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EYE on Environment

U. S. Department of Energy ♦ National Petroleum Technology Office ♦ P. O. Box 3628 ♦ Tulsa, OK 74101-3628

ALASKAN NORTH SLOPE OIL AND GAS CONFERENCE

By Viola Rawn-Schatzinger,
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The workshop *"Established Oil & Gas Practices and Technologies on Alaska's North Slope"* was held in Anchorage, Alaska on April 25-26, 2000. The workshop, sponsored by the U. S. Department of Energy (DOE) and The State of Alaska, focused on the unique challenges of environmentally sound oil and gas development of Alaska's North Slope and the innovative practices and technologies used to meet this challenge. The Alaskan workshop was the first effort to promote DOE's new initiative, Preferred Upstream Management Practices (PUMP). Organizations cooperating in the workshop included: Alaska Dept. Fish & Game, Alaska Oil & Gas Assoc., Alaska Oil &

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Figure 1 Winter and summer views of a drilling pad showing the lack of impact following development of a drilling site. Photo credit Kevin Meyers, ARCO/Phillips Alaska.

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Gas Conservation Commission, ARCO Alaska/Phillips Alaska, BP-Amoco Alaska, Bureau of Land Management, and Minerals Management Service. **Figure 1** illustrates the type of improvements brought about in 20 years of practices designed to protect the environment.

An integrated program of speakers from Federal, Alaskan State, industry, environmental and Native American groups presented information on the problems and solutions of oil and gas development on the North Slope. The conference offered an opportunity to show how government and industry has worked together for the benefit of the public.

Many of the technologies currently in use in Alaska were developed specifically to overcome the difficulties of harsh weather conditions and the fragile Alaskan environment. Drilling and development technologies have evolved in the past 30 years, many of which use the winter snow and ice as a means of protecting the Arctic ecosystem.

Goals

Bob Gee, Assistant Secretary of Fossil Energy, DOE, addressed the Federal government's goals for the Alaskan North Slope team effort as environmental protection and resource development. Federal policies have involved energy efficient practices, tax incentives, development of innovative technologies, methods to prevent near term abandonment, and promote responsible resource management of oil and gas. The enormous oil and gas potential of Alaska must reflect balanced use of environmental protection, subsistence living, economic (energy) development, recreation and good land management.

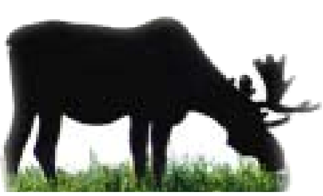

Figure 2 A production module being transported on an ice road. Photo credit James Trantham, ARCO/Phillips Alaska.

Michelle Brown, Alaskan Dept. of Conservation, summed up the state's goal for resource development, "It must be done right or it shouldn't be done at all." The two-day workshop stressed the technologies and practices developed in Alaska that are "doing it right". Because of the difficulties in development of oil and gas in the Arctic, special areas were addressed: **1)** solid waste disposal and minimization, **2)** effluent disposal, **3)** air emissions, **4)** drilling technologies, **5)** corrosion protection and infrastructure integrity, **6)** transportation (including ice roads, pipelines, caribou crossings), **7)** site rehabilitation, and **8)** wildlife protection.

Minimization: Key to Environmental Protection

Among the unique and innovative technologies developed for the North Slope are methods to minimize the development footprint. ARCO/Phillips Alaska's development of the Alpine field discovered in 1994 has set a new standard for minimizing environmental impact, placing a high priority on safety, economics and Native American lifestyle while at the same time developing the largest U.S. oil discovery of the past decade. Transportation of the drilling pads and construction facilities are done over ice roads. Ice roads are capable of carrying extremely large and heavy loads without damage to the tundra **(Figure 2)**. Seismic acquisition is performed only in the winter once the tundra is frozen with at least 6 inches of snow cover. Ice road technology has allowed roadless development of Alpine field using low impact vehicles. Specialized technologies and facility construction designed to minimize impact have led to surface development of 97 acres for Alpine field, which represents only 2/10 of 1% of the total field size. Development of ice roads and ice pads for transportation and drilling leaves minimal impact on the tundra surface once facilities are removed and ice and snow melt see **Figure 1**.

Waste Disposal

Disposal of solid wastes, effluents and air emissions are a major concern of government agencies, industry and environmental groups. Proper waste disposal includes: requirements for safety; advanced disposal technologies; protection of the environment; and rehabilitation of former disposal sites, which the public no longer finds acceptable. Environmental studies have shown a variety of problems with earlier disposal methods: unsightly waste pits; polluted or blocked streams, which harmed fish and obstructed waterflow; abandoned airstrips and drilling pads; and garbage dumps, which put men and bears in potentially dangerous conflict.

Reinjection of produced water and waste fluids began in the 1940s and led to increased production. Today reinjection of produced water on the North Slope is carefully managed to achieve the multiple goals of pressure maintenance, waterflooding and disposal. In 1999 ARCO reinjected 69 million barrels of fluids.

