EEG-62

FLUID INJECTION FOR SALT WATER DISPOSAL AND ENHANCED OIL RECOVERY AS A POTENTIAL PROBLEM FOR THE WIPP: PROCEEDINGS OF A JUNE 1995 WORKSHOP AND ANALYSIS

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Environmental Evaluation Group
New Mexico

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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 repository is sited in the New Mexico portion of the Delaware Basin, at a depth of 655 meters, in the salt beds of the Salado Formation. The WIPP is surrounded by reserves and production of potash, crude oil and natural gas.

In selecting a repository site, concerns about extensive oil field development eliminated the Mescalero Plains site in Chaves County (U.S. DOE 1980, 2-10) and concerns about future waterflooding in nearby oil fields helped eliminate the Alternate II site in Lea County (Griswold 1977, 13). Ultimately, the Los Medaños site in Eddy County was selected, relying in part on the conclusion that there were no oil reserves at the site (U.S. DOE 1980, 2-15).

For oil field operations, the problem of water migrating from the injection zone, through other formations such as the Salado, and onto adjacent property has long been recognized (Ramey 1976). In 1980, the DOE intended to prohibit secondary recovery by waterflooding in a one mile buffer surrounding the WIPP Site (U.S. DOE 1980, 8-4). However, the DOE relinquished the right to restrict waterflooding (McGough 1983) based on a natural resources report (Brausch et al. 1982, 30) which maintained that there was a minimal amount of crude oil likely to exist at the WIPP site, hence waterflooding adjacent to the WIPP would be unlikely.

In the early 1990s, the Delaware Basin experienced a drilling boom that included oil field discoveries surrounding and underlying the WIPP Site (Broadhead et al. 1995). Salt water disposal wells are now operating throughout the area (Silva 1994; Broadhead et al. 1995) and waterflooding is just beginning with new oil field pressure maintenance programs underway (Broadhead et al. 1995).

Beginning in 1988, sudden water level rises in the Culebra aquifer to the south of the WIPP site raised questions about the water injection activities of the oil and gas industry (Bailey 1990; LaVenue 1991). LaVenue (1991) cautioned the WIPP Performance Assessment (PA) team about the yet to be determined impact of these activities. However, the WIPP PA team did not include the impact of fluid injection in the calculations citing either "low consequence" arguments for human activities adjacent to the WIPP (SNL 1991, SNL 1992) or "consequences greater than that of exploratory drilling" in the case of human intrusion (SNL 1992). In 1993, the WIPP project was again cautioned about injected oil field water fracturing the Salado Formation and migrating into adjacent properties. An oil and gas producer in southeast New Mexico had suffered a major salt water blowout as a result of a waterflood operation two miles away (Hartman 1993).

The potential impact of brine injection on the long-term performance of the WIPP prompted the Environmental Evaluation Group (EEG) to organize a June 13, 1995, workshop on the issue. This report publishes the workshop presentations (Chapter 2) and presents the author's analysis of the workshop issues (Chapter 3) based on information from the scientific literature, public records, the draft compliance application submitted by the DOE to the U.S. Environmental Protection Agency (EPA), and the WIPP specific compliance Criteria promulgated by the EPA. The workshop included presentations describing the extent of oil and gas resources, the anomalous water level rises in the Culebra Aquifer, the documented effects of water flooding on the Salado Formation, the geology of waterflooded areas in southeast New Mexico, the current petroleum production practices, the treatment of water injection by the performance assessment effort, and the need for a water flooding scenario in the WIPP PA calculations. As was intended, a number of issues were deliberated. On many issues there was no consensus. Nonetheless, the workshop was an excellent example of cooperation and open exchange of information by various federal and state agencies, private industry, the university sector, and other interested parties.

In addition to exploring the potential impact of waterflooding and salt water disposal on the WIPP, Chapter 3 identifies a number of unresolved issues. Some unresolved topics are currently in litigation between oil and gas companies and the federal government for operations adjacent to the WIPP. The issues identified in Chapter 3 include questions about a) the productive life of an oil field in the Delaware Basin, b) the extent of oil and gas reserves in unexplored areas, c) the potential for waterflooding and other secondary recovery methods, d) the volumes of water to be injected, e) the availability of water for waterflooding, f) delays in oil and gas drilling due to the presence of potash g) the true extent of potash reserves, h) evidence of communication between formations above and below the WIPP through vertical pathways possibly created by the improper abandonment of wells, poorly cemented and cased wells, degraded well casings and cement in saline environments, and i) violation of existing regulations.

This report also raises questions about how much credit for protection from out-of-zone injection the WIPP project can justify, based on state regulations unique to the Known Potash Lease Area. The state regulations were never intended to address the needs of WIPP. Rather, the state regulations were promulgated to address the concerns of the potash and oil and gas industries (LeMay et al. 1988). In light of the information presented in this report, it would seem prudent for the WIPP project to analyze the historical effectiveness of the New Mexico regulations specifically intended to address fluid injection, Rule 701, 702, and 703.

