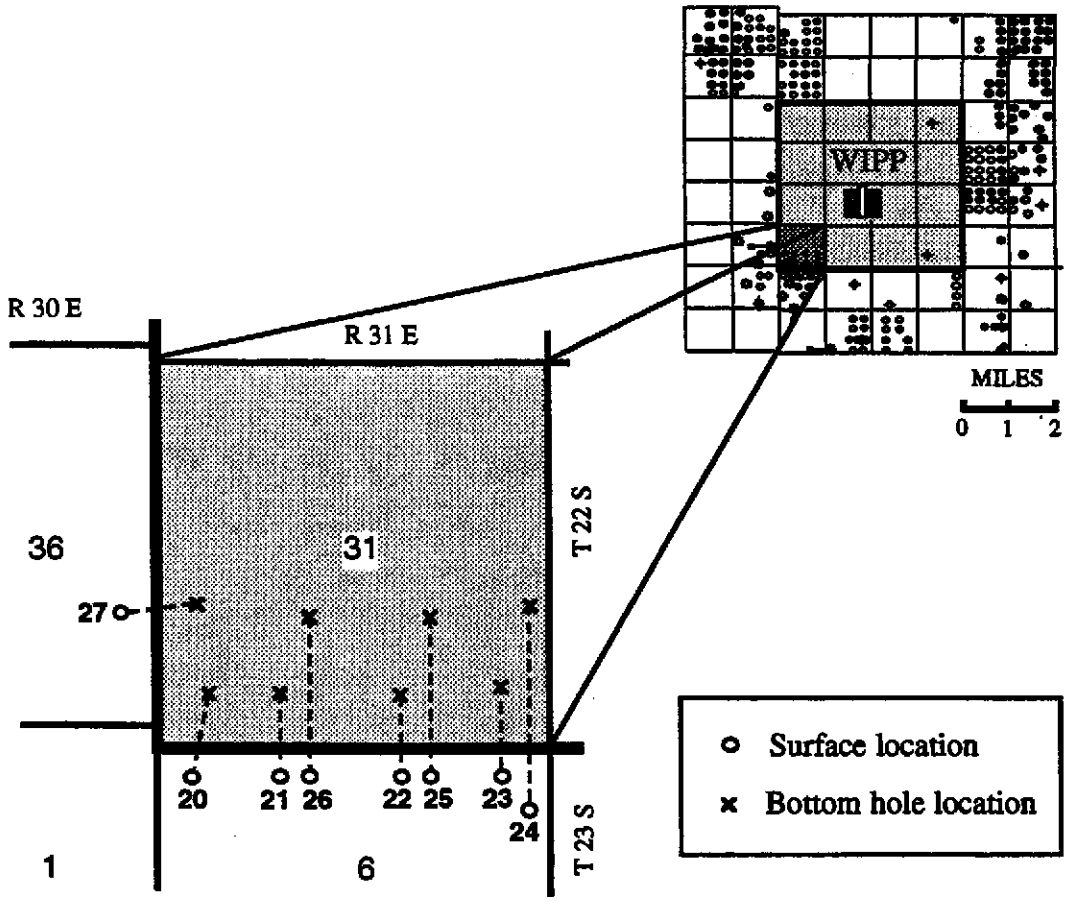

Figure 14. March 1993 applications to directionally drill eight oil wells to be completed within WIPP Site Boundary.

and the bottom hole locations are shown as x's. Drilling would initiate on the surface outside the WIPP Site Boundary, proceed downward at least 6000 feet, then deviate into the WIPP Site Boundary. On April 26, 1993, the BLM (Manus, 1993) sent the applications to the DOE for review stating that BLM would withhold approval on these APDs until comments were received from the DOE. Under 43 CFR 3162, the BLM has a 30 day period for the processing of APDs and following that period, BLM makes a decision to permit, deny, or postpone the applications. On May 27, 1993, the DOE WIPP Project Site Office (Hunt, 1993a) notified the BLM that the applications would require the review of the DOE Headquarters and the Administrator of the EPA. The DOE suggested that BLM apply subsection 3162.3-1(h)(3) of 43 CFR 3162 to allow DOE and EPA additional time to review the applications. On July 26, 1993, the DOE (Hunt, 1993b) requested an additional extension or deferral to allow completion of EPA's decision making process. On October 28, 1993, the EPA suggested that the DOE and the EPA could jointly ask the BLM to delay judgment on the applications to drill (Shapiro, 1993). As of April 1994, the status of these applications appears to remain unresolved.

The 1992 WIPP Land Withdrawal Act requires the Administrator of EPA to make a recommendation on the acquisition of the leases in Section 31. However, an EPA recommendation requires the completion of the performance assessment calculations, which will not be completed for several more years. EPA may not be able to make a recommendation on the drilling applications until then (Shapiro, 1993). According to the 1992 WIPP Land Withdrawal Act (Waste Isolation Pilot Plant Land Withdrawal Act, 1992), the recommendation must come from EPA, not DOE. If neither DOE nor EPA can object, the BLM can presumably approve the drilling applications.

