

For many operators in the Gulf Coast area, produced water is discharged directly to adjacent water bodies. Fields in this region have an average water/oil ratio of from 4:1 to 6:1. The Louisiana Department of Environmental Quality (DEQ) is now requiring that operators apply for permits for these discharges. At this writing, the Louisiana DEQ had received permit applications for approximately 750 to 800 discharge points. Results of field work done by the Louisiana DEQ, the Louisiana Geological Survey, and the Louisiana University Marine Consortium show that roughly 1.8 to 2.0 million barrels of produced water are discharged daily in this area. According to the Louisiana Geological Survey, many receiving water bodies contain fresh water, with some receiving water bodies 70 times fresher than the oil field discharges. The U.S. Fish and Wildlife Service has stated that it will aggressively oppose any permits for produced water discharges in the Louisiana wetlands of the Gulf Coast.

The average depth of a new well drilled in northern Louisiana in 1985 was 2,713 feet; along the Gulf Coast it was 10,150 feet. In the northern part of the State, 244 exploratory wells were drilled and 4,033 production wells were completed. In the southern part of the State, 215 exploratory wells were drilled and 1,414 production wells were completed.

### Types of Operators

In Arkansas, operators are generally small to mid-sized independents, including some established operators and others new to the industry. Because production comes mostly from stripper wells, operators tend to be vulnerable to market fluctuations.

Northern Louisiana's operators, like those in Arkansas, tend to be small to mid-sized independents. They share the same economic vulnerabilities with their neighbors in Arkansas. In addition, however,

Louisiana's more marginal operations may be particularly stressed by the new Rule 29B, which requires the closing out and elimination of all current and future onsite produced water disposal pits by 1989. Estimated closing costs per pit are \$20,000.

Operators in southern Louisiana tend to be major companies and large independents. They are less susceptible to fluctuating market conditions in the short term. Projects in the south tend to be larger than those in the north and are located in more environmentally sensitive areas.

## Major Issues

### Ground-Water Contamination from Unlined Produced Water Disposal Pits and Reserve Pits

Unlined produced water disposal pits have been used in Louisiana for many years and are only now being phased out under Rule 29B. Past practice has, however, resulted in damages to ground water and danger to human health.

In 1982, suit was brought on behalf of Dudley Romero et al. against operators of an oil waste commercial disposal facility, PAB Oil Co. The plaintiffs stated that their domestic water wells were contaminated by wastes dumped into open pits in the PAB Oil Co. facility which were alleged to have migrated into the ground water, rendering the water wells unusable. Oil field wastes are dumped into the waste pits for skimming and separation of oil. The pits are unlined. The PAB facility was operating prior to Louisiana's first commercial oil field waste facility regulations. After promulgation of new regulations, the facility continued to operate for 2 years in violation of the new regulations, after which time the State shut down the facility.

The plaintiff's water wells are downgradient of the facility, drilled to depths of 300 to 500 feet. Problems with water wells date from 1979. Extensive analysis was performed by Soil Testing Engineers, Inc., and U.S. EPA, on the plaintiff's water wells adjacent to the site to determine the probability of the well contamination coming from the PAB Oil Co. site. There was also analysis on surface soil contamination. Soil Testing

Engineers, Inc., determined that it was possible for the wastes in the PAB Oil Co. pits to reach and contaminate the Romeros' water wells. Surface sampling around the perimeter of the PAB Oil Co. site found high concentrations of metals. Resistivity testing showed that plumes of chloride contamination in the water table lead from the pits to the water wells. Borings that determined the substrata makeup suggested that it would be possible for wastes to contaminate the Romero ground water within the time that the facility had been in operation if the integrity of the clay cap in the pit had been lost (as by deep excavation somewhere within it). The pit was 12 feet deep and within range to percolate into the water-bearing sandy soil.

The plaintiffs complained of sickness, nausea, and dizziness, and a loss of cattle. The case was settled out of court. The plaintiffs received \$140,000 from PAB Oil Co. (LA 67)<sup>24</sup>

Unlined commercial disposal pits are now illegal in Louisiana.

The ground in this area is highly permeable, allowing pit contents to leach into soil and ground water. Waste constituents potentially leaching into ground water from unlined pits include arsenic, cadmium, chromium, copper, lead, nickel, zinc, and chlorides. There have been incidents illustrating the permeability of subsurface formations in this area.<sup>25</sup>

#### Allowable Discharge of Drilling Mud into Gulf Coast Estuaries

Under existing Louisiana regulations, drilling muds from onshore operations may be discharged into estuaries of the Gulf of Mexico. The State issues permits for this practice on a case-by-case basis. These

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<sup>24</sup> References for case cited: Soil Testing Engineers, Inc., Brine Study, Romero, et al., Abbeville, Louisiana, 10/19/82. U.S. EPA lab analysis of pits and wells, 10/22/81. Dateline, Louisiana: Fighting Chemical Dumping, by Jason Berry, May-June, 1983.

<sup>25</sup> A gas well operated by Conoco, which had been plugged and abandoned, blew out below the surface from December 11, 1985, to January 9, 1986. The blowout sent gas through fault zones and permeable formations to the land surface owned by Claude H. Gooch. The gas could be ignited by a match held to the ground. The gas was also determined to be a potential hazard to drinking water wells in the immediate area.

estuaries are often valuable commercial fishing grounds. Since the muds can contain high levels of toxic metals, the possibility of bioaccumulation of these metals in shellfish or finfish is of concern to EPA.

In 1964, the Glendale Drilling Co., under contract to Woods Petroleum, was drilling from a barge at the intersection of Taylor's Bayou and Cross Bayou. The operation was discharging drill cuttings and mud into the bayou within 1,300 feet of an active oyster harvesting area and State oyster seeding area. At the time of discharge, oyster harvests were in progress. (It is State policy in Louisiana not to grant permits for the discharge of drill cuttings within 1,300 feet of an active oyster harvesting area. The Louisiana Department of Environmental Quality does not allow discharge of whole mud into estuaries.)

A State Water Pollution Control Division inspector noted that there were two separate discharges occurring from the barge and a low mound of mud was protruding from the surface of the water beneath one of the discharges. Woods Petroleum had a letter from the Louisiana Department of Environmental Quality authorizing them to discharge the drill cuttings and associated mud, but this permit would presumably not have been issued if it had been known that the drilling would occur near an oyster harvesting area. While no damage was noted at time of inspection, there was great concern expressed by the Louisiana Oyster Growers Association, the Louisiana Department of Wildlife and Fisheries, Seafood Division, and some parts of the Department of Water Pollution Control Division of the Department of Environmental Quality. The concern of these groups stemmed from the possibility that the discharge of muds and cuttings with high content of metals may have long-term impact on the adjacent commercial oyster fields and the State oyster seed fields in nearby Junop Bay. In such a situation, metals can precipitate from the discharge, settling in progressively higher concentrations in the bayou sediments where the oysters mature. The bioaccumulation of these metals by the oysters can have an adverse impact on the oyster population and could also lead to human health problems if contaminated oysters are consumed.

The Department of Environmental Quality decided in this case to direct the oil company to stop the discharge of drill cuttings and muds into the bayou. In this instance, the Department of Environmental Quality ordered that a drill cutting barge be used to contain the remainder of the drill cuttings. The company was not ordered to clean up the mound of drill cuttings that it had already deposited in the bayou. (LA 20)<sup>26</sup>

Activities in this case, though allowed by the State, are illegal according to State law.

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<sup>26</sup> References for case cited: Louisiana Department of Environmental Quality, Water Pollution Control Division, Office of Water Resources, internal memorandum, 6/3/85.

## Illegal Disposal of Oil Field Waste in the Louisiana Gulf Coast Area

The majority of damage cases collected in Louisiana involve illegal disposal or inadequate facilities for containment of wastes generated by operations on the Gulf Coast. For example:

Two Louisiana Water Pollution Control inspectors surveyed a swamp adjacent to a KEDCO Oil Co. facility to assess flora damage recorded on a Notice of Violation issued to KEDCO on 3/13/81. The Notice of Violation discussed produced water discharges into an adjacent canal that emptied into a cypress swamp from a pipe protruding from the pit levee. Analysis of a sample collected by a Mr. Martin, the complainant, who expressed concern over the high-chloride produced water discharge into the canal he used to obtain water for his crawfish pond, showed salinity levels of 32,000 ppm (seawater is 35,000 ppm).

On April 15, 1981, the Water Pollution Control inspectors made an effort to measure the extent of damage to the trees in the cypress swamp. After surveying the size of the swamp, they randomly selected a compass bearing and surveyed a transect measuring 200 feet by 20 feet through the swamp. They counted and then classified all trees in the area according to the degree of damage they had sustained. Inspectors found that "...an approximate total area of 4,088 acres of swamp was severely damaged." Within the randomly selected transect, they classified all trees according to the degree of damage. Out of a total of 105 trees, 73 percent were dead, 18 percent were stressed, and 9 percent were normal. The inspectors' report noted that although the transect ran through a heavily damaged area, there were other areas much more severely impacted. They therefore concluded, based upon data collected and firsthand observation, that the percentages of damaged trees recorded "...are a representative, if not conservative, estimate of damage over the entire affected area." In the opinion of the inspectors, the discharge of produced water had been occurring for some time, judging by the amount of damage sustained by the trees. KEDCO was fined \$9,500 by the State of Louisiana and paid \$4,500 in damages to the owner of the affected crawfish farm. (LA 45)<sup>27</sup>

This discharge was in violation of Louisiana regulations.

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<sup>27</sup> References for case cited: Louisiana Department of Natural Resources, Water Pollution Control Division, internal memo, Cormier and St. Pe to Givens, concerning damage evaluation of swamp near the KEDCO Oil Co. facility 6/24/81. Notice of Violation, Water Pollution Control Log #2-8-81-21.

Most of the damage cases collected involved small operations run by independent companies. Some incidents, however, involved major oil companies:

Sun Oil Co. operates a site located in the Chacahoula Field. A Department of Natural Resources inspector noted a site configuration during an inspection (6/25/82) of a tank battery surrounded by a pit levee and a pit (30 yards by 50 yards). The pit was discharging produced water into the adjacent swamp in two places, over a low part in the levee and from a pipe that had been put through the ring levee draining directly into the swamp. Produced water, oil, and grease were being discharged into the swamp. Chloride concentrations from samples taken by the inspectors ranged from 2,948 to 4,848 ppm, and oil and grease concentrations measured 12.6 to 26.7 ppm. The inspector noted that the discharge into the swamp was the means by which the company drains the tank battery ring levee area. A notice of violation was issued to Sun Oil by the Department of Natural Resources. (LA 15)<sup>28</sup>

This discharge was in violation of Louisiana regulations.

Some documented cases noted damage to agricultural crops:

Dr. Wilma Subra documented damage to D.T. Caffery's sugar cane fields adjacent to a production site, which included a saltwater disposal well, in St. Mary Parish. The operator was Sun Oil. The documentation was collected between July of 1985 and November of 1986 and included reports of salt concentrations in soil at various locations in the sugar cane fields, along with descriptions of accompanying damage. Dr. Subra noted that the sugar cane fields had various areas that were barren and contained what appeared to be sludge. The production facility is upgradient from the sugar cane fields, and Dr. Subra surmised that produced water was discharged onto the soil surface from the facility and that a plume of salt contamination spread downgradient, thereby affecting 7.3 acres of sugar cane fields, over a period of a year and a half.

In July 1985, Dr. Subra noted that the cane field, though in bad condition, was predominantly covered with sugar cane. There were, however, weeds or barren soil covering a portion of the site. The patch of weeds and barren soil matched the area of highest salt concentration. In the area where the topography suggested that brine concentrations would be lowest, the sugar cane appeared healthy. Subsequent field investigation and soil sampling conducted by Dr. Subra in November of 1986 found the field to be nearly barren, with practically no sugar cane growing.

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<sup>28</sup> References for case cited: Louisiana Department of Natural Resources, Water Pollution Control Division, internal memo from Cormier to Givens, 8/16/82, concerning Sun Oil Co. brine discharge, Chacahoula Field. Log #2-8-81-122. Lab analysis, 7/2/82.

Dr. Subra measured concentrations of salts in the soil ranging from a low of 1,403 ppm to 35,265 ppm at the edge of the field adjacent to the oil operation. Sun has undertaken a reclamation project to restore the land. It is estimated that the project will take 2 to 3 years to complete. In the interim, Sun Oil Co. will pay the sugar cane farmer for loss of crops.<sup>29</sup> (LA 63)<sup>30</sup>

The State of Louisiana has not taken any enforcement action in this case; it is unclear whether any State regulations were violated.

Most damage associated with illegal disposal involves disposal of produced water containing high levels of chloride (brine). Illegal disposal of other types of oil field waste also result in environmental damage:

Chevco-Kengo Services, Inc. operates a centralized disposal facility near Abbeville, Louisiana. Produced water and other wastes are transported from surrounding production fields by vacuum truck to the facility. Complaints were filed by private citizens alleging that discharges from the facility were damaging crops of rice and crawfish, and that the facility represented a threat to the health of nearby residents. An inspection of the site by the Water Pollution Control Division of the Department of Natural Resources found that a truck washout pit was emptying oil field wastes into a roadside ditch flowing into nearby coulees.

Civil suit was brought by private citizens against Chevco-Kengo Services, Inc., asking for a total of \$4 million in property damages, past and future crop loss, and exemplary damages. Lab analysis performed by the Department of Natural Resources of waste samples indicated high metals content of the wastes, especially in samples taken from the area near the facility and in the adjacent rice fields, indicating that the discharge of wastes from the facility was the source of damage to the surrounding land. The case is in litigation.<sup>31</sup> (LA90)<sup>32</sup>

The State did not issue a notice of violation in this case. However, this type of discharge is illegal.

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<sup>29</sup> API states that an accidental release occurred in this case. EPA records show this release lasted 2 years.

<sup>30</sup> References for case cited: Documentation from Dr. Wilma Subra, including a series of maps documenting changes in the sugar cane over a period of time, 12/86. Maps showing location of sampling and salt concentrations.

<sup>31</sup> API states that these discharges were accidental.

<sup>32</sup> References for case cited: Louisiana Department of Natural Resources, Water Pollution Control Division, internal memo, lab analysis, and photographs, 8/25/83. Letter from Westland Oil Development Corp. to Louisiana Department of Natural Resources, 4/15/83.

## Illegal Disposal of Oil Field Waste in Arkansas

The majority of damage cases found in Arkansas relate to illegal dumping of produced water and oily waste from production units. Damages typically include pollution of surface streams and contamination of soil with high levels of chlorides and oil, documented or potential contamination of ground water with elevated levels of chlorides, and damage to vegetation (especially forest and timberland), from exposure to high levels of chlorides.

An oil production unit operated by Mr. J. C. Langley was discharging oil and produced water in large quantities onto the property of Mr. Melvin Dunn and Mr. W. C. Shaw. The oil and produced water discharge allegedly caused severe damage to the property, interfered with livestock on the property, and delayed construction of a planned lake. Mr. Dunn had spoken repeatedly with a company representative operating the facility concerning the oil and produced water discharge, but no changes occurred in the operation of the facility. A complaint was made to Arkansas Department of Pollution Control and Ecology (ADPCE), the operator was informed of the situation, and the facility was brought into compliance. Mr. Dunn then hired a private attorney in order that remedial action be taken. It is not known whether the operator cleaned up the damaged property.<sup>33</sup> (AR 07)<sup>34</sup>

This discharge was in violation of Arkansas regulations.

On September 20, 1984, an anonymous complaint was filed with ADPCE concerning the discharge of oil and produced water in and near Smackover Creek from production units operated by J. S. Beebe Oil Account. Upon investigation by ADPCE, it was found that saltwater was leaking from a salt water disposal well located on the site. Mr. Beebe wrote a letter stating his willingness to correct the situation. On November 16, 1984, the site was again investigated by ADPCE, and it was found that pits on location were being used as the primary disposal facility and were

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<sup>33</sup> API states that this incident constituted a spill and is therefore a non-RCRA issue.

<sup>34</sup> References for case cited: Arkansas Department of Pollution Control and Ecology (ADPCE) Complaint form, #EL 1721, 5/14/84. Letter from Michael Landers, attorney to Mr. Dunn, requesting investigation from Wayne Thomas concerning Langley violations. Letter from J. C. Langley to Wayne Thomas, ADPCE, denying responsibility for damages of Dunn and Shaw property, 6/5/84. Certified letter from Wayne Thomas to J. C. Langley discussing violations of facility and required remedial actions, 5/30/87. Map of violation area, 5/29/84. ADPCE oil field waste survey documenting unreported oil spill on Langley unit, 5/25/84. Letter from Michael Landers, attorney to ADPCE, discussing damage to property of Dunn and Shaw, 5/11/84.



overflowing and leaking into Smackover Creek. The ADPCE issued a Notice of Violation (LIS 84-066) and noted that the pits were below the creek level and overflowed into the creek when heavy rains occurred. One pit was being siphoned over the pit wall, while waste from another pit was flowing onto the ground through an open pipe. The floors and walls of the pits were saturated, allowing seepage of waste from the pits. ADPCE ordered Mr. Beebe to shut down production and clean up the site and fined him \$10,500. (AR 10)<sup>35</sup>

These discharges were occurring in violation of Arkansas regulations.

The State of Arkansas has limited resources for inspecting disposal facilities associated with oil and gas production. (See Table VII-7.) Furthermore, the two State agencies responsible for regulating oil and gas operations (the Arkansas Oil and Gas Commission (OGC) and the Arkansas Department of Pollution Control and Ecology (ADPCE)) have overlapping jurisdictions. In the next case, the landowner is the Arkansas Game and Fish Commission, which attempted to enforce a permit it issued to the operator for drilling activity on the Commission's land. As of summer 1987, no permit had been issued by either the OGC or the ADPCE.

In 1983 and again in 1985, James M. Roberson, an oil and gas operator, was given surface access by the Arkansas Game and Fish Commission for drilling in areas in the Sulphur River Wildlife Management Area (SRWMA), but was not issued a drilling permit by either of the State agencies that share jurisdiction over oil and gas operations. Surface rights are owned by the Arkansas Game and Fish Commission. The Commission attempted to write its own permits for this operation to protect the wildlife management area resources. Mr. Roberson repeatedly violated the requirements contained in these surface use permits, and the Commission also determined that he was in violation of general State and Federal regulations applicable to his operation in the absence of OGC or ADPCE permits. These violations led to release of oil and high-chloride produced water into the wetland areas of the Sulphur River and Mercer Bayou from a leaking saltwater disposal well and illegal produced water disposal pits maintained by the operator.

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<sup>35</sup> References for case cited: ADPCE complaint form #EL 1792, 9/20/84, and 8/23/84. ADPCE inspection report, 9/5/84. Letter from ADPCE to J. S. Beebe outlining first run of violations, 9/6/84. Letter stating willingness to cooperate from Beebe to ADPCE, 9/14/84. ADPCE complaint form #EL 1789, 9/19/84. ADPCE inspection report, 9/25 and 9/26/84. ADPCE complaint form #EL 1822, 11/16/84. ADPCE Notice of Violation, Findings of Fact, Proposed Order and Civil Penalty Assessment, 11/21/84. Map of area. Miscellaneous letters.