The potash companies carefully monitor activities with a potential impact on the Salado Formation. For instance, the New Mexico Oil Conservation Division held a hearing on November 16, 1995, for a proposed oil field pressure maintenance well to be located one mile from the outer boundary of the WIPP and eight miles from IMC's existing potash mine workings. At the hearing IMC expressed concern that injected water could escape or otherwise migrate from the proposed injection interval into potash bearing formations. The DOE was notified of the hearing but did not attend (LeMay 1995b). The injection well was approved to operate at a pressure that exceeds the lithostatic pressure at the WIPP horizon.

The oil and gas industry is also concerned about the operation of injection wells in close proximity to its hydrocarbon reserves. When Yates Petroleum proposed converting an oil production well to salt water injection, another oil company objected. Mitchell Energy was concerned about excessive injection pressures and the loss of reserves as a result of injection into potential oil producing horizons (Stephenson 1991). An agreement was reached between the two oil companies (Kellahin 1991). The salt water disposal well was approved by the New Mexico Oil Conservation Division (LeMay 1991). The DOE appeared unaware that there was a salt water injection well operating within one mile of the WIPP Site Boundary and continued to list the well as an oil producing well (Arthur 1993a; Arthur 1993b; Silva 1994, 55-56; Kehrman 1995, 254, lines 18-20).

The DOE Draft Compliance Certification Application (DCCA), submitted to EPA in July 1995, did not include fluid injection in the performance assessment calculations. Citing Cranwell et al. (1990), fluid injection within the WIPP site was screened out on the basis of "regulatory guidance" (U.S. DOE 1995, 6-38), but this criterion is not found in Cranwell et al. (1990). Furthermore, DOE's expert elicitation exercise of 1990 identified industrial fluid injection as a potential human intrusion activity for the full 10,000 year regulatory period (Hora et al. 1991, Table IV-16). Fluid injection due to activities on adjacent properties was screened out on the basis of "low consequence" although the DOE draft application had no documentation to support that position (U.S. DOE 1995, SCR-72). With respect to fluid injection adjacent to the WIPP Site, the February 1996 EPA Criteria (40 CFR 194) require performance assessment to include the effects of any near future activities on lands surrounding the WIPP. A credible compliance application should include performance assessment calculations that fully consider the distinct activities of 1) fluid injection for resource recovery and 2) waste disposal activities within the site and adjacent to the site for the regulatory period of 10,000 years.

1. INTRODUCTION

The Waste Isolation Pilot Plant (WIPP) is intended to serve as a repository for the disposal of transuranic (TRU) waste generated by the defense activities of the United States Government. The WIPP is situated in the lower portion of the Salado Formation 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 (Foster 1974; Keesey 1976, 1977, and 1979; Griswold 1977; Powers et al. 1978; U.S. DOE 1980; Brausch et al. 1982; Neill et al. 1983; Weart 1983; Silva 1994; Griswold 1995a; Broadhead et al. 1995; U.S. DOE 1995).

1.1 Natural Resources and Water Injection at Other Candidate Sites

The problem of natural resources and the use of water injection in the vicinity of a nuclear waste repository has long been recognized. In 1972, the Lyons, Kansas site for a proposed TRU waste repository was rejected because there were too many drill holes in the area that could not be positively located, and nearby solution mining was experiencing unexplained water losses (U.S. DOE 1980, 2-7; U.S. DOE 1993, 26). Of the three areas in New Mexico chosen for further study, the Mescalero Plains area in Chaves County was disqualified because of extensive oil field development (U.S. DOE 1980, 2-10). In the Carlsbad vicinity, two of eight sites survived the screening criteria, the current Los Medaños site and the Alternate II. However, Alternate II in Lea County was rejected for a variety of reasons including the observation that it lay adjacent to the Double X and Triple X oil fields where waterflooding for secondary recovery could occur (Griswold 1977, 13).

1.2 Oil Field Waterflooding and the Salado

Typical oil field operations include two types of water injection activities - salt water disposal and waterflooding. In a successful salt water disposal operation, the unwanted brine is injected through a disposal well into an approved zone or zones. The production of oil, particularly in the Delaware Basin, is often accompanied by the production of large volumes of reservoir brine.

Oil production by primary recovery relies on natural reservoir energy to drive oil towards the well bore. These sources of natural energy include fluid and rock expansion, solution gas drive, gravity drainage, and the influx of water from connected aquifers. As oil, gas, and reservoir brine are produced, the natural reservoir energy is expended. Waterflooding aims to enhance crude oil recovery by restoring or supplementing reservoir energy (Willhite 1986). A successful waterflood injects pressurized water through the well bore into the oil bearing zone to force additional oil to flow towards the producing well.