The C&C Agreement (U.S. DOE and NM, 1981) prohibits slant drilling as long as active institutional controls are maintained (Weart et al., 1991). In general, the WIPP LWA (Section 21) does not affect the C&C Agreement. However, the WIPP LWA appears to supersede the DOE and State agreement on the prohibition of slant drilling. Section 4(b)5(A) and 4(b)5(B) of the WIPP LWA prohibits slant

drilling, except for the two leases described above. Thus, the active institutional control, cited by Weart et al. (1991) and presented to the elicitation panels, does not prohibit slant drilling into active oil and gas leases.

5.4 Lack of a Commitment to Active Institutional Control

In evaluating the suitability of the WIPP Site, the EEG recommended:

> The federal government shall exercise active institutional control at the site for this purpose for at least 100 years after repository decommissioning (Neill et al., 1983, p. iii).

The First Modification to the C&C Agreement stated:

> the consultation process concerning the length and extent of the post-closure institutional control, shall be negotiated and resolved by the parties in the future, and at least one year prior to the start of the decontamination and decommissioning of WIPP.

Apparently the DOE does not intend to negotiate and resolve the length and extent of institutional control until three decades after the completion of the performance assessment calculations and the disposal decision. Despite the lack of a formal commitment or even a plan, the DOE continues to take full credit for active institutional control in the performance assessment calculations. Furthermore, despite the lack of a plan and formal commitment, the DOE proposes to take substantial credit for passive institutional control in the performance assessment calculations.

5.5 DOE and Passive Institutional Control

During the review of institutional controls, other problems surfaced which raised questions about some components of passive institutional control, such as markers

and records, to effectively convey accurate information. In response to EEG-50, the DOE argued:

> ... there are over 30 wells within a mile of the WIPP Site Boundary. We know about every one of these wells and we know that none of these wells pose a problem for the repository (Arthur, 1992).

The DOE subsequent list of wells (Arthur, 1993a) contained several mistakes including six incorrect locations for wells within various sections, an incorrect section, an incorrect township, three wells not mentioned, a well that doesn't exist, two incorrect lease designations, and five minor misspellings of leases and leaseholders. Even though the well markers failed to convey an accurate message, the DOE apparently relied primarily on the field markers and did not consult records.

For example, the sign at the well on Barclay State No. 1 gave the wrong location. NMOCD and BLM records show the well to be located 660 feet from the east line and 1,980 feet from the south line. Yet the sign at the well head reads "660 feet from the south line and 1,980 feet from the west line." The DOE relied on the incorrect information on the marker.

The sign at James Ranch Unit #1 led the DOE to list the well in the wrong quadrant, in the wrong section, and in the wrong township. The sign at the well head reads, "James Ranch Unit Battery No. 1, NW/4, SW/4, Sec. 6, T23S, R31E, Eddy Co., NM-04473." The correct location, according to BLM records, is the SW/4, SE/4, of Sec 36, T22S, R30E. It appears that in preparing the list, the DOE failed to consult either the BLM records, the NMOCD records, or even a map.

Three abandoned wells were not mentioned. In letters of February 9, 1993, (Arthur, 1993a) and May 10, 1993, (Arthur, 1993b), the DOE stated that their list of wells was confined only to oil and/or gas wells that appear to be capable of production. The DOE list incorrectly identified a clearly labeled salt water

disposal well as an oil well (David Ross AIT Federal #1, NM65419, Section 35, T22S, R31E) although there is no oil production equipment on this well. Furthermore, the sign at the well clearly states "David Ross 'AIT' Fed. #1 - SWD." "SWD" is an acronym for salt water disposal. The BLM maps also show this as a salt water disposal well. BLM and the NMOCD records also document the proposal and approval of this well for salt water disposal in 1991, shortly after the well was completed. The absence of oil production equipment, the presence of a marker labeled "SWD," the "SWD" label on the BLM map, and BLM and NMOCD records clearly stating "salt water disposal well" failed to convey the message to the DOE that this is a salt water disposal well and not a producing oil and gas well.

One well on the DOE list did not exist. It was a crossover on a natural gas pipeline that was misidentified as a well.

In summary, some markers were incorrect and other markers failed to convey their message. Further, it appears that the DOE did not initially verify the information on the markers by consulting records maintained at the BLM Carlsbad Resource Area Office. These observations document the failure of markers and public records, key components of institutional control, to convey accurate information.

5.6 Panel Reservations about Institutional Control

Some of the "most valuable" (Hora et al., 1991, p. V-8) comments elicited from the expert panels appear to have been ignored by the WIPP performance assessment team. Several experts on the future societies panel were quite pessimistic about the possibility of maintaining active control, for any period of time, even 100 years (Hora et al., 1991). Nonetheless, the performance assessment calculations continue to assume full credit for active institutional control for 100 years (Hora, 1992, p. A-87).