The most important advance in waste disposal is reinjection of drill cuttings and other solid and fluid waste material into the formation. This process includes collecting all waste for reprocessing, crushing solids, mixing the solids in a suspension, and injecting the slurry into wells and back into the producing formation. Reinjection of solid waste has resulted in a 70% to 80% reduction in habitat loss formerly associated with waste pits. In 1999 on the North Slope 1.2 million cubic yards of solids were reinjected. This represents enough gravel to make a road 3-ft high by 27 ft wide and 75 miles long. Speakers from BP Amoco emphasized that in the past 12 years they have made a concentrated effort to eliminate all past surface waste facilities including those originally operated by other companies and surface mining operations.

In the air quality sector, elective catalytic reduction engines have achieved a 90% reduction in nitrous oxide (NO) air emissions on the North Slope. A preliminary 1989-94 air quality study downwind of major facilities indicated no observed damage or impact on the vegetation from air emissions.

Waste disposal methods all strive for the Environmental Protection Agency's goal of using the Best Available Technology (BAT) that is economically possible. As a preventive approach to waste management, training and management practices strive to reduce the amounts of waste produced. Techniques include: **1)** Drilling smaller diameter wells, which produce a smaller volume of drill cuttings. **2)** Use of water conservation methods, because water is a limited resource in the Arctic. **3)** Use of high-energy-efficient vehicles. **4)** Recycling of all possible materials and containers. **5)** Grinding and reinjection of solid waste, which takes considerably less surface space than traditional disposal methods.

Horizontal Drilling

One of the most successful technologies implemented on the North

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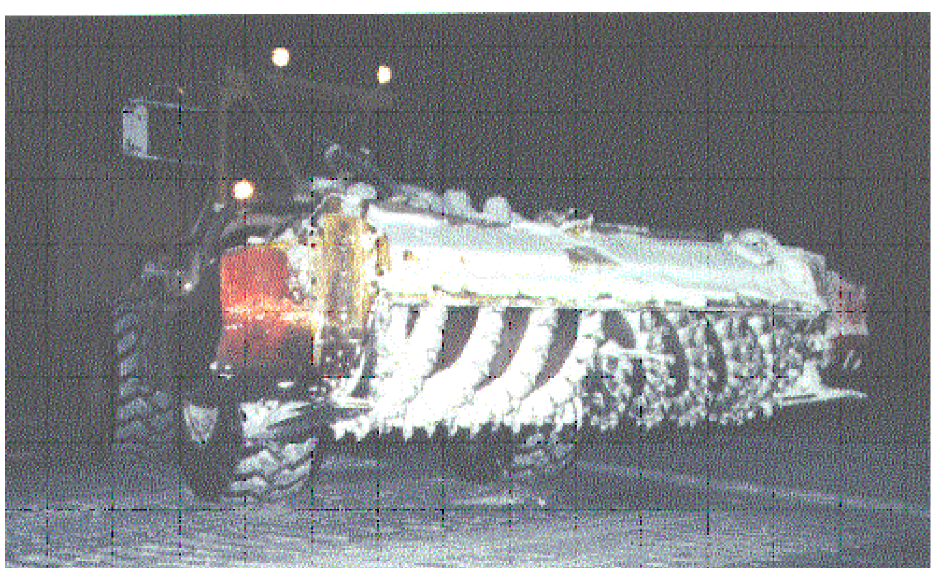

Figure 3 Ice chipper used in ice road construction. Photo credit Kevin Meyers, ARCO/Phillips Alaska.

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Slope is horizontal drilling, which has minimized the footprint. A horizontal well on the North Slope can extend over a mile and economically produce from a pay zone only 8-10 ft thick. Improvements in drilling technology have led to a dramatic reduction of surface facility space requirements. Use of old vertical wells as access for horizontal drilling further reduces surface disturbance, and may cost 1/10 of the cost of drilling a horizontal well from scratch. In 2000, a five-acre well pad can support 35 wells, with horizontals extending in all directions. Because of both economics and environmental restrictions, development of the North Slope could have halted several years ago without the advent of horizontal wells.

Corrosion

Corrosion prevention and protection is an economic and safety necessity, that also benefits the environment. Extreme cold and permafrost heaving add components of corrosion not found in pipelines and facilities in more temperate climates. The emphasis is on preventing leaks and spills through continuous monitoring, maintenance, equipment replacement scheduling, special design, and chemical coatings on pipelines and facilities.

Ice Roads

Ice road and ice pad technology has evolved as a BAT in Alaska as a means of economic development and protection of the environment. Rapid development from discovery to enhanced production in only five years has been made possible by innovative transportation, that makes use of the ice and snow of the winter season. Ice road technology has advanced from simple packed snow in the 1960s-1970s, to specified depths of ice and chipped ice in the 1980s, and to ice coating and specialized low-impact vehicles in the 1990's. Use of ice roads and ice pads for transportation, drilling and facilities construction has extended the development season on the North Slope up to nine months a year. **Figure 3** shows an ice chipper developed in the 1990s. Vehicles developed for summer use are designed as low-impact, wide-tire vehicles which can drive over the tundra without leaving tracks.

One of the original drivers for development of ice pads for drilling was the lack of and difficulty in transport of sufficient gravel to build conventional roads. Even crossing rivers with reinforced ice bridges in the winter is easier, less expensive and less damaging to the environment than conventional bridges. Floating ice bridges can be designed to handle enormous weight. Increased use of insulation materials in the building of ice pads and roads will further lengthen the working season while protecting the tundra.

Alaskan Environmental Agencies

One of the reasons that Alaska has developed such innovative methods of oil exploration and production while protecting the environment has been the cooperation of the many state and federal environmental and wildlife protection agencies. Alaskan officials early recognized the danger to the tundra posed by oil development. Several of the presentations at the conference were the summation of over

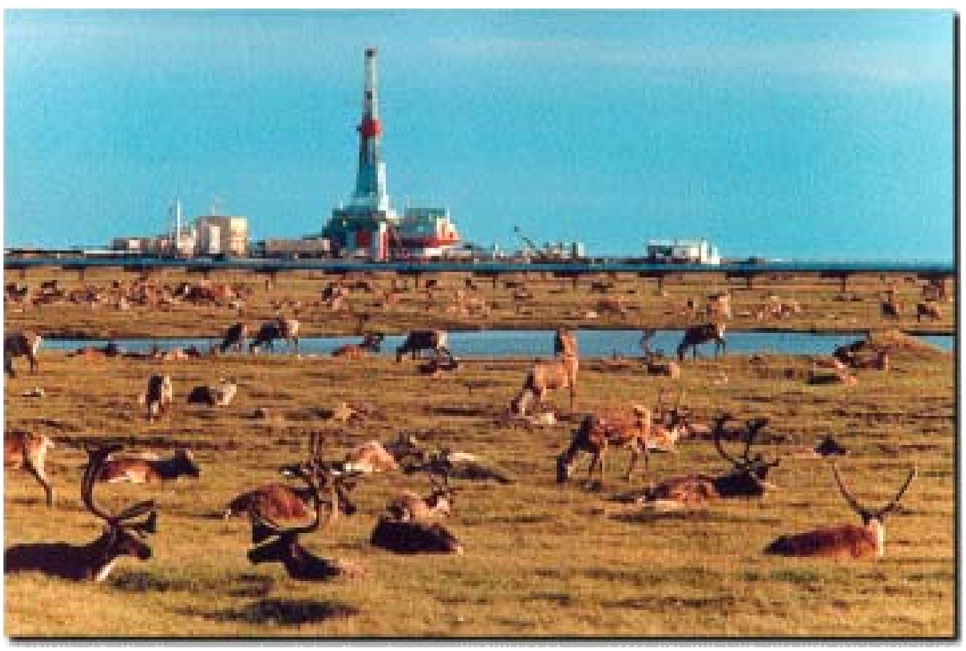

Figure 4 "Happy Caribou" illustrate the adjustment caribou have made to oil and gas development of the North Slope. Photo credit Mike Joyce, ARCO/Phillips Alaska.

25 years of environmental monitoring and interaction of wildlife management experts with cooperation from oil company personnel analyzing what works and what doesn't work to preserve the Arctic tundra habitats.

Twenty-five years of experience has shown how to design pipelines and facilities that don't interfere with caribou migrations or calving. Studies to determine where caribou want to go aid in placement of crossing ramps and elevated pipelines. Something as simple as separating pipelines from work roads allows caribou the visual "safe space" they require. Traffic control to limit unnecessary movement on roads during peak caribou migration and calving has helped decrease problems. In the several generations of caribou and oil industry interaction, the caribou have adapted to change. Caribou traditionally spend time on gravel bars and beaches to avoid flies and mosquitoes in the summer. Gravel pads and facilities provide some of the same protection. During the period from 1970 to 1999 the Central Arctic herd has increased from 3,000 to nearly 20,000 caribou. **Figure 4** shows the success of the caribou's adjustment. Long-term mapping of caribou migration and calving patterns shows that caribou will avoid places they don't like, but that localized displacement of caribou herds on the North Slope is minimal.

In addition to protecting caribou herds, wildlife management has developed recommendations for avoiding human conflict with grizzly and polar bears. This has largely involved training oil field personnel never to feed wildlife or leave food or other attractive substances where bears can get to them; designing building entrances and facilities, which bears can't enter; and developing a protocol for working in bear country. The bear interaction program is a voluntary program of improvements in site design, training, monitoring and notification of the Alaskan Department of Wildlife officials if there is a problem bear.

Figure 5 Pipeline crossing under the 1-mile Colville River. Photo credit Kevin Meyers, ARCO/Phillips Alaska.

Gravel Mining and Wildlife Habitat

Correctly managed gravel mining with stabilization of water level between rivers and gravel pits has shown benefit to fish and waterfowl. Deepening certain channels and forming pools allows for winter protection for fish, and improved waterfowl habitat.

Gravel mining, and pipeline and road crossings over streams and rivers must be designed not to limit or restrict flow and must be able to handle the flashy spring snowmelt and ice problems associated with ice breakup. Planning and consultation with wildlife and environmental agencies aids in avoiding construction in particularly sensitive areas, such as fish spawning areas or waterfowl nesting sites. Proper construction of culverts to allow water and fish to pass under bridges and pipelines, and additional protection from ice movement and breakage must be followed by constant monitoring, cleaning, and annual repairs. To protect larger streams, used by migrating fish, bridges rather than culvert batteries are recommended to maintain water flow. Over the life of a struc-

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ture, maintenance and construction costs may be lower for bridges than the widely used and easy to construct culvert batteries.

Large river crossings present special problems. The over one mile wide Colville River presented a construction challenge that ARCO met by designing a subsurface pipeline crossing **(Figure 8)**. Difficult drilling, insulation and pipeline integrity problems had to be solved because the changing width of the river made a bridge infeasible and environmentally unsound.

Site Rehabilitation and Future Development

Major oil companies recognized their responsibilities to the public and participated in developing technologies and strategies to protect the North Slope environment. Rehabilitation of sites has become part of the management practices. In addition to removing trash and beginning the process of re-vegetation and rehabilitation of their own sites, major oil companies have begun to clean and rehabilitate abandoned sites left by oil companies and surface mining facilities no longer operating. Current and future facilities are designed to minimize impact on the tundra. Gravel pads 5-ft thick are laid under permanent facilities as an insulation to prevent sinking and damage to the tundra. Whenever possible facilities are built off the ground as a further insulation to prevent melting the permafrost. The use of gravel and ice for road and pad construction has been driven both by economics and environmental protection.

Modern habitat mapping technology has advanced understanding of the 24 major tundra habitats. GIS maps and databases can trace existing vegetation, wildlife, and land use development. The database system can easily handle changes, corrections and provide visual updates necessary for planning development in the best economic manner, while minimizing impact on the fragile environment of the North Slope of Alaska.

Report

The proceedings are being prepared by the Idaho National Engineering and Environmental Laboratory, and will be available both in hardcopy and CD-ROM format. The target date for release of the workshop proceedings is November, 2000. The proceedings of the *"Established Oil & Gas Practices and Technologies on Alaska's North Slope"* will be available from the National Petroleum Technology Office, contact Herb Tiedemann, Tel: (918) 699-2017 or email htiedema@npto.doe.gov.

Acknowledgments

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Salt Caverns for Oil Field Waste Disposal

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In 1995 DOE's National Petroleum Technology Office (NPTO) funded Argonne National Laboratory to investigate the technical feasibility and legality of disposing of oil field wastes in salt caverns. The Texas Railroad Commission (TRRC) requested the research, and early efforts concentrated on baseline studies on caverns in Texas. The report found that disposal of wastes in caverns was technically feasible and that there were no federal or state legal prohibitions against cavern disposal. However some states may need to revise their regulations to make salt cavern disposal feasible.

Following release of Argonne's feasibility report, DOE recommended that several research organizations join forces to coordinate their salt cavern research. Argonne National Laboratory, Sandia National Laboratories, the Texas Bureau of Economic Geology, and the Solution Mining Research Institute jointly formed the Salt Cavern Research Partnership. The Partnership established a government/industry advisory committee that helped to identify the most important salt cavern research needs.

Salt Cavern Locations

The use of caverns for oil field waste disposal is dependent on two primary factors – the presence of suitable salt formations and a large enough volume of oil field wastes to make a cavern economical. **Figure 6** shows the location of underground salt formations in the United States, although most of these salt locations are not good candidates for disposal caverns. A second map shows current salt cavern hydrocarbon storage use in Texas **(Figure 7)**. Currently, Texas, Canada and several sites in Europe are the only locations that have approved oil field disposal in salt caverns. To deal with the potential of cavern leakage a number of criteria are used in the design and placement of disposal caverns including depth, size, distance from drinking water sources, surface development, and monitoring plans.

Since the initial feasibility studies on salt cavern disposal and NORM disposal were published, the TRRC has permitted two caverns for disposal of NORM waste.

Waste Disposal

Salt caverns used for oil field waste disposal are created in salt formations by solution mining. When created, caverns are filled with brine. Wastes are introduced into the cavern by pumping them under low pressure. Each barrel of waste injected to the cavern displaces a barrel of brine to the surface. The brine is either used for drilling mud or

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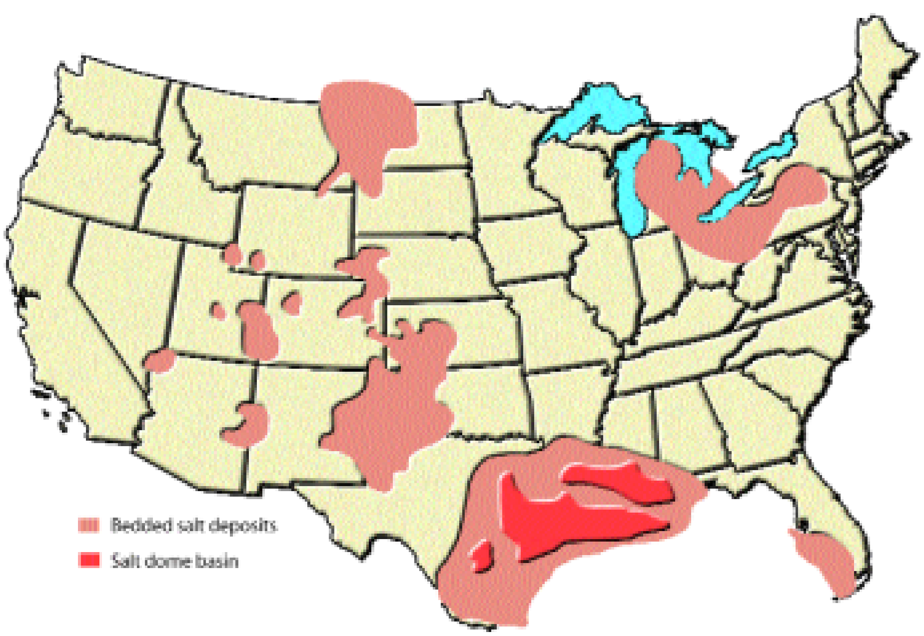

Figure 6 Major U.S. salt deposit locations.

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is disposed of in an injection well. **Figure 8** shows an injection pump used at disposal cavern facilities in west Texas. Several types of oil field waste may be pumped into caverns for disposal. These include drilling muds, drill cuttings, produced sands, tank bottoms, contaminated soil, and completion and stimulation wastes. Waste blending facilities are constructed at the site of cavern disposal to mix the waste into a brine solution prior to injection **(Figure 9)**.

Cost Study

NPTO funded Argonne to conduct additional baseline studies on cost and risk. The cost study found that disposal in caverns could compete economically with other types of waste disposal facilities used in the same geographic areas. Costs for oil field waste disposal in caverns in Texas were compared to other types of commercial disposal facilities. Figures for 1997 indicate that disposal costs using salt caverns in Texas range from $1.95 to $6.00 per barrel of waste. Other methods (evaluated as cost per barrel) used in the Texas and New Mexico area include:

Land spreading
$5.50 - $16.00

Landfill or pit disposal
$2.25 - $ 3.25

Evaporation
$2.50 - $ 2.75

Treatment and injection
$8.50 - $11.0

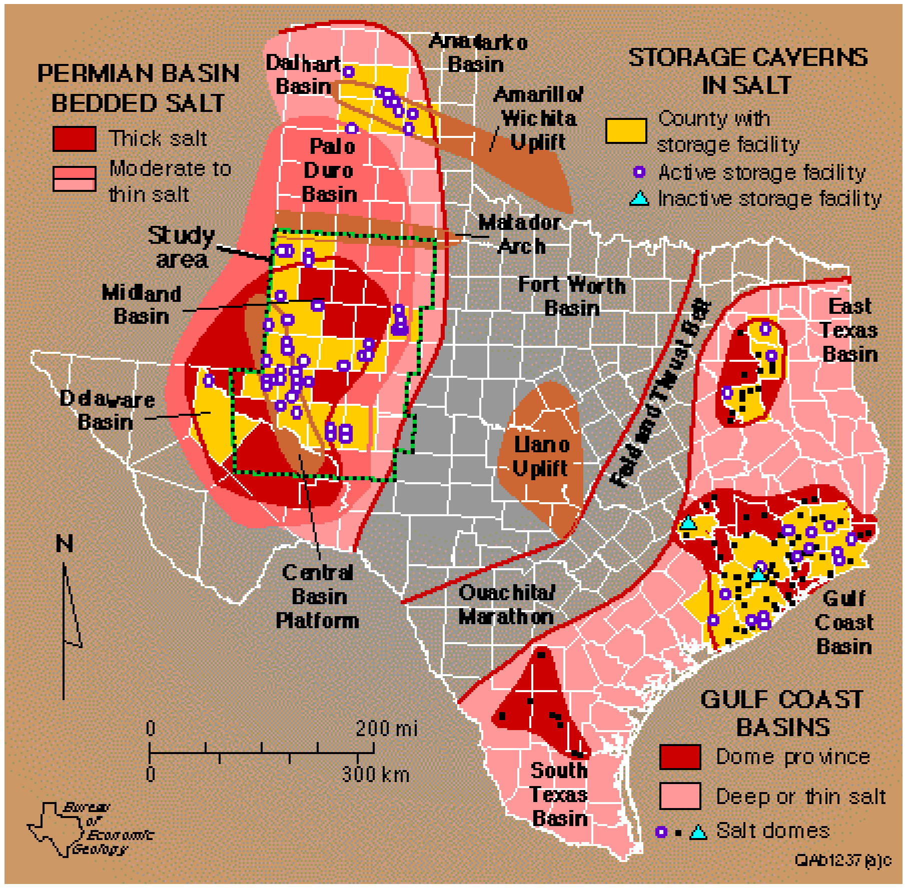

Figure 7 Locations of salt deposit and storage use in Texas.

Overall advantages of salt cavern disposal include a medium price range for disposal cost, large capacity and availability of salt caverns, limited surface land requirement, increased safety, and ease of establishment of individual state regulations.

Post-Closure Behavior

An additional aspect of oil-field waste disposal in salt caverns is evaluating the processes that may affect the cavern over time. Once a cavern has been filled with waste, any oily layer floating on the top surface is removed and the well leading to the cavern is plugged permanently, sealing the cavern. Internal pressure will increase after sealing due to deformation of the salt deposit under the weight of overburden rock. As the salt flows into the cavern, a process known as salt creep, the volume of the cavern is reduced. Geothermal energy in the rocks may cause the waste contents to expand. Both are very slow processes, and as the fluid pressure increases, the cavern may reach a point that the cavern walls crack or leak, or the waste material might migrate into the salt formation.

Since no disposal caverns have been closed anywhere in the world, no data is yet available on cavern behavior following closure. Additional laboratory and field research continues to study the effects of pressure rise on oil field wastes disposed of in salt caverns. The Solution Mining Research Institute over-

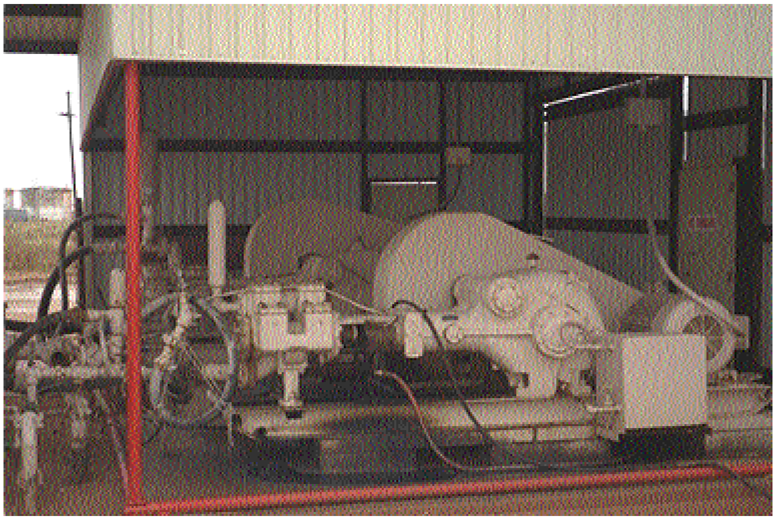

Figure 8 Injection pumps used at salt cavern disposal facilities in West Texas.

saw preparation of a bibliography for cavern behavior following plugging, including salt creep and rock strength behavior, the permeability of rock salt, temperature and pressure build up, and plugging and sealing issues.

Risk Study

The risk study found that the health risks associated with various types of cavern failure scenarios were all below the Environmental Protection Agency's (EPA) acceptable risk threshold, even when the analysis assumed that all caverns would leak. Many of the contaminants in fluids leaking from the cavern would be bound up by soil and rock and would not migrate to locations where they could affect drinking water wells. Portions of the work on salt cavern waste disposal of oil field waste and Naturally Occurring Radioactive Materials (NORM) wastes were reported in earlier issues of EYE on Environment. An article in the Summer 1997 issue (Vol. 2 # 2) discussed the formation of salt caverns and the mechanics of oil field waste disposal. The Winter 2000 issue (Vol. 5 # 1) mentioned the disposal of NORM in salt caverns.

Salt Formation Study

NPTO funded the Bureau of Economic Geology to conduct an extensive study of bedded salt formations in the Permian Basin of West Texas. The study mapped total salt thickness, depth from the surface to the top of the salt deposits, and the processes of salt dissolution in the formation of caverns. These factors were used to assess the potential for storage in salt formations and the parameters necessary to establish environmentally safe waste disposal in salt caverns.

Modeling Efforts

NPTO also funded Sandia National Laboratories to model the behavior of horizontal caverns formed in salt structures. Sandia identified potential sites for horizontal caverns, evaluated the stability of their roofs, and calculated leaching times for different sized caverns.

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Figure 9 Waste blending and mixing facility as a West Texas salt cavern disposal site.

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Various monitoring methods, including sonar, can give indications of the interior dimensions of caverns. **Figure 10** shows graphic images of two different crude oil storage caverns that are part of DOE's Strategic Petroleum Reserve.

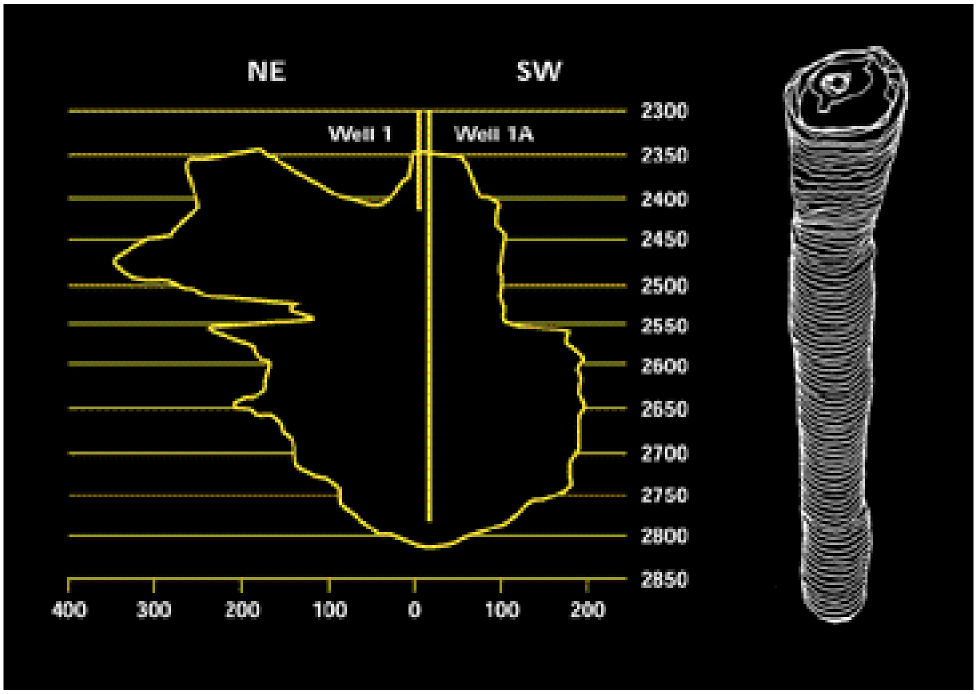

Figure 10 Sonar mapping providing two- and three-dimensional views of cavern site and shape allows for monitoring of waste disposal.

Brochure and Website

Additional information on oil field waste disposal in salt caverns may be obtained by requesting the brochure, "An Introduction to Salt Caverns & Their Use for Disposal of Oil Field Wastes" from the Argonne National Laboratory, John Veil, email, jveil@anl.gov, or telephone, 202-488-2450. The Salt Cavern Information website may be accessed at www.npto.doe.gov/saltcaverns.

The website has extensive photos and graphics that show salt cavern formation and waste injection techniques.

Acknowledgments

Mr. Veil's participation in this project is funded by DOE's Office of Fossil Energy and the National Petroleum Technology Office under contract W-31-109-ENG-38.

Photo Credits: John Veil and Dann Sarro, Argonne National Laboratory.

7th International Petroleum Environmental Conference
November 7-10, 2000
Albuquerque, New Mexico

Albuquerque Hilton Hotel
1901 University Blvd. NE
Albuquerque NM 87102

The International Petroleum Environmental Conference brings together professionals from both the oil and gas industries and academia who seek solutions to environmental problems of a technical, legal and regulatory nature. Issues to include: exploration, production and refining.

Room reservations at either conference hotel need to be made no later than October 6, 2000. To obtain conference room rates, please identify yourself as attending The University of Tulsa 7th International Petroleum Environmental Conference.

Albuquerque Hilton Hotel
(505) 884-2500 ($98 single, $108 double)
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(505) 889-4000 ($43 single, $73 double)

Conference Fee Schedule

Speaker fee	
Full conference	$395
One day	$245
Half day	$145
Participant Fee	
Full conference	$495
Full conference (after10/23/00)	$595
Group discount (3 or more, same org.)	$395
One Day	$275
Half day	$145
Full Time Student	
Department letter of verification required	$145

More Information About the NORM Technologies Website

The DOE is developing a NORM Technologies Website to assist operators in their efforts to resolve NORM-related waste management issues. The NORM Technologies Website, which will be hosted by the Interstate Oil and Gas Compact Commission (IOGCC), will provide easy access to current information about companies providing all types of NORM services, including site characterization and remediation support, sample collection and analysis, radiation safety program development, radiation safety training, transportation, and NORM waste treatment and disposal. Company-specific information that will be available on the website will include current contact information plus a description of the company's experience and, if available, a link to the company's own website. Company participation in the website will be free, meaning that any company wishing to post information about itself will be able to do so at no charge. Similarly, public access to the website also will be free.

The NORM Technologies Website will also provide access to current information about state agencies that have jurisdiction over NORM wastes, including links to state websites providing access to the applicable regulations. In addition, the NORM Technologies Website will host a mail list to allow individuals to post and respond to specific questions related to NORM management.

Figure 11 shows the states belonging to the IOGCC.

It is anticipated that the NORM Technologies Website will be publicly accessible sometime in late 2000. Argonne National Laboratory is developing the website with funding from DOE's National Petroleum Technology Office. Individuals seeking additional information about this website may contact Karen P. Smith at Argonne National Laboratory. Ms. Smith's phone number is (303) 986-1140, ext. 267 and her email address is smithk@anl.gov.

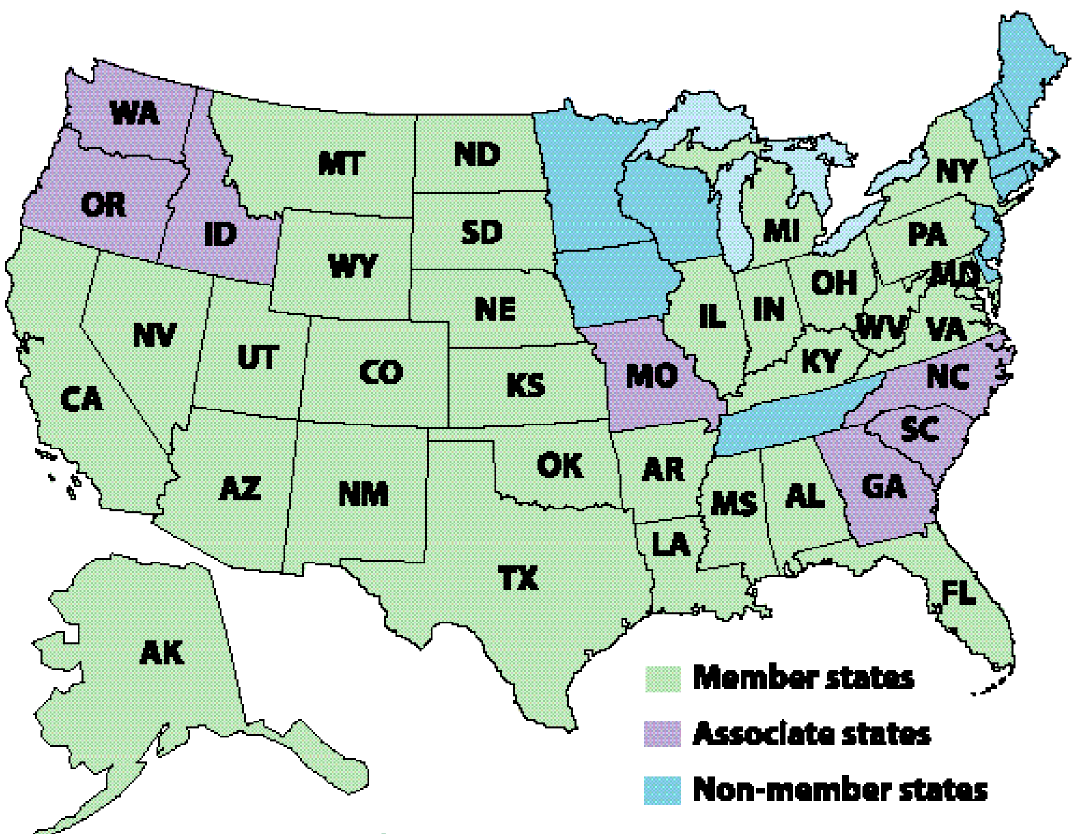

Figure 11 IOGCC membership.

Calendar

NOVEMBER 7-10,2000

7th International Petroleum Environmental Conference
Albuquerque, New Mexico
Contact: Kerry Sublette, Conference Chair
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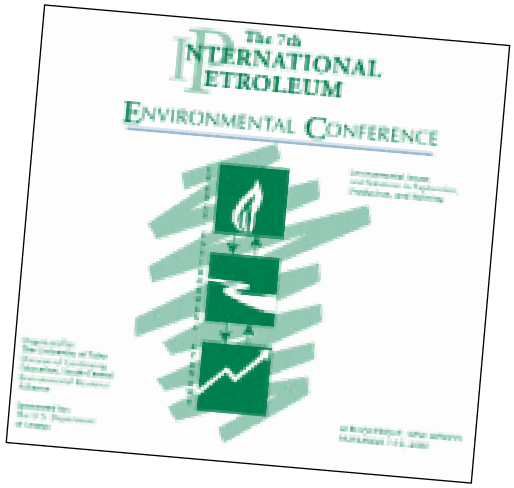

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