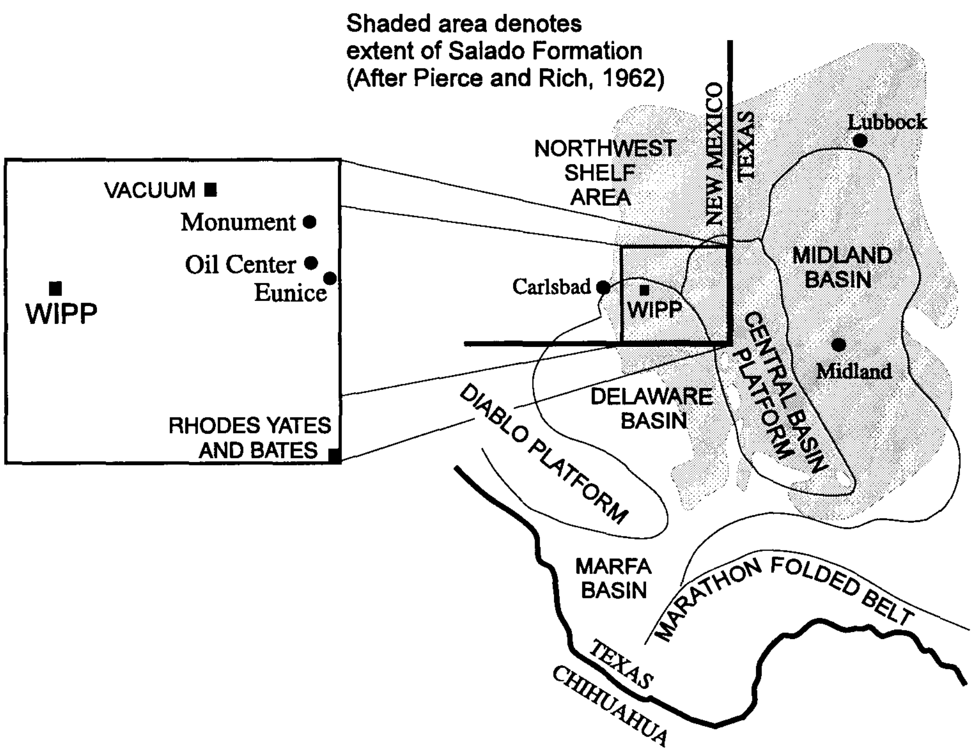

Figure 1-1. Physiographic provinces, extent of the Salado Formation, and oil field locations.

Figure 1-1 shows the locations of the physiographic zone and oil fields mentioned throughout the report. For oil fields underlying the Salado Formation, the problem of water escaping from the injection zone and migrating through the Salado Formation to adjacent properties has long been well known. For example, in a May 5, 1976, letter, Joe D. Ramey, Director of the Oil Conservation Division, advised the Secretary of the New Mexico Energy and Minerals Department (NMEMD), John F. O'Leary, of the situation:

> 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.... (Ramey 1976)

In 1980, the U.S. Department of Energy (DOE) intended to prohibit secondary recovery by waterflooding (U.S. DOE 1980, 8-4) in former control zone IV - the area that now forms much of the one mile buffer outside the 4-mile by 4-mile WIPP Land Withdrawal Boundary.[1] The DOE natural resources report (Brausch et al. 1982) maintained there was a minimal amount of crude oil likely to exist at the WIPP site and did not evaluate the potential impact of waterflooding. The DOE subsequently relinquished the right to restrict waterflooding for hydrocarbon recovery in former control zone IV (McGough 1983b).

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[1]See Silva (1994) for a discussion of how previous control zone III was squared off to form the current WIPP site boundary.

FORMATION		DEPTH TO CONTACT AT WIPP (FEET)	PRINCIPAL LITHOLOGY
Surficial Sand		10	Blanket sand and dune sand, some alluvium included.
Mescalaro Caliche and Gatuna Fm.		40	Pale reddish-brown, fine-grained friable sandstone; capped by a 5-10 ft. hard, white crystalline caliche (limestone) crust
Santa Rosa Sandstone		50	Pale red to gray, cross-bedded, non-marine, medium to course-grained friable sandstone; pinches out accross site.
Dewey Lake Redbeds		540	Uniform dark red-brown marine mudstone and sitlestone with interbedded very fine-grained sandsonte; thins westward.
Rustler		850	Anhydrite with siltstone interbeds. Contains two dolomite marker beds: Magenta and Culebra. Thickens eastward due to increasing content of undissolved rock salt.
Salado	Upper member		Mainly rock salt (85-90%) with minor interbedded anhydrite (43 marker beds), polyhalite and clayey to silty clastics. Potash minerals in McNutt Zone.
	McNutt member		
	Lower member	← WIPP REPOSITORY	
		2825	
Castile	Anh. III-IV		Varved anhydrite-calcite units alternating with thick halite (rock salt).
	Hal. II		
	Anh. II		
	Hal. I		
	Anh. I	4075	
Delaware Mountain Group	Bell Canyon		Mostly fine-grained sandstone with shaly and limy intervals. Bell Canyon is used for salt water disposal. Cherry Canyon and Brushy Canyon contain oil producing zones.
	Cherry Canyon		
	Brushy Canyon	~8000	