The EPA Standards state:

> To comply with § 191.14(a), the implementing agency will assume that none of the active institutional controls prevent or reduce radionuclide releases for more than 100 years after disposal (U.S. EPA, 1985, p. 38088, U.S. EPA, 1993).

This Guidance does not prevent the repository operator from automatically assuming that active institutional control will deter all inadvertent human intrusion for 100 years. The 1992 performance assessment (Hora, 1992, p. A-87) takes credit for 100 percent active institutional control for 100 years. Yet members from each of the four futures teams expressed reservations about the ability of the project to fully maintain active control for even a very short period of time. Participants in the elicitation exercise were asked to address seven specific issues including the issue of active controls.

> Assuming that the radioactive waste exists and is harmful, what is the likelihood that active controls (continued management of the site) have been maintained to prevent inadvertent intrusions? (Hora et al., 1991, p. G-4).

5.6.1 Washington A Team

Three of the four members of the Washington A Team were pessimistic about the possibility of maintaining active controls for any period of time, even 100 years. The fourth member felt long term active control was possible, but it might be bought at substantial human cost, possibly the loss of human rights (Hora et al., 1991, p. IV-53). The first three members predicted a steep decline in the probability of active controls as a function of time beginning immediately after closure (Hora et al., 1991, Figure IV-10). At 50 years after closure, their predicted probability of active control for all four postulated future states range from a low of 0.1 to a high of only 0.5. The fourth member also predicted an immediate decline, although at a slower rate, in the probability of active control

after closure (Hora et al., 1991, Figure IV-11). Their predictions on the immediate decline in institutional control are shown in Figures 15a and 15b. In summary, each and every member of the Washington A Team predicted less than total active institutional control for the first 100 years beginning immediately after closure.

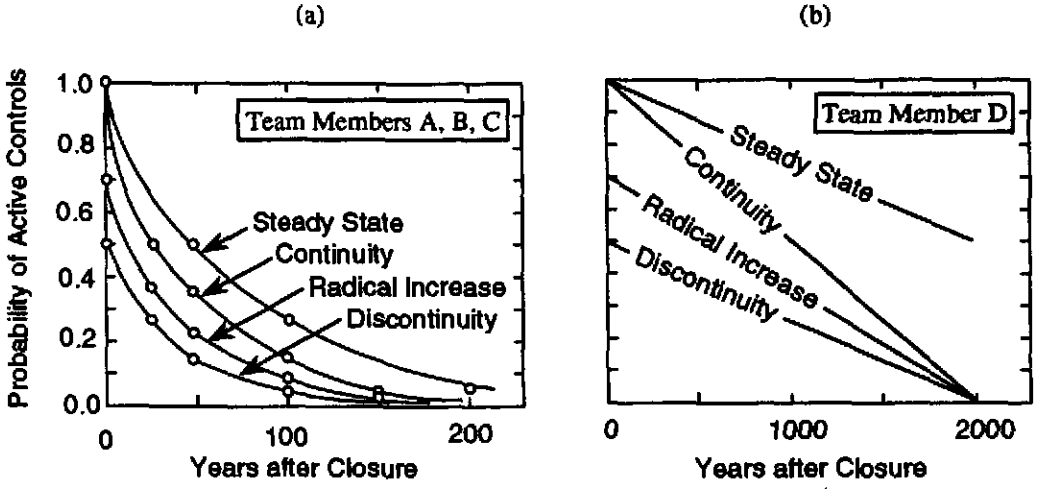

Figure 15. Washington A Team predicted probability of existence of active controls as a function of time and futures (Hora et al., 1991, pp. IV-45 and IV-46).

5.6.2 Washington B Team

The Washington B Team assigned probabilities that the government would continue to maintain prudent and effective control over the WIPP. The Washington B Team defined the near future as 0-200 years after closure (Glickman et al., pp. F-4, F-27; Hora et al., p. IV-55). This team questioned the effectiveness of active control for the near future and assigned a probability 0.8, and *not* 1.0, for prudent and effective control for the near future (Hora, 1992, p. IV-56).

5.6.3 Boston Team

Hora stated that the Boston Team allowed credit for 100 years of administrative control (Hora, 1992, p. A-87). However, scrutiny of the Boston Team report (Gordon et al., 1991) and the report by Hora et al. (1991) suggests otherwise. It appears that the input was adjusted to fit the needs of the performance assessment calculations as explained below. This adjustment, and not the Boston Team, allowed credit for 100 years administrative control.