Oil and saltwater damage to the area was documented in a study conducted by Hugh A. Johnson, Ph.D., a professor of biology at Southern Arkansas University. His study mapped chloride levels around each well site and calculated the affected area. The highest chloride level recorded in the wetland was 9,000 ppm (native vegetation begins to be stressed from exposure to 250 ppm chlorides). He found that significant areas around each well site had dead or stressed vegetation related to excessive chloride exposure. The Game and Fish Commission fears that continued discharges of produced water and oil in this area will threaten the last remaining forest land in the Red River bottoms.<sup>36</sup> (AR 04)<sup>37</sup>

These discharges were in violation of State and Federal regulations.

Jurisdiction in the above case is unclear. Under a 1981 amendment to the State Oil and Gas Act, OGC was granted formal permit authority over oil and gas operations, but this authority is to be shared in certain situations with the ADPCE. Jurisdiction is to be shared where Underground Injection Control (UIC) wells are concerned, but is not clearly defined with respect to construction or management of reserve pits or disposal of drilling wastes. ADPCE has made attempts to clarify the situation by issuing informal letters of authorization to operators, but these are not universally recognized throughout the State. (A full discussion of this issue can be found in Chapter VII and in Appendix A.)

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<sup>36</sup> API states that the Arkansas Water and Air Pollution Act gives authority at several levels to require cleanup of these illegal activities and to prevent further occurrences. EPA believes that even though State and Federal Laws exist which prohibit this type of activity, no mechanism for enforcement is in place.

<sup>37</sup> References for case cited: Letter from Steve Forsythe, Department of the Interior (DOI), to Pat Stevens, Army Corps of Engineers (ACE), stating that activities of Mr. Roberson have resulted in significant adverse environmental impacts and disruptions and that DOI recommends remedial action be taken. Chloride Analysis of Soil and Water Samples of Selected Sites in Miller County, Arkansas, by Hugh A. Johnson, Ph.D., 10/22/85. Letter to Pat Stevens, ACE, from Dick Whittington, EPA, discussing damages caused by Jimmy Roberson in Sulphur River Wildlife Management Area (SRWMA) and recommending remedial action and denial of new permit application. Oil and Gas well drilling permits dated 1983 and 1985 for Roberson activities. A number of letters and complaints addressing problems in SRWMA resulting from activities of James Roberson. Photographs. Maps.

## Improperly Operated Injection Wells

Improper operation of injection wells raises the potential for long-term damage to ground-water supplies, as the following case from Arkansas illustrates.

On September 19, 1984, Mr. James Tribble made a complaint to the Arkansas Department of Pollution Control and Ecology concerning salt water that was coming up out of the ground in his yard, killing his grass and threatening his water well. There are many oil wells in the area, and water flooding is a common enhanced recovery method at these sites. Upon inspection of the wells nearest to his residence, it was discovered that the operator, J. C. McLain, was injecting salt water into an unpermitted well. The salt water was being injected into the casing, or annulus, not into tubing. Injection into the unsound casing allegedly allowed migration into the freshwater zone. A produced water pit at the same site was near overflowing. State inspectors later noted in a followup inspection that the violations had been corrected. No fine was levied. (AR 12) <sup>38</sup>

Operation of this well would now be in violation of UIC requirements.

## MIDWEST

The Midwest zone includes the States of Michigan, Iowa, Indiana, Wisconsin, Illinois, and Missouri. Damage cases were collected in Michigan.

### Operations

Michigan produces both oil and gas from limestone reef formations at sites scattered throughout the State at a depth of 4,000 to 6,000 feet.

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<sup>38</sup> References for case cited: ADPCE Complaint form, #EL 1790, 9/19/84. ADPCE inspection report, 9/20/84. Letter from ADPCE to Mr. J. C. McLain describing violations and required corrective action, 9/21/84. ADPCE reinspection report, 10/11/84.

Oil and gas development is relatively new in this area, and most production is primary (that is, as yet it involves no enhanced or secondary recovery methods, such as water flooding). Exploration in Michigan is possibly the most intense currently under way anywhere in the country. The average depth of new wells drilled in 1985 was 4,799 feet. In that year 863 wells were completed, of which 441 were exploration wells.

### Types of Operators

Operators in Michigan include everything from small independent companies to the major oil companies.

### Major Issues

#### Ground-Water Contamination in Michigan

All the damage cases gathered in Michigan are based on case studies written by the Michigan Geological Survey, which regulates oil and gas operations in the State. All of these cases deal with ground water contamination with chlorides. While the State has documented that damages have occurred in all cases, sources of damages are not always evident. Usually, several potential sources of contamination are listed for each case, and the plume of contamination is defined by using monitoring wells. Most of the cases involve disposal of produced waters.

In June 1983, a water well owned by Mrs. Geneva Brown was tested after she had filed a complaint to the Michigan Geological Survey. After responding, the Michigan Geological Survey found a chloride concentration of 490 ppm in the water. Subsequent sampling from the water well of a neighbor, Mrs. Dodder, showed that her well measured 760 ppm chloride in August. There are a total of 15 oil and gas wells in the area surrounding the contaminated water wells. Only five of the wells are still producing, recovering a combination of oil and produced water. The source of the pollution was evidently the H. E. Trope, Inc., crude oil separating facilities and brine storage tanks located upgradient from the contaminated water wells. Monitoring wells were installed to confirm the source of the contamination. Stiff diagrams were used to confirm the similarity of the constituents of the formation brine and the chloride contamination of the

affected water wells. Sample results located two plumes of chloride contamination ranging in concentration from 550 to 1,800 ppm that are traveling in a southeasterly direction downgradient from the produced water storage tanks and crude oil separator facilities owned by H.E. Trope. (MI 05)<sup>39</sup>

Produced water spills from production facilities are covered by Michigan regulations.

Ground-water contamination in the State has also been caused by injection wells, as illustrated by the following case:

In April 1980, residents of Green Ridge Subdivision, located in Section 15, Laketon Township, Muskegon County, complained of bad-tasting water from their domestic water wells. Some wells sampled by the local health department revealed elevated chloride concentrations. Because of the proximity of the Laketon Oil Field, an investigation was started by the Michigan Geological Survey. The Laketon Oil Field consists of dry holes, producing oil wells, and a produced water disposal well, the Harris Oil Corp. Lappo #1. Oil wells produce a mixture of oil and produced water. The produced water is separated and disposed of by gravity in the produced water disposal well and is then placed back in the producing formation. After reviewing monitoring well and electrical resistivity survey data, the Michigan Geological Survey concluded that the source of the contamination was the Harris Oil Corp. Lappo #1 produced water disposal well, which was being operated in violation of UIC regulations. (MI 06)<sup>40</sup>

This disposal well was being operated in violation of State regulations.

Damage to ground water under a drill site can occur even where operators take special precautions for drilling near residential areas. An example follows:

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<sup>39</sup> References for case cited: Open file report, Michigan Department of Natural Resources, Investigation of Salt-Contaminated Groundwater in Cat Creek Oil Field, Hersey Township, conducted by D. W. Forstat, 1984. Appendix includes correspondence relating to investigation, area water well drilling logs, Stiff diagrams and water analysis, site monitor well drilling logs, and water sample analysis for samples used in the investigation.

<sup>40</sup> References for case cited: Open file report, Michigan Department of Natural Resources, Investigation of Salt-Contaminated Groundwater in Green Ridge Subdivision, Laketon Township, conducted by B. P. Shirey, 1980. Appendix includes correspondence relating to investigation, area water well drilling logs, Stiff diagrams and water analysis, site monitor well drilling logs, and water sample analysis for samples used in the investigation.

Drilling operations at the Burke Unit #1 caused the temporary chloride contamination of two domestic water wells and longer lasting chloride contamination of a third well closer to the drill site. The operation was carried out in accordance with State regulations and special site restrictions required for urban areas, using rig engines equipped with mufflers, steel mud tanks for containment of drilling wastes, lining for earthen pits that may contain salt water, and the placement of a conductor casing to a depth of 120 feet to isolate the well from the freshwater zone beneath the rig.

The drilling location is underlain by permeable surface sand, with bedrock at a depth of less than 50 feet. Contamination of the ground water may have occurred when material flushed from the mud tanks remained in the lined pit for 13 days before removal. (The material contained high levels of chlorides, and liners can leak.) According to the State report, this would have allowed for sufficient time for contaminants to migrate into the freshwater aquifer. A leak from the produced water storage tank was also reported by the operator to have occurred before the contamination was detected in the water wells. One shallow well was less than 100 feet directly east of the drill pit area and 100 to 150 feet southeast of the produced water leak site. Chloride concentrations in this well measured by the Michigan Geological Survey were found to range from 750 (9/5/75) to 1,325 (5/23/75) ppm. By late August, two of the wells had returned to normal, while the third well still measured 28 times its original background concentration of chloride. (MI 04)<sup>41</sup>

In this case, damages resulted from practices that are not in violation of State regulations.

## PLAINS

The Plains zone includes North Dakota, South Dakota, Nebraska, and Kansas. All of these States have oil and gas production, but for this study, Kansas was the only State visited for damage case collection. Discussion is limited to that State.

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<sup>41</sup> References for case cited: Open file report, Michigan Department of Natural Resources, Report on Ground-Water Contamination, Sullivan and Company, J.D. Burke No. 1, Pennfield Township, conducted by J. R. Byerlay, 1976. Appendix includes correspondence relating to investigation, area water well drilling logs, Stiff diagrams and water analysis, site monitor well drilling logs, and water sample analysis for samples used in the investigation.

## Operations

Oil and gas production in Kansas encompasses a wide geographical area and ranges from marginal oil production in the central and eastern portions of the State to significant gas production in the western portion of the State. Kansas is the home of one of the largest gas fields in the world, the Giant Hugoton field. Other major areas of oil production in Kansas include the Central Kansas Uplift area, better known as the "Kansas Oil Patch," the El Dorado Field in the east and south, and the Eastern Kansas Shoestring sandstone area. The Eastern Kansas Shoestring sandstone production area is composed mainly of marginal stripper operations. The overall ratio of produced water to oil in Kansas is about 40:1, but the ratio varies depending on economic conditions, which may force the higher water-to-oil ratio wells (i.e., those in the Mississippian and Arbuckle producing formations) to shut down.

The average depth of a new well drilled in Kansas in 1985 was 3,770 feet. In that year 6,025 new wells were completed. Of those, 1,694 were exploratory.

## Types of Operators

Operators in Kansas include the full range from majors to small independents. The Hugoton area is dominated by majors and mid-sized to large independents. Spotty oil production in the northern half of eastern Kansas is dominated by small independent producers, and oil production is densely developed in the southern half.

## Major Issues

### Poor Lease Maintenance

There are documented cases in Kansas of damage associated with inadequate lease maintenance and illegal operation of pits. These cases commonly result in contamination of soil and surface water with high levels of chlorides as well as long-term chloride contamination of ground water.

Temple Oil Company and Wayside Production Company operated a number of oil production leases in Montgomery County. The leases were operated with illegally maintained saltwater containment ponds, improperly abandoned reserve pits, unapproved emergency saltwater pits, and improperly abandoned saltwater pits. Numerous oil and saltwater spills were recorded during operation of the sites. Documentation of these incidents started in 1977 when adjacent landowners began to complain about soil pollution, vegetation kills, fish kills, and pollution of freshwater streams due to oil and saltwater runoff from these sites. The leases also contain a large number of abandoned, unplugged wells, which may pose a threat to ground water.<sup>42</sup> Complaints were received by the Conservation Division, Kansas Department of Health and the Environment (KDHE), Montgomery County Sheriff, and Kansas Fish and Game Commission. A total of 39 violations on these leases were documented between 1983 and 1984.

A sample taken by KDHE from a 4 1/2-foot test hole between a freshwater pond and a creek on one lease showed chloride concentrations of 65,500 ppm. Water samples taken from pits on other leases showed chloride concentrations ranging from 5,000 to 82,000 ppm.

The Kansas Corporation Commission (KCC) issued an administrative order in 1984, fining Temple and Wayside a total of \$80,000. Initially, \$25,000 was collected, and the operators could reapply for licenses to operate in Kansas in 36 months if they initiated adequate corrective measures. The case is currently in private litigation. The KCC found that no progress had been made towards bringing the leases into compliance and, therefore, reassessed the outstanding \$55,000 penalty. The KCC has since sought judicial enforcement of that penalty in the District Court, and a journal entry has been signed and was reviewed by the KCC and is now ready to be filed in District Court. Additionally, in a separate lawsuit between the landowners, the lessors, and the Temples regarding operation of the leases, the landowners were successful and the leases have reverted back to the landowners. The new operators are prevented from operating without KCC authority. (KS 01)<sup>43</sup>

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<sup>42</sup> Comments in the Docket by the Kansas Corporation Commission (Beatrice Stong) pertain to KS 01. With regard to the abandoned wells, Kansas Corporation Commission states that these wells are "...cemented from top to bottom...", they have "...limited resource energy..." and the static fluid level these reservoirs could sustain are "...well below the location of any drinking or usable water."

<sup>43</sup> References for case cited: The Kansas Corporation Commission Court Order describing the evidence and charges against the Temple Oil Co., 5/17/84.



This case represents habitual violation of Kansas regulations.

On January 31, 1986, the Kansas Department of Health and the Environment (KDHE) inspected the Reitz lease in Montgomery County, operated by Marvin Harr of El Dorado, Arkansas. The lease included an unpermitted emergency pond containing water that had 56,500 ppm chlorides. A large seeping area was observed by KDHE inspectors on the south side of the pond, allowing the flow of salt water down the slope for about 30 feet. The company was notified and was asked to apply for a permit and install a liner because the pond was constructed of sandy clay and sandstone. The operator was directed to immediately empty the pond and backfill it if a liner was not installed. On February 24, the lease was reinspected by KDHE and the emergency pond was still full and actively seeping. It appeared that the lease had been shut down by the operator. A "pond order" was issued by KDHE requiring the company to drain and backfill the pond. On April 29, the pond was still full and seeping.

Water samples taken from the pit by KDHE showed chloride concentrations of from 30,500 ppm (4/29/86) to 56,500 ppm (1/31/86). Seepage from the pit showed chloride concentrations of 17,500 ppm (2/24/86). The Kansas Department of Health and the Environment stated that "...the use of the pond...has caused or is likely to cause pollution to the soil and the waters of the State." An administrative penalty of \$500 was assessed against the operator, and it was ordered that the pond be drained and backfilled. (KS 08)<sup>44</sup>

This activity is in violation of current Kansas regulations.

Such incidents are a recognized problem in Kansas. On May 13, 1987, the Kansas Corporation (KCC) added new lease maintenance rules to their oil and gas regulations. These new rules require permits for all pits, drilling and producing, and require emptying of emergency pits within 48 hours. Spills must now be reported in 24 hours. The question of concern is how stringently these rules can be enforced, in the light of the evident reluctance of some operators to comply. (See Table VII-7.)

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<sup>44</sup> References for case cited: Kansas Department of Health and Environment Order assessing civil penalty, in the matter of Marvin Harr, Case No. 86-E-77, 6/10/86. Pond Order issued by Kansas Department of Health and Environment, in the matter of Marvin Harr, Case No. 86-PO-008, 3/21/86.

## Unlined Reserve Pits

Problems with unlined reserve pits are illustrated in the following cases.

Between February 9 and 27, 1986, the Elliott #1 was drilled on the property of Mr. Lawrence Koehling. The Hutchinson Salt member, an underground formation, was penetrated during the drilling of Elliott #1. The drilling process dissolved between 100 and 200 cubic feet of salt, which was disposed of in the unlined reserve pit. The reserve pit lies 200 feet away from a well used by Mr. Koehling for his ranching operations. Within a few weeks of the drilling of the Elliott #1, Mr. Koehling's nearby well began to pump water containing a saltwater drilling fluid.

Ground water on the Koehling ranch has been contaminated with high levels of chlorides allegedly because of leaching of the reserve pit fluids into the ground water. Water samples taken from the Koehling livestock water well by the KCC Conservation Division showed a chloride concentration of 1650 mg/L. Background concentrations of chlorides were in the range of 100 to 150 ppm. It is stated in a KCC report, dated November 1986, that further movement of the saltwater plume can be anticipated, thus polluting the Koehling domestic water well and the water well used by a farmstead over 1 mile downstream from the Koehling ranch. It is also stated in this KCC report that other wells drilled in the area using unlined reserve pits would have similarly affected the groundwater.

The KCC now believes the source of ground-water contamination is not the reserve pit from the Elliott #1. The KCC has drilled two monitoring wells, one 10 feet from the edge of the reserve pit location and the other within 400 feet of the affected water well, between the affected well and the reserve pit. The monitoring well drilled 10 feet from the reserve pit site tested 60 ppm chlorides. (EPA notes that it is not known if this monitoring well was located upgradient from the reserve pit.) The monitoring well drilled between the affected well and the reserve pit tested 750 ppm chlorides. (EPA notes that the level of chlorides in this monitoring well is more than twice the level of chlorides allowed under the EPA drinking water standards). The case is still open, pending further investigation. EPA believes that the evidence presented to date does not refute the earlier KCC report, which cited the reserve pit as the source of ground-water contamination, since the recent KCC report does not suggest an alternative source of contamination. (KS 05)<sup>45</sup>

Unpermitted reserve pits are in violation of current Kansas regulations.

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<sup>45</sup> References for case cited: Summary Report, Koehling Water Well Pollution, 22-10-15W, KCC, Conservation Division, Jim Schoof, Chief Engineer, 11/86.

Mr. Leslie, a private landowner in Kansas, suspected that chloride contamination of a natural spring occurred as a result of the presence of an abandoned reserve pit used when Western Drilling Inc. drilled a well (Leslie #1) at the Leslie Farm. Drilling in this area required penetration of the Hutchinson Salt member, during which 200 to 400 cubic feet of rock salt was dissolved and discharged into the reserve pit. The ground in the area consists of highly unconsolidated soils, which would allow for migration of pollutants into the ground water. Water at the top of the Leslie #1 had a conductivity of 5,050 umhos. Conductivity of the spring water equaled 7,250 umhos. As noted by the KCC, "very saline water" was coming out of the springs. Conductivity of 2,000 umhos will damage soil, precluding growth of vegetation. No fines were levied in this case as there were no violations of State rules and regulations. The Leslies filed suit in civil court and won their case for a total of \$11,000 from the oil and gas operator.<sup>46</sup> (KS 03)<sup>47</sup>

Current Kansas regulations call for a site-by-site evaluation to determine if liners for reserve pits are appropriate.

### Problems with Injection Wells

Problems with injection wells can occur as a result of inadequate maintenance, as illustrated by the following case.

On July 12, 1981, the Kansas Department of Health and the Environment (KDHE) received a complaint from Albert Richmeier, a landowner operating an irrigation well in the South Solomon River valley. His irrigation well had encountered salty water. An irrigation well belonging to an adjacent landowner, L. M. Paxson, had become salty in the fall of 1980. Oil has been produced in the area since 1952, and since 1962 secondary recovery by water flooding has been used. Upon investigation by the KDHE, it was discovered that the cause of the pollution was a saltwater injection well nearby, operated by Petro-Lewis. A casing profile caliper log was run by an operator-contractor under the direction of KDHE staff, which revealed numerous holes in the casing of the injection well. The producing formation, the Kansas City-Lansing, requires as much as 800 psi at the wellhead while injecting fluid to create a profitable enhanced oil recovery project. To remediate the contamination, the alluvial aquifer was pumped, and the initial chloride concentration of 6,000 mg/L was lowered to 600 to 700 mg/L in a year's time. Chloride contamination in some areas was lowered from 10,000 mg/L to near background levels. However, a contamination problem continues in the Paxson well, which shows chlorides in the range of 1,100 mg/L even though KDHE, through pumping, has tried to reduce the

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<sup>46</sup> API states that KDHE had authority over pits at this time. The KCC now requires permits for such pits.