Figure 1-2. Stratigraphic cross section at the WIPP Site.

In April 1988, anomalous water level rises in the Culebra Dolomite aquifer were measured in several observation wells to the south of the WIPP site (Beauheim 1990). LaVenue (1991) conducted an investigation that raised serious questions about oil field operations. Bailey (1990), a certified professional geologist and petroleum engineer with the New Mexico State Land Office, described waterflooding problems for the Vacuum Field (an oil field overlain by the Salado and Rustler Formations) in a letter to Marsh LaVenue and suggested that the anomalous water level rises in the WIPP wells may have similar origin:

> Although the Vacuum Field, located in Township 17-18 South, Ranges 34-35 East, 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.
>
> Discussions at the Vacuum Field Salt Water Flow Committee meetings with the Oil Conservation Division in 1986-1987 indicated that the uppermost water flow occurred at the base of the Rustler and the lowest flow occurred at the top of the Tansill Formation. The most numerous flows were found near the crest of the anticline, but flows were encountered throughout the field. 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.

After years of study, thousands of pressure tests, installation of pressure monitoring wells, and chemical analyses, the Water Flow Committee, 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 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 (Bailey 1990).

The problem of injected water migrating "out of zone" is widespread. Bailey (1990) noted that waterfloods in and around Eunice, Oil Center, and Monument (Fig. 1-1) resulted in water flow problems through the Salado Formation. Nor is this strictly a problem of the past. Water migrating out of zone continues to plague other oil fields underlying the Salado.

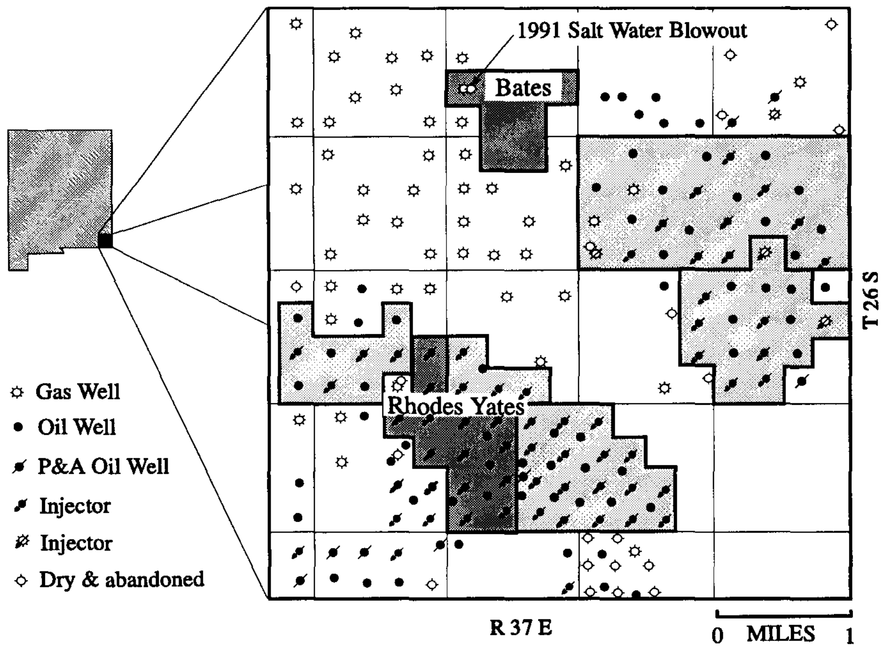

Figure 1-3. Bates Lease (Hartman), Rhodes Yates Waterflood (Texaco) and other nearby leases with injection wells.

1.2.1 Hartman vs. Texaco

On November 22, 1993, Mr. Doyle Hartman (1993) sent Sandia National Laboratories a copy of his November 17, 1993, Complaint (CIV93 1349M) filed in the Federal Court for the District of New Mexico. He stated that he furnished a copy of the complaint to familiarize Sandia "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 claimed that a neighboring waterflood, Texaco's Rhodes Yates, allowed large quantities of injected water to escape out of the approved injection zone, part and dissolve the Salado Formation, and migrate to Hartman's Bates Lease (Hartman 1993, 13).