The Boston Team did not offer direct estimates of the duration of active institutional control. Rather, the Boston Team predicted socio-technical factors at 100 years, 1000 years, and 10,000 years (Gordon et al., 1991, p. C-5). Points in time were incompatible with the needs of performance assessment. As noted by Hora et al. (1991, p. IV-3) "...the performance assessment calculations require rates of intrusion during the entire continuum from 100 to 10,000 years after closure." Thus, the use of midpoints on the logarithmic scale was introduced to define time periods. For example, the 100 year point was converted to a period of 0 to 300 years after closure (Hora et al., pp. IV-3 to IV-4). The first 100 years were then dropped and the results of the elicitation for ten tables were presented for time periods from 100-300 years (Hora et al., 1991, Tables IV-2 through IV-11) and not from 0-300 years. However, Table IV-14 (Hora et al., 1991) presents the calculated drilling rate probability for 0-300 years after closure. This table suggests that the Boston Team did not allow for 100 years administrative control.

Moreover, one member of the Boston Team disputed the existence of administrative control for even a short period of time. In an appendix to the Boston Team report (Gordon et al., 1991), Baram addressed the question "Can memory of WIPP be retained?" Rather than argue in the abstract, he cited examples of the factual loss of history or active control for periods shorter than 50 years. The examples included:

1) the loss of drilling history at Lyons, Kansas that was fortuitously recaptured by opponents to a proposed repository at that location,

2) the loss of information for 45 years on the dumping of barrels of radioactive waste from the Manhattan Project in the late 1940's by the Department of Defense at the Massachusetts Bay site,

3) the unavailability of information until 1986 on the release of radiation and exposure of thousands of people near Hanford beginning in 1944,

4) the use of uranium mill tailings in Colorado to construct homes and other concrete structures despite a prohibition against such activity,

5) the 1982 sewer line construction and inadvertent intrusion into a poison gas container abandoned by the Army when it closed an airfield in 1945.

These examples document Baram's reservations on full administrative control.[26]

5.6.4 *Southwest Team*

The Southwest Team assumed that active control would be maintained at the WIPP site during the operational phase and for 100 years after closure (Benford et al., 1991, p. D-10). However, the elicitation exercise posed three questions including the question - When will there be a loss of *active controls and markers*?

"The [Southwest] team was fairly pessimistic with respect to society's ability to maintain active controls and effective markers" (Hora et al., 1991, p. IV-31). One member speculated that controls and markers may last as long as 1,000 years, two members felt that loss would likely occur within hundreds of years, and one member thought loss of markers and active control would occur in less

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[26]The examples were offered by Baram and, as such, represent his interpretation of events indicative of the loss of administrative control

than 100 years. While there was no consensus, the last observation by a member of the Southwest Team is at odds with the assumption of 100 years administrative control. Further, the question did not separate markers from active controls. Markers are considered a component of passive institutional control (U.S. EPA, 1985, p. 38085). Yet the team was asked a question which inherently included the benefit of this more durable component in their assessment of active controls.

5.7 Summary Comments on Credit for Institutional Control

In summary, two oil and gas leases were forgotten by the DOE in spite of the lease, drilling, and production records filed with the federal government, a condemnation suit filed in civil court by the federal government, agreements between the State of New Mexico and the federal government, technical reports to the federal government on area oil and gas resources, and the existence of a producible gas well visible from the south access highway into the WIPP facility. The DOE and the BLM failed to implement procedures crucial to protecting the site in 88% of the twenty-five applications filed the first two years a Memorandum of Understanding was in effect. The DOE review of the interface with the BLM failed to detect the problem. Members from all four teams in the elicitation exercise on future societies expressed reservations about the project's ability to maintain active control for even a short period of time. There is no plan nor commitment by DOE to active institutional control. The DOE intends to negotiate the extent of active institutional control with the State of New Mexico just prior to decommissioning the facility or approximately 30 years after having taken full credit for active institutional control in the performance assessment calculations. Despite these observations, the project continues to assume full credit for active institutional control for 100 years.

The current wording in the EPA Standards permits the assumption that active institutional control can completely deter inadvertent human intrusion for up to 100 years. The present assumptions about the effectiveness of active institutional control need to be reconsidered because of this experience. The EPA should reexamine whether any credit for 100 years of active institutional control is

reasonable given the actual experience of inaccurate record keeping. At the very least, the EPA should require the implementing agency to publish specific plans on how the agency intends to maintain active institutional control. Even in the absence of such a requirement, the DOE should publish detailed plans now that specify how the Department intends to maintain control of activities in the area of the repository for 100 years after decontamination and decommissioning and how that control will completely or partially deter human intrusion.

Public records and markers, components of institutional control failed to communicate the existence and location of oil and gas wells. Despite extensive public records, the DOE also lost knowledge of a gas well and two active oil and gas leases within the WIPP Site Boundary. Furthermore, the project failed to implement the procedures described by the DOE as crucial to protecting the site from inadvertent human intrusion. The failure of two neighboring federal agencies to communicate and the loss of knowledge in such a short period of time without any changes in language, government, technology, or culture is cause for concern. EPA needs to assess the effectiveness of records to convey information and determine how much credit, if any, can be reasonably allowed.