<sup>47</sup> Reference for case cited: Final Report, Gary Leslie Saltwater Pollution Problem, Kingman County, KCC Conservation Division, Jim Schoof, Chief Engineer, 9/86. Contains letters, memos, and analysis pertaining to the case.

concentration. After attempts at repair, Petro-Lewis decided to plug the injection well.<sup>48</sup> (KS 06)<sup>49</sup>

Operation of such a well would violate current Kansas and UIC regulations.

## TEXAS/OKLAHOMA

The Texas/Oklahoma zone includes these two States, both of which are large producers of oil and gas. As of December 1986, Texas ranked as the number one producer in the U.S. among all oil-producing States. Because of scheduling constraints, research on this zone concentrated on Texas, and most of the damage cases collected come from that State.

### Operations

Oil and gas operations in Texas and Oklahoma began in the 1860s and are among the most mature and extensively developed in the U.S. These two States include virtually all types of operations, from large-scale exploratory projects and enhanced recovery projects to marginal small-scale stripper operations. In fact, the Texas/Oklahoma zone includes most of the country's stripper well production. Because of their maturity, many operations in the area generate significant quantities of associated produced water.

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<sup>48</sup> Comments in the Docket by the KCC (Bill Bryson) pertain to KS 06. KCC states that of the affected irrigation wells, one is "...back in service and the second is approaching near normal levels as it continues to be pumped." API states that Kansas received primacy for the UIC program in 1984.

<sup>49</sup> References for case cited: Richmeier Pollution Study, Kansas Department of Health and Environment, G. Blackburn and W. R. Bryson, 1983.

Development of oil and gas reserves remains active. In 1985, some 9,176 new wells were completed in Oklahoma, 385 of which were exploration wells. In Texas in the same year, 25,721 wells were completed on shore, 3,973 of which were exploration wells. The average depth of wells in the two areas is comparable: Oklahoma, 4,752 feet; Texas, 4,877 feet. Because the scale and character of operations varies so widely, cases of environmental damage from this zone are also varied and are not limited to any particular type of operation.

### Types of Operators

Major operators are the principal players in exploration and development of deep frontiers and capital-intensive secondary and tertiary recovery projects. As elsewhere, the major companies have the best record of compliance with environmental requirements of all types; they are least likely to cut corners on operations, tend to use high-quality materials and methods when drilling, and are generally responsible in handling well abandonment obligations.

Smaller independent operators in the zone are more susceptible to fluctuating market conditions. They may lack sufficient capital to purchase first-quality materials and employ best available operating methods.

### Major Issues

#### Discharge of Produced Water and Drilling Muds into Bays and Estuaries of the Texas Gulf Coast

Texas allows the discharge of produced water into tidally affected

estuaries and bays of the Gulf Coast from nearby onshore development. Cases in which permitted discharges have created damage include:

In Texas, oil and gas producers operating near the Gulf Coast are permitted to discharge produced water into surface streams if they are found to be tidally affected. Along with the produced water, residual production chemicals and organic constituents may be discharged, including lead, zinc, chromium, barium, and water-soluble polycyclic aromatic hydrocarbons (PAHs). PAHs are known to accumulate in sediment, producing liver and lip tumors in catfish and affecting mixed function oxidase systems of mammals, rendering a reduced immune response. In 1984, a study conducted by the U.S. Fish and Wildlife Service of sediment in Tabb's Bay, which receives discharged produced water as well as discharges from upstream industry (i.e., discharges from ships in the Houston Ship Channel), indicates severe degradation of the environment by PAH contamination. Sediment was collected from within 100 yards of several tidal discharge points of oil field produced water. Analytical results of these sediments indicated severe degradation of the environment by PAH contamination. The study noted that sediments contained no benthic fauna, and because of wave action, the contaminants were continuously resuspended, allowing chronic exposure of contaminants to the water column. It is concluded by the U.S. Fish and Wildlife Service that shrimp, crabs, oysters, fish, and fish-eating birds in this location have the potential to be heavily contaminated with PAHs. While these discharges have to be within Texas Water Quality Standards, these standards are for conventional pollutants and do not consider the water soluble components of oil that are in produced water such as PAHs.<sup>50</sup> (TX 55)<sup>51</sup>

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<sup>50</sup> NPDES permits have been applied for, but EPA has not issued permits for these discharges on the Gulf Coast. The Texas Railroad Commission (TRC) issues permits for these discharges. The TRC disagrees with the source of damage in this case.

<sup>51</sup> References for case cited: Letter from U.S. Department of the Interior, Fish and Wildlife Service, signed by H. Dale Hall, to Railroad Commission of Texas, discussing degradation of Tabb's Bay because of discharge of produced water in upstream estuaries; includes lab analysis for polycyclic aromatic hydrocarbons in Tabb's Bay sediment samples. Texas Railroad Commission Proposal for Decision on Petronilla Creek case documenting that something other than produced water is killing aquatic organisms in the creek. (Roy Spears, Texas Parks and Wildlife, did LC50 study on sunfish and sheepshead minnows using produced water and Aranssas Bay water. Produced water diluted to proper salinity caused mortality of 50 percent. (Seawater contains 19,000 ppm chlorides.)

These discharges are not in violation of existing regulations.

Produced water discharges contain a high ratio of calcium ions to magnesium ions. This high ratio of calcium to magnesium has been found by Texas Parks and Wildlife officials to be lethal to common Atlantic croaker, even when total salinity levels are within tolerable limits. In a bioassay study conducted by Texas Parks and Wildlife, this fish was exposed to various ratios of calcium to magnesium, and it was found that in 96-hour LC50 studies, mortality was 50 percent when exposed to calcium-magnesium ratios of 6:1, the natural ratio being 1:3. Nearly all of oil field produced water discharges on file with the Army Corps of Engineers in Galveston contain ratios exceeding the 6:1 ratio, known to cause mortality in Atlantic croaker as established by the LC50 test.<sup>52</sup> (TX 31)<sup>53</sup>

These discharges are not in violation of current regulations.

Until very recently, the Texas Railroad Commission (TRC) allowed discharge of produced water into Petronilla Creek, parts of which are 20 miles inland and not tidally affected.

For over 50 years, oil operators (including Texaco and Amoco) have been allowed to discharge produced water into Petronilla Creek, a supposedly tidally influenced creek. Discharge areas were as much as 20 miles inland and contained fresh water. In 1981, the pollution of Petronilla Creek from discharge of produced water became an issue when studies done by the Texas Parks and Wildlife and Texas Department of Water Resources documented the severe degradation of the water and damage to native fish and vegetation. All freshwater species of fish and vegetation were dead because of exposure to toxic constituents in discharge liquid. Portions of the creek were black or bright orange in color. Heavy oil slicks and oily slime were observable along discharge areas.

Impacts were observed in Baffin Bay, into which the creek empties. Petronilla Creek is the only freshwater source for Baffin Bay, which is a nursery for many fish and shellfish in the Gulf of Mexico. Sediments in Baffin Bay show elevated levels of toxic constituents found in Petronilla Creek. For 5 years, the Texas Department of Water Resources and Texas Parks and Wildlife, along with environmental groups, worked to have the discharges stopped. In 1981, a hearing was held by the Texas Railroad Commission (TRC). The conclusion of the hearing was that discharge of the produced water plus disposal of other trash by the public was degrading Petronilla Creek. The TRC initiated a joint committee (Texas Department of Water Resources, Texas Parks and Wildlife Department, and TRC) to establish the source of the trash, clean up

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<sup>52</sup> API comments in the Docket pertain to TX 31. API states that models show that "...rapid mixing in Bay waters results in no pollution to Bay waters as a whole from calcium ions or from the calcium-magnesium ratio."

<sup>53</sup> References for case cited: Toxic Effects of Calcium on the Atlantic Croaker: An Investigation of One Component of Oil Field Brine, by Kenneth N. Knudson and Charles E. Belaire, undated.

trash from the creek, and conduct additional studies. After this work was completed, a second hearing was held in 1984. The creek was shown to contain high levels of chromium, barium, oil, grease, and EPA priority pollutants naphthalene and benzene. Oil operators stated that a no dumping order would put them out of business because oil production in this area is marginal. In 1986, the TRC ordered a halt to discharge of produced water into nontidal portions of Petronilla Creek. (TX 29)<sup>54</sup>

Although discharges are now prohibited in this creek, they are allowed in other tidally affected areas.

Long-term environmental impacts associated with this type of discharge are unknown, because of limited documentation and analysis. Bioaccumulation of heavy metals in the food chain of estuaries could potentially affect human health through consumption of crabs, clams, and other foods harvested off the Texas Gulf Coast.

Alternatives to coastal discharge do exist. They include underground injection of produced water and use of produced water tanks. While the Texas Railroad Commission has not stopped the practice of coastal discharge, it is currently evaluating the need to preclude this type of discharge by collecting data from new applications, and it is seeking delegation of the NPDES program under the Federal Clean Water Act. The TRC currently asks applicants for tidal discharge permits to analyze the produced water to be discharged for approximately 20 to 25 constituents.

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<sup>54</sup> References for case cited: The Effects of Brine Water Discharges on Petronilla Creek, Texas Parks and Wildlife Department, 1981. Texas Department of Water Resources interoffice memorandum documenting spills in Petronilla Creek from 1980 to 1983. The Influence of Oilfield Brine Water Discharges on Chemical and Biological Conditions in Petronilla Creek, by Frank Shipley, Texas Department of Water Resources, 1984. Letter from Dick Whittington, EPA, to Richard Lowerre, documenting absence of NPDES permits for discharge to Petronilla Creek. Final Order of TRC, banning discharge of produced water to Petronilla Creek, 6/23/86. Numerous letters, articles, legal documents, on Petronilla Creek case.



## Leaching of Reserve Pit Constituents into Ground Water

Leaching of reserve pit constituents into ground water and soil is a problem in the Texas/Oklahoma zone. Reserve pit liners are generally not required in Texas and Oklahoma. When pits are constructed in permeable soil without liners, a higher potential exists for migration of reserve pit constituents into ground water and soil. Although pollutant migration may not always occur during the active life of the reserve pit, problems can occur after closure when dewatered drilling mud begins to leach into the surrounding soil. Pollutants may include chlorides, sodium, barium, chromium, and arsenic.

On November 20, 1981, the Michigan-Wisconsin Pipe Line Company began drilling an oil and gas well on the property of Ralph and Judy Walker. Drilling was completed on March 27, 1982. Unlined reserve pits were used at the drill site. After 2 months of drilling, the water well used by the Walkers became polluted with elevated levels of chloride and barium (683 ppm and 1,750 ppb, respectively). The Walkers were forced to haul fresh water from Elk City for household use. The Walkers filed a complaint with the Oklahoma Corporation Commission (OCC), and an investigation was conducted. The Michigan-Wisconsin Pipe Line Co. was ordered to remove all drilling mud from the reserve pit.

In the end, the Walkers retained a private attorney and sued Michigan-Wisconsin for damages sustained because of migration of reserve pit fluids into the freshwater aquifer from which they drew their domestic water supply. The Walkers won their case and received an award of \$50,000.<sup>55</sup> (OK 08)<sup>56</sup>

Constructing a reserve pit over a fractured shale, as in this case, is a violation of OCC rules.

In 1973, Horizon Oil and Gas drilled an oil well on the property of Dorothy Moore. As was the common practice, the reserve pit was dewatered, and the remaining mud was buried on site. In 1985-86, problems from the buried reserve pit waste began to appear. The reserve pit contents

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<sup>55</sup> API states that the Oklahoma Corporation Commission is in the process of developing regulations to prevent leaching of salt muds into ground water.

<sup>56</sup> References for case cited: Pretrial Order, Ralph Gail Walker and Judy Walker vs. Michigan-Wisconsin Pipe Line Company and Big Chief Drilling Company, U.S. District Court, Western District of Oklahoma, #CIV-82-1726-R. Direct Examination of Stephen G. McLin, Ph. D. Direct Examination of Robert Hall. Direct Examination of Laurence Alatshuler, M. D. Lab results from Walker water well.

were seeping into a nearby creek and pond. The surrounding soil had very high chloride content as established by Dr. Billy Tucker, an agronomist and soil scientist. Extensive erosion around the reserve pit became evident, a common problem with high-salinity soil. Oil slicks were visible in the adjacent creek and pond. An irrigation well on the property was tested by Dr. Tucker and was found to have 3000 ppm chlorides; however, no monitoring wells had been drilled to test the ground water prior to the drilling of the oil well, and background levels of chlorides were not established. Dorothy Moore has filed civil suit against the operator for damages sustained during the oil and gas drilling activity. The case is pending.<sup>57</sup>  
(OK 02)<sup>58</sup>

Oklahoma performance standards prohibit leakage of reserve pits into ground water.

### Chloride Contamination of Ground Water from Operation of Injection Wells

The Texas/Oklahoma zone contains a large number of injection wells used both for disposal of produced water and for enhanced or tertiary recovery projects. This large number of injection wells increases the potential for injection well casing leaks and the possibility of ground water contamination.

The Devore #1, a saltwater injection well located on the property of Ver1 and Virginia Hentges, was drilled in 1947 as an exploratory well. Shortly afterwards, it was permitted by the Oklahoma Corporation Commission (OCC) as a saltwater injection well. The injection formation, the Layton, was known to be capable of accepting 80 barrels per hour at 150 psi. In 1984, George Kahn acquired the well and the OCC granted an exception to Rule 3-305, Operating Requirements for Enhanced Recovery Injection and Disposal Wells, and permitted the well to inject 2,000 barrels per day at 400 psi. Later in 1984, it appeared that there was saltwater migration from the intended injection zone of the Devore #1 to the surface.<sup>59</sup> The Hentges alleged that the migrating salt water had polluted the ground water used on their ranch.

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<sup>57</sup> API comments in the Docket pertain to OK 02. API states that "...there is no evidence that there has been any seepage whatsoever into surface water." API states that there are no irrigation wells on Mrs. Moore's farm. Further, it states that erosion has been occurring for years and is the "...result of natural conditions coupled with the failure of Mrs. Moore to repair terraces to prevent or limit such erosion." API has not provided supporting documentation.

<sup>58</sup> References for case cited: Extensive soil and water analysis results collected and interpreted by Dr. Billy Tucker, agronomist and soil scientist, Stillwater, Okla. Correspondence and conversation with Randall Wood, private attorney, Stack and Barnes, Oklahoma City, Okla.

<sup>59</sup> Comments by API in the Docket pertain to OK 06. API states that "...tests on the well pressure test and tracer logs indicate the injection well is not a source of salt water." API has not provided documentation with this statement.

In addition, they alleged that the migrating salt water was finding its way to the surface and polluting Warren Creek, a freshwater stream used by downstream residents for domestic water. Salt water discharged to the surface had contaminated the soil and had caused vegetation kills. A report by the OCC concluded that "...the Devore #1 salt water disposal well operations are responsible for the contaminant plume in the adjacent alluvium and streams." The OCC required that a workover be done on the well. The workover was completed, and the operator continued to dispose of salt water in the well. The Hentges then sought private legal assistance and filed a lawsuit against George Kahn, the operator, for \$300,000 in actual damages and \$3,000,000 in punitive damages. The lawsuit is pending, scheduled for trial in October 1987.<sup>60</sup>  
(OK 06)<sup>61</sup>

Although at the time, the OCC permitted injection into the well at pressures that may have polluted the ground water, Oklahoma prohibits any contamination of drinking-water aquifers.

### Illegal Disposal of Oil and Gas Wastes

Illegal disposal of oil and gas exploration and production wastes is a common problem in the Texas/Oklahoma zone. Illegal disposal can take many forms, including breaching of reserve pits, emptying of vacuum trucks into fields and ditches, and draining of produced water onto the land surface. Damage to surface soil, vegetation, and surface water may result as illustrated by the examples below.

On May 16, 1984, Esenjay Petroleum Co. had completed the L.W. Bing #1 well at a depth of 9,900 feet and had hired T&L Lease Service to clean up the drill site. During cleanup, the reserve pit, containing high-chromium drilling mud, was breached by T&L Lease Service, allowing drilling mud to flow into a tributary of Hardy Sandy Creek. The drilling mud was up to 24 inches deep along the north bank of Hardy Sandy. Drilling mud had been pushed into the trees and brush adjacent to the drill site. The spill was reported to the operator and the Texas Railroad Commission (TRC). The TRC ordered cleanup, which began on May 20.

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<sup>60</sup> API states that the operator now believes old abandoned saltwater pits to be the source of contamination as the well now passes UIC tests.

<sup>61</sup> References for case cited: Remedial Action Plan for Aquifer Restoration within Section #2, Township 21 North, Range 2 West, Noble County, Oklahoma, by Stephen G. McLin, Ph. D. Surface Pollution at the De Vore #1 Saltwater Disposal Site, Oklahoma Corporation Commission, 1986. District Court of Noble County, Amended Petition, Verl E. Hentges and Virginia L. Hentges vs. George Kahn, #C-84-110, 7/25/85. Lab analysis records of De Vore well from Oklahoma Corporation Commission and Southwell Labs. Communication with Alan DeVore, plaintiffs' attorney.

Because of high levels of chromium contained in the drilling mud, warnings were issued by the Lavaca-Navidad River Authority to residents and landowners downstream of the spill as it represented a possible health hazard to cattle watering from the affected streams. The River Authority also advised against eating the fish from the affected waters because of the high chromium levels in the drilling mud. (TX 21)<sup>62</sup>

This discharge was a violation of State and Federal regulations.

On September 15, 1983, TXO Production Company began drilling its Dunn Lease Well No. B2 in Live Oak County. On October 5, 1983, employees of TXO broke the reserve pit levee and began spreading drilling mud downhill from the site, towards the fence line of property owned by the Dunns. By October 9, the mud had entered the draw that flows into two stock tanks on the Dunn property. On November 24 and 25, dead fish were observed in the stock tank. On December 17, Texas Parks and Wildlife documented over 700 fish killed in the stock tanks on the Dunn property. Despite repeated requests by the Dunns, TXO did not clean up the drilling mud and polluted water from the Dunn property.

Lab results from TRC and Texas Department of Health indicated that the spilled drilling mud was high in levels of arsenic, barium, chromium, lead, sulfates, other metals, and chlorides. In February 1984, the TRC stated that the stock tanks contained unacceptable levels of nitrogen, barium, chromium, and iron, and that the chemicals present were detrimental to both fish and livestock. (The Dunns water their cows at this same stock tank.) After further analysis, the TRC issued a memorandum stating that the fish had died because of a cold front moving through the area, in spite of the fact that the soil, sediment, and water in and around the stock pond contained harmful substances. Ultimately, TXO was fined \$1,000 by the TRC, and TXO paid the Dunns a cash settlement for damages sustained.<sup>63</sup> (TX 22)<sup>64</sup>

This activity was in violation of Texas regulations.