On January 15, 1991, while drilling through the Salado Formation, Hartman experienced a salt water blowout, which flowed uncontrolled for five days. The suspected waterflood operation was approximately two miles away. On December 12, 1994, after two weeks of hearing testimony and viewing exhibits, the jury found in favor of Hartman's claim for damages. On January 20, 1995, the court ordered the defendant, Texaco, to compensate Hartman for 5.6 million dollars for damages and for value of the property injured and destroyed due to defendants' trespass (Herrera 1995).[2]

Observations of waterflows during drilling and production in waterflood areas appear to be fairly widespread in time and location. Part of the evidence gathered by Hartman's engineers included a listing of 189 waterflows reported throughout various oil and gas fields in District One[3] of southeast New Mexico for the time period from 1978 to 1993. These may not represent all the water flows encountered in this district because not every waterflow encountered during drilling is reported to the New Mexico Oil Conservation Division (NMOCD) (Lanphere and Sullivan 1994a).

1.2.2 Bass vs. United States of America

The potential impact of water flooding and fluid injection on the WIPP has been cited in the recent denial of a valid lease to directionally drill oil wells under the WIPP site from a surface location immediately adjacent to the WIPP site. In April 1993, Bass Enterprises submitted applications to directionally drill eight

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[2]The Environmental Evaluation Group understands that portions of this judgment may be in the appeal process. The Environmental Evaluation Group has no direct nor implied opinion about the case.

[3]District One of the New Mexico Oil Conservation District consists of Lea, Roosevelt, Curry, and part of Chavez County.

additional oil 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. Drilling would have initiated on the surface outside the WIPP site Boundary, proceeded downward 6,000 feet, then deviated into the WIPP site Boundary. On August 22, 1994, the BLM denied approval to drill the eight proposed wells "due to the uncertainty of when a final determination will be made, ***and the unknown impacts from injection wells and water flooding***"[4] (Calkins 1994). On January 23, 1995, Bass Enterprises et al. (1995) filed suit against the federal government for a taking.[5]

1.3 Oil Field Salt Water Disposal

Waterflooding to promote oil recovery is not the only oil field water injection practice of concern. In a memo to LaVenue, Bailey (1990) suggested that a salt water disposal well may be the source of the water level rises south of the WIPP site:

> Because a water injection well or salt water disposal well is the most logical source of a long term or continuous increases in fluids in the monitor well (H-9), I investigated locations of such wells in the area, concentrating on any wells located north-northeast. Spot checking of production wells in the section adjacent to the monitor well had not shown a logical production well as the source of a large fluid pressure increase.... In my opinion, the most likely source of increased fluid pressure is the Devon Energy Corp. Todd 26 Federal Well #3 salt water disposal (SWD) well located northeast and upgradient of the monitor well... Since 1971,

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[4]Emphasis added.

[5]The Environmental Evaluation Group understands that this case may be in litigation. The Environmental Evaluation Group has no direct nor implied opinion with respect to this case.

2,962,402 barrels of produced water have been injected at a current average pressure of 795 psi. No records of any casing repairs are found in the OCD well files.

This observation invites the following questions. Is there evidence to indicate that the Todd 26 Federal #3 well is the source of the water level rises? How was this well completed? What is the status of this well? If the casing, tubing, and cement of this well are intact, are there other available pathways in the area providing communication? Most importantly, over the next 10,000 years, to what extent will there be salt water disposal in the vicinity of the repository?

The first four questions are explored in the EEG workshop presentations and analysis. As to the last question, salt water disposal in the vicinity of the WIPP is already taking place. As noted by Matthew Silva, Ron Broadhead, and Dan Stoelzel, in their respective presentations (Chapter 2), the Delaware wells surrounding the WIPP site produce a very high fraction of water (water cut), on the order of 50% to 70% by volume, as reflected in production records and tabulated by Broadhead et al. (1995, Table 8). Silva (1994, Figure 13) showed four salt water disposal wells within two miles of the WIPP site Boundary as of 1993. Broadhead et al. (1995, Table 7) tabulates ten salt water disposal wells and two pressure maintenance wells within the nine township area surrounding the WIPP as of 1994.

1.4 Oil Field Brine Disposal and the Potash Industry

The issue of salt water disposal in the Delaware Basin appears to be of concern to members of the potash mining industry, which also operate in the Salado Formation. On November 19, 1993, representatives from Bass Enterprises Production Company, an oil company, met with representatives from Western Ag-Minerals Company, a potash mining company, to discuss the Bass proposal to operate a brine injection well two miles west of the WIPP site. Western Ag was concerned about its substantial potash reserves surrounding the well location.