Members from of each of the four futures teams expressed reservations about the ability of the project to maintain full active control for even a very short period of time. Nonetheless, the 1992 performance assessment calculations continue to assume full credit for active institutional control for 100 years (Hora, 1992, p. A-87). However, the expert panel reservations on active control, their estimates of the probability of intrusion during active control, and the drilling rates inferred from expert elicitation for the first 100 years were not considered in the 1992 performance assessment.

6. PETROLEUM PRODUCTION PRACTICES

The practices of the oil and gas industry merit careful review because the WIPP is located in a petroleum rich area. The area will be subjected to the exploration, production, and abandonment practices of the petroleum industry. The WIPP project must consider the impact of petroleum exploration and production on the repository. This report identifies potential problems to be addressed.

6.1 Limitations of Blowout Preventers

The 1992 performance assessment publication suggests that if drillers encounter a gas-pressurized formation, blowout preventers will be quickly engaged to curtail gas migration into the borehole (SNL, 1992, vol. 2, p. 7-28). Recent field experience identifies some limitations. While drilling an oil well on March 21, 1991, in a lease immediately adjacent to the WIPP Site Boundary, pressurized gas in the Salado Formation propelled the entire column of brine out of the well bore, through the derrick mast, over the top of the derrick, into the air, and onto the drill pad and highway before blow out preventer equipment could control the pressure. The well was Federal 23 No. 5 on the lease NM-62589, which is immediately adjacent to the WIPP Site Boundary. The report notes that only the BLM was notified.

6.2 Loss of Circulation During Drilling for Oil and Gas

On April 2, 1991, drilling was initiated for a gas well on Lincoln Federal No. 1 in Section 26, T21S, R32E, NMPM, in Lea County, New Mexico about 8 miles (13 km) east-northeast of the WIPP Site Boundary (Collins & Ware, Inc., 1991 pp. 1-4). On the third day of drilling and upon reaching a depth of 1292 feet, all of the circulating fluid was lost to the formation. The driller began hauling in water to continue drilling. Drilling with water continued for ten additional hours on the fourth day. A survey confirmed 100% circulation loss in the two foot interval from 1290' to 1292'. Attempts to seal the formation with cement over the next 5 days largely failed as evidenced by the continued loss of circulating

water to the formation. Nonetheless, on the tenth day, drilling continued until an air pocket and brine flow were encountered at 2000 feet. Brine from this formation began filling the surface pit, which is used to contain the circulating fluid. Drilling continued for 1 1/2 hours with brine flowing into the pit. The driller then hauled eight loads of brine to disposal and continued drilling for 9 hours with partial returns of brine to the surface. Apparently, while the brine flowed to the surface, much of the brine continued to flow into the two foot interval between 1290' and 1292'. The drilling report documented an additional 7 hours of drilling with no returns. On the eleventh day, after 3 1/2 hours of drilling with no returns, air drilling was initiated. As drilling continued, the pit filled with formation brine. Once there was sufficient brine in the pit, the brine was used as the circulating fluid for drilling until the pit was nearly depleted. Then air drilling resumed until the pit again filled with brine.

The drilling report raises several questions. Has the project considered the documented scenario of continuous flow during drilling from a lower zone such as the Salado into an overlying formation, possibly an aquifer? Based on isopach maps of overburden (SNL, 1992, vol. 2, p. 2-20) and more recent drilling records, it appears that the thief zone was the Culebra Aquifer. How much brine flowed from the lower formation to the overlying formation during drilling? In terms of current drilling practices, was the brine checked for radioactivity prior to transport and disposal? Was the brine sent to a salt water disposal lake or was the brine sent to a saltwater disposal well?

6.3 Potential Problems Due to Secondary Recovery of Crude Oil

Potential problems as a result of secondary and tertiary oil recovery have not been addressed by the WIPP project. Secondary recovery was not addressed in the 1982 natural resources study by Brausch et al. (1982) because that study assumed that there were minimal amounts of crude oil reserves likely to exist within the WIPP Site. However, crude oil reserves are currently being produced from former control zone IV. As shown in Figure 12, many oil wells have been drilled on forty acres spacings and primary recovery is underway. Secondary

recovery methods such as waterflooding are commonly employed in portions of the Delaware Basin that contain practical quantities of crude oil (Brausch et al., 1982, p. 30). The potential impact of waterflooding, as practiced in southeastern New Mexico, remains to be addressed by the WIPP project.