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<sup>62</sup> References for case cited: Memorandum from Lavaca-Navidad River Authority documenting events of Esenjay reserve pit discharge, 6/27/84, signed by J. Henry Neason. Letter to TRC from Lavaca-Navidad River Authority thanking the TRC for taking action on the Esenjay case, "Thanks to your enforcement actions, we are slowly educating the operators in this area on how to work within the law." Agreed Order, Texas Railroad Commission, #2-83,043, 11/12/84, fining Esenjay \$10,000 for deliberate discharge of drilling muds. Letter from U.S. EPA to TRC inviting TRC to attend meeting with Esenjay Petroleum to discuss discharge of reserve pit into Hardy Sandy Creek, 6/1/84, signed by Thomas G. Giesberg. Texas Railroad Commission spill report on Esenjay operations, 5/18/84.

<sup>63</sup> API states that the fish died from oxygen depletion of the water. The Texas Railroad Commission believes that the fish died from exposure to cold weather.

<sup>64</sup> References for case cited: Texas Railroad Commission Motion to Expand Scope of Hearing, #2-82,919, 6/29/84. Texas Railroad Commission Agreed Order, #2-82,919, 12/17/84. Analysis by Texas Veterinary Medical Diagnostic Laboratory System on dead fish in Dunn stock tank. Water and soil sample analysis from the Texas Railroad Commission. Water and soil samples from the Texas Department of Health. Letter from Wendell Taylor, TRC, to Jerry Mullican, TRC, stating that the fish kill was the result of cold weather, 7/13/84. Miscellaneous letters and memos.

## NORTHERN MOUNTAIN

The Northern zone includes Idaho, Montana, and Wyoming. Idaho has no commercial production of oil or gas. Montana has moderate oil and gas production. Wyoming has substantial oil and gas production and accounts for all the damage cases discussed in this section.

### Operations

Significant volumes of both oil and gas are produced in Wyoming. Activities range from small, marginal operations to major capital- and energy-intensive projects. Oil production comes both from mature fields producing high volumes of produced water and from newly discovered fields, where oil/water ratios are still relatively low. Gas production comes from mature fields as well as from very large new discoveries.

Although the average new well drilled in Wyoming in 1985 was about 7,150 feet, exploration in the State can be into strata as deep as 25,000 feet. In 1985, 1,332 new wells were completed in Wyoming, of which 541 were exploratory.

### Types of Operators

Because of the capital-intensive nature of secondary and tertiary recovery projects and large-scale drilling projects, many operations in the State are conducted by the major oil companies. These companies are likely to implement environmental controls properly during drilling and completion and are generally responsible in carrying out their well abandonment obligations. Independents also operate in Wyoming, producing

a significant amount of oil and gas in the State. Independent operators may be more vulnerable to fluctuating market conditions and may be more likely to maintain profitability at the expense of environmental protection.

## Major Issues

### Illegal Disposal of Oil and Gas Wastes

Wyoming Department of Environmental Quality officials believe that illegal disposal of wastes is the most pervasive environmental problem associated with oil and gas operations in Wyoming. Enforcement of State regulations is made difficult as resources are scarce and areas to be patrolled are large and remote. (See Table VII-7.)

Altex Oil Company and its predecessors have operated an oil production field for several decades south of Rozet, Wyoming. (Altex purchased the property in 1984.) An access road runs through the area, which, according to Wyoming Department of Environmental Quality (WDEQ), for years was used as a drainage for produced water from the oil field operations.

In August of 1985, an official with WDEQ collected soil samples from the road ditch to ascertain chloride levels because it had been observed that trees and vegetation along the road were dead or dying. WDEQ analysis of the samples showed chloride levels as high as 130,000 ppm. The road was chained off in October of 1985 to preclude any further illegal disposal of produced water.<sup>65</sup> (WY 03)<sup>66</sup>

In early October 1985, Cities Service Oil Company had completed drilling at a site northeast of Cheyenne on Highway 85. The drilling contractor, Z&S Oil Construction Company, was suspected of illegally disposing of drilling fluids at a site over a mile away on the Pole Creek Ranch. An employee of Z&S had given an anonymous tip to a County detective. A stake-out of the

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<sup>65</sup> Comments in the Docket from the Wyoming Oil and Gas Conservation Commission (WOGCC) (Mr. Don Basko) pertain to WY 03. WOGCC states that "...not all water from Altex Oil producing wells... caused the contamination problem." Further, WOGCC states that "Illegal dumping, as well as a flow line break the previous winter, had caused a high level of chloride in the soil which probably contributed to the sagebrush and cottonwood trees dying."

<sup>66</sup> References for case cited: Analysis of site by the Wyoming Department of Environmental Quality (WDEQ), Quality Division Laboratory, File #ej52179, 12/6/85. Photographs of dead and dying cottonwood trees and sagebrush in and around site. Conversation with WDEQ officials.

illegal operation was made with law enforcement and WDEQ personnel. Stake-out personnel took samples and photos of the reserve pit and the dump site. During the stake-out, vacuum trucks were witnessed draining reserve pit contents down a slope and into a small pond on the Pole Creek Ranch. After sufficient evidence had been gathered, arrests were made by Wyoming law enforcement personnel, and the trucks were impounded. The State sued Z&S and won a total of \$10,000. (WY 01)<sup>67</sup>

This activity was in violation of Wyoming regulations.

During the week of April 8, 1985, field personnel at the Byron/Garland field operated by Marathon Oil Company were cleaning up a storage yard used to store drums of oil field chemicals. Drums containing discarded production chemicals were punctured by the field employees and allowed to drain into a ditch adjacent to the yard. Approximately 200 drums containing 420 gallons of fluid were drained into the trench. The chemicals were demulsifiers, reverse demulsifiers, scale and corrosion inhibitors, and surfactants. Broken transformers containing PCBs were leaking into soil in a nearby area. Upon discovery of the condition of the yard, Wyoming Department of Environmental Quality (WDEQ) ordered Marathon to begin cleanup procedures. At the request of the WDEQ, ground-water monitors were installed, and monitoring of nearby Arnoldus Lake was begun. The State filed a civil suit against Marathon and won a \$5000 fine and \$3006 in expenses for lab work.<sup>68</sup> (WY 05)<sup>69</sup>

This activity was in direct violation of Wyoming regulations.

### Reclamation Problems

Although Wyoming's mining industry has rules governing reclamation of sites, no such rules exist covering oil and gas operations. As a result, reclamation on privately owned land is often inadequate or entirely lacking, according to WDEQ officials. By contrast, reclamation on Federal lands is believed to be consistently more thorough, since Federal

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<sup>67</sup> References for case cited: WDEQ memorandum documenting chronology of events leading to arrest of Z&S employees and owners. Lab analysis of reserve pit mud and effluent, and mud and effluent found at dump site. Consent decree from District Court of First Judicial District, Laramie County, Wyoming, docket #108-493, The People of the State of Wyoming vs. Z&S Construction Company. Photographs of vacuum trucks dumping at Pole Creek Ranch.

<sup>68</sup> API states that the operator, thinking the drums had to be empty before transport offsite, turned the drums upside down and drained 420 gallons of chemicals into the trench.

<sup>69</sup> References for case cited: Summary of Byron-Garland case by Marathon employee J. C. Fowler. List of drums, contents, and field uses. Cross-section of disposal trench area. Several sets of lab analyses. Map of Garland field disposal yard. Newspaper articles on incident. District court consent decree, The People of the State of Wyoming vs. Marathon Oil Company, #108-87.

leases specify reclamation procedures to be used on specific sites. WDEQ officials state that this will be of growing concern as the State continues to be opened up to oil and gas development.<sup>70</sup>

WDEQ officials have photographs and letters from concerned landowners, regarding reclamation problems, but no developed cases. The Wyoming Oil and Gas Conservation Commission submitted photographs documenting comparable reclamation on both Federal and private lands. The issue is at least partially related to drilling waste management, since improper reclamation of sites often involves inadequate dewatering of reserve pits before closure. As a result of this inadequate dewatering, reserve pit constituents, usually chlorides, are alleged to migrate up and out of the pit, making revegetation difficult. The potential also exists for migration of reserve pit constituents into ground water.

#### Discharge of Produced Water into Surface Streams

Because much of the produced water in Wyoming is relatively low in chlorides, several operations under the beneficial use provision of the Federal NPDES permit program are allowed to discharge produced water directly into dry stream beds or live streams. The practice of chronic discharge of low-level pollutants may be harmful to aquatic communities in these streams, since residual hydrocarbons contained in produced water appear to suppress species diversity in live streams.

A study was undertaken by the Columbia National Fisheries Research Laboratory of the U. S. Fish and Wildlife Service to determine the effect of continuous discharge of low-level oil effluent into a stream and the resulting effect on the aquatic community in the stream. The discharges to the stream contained 5.6 mg/L total hydrocarbons. Total hydrocarbons in the receiving sediment were 979 mg/L to 2,515 mg/L. During the study, samples were taken upstream

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<sup>70</sup> WOGCC disagrees with WDEQ on this statement.



and downstream from the discharge. Species diversity and community structure were studied. Water analysis was done on upstream and downstream samples. The study found a decrease in species diversity of the macrobenthos community (fish) downstream from the discharge, further characterized by total elimination of some species and drastic alteration of community structure. The study found that the downstream community was characterized by only one dominant species, while the upstream community was dominated by three species. Total hydrocarbon concentrations in water and sediment increased 40 to 55 fold downstream from the discharge of produced water. The authors of the study stated that "...based on our findings, the fisheries and aquatic resources would be protected if discharge of oil into fresh water were regulated to prevent concentrations in receiving streams water and sediment that would alter structure of macrobenthos communities." (WY 07)<sup>71</sup>

These discharges are permitted under NPDES.

## SOUTHERN MOUNTAIN

The Southern Mountain zone includes the States of Nevada, Utah, Arizona, Colorado, and New Mexico. All five States have some oil and gas production, but New Mexico's is the most significant. The discussion below is limited to New Mexico.

### Operations

Although hydrocarbon production is scattered throughout New Mexico, most comes from two distinct areas within the State: the Permian Basin in the southeast corner and the San Juan Basin in the northwest corner.

Permian Basin production is primarily oil, and it is derived from several major fields. Numerous large capital- and energy-intensive enhanced recovery projects within the basin make extensive use of CO<sub>2</sub> flooding. The area also contains some small fields in which production

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<sup>71</sup> References for case cited: Petroleum Hydrocarbon Concentrations in a Salmonid Stream Contaminated by Oil Field Discharge Water and Effects on the Macrobenthos Community, by D.F. Woodward and R.G. Riley, U.S. Department of the Interior, Fish and Wildlife Service, Columbia National Fisheries Research Laboratory, Jackson, Wyoming, 1980; submitted to Transactions of the American Fisheries Society.

is derived from marginal stripper operations. This is a mature production area that is unlikely to see extensive exploration in the future. The Tucumcari Basin to the north of the Permian may, however, experience extensive future exploration if economic conditions are favorable.

The San Juan Basin is, for the most part, a large, mature field that produces primarily gas. Significant gas finds are still made, including many on Indian Reservation lands. As Indian lands are gradually opened to oil and gas development, exploration and development of the basin as a whole will continue and possibly increase.

Much of the State has yet to be explored for oil and gas. The average depth of new wells drilled in 1985 was 6,026 feet. The number of new wells drilled in 1985 was 1,734, of which 281 were exploratory.

#### Types of Operators

The capital- and energy-intensive enhanced recovery projects in the Permian Basin, as well as the exploratory activities under way around the State, are conducted by the major oil companies. Overall, however, the most numerous operators are small and medium-sized independents. Small independents dominate marginal stripper production in the Permian Basin. Production in the San Juan Basin is dominated by midsize independent operators.

#### Major Issues

##### Produced Water Pit and Oil Field Waste Pit Contents Leaching into Ground Water

New Mexico, unlike most other States, still permits the use of unlined pits for disposal of produced water. This practice has the potential for contamination of ground water.

In July 1985, a study was undertaken in the Duncan Oil Field in the San Juan Basin by faculty members in the Department of Chemistry at New Mexico State University, to analyze the potential for unlined produced water pit contents, including hydrocarbons and aromatic hydrocarbons, to migrate into the ground water. The oil field is situated in a flood plain of the San Juan River. The site chosen for investigation by the study group was similar to at least 1,500 other nearby production sites in the flood plain. The study group dug test pits around the disposal pit on the chosen site. These test pits were placed abovegradient and downgradient of the disposal pit, at 25- and 50-meter intervals. A total of 9 test pits were dug to a depth of 2 meters, and soil and ground-water samples were obtained from each test pit. Upon analysis, the study group found volatile aromatic hydrocarbons were present in both the soil and water samples of test pits downgradient, demonstrating migration of unlined produced water pit contents into the ground water.

Environmental impact was summarized by the study group as contamination of shallow ground water with produced water pit contents due to leaching from an unlined produced water disposal pit. Benzene was found in concentrations of 0.10 ppb. New Mexico Water Quality Control Commission standard is 10 ppb. Concentrations of ethylbenzene, xylenes, and larger hydrocarbon molecules were found. No contamination was found in test pits placed abovegradient from the disposal pit. Physical signs of contamination were also present, downgradient from the disposal pit, including black, oily staining of sands above the water table and black, oily film on the water itself. Hydrocarbon odor was also present. (NM 02)<sup>72</sup>

It is now illegal to dispose of more than five barrels per day of produced water into unlined pits in this part of New Mexico.

As a result of this study, the use of unlined produced water pits was limited by the State to wells producing no more than five barrels per day of produced water. While this is a more stringent requirement than the previous rule, the potential for contamination of ground water with hydrocarbons and chlorides still exists. It is estimated by individuals familiar with the industry in the State that 20,000 unlined emergency

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<sup>72</sup> References for case cited: Hydrocarbons and Aromatic Hydrocarbons in Groundwater Surrounding an Earthen Waste Disposal Pit for Produced Water in the Duncan Oil Field of New Mexico, by G.A. Eiceman, J.T. McConnon, Masud Zaman, Chris Shuey, and Douglas Earp, 9/16/85. Polycyclic Aromatic Hydrocarbons in Soil at Groundwater Level Near an Earthen Pit for Produced Water in the Duncan Oil Field, by B. Davani, K. Lindley, and G.A. Eiceman, 1986. New Mexico Oil Conservation Commission hearing to define vulnerable aquifers, comments on the hearing record by Intervenor Chris Shuey, Case No. 8224.

produced water disposal pits are still in existence in the San Juan Basin area of New Mexico.<sup>73</sup>

New Mexico has experienced problems that may be due to centralized oil field waste disposal facilities:

Lee Acres "modified" landfill (meaning refuse is covered weekly instead of daily as is done in a "sanitary" landfill) is located 4.5 miles E-SE of Farmington, New Mexico. It is owned by the U.S. Bureau of Land Management (BLM). The landfill is approximately 60 acres in size and includes four unlined liquid-waste lagoons or pits, three of which were actively used. Since 1981, a variety of liquid wastes associated with the oil and gas industry have been disposed of in the lagoons. The predominant portion of liquid wastes disposed of in the lagoons was produced water, which is known to contain aromatic volatile organic compounds (VOCs). According to the New Mexico Department of Health and Environment, Environmental Improvement Division, 75 to 90 percent of the produced water disposed of in the lagoons originated from Federal and Indian oil and gas leases managed by BLM. Water produced on these leases was hauled from as far away as Nageezi, which is 40 miles from the Lee Acres site. Disposal of produced water in these unlined pits was, according to New Mexico State officials, in direct violation of BLM's rule NTL-2B, which prohibits, without prior approval, disposal of produced waters into unlined pits, originating on Federally owned leases. The Department of the Interior states that disposal in the lagoons was "...specifically authorized by the State of New Mexico for disposal of produced water." The State of New Mexico states that "There is no truth whatsoever to the assertion that the landfill lagoons were specifically authorized by the State of New Mexico for disposal of produced water." Use of the pits ceased on 4/19/85; 8,800 cubic yards of waste were disposed of prior to closure.

New Mexico's Environmental Improvement Division (NMEID) asserts that leachate from the unlined waste lagoons that contain oil and gas wastes has contributed to the contamination of several water wells in the Lee Acres housing subdivision located downgradient from the lagoons and downgradient from a refinery operated by Giant, located nearby. NMEID has on file a soil gas survey that documents extensive contamination with chlorinated VOCs at the landfill site. High levels of sodium, chlorides, lead, chromium, benzene, toluene, xylenes, chloroethane, and trichloroethylene were found in the waste lagoons. An electromagnetic terrain survey of the Lee Acres landfill site and surrounding area, conducted by NMEID, located a plume of contaminated ground water extending from the landfill. This plume runs into a plume of contamination known to exist, emanating from the refinery. The plumes have become mixed and are the source of

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<sup>73</sup> Governor Carruthers refutes this and states that "Unlined pits in fresh water areas in Southeast New Mexico were banned beginning in 1956, with a general prohibition adopted in 1967." EPA notes that New Mexico still permits unlined pits to be used for disposal of produced water if the pit does not receive more than five barrels of produced water per day.

contamination of the ground water serving the Lee Acres housing subdivision.<sup>74</sup> One domestic well was sampled extensively by NMEID and was found to contain extremely high levels of chlorides and elevated levels of chlorinated VOCs, including trichloroethane. (Department of the Interior (DOI) states that it is unaware of any violations of New Mexico ground-water standards involved in this case. New Mexico states that State ground-water standards for chloride, total dissolved solids, benzene, xylenes, 1,1-dichloroethane, and ethylene dichloride have been violated as a result of the plume of contamination. In addition, the EPA Safe Drinking Water Standard for trichloroethylene has been violated.) New Mexico State officials state that "The landfill appears to be the principal source of chloride, total dissolved solids and most chlorinated VOCs, while the refinery appears to be the principal source of aromatic VOCs and ethylene dichloride."

During the period after disposal operations ceased and before the site was closed, access to the lagoons was essentially unrestricted. While NMEID believes that it is possible that non-oil and gas wastes illegally disposed of during this period may have contributed to the documented contamination, the primary source of ground-water contamination appears to be from oil and gas wastes.

The State has ordered BLM to provide public water to residents affected by the contamination, develop a ground-water monitoring system, and investigate the types of drilling, drilling procedures, and well construction methods that generated the waste accepted by the landfill. BLM submitted a motion-to-stay the order so as to include Giant Refining Company and El Paso Natural Gas in cleanup operations. The motion was denied. The case went into litigation. According to State officials, "The State of New Mexico agreed to dismiss its lawsuit only after the Bureau of Land Management agreed to conduct a somewhat detailed hydrogeologic investigation in a reasonably expeditious period of time. The lawsuit was not dismissed because of lack of evidence of contamination emanating from the landfill." The refinery company has completed an

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In a letter dated 8/20/87, Giant Refining Company states that "Benzene, toluene and xylenes are naturally occurring compounds in crude oil, and are consequently in high concentrations in the produced water associated with that crude oil. The only gasoline additive used by Giant that has been found in the water of a residential well is DCA (ethylene dichloride) which has also been found in the landfill plume." Giant also notes that the refinery leaks in the last 2 years resulted in less than 30,000 gallons of diesel being released rather than the 100,000 gallons stated by the Department of Interior in a letter to EPA of 8/11/87.

extensive hydrogeologic investigation and has implemented containment and cleanup measures.<sup>75</sup> (NM 05)<sup>76</sup>

Current New Mexico regulations prohibit use of unlined commercial disposal pits.

### Damage to Ground Water from Inadequately Maintained Injection Wells

As in other States, New Mexico has experienced problems with injection wells.

A saltwater injection well, the B0-3, operated by Texaco, is used for produced water disposal for the Moore-Devonian oil field in southeastern New Mexico. Injection occurs at about 10,000 ft. The Ogallala aquifer, overlying the oil production formation, is the sole source of potable ground water in much of southeastern New Mexico. Dr. Daniel B. Stephens, Associate Professor of Hydrology at the New Mexico Institute of Mining and Technology, concluded that injection well B0-3 has contributed to a saltwater plume of contamination in the Ogallala aquifer. The plume is nearly 1 mile long and contains chloride concentrations of up to 26,000 ppm.

A local rancher sustained damage to crops after irrigating with water contaminated by this saltwater plume. In 1973, an irrigation well was completed satisfactorily on the ranch of Mr. Paul Hamilton, and, in 1977, the well began producing water with chlorides of 1,200 ppm. Mr. Hamilton's crops were severely damaged, resulting in heavy economic losses, and his farm property was foreclosed on. There is no evidence of crop damage from irrigation prior to 1977. Mr. Hamilton initiated a private law suit against Texaco for damages sustained to his ranch. Texaco argued that the saltwater plume was the result of leachate of brines from unlined brine disposal pits, now banned in the area. Dr. Stephens proved that if old pits in the vicinity,

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<sup>75</sup> Comments in the Docket from BLM and the State of New Mexico pertain to NM 05. BLM states that the refinery upgradient from the subdivision is responsible for the contamination because of their "...extremely sloppy housekeeping practices..." which resulted in the loss of "...hundreds of thousands of gallons of refined product through leaks in their underground piping system." The Department of the Interior states that "There is, in fact, mounting evidence that the landfill and lagoons may have contributed little to the residential well contamination in the subdivisions." DOI states "...we strongly recommend that this case be deleted from the Damage Cases [Report to Congress]." "New Mexico states that "EID [Environmental Improvement Division] strongly believes that the Lee Acres Landfill has caused serious ground water contamination and is well worth inclusion in the Oil and Gas Damage Cases chapter of your [EPA] Report to Congress on Oil, Gas and Geothermal Wastes."

<sup>76</sup> References for case cited: State of New Mexico Administrative Order No. 1005; contains water analysis for open pits, monitor wells, and impacted domestic wells. Motion-to-stay Order No. 1005. Denial of motion to stay. Newspaper articles. Southwest Research and Information Center, Response to Hearing before Water Quality Control Commission, 12/2/86. Letter to Dan Derkics, EPA, from Department of the Interior, refuting Lee Acres damage case, 8/11/87. Letter to Dan Derkics, EPA, from NMEID, refuting Department of the Interior letter of 8/11/87, dated 8/18/87. Letter to Dan Derkics, EPA, from Giant Refining Company, 8/20/87.

previously used for saltwater disposal, had caused the contamination, high chloride levels would have been detected in the irrigation well prior to 1977. Dr. Stephens also demonstrated that the B0-3 injection well had leaked some 20 million gallons of brine into the fresh ground water, causing chloride contamination of the Ogallala aquifer from which Mr. Hamilton drew his irrigation water. Based on this evidence a jury awarded Mr. Hamilton a cash settlement from Texaco for damages sustained both by the leaking injection well and by the abandoned disposal pits. The well has had workovers and additional pressure tests since 1978. The well is still in operation, in compliance with UIC regulations. (NM 01)<sup>77</sup>

Current UIC regulations require mechanical integrity testing every 5 years for all Class II wells.

The well in the above case was tested for mechanical integrity several times during the course of the trial, during which the plaintiff's hydrologist, after contacting the Texas Railroad Commission, discovered that this injection well would have been classed as a failed well using criteria established by the State of Texas for such tests. However, at the time, the well did not fail the test using criteria established by the State of New Mexico. Both States have primacy under the UIC program.

## WEST COAST

The West Coast zone includes Washington, Oregon, and California. Of the three states, California has the most significant hydrocarbon production; Washington and Oregon have only minor oil and gas activity. Damage cases were collected only in California.

### Operations

California has a diverse oil and gas industry, ranging from stripper production in very mature fields to deep exploration and large enhanced recovery operations. Southern California and the San Joaquin Valley are dominated by large capital- and energy-intensive enhanced recovery

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<sup>77</sup> References for case cited: Oil-Field Brine Contamination - A Case Study, Lea Co. New Mexico, from Selected Papers on Water Quality and Pollution in New Mexico - 1984; proceedings of a symposium, New Mexico Bureau of Mines and Resources.

projects, while the coastal fields are experiencing active exploration. California's most mature production areas are in the lower San Joaquin Valley and the Sacramento Basin. The San Joaquin produces both oil and gas. The Sacramento Valley produces mostly gas.

The average depth of new wells drilled in California in 1985 was 4,176 feet. Some 3,413 new wells were completed in 1985, 166 of which were exploratory.

### Types of Operators

Operators in California range from small independents to major producers. The majors dominate capital- and energy-intensive projects, such as coastal development and large enhanced recovery projects. Independents tend to operate in the mature production areas dominated by stripper production.

### Major Issues

#### Discharge of Produced Water and Oily Wastes to Ephemeral Streams

In the San Joaquin Valley, the State has long allowed discharge of oily high-chloride produced water to ephemeral streams. After discharge to ephemeral streams, the produced water is diverted into central sumps for disposal through evaporation and percolation. Infiltration of produced water into aquifers is assumed to occur, but official opinion on its potential for damage is divided. Some officials take the position that the aquifers are naturally brackish and thus have no beneficial use for agriculture or human consumption. A report by the Water Resources Control Board, however, suggests that produced water may percolate into useable ground-water structures.



For the purposes of this study conducted by Bean/Logan Consulting Geologists, ground water in the study area was categorized according to geotype and compared to produced water in sumps that came from production zones. Research was conducted on sumps in Cymric Valley, Mckittrick Valley, Midway Valley, Elk Hills, Buena Vista Hills, and Buena Vista Valley production fields. While this recent research was not investigating ground-water damages per se, the study suggests obvious potential for damages relating to the ground water. The hydrogeologic analysis prepared for the California State Water Resources Control Board concludes that about 570,000 tons of salt from produced water were deposited in 1981 and that a total of 14.8 million tons have been deposited since 1960. The California Water Resources Board suspects that a portion of the salt has percolated into the ground water and has degraded it. In addition to suspected degradation of ground water, officers of the California Department of Fish and Game often find birds and animals entrapped in the oily deposits in the affected ephemeral streams. Exposure to the oily deposits often proves to be fatal to these birds and animals.<sup>78</sup> (CA 21)<sup>79</sup>

This is a permitted practice under current California regulations.

Aside from concerns over chronic degradation of ground water, this practice of discharge to ephemeral streams can cause damage to wildlife. The volume of wastes mixed with natural runoff sometimes exceeds the holding capacity of the ephemeral streams. The combined volume may then overflow the diversions to the sump areas and continue downstream, contaminating soil and endangering sensitive wildlife habitat. The oil and gas industry contends that it is rare for any wastes to pass the diversions set up to channel flow to the sumps, but the California Department of Fish and Game believes that it is a common occurrence.

Produced water from the Crocker Canyon area flows downstream to where it is diverted into Valley Waste Disposal's large unlined evaporation/percolation sumps for oil recovery (cooperatively operated by local oil producers). In one instance, discovery by California Fish and Game officials of a significant spill was made over a month after it occurred. According to the California State Water Quality Board, the incident was probably caused by heavy rainfall, as a consequence of which the volume of rain and waste exceeded the containment capacity of the disposal facility. The sumps became eroded, allowing oily waste to flow down the valley and into a wildlife habitat occupied by several endangered species including blunt-nosed leopard lizards, San Joaquin kit foxes, and giant kangaroo rats.

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<sup>78</sup> API states that the California Regional Water Quality Board and EPA are presently deciding whether to promulgate additional permit requirements under the Clean Water Act and NPDES.

<sup>79</sup> References for case cited: Lower Westside Water Quality Investigation Kern County, and Lower Westside Water Quality Investigation Kern County: Supplementary Report, Bean/Logan Consulting Geologists, 11/83; prepared for California State Water Resources Control Board. Westside Groundwater Study, Michael R. Rector, Inc., 11/83; prepared for Western Oil and Gas Association.

According to the State's report, there were 116 known wildlife losses including 11 giant kangaroo rats. The count of dead animals was estimated at only 20 percent of the actual number of animals destroyed because of the delay in finding the spill, allowing poisoned animals to leave the area before dying. Vegetation was covered with waste throughout the spill area. The California Department of Fish and Game does not believe this to be an isolated incident. The California Water Resources Control Board, during its investigation of the incident, noted "...deposits of older accumulated oil, thereby indicating that the same channel had been used for wastewater disposal conveyance in the past prior to the recent discharge. Cleanup activities conducted later revealed that buildup of older oil was significant." The companies implicated in this incident were fined \$100,000 and were required to clean up the area. The companies denied responsibility for the discharge. (CA 08)<sup>80</sup>

This release was in violation of California regulations.

## ALASKA

The Alaska zone includes Alaska and Hawaii. Hawaii has no oil or gas production. Alaska is second only to Texas in oil production.

### Operations

Alaska's oil operations are divided into two entirely separate areas, the Kenai Peninsula (including the western shore of Cook Inlet) and the North Slope. Because of the areas' remoteness and harsh climate, operations in both areas are highly capital- and energy-intensive. For the purposes of damage case development, and indeed for most other types of analysis, operations in these two areas are distinct. Types of damages identified in the two areas have little in common.

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<sup>80</sup> References for case cited: Report of Oil Spill in Buena Vista Valley, by Mike Glinzak, California Division of Oil and Gas (DOG), 3/6/86; map of site and photos accompany the report. Letters to Sun Exploration and Production Co. from DOG, 3/12 and 3/31/86. Newspaper articles in Bakersfield Californian, 3/8/86, 3/11/86, and undated. California Water Quality Control Board, Administrative Civil Liability Complaint #ACL-016, 8/8/86. California Water Quality Control Board, internal memoranda. Smith to Pfister concerning cleanup of site, 5/27/86; Smith to Nevins concerning description of damage and investigation, including map, 8/12/86. California Department of Fish and Game, Dead Endangered Species in a California Oil Spill, by Capt. E.A. Simons and Lt. M. Akin, undated. Fact Sheets: Buena Vista Creek Oil Spill, Kern County, 3/7/86, and Mammals Occurring on Elk Hills and Buena Vista Hills, undated. Letter from Lt. Akin to EPA contractor, 2/24/87.

Activities on the Kenai Peninsula have been in progress since the late 1950s, and gas is the primary product. Production levels are modest as compared to those on the North Slope.

North Slope operations occur primarily in the Prudhoe Bay area, with some smaller fields located nearby. Oil is the primary product. Production has been under way since the trans-Alaska pipeline was completed in the mid 1970s. Much of the oil recovery in this area is now in the secondary phase, and enhanced recovery through water flooding is on the increase.

There were 100 wells drilled in the State in 1985, all of them on the North Slope. In 1985, one exploratory well was drilled in the National Petroleum Reserve - Alaska (NPRA) and two development wells were drilled on the Kenai Peninsula.

### Types of Operators

There are no small, independent oil or gas operators in Alaska because of the high capital requirements for all activities in the region. Operators in the Kenai Peninsula include Union Oil of California and other major companies. Major producers on the North Slope are ARCO and Standard Alaska Production Company.

### Major Issues

#### Reserve Pits, North Slope

Reserve pits on the North Slope are usually unlined and made of permeable native sands and gravels. Very large amounts of water flow in this area during breakup each spring in the phenomenon known as "sheet flow." Some of this water may unavoidably flow into and out of the reserve pits; however, the pits are designed to keep wastes in and keep

surface waters out. Discharge of excess liquids from the pits directly onto the tundra is permitted under regulations of the Alaska Department of Environmental Conservation (ADEC) if discharge standards are met. (See summary on State rules and regulations.)

Through the processes of breakup and discharge, ADEC estimates that 100 million gallons of supernatant are pumped onto the tundra and roadways each year,<sup>81</sup> potentially carrying with it reserve pit constituents such as chromium, barium, chlorides, and oil. Scientists who have studied the area believe this has the potential to lead to bioaccumulation of heavy metals and other contaminants in local wildlife, thus affecting the food chain. However, no published studies that demonstrate this possibility exist. Results from preliminary studies suggest that the possibility exists for adverse impact to Arctic wildlife because of discharge of reserve pit supernatant to the tundra:

In 1983, a study of the effects of reserve pit discharges on water quality and the macroinvertebrate community of tundra ponds was undertaken by the U. S. Fish and Wildlife Service in the Prudhoe Bay oil production area of the North Slope. Discharge to the tundra ponds is a common disposal method for reserve pit fluid in this area. The study shows a clear difference in water quality and biological measures among reserve pits, ponds receiving discharges from reserve pits (receiving ponds), distant ponds affected by discharges through surface water flow, and control ponds not affected by discharges. Ponds directly receiving discharges had significantly greater concentrations of chromium, arsenic, cadmium, nickel, and barium than did control ponds, and distant ponds showed significantly higher levels of chromium than did control ponds. Chromium levels in reserve pits and in ponds adjacent to drill sites may have exceeded EPA chronic toxicity criteria for protection of aquatic life. (AK 06)<sup>82</sup>

These discharges were permitted by the State of Alaska. No NPDES permits have been issued for these discharges. New Alaska regulations have more stringent effluent limits.

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<sup>81</sup> Statement by Larry Dietrick to Carla Greathouse.

<sup>82</sup> References for case cited: The Effects of Prudhoe Bay Reserve Pit Fluids on the Water Quality and Macroinvertebrates of Tundra Ponds, by Robin L. West and Elaine Snyder-Conn, Fairbanks Fish and Wildlife Enhancement Office, U.S. Fish and Wildlife Service, Fairbanks, Alaska, 9/87.

In the summer of 1985, a field method was developed by the U. S. Fish and Wildlife Service to evaluate toxicity of reserve pit fluids discharged into tundra wetlands at Prudhoe Bay, Alaska. Results of the study document acute toxicity effects of reserve pit fluids on Daphnia. Acute toxicity in Daphnia was observed after 96 hours of exposure to liquid in five reserve pits. Daphnia exposed to liquid in receiving ponds also had significantly higher death/immobilization than did Daphnia exposed to liquid in control ponds after 96 hours. At Drill Site 1, after 96 hours, 100 percent of the Daphnia introduced to the reserve pit had been immobilized or were dead, as compared to a control pond which showed less than 5 percent immobilized or dead after 96 hours. At Drill Site 12, 80 percent of the Daphnia exposed to the reserve pit liquid were dead or immobilized after 96 hours and less than 1 percent of Daphnia exposed to the control pond were dead or immobilized.<sup>83</sup> (AK 07)<sup>84</sup>

In June 1985, five drill sites and three control sites were chosen for studying the effects of drilling fluids and their discharge on fish and waterfowl habitat on the North Slope of Alaska. Bioaccumulation analysis was done on fish tissue using water samples collected from the reserve pits. Fecundity and growth were reduced in daphnids exposed for 42 days to liquid composed of 2.5 percent and 25 percent drilling fluid from the selected drill sites. Bioaccumulation of barium, titanium, iron, copper, and molybdenum was documented in fish exposed to drilling fluids for as little as 96 hours. (AK 08)<sup>85</sup>

Erosion of reserve pits and subsequent discharge of reserve pit contents to the tundra constitute another potential environmental problem on the North Slope. If exploration drilling pits are not closed out at the end of a drilling season, they may breach during "breakup." Reserve pit contaminants are then released directly to the tundra. (As described in Chapter III, production reserve pits are different from exploration reserve pits. Production reserve pits are designed to last for as long as 20 years.) A reserve pit wall may be poorly constructed or suffer structural damage during use; the wall may be breached by the hydrostatic head on the walls due to accumulation of precipitation and produced fluids. New exploration reserve pits are generally constructed below-grade. Flow of gravel during a pit breach can choke or cut off tundra streams, severely damaging or eliminating aquatic habitat.

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<sup>83</sup> API comments in the Docket pertain to AK 07. API discusses the relevance of the Daphnia study to the damage cases.

<sup>84</sup> References for case cited: An In Situ Acute Toxicity Test with Daphnia: A Promising Screening Tool for Field Biologists? by Elaine Snyder-Conn, U.S. Fish and Wildlife Service, Fish and Wildlife Enhancement, Fairbanks, Alaska, 1985.

<sup>85</sup> References for case cited: Effects of Oil Drilling Fluids and Their Discharge on Fish and Waterfowl Habitat in Alaska, U.S. Fish and Wildlife Service, Columbia National Fishery Research Laboratory, Jackson Field Station, Jackson, Wyoming, February 1986.

The Awuna Test Well No. 1, which is 11,200 feet deep, is in the National Petroleum Reserve in Alaska (NPRA) and was a site selected for cleanup of the NPRA by the U.S. Geological Survey (USGS) in 1984. The site is in the northern foothills of the Brooks Range. The well was spud on February 29, 1980, and operations were completed on April 20, 1981. A side of the reserve pit berm washed out into the tundra during spring breakup, allowing reserve pit fluid to flow onto the tundra. As documented by the USGS cleanup team, high levels of chromium, oil, and grease have leached into the soil downgradient from the pit. Chromium was found at 2.2 to 3.0 mg/kg dry weight. The high levels of oil and grease may be from the use of Arctic Pack (85 percent diesel fuel) at the well over the winter of 1980. The cleanup team noted that the downslope soils were discolored and putrefied, particularly in the upper layers. The pad is located in a runoff area allowing for erosion of pad and pit into surrounding tundra. A vegetation kill area caused by reserve pit fluid exposure is approximately equal to half an acre. Areas of the drill pad may remain barren for many years because of contamination of soil with salt and hydrocarbons. The well site is in a caribou calving area.<sup>86</sup> (AK 12)<sup>87</sup>

This type of reserve pit construction is no longer permitted under current Alaska regulations.

### Waste Disposal on the North Slope

Inspection of oil and gas activities and enforcement of State regulations on the North Slope is difficult, as illustrated by the following case:

North Slope Salvage, Inc. (NSSI) operated a salvage business in Prudhoe Bay during 1982 and 1983. During this time, NSSI accepted delivery of various discarded materials from oil production companies on the North Slope, including more than 14,000 fifty-five gallon drums, 900 of which were full or held more than residual amounts of oils and chemicals used in the development and recovery of oil. The drums were stockpiled and managed by NSSI in a manner that allowed the discharge of hazardous substances. While the NSSI site may have stored chemicals and wastes from other operations that supported oil and gas exploration and production (e.g., vehicle maintenance materials), such storage would have constituted a very small percentage of NSSI's total inventory.

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<sup>86</sup> API states that exploratory reserve pits must now be closed 1 year after cessation of drilling operations. EPA notes that it is important to distinguish between exploratory and production reserve pits. Production reserve pits are permanent structures that remain open as long as the well or group of wells is producing. This may be as long as 20 years.

<sup>87</sup> References for case cited: Final Wellsite Cleanup on National Petroleum Reserve - Alaska, USGS, July 1986.

The situation was discovered by the Alaska Department of Environmental Conservation (ADEC) in June 1983. At this time, the State of Alaska requested Federal enforcement, but Federal action was never taken. An inadequate cleanup effort was mounted by NSSI after confrontation by ADEC. To preclude further discharges of hazardous substances, ARCO and Sohio paid for the cleanup because they were the primary contributors to the site. Cleanup was completed on August 5, 1983, after 58,000 gallons of chemicals and water were recovered. It is unknown how much of the hazardous substances was carried into the tundra. The discharge consisted of oil and a variety of organic substances known to be toxic, carcinogenic, mutagenic, or suspected of being carcinogenic or mutagenic.<sup>88</sup> (AK 10)<sup>89</sup>

### Disposal of Drilling Wastes, Kenai Peninsula

Disposal of drilling wastes is the principal practice leading to potential environmental degradation on the Kenai Peninsula. The following cases involve centralized facilities, both commercial and privately run, for disposal of drilling wastes:

Operators of the Sterling Special Waste Site have had a long history of substandard monitoring, having failed during 1977 and 1978 to carry out any well sampling and otherwise having performed only irregular sampling. This was in violation of ADEC permit requirements to perform quarterly reports of water quality samples from the monitoring wells. An internal ADEC memo (L.G. Elphic to R.T. Williams, 2/25/76) noted "...we must not forget...that this is the State's first sanctioned hazardous waste site and as such must receive close observation during its initial operating period."<sup>90</sup>

A permit for the site was reissued by ADEC in 1979 despite knowledge by ADEC of lack of effective ground-water monitoring. In July of 1980, ADEC Engineer R. Williams visited the site and filed a report noting that the "...operation appears completely out of control." Monitoring well samples were analyzed by ADEC at this time and were found to be in excess of drinking water standards for iron, lead, cadmium, copper, zinc, arsenic, phenol, and oil and grease. One private water well in the vicinity showed 0.4 ppb 1,1,1-trichloroethane. The Sterling School well showed 2.1 g/L mercury. (Subsequent tests show mercury concentration below detection limits--0.001 mg/kg.) Both contamination incidents are alleged to be caused by the Sterling

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<sup>88</sup> Alaska Department of Environmental Conservation (ADEC) states that this case "...is an example of how the oil industry inappropriately considered the limits of the exemption [under RCRA Section 3001]."

<sup>89</sup> References for case cited: Report on the Occurrence, Discovery, and Cleanup of an Oil and Hazardous Substances Discharge at Lease Tract 57, Prudhoe Bay, Alaska, by Jeff Mach - ADEC, 1984. Letter to Dan Derkics, EPA, from Stan Hungerford, ADEC, 8/4/87.

<sup>90</sup> The term "hazardous waste site" as used in this memo does not refer to a "RCRA Subtitle C hazardous waste site."

Special Waste Site. Allegations are unconfirmed by the ADEC. (AK 03)<sup>91</sup>

Practices at the Sterling site were in violation of the permit.

This case involves a 45-acre gravel pit on Poppy Lane on the Kenai Peninsula used since the 1970s for disposal of wastes associated with gas development. The gravel pit contains barrels of unidentified wastes, drilling muds, gas condensate, gas condensate-contaminated peat, abandoned equipment, and soil contaminated with diesel and chemicals. The property belongs to Union Oil Co., which bought it around 1968. Dumping of wastes in this area is illegal; reports of last observed dumping were in October 1985, as witnessed by residents in the area. In this case, there has been demonstrated contamination of adjacent water wells with organic compounds related to gas condensate (ADEC laboratory reports from October 1986 and earlier). Alleged health effects on residents of neighboring properties include nausea, diarrhea, rashes, and elevated levels of metals (chromium, copper) in blood in two residents. Property values have been effectively reduced to zero for residential resale. A fire on the site on July 8, 1981, was attributed to combustion of petroleum-related products, and the fire department was unable to extinguish it. The fire was allegedly set by people illegally disposing of wastes in the pit. Fumes from organic liquids are noticeable in the breathing zone onsite. UNOCAL has been directed on several occasions to remove gas condensate in wastes from the site. Since June 19, 1972, disposal of wastes regulated as solid wastes has been illegal at this site. The case has been actively under review by the State since 1981. (AK 01)<sup>92</sup>

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<sup>91</sup> References for case cited: Dames and Moore well monitoring report, showing elevated metals referenced above, October 1976. Dowling Rice & Associates monitoring results, 1/15/80, and Mar Enterprises monitoring results, September 1980, provided by Walt Pederson, showing elevated levels of metals, oil, and grease in ground water. Detailed letter from Eric Meyers to Glen Aikens, Deputy Commissioner, ADEC, recounting permit history of site and failure to conduct proper monitoring, 1/22/82. Testimony and transcripts from Walt Pederson on public forums complaining about damage to drinking water and mismanagement of site. Transcripts of waste logs of site from 9/1/79 to 8/20/84, indicating only 264,436 bbl of muds received, during a period that should have generated much more waste. Letter from Howard Keiser to Union Oil, 12/7/81, indicating that "...drilling mud is being disposed of by methods other than at the Sterling Special Waste Site and by methods that could possibly cause contamination of the ground water."

<sup>92</sup> References for case cited: Photos showing illegal dumping in progress. Field investigations. State of Alaska Individual Fire Report on "petroleum dump," 7/12/81. File memo on site visit by Howard Keiser, ADEC Environmental Field Officer, in response to a complaint by State Forestry Officer, 7/21/81. Memo from Howard Keiser to Bob Martin on his objections to granting a permit to Union Oil for use of site as disposal site on basis of impairment of wildlife resources, 7/28/83. Letter, ADEC to Union Oil, objecting to lack of cleanup of site despite notification by ADEC on 10/3/84. Analytical reports by ADEC indicating gas condensate contamination on site, 8/14/84. EPA Potential Hazardous Waste Site Identification, indicating continued dumping as of 8/10/85. Citizens' complaint records. Blood test indicating elevated chromium for neighboring resident Jessica Black, 1/16/85. Letter to Mike Lucky of ADEC from Union Oil confirming cleanup steps, 2/12/85. Memo by Carl Reller, ADEC ecologist, indicating presence of significant toxics on site, 8/14/85. Minutes of Waste Disposal Commission meeting, 2/10/85. ADEC analytic reports indicating gas condensate at site, 10/10/85. Letters from four different real estate firms in area confirming inability to sell residential property in Poppy Lane area. Letter from Bill Lamoreaux, ADEC, to J. Black and R. Sizemore referencing high selenium/chromium in the ground water in the area. Miscellaneous technical documents. EPA Potential Hazardous Waste Site Preliminary Assessment, 2/12/87.



These activities are illegal under current Alaska regulations.

## MISCELLANEOUS ISSUES

### Improperly Abandoned and Improperly Plugged Wells

Degradation of ground water from improperly plugged and unplugged wells is known to occur in Kansas, Texas, and Louisiana. Improperly plugged and unplugged wells enable native brine to migrate up the wellbore and into freshwater aquifers. The damage sustained can be extensive.

Problems also occur when unidentified improperly plugged wells are present in areas being developed as secondary recovery projects. After the formation has been pressurized for secondary recovery, native brine can migrate up unplugged or improperly plugged wells, potentially causing extensive ground-water contamination with chlorides.

In 1961, Gulf and its predecessors began secondary recovery operations in the East Gladys Unit in Sedgwick County, Kansas. During secondary recovery, water is pumped into a target formation at high pressure, enhancing oil production. This pumping of water pressurizes the formation, which can at times result in brines being forced up to the surface through unplugged or improperly plugged abandoned wells. When Gulf began their secondary recovery in this area, it was with the knowledge that a number of abandoned wells existed and could lead to escape of salt water into fresh ground water.

Gerald Blood alleged that three improperly plugged wells in proximity to the Gladys unit were the source of fresh ground-water contamination on his property. Mr. Blood runs a peach orchard in the area. Apparently native brine had migrated from the nearby abandoned wells into the fresh ground water from which Mr. Blood draws water for domestic and irrigation purposes. Contamination of irrigation wells was first noted by Mr. Blood when, in 1970, one of his truck gardens was killed by irrigation with salty water. Brine migration contaminated two more irrigation wells in the mid-1970s. By 1980, brine had contaminated the irrigation wells used to irrigate a whole section of Mr. Blood's land. By this time, adjacent landowners also had contaminated wells. Mr. Blood lost a number of peach trees as a result of the contamination of his irrigation well; he also lost the use of his domestic well.

The Bloods sued Gulf Oil in civil court for damages sustained by their farm from chloride contamination of their irrigation and residential wells. The Bloods won their case and were awarded an undisclosed amount of money.<sup>93</sup> (KS 14)<sup>94</sup>

Current UIC regulations prohibit contamination of groundwater.

The potential for environmental damage through ground-water degradation is high, given the thousands of wells abandoned throughout the country prior to any State regulatory plugging requirements.

In West Texas, thousands of oil and gas wells have been drilled over the last several decades, many of which were never properly plugged. There exists in the subsurface of this area a geologic formation known as the Coleman Junction, which contains extremely salty native brine and possesses natural artesian properties. Since this formation is relatively shallow, most oil and gas wells penetrate this formation. If an abandoned well is not properly plugged, the brine contained in the Coleman Junction is under enough natural pressure to rise through the improperly plugged well and to the surface.

According to scientific data developed over several years, and presented by Mr. Ralph Hoelscher, the ground water in and around San Angelo, Texas, has been severely degraded by this seepage of native brine, and much of the agricultural land has absorbed enough salt as to be nonproductive. This situation has created a hardship for farmers in the area. The Texas Railroad Commission states that soil and ground water are contaminated with chlorides because of terracing and fertilizing of the land. According to Mr. Hoelscher, a long-time farmer in the area, little or no fertilizer is used in local agriculture. (TX 11)<sup>95</sup>

Improper abandonment of oil and gas wells is prohibited in the State of Texas.

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<sup>93</sup> API states that damage in this case was brought about by "old injection practices."

<sup>94</sup> References for case cited: U.S. District Court for the district of Kansas, Memorandum and Order, Blood vs. Gulf; Response to Defendants' Statement of Uncontroverted Facts; and Memorandum in Opposition to Motion for Summary Judgment. Means Laboratories, Inc., water sample results. Department of Health, District Office #14, water samples results. Extensive miscellaneous memoranda, letters, analysis.

<sup>95</sup> References for case cited: Water analysis of Ralph Hoelscher's domestic well. Soil Salinity Analysis, Texas Agricultural Extension Service - The Texas A&M University System, Soil Testing Laboratory, Lubbock, Texas 79401. Photographs. Conversation with Wayne Farrell, San Angelo Health Department. Conversation with Ralph Hoelscher, resident and farmer.

# CHAPTER V

## RISK MODELING

### INTRODUCTION

This chapter summarizes the methods and results of a risk analysis of certain wastes associated with the onshore exploration, development, and production of crude oil and natural gas. The risk analysis relies heavily on the information developed by EPA on the types, amounts, and characteristics of wastes generated (summarized in Chapter II) and on waste management practices (summarized in Chapter III). In addition, this quantitative modeling analysis was intended to complement EPA's damage case assessment (Chapter IV). Because the scope of the model effort was limited, some of the types of damage cases reported in Chapter IV are not addressed here. On the other hand, the risk modeling of ground-water pathways covers the potential for certain more subtle or long-term risks that might not be evidenced in the contemporary damage case files. The methods and results of the risk analysis are documented in detail in a supporting EPA technical report (USEPA 1987a).

EPA's risk modeling study estimated releases of contaminants from selected oil and gas wastes into ground and surface waters, modeled fate and transport of these contaminants, and estimated potential exposures, health risks, and environmental impacts over a 200-year modeling period. The study was not designed to estimate absolute levels of national or regional risks, but rather to investigate and compare potential risks under a wide variety of conditions.

### Objectives

The main objectives of the risk analysis were to (1) characterize and classify the major risk-influencing factors (e.g., waste types, waste

management practices, environmental settings) associated with current operations at oil and gas facilities;<sup>1</sup> (2) estimate distributions of major risk-influencing factors across the population of oil and gas facilities within various geographic zones; (3) evaluate these factors in terms of their relative effect on risks; and (4) develop, for different geographic zones of the U.S., initial quantitative estimates of the possible range of baseline health and environmental risks for the variety of existing conditions.

### Scope and Limitations

The major portion of this risk study involved a predictive quantitative modeling analysis focusing on large-volume exempt wastes managed according to generally prevailing industry practices. EPA also examined (but did not attempt quantitative assessment of) the potential effects of oil and gas wastes on the North Slope of Alaska, and reviewed the locations of oil and gas activities relative to certain environments of special interest, including endangered species habitats, wetlands, and public lands.

Specifically, the quantitative risk modeling analysis estimated long-term human health and environmental risks associated with the disposal of drilling wastes in onsite reserve pits, the deep well injection of produced water, and the direct discharge of produced water from stripper wells to surface waters. These wastes and waste management practices encompass the major waste streams and the most common management practices within the scope of this report, but they are not necessarily those giving rise to the most severe or largest number of damage cases of the types presented in Chapter IV. For risk modeling purposes, EPA generally assumed full compliance with applicable current State and

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<sup>1</sup> References in this chapter to oil and gas facilities, sites, or activities refer to exploration, development, and production operations.

Federal regulations for the practices studied. Risks were not modeled for a wide variety of conditions or situations, either permitted or illegal, that could give rise to damage incidents, such as waste spills, land application of pit or water wastes, discharge of produced salt water to evaporation/percolation pits, or migration of injected wastes through unplugged boreholes.

In this study, EPA analyzed the possible effects of selected waste streams and management practices by estimating risks for model scenarios. Model scenarios are defined as hypothetical (but realistic) combinations of variables representing waste streams, management practices, and environmental settings at oil and gas facilities. The scenarios used in this study were, to the extent possible, based on the range of conditions that exist at actual sites across the U.S. EPA developed and analyzed more than 3,000 model scenarios as part of this analysis.

EPA also estimated the geographic and waste practice frequencies of occurrence of the model scenarios to account for how well they represent actual industry conditions and to account for important variations in oil and gas operations across different geographic zones of the U.S.<sup>2</sup> These frequencies were used to weight the model results, that is, to account for the fact that some scenarios represent more sites than others. However, even the weighted risk estimates should not be interpreted as absolute risks for real facilities because certain major risk-influencing factors were not modeled as variables and because the frequency of occurrence of failure/release modes and concentrations of toxic constituents were not available.

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<sup>2</sup> The 12 zones used in the risk assessment are identical to the zones used as part of EPA's waste sampling and analysis study (see Chapter II), with one exception: zone 11 (Alaska) was divided into zone 11A representing the North Slope and zone 11B representing the Cook Inlet-Kenai Peninsula area.

A principal limitation of the risk analysis is that EPA had only a relatively small sample set of waste constituent concentration data for the waste streams under study. As a result, the Agency was unable to construct regional estimates of toxic constituent concentrations or a national frequency distribution of concentrations that could be directly related to other key geophysical or waste management variables in the study. Partly because of this data limitation, all model scenarios defined for this study were analyzed under two different sets of assumptions: a "best-estimate"<sup>3</sup> set of assumptions and a "conservative" set of assumptions. The best-estimate and conservative sets of assumptions are distinguished by different waste constituent concentrations, different timing for releases of drilling waste and produced water, and, in some cases, different release rates (see the later sections on model scenarios and model procedures for more detail). The best-estimate assumptions represent a set of conditions which, in EPA's judgment, best characterize the industry as a whole, while the conservative assumptions define higher-risk (but not worst-case) conditions. It is important to clarify that the best-estimate and conservative assumptions are not necessarily based on a comprehensive statistical analysis of the frequency of occurrence or absolute range of conditions that exist across the industry; instead, they reflect EPA's best judgment of a reasonable range of conditions based on available data analyzed for this study.

Another major limitation of the study is the general absence of empirical information on the frequency, extent, and duration of waste releases from the oil and gas field management practices under consideration. As described below, this study used available engineering judgments regarding the nature of a variety of failure/release mechanisms for waste pits and injection wells, but no assumptions were made

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<sup>3</sup> As used here, the term best estimate is different from the statistical concept of maximum likelihood (i.e., best) estimate.

regarding the relative frequency or probability of occurrence of such failures.

Although EPA believes that the scenarios analyzed are realistic and representative, the risk modeling for both sets of scenarios incorporated certain assumptions that tend to overestimate risk values. For example, for the health risk estimates it was assumed that individuals ingest untreated contaminated water over a lifetime, even if contaminant concentrations were to exceed concentrations at which an odor or taste is detectable. In addition, ingested concentrations were assumed to equal the estimated center line (i.e., highest) concentration in the contaminant plume.

Other features of the study tend to result in underestimation of risk. For example, the analysis focuses on risks associated with drilling or production at single oil or gas wells, rather than on the risks associated with multiple wells clustered in a field, which could result in greater risks and impacts because of overlapping effects. Also, the analysis does not account for natural or other source background levels of chemical constituents which, when combined with the contamination levels from oil and gas activities, could result in increased risk levels.

## **QUANTITATIVE RISK ASSESSMENT METHODOLOGY**

EPA conducted the quantitative risk assessment through a four-step process (see Figure V-1). The first three steps--collection of input data, specification of model scenarios, and development of modeling procedures--are described in the following subsections. The last step, estimation of effects, is described in subsequent sections of this chapter that address the quantitative modeling results.

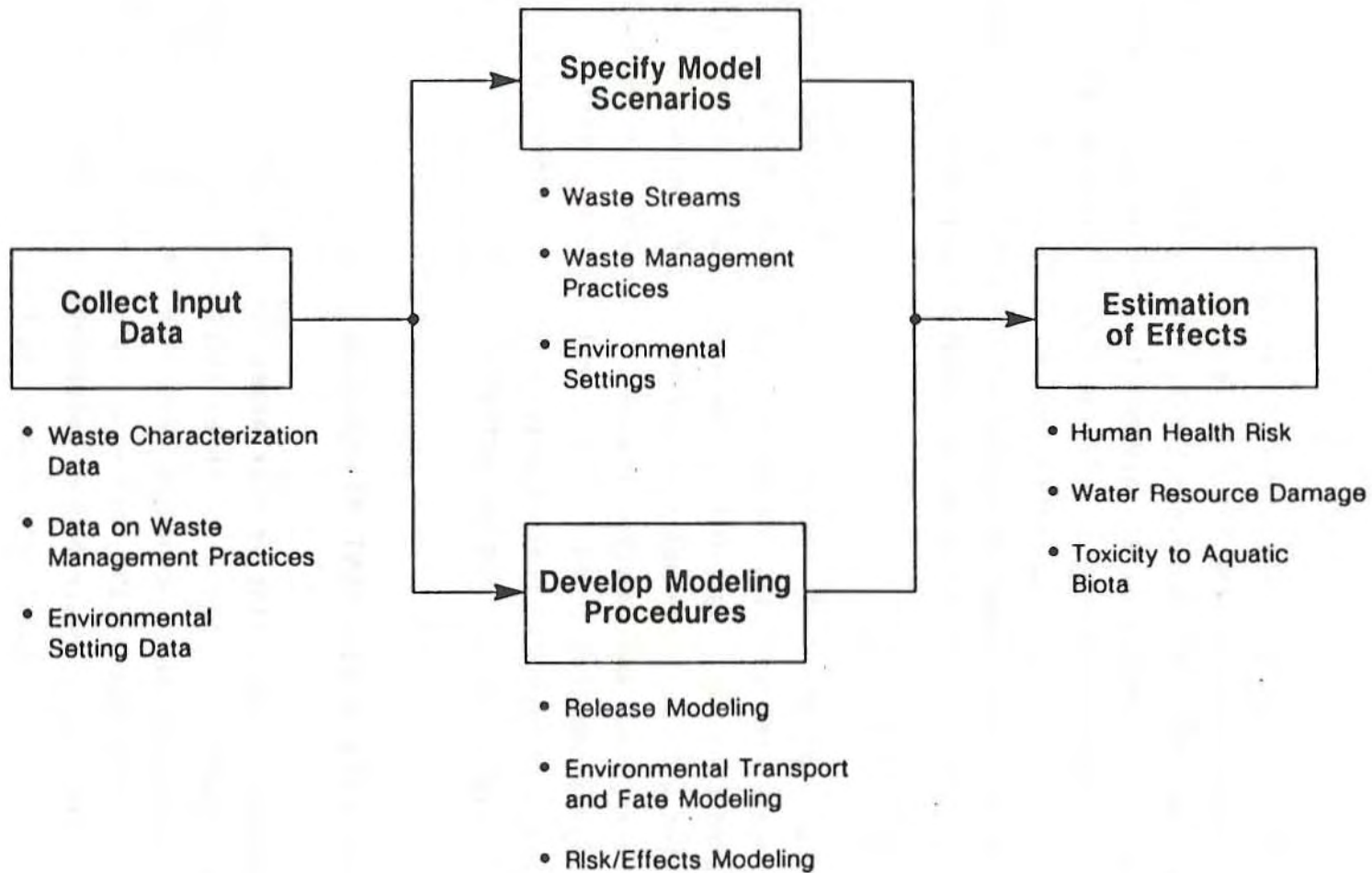


Figure V-1 Overview of Quantitative Risk Assessment Methodology



## Input Data

EPA collected three main categories of input data for the quantitative modeling: data on waste volumes and constituents, waste management practices, and environmental settings. Data on waste volumes were obtained from EPA's own research on sources and volumes of wastes, supplemented by the results of a survey of oil and gas facilities conducted by the American Petroleum Institute (API) (see Chapter II). Data on waste constituents were obtained from EPA's waste stream chemical analysis study. The results of EPA's research on current waste management practices, supplemented by API's studies (see Chapter III), were the basis for defining necessary input parameters concerning waste management practices. Data needed to characterize environmental settings were obtained from an analysis of conditions at 266 actual drilling and production locations sampled from areas with high levels of oil and gas activity (see USEPA 1987a, Chapter 3, for more detail on the sample selection and analytical methods).

## Model Scenarios

The model scenarios in this analysis are unique combinations of the variables used to define waste streams, waste management practices, and environmental settings at oil and gas facilities. Although the model scenarios are hypothetical, they were designed to be:

- Representative of actual industry conditions (they were developed using actual industry data, to the extent available);
- Broad in scope, covering prevalent industry characteristics but not necessarily all sets of conditions that occur in the industry; and
- Sensitive to major differences in environmental conditions (such as rainfall, depth to ground water, and ground-water flow rate) across various geographic zones of the U.S.

As illustrated in Figure V-2, EPA decided to focus the quantitative analysis on the human health and environmental risks associated with three types of environmental releases: leaching of drilling waste chemical constituents from onsite reserve pits to ground water below the pits (drilling sites); release of produced water chemical constituents from underground injection wells to surface aquifers<sup>4</sup> (production sites); and direct discharge of produced water chemical constituents to streams and rivers (stripper well production sites).

### Chemical Constituents

EPA used its waste sampling and analysis data (described in Chapter II) to characterize drilling wastes and produced water for quantitative risk modeling. Based on the available data, EPA could not develop separate waste stream characterizations for various geographic zones; one set of waste characteristics was used to represent the nation. The model drilling waste represents only water-based drilling muds (not oil-based muds or wastes from air drilling), which are by far the most prevalent drilling mud type. Also, the model drilling waste does not represent one specific process waste, but rather the combined wastes associated with well drilling that generally are disposed of in reserve pits.

For both drilling wastes and produced water, EPA used a systematic methodology to select the chemical constituents of waste streams likely to dominate risk estimates (see USEPA 1987a, Chapter 3, for a detailed description of this methodology). The major factors considered in the chemical selection process were (1) median and maximum concentrations in

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<sup>4</sup> For the purpose of this report, a surface aquifer is defined as the geologic unit nearest the land surface that transmits sufficient quantities of ground water to be used as a source of drinking water. It is distinguished from aquifers at greater depths, which may be the injection zone for an underground injection well or are too deep to be generally used as a drinking water source.

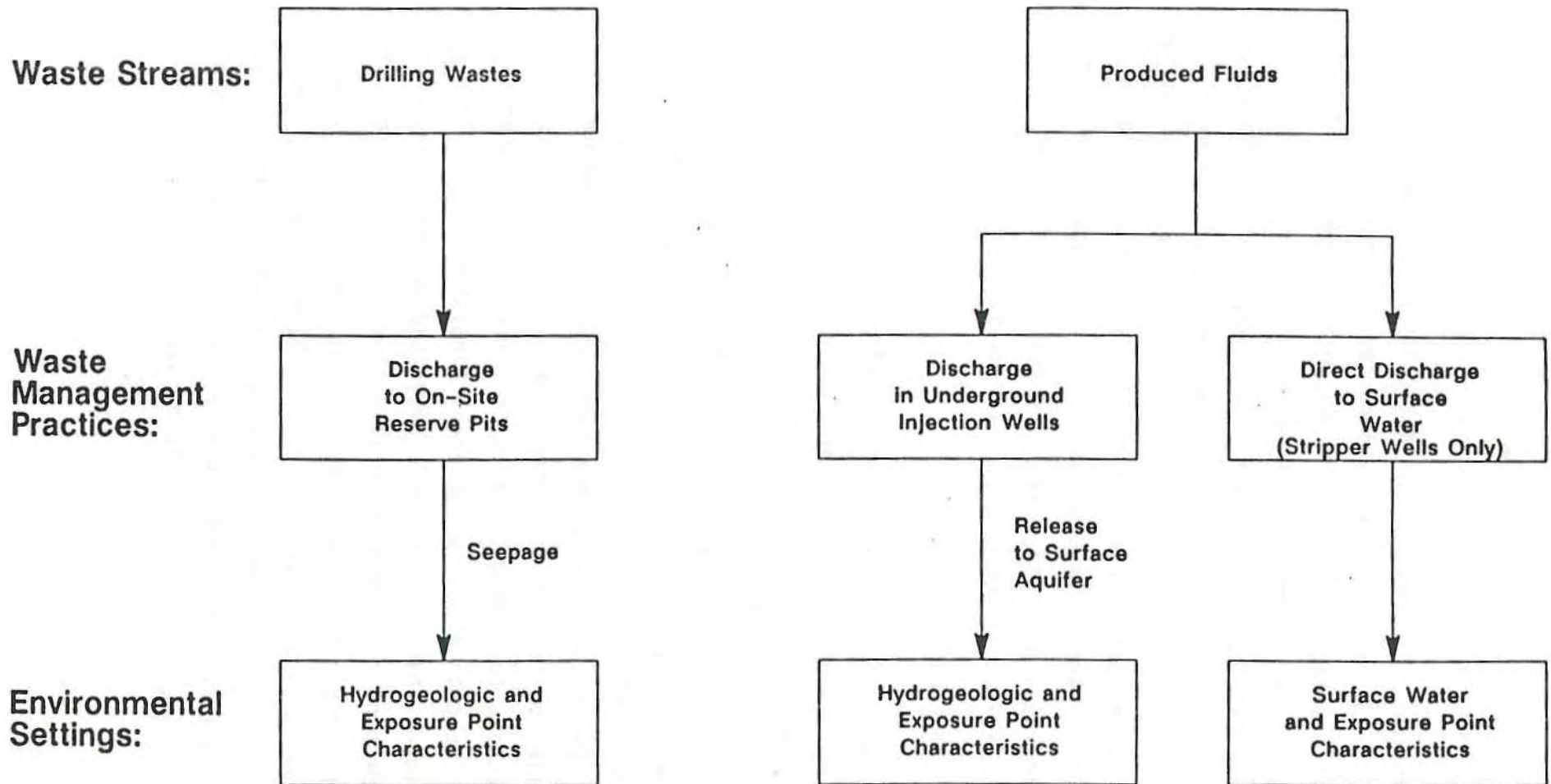


Figure V-2 Overview of Modeling Scenarios Considered in the Quantitative Risk Assessment

the waste samples; (2) frequency of detection in the waste samples; (3) mobility in ground water; and (4) concentrations at which human health effects, aquatic toxicity, or resource damage start to occur. Through this screening process, EPA selected six chemicals for each waste type that were likely to dominate risk estimates in the scenarios modeled. For each selected chemical, two concentrations were determined from the waste characterization data. The 50th percentile (median) was used to set constituent concentrations for a "best-estimate" waste characterization, while the 90th percentile was used for a "conservative" waste characterization. The selected chemicals and concentrations, shown in Table V-1, served as model waste streams for the quantitative risk analysis.

Of the chemicals selected, arsenic and benzene were modeled as potential carcinogens. Both substances are rated as Group A in EPA's weight-of-evidence rating system (i.e., sufficient evidence of carcinogenicity in humans). Some scientists, however, believe that arsenic may not be carcinogenic and may be a necessary element at low levels. Sodium, cadmium, and chromium VI were modeled for noncarcinogenic effects. The critical (i.e., most sensitive) health effects for these constituents are hypertension for sodium and liver and kidney damage for cadmium and chromium VI. It is emphasized that the effect threshold for sodium used in this analysis was based on potential effects in the high-risk (not general) population. (The level used is slightly higher than EPA's 20 mg/L suggested guidance level for drinking water.) The high-risk population is defined to include individuals with a genetic predisposition for hypertension, pregnant women, and hypertensive patients. Finally, boron, chloride, sodium, cadmium, chromium VI, and total mobile ions were modeled for their potential aquatic toxicity and resource damage effects. Table V-2 lists the cancer potency factors and effects thresholds used in the study.

Table V-1 Model Constituents and Concentrations<sup>a</sup>

Produced water constituents	Concentrations	
	Median (mg/L)	Upper 90% (mg/L)
Arsenic	0.02	1.7
Benzene	0.47	2.9
Boron	9.9	120
Sodium	9,400	67,000
Chloride	7,300	35,000
Mobile ions <sup>b</sup>	23,000	110,000

Drilling waste (water-based) constituents	Concentrations					
	Pit liquids		Pit solids/TCLP <sup>c</sup>		Pit solids/direct	
	Median (mg/L)	Upper 90% (mg/L)	Median (mg/L)	Upper 90% (mg/L)	Median (mg/kg)	Upper 90% (mg/kg)
Arsenic	0.0	0.16	0.0	0.002 <sup>d</sup>	0.0	0.010
Cadmium	0.056	1.4	0.011	0.29	2.0	5.4
Sodium	6,700	44,000	1,200 <sup>e</sup>	4,400 <sup>e</sup>	8,500	59,000
Chloride	3,500	39,000	2,000 <sup>f</sup>	11,000 <sup>f</sup>	17,000	88,000
Chromium VI	0.43	290	0	0.78	22	190
Mobile ions <sup>b</sup>	17,000	95,000	4,000	16,000	100,000	250,000

<sup>a</sup>The median constituent concentrations from the relevant samples in the EPA waste sampling/analysis study were used for a "best-estimate" waste characterization, and the 90th percentile concentrations were used for a "conservative" waste characterization (data source: USEPA 1987b).

<sup>b</sup>Mobile ions include chloride, sodium, potassium, calcium, magnesium, and sulfate.

<sup>c</sup>TCLP = toxicity characteristic leaching procedure.

<sup>d</sup>Upper 90th percentile arsenic values estimated based on detection limit.

<sup>e</sup>Preliminary examinations indicate that the sodium TCLP values may overestimate the actual leachable sodium concentrations in reserve pit samples. The accuracy of these concentrations is the subject of an ongoing evaluation.

<sup>f</sup>Chloride TCLP values are estimated based on sodium data.

Table V-2 Toxicity Parameters and Effects Thresholds<sup>a</sup>

Model constituent	Cancer potency factor (mg/kd-d) <sup>-1</sup>	Human noncancer threshold (mg/kg-d)	Aquatic toxicity threshold (mg/L)	Resource damage threshold (mg/L)
Benzene	0.052	NA	NA <sup>b</sup>	NA
Arsenic	15	NA	NA	NA
Sodium	NA	0.66	83.4	NA
Cadmium	NA <sup>c</sup>	0.00029	0.00066	NA
Chromium VI	NA <sup>c</sup>	0.005	0.011	NA
Chloride	NA	NA	NA	250
Boron	NA	NA	NA	1
Total mobile ions <sup>d</sup>	NA	NA	NA	335 <sup>e</sup> 500 <sup>f</sup>

<sup>a</sup>See USEPA 1987a for detailed description and documentation.

<sup>b</sup>NA = not applicable; indicates that an effect type was not modeled for a specific chemical.

<sup>c</sup>Not considered carcinogenic by the oral exposure route.

<sup>d</sup>Represents total mass of ions mobile in ground water.

<sup>e</sup>For surface water only (assumes a background level of 65 mg/L and a threshold limit of 400 mg/L).

<sup>f</sup>For ground water only.

The chemicals selected for risk modeling differ from the constituents of potential concern identified in Chapter II for at least three important reasons. First, the analysis in Chapter II considers the hazards of the waste stream itself but, unlike the selection process used for this risk analysis, does not consider the potential for waste constituents to migrate through ground water and result in exposures at distant locations. Second, certain constituents were selected based on their potential to cause adverse environmental (as opposed to human health) effects, while the analysis in Chapter II considers only human health effects. Third, frequency of detection was considered in selecting constituents for the risk modeling but was not considered in the Chapter II analysis.

#### Waste Management Practices

Three general waste management practices were considered in this study: onsite reserve pits for drilling waste; underground injection wells for produced water; and direct discharge of produced water to rivers and streams (for stripper wells only).<sup>5</sup> EPA considered the underground injection of produced water in disposal wells and waterflooding wells.<sup>6</sup> The design characteristics and parameter values modeled for the different waste management practices are presented in Tables V-3 and V-4. These values were developed from an evaluation of EPA's and API's waste volume data (see Chapter II) and waste management practice survey results (see Chapter III) for the nation as a whole.

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<sup>5</sup> At present, there are no Federal effluent guidelines for stripper wells (i.e., oil wells producing less than ten barrels of crude oil per day), and, under Federal law, these wells are allowed to discharge directly to surface waters subject to certain restrictions. Most other onshore oil and gas facilities are subject to the Federal zero-discharge requirement.

<sup>6</sup> Waterflooding is a secondary recovery method in which treated fresh water, seawater, or produced water is injected into a petroleum-bearing formation to help maintain pressure and to displace a portion of the remaining crude oil toward production wells. Injection wells used for waterflooding may have different designs, operating practices, and economic considerations than those of disposal wells, which are used simply to dispose of unwanted fluid underground.

Table V-3 Drilling Pit Waste (Water-Based) Management Practices

Onsite pit size	Waste amount <sup>a</sup> (barrels)	Disposal practice	Pit dimensions(m)		
			L	W	D
Large	26,000	Reserve pit-unlined	59	47	2.3 <sup>b</sup>
		Reserve pit-lined, capped			
Medium	5,900	Reserve pit-unlined	32	25	2.0 <sup>b</sup>
		Reserve pit-lined, capped			
Small	1,650	Reserve pit-unlined	17	14	1.9 <sup>b</sup>
		Reserve pit-lined, capped			

<sup>a</sup>Per well drilled (includes solids and liquids).

<sup>b</sup>Waste depths for large, medium, and small pits were 1.5, 1.2, and 1.1 meters, respectively.



Table V-6 Definition of Best-Estimate and Conservative Release Assumptions

Release source	Release assumption	Constituent concentration in waste <sup>a</sup>	Failure/release timing	Release volume
Unlined Pits	Best-estimate	50th % (median)	Release begins in year 1	Calculated by release equations
	Conservative	90th %	Release begins in year 1	Calculated by release equations (same as best-estimate)
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Lined Pits	Best-estimate	50th %	Liner failure begins in year 25	Calculated by release equations
	Conservative	90th %	Liner failure begins in year 5	Calculated by release equations (same as best-estimate)
-----				
Injection Wells/ Casing Failure	Best-estimate	50th %	One year release in year 1 for waterflood wells; constant annual releases during years 11-13 for disposal wells	0.2-96 bbl/d for waterflood wells; 0.05-38 bbl/d for disposal wells
	Conservative	90th %	Constant annual releases during years 11-15 for waterflood and disposal wells	Same as best-estimate
-----				
Injection Wells/ Grout Seal Failure	Best-estimate	50th %	Constant annual releases during years 11-15 for waterflood and disposal wells	0.00025-0.0025 bbl/d for waterflood wells; 0.00025-0.0075 bbl/d for disposal wells
	Conservative	90th %	Constant annual releases during years 1-20 for waterflood and disposal wells (immediate failure, no detection)	0.05-0.5 bbl/d for waterflood wells; 0.05-1.5 bbl/d for disposal wells

<sup>a</sup>See Table V-1.

the same layers considered during the active period. For unlined pits, release was assumed to begin immediately at the start of the modeling period. For lined pits, failure (i.e., increase in hydraulic conductivity of the liner) was assumed to occur either 5 or 25 years after the start of the modeling period. It was assumed that any liquids remaining in unlined reserve pits at the time of closure would be land applied adjacent to the pit. Liquids remaining in lined pits were assumed to be disposed offsite.

For modeling releases to surface aquifers from Class II injection wells, a 20-year injection well operating period was assumed, and two failure mechanisms were studied: (1) failure of the well casing (e.g., a corrosion hole) and (2) failure of the grout seal separating the injection zone from the surface aquifer. At this time, the Agency lacks the data necessary to estimate the probability of casing or grout seal failures occurring. A well casing failure assumes that injected fluids are exiting the well through a hole in the casing protecting the surface aquifer. In most cases, at least two strings of casing protect the surface aquifer and, in those cases, a release to this aquifer would be highly unlikely. The Agency has made exhaustive investigations of Class I well (i.e., hazardous waste disposal well) failures and has found no evidence of release of injected fluids through two strings of casing. However, the Agency is aware that some Class II wells were constructed with only one string of casing; therefore, the scenarios modeled fall within the realm of possible failures. Since integrity of the casing must be tested every 5 years under current EPA guidelines (more frequently by some States), EPA assumed for the conservative scenarios that a release would begin on the first day after the test and would last until the next test (i.e., 5 years). For the best-estimate scenarios, EPA assumed that the release lasted 1 year (the minimum feasible modeling period) in the case of waterflood wells and 3 years in the case of disposal wells, on the supposition that shorter release durations would be more likely for

waterflooding where injection flow rates and volumes are important economic considerations for the operation. EPA also assumed here that the release flow from a failed well would remain constant over the duration of the failure. This simplifying assumption is more likely to hold in low-pressure wells than in the high-pressure wells more typical of waterflooding operations. In high-pressure wells the high flow rate would likely enlarge the casing holes more rapidly, resulting in more injection fluid escaping into the wrong horizon and a noticeable drop of pressure in the reservoir.

For the grout seal type of failure, EPA estimated for conservative modeling purposes that the failure could last for 20 years (i.e., as long as the well operates). This is not an unreasonable worst-case assumption because the current regulations allow the use of cementing records to determine adequacy of the cement job, rather than actual testing through the use of logs. If the cementing records were flawed at the outset, a cementing failure might remain undetected. As part of its review of the Underground Injection Control (UIC) regulations, the Agency is considering requiring more reliable testing of the cementing of wells, which would considerably lessen the likelihood of such scenarios. For an alternative best-estimate scenario, the Agency assumed a 5-year duration of failure as a more typical possibility.

Because of a lack of both data and adequate modeling methods, other potentially important migration pathways by which underground injection of waste could contaminate surface aquifers (e.g., upward contaminant migration from the injection zone through fractures/faults in confining layers or abandoned boreholes) were not modeled.

Chemical transport was modeled for ground water and surface water (rivers). Ground-water flow and mass transport were modeled using EPA's Liner Location Risk and Cost Analysis Model (LLM) (USEPA 1986). The LLM

uses a series of predetermined flow field types to define ground-water conditions (see Table V-7); a transient-source, one-dimensional, wetting-front model to assess unsaturated zone transport; and a modified version of the Random Walk Solute Transport Model (Prickett et al. 1981) to predict ground-water flow and chemical transport in the saturated zone. All ground-water exposure and risk estimates presented in this report are for the downgradient center line plume concentration. Chemical transport in rivers was modeled using equations adapted from EPA (USEPA 1984a); these equations can account for dilution, dispersion, particulate adsorption, sedimentation, degradation (photolysis, hydrolysis, and biodegradation), and volatilization.

EPA used the LLM risk submodel to estimate cancer and chronic noncancer risks from the ingestion of contaminated ground and surface water. The measure used for cancer risk was the maximum (over the 200-year modeling period) lifetime excess<sup>7</sup> individual risk, assuming an individual ingested contaminated ground or surface water over an entire lifetime (assumed to be 70 years). These risk numbers represent the estimated probability of occurrence of cancer in an exposed individual. For example, a cancer risk estimate of  $1 \times 10^{-6}$  indicates that the chance of an individual getting cancer is approximately one in a million over a 70-year lifetime. The measure used for noncancer risk was the maximum (over the 200-year modeling period) ratio of the estimated chemical dose to the dose of the chemical at which health effects begin to occur (i.e., the threshold dose). Ratios exceeding 1.0 indicate the potential for adverse effects in some exposed individuals; ratios less than 1.0 indicate a very low likelihood of effect (assuming that background exposure is zero, as is done in this study). Although these ratios are not probabilities, higher ratios in general are cause for greater concern.

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<sup>7</sup> Excess refers to the risk increment attributable only to exposure resulting from the releases considered in this analysis. Background exposures were assumed to be zero.

Table V-7 Definition of Flow Fields Used in Ground-Water Transport Modeling

Flow field	Key variables defining flow field <sup>a</sup>	
	Aquifer configuration <sup>b</sup>	Horizontal ground-water velocity
A	Unconfined aquifer	1 m/yr
B	Unconfined aquifer	10 m/yr
C	Unconfined aquifer	100 m/yr
D	Unconfined aquifer	1,000 m/yr
E	Unconfined aquifer	10,000 m/yr
F	Confined aquifer	0.05 m/yr in the confining layer and 100 m/yr within the aquifer
K	Confined aquifer	0.05 m/yr in the confining layer and 10 m/yr within the aquifer

<sup>a</sup>Several other variables, such as porosity, distinguish the flow fields, but the variables listed here are the most important for the purpose of this presentation.

<sup>b</sup>In general, an aquifer is defined as a geological unit that can transmit significant quantities of water. An unconfined aquifer is one that is only partly filled with water, such that the upper surface of the saturated zone is free to rise and decline. A confined aquifer is one that is completely filled with water and that is overlain by a confining layer (a rock unit that restricts the movement of ground water).

As a means of assessing potential effects on aquatic organisms, EPA estimated, for each model scenario involving surface water, the volume contaminated above an aquatic effects threshold. EPA also estimated the volumes of ground and surface water contaminated above various resource damage thresholds (e.g., the secondary drinking water standard for chloride).

## QUANTITATIVE RISK MODELING RESULTS: HUMAN HEALTH

This section summarizes the health risk modeling results for onsite reserve pits (drilling wastes), underground injection wells (produced water), and direct discharges to surface water (produced water, stripper well scenarios only). Cancer risk estimates are presented separately from noncancer risk estimates throughout. This section also summarizes EPA's preliminary estimates of the size of populations that could possibly be exposed through drinking water.

### Onsite Reserve Pits--Drilling Wastes

Cancer and noncancer health risks were analyzed under both best-estimate and conservative modeling assumptions for 1,134 model scenarios<sup>8</sup> of onsite reserve pits. Arsenic was the only potential carcinogen among the constituents modeled for onsite reserve pits. Of the noncarcinogens, only sodium exceeded its effect threshold; neither cadmium nor chromium VI exceeded their thresholds in any model scenarios (in its highest risk scenario, cadmium was at 15 percent of threshold; chromium VI, less than 1 percent).

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<sup>8</sup> 1,134 = 9 infiltration/unsaturated zone types x 7 ground-water flow field types x 3 exposure distances x 3 size categories x 2 liner types.

## Nationally Weighted Risk Distributions

Figure V-3 presents the nationally weighted frequency distributions of human health risk estimates associated with unlined onsite reserve pits. The figure includes best-estimate and conservative modeling results for both cancer (top) and noncancer (bottom) risks. Only the results for unlined reserve pits are given because the presence or absence of a liner had little influence on risk levels (see section on major factors affecting health risk). Many of the scenarios in the figure show zero risk because the nearest potential exposure well was estimated to be more than 2 kilometers away (roughly 61 percent of all scenarios).

Under best-estimate assumptions, there were no cancer risks from arsenic because arsenic was not included as a constituent of the modeled waste (i.e., the median arsenic concentration in the field sampling data was below detection limits; see Table V-1). Under conservative assumptions, nonzero cancer risks resulting from arsenic were estimated for 18 percent of the nationally weighted reserve pit scenarios, with roughly 2 percent of the scenarios having cancer risks greater than  $1 \times 10^{-7}$ . Even under conservative modeling assumptions, drilling waste pit scenarios produced maximum lifetime cancer risks of less than 1 in 100,000 for individuals drinking affected water.

A few threshold exceedances for sodium were estimated under both best-estimate and conservative assumptions. Under best-estimate assumptions, more than 99 percent of nationally weighted reserve pit scenarios posed no noncancer risk (i.e., they were below threshold). A few model scenarios had noncancer risks, but none exceeded 10 times the sodium threshold. Under conservative assumptions, 98 percent of nationally weighted reserve pit scenarios did not pose a noncancer risk. The remaining 2 percent of reserve pit scenarios had estimated exposure point sodium concentrations between up to 32 times the threshold.

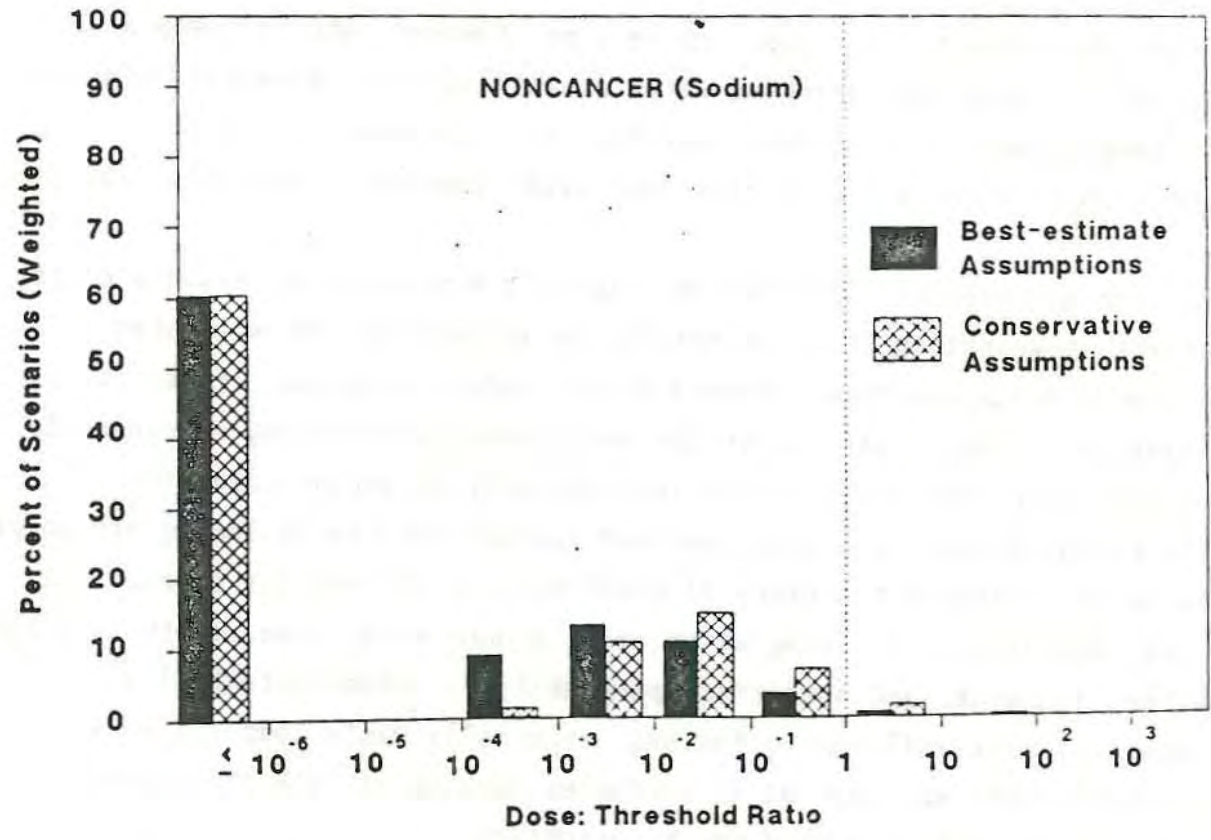
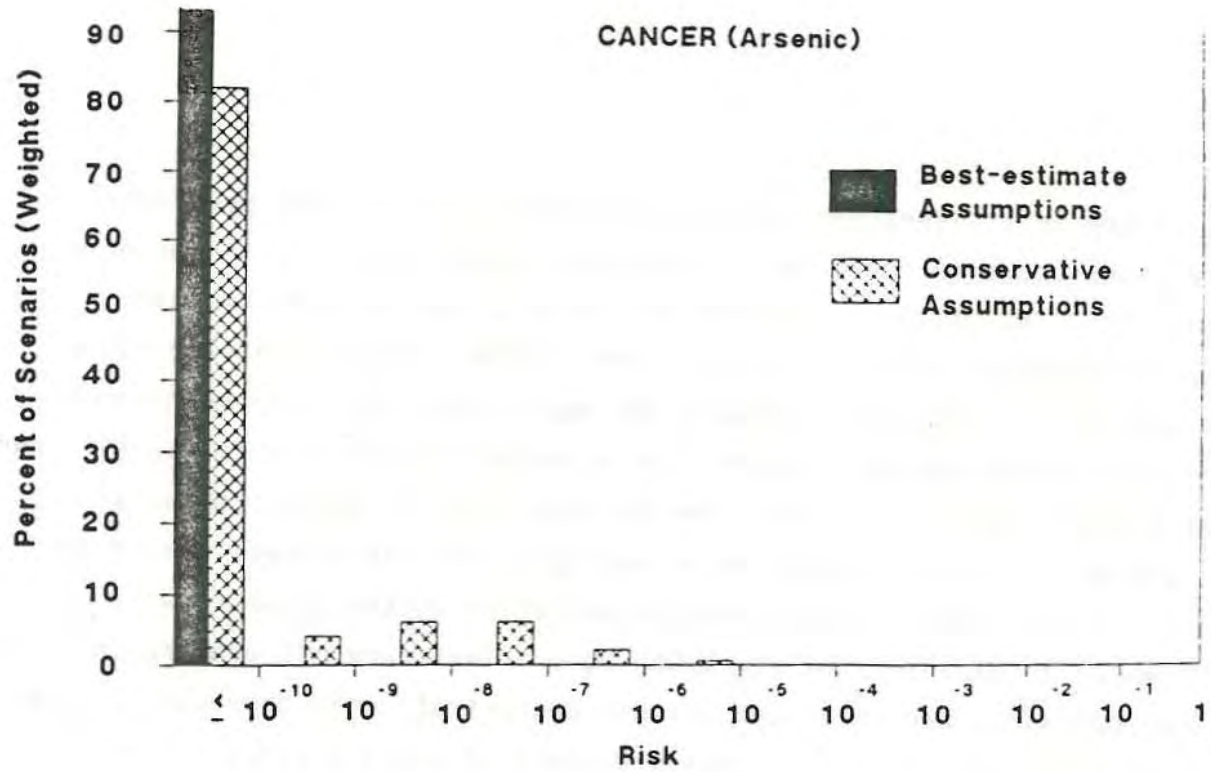


Figure V-3 Nationally Weighted Distribution of Health Risk Estimates. Unlined Reserve Pits



Based on a literature review conducted as part of the development of the Liner Location Model data base (USEPA 1986), chloride is the only model drilling waste constituent for which either a taste or odor threshold concentration is known. EPA (1984b) reports that the taste threshold for chloride is roughly 250 mg/L (i.e., this is the minimum chloride concentration in water that a person may be able to taste). For the highest cancer risk case, the maximum chloride concentration at the exposure well was estimated to be 400 mg/L; for the highest noncancer risk case, the maximum chloride concentration at the exposure well was estimated to be approximately 5,000 mg/L. Therefore, it appears that, if water contained a high enough arsenic concentration to pose cancer risks on the order of  $1 \times 10^{-5}$  or sodium concentrations 100 times the effect threshold, people may be able to taste the chloride that would also likely be present. The question remains, however, whether people would actually discontinue drinking water containing these elevated chloride concentrations. EPA (1984b) cautions that consumers may become accustomed to the taste of chloride levels somewhat higher than 250 mg/L.

For purposes of illustration, Figure V-4 provides an example of the effect of weighting the risk results to account for the estimated national frequency of occurrence of the model scenarios. Essentially, weighting allows risk results for more commonly occurring scenarios to "count" more than results from less commonly occurring scenarios. Weighting factors were developed and applied for the following variables, based on estimated frequency of occurrence at oil and gas sites: pit size, distance to drinking water well, ground-water type, depth to ground water, recharge, and subsurface permeability. Other potentially important risk-influencing factors, especially waste composition and strength, were not modeled as variables because of lack of information and thus are not accounted for by weighting.

In the example shown in Figure V-4 (conservative-estimate cancer risks for unlined onsite pits), weighting the risk results decreases the

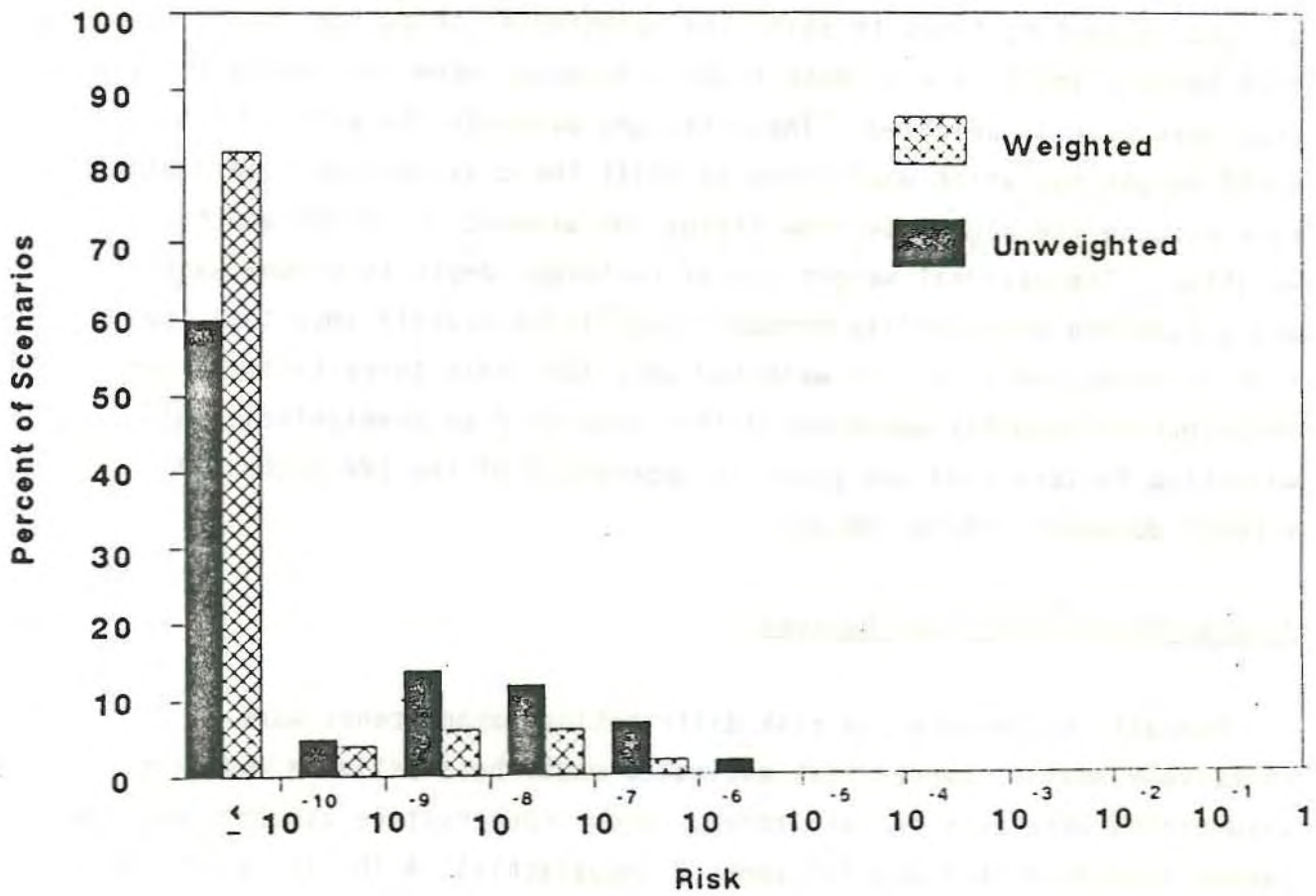


Figure V-4 Weighted vs. Unweighted Distribution of Cancer Risk Estimates. Unlined Reserve Pits. Conservative Modeling Assumptions