New Environmental Projects Announced–Details on page 19

eye on environment

Handling Our Water Resources

INTRODUCTION

Management of water issues is a major emphasis of the DOE's Oil and Gas Environmental Program administered by the National Energy Technology Laboratory's National Petroleum Technology Office. Water issues have several concerns; injection water, produced water (including Coalbed Methane-CBM) and its effects on the environment, treatment of waste water, and the availability of water in arid lands. NETL has 26 projects grouped under Water Management Approaches and Analysis, Water Management Technologies, and Coalbed Methane and Produced Water. NETL's goal is focused on ensuring that water produced through oil and gas development does not adversely impact the environment and that it is put to beneficial uses where possible.

WATER MANAGEMENT APPROACHES AND ANALYSIS

Water Management Approaches include regulatory issues, methods and strategies to improve water management, and research on water handling problems to provide input to local, state and federal agencies. Projects address a number of water management concerns from initial research stages to implementation of new methods and permitting.

Water and Waste Regulatory Analysis - *Argonne National Laboratory*

DOE's Office of Fossil Energy programs are geared to ensuring an adequate, reasonably-priced supply of oil and gas resources for the nation. DOE is responsible for assessing proposed environmental regulations that might affect the cost of producing oil and gas and evaluating innovative technologies that can offer lower cost and better environmental protection. Argonne National Laboratory is funded to monitor and review water regulatory developments and provide technical analysis that can be submitted to EPA during public comment periods. Argonne reviews EPA's data, assumptions, and analyses and offers scientifically-based data, and analyses where appropriate.

In the 1990s, EPA developed national effluent limitations guidelines (ELG) for offshore oil and gas discharges, for coastal oil and gas activities, and for synthetic-based drilling mud discharges. The ELGs were used by EPA regional offices to develop National Pollutant Discharge Elimination System general permits. Argonne reviewed the documents and permits, and prepared extensive analysis that allowed DOE to provide a comprehensive set of comments to EPA.

Benefits: *Scientific evaluation and comments prepared for EPA have resulted in significant cost-saving changes to final guidelines and permits. Argonne has*

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This edition of Eye on Environment highlights the research in produced water management to maintain:

- **Environmental protection**
- **Economic development**
- **Energy availability**

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prepared reports on the regulatory barriers posed by existing water regulations, such as prohibition of discharges from marginal gas wells and the complex requirements for discharges from coal bed methane wells; and continues to track important developing water regulatory issues in which DOE has a stake, such as total maximum daily loads, cooling water intake structures, wetlands, stormwater runoff, underground injection, and others. **Contact:** David Alleman, (918) 699-2057 or David.Alleman@npto.doe.gov; **Performer:** John Veil, ANL, Washington D.C., (202) 488-2450 or jveil@anl.gov. **Performance period:** 10/1999 to 4/2003.

Provide Support to Produced Water: Osage-Skiatook Petroleum Environmental Research Project - *United States Geological Survey*

The objective of the research is to evaluate two petroleum field sites impacted with produced water and associated oil and chemicals in Osage County, Oklahoma. The project will evaluate the long-term and short term effects of hydrocarbons, dissolved and suspended constituents of produced water on soil, ground and surface water. Mitigation effects of natural processes at older sites and active sites will also be examined. The geologic and climatic setting of these two sites resembles that of much of the major southern mid-continent oil- and gas-producing area of the U.S. Oil and gas production has occurred in this area for over one hundred years, thus the fields provide an opportunity for a study of the long-term effects of produced water on soils, water and vegetation. Examination of the sites shows that local effects include soil salinization with resultant destruction of soil textures and deep erosion, death of nearby vegetation, sparse or stunted vegetation in the general area; salinization of surface water and ground water; saturation of soils with crude oil of varying age, and weathering and dispersal of crude oil components and trace elements. **Figure 1** shows some of the resulting destruction of vegetation, and pollution of water impoundments.

Photo credit: Yousif Kharaka

Figure 1. Battery showing produced water discharge to holding pond.

This investigation involves scientists from DOE, EPA, Bureau of Indian Affairs, USGS, and the Osage Environmental Office. Initial work included mapping and characterization of geologic, geophysical, vegetation and soil resources; and sampling and analysis of oil, gas and produced water sources.

Fifty sampling wells were drilled to delineate produced water and hydrocarbon sources, to collect samples, and develop transport models for geochemical and microbial toxins. Additional samples were taken from the wells several months after the first collection to allow study of short-term changes and seasonal differences. The analysis will be used to assess the signatures of disturbed and undisturbed sites, the geochemical impacts on oak trees, the recovery of oak forest ecosystems, and the interchange between the water and sediments in the reservoir and contaminated surface and groundwater. The changes in the soil and water in respect to oil saturation and trace elements, and the impact of local fish species will also be analyzed.

Benefits: *Investigation of the hydrology, geochemistry, microbiology, geology and ecosystem dynamics will provide better remediation practices through an understanding of the fate and ecosystem interactions of organic and inorganic contaminants at these research sites, and will be applicable to similar sites.* **Contact:** Nancy Comstock, (918) 699-2059 or **Nancy.Comstock@npto.doe.gov**; **Performer:** Yousif Kharaka, USGS, Menlo Park, CA, (650) 329-4535 or **ykharaka@usgs.gov**. **Performance period:** 10/2001 to 9/2003.

Brine Impact on Aquifers in Seminole County, Oklahoma - *Bureau of Land Management*

The project is an investigation of the effects of brine leakage from historic oil reservoirs on aquifer quality. Researchers from the University of Tulsa will use a combination of field sampling of streams and rivers, and water wells. The project will made recommendations concerning how to remediate impacts of brine pollution.

The data collected during the 2001 summer field season included: the location of the sampling sites, sample collection, development of the gradient flow model for the aquifer, and location and production history of oil and gas fields in Seminole County, Oklahoma. A water probe was used to measure dissolved O_2, conductivity, salinity, temperature and pH from 155 samples initially collected. Ground water sampling continued in the spring of 2002. All rivers, streams, ponds and brine scars in Seminole County were digitized utilizing GIS, quadrangle maps and aerial photographs. All current and historic oil and gas well have been integrated in the GIS model. Both oil and new gas and oil tanks have been mapped, and the property of map of Seminole County has been scanned for inclusion in the GIS model. Logs for water wells from the Chickasaw Nation in Ada are being used to determine the top of the water table throughout Seminole County.

Benefits: *Modeling of the ground water flow will aid the goal of planning remediation and preventing future damage to aquifers in Seminole County, Oklahoma.* **Contact:** David Alleman, (918) 699-2057 or **David.Alleman@npto.doe.gov**; **Performer:** Sandford Wells, BLM Tulsa, OK (918) 621-4141, Brian Tapp, University of Tulsa (918) 631-2517. **Performance period:** 8/2001 to 1/2003.

Reducing Chemical Use and Toxicity in Produced Water Systems - *Argonne National Laboratory*

The objectives of the project were to: (1) minimize the environmental discharge of hydrocarbons and treatment chemicals due to failures resulting from sustained localized pitting corrosion of oilfield equipment including pipes and flow lines, (2) reduce the amount of toxic treatment chemicals used by field operators to prevent those failures, and (3) identify alternate treatments that reduce the use of toxic chemicals. A method to detect pitting is required to permit treatment at only those sites on pipes and lines that are affected and to be able to monitor the effectiveness of the treatments.

An electrochemical noise analysis (ENA) technique for detection of sustained localized pitting corrosion and control has been developed. The effectiveness of the ENA technique was tested in four different localities using the facilities of Southern California Gas Company in Los Angeles, CA. Use of the ENA system correlated very well with maximum pitting rates, as measured by microscopic examination of the surface morphology.

A modified electrode design was developed to increase the sensitivity of the electrodes to sustained localized pitting corrosion caused by sulfate reducing bacteria and acid producing bacteria responsible for microbially-influenced corrosion.

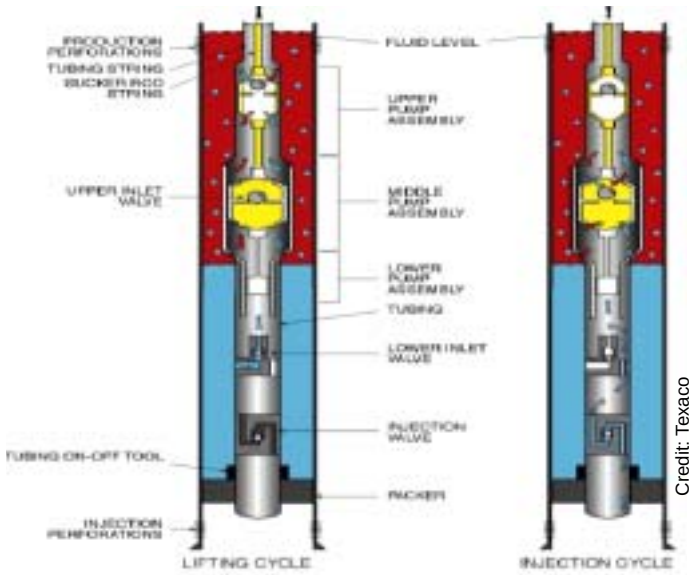
A user-friendly software package for automatic electrochemical measurement and data interpretation and corrosion monitoring was completed. The new software analysis package will be used to determine if it is possible to differentiate between chemically or bacterially-influenced sustained localized pitting corrosion. Two patents have been issued on the electrochemical probe. The first is for detection of pitting and the second is for improved design for corrosion monitoring.

Benefits: *Pitting and corrosion caused by produced water is a significant expense to oil field operators. Failure to correct corrosion before is breaches flow lines can cause pollution to soils and surface waters. The electrochemical noise analysis probe offers a cost-effective means of identifying corrosion pitting and the cause (chemical or microbial) so that appropriate action can be taken.* **Contact:** Nancy Comstock, (918) 699-2059 or Nancy.Comstock@npto.doe.gov; **Performer:** James Frank, Argonne National Laboratory, Argonne, IL, (630) 252-6793 or jfrank@anl.gov. **Performance period:** 4/1998 to 9/2002.

Simultaneous Injection Pilot Project: Phase I - Feasibility Study - *Argonne National Laboratory*

The objective of the feasibility study is to test a relatively new technology, simultaneous injection, via downhole oil/water separators as a method to reduce the cost of handling produced water during petroleum production. Produced water is the largest waste stream associated with oil production, and the cost of handling and disposal can be significant. Downhole oil/water separators (DOWS) shown in **Figure 2** are devices that separate oil from produced water at the bottom of the well and reinject the produced water into another formation, while the oil is pumped to the surface. Argonne's feasibility study included data from 37 installations of DOWS in North America. The findings of the study indicate that the technology has great promise, but that many of the field installations did not meet expectations or did not remain in service long enough to justify investments. DOE funded Argonne to subsidize the cost of installing new DOWS in exchange for detailed operating data from the operators.

Benefits: *Since produced water is not pumped to the surface, treated, and then pumped back from the surface to a deep formation, the cost of handling produced water is greatly reduced. DOWS also minimizes the opportunity for contamination of underground sources of drinking water through leaks in tubing and casing during the pumping and injection process.* **Contact:** Nancy Comstock, (918) 699-2059 or Nancy.Comstock@npto.doe.gov; **Performer:** John Veil, ANL, Washington D.C., (202) 488-2450 or jveil@anl.gov. The data summaries from these trials and the earlier DOWS feasibility report may be downloaded at: http://www.ead.anl.gov/project/dsp_topicdetail.cfm?topicid=18. **Performance period:** 8/1997 to 12/2001.



Credit: Texaco

Figure 2. Diagram of downhole oil/water separator demonstrated by Texaco.

Physical Property Measurement of Produced Water/Characterization of Soluble Organics in Produced Water - *Oak Ridge National Laboratory*

Production facilities and refineries have to meet environmental regulatory discharge requirements for dissolved organics. Deep-water crude oil has a large polar constituent, which increases the amount of dissolved hydrocarbons in produced water and refinery effluents. Neither the chemistry involved in the production of soluble organics in the petroleum industry nor the toxicity of these compounds is well understood. Several industrial companies, including Shell, Chevron-Texaco, Phillips, and Statoil, have developed a collaborative Petroleum and Environmental Research

Forum (PERF) project to characterize and evaluate water solubles, aimed at increasing the understanding of the production of these contaminants. Between 1999 and 2002, ORNL, working with PERF, has completed a study of the characterization of crude oils and water solubles in produced water under a variety of experimental conditions. The water-soluble organics were quantitatively determined by accurate measurements in samples of Gulf of Mexico brine that had been in contact with crude oil.

The water-soluble organics content of produced water was quantified as a function of several experimental parameters. Industrial partners provided ORNL with two samples of GOM deep-water crude. The identities of semi-volatile organic compounds were determined in crude and produced water samples using the standard protocol. These analyses were supplemented with measurements of total petroleum hydrocarbon (TPH) content in the gas, diesel, and oil; carbon ranges as determined by both gas chromatographic – flame ionization detection and infrared analyses. Inorganic constituents in the produced water were analyzed by ion-selective electrodes and inductively coupled plasma – atomic emission spectrometry.

Gas chromatographic results indicated that water-soluble organics compounds found in produced water samples were primarily polar in nature and distributed between the low and midrange carbon ranges. Formic, acetic, and propionic acids were also found in the produced water by ion chromatography.

Of the five tested parameters, the factor that had the most control over the solubility of organics in produced water was aqueous phase pH. Polar organic compounds such as acids and phenols become more soluble as they alter in a basic aqueous phase, as suggested by the apparent inflection point in the solubility data at pH 7, indicated as a vertical line on **Figure 3**.

Of the other physical variables tested, only temperature had a significant effect, changing the relative amounts of soluble organics in different size ranges. An increase in carbon levels was observed that may have arisen from the dissociation of longer chain hydrocarbons. Other variables, such as pressure or water cut, may slightly alter the quantity of organic contaminants in brine.

Starting in 2002, ORNL will assist PERF partners in the development of a model to predict the production of water-soluble organic compounds from formation conditions, crude oil characteristics and water properties. The predictive model will allow ORNL and its partners to evaluate the impact of produced water treatment methods and downstream processing on polar contaminants, and evaluate the toxic effects of water soluble compounds in produced water discharges.

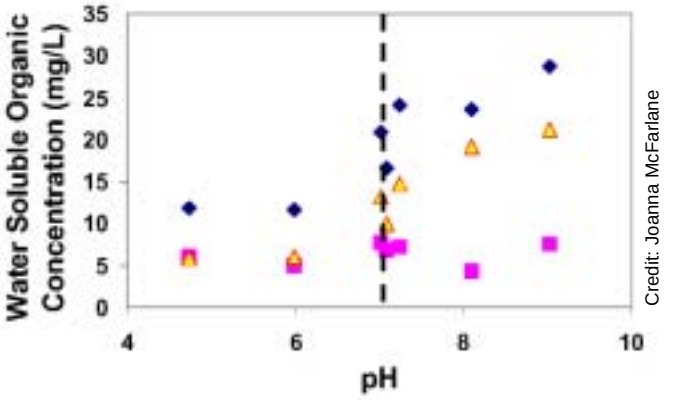


Figure 3. Fractions of water soluble organic concentrations as a function of pH to different carbon sizes are shown. Methylene chloride extractable materials are shown with diamonds, hexane-soluble C10 with squares, and C10 to C20 with triangles.

Benefits: *The project will ultimately result in reduced production of water solubles and allow the development of improved guidelines for effluent treatment.* **Contact:** Nancy Comstock, (918) 699-2059 or Nancy.Comstock@npto.doe.gov; **Performer:** Joanna McFarlane, ORNL, Oak Ridge, TN, 865) 576-7695 or mcfarlanej@ornl.gov. **Performance period:** 4/1999 to 4/2002.

Dominguez Channel Modeling and Analysis for Pollutant Transport and Total Maximum Daily Loads - *Lawrence Berkeley National Laboratory*

Dominguez Channel Environmental Modeling and Decision Support - *Lawrence Livermore National Laboratory*

The two projects are part of an interactive process

that will encourage the use of sound science in developing Total Maximum Daily Load (TMDL) requirements for pollutants in the Dominguez Channel watershed. The Dominguez Channel watershed includes Los Angeles, Long Beach and ports and other smaller costal communities in southern California. A TMDL refers to the "total maximum daily load" of a pollutant that achieves compliance with a water quality standard defines by the Environmental Protection Agency (EPA). The TMDL process refers to a plan for development and implementation.

For many years, water quality has been controlled by limiting the amount of pollutants that could be emitted by point sources (easily identified sources that had permits for injection effluent into a water body). Since many waterways are still not in compliance, implementation of TMDL's will have to include point sources and non-point sources. California is in the process of developing TMDL's for several water bodies, including the Dominguez Channel.

In the absence of data that can be used to determine the contribution of all sources of pollutants that enter a water body, there is a tendency to set the limits on point sources lower and lower. This could severely restrict water usage for refiners and producers of both oil and gas. Restricted water usage could lead to reduced refining capacity and hamper both oil and gas production. The U. S. Department of Energy's funding of research by Lawrence Berkeley (LBNL) and Lawrence Livermore (LLNL) National Labs is to provide scientific data to aid in the regulatory decision making process. LBNL is developing models of pollutant and contaminant sources, and assessing effectiveness of different water quality management strategies or actions. LLNL is analyzing the coupled atmosphere-land surface-ground water-harbor circulation model to understand hydrologic cycling in the Dominguez Channel watershed.

The thrust of research at LBNL has been to evaluate all the input parameters in the watershed, including precipitation and effluents; and to complex hydrologic cycle at Dominguez Channel. The study will provide educational outreach to interested parties, stakeholders, and policy-makers to understand the watershed and pollutant transport and modeling concepts. **Figure 4** illustrates the hydrologic cycle. Factors influencing the hydrologic cycle include:

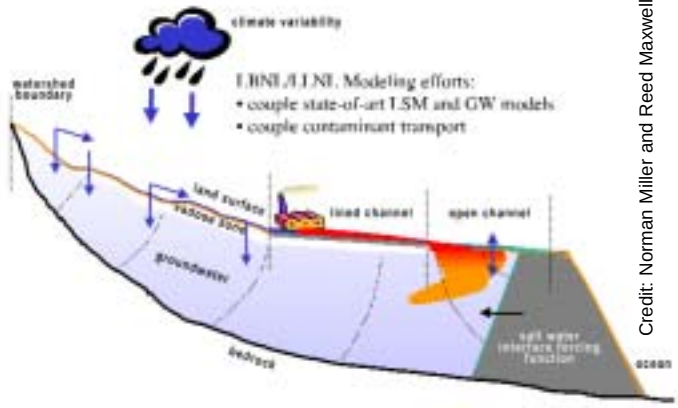
- Precipitation (snowmelt, runoff, and stream flow)
- Sediment input and removal
- Soil and water temperatures
- Dissolved gas concentration in water and bacteria
- Pesticide content
- Nitrogen and phosphorus content

Credit: Norman Miller and Reed Maxwell

Figure 4. Hydrologic cycle showing: atmosphere – land surface – ground water – harbor – atmosphere circulation.

Several stages to the circulation model involve climate variability, characteristics of lower infiltration and lower flow regime versus higher infiltration and higher flow regime, and the mechanisms of contaminant transport by surface water or groundwater. The composite harbor circulation model, shown in **Figure 5**, illustrates the contaminant transport and hydrologic parameters, which effect flow.

LLNL will concentrate on evaluation of the harbor circulation model to improve the determination of TMDLs, and processes occurring in the Dominguez Channel. The final task in the project will be to develop analytical tools for identifying the most cost effective measures for controlling contaminants in the watershed. In the past the largest contributors to pollution have been required to cleanup individual sources. The most cost effective approach to reducing concentration may involve reduction measures affecting several contaminants rather than targeting individual

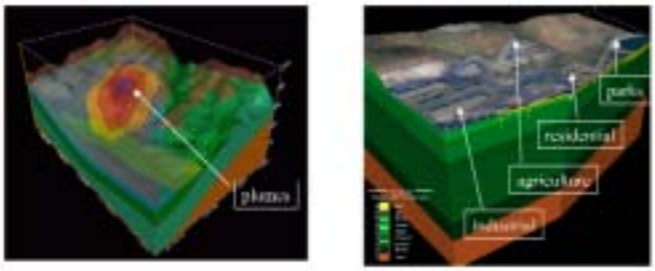


Credit: Norman Miller and Reed Maxwell

Figure 5. Dominguez model demonstrating how contaminants enter the hydrologic cycle.

point sources. **Figure 6** is a 3-dimensional representation of the land and water contaminants sources and areas that may be affected.

Evaluation of the water circulation model takes into account various options for management depending on the nature of the site, future plans, the level of government decision making, and how performance is measured. Harbor facilities, land use, industry, health and environmental concerns, local, state and federal governments – all factors must be evaluated and integrated into management strategies. The key is to address the important features systematically and to develop a model for Dominguez that will be applicable to similar harbor and coastal areas.



Credit: Norman Miller and Reed Maxwell

Figure 6. TMDL allocation data in hydrological and land use models.

Public attitudes and interest groups need to be made aware of the different levels of pollution control possible. Some remedies destroy the contaminant (e.g. bio degradation), and do not allow future releases. Remedies may remove the contaminant from one medium to another. Certain situations require monitoring of the natural processes of cleanup and renewal (no further contamination or dispersion). In some cases of pollution reduction the information is lacking to identify the source or the technology to prevent further source contamination is not available. In other cases while the source of contamination is unclear, a proven technology is available to prevent future contamination. The final level includes cases where there is no technology to cleanup pollution and the only prevention measure is to control exposure.

Benefits: *Better understanding of hydrologic cycling by use of the Dominguez Harbor water circulation model will increase public awareness and aid government decision-making. With better knowledge policy makers will be able to address interest groups and businesses that want specific areas or projects excluded from regulations or that threaten to relocate if costs are excessive. The water circulation model will improve clean-up rates and allow for tradeoffs among the attributes for watershed management. The framework of the model will allow evaluation of the impact of conditions from year to year and from harbor to harbor to develop better strategies for contaminant management.* **Contact**: Kathy Stirling, (918) 699-2008 or **Kathy.Stirling@npto.doe.gov**;**Performers:** Norman Miller, LLBL, (510) 495-2374, **nlmiller@lbl.gov**, Reed Maxwell, LLNL, (925) 422-7436, **maxwell5@llnl.gov**. **Performance period:** 2/2002 to 9/2005.

WATER MANAGEMENT TECHNOLOGIES

Projects focus on new technologies to address water handling problems, and meet the regulations imposed by government agencies. National Laboratories and universities are especially well equipped to perform the fundamental research necessary to develop new technologies. Partnerships of National Labs, universities, consultants, operating companies, and cooperating government agencies is essential in the development and testing of new technologies.

Bioreactor Design and Demonstration for Microbial Oxidation of Sulfides/Sulfide Removal by Microbial Methods - *Idaho National Engineering and Environmental Laboratory*

The presence of sulfide (H_2S, HS, and S^2) in reser-

voirs and produced fluids and gas is known to be a function of microbial, electrochemical, and geochemical processes. The most common source of sulfides in reservoirs and surface equipment is sulfate-reducing bacteria (SRB), which oxidize water-soluble organic compounds found in reservoir brines while reducing sulfate to sulfide. The accumulation of H_2S in the reservoir results in souring of crude oil, natural gas, and produced brines, as well as damage to production infrastructure through corrosion and formation of iron sulfides. Control of sulfides is difficult and expensive, but necessary to meet safety (**Figure 7**), environmental, operational, and sales standards. Specific problems include circulation of corrosive sulfide-containing fluids leading to weakened infrastructure, reduced performance of fluid handling equipment, toxic air emissions, and unpleasant odors.

Photo credit: Gregory Bala

Figure 7. Oil fields post warnings where hazardous gas may be present.

Strategies for the control of H_2S related hazards and corrosion in the oil and gas exploration and production include suppression of biogenesis in reservoirs and processing equipment with biocides or treatment of produced fluids to remove and dispose of H_2S. Surface treatment methods include stripping of H_2S from its source stream with subsequent treatment of the stripper stream; caustic washing or scrubbing; precipitation; and direct chemical oxidation methods that convert H_2S to elemental sulfur or sulfate. Some problems with these technologies include their ineffectiveness, high costs, high-energy requirements, and generation of environmentally toxic wastes.

The INEEL, Phillips Petroleum, and the University of Tulsa continue the development of a low toxicity, robust, biocatalytic system to remove sulfides (H_2S) from natural gas that is suitable for integration into existing gas handling infrastructure. **Figures 8** and **9** illustrate equipment designed and adapted for sampling and testing.

Benefits: *Biological oxidation of sulfides offers the potential of a sulfide scavenging technology that is regenerable, selective for sulfides, non-hazardous, effective at low temperatures, economical, and applicable to treatment of both sour produced brines and sour gases. This technology will mitigate air and liquid sulfide effluents originating in aqueous field output, reduce corrosion facilitated by sulfides, reduce sulfide concentrations in produced gas and oil, and reduce the toxicity of produced water. It has the potential to minimize the application of biocides and corrosion inhibitors.* **Contact:** Nancy Comstock, (918) 699-2059 or Nancy.Comstock@npto.doe.gov; **Performer:** Gregory Bala, INEEL, Idaho Falls, ID, (208) 526-8178 *or* Bg3@inel.gov. **Performance period:** 4/1998 to 4/2002.

Photo credit: Gregory Bala

Figure 8. Introducing an inert gas (N_2) headspace over well-head samples to prevent oxidation and preserve samples for laboratory analysis.

Photo credit: Gregory Bala

Figure 9. Bioreactor operating on a gas feed of hydrogen sulfide. The inoculum is a microbial consortium of nitrate reducing sulfide oxidizing bacteria.

Treatment of Produced Oil and Gas Waters with Surfactant-Modified Zeolite - *University of Texas at Austin*

A system for reducing contaminants, such as oil, grease and other dissolved solids, found in produced water from oil drilling and production is being developed. Hydrocarbon traces and solid particles must be removed from produced water from onshore wells before it can be discharged or reinjected. Researchers at laboratories at The University of Texas, New Mexico Tech and Los Alamos National Laboratory are evaluating a surfactant modified zeolite, a silicate mineral, for its potential to absorb contaminants from water. The regeneration or recycling ability of the surfactant modified zeolite will be tested by stripping, washing, aeration, heat solvent extraction and other methods to determine if it can be repeatedly used as the absorbent. Additional tests will be conducted to study the overall cost-efficient removal of organic material by the zeolite system in pilot field studies. The first contaminants tested with the surfactant modified zeolite system were benzene and toluene. Findings were compared to previous studies of contaminants absorption by percolation through soils.

Benefits: *Development of the surfactant modified zeolite will provide an effective method for removing oil and solid contaminants from produced water. The technology can achieve significant cost-savings if the zeolite is recycled.* **Contact:** Nancy Comstock, (918) 699-2059 or **Nancy.Comstock@npto.doe.gov**; **Performer:** Lynn Katz, The University of Texas at Austin, Austin, TX, (512) 471-4244 or **lynnkatz@mail.utexas.edu**. **Performance period:** 9/1999 to 9/2002.

Development of an In-Well Oil/Water Separator for In Situ Recycle of Produced Water/Downhole H_2O Separator - *Oak Ridge National Laboratory*

Development of the downhole oil/water separator at Oak Ridge National Laboratory began in 1997 with laboratory testing of the separation efficiency of centrifugal separators for various crude oils and water. The project has continued with the design, fabrication and operation of a prototype Centrifugal Down Hole Separator (CDS) in the laboratory. Testing of the CDS to adapt centrifugal separators to use in in-well separators of oil, produced water and solids continued with recommendations for field testing. Laboratory testing used crude oil samples from the Gulf of Mexico supplied by Texaco.

DOE and Oak Ridge pursued the new separator to overcome the limitations of current technology: low flow rules, low tolerance for produced solids, and high maintenance. More than 250 million bbl of produced water are discharged each year to surface waters in both Texas and Louisiana. The produced water in the Gulf Coast region is typically a mixture of formation and injection process water that contains oil, salts, chemicals, solids, and trace metals. Because representatives from the industrial partners for the project indicated an interest in the performance of the separator at high oil feed ratios, tests have been performed at a feed ration of 1:19 (water-to-oil). Bench-scale tests have shown that the centrifugal separator can provide a good separation for feed streams containing from 10% to 95% oil. Previous hydrocyclone separators could not achieve high oil-water separation efficiency when operating at a low water-to-oil ratio. The presence of gas in the oil-water mixture disrupted the operation in hydrocyclone separators, but does not adversely affect centrifugal separators. Field testing and modeling of the centrifugal separator and pumping capacity to simulate existing conditions in Gulf Coast wells continues.

Benefits: *The Centrifugal Down Hole Separator is more efficient than previously used hydrocyclone separators. More efficient operation to separate oil and waste products from the large volumes of produced water generated in the Gulf Coast will significantly reduce costs, increase oil production and provide cleaner produced water that meets environmental standards.* **Contact:** Nancy Comstock, NPTO, (918) 699-2059 or **Nancy.Comstock@npto.doe.gov**; **Performer:** Joseph Birdwell, Jr., ORNL, Oak Ridge, TN, (865) 607-9474 or **birdwelljfjr@ornl.gov**. **Performance period:** 7/1997 to 12/2002.

Ozone Treatment of Soluble Organics in Produced Water - *Argonne National Laboratory*

This project was an extension of previous research to improve the applicability of ozonation and will

help address the petroleum industry problem of treating produced water containing soluble organics. Oil production is shifting from shallow wells (0-650 ft) to offshore deepwater operations (650 to > 2,600 ft). The crude from deep wells has an increased amount of dissolved organic materials, which must be removed. The goal of this project was to maximize oxidation of hexane extractable organics during a single-pass operation. The project investigated: (1) oxidant production by electrochemical and sonochemical methods, (2) increasing the mass transfer rate in the reactor by forming microbubbles during ozone injection into the produced water, and (3) using ultraviolet irradiation to enhance the reaction if needed.

Sonochemical oxidation can be effective in destroying some compounds such as benzene, toluene, ethylbenzene, and xylenes (BTEX); however, no destruction of a representative organic acid (hexanoic acid) was measured. The combination of ozone and hydrogen peroxide did not improve the oxidation of organics to CO_2. The effect of ultraviolet irradiation had a very minor effect on the ozonation of the extractable organics present in complex waters. UV light, when used in combination with ozone, did however improved the destruction of BTEX.

Destruction of extractable organics in samples indicated that ozone is an effective oxidation agent. Rate data suggested that there are several competing reactions demanding ozone and some of these reactions proceed at a faster rate, while some occur only after prolonged exposure to ozone. The results from this study were consistent with the data collected in an earlier work, although the reactor systems were quite different. Both studies show the degradation to be dependent on time, indicating that the degradation rate is slow.

An economic evaluation indicated that a system for 75% conversion of extractable organics would have fixed capital costs in the range of $3.2 million, with annual operating costs of $1.1 million (or $7.31/1000 gal). The estimation was based on a produced water flow rate of 10,000 bbl/day (17,500 gal/hr), an initial content of 100 ppm of hexane-extractable organics, a liquid residence time of 30 minutes, and an ozone consumption of 10 g ozone/g extractable organics. It should be noted that treating this volume of produced water would require a very large contact vessel (36 feet tall). **Figure 10** illustrates the laboratory model. The fixed capital costs were strongly dependent on the contact time and ozone demand.

Photo credit: K. Thomas Klasson

Figure 10. Type of reactors used in large-scale water column experiments.

Benefits: *Significant reduction in operating costs of deepwater offshore wells for removal of hexane-extractable organics is achievable. The current methodology may be able to reduce the contact time from 30 min to 10 min. The capital cost would be reduced by approximately 10%, and the size of the vessel would be reduced by 67%.* **Contact:** Nancy Comstock, (918) 699-2059 or **Nancy.Comstock@npto.doe.gov**; **Performer:** K. Thomas Klasson, ORNL, Oak Ridge, TN, (865) 574-6813 or **klassonkt@ornl.gov**. **Performance period:** 5/1998 to 5/2002.

Modified Reverse Osmosis System for Treatment of Produced Water - *New Mexico/Petroleum Recovery Research Center*

Modified Reverse Osmosis System for Treatment of Produced Waters is being conducted at the Petroleum Recovery Research Center, New Mexico Tech. The first objective is to test the use of clay membranes in the treatment of produced waters

using reverse osmosis. It has been known that clays exhibit membrane properties. An ultra-thin (0.041 to 0.064 mm) bentonite clay membrane is compacted and used in this project. The second objective is to test the clay membrane's ability to remove salts from reverse osmosis waste streams as a solid. In conventional reverse osmosis mineral precipitation plugs membranes and limits their useful life. Theoretically, a salt hyper-saturated layer near the membrane causes dissolved metals to precipitate. The trailer-mounted membrane system can be moved from site to site.

The dissolved organics present in produced water may damage polymer membranes used in the conventional reverse osmosis process. It is believed that clay membranes should overcome this drawback. In this project, a clay membrane made of bentonite is compacted inside a specially made cross-flow experimental cell with an integral piston. Both synthetic NaCl solution and produced water are used to test the clay membrane and determine various membrane properties from the bench experiments. For produced water, the rejection rates of the ions are decreasing when TDS (Total Dissolved Solids) increases (**Figure 11**). **Figure 12** shows the NaCl crystals distribution across the surface of the clay membrane under Microprobe Scan. Efforts to increase the quantity and speed of this crystallization process are ongoing.

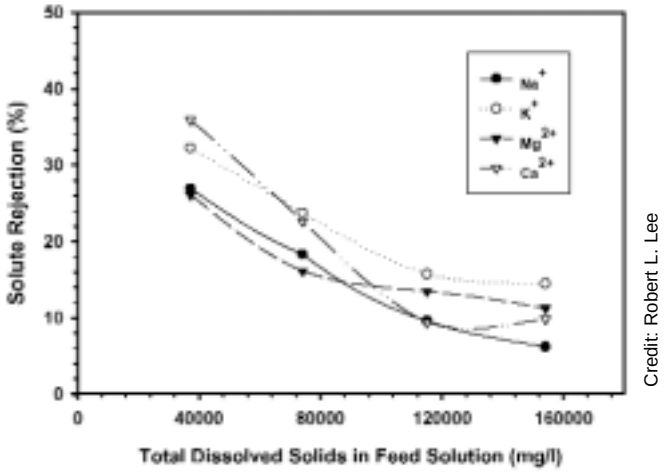


Figure 11. Solute rejection of cation as a function of TDS (membrane compacted to 36.1 Mpa).

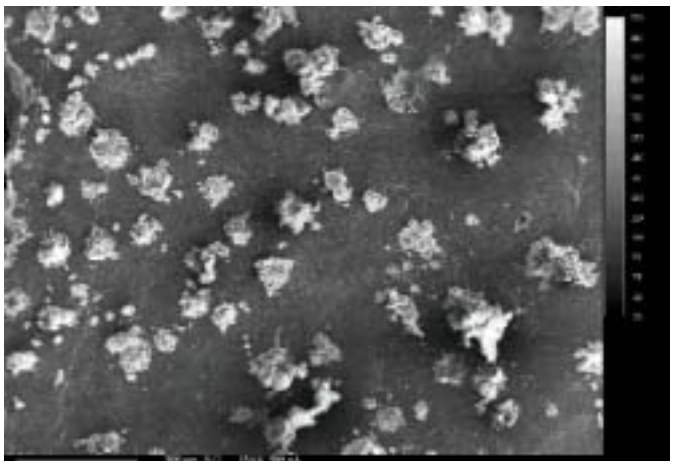


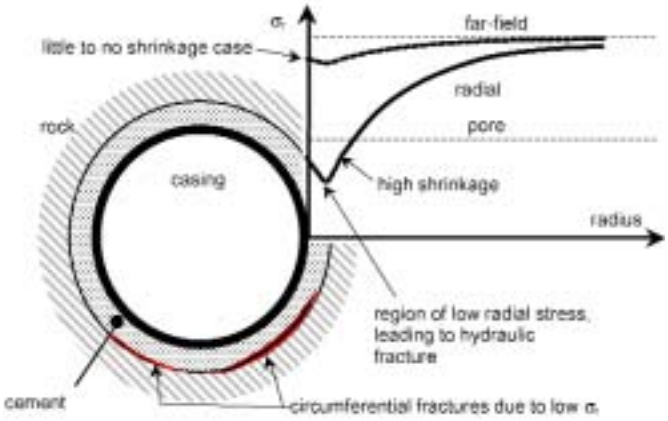
Figure 12. Microprobe scan showing distribution of NaCl crystals across the surface of the clay membrane.

Benefits: *The reverse osmosis waste reduction system for produced waters is expected to be able to precipitate highly soluble dissolved minerals, such as sodium chloride, as well as other less soluble dissolved minerals, and improve produced water treatment. Development of a portable (trailer-mounted), low cost produced water treatment system will allow operators and communities to use produced water instead of re-injecting it. Use of clay membranes in the reverse osmosis system will reduce treatment costs.* **Contact:** John Ford, (918) 699-2061 or John.Ford@npto.doe.gov; **Performer:** Robert L. Lee, New Mexico Institute of Mining and Technology, Socorro, NM, (505) 835-5408 or Lee@prrc.nmt.edu. **Performance period:** 7/1997 to 7/2002.

Cement-Casing Rock Interaction - *University of Waterloo/ Porous Media Research Institute*

Why Old Wells Leak: Before suitable solutions can be found to the massive environmental problems associated with gas seeping from thousands of abandoned wells in the United States, the physical mechanisms must be clearly understood. The leakage phenomenon arises because of inadequate cement seals between the steel casings and the rock. Under the temperatures and pressures at depth, all conventional oilfield cements placed at ordinary slurry densities will shrink. Poor quality control of placement density exacerbates shrinkage, and old wells in particular suffer from poor quality cement placement. Because of the shrink-

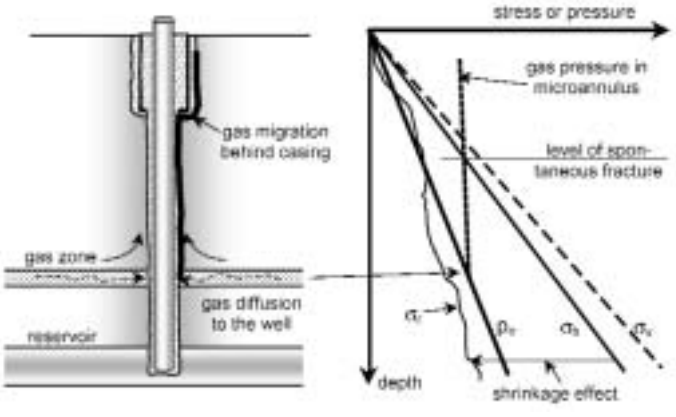
age, the radial sealing stress between the cement and the rock can be very low, even below the pressure of the fluids, therefore a thin micro-annulus develops in some zones, perhaps only 10-40 microns in width (**Figure 13**).



Credit: Maurice Dusseault

Figure 13. Cement shrinkage leads to loss of sealing stress.

Because there are many thin gas-containing zones in any sedimentary basin, slow free gas accumulation takes place over years, even decades. The density of gas is far lower than that of water, so it tends to migrate upward between the cement and the rock by a process of hydraulic fracturing until there is a thin channel open all the way to the ground surface (**Figure 14**). Old oil and gas wells sites in wet areas can often be identified by the slow bubbling of methane. Usually, the methane that migrates slowly upward behind the casing in this manner is sweet because any H_2S has been stripped off by dissolution in formation waters. However, as methane enters groundwater it charges the water, and generates aquifer problems.



Credit: Maurice Dusseault

Figure 14. Vertical fracture growth because of gradient differences.

Most if not all of the future problems could be solved by the use of genuinely non-shrinking cement and better abandonment regulations. However, in some cases, old wells must be re-entered and re-abandoned using a more secure method.

Non-shrinking additives for cement available from service companies have been criticized because laboratory evidence indicates that they may still shrink in difficult conditions. This project developed a non-shrinking cement formulation that does not use any additives, and has a smaller percentage of the portlandite phase, usually the culprit in shrinkage. It is denser than regular cements, but light-weight agents can be added, just as for regular cements. Test data show that it is far stronger than regular cement, and does not shrink or lose strength even with heating to 350°C. Because the dense formulation is entirely mineral-based, it cannot suffer from unusual reactions or thermal degradation. Properly placed, it will not leak in the future.

The other part of the solution is better abandonment methods for all wells. This involves not only bridge plugs and internal placement of cement, it involves perforating the casing and squeezing dense cement into place to form a strong stress barrier against any gas seepage. Special chemicals and complex methods is to be avoided because they are unreliable. The cement is being marketed by PRISM Production Technologies, Inc. of Edmonton, Alberta.

Benefits: *A non-shrinking cement formulation that does not use any additives had been developed. It is stronger and more heat resistant than traditional cements and will prevent gas seepage and aquifer pollution. Better seals will make remediation of old wells more cost-effective.* **Contact:** John Ford, (918) 699-2061 or **John.Ford@npto.doe.gov**; **Performer:** Maurice Dusseault, University of Waterloo, Waterloo, Ontario, CAN, (519) 888-4590 or **mauriced@sciborg.uwaterlol.ca**. **Performance period:** 4/2001 to 4/2003.

COALBED METHANE AND PRODUCED WATER

Credit: ALL Consulting

Figure 15. Produced water fish pond.

Coalbed methane development has become a significant source of natural gas in the U. S. During 2000, 1.4 trillion cubic feet (Tcf) of CMB was produced in the U. S., which amounts to about 7.5% of total production. The Powder River Basin in Wyoming and Montana is the site of the fastest growing domestic natural gas play. CBM resources in the Powder River Basin are estimated to be about 25 Tcf, and it is estimated that 50,000 wells will be required to develop the resource. Development of the CBM resource has generated controversy in the Powder River Basin, and several DOE funded projects are investigating various aspects of handling the produced waters to provide environmental protection for the soil, water and agriculture business of the Powder River Basin (**Figure 15**).

"The Federal government must overcome the produced water issue and groups opposed to drilling, because the United States needs to increase its energy supply. Energy development can take place in an environmentally sensitive manner and beneficial uses can be found for produced water."

– Gail Norton,
Secretary of the Interior

Source: Inside Energy, August 5, 2002

Evaluation of Phytoremediation of Coal Bed Methane Product Water and Water of Quality similar to that associated with Coalbed Methane Reserves of the Powder River Basin, Montana and Wyoming - *Montana State University*

Assessment of Drainages into Tongue and Powder River Basins and the Impact of Coal Bed Methane Produced Water - *Montana State University*
The primary focus of the Montana State University CBM research team effort on concurrent projects is two-fold: (1) identification and characterization of plant - soil - water relationships associated with CBM product water from the Montana portion of the Powder River basin. (2) Single focus, multiple option/conjunctive methods for environmentally and economically acceptable management; beneficial use; and disposal of coalbed methane product water. These studies constitute an assessment of the interaction and potential impacts of coalbed methane produced water on soil, landscapes, and agricultural, native, and culturally significant plants in the areas of proposed coalbed methane development.

The single most significant issue facing environmentalists, regulatory agency representatives, land managers, and private land owners in the Powder River Basin is the management of coalbed methane produced water, a requirement of coalbed methane extraction. In short, the issues are concerns about the chemistry and quantity of coalbed methane produced water and the potential adverse or undesirable interactions between coalbed methane product water dispersed on the land surface or into ephemeral and perennial streams, native and culturally significant plants, agricultural crops, and agricultural soils. The second most significant issue facing these same individuals is the hydrologic significance of withdrawals of large volumes of coalbed methane produced water from confined coal seams and subsequent dispersal or introduction of these volumes of water to hydrologically isolated surface channels, streams, and shallow alluvial aquifers.

From the perspective of coalbed methane industry developers, one of the most challenging aspects of

environmentally and sustainably sound and economically feasible coalbed methane production is management of large volumes of coal seam product water, a byproduct of CBM production. Field investigations are being conducted to characterize (and estimate) the likely signature (chemical composition) of CBM product water derived from the Powder River basin.

The Montana State University CBM research team currently has 4 long-term greenhouse experiments, 3 laboratory experiments, and three field investigations dealing with management, disposal, and beneficial use of coalbed methane product water. The phytoremediation study of CBM and Powder River water with selected plants (approximately 40 weeks in duration at present) is intended to determine the ability of 3 rangeland/dryland plant species to mine salt (sodium) or mitigate/moderate the salinity/sodicity of input water. The greenhouse, an isolated growth facility, and field experiments are used to determine species responsiveness and forage production potential relative to salinity-sodicity using CBM product water and mixed waters. Greenhouse experiments will determine the interactive nature of CBM product water and plant communities on physical and chemical properties of soil and drainage water characteristics.

Benefits: *This research is directed to answer the question - can a designed agricultural crop suite or wetland/transition suite effectively treat CBM product water so that it can be safely discharged or used in agriculture.* **Contact:** John Ford, (918) 699-2061 or **John.Ford@npto.doe.gov**; **Performer:** James Bauder, Montana State University, Bozeman, MT, (406) 994-5685 or **jbauder@montana.edu**. **Performance period:** 9/2001 to 4/2004.

Northern Cheyenne Reservation Coal Bed Natural Gas Resource Assessment and Analysis of Produced Water Disposal Options - *INEEL*

The Idaho National Engineering and Environmental Laboratory (INEEL) in collaboration with the Northern Cheyenne Tribe and Montana Bureau of Mines are developing water-handling strategies to maximize the beneficial use of produced CBM water. The goal is to provide economic use coal bed methane resource and the produced water for the Northern Cheyenne Tribe, while minimizing the adverse environmental impacts. Preliminary tasks include a geologic description of the coal beds and the types of disposal options for produced water. Reinjection into deeper formations, and treatment options for surface discharge, and potential agricultural uses of the produced water are primary considerations. Reservoir simulation modeling of the coal bed methane resource is being used to determine the amount of CBM, the quantities of water to be produced and the length of time production will continue.

Benefits: *The Northern Cheyenne Tribe will benefit significantly from developing coal bed methane deposits on tribal land. The development of a resource management plan, and analysis of how to handle the produced water resulting from CBM before extensive production begins is a positive, progressive strategy, which ultimately will reduce time consuming and costly permitting and environmental regulatory constraints.* **Contact:** Jesse Garcia, (918) 699-2036 or **Jesse.Garcia@npto.doe.gov**; **Performer:** Shaochang Wo, INEEL, (208) 526-7456, and David Lopez, Montana Bureau of Mines and Geology, (406) 657-2653 or **dlopez@mtech.edu**. **Performance period:** 9/2001 to 9/2004.

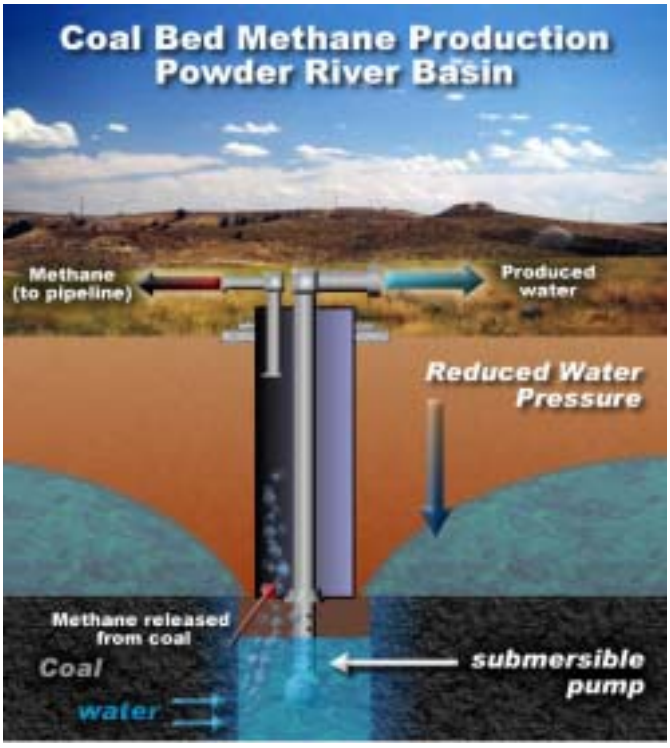
Development of Best Management Practices for Coalbed Methane Utilizing GIS Technologies - *ALL Consulting*

The heightened concern of environmental issues related to present-day production practices for coalbed methane – including water production, hydraulic fracturing, pipeline construction, storage facilities, water impoundment and disposal facilities, underground injection activities, compression station operations, etc. – increases the importance of using practices and mitigation strategies that facilitate resource development in an effective, timely, and environmentally sound manner. These issues have placed increased pressure on federal, state and local regulatory agencies; land and resource managers; industry; landowners; and the general public to develop methodologies to accurately define specific areas of environ-

mental risk along with defining Best Management Practices and mitigation strategies to aid in minimizing and alleviating these risks.

The *Handbook on Best Practices and Mitigation Strategies for Coal Bed Methane in the Montana Portion of the Powder River Basin* was developed as a resource guide for industry, regulators, land managers and concerned citizens. The focus of the research for the guidebook was to provide an increased level of understanding of all the issues related to coal bed methane production and associated environment concerns and the best methods and technologies for protecting the environment while at the same time developing this valuable energy source. Fieldwork for the Handbook included studies in eight western states where coal bed methane is currently under development. A schematic diagram of a coal bed methane well is illustrated in **Figure 16**. This figure shows the interactions of the various components in a typical CBM well.

A second phase is the development of a *Primer*, which will review and summarize the development and mitigation practices employed in various coal bed methane areas. The *Primer* will focus on discussions of coal deposits, methane as a natural formed gas, split mineral estates, development techniques, operational issues, producing methods, applicable regulatory frameworks, land and resource management, mitigation measures, preparation of project plans, data availability, Indian Trust issues, and relevant environmental technologies. The most crucial element of successfully developing coal bed methane resources is stakeholder education; the Primer is designed to address this need.



Credit: ALL Consulting

Figure 16. Illustration of coal bed methane production well.

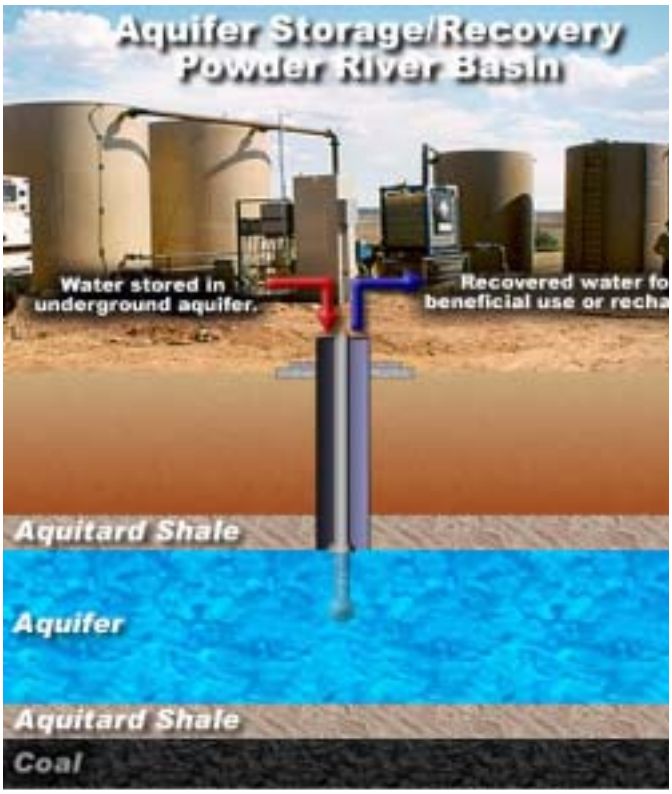
Benefits: *The Handbook will provide a review of all available methodologies so that the most effective, low-cost strategies can be applied to a specific region depending on local soil, water, climate and land use conditions.* **Contact:** John Ford, (918) 699-2061 or **John.Ford@npto.doe.gov**; **Performer:** Daniel Arthur, ALL Consulting, Tulsa, OK, (918) 382-7581 or **darthur@ALL-LLC.com**. **Performance period:** 1/2001 to 1/2003.

Feasibility Study for Beneficial Uses of Coal Bed Methane Produced Water - *ALL Consulting*

ALL Consulting was recently selected to study the various available and potential beneficial uses that could be applied to produced water from coal bed methane (CBM) wells. The study covers a broad area, including New Mexico, Colorado, Utah, Wyoming, and Montana. Emphasis will include the San Juan Basin and the Powder River Basin due to the existing level of CBM development and the relatively high quality of water from underground coal seam aquifers that are also used or targeted for methane production. The study will address the technical feasibility of various alternatives, water rights issues, regulatory issues, conceptual design options, and economics.

Figure 17 illustrates the relationship of the coal bed methane reservoirs to the aquifer storage and groundwater. Such modeling is part of the study to determine how best to handle and recycle produced water from coal bed methane production. Multiple CBM producers have volunteered to participate in the study and will be supplying data for

analysis purposes. The study is co-funded by the Ground Water Protection Research Foundation and the Bureau of Land Management.



Credit: ALL Consulting

Figure 17. Well schematic of aquifer storage and recovery.

Benefits: *An in depth study of coal bed methane produced waters and its potential uses and impacts will benefit all operators in the Powder River and San Juan Basins and the public land owners by providing accurate, up to date data on water handling methods and regulatory issues.* **Contact:** John Ford, (918) 699-2061 or **John.Ford@npto.doe.gov**; **Performer:** Daniel Arthur, ALL Consulting, Tulsa, OK, (918) 382-7581 or **darthur@ALL-LLC.com**. **Performance period:** 4/2002 to 4/2004.

Evaluation of Effects of Land Application of Coal Bed Methane Produced Water on Powder River Basin soils, Powder River Basin, Wyoming and Montana - *Bureau of Land Management*

Most CBM produced water in the Powder River Basin currently discharges into surface impoundments or local stream channels. Recently concerns have been raised regarding the salinity and sodium concentration of the produced water, and its potential impact on downstream irrigation, and vegetation. Currently there are over 4,000 coalbed methane wells producing in the Powder River Basin. On average CBM wells yield 10 gallons of produced water per minute.

The estimated production life of a CBM well is 7 to 10 years, and the potential for produced water problems including increased salinization, sodicitiy and sedimentation will increase as the number of wells increases. The operator response to the concerns over CBM produced water has been to seek alternative water management techniques, including land application shown in **Figure 18**. Good water management practices make it essential to evaluate the application of CBM produced water on soils, vegetation and stream channels in the Powder River Basin.

Photo credit: Joe Meyer

Figure 18. Land application of CBM produced water, Powder River Basin, WY.

BLM field studies funded by DOE are evaluating soil and water chemical and physical parameters important to proper resource management. Soil and CBM water samples collected in the Wyoming and Montana watersheds are being characterized to understand how land and water management practices may be influenced through the use of CBM produced water. The effect of irrigation using CBM produced water is being examined by evaluating data on soil properties, agricultural crop and forage grass yields and plant physiologic reactions (possible changes is root system, leaf tissue, etc). The irrigation study includes analysis of soil chem-

istry, soil salinity, accumulation of trace elements, sodium adsorption ratio, soil drainage properties and soil texture. Potential physical and chemical methods such as adsorption and precipitation will be studied on how to remove contaminants from CBM produced water.

Benefits: *The main objective of this study is to determine the short and long-term effects of CBM water on agriculture, vegetation, soil chemical, physical and microbial properties. A thorough understanding of the potential effects of CBM produced water is a necessary step in avoiding problems. The data gathered will be used to develop guidelines specific to application of produced water that can be used by regulatory agencies and methane producers to develop methods for using produced water for land application, irrigation or land disposal.* **Contact:** David Alleman, (918) 699-2057 or **David.Alleman@npto.doe.gov**; **Performer:** Joe Meyer, BLM, Casper, WY, (307) 261-7641. **Performance period:** 7/2001 to 1/2003.

Site Evaluation for Disposal of Coal Bed Methane Produced Water - *Bureau of Land Management*
Researchers from the Montana Bureau of Mining and Geology working with the Bureau of Land Management are part of a DOE/BLM cooperative agreement. The project starting in July 2002 will interpret the potential transport mechanisms and fate of soluble salts in the shallow flow systems under coal bed methane holding ponds, and will develop predictive tools for future water-management decision making.

The production of coal bed methane requires that significant volumes of water be pumped to reduce the hydrostatic pressure in the coal aquifer, allowing the methane to desorb from the coal surfaces. During the early stages of production, water is discharged at fairly high rates, often exceeding 20 gallons per minute (gpm). During later stages of production discharge rates decrease to 5 gpm or less. Current water production from existing coal bed methane wells in Montana averages 8.6 gpm. Productive life of individual wells is expected to range from 5 to 20 years. The potential for 7,500 to 26,000 coalbed methane wells in Montana in the next 20 years has prompted the development of Montana's Draft Environmental Impact Statement (DEIS).

The concern in Montana is that coalbed methane is high in bicarbonate relative to sulfate, and has low concentrations of calcium and magnesium and relatively high sodium concentrations. In southeastern Montana coalbed water has higher salinity and higher sodium adsorption ratios than in producing areas in the southern Powder River Basin in Wyoming. Due to the high salinity and sodium concentrations, the quantity of coal bed methane produced water is expected to exceed the amount that can be assimilated by surface waters. Infiltration basins or holding ponds will be proposed by Montana DEIS as the preferred disposal method for large volume of coal bed methane produced water. As the sodium-bicarbonate rich water from coal bed methane production settles down through the shallow weathered bedrock, a series of chemical reactions may increase the salt load in the water. The project will examine the rates of oxidation and reduction and transportation of the sodium/bicarbonate waters and determine the optimum methods to prevent leakage from infiltration basins.

Benefits: *Infiltration basins have been in use in Wyoming and Montana for several years. They are inexpensive and allow more flexibility in pumping rates for the producing companies. The produced water, which comes from primary aquifers in the area, can help to recharge the shallow ground-water system. The data collected during the project will be used to determine long-term infiltration rates and aquifer recharge.* **Contact:** David Alleman, (918) 699-2057 or **David.Alleman@npto.doe.gov**; **Performer:** Andrew L. Bobst, BLM, Miles City, MT, (406 233-2804, **abobst@mt.blm.gov**. **Performance period:** 7/2002 to 7/2003.

Coal Bed Methane-Ground Water Monitoring and Water Quality Protection - *Bureau of Land Management*
The project is part of a continuing Cooperative agreement with the BLM. The project is involved in evaluation of methods of handling produced water resulting from the production of coal bed methane in the Powder River Basin of Wyoming and

Montana. The goals is development of a monitoring system to insure that completion procedures used for methane production minimize inter-aquifer communication and protect water quality and aquifers adjacent to coal bed methane production wells. **Figure 19** shows part of the monitoring equipment at a Powder River Basin coal bed methane well location.

The soluble salts from coal bed methane produced water will be sampled from produced water holding ponds. Data will be used to develop predictive tools for produced water management. The results will be used by Montana, Wyoming state regulators and Federal regulatory agencies.

Benefits: *Reliable data on the water quality and soluble salt content will provide a basis for establishing state and federal guidelines for permitting and producing coal bed methane.* **Contact:** David Alleman, (918) 699-2057 or **David.Alleman@npto.doe.gov**; **Performer:** Mike Brogan, BLM, Casper, WY, (307) 261-7640. **Performance period:** 9/2000 to 9/2002.

Photo credit: Mike Brogan

Figure 19. Monitoring equipment, Powder River Basin, WY.

Powder River Basin CBM Water Injection Study/Advanced Resources International - *Advanced Resources International*

Currently the Powder River Basin produces 800 million cubic feet per day of CBM and 1.4 million barrels per day of water from 8,000 producing wells. For the most part, these waters are surface discharged and provide beneficial uses for agriculture, stock watering and grasslands. DOE is sponsoring a comprehensive analysis that will examine; the underlying CBM resources, future CBM and water production, and the impacts of alternative produced water management practices in the Powder River Basin

The purpose of the study is to gain a comprehensive understating of the energy impacts of alternative water disposal options. The study will review the situation in a holistic manner and is designed to provide answers to questions such as:

- What quantity of resource would likely be impacted?
- How much would tax and royalty receipts likely be reduced?
- How much would production costs likely increase?

CBM operators will need to consider alternative produced water treatment including:

- Pre-treatment of water; 1) chemical additives to reduce the sodium adsorption ratio, and 2) reverse osmosis or other means to reduce total dissolved solids.
- Shallow re-injection to conserve water for future use
- Deep re-injection into non-potable water disposal aquifers

Benefits: *The information generated by the study will assist in defining R&D activities that would help lower the costs of water treatment and disposal, and identify water management strategies (such as centralized disposal facilities) that could be of benefit to not only the producers in the basin but also to ranchers, outdoorsmen, et al. The analysis will help to resolve the considerable uncertainties that exist with the costs of these alternative water management strategies and how they could affect the economic viability of fully developing natural gas reserves from the coal seams of the Powder River Basin.* **Contact**: John Ford, (918) 699-2061 or **John.Ford@npto.doe.gov**; John Duda, National Energy Technology Laboratory, Morgantown, WV, (304) 285-4217 or **John.duda@netl.doe.gov**; **Performer:** Vello Kuuskraa, ARI, (703) 528-8420 or **vkuuskraa@adv-res.com**. **Performance period:** 4/2002 to 11/2002.

eye on environment

EoE features oil- and gas-related projects implemented through DOE's oil and gas environmental research program.

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Environmental Program Awards

Treatment of Produced Waters Using a Surfactant Zeolite/Vapor Phase Bioreactor System, The University of Texas, Austin

Principal Investigator-Lynn Katz
Austin, TX
(512) 471-4244

The primary goal of this project is to develop a robust surfactant-modified zeolite/vapor phase bioreactor treatment system to efficiently remove the organic constituents from produced water in a cost-effective manner. Following previous studies this project will conduct a detailed cost and feasibility evaluation to compare this treatment technology with existing techniques for treating produced water. **Total Funding $1,150K, DOE $909K, Non-DOE $241K.**

Using Constructed Wetlands to Treat Produced Water for Beneficial Reuse, ChevronTexaco

Principal Investigator-Jim Meyers
Bellaire, TX
(713) 432-6689

This project will test wetland-treated produced water for reuse in irrigation, wildlife habitat creation and aquaculture. The overall objective of this project is to demonstrate that constructed wetlands can treat produced water for beneficial use. **Total Funding $826K, DOE $676K, Non-DOE $150K.**

Recovery of More Oil-in-Place at Lower Production Costs while Creating a Beneficial Water Resource, AERA Energy LLC

Principal Investigator-Robert Liske
Baskerfield, CA
(661) 665-5446

The major objective of this project is to operate a produced water treatment plant to demonstrate that produced water can be economically treated to create potable water. **Total Funding $1,365K, DOE $1,087K, Non-DOE $277K.**

U.S. Department of Energy
National Energy Technology Laboratory
National Petroleum Technology Office
One West Third St., Ste. 1400
Tulsa, OK 74103-3519

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Summer 2002

Upcoming Events/Meetings

October 15-17, 2002, Ground Water Protection Council (GWPC), *Produced Water Conference*, Colorado Springs, CO, (703) 836-4700, www.gwpc.org.

October 22-25, 2002, The 9th International Petroleum Environmental Conference (IPEC), *Issues and Solutions in Exploration, Production and Refining*, Albuquerque, NM, http://ipec.ens.utulsa.edu

November 6-7, 2002, National Ground Water Association (NGWA) *Petroleum Hydrocarbons and Organic Chemicals in Ground Water Prevention, Assessment and Remediation*, Atlanta, GA, Booth #322, www.ngwa.org.

November 13-16, 2002, National TMDL Science and Policy Conference, Phoenix, AZ, www.asiwpca.org.

December 9-11, 2002, National Ground Water Association (NGWA) *54th Annual Ground Water Expo*, Las Vegas, NV, Booth #983, www.ngwa.org.

February 27-28, 2003, DOE Alaska Workshop, *Reducing the Effects of Oil and Gas Exploration and Production on Alaska's North Slope: Issues, Practices, and Technologies*, Anchorage, AK. Contact: Rhonda Lindsey, (918) 699-2037 or E-mail: Rhonda.Lindsey@npto.doe.gov

March 10-12, 2003, SPE/EPA/DOE Exploration and Production Environmental Conference, San Antonio, TX, www.spe.org.

April 23-25, 2003, The 6th National Mitigation Banking Conference, San Diego, CA, http://www.mitigationbankingconference.com

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