In a memorandum discussing anomalous water level rises in the Culebra Formation near the WIPP Site, LaVenue (1991) discussed a casing failure problem in the Vacuum Field waterflood located in Townships 17 to 18 South and Ranges 34 to 35 East, approximately 15 miles northeast of the WIPP Site. LaVenue quotes from a memorandum prepared by Bailey (1990), a petroleum engineer with the New Mexico State Land Office, as follows:

> Although the Vacuum Field is located some distance northeast of the monitor wells in question, I believe the hydrogeologic setting is analogous to the well field you are currently investigating. The Vacuum Field is also overlain with Dewey Lake Red Beds and the Rustler and Salado Formations. Numerous water flows in the Salado were creating oil field casing failures and drilling and cementing problems and many people were concerned that the situation could cause contamination of the Ogallala aquifer... Spot checking of old oil well drilling records indicate water flow drilling problems and numerous casing leak repairs in the Dewey Lake Red Beds, Rustler and Salado formation for many years. These water flows are still occurring in the Vacuum Field although at a lesser rate than during the 1970's and 1980's.
>
> These water flows are characterized as strong, intermittent and spotty. Not all wells have encountered flows, but when they did, the flows were estimated at 1,000 - 2,000 barrels (42,000 - 84,000 gallons) per day. The flows often would last 4-5 days before stopping by themselves. The Oil and Gas Conservation District was greatly concerned about the effects of these flows and the potential for dissolution, vertical fracturing and collapse of the upper beds, and the contamination of the Ogallala aquifer (Bailey, 1990).

LaVenue then quotes from a letter prepared by Joe D. Ramey of the Oil and Gas Conservation District to John F. O'Leary, dated May 5, 1976.

> It has recently come to our attention that there are numerous salt water flows in and around waterfloods in Lea County... Basically the problem is that water injected at around 3600' is escaping from the injection interval, migrating upward to the base of the salt section and then moving horizontally through this section. Waterflows of 5000-6000 barrels per day and recorded surface pressures of 1600 pounds on wells outside waterflood areas are not uncommon. This had resulted in collapsed casing in several wells but the critical aspect in this is the threat of widespread contamination of fresh water....

LaVenue then again quotes Bailey:

> After years of study, thousands of pressure tests, installation of pressure monitoring wells, and chemical analyses, the Water Flow Committee *[a committee formed of oil and gas company representatives to investigate the salt water flow problem]*[27], decided that no one knew the origin of the early flows, or specifically where the water was stored. However, individual flows were correlated throughout the field to distinct horizons within the Salado Formation where fluid flow is facilitated along bedding planes at clastic-evaporite interfaces. Chemical dissolution of bounding salts and mechanical fracturing enable large volumes of fluids to be transported over large areas.
>
> Chemical and isotopic analyses of the waterflow brines indicated that the waters were not naturally occurring connate waters produced by the evaporation of Permian seawater. (18)Oxygen/(16)Oxygen ratios and (18)Oxygen/Magnesium ratios indicated injected produced water as a strong candidate as a source of at least some of the water flows in the

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[27]Comment inserted by LaVenue (1991).

Salado Formation. Because the Vacuum waterflood project injection zone is at an approximate depth of 4320'-4720', casing leaks through the salt section are the most logical pathways for introduction of fluids into the Salado Formation *[whereas collapsed casing occurred as a result of the flow of these introduced fluids along bedding planes at clastic-evaporite interfaces.]*[28]

LaVenue notes that the Vacuum Field is 10 to 15 miles northeast of the WIPP Site and the Vacuum Field is in an area in which the lithology of the Salado may be described as a back-reef facies in which clastics were also deposited. LaVenue maintains that there is an absence of clastics in the Salado near the WIPP-Site region, hence there are no clastics to facilitate fluid flow such as has occurred in the Vacuum Field along the clastic-evaporite bedding planes. From this position, LaVenue suggests that the probability of collapsed casing in the WIPP Site area would be lower. However, the issue is not solely dependent on the presences of clastic rocks. There is a much broader question. Can a future waterflood adjacent to or near the WIPP inadvertently force water into the Salado Formation or an overlying aquifer?

On November 22, 1993, Mr. Doyle Hartman sent Sandia National Laboratories a copy of a Complaint (CIV93 1349M)[29] which he had filed in the Federal Court for the District of New Mexico on November 17, 1993. Mr. Hartman stated that he furnished a copy of the complaint to familiarize Sandia National Laboratories "with the Lea County situation so that the proper safety measures will always be taken to preclude the occurrence of such a potentially disastrous event in the close vicinity of the WIPP site in Eddy County, New Mexico." Mr. Hartman claims that a neighboring waterflood operation allowed substantial quantities of injection water:

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[28]Comment inserted by LaVenue (1991).

[29]The Environmental Evaluation Group understands that this case may still be in litigation and the Environmental Evaluation Group has no direct nor implied opinion on this case.

to escape away from the approved injection zone into other formations causing the parting and dissolution of the Salado Formation and the consequent migration of huge quantities of high-pressure salt-saturated waste through the Salado Formation so as to invade the Salado Formation directly underlying the Bates Lease (Hartman, 1991, p. 13).

At about midnight on January 15, 1991, while drilling with the highly plastic and naturally impermeable Salado Formation, Hartman encountered an extraordinarily high-pressured salt-saturated water flow. At approximately 1:45 a.m. on January 16, 1991, despite the Bates No. 2 being equipped with a blowout prevention system, as a direct result of the abnormally high-pressure high-volume water flow, the Bates No. 2 experienced a "salt water" blowout which blowout continued to flow uncontrolled from the well until finally being brought under control five days later. Neither the surface casing nor any other equipment at the drilling site were designed to control the totally unnatural high pressure high-volume water flow. Within seven hours after the initial salt water blowout, the Bates No. 2 was "out of control" and threatening danger of bodily harm to workmen, destruction of the drilling equipment, and ruination of the surrounding surface environment and subsurface shallow fresh water formations (Hartman, 1993, p. 11).

Although this lease lies approximately 45 miles (72 km) southeast of the WIPP, it merits investigation by the WIPP project because it is an incident that occurred in southeastern New Mexico while drilling through the Salado Formation and there is a claim ***alleging*** that a waterflood project more than a mile away injected water into the Salado Formation and caused the problem.

6.4 Hydrology of the Culebra Altered by Leaking Wells

In 1991, LaVenue examined the water levels of the Culebra Aquifer which had been rising since April 1988 at several observation wells. While the actual source

of the recharge into the Culebra remained largely unknown, the evidence collected by LaVenue suggested that leakage from an oil and gas well or, more likely, from a nearby salt-water disposal well was responsible (LaVenue, 1991).

Casing leaks and/or bad cement jobs have been documented for wells in southeastern New Mexico even in wells that are only 9 years old (LaVenue, 1991, p. 3). The highly saline environment promotes rapid corrosion of the well casings and promotes degradation of the grout that is intended to hold the casing in place. Leakage from one of these wells into the Culebra would change the hydrology of that aquifer. Hence, it could be difficult to determine if such leakage would promote or deter radionuclide migration. The observation introduces additional uncertainty into the performance assessment calculations because the future location of oil, gas, or salt water disposal wells with future leaks would be difficult to predict.

6.5 Inadequate Borehole Sealing and Abandonment Practices

The potential impact of existing boreholes has long been recognized (ORNL, 1973).

> Another factor of particular importance related to mineral resources is the number of existing boreholes in the area. These holes are important because they represent a potential hydraulic connection between the salt formations and both higher and lower aquifer systems. In a very few known cases, circulation of this type has become established and resulted in very rapid local dissolution of the salt. It is obvious that this type of dissolutioning at any proposed site or within the buffer zone could render it unacceptable. Consequently, all existing boreholes have to be located, evaluated as to their potential to form a hydraulic connection between the salt formation and both higher and lower aquifer systems, re-entered, cleaned out, and replugged in as permanent a manner as possible in order to protect the salt against the development of circulations of this type in

the future. The advantage of selection a site with a minimum number of existing boreholes is apparent (ORNL, 1973).

In 1980, the DOE intended to prescribe sealing of oil and gas boreholes immediately adjacent to the present WIPP Site Boundary in what was then designated as control zone IV. DOE stated that new wells for oil and gas production would be drilled in conformance with DOE standards to facilitate eventual plugging (U.S. DOE, 1980). However, in 1983, the DOE squared off control zone III and relinquished the remainder of control zone IV. Much of the former control zone IV area has since been leased and developed for the production of crude oil and natural gas.

Concerns about improperly abandoned oil and gas wells are justified. Inadequate practices on BLM properties are documented (U.S. DOI, 1989, U.S. DOI, 1990, Baier, 1990). A 1989 evaluation (U.S. DOI, 1989) by the Inspector General for the U.S. Department of Interior identifies considerable problems on U.S. Bureau of Land Management properties. Although the 1989 report stated that the Code of Federal Regulations requires all wells to be promptly plugged and abandoned, "the Bureau of Land Management's (BLM) existing guidelines on well completions, workovers and abandonments have never been formalized and published." (U.S. DOI, 1991, p. 20568.) Enforcement does not yet carry the weight of federal regulation. As to state regulation on federal land, the New Mexico Oil Conservation Division relies on the BLM to enforce BLM guidelines on U.S. Government Land within New Mexico and on the operators to file with the NMOCD, forms approved by the U.S. BLM for wells on U.S. Government Land (NMOCD, 1993, Rule 4 and Rule 1128).

With respect to inadequately abandoned wells on BLM properties, the 1989 BLM Inspector General's report states:

> Violations of existing regulations have resulted in environmental damage, lost or unpaid royalties, and a potentially substantial Government liability for plugging abandoned wells and cleaning up well sites. We determined

> that the potential cost for plugging and cleaning up wells that are no longer producing in the Tulsa, Moab, Jackson, Bakersfield, San Juan, Carlsbad, Farmington, and Great Falls areas could be in excess of $131 million, for which the Government may be partially responsible, primarily in those instances where the operator is bankrupt or the operator's bond is insufficient to cover the cost of plugging....(U.S. DOI, 1989, p. 4)

> At Carlsbad [Resource Area], we reviewed the statuses of 2 shut-in and 11 temporarily abandoned wells on a 15-well lease. These wells had been classified as shut-in or temporarily abandoned since the late 1960's without approval. There was no evidence that these wells had been properly tested to ensure that they were capable of producing oil and gas and properly classified. The operator of this lease stated that he did not perform well integrity tests because it would cost about $2,000 per well. Additionally, he stated that he did not permanently plug wells because that would cost about $10,000 per well. (U.S. DOI, 1989, pp. 6-7)

However, Baier (1990) suggested that the Federal Oil and Gas Reform Act does provide at least some incentive for a medium or large company to plug their abandoned wells. If a company refuses to plug a well after ordered, that company can be refused additional federal leases (Baier, 1990). Baier also states that well abandonments on federal land require cement plugs to protect mineral resources, such as potash, and these abandonments are often witnessed.

The State of New Mexico Oil Conservation Division issues and enforces rules and regulations for state lands and private lands. The general NMOCD rules and regulations (NMOCD, 1993) recommends consulting NMOCD Order No. R-111-P, *The Rules and Regulations Governing the Exploration and Development of Oil and Gas in Certain Areas Herein Defined, Which Are Known to Contain Potash Reserves* (1988). In addition to the general rules, the presence of potash imposes two additional rules for plugging and abandonment of wells. First, Order No. R-111-P states that a well must be filled with a solid cement plug through the salt

section and any water-bearing horizon and prevent liquids or gases from entering the hole above or below the salt section. Second, within specified limits, the fluid used to mix the cement shall be saturated with salts common to the salt section penetrated. In addition to the actual practices on BLM property, the WIPP project needs to assess the actual experience and practices of the oil and gas industry on state property because there are also state owned sections immediately adjacent to the WIPP Site Boundary.

6.6 Summary: Exploration, Production and Abandonment Practices

The WIPP facility is surrounded by natural gas and crude oil reserves. Assessment of the repository performance must consider the actual exploration, production, and abandonment practices of the petroleum industry.

The performance assessment effort has assumed that drilling technology in the distant future, thousands of years from now, will employ the best features of the present drilling technology. For example, it has been assumed that blowout preventers will be quickly engaged if a pressurized gas pocket in the Salado is encountered. Actual experience indicates some limitations. In a recently drilled well immediately adjacent to the WIPP Site, a pressurized gas was encountered in the Salado Formation and the entire column of drilling fluid was propelled out of the well bore before the blowout preventers could control the pressure.

The performance assessment has not taken into account potential problems due to secondary and tertiary recovery. Now that crude oil reserves are known to exist in the immediate vicinity of the WIPP and primary production is underway, secondary recovery by waterflooding or tertiary recovery should be anticipated. Problems with waterflooding in southeastern New Mexico strongly suggest that the issue needs to be revisited. Of particular concern is the potential migration of water through the Salado Formation.

Leakage of oil, gas, and salt-water injection wells appears to have a potential impact on the regional hydrology. In addition to faulty cement jobs, leakage can

result from rapid corrosion of well casings in the highly corrosive saline environment found throughout southeastern New Mexico.

The problems with inadequate borehole sealing and abandonment practices on BLM properties are documented. The potential impact of these vertical pathways on the regional hydrology and on the performance of the repository remains open for investigation and resolution.

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8. LIST OF ACRONYMS

APD	Applications for permit to drill
BBL	Barrels
BLM	Bureau of Land Management
C&C	Consultation and Cooperation
CFR	Code of Federal Regulations
CH-TRU	Contact-Handled TRU (waste)
DOE	U.S. Department of Energy
EEG	Environmental Evaluation Group
EPA	U.S. Environmental Protection Agency
ERDA	Energy Research and Development Administration
FEIS	Final Environmental Impact Statement
FSAR	Final Safety Analysis Report
GCR	Geological Characterization Report
MCF	Thousand standard cubic feet
LWA	Land Withdrawal Act
MOU	Memorandum of Understanding
NMBM&MR	New Mexico Bureau of Mines and Mineral Resources
NMEMD	New Mexico Energy and Minerals Department
NMOCD	New Mexico Oil Conservation Division
NMPM	New Mexico Principal Meridian
ORNL	Oak Ridge National Laboratory
RH-TRU	Remote-Handled TRU (waste)
SNL	Sandia National Laboratories
TRU	Transuranic
U.S.G.S	U.S. Geological Survey
WIPP	Waste Isolation Pilot Plant

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