Rather than rely solely on state regulations to protect their portion of the Salado Formation, Western Ag outlined twelve additional operating provisions that would satisfy their concerns (Heinen 1994). The twelve provisions included notification of any request to increase injection pressure above 765 psi, immediate notification of tubing, casing, or packing failure and cessation of injection until the problem is corrected, an annual chemical analysis of injected brine, an annual test to determine migration of brine into other formations, and specifications for well abandonment.

1.5 Well Abandonment

Concerns about improper abandonment of wells appear to be justified. As discussed by Silva (1994), inadequate practices on U.S. Bureau of Land Management (BLM) properties are documented (U.S. DOI 1989, 1990; Baier 1990). A 1989 evaluation (U.S. DOI 1989) by the Inspector General for the U.S. Department of Interior identified considerable problems on the BLM properties resulting largely from "violations of existing regulations" (U.S. DOI 1989, 4). The report cited problems with wells in BLM's Carlsbad Area (U.S. DOI 1989, 6-7)

In arguing a difference between exploratory and development wells[6], the DOE has also brought the problem of improperly abandoned oil and gas wells to the attention of the EPA. As the DOE Carlsbad Area Office noted:

> Development wells are generally abandoned only after many years of production. Many development wells change ownership several times during their operational lifespan, and may not produce continuously. They may ultimately be abandoned improperly (Dials 1994, Supplemental Information to Options 2, 4 and 3, 12).

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[6]For other views on well definitions see Neill 1995; Vaughn 1995; Carroll and Bogle 1996; also Gorenflo vs Texaco, 566 F. Supp. 722 (1983); Sun vs. Jackson, 715 S.W. 2D 199 (1986) and 783 S.W. 2d 202 (1989).

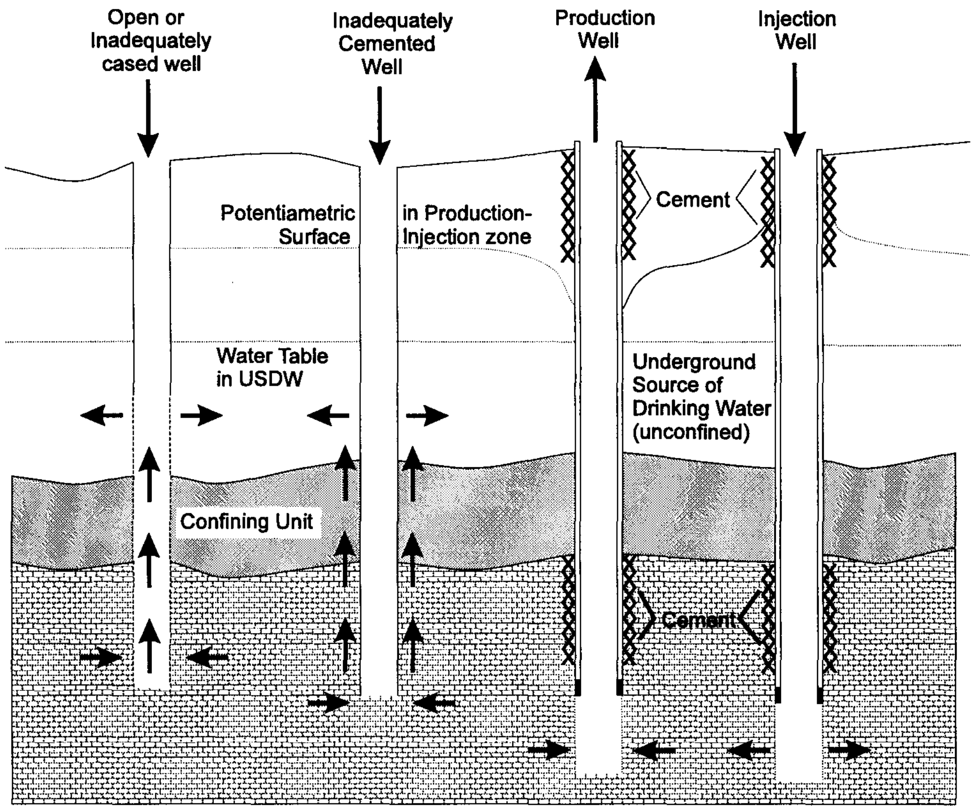

Figure 1-4. Upward flow from underlying hydrocarbon-producing zone to an underground source of drinking water through inadequately plugged wells. After Kreitler et al., 1994.

Improperly abandoned wells, in the vicinity of oil field injection wells, can serve as a pathway for contamination of underground sources of drinking water. The Texas Bureau of Economic Geology, with funding from the American Petroleum Institute, designed a method for use by regulators and operators to identify such areas (Kreitler et al. 1994).

In developing the method, Kreitler et al. (1994 pp. 64, 77) plotted the estimated density and distribution of oil field brine injection wells, as shown in Figure 1-5, and abandoned wells, as shown in Figure 1-6, throughout the greater Permian Basin, which includes the Delaware Basin.

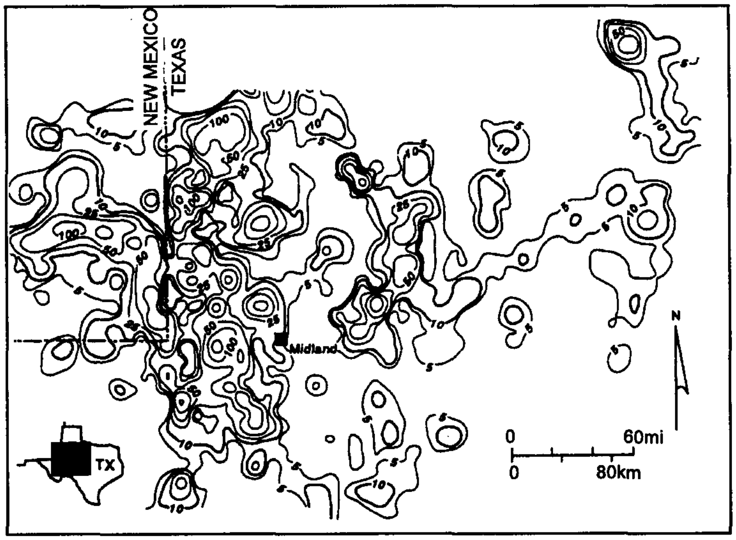

Figure 1-5. Density of Class II injection wells at 0.1°× 0.1° scale. After Kreitler et al. 1994.

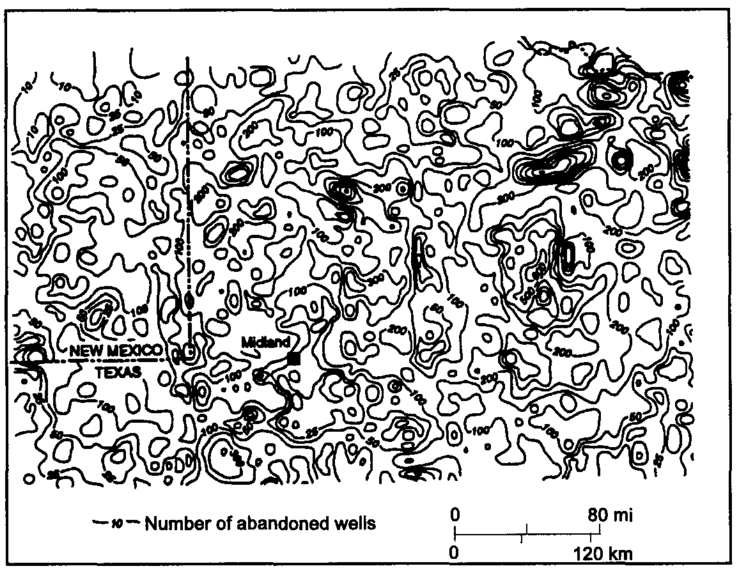

Figure 1-6. Estimated distribution of abandoned wells at 0.1°× 0.1° scale. After Kreitler et al. 1994.

They found that the most extensive area of upward hydraulic gradients occurs in the eastern Delaware Basin, Central Basin Platform, and western Midland Basin. Residual mapping indicates upward gradients with hydraulic head differentials as large as 6,000 ft (1,800 m) (Kreitler, et al. 1994, 73-74).

As part of their study, Kreitler et al. (1994) also offered insight into the problem of abandoned wells completed through salt formations. They note that in addition to less stringent construction and abandonment standards in past decades, the mechanical degradation of older wells may also reflect lengthy periods of exposure to corrosive brines. In the Permian Basin, wells that pass through a larger number of saline units are of particular concern (Kreitler et al. 1994, 76). LaVenue also commented on 20 to 30 years of exposure to the corrosive saline environment promoting a leak in the casing and/or degrading the grout holding the casing in place (LaVenue 1991, 2). This is consistent with the DOE position that the highly saline environment of some units can promote rapid corrosion of well casings and may result in fluid loss from wellbores (U.S. DOE 1995, SCR-73). All well casings to be abandoned in the WIPP vicinity will be exposed to more than two thousand feet of salt, not only in the Salado Formation, but also in the Castile Formation, a formation unique to the Delaware Basin. It seems prudent to assume saline environments promote rapid corrosion of well casing (Kreitler et al. 1994, 76; LaVenue 1991, 2; U.S. DOE 1995, SCR-73), existing regulations are violated (U.S. DOI 1989), and wells are improperly abandoned (U.S. DOI 1989; Dials 1994). Given these observations, do the existing and yet to be drilled wells in the vicinity of the WIPP represent viable vertical pathways for the upward migration of injected fluids either into the interbeds of the Salado Formation or into overlying aquifers such as the Culebra, the Magenta, and the Dewey Lake Redbeds?

1.6 WIPP and Performance Assessment

To proceed with TRU waste disposal, the WIPP Land Withdrawal Act requires the DOE to receive certification from the EPA that the facility is in compliance with the EPA radioactive waste disposal regulations (U.S. EPA 1985; 1993, 40 CFR 191) including containment and assurance requirements. This requires analyses that the probability and amount of radionuclides released to the accessible environment over the next 10,000 years will not exceed limits specified in the EPA Standards. The performance assessment (PA) calculations published to date have identified future drilling for oil and gas reserves as an event that could disrupt the repository and release radionuclides in excess of the standards (SNL 1992, 4.1.2). The calculations have not addressed the impact on WIPP's performance of the oil and gas industry practices of salt water disposal and waterflooding for enhanced oil recovery - two expanding activities now underway in the vicinity of the WIPP.

The 1991 DOE PA stated that such fluid injection could be eliminated from consideration in performance assessment on the basis of low consequence:

> The effects of injection wells on groundwater flow in units shallower than the Salado Formation is likely to be negligible. Units selected for injection will be thousands of feet deeper than the Rustler Formation, which is the most likely path for the groundwater transport of radionuclides to the accessible environment. The low permeability Bell Canyon, Castile, and Salado Formations are approximately 4,000 feet (1,220 meters) thick at the WIPP (Powers et al. 1978), and these low-permeability units will isolate flow in the Rustler Formation from the pressure increases in the much deeper units caused by the injection of fluids (SNL 1991, 1:4-36).

This explanation appears to be inconsistent with salt water disposal practices in the Delaware Basin, the observed water level rises in the Culebra, LaVenue's analyses (1991), and Bailey's comments (1990).[7] Records indicate that every salt water disposal well within the nine township area surrounding the WIPP injects into the Bell Canyon Formation (see Broadhead et al. 1995, Table 7). Hence, the Bell Canyon is not serving as an impermeable layer. Further, LaVenue's (1991) analyses indicated that the Bell Canyon Formation, which is below the WIPP horizon, is already in communication with the Rustler Formation, which is above the WIPP horizon. Hence, thousands of feet of vertical separation by

[7]Despite a January 28, 1991, distribution to the WIPP PA Department, the memos of LaVenue (1991), Bailey (1990), and Ramey (1976) are not referenced in either the December 1991 PA publication or in the December 1992 PA publication.

impermeable layers of salt do not appear to be isolating the Rustler from the fluid injected into the deeper units.

The 1992 PA also did not calculate the effect of adjacent fluid injection on performance assessment, maintaining that injection wells that do not penetrate the repository can be screened out on the basis of low consequence despite the 1976 Ramey memo, 1990 Bailey memo, and the 1991 LaVenue memo, and public records on fluid injection practices in the Delaware Basin.

With respect to any human related activity within the site, including fluid injection, the 1992 PA introduced a new criteria not found in Cranwell et al. (1990) for screening events and processes (SNL 1992, 2:4-3 to 4-4). The 1992 PA stated that the EPA regulations did not require the impact of fluid injection to be evaluated. The WIPP PA Department's interpretation (SNL 1992, 2:4-3) of the non-binding guidance for the disposal of transuranic waste (SNL 1992, 2:4-4) advances the argument that disruptive human activities, such as fluid injection, need not be considered because the consequences are greater than that of exploratory drilling (SNL 1992, 2:4-4). The impact of a future disposal well was limited to drilling and the consequences were assumed to be identical to drilling an exploratory well (SNL 1992, 2:4-4).

1.7 Issue

WIPP is surrounded by new oil producing wells. Many more are planned but have been delayed due to the presence of potash (Woodard 1992; Burski 1994). Oil production is accompanied by salt water injection either for salt water disposal or waterflooding. Forcing large volumes of such brine into the designated formation requires energy in the form of fluid pressure (force per unit area). Brine migration, with energy in the form of pressure, is the same mechanism by which radionuclides can be carried out of the repository and away from the WIPP site.

The potential impact of brine injection on the long-term performance of the WIPP prompted the Environmental Evaluation Group to organize a June 13, 1995, workshop on the issue. The workshop included presentations describing the extent of oil and gas resources, the anomalous water level rises in the Culebra Aquifer, the documented effects of water flooding on the Salado Formation, the geology of waterflooded areas in southeast New Mexico, the current petroleum production practices, the treatment of water injection by the performance assessment effort, and the need for a water flooding scenario in the WIPP PA calculations. As was intended, a number of issues were deliberated. On many issues there was no consensus. The workshop did not address the impact of solution mining of potash surrounding the WIPP or the disposal of potash brine.