Review of the U.S. Department of Energy's Environmental Program

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Complied by

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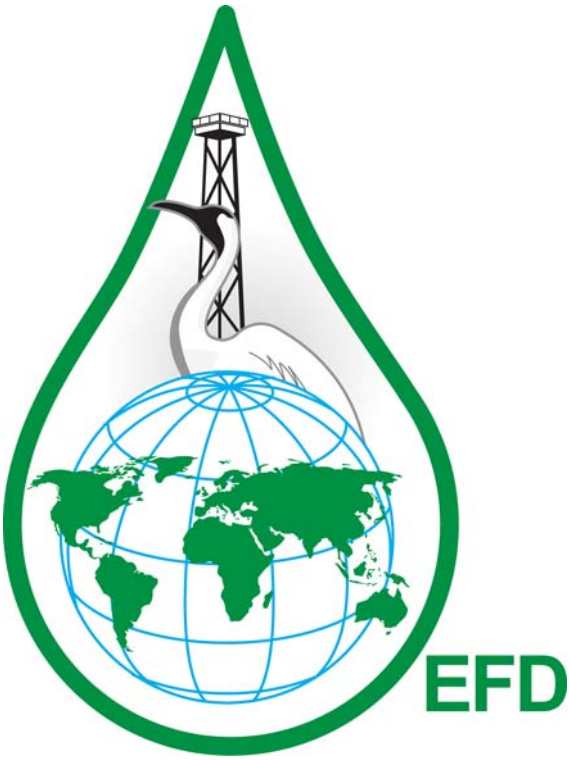
Environmentally Friendly Drilling Systems Program



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EXECUTIVE SUMMARY

One of the required tasks in the Environmentally Friendly Drilling (EFD) program was to identify related technologies and research. A literature search was conducted and submitted to RPSEA.

The objective of this study was to identify Department of Energy (DOE) funded projects and the investigators of certain projects that complement the EFD program. We initiated this because the program would benefit from identifying prior projects that could be brought up to date, highlight others that may now be commercial, and expand the EFD program network to the overall benefit of our mission. We discovered that some of the projects were recently completed or on-going. After reviewing many projects there were some technologies that are related to EFD and are listed in this report. Since this initiative has been undertaken, researchers have been contacted by the EFD project team and some are now an active part of the EFD team. The report highlights some of the pertinent projects which are related directly to the EFD program. There were many other successful DOE funded projects where the technology is being used today that are not included because of the broad nature of the DOE environmental program.

The majority of DOE environmental research funding has gone to Universities and National Laboratories. The EFD project has initiated the "University National Lab Alliance" and many of the recipients of prior DOE funding are now participating in the EFD program through this Alliance. As additional funding is identified or becomes available, the Alliance members are asked to lend their expertise in response to request for proposals. The EFD program has a major technology transfer element, which promotes the prior accomplishments and the capabilities to meet the challenges to continue to improve the environmental performance in the oil and gas industry. Hundreds of reports, technical papers and articles have been reviewed in this study.

BACKGROUND

The objective of this report was to review all the US Department of Energy (DOE) reports that are compiled on a CD "U.S. Department of Energy's Environmental Program Archive Program Results 1991 to 2008."

The U. S. Department of Energy's Natural Gas and Oil Environmental Research Program grew out of efforts to promote Environmental Safety and Health (ES&H) issues in the petroleum industry at the National Institute for Petroleum and Energy Research (NIPER) in Bartlesville, Oklahoma. The Environmental Research Program was first created in 1991 as part of the oil technology budget and for several years was run from DOE's Metairie, Louisiana office with direction from the NIPER office in Oklahoma. The program also worked closely with the DOE FE HQ office in Washington DC and Germantown, MD because of the policy implications of the research. The primary focus of the Environmental Research Program initially was on technologies that reduce the cost of environmental compliance. The oil and gas program's were then managed in separate divisions, the oil program in Oklahoma and the natural gas in West Virginia and were not combined until 2004 when the entire oil and gas program came under the direction of the National Energy Technology Laboratory (NETL) operating from Morgantown, West Virginia.

Throughout the changes in location and management, the DOE Environmental Research Program continued to fund, monitor and provide assistance to research projects all over the United States ranging from workshops promoting environmentally sound oil and gas development, collaborative studies with other Federal and State agencies to applied research and development.

Environmental research in the 1990s focused on regulatory streamlining, air emissions and water purity. Assistance to the petroleum industry in regulatory streamlining was a significant achievement of the Environmental Research Program in the 1990s. Under this initiative the Environmental program helped industry to meet Federal regulations by increasing the efficiency of the permitting process, enhancing the flow of information, improving understanding of regulatory issues, and developing methodologies to comply with changing regulations without impeding production.

By 2000 the focus had shifted to produced water management and even downstream research. By 2004 it had become increasingly apparent to DOE that much of the remaining natural gas and oil resources in the domestic U.S. were in environmentally sensitive areas. Sensitive surface environments required less intrusive technologies for extraction of the petroleum resources. New initiatives to address permitting delays on Federal Lands were added to the Environmental Research Program in 2004.

The initial funding for the Environmentally Friendly Drilling program came from a competitive award from the NETL to Texas A&M University as the prime contractor DE-FC26-05NT42658.

This report does not describe the results of most of the projects funded through the Environmental Research Program, but it highlights some of the major efforts and accomplishments of technologies and organizations that benefit the mission of the EFD program.

DOE's ENVIRONMENTAL RESEARCH PROGRAM

The reports archived on the Environmental Program CD are a good research tool and can be found through the DOE's NETL web site. Reports are grouped under Produced Water Management (including Coalbed Methane), Regulatory Streamlining, Air, Soil, Federal Lands Access, Alaskan, and general projects. Several additional sections include reports on Analysis of the Environmental Program, Workshops, and Presentations made on portions of the program.

The DOE has spent millions of dollars on this program since 1991, and had a peer review by the National Science Foundation on the effectiveness. The report can be found on the CD. DOE funded an environmental workshop at the University of Tulsa for a few years however the proceedings and agendas were not published in this CD. The Society of Petroleum Engineers has been a recipient of DOE funding for their environmental conferences where a number of excellent papers can be found through the SPE website.

The topic areas of the DOE Environmental Program include: Air, Produced Water Management, Solids (Waste Management and Spill Remediation), Federal Lands Access, Emerging Issues/Regulatory Streamlining and Processing and Fuels.

A significant portion of the Environmental Program focused on science for regulators to base informed decisions on policy and regulations that impact or could have impacted the petroleum industry. Much of the DOE Environmental Program major accomplishments can be attributed to funding collaborative programs with State and Federal regulatory agencies, studies initiated through working through non-profit organizations, such as the Interstate Oil and Gas Compact Commission (IOGCC), Ground Water Protection Council (GWPC), Petroleum Environmental Research Forum (PERF), and Petroleum Technology Transfer Council (PTTC). This broadened the scope of interaction with the petroleum industry and the public which encouraged the sharing of technologies, methodologies and ideas on environmental protection with other regions experiencing similar problems. Cooperation and data sharing reduced duplicate efforts, increased efficiency in regulatory matters and reduced the time required for permits.

The initiatives contained in the CD included:

- Project fact sheets for individual projects and subprograms within the Environmental Program.

- Annual, topical, final reports for projects and program initiatives conducted under the Environmental Program.

The areas are:

- Produced Water Management Projects – dealing with handling produced water from oil and gas operations
  - Produced water – projects on produced water management and improved technologies
  - Coal Bed Methane produced water – projects focused on treatment technologies and beneficial use of coalbed methane produced water
  - Total Maximum Daily Load – studies of airborne contaminants to the Los Angeles watershed:

- Regulatory Streamlining and Regulatory Impact

- General Regulatory – a number of projects addressing specific regulatory issues
- Risk Based Data Management System (RBDMS) and analysis – a long term effort to improve data management and permitting for oil and gas development
- Area of Review – studies on reporting requirements for injection wells
- Safety and Environmental Management Practices and (SEMP) – development of safety manuals for offshore platforms for the Minerals Management Service

- Air Projects
  - Monitoring and Air Emissions – projects concerns with air quality issues

- Soil Projects
  - Remediation – projects on soil remediation and disposal of solid wastes and brines
  - Naturally Occurring Radioactive Materials (NORM) – projects on monitoring and disposal of NORM contaminated oil field wastes
  - Salt Caverns – research on the formation of salt caverns and their use for disposal of oil field brines and wastes

- Processing (Refining) and Downstream Projects –fuels research including bioreactors and chemical upgrading, fundamental chemistry, refinery process for crude oil

- Federal Lands Access Projects
  - Modeling/General – includes a number of cooperative efforts with BLM, non-profit organisms and university to improve permitting on Federal Lands
  - National Environmental Policy Act – a long term effort to assist oil and gas operators to meet NEPA standards
  - Low Impact Natural Gas and Oil (LINGO) – projects selected to provide information on how to conduct oil and gas development on sensitive environmental areas

- Alaskan Projects – projects dealing with environmental approaches to oil and gas development in Alaska's unique tundra environment

- General Projects – included a variety of reports and projects that do not readily fit into the above categories, or that cover several categories. Also listed are conference support and specific tasks that did not generate reports.

- Workshops / Conferences
  - Proceedings, Presentations and Materials from several DOE sponsored Workshops
  - Proceeding of the International Petroleum Environmental Conferences (reprinted with permission) since many of the projects funded by DOE are contained within and DOE has long collaborated with and supported the conference.
  - Posters- highlighting projects of subprogram of the Environmental Research Program

- Newsletters – the newsletters focus on research and results that DOE wished to emphasize
  - ***EYE on Environment –*** focus on the main environmental program

- ***Downstream Details*** – focus on the fuels, refinery and processing issues
- ***Gas TIPS*** Newsletter – a series of three newsletters on Coalbed Methane
- ***NGOTP (Partnership)*** Newsletter – National Laboratory projects

The remainder of this report lists organizations that have been contacted, many visited and in several cases they are now a part of the EFD program. (*Not listed in any particular order*)

Ground Water Protection Council's (GWPC's)

From 1991 to 2008 GWPA has administered five DOE grants (some included multiple tasks): Risk Based Data Management (DE-AP26-97BC15051), Enhanced Oil and Gas Production to Ensure Protection of the Environment (DE-FC26-01BC15371), Class II State Peer Review (DE-FC-26-03NT15428), Interagency Data Sharing (Federal Lands) (DE-FC26-04NT15542 and DE-FC26-04NT15455), eBusiness (DE-FC26-03NT15428), and Energy in the Environment initiatives 2004-2008 (DE-FG26-04NT15455).A hallmark of the philosophy underlying the technical execution of these various initiatives is the "Cost Effective Regulatory Approach" (CERA),which consists of a collection of more effective and efficient policies and environmental program improvements that can be implemented by all state regulatory agencies. The GWPC and its member-state regulatory agencies' approach to increasing data availability to industry operators focuses on partnering with industry groups and other federal and state agencies to develop and sustain a family of Internet data applications that have specific purposes for oil and gas regulation and water resources protection. These data-driven Web applications are public interfaces for data housed in the Risk Based Data Management System (RBDMS), a mature data management system underwritten by the U.S. Department of Energy (DOE) and now used in 21 oil and gas regulatory agencies nationwide. These Web interfaces to RBDMS have multiple purposes, including: data mining, regulatory reporting, and permit management. Because the petroleum industry is one of the most heavily regulated industries in the United States, state and federal agencies have been collecting information about exploration and production, environmental protection measures, and refinery operations into such data vaults as the Risk Based Data Management System (RBDMS) for years. The GWPC initiative is unlock this vault through e-commerce, giving industry better access to regulatory agency data and the opportunity to do more exploration work in company rather than agency offices. A noteworthy accomplishment was in 2000 was the announcement that the Ground Water Protection Council (GWPC) had received the Department of Energy's Energy 100 award for development of the Risk Based Data Management System (RBDMS) as one of the "best scientific and technological achievements of DOE in the Twentieth Century".

Argonne National Lab

Argonne National Lab was far and away the largest recipient of DOE funding from this program, with well over 100 projects. The majority of the work included studies, reports and positions papers on the hot issues of the year – NORM (Karen Smith was PI), Waste Management and Produced Water, Sagebrush Grouse, cleaning agents for membranes, and a study on waste disposal in salt caverns. The data from some of these studies complements the mission of EFD. Many of the projects were in collaboration with a variety of research teams. Argonne conducted a couple of projects related to compressor noise in 2000-2001. Another on slurry injection for drilling waste in 2003 - the practice is pretty common today; a policy study for offshore waste management. Somewhat ironically, Argonne also received 150K award to conduct a summary of the environmental program of which they were a large recipient.

DOE sponsored a risk assessment conducted by Argonne National Laboratory to examine the real risk to workers, the public and the environment from NORM handling and disposal associated with oil production. DOE also conducted a survey of current state regulations governing the handling and disposal of NORM. DOE's work showed that the risk from NORM was generally much less than had been assumed, but that some risks did exist. DOE's work also showed that, for the most part, states already had effective programs for regulating NORM. Industry groups had brought similar data to EPA, but it was dismissed as biased. Based largely on the DOE work, EPA chose not to proceed with the rulemaking. Argonne established working groups for the oilfield service industry, Federal agencies and regulatory agencies including the Synthetic Fluids Discussion Group and the Toxicity Work Group, to provide analysis, technical advice and support to assist EPA's decision making. Argonne's research was instrumental in characterizing SBM's and demonstrating the advantages of SBM drilling fluids, and as such it paved the way for favorable rulings by EPA.

Argonne developed a series of sediment sampling and laboratory tests on Synthetic Based Mud (SBM), and the impact of SBM discharge into the sea. SBM contain no harmful, polynuclear aromatic hydrocarbons, exhibited lower toxicity, and bio-accumulation potential and biodegrade faster than oil-based muds. The study found that SBM were less likely than oil-based muds to accumulate and cause adverse impacts on the seafloor and marine life. Argonne summarized the advantages of use of SBM and demonstrated the value of this innovative pollution preventing technology for offshore drilling operations. In November 1998, the National Pollutant Discharge Elimination System permit for the Outer Continental Shelf recognized that SBM were distinct from oil-based muds and lacked terminology to prohibit use of SBM. The process of modifying EPA regulations often takes four to six years, but EPA recognize the oil and gas industry's need to resolve the discharge issue in a timely manner, and scheduled a final ