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Petroleum Recovery Research Center

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Introduction

Oil and natural gas production both uses and generates large quantities of water. Producers are responsible for approximately 2% of industrial water use in New Mexico every year. This water, from varying sources, is injected underground through injection wells to help force oil and natural gas out of the reservoir rock. A quantity of water then accompanies produced oil and natural gas to the surface. For each barrel of oil produced, an average of eight barrels of saline water is produced as well. In 2001, 26.9 billion gallons of produced water from oil and natural gas fields in New Mexico were pumped out of the ground. This oil- and gas-field produced water can be nearly six times as salty as seawater and may also contain dissolved hydrocarbons. Produced water is hard to clean and desalinate and has generally been classified as waste.

The cost of disposing of produced water, ranging from \$0.25 to \$3.00 per barrel, is an important economic issue for producers. Stripper (marginal) wells, common in New Mexico, are hardest hit; produced water disposal costs typically make stripper well operation uneconomical. Successful and economical desalination and purification methods would reduce industry costs for water disposal, and these wells could be returned to economic production. Produced water, purified to a certain level, could have many applications, such as irrigating crops or watering livestock.

New Mexico's oil and natural gas producers were given a new inducement to tackle the produced water problem when the New Mexico legislature passed the Produced Water Tax Incentive in 2001. A tax credit for the cleanup of water pumped from oil and gas drilling operations is expected to put 12,000 acre-ft of water back into the Pecos River and save the state more than \$17 million in water rights purchases. This initiative gives oil field operators the opportunity to transform unusable water into an operative new mineral right. The state also hopes that this initiative will help it come up with some of the annual 34,000 acre ft of water that it owes to Texas, as outlined in the Pecos River Compact. However, the technology to do so is not yet on the scene.

The Petroleum Recovery Research Center (PRRC) at New Mexico Tech, as the research arm of the petroleum industry in New Mexico, is responding to industry's needs by coordinating a four-pronged approach to the state's produced water issues through projects that:

- Reduce or shut off excess water production during oil and gas recovery operations with the proper use and placement of gels;
- Identify the best methods for management and treatment both in northern and southern New Mexico, as well as appropriate uses for produced water that has been treated with advanced purification methods;
- Develop GIS-based well mapping and an information database on produced water, including water quality data, for oil and gas producers to use in their daily operations and planning activities; and
- Fabricate a low-cost reverse osmosis membrane for eventual field use.

The PRRC has joined with the New Mexico Oil Conservation Division, Sandia National Laboratories, and the University of Missouri–Rolla in targeting these areas of research.

Water shutoff and conformance improvement

Excess water production plagues many improved oil recovery (IOR) projects, aggravating economic and disposal worries for producers. This problem has many different causes, and each requires a different approach for the optimum solution.

Research performed by the PRRC Reservoir Sweep Improvement Group, headed by Dr. Randy Seright, focuses on developing methods of preventing excess water production during oil recovery. The group specializes in engineering-based design methods for using gels and gelants to treat fracture problems. Gelants are fluid, water-based polymer solutions that undergo chemical reactions to form impermeable, semi-solid gels. A preformed gel treatment is a gel that is formed (i.e., the crosslinking reaction occurs) before the gel contacts the reservoir rock. Both Dr. Seright and group member Mr. Robert Sydansk—developer

TABLE 1—The PRRC Reservoir Sweep Improvement Group has developed four categories of excess water production problems and recommended treatments (Petroleum Recovery Research Center, 2002).

Category A: Easiest problems	Category B: Intermediate difficulty	Category C: Intermediate difficulty	Category D: Most difficult problems
Problem			
1. Casing leaks without flow restrictions (moderate to large holes)	4. Casing leaks with flow restrictions (pinhole leaks)	8. Faults or fractures crossing a deviated or horizontal well	11. Three-dimensional coning
2. Flow behind pipe without flow restrictions (typically no primary cement)	5. Flow behind pipe with flow restrictions (narrow channels)	9. Single fracture causing channeling between wells	12. Cusping
3. Unfractured wells (injectors or producers) with effective barriers to cross flow	6. Two-dimensional coning through a hydraulic fracture from an aquifer	10. Natural fracture system allowing channeling between wells	13. Channeling through strata (no fractures) with cross flow
	7. Natural fracture system leading to an aquifer		
Recommended treatment			
Conventional treatments (e.g., cement, mechanical devices) normally are an effective choice.	Gelant treatments normally are an effective choice.	Preformed gel treatments work best.	Gelant or gel treatments should NOT be used.

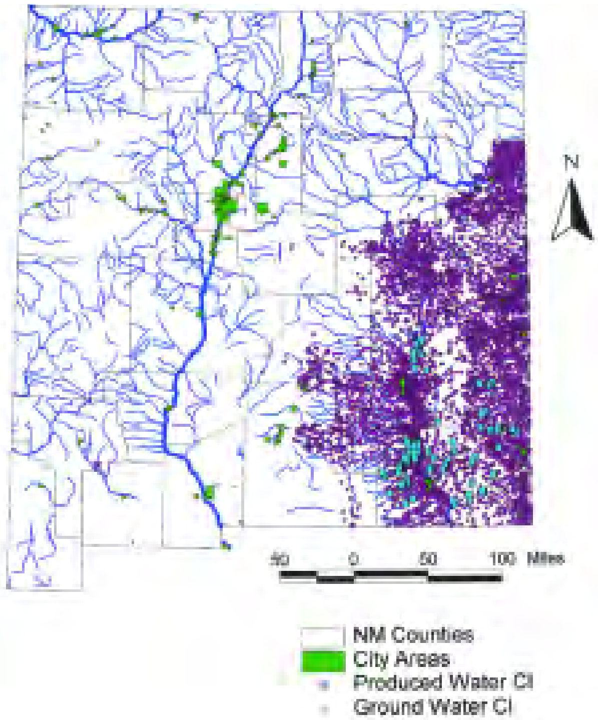

FIGURE 1—Map of locations of produced water and ground water quality data in NM WAIDS database.

of the gel now most commonly used for water shutoff in oil production—are among the world's leading authorities in this field.

In addition to their research, the Reservoir Sweep Improvement Group has developed a strategy for diagnosing and solving water production problems that advocates attacking the easiest problems first and beginning diagnosis with information already at hand. They have categorized various types of produced water problems and have prioritized them from least to most difficult, recommending treatments of choice for all cases (Table 1).

Optimal process identification

The PRRC has joined New Mexico State University, Sandia National Laboratories, and a consortium of New Mexico oil and gas producers for a dual effort in the north and south ends of the state. This research team is seeking an integrated approach to produced water management in coalbed methane production, and for the best means of pretreating oil field produced waters before desalinating them.

North—coalbed methane produced water management

Produced water issues in coalbed methane (CBM) production are especially problematic for producers. Because water is usually not reinjected into CBM-producing formations, the anticipated rapid growth of CBM production in New Mexico's San Juan and Raton Basins is expected to result in unprecedented volumes of produced water requiring treatment, surface discharge, or deep subsurface disposal. In basins where fresh water aquifers, springs, or wells are hydraulically connected to producing coal bed zones, CBM production could seriously deplete valuable ground water resources. In other basins, where CBM produced water quality can range from 10,000 to 100,000 mg/L total dissolved solids, inappropriate water treatment and disposal could contaminate the soil, surface water, and ground water. CBM operators are facing increasing environmental problems and expense in disposing of produced water that might jeopardize natural gas production.

In the San Juan and Raton Basins project, the team's capabilities in water modeling and in surface and subsurface contaminant transport will be used to assess the impacts of CBM produced water on water in connected aquifers and on surface water systems and to assess surface and subsurface disposal options. Several different pretreatment techniques will be evaluated for removing the organic content of the CBM water, which can be as great as 100 ppm or higher. Newly developed water treatment techniques for anionic and cationic contaminants such as salts and metals may also be applied, depending on the contents of the CBM produced water.

South—best methods for pretreating oil field brines

In the team's second project, Lea County in southeast New Mexico is being used as a model to identify the cost/benefit ratios of oil field brine reclamation, first on a pilot scale, then on a large scale.

Reclaiming oil field brine for beneficial use could prove economical worldwide, if relevant performance factors can be worked out first at the pilot scale. For New Mexico, benefits could include lower oil field operating costs and an exportable technology for regions where similar operations exist. A new industry would be brought to the state. Most importantly, drawdown of useable ground water could be reduced significantly, conserving our shrinking water supplies.

Most reclamation methods for oil field produced water require pretreatment of water to remove hydrocarbons, solids, and gases. These pretreated brines then undergo reverse osmosis, involving passage through a membrane (or other newer desalination processes) to be converted for beneficial reuse.

Biofouling of membranes by organic material has historically been responsible for the largest number of failures in reverse osmosis desalination processes. Thus, effective pretreatment of oil field produced brines is necessary to prevent biofouling and scaling of reverse osmosis membranes.

The Lea County project will evaluate several different methods for pretreating oil field produced brines. Each method will first be examined and evaluated by past field performance, further laboratory work, and/or actual field trials. The most promising pretreatment protocols will be tested in a producing oil field under varying conditions of brine salinity and residual oil. Each pretreatment process will be evaluated for its economics, effectiveness, and environmental impact. When this work is completed a pilot test, from pretreatment through desalination, for two separate pretreatment processes will be developed and performed.

Future developments

The large potential market for membranes needed to reclaim CBM and oil field produced brines is attracting the attention of the membrane industry. These projects will culminate in developing solid institutional and economic bases for the beneficial uses of desalinated brine.

Produced water quality data/mapping

The PRRC's Industry Service and Outreach Group is working on several produced water issues in southeastern New Mexico in their DOE-funded project (DE-FC26-02NT15134), "New Mexico Water and Infrastructure Data System (NM WAIDS"; Figs. 1 and 2).

Produced water quality data are becoming increasingly important as people begin to recognize that even these waters are potential assets for the arid West. However, produced water quality data are often difficult and time-consuming to find. For example, no single inventory for water chemistry data exists for the Permian Basin.

Spills of produced water may cause surface and ground water damage, and may have reporting requirements to regulatory agencies. Necessary data for these reports, including depth to ground water, location of water handling facilities, wellhead protection areas, surface water resources, or other vulnerable resources, are often scattered among various offices, agencies, and locations.

The New Mexico WAIDS project undertakes the design and implementation of a geographical information system (GIS) and integral tools that will provide operators and regulators with necessary data and useful information to help them make management and regulatory decisions. This information will be available through both a text-based and GIS interface. Project tools include the following:

- Searchable on-line databases on produced water quality, cultural data, ground water data, oil pipeline and infrastructure data, and corrosion information;
- A Web site capable of displaying produced water and infrastructure data in a geographical information system or accessing some of the data by text-based queries;
- A fuzzy logic-based site risk assessment tool that can be used to help assess the relative seriousness of a spill of produced water based on proximity to water sources and other parameters deemed essential by the New Mexico Oil Conservation Division; and
- A corrosion management toolkit that will provide operators with data and information on produced waters that will aid them in deciding how to address corrosion issues.

All of these components will be integrated into a Web site with a user-friendly interface that will provide access to data and information heretofore difficult to obtain. NM WAIDS, when completed, will offer significant savings in time and labor needed to look up data for regulatory purposes, but the greatest benefits may go to operators who will be able to implement the best corrosion management plans based on information provided by the program.

Brine treatment innovations

The question of how to develop a cost-effective, portable desalination unit that can be easily applied in the oil field has been occupying scientists for years, and promises to intrigue them for some time to come. The need for an efficient system for the pretreatment and disposal of produced water at the wellhead, which is also economical to operate and capable of treating water to meet EPA standards, is a pressing concern for oil and natural gas producers.

One method now being investigated by PRRC scientists jointly with Dr. T. Michael Whitworth of the University of Missouri–Rolla (formerly with the New Mexico Bureau of Geology and Mineral Resources) is the use of clay membranes for reverse osmosis treatment of produced water. Reverse osmosis is currently used worldwide on a large scale for purifying water for drinking. On a small scale, however, the costs of the synthetic membranes now used for this process are prohibitive.

In a project funded by the U.S. Department of Energy (DOE)/National Energy

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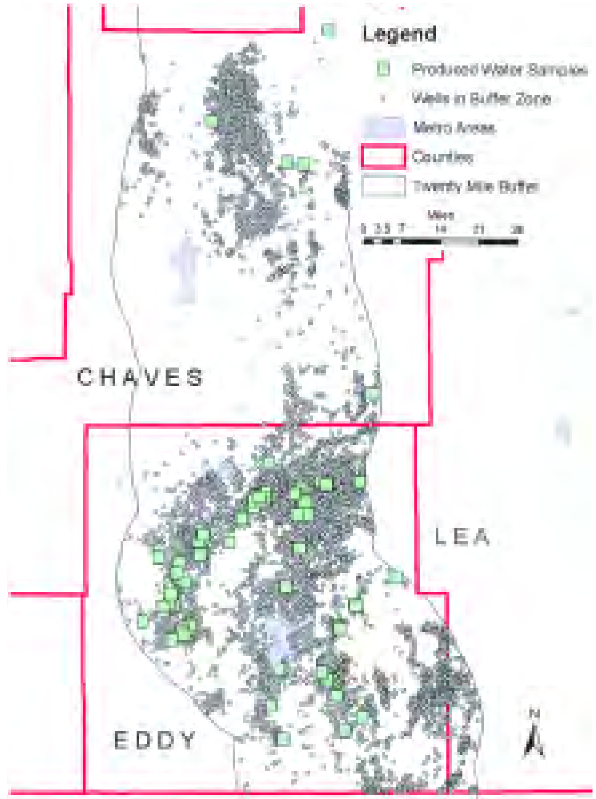

FIGURE 2—Pecos River producing wells and water samples.

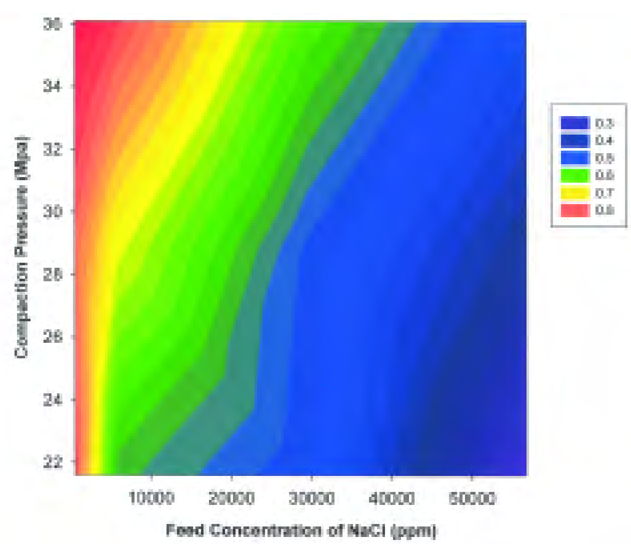

FIGURE 3—The influence of compaction pressure and feed concentration on the efficiency of a clay membrane.

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Technology Laboratory (NETL), "Modified Reverse Osmosis System for Treatment of Produced Water," inexpensive clay membranes are being constructed and tested for their ability to separate solutes from very highly saturated water without requiring unreasonable fluid pressures (Fig. 3).

Work is progressing in the fabrication of membranes in various configurations and degrees of compression. In addition, data on water chemistry from New Mexico oil fields are being collected, in order to target the formulation of these membranes to specific problems.

Researchers do not expect a prototype reverse osmosis unit for oil field use—the desired outcome of this work—to be realized for some time to come. The steady advancement of their research is encouraging, particularly with the support it has earned statewide from the oil and gas industry. The development of an effective prototype will require careful long-term planning and bench testing of several innovative treatment methods. When this system is finally achieved, its applications may well extend beyond the oil field.

Reference

Petroleum Recovery Research Center, 2002, Produced water strategies in New Mexico: New Mexico Institute of Mining and Technology, Petroleum Recovery Research Center, 12 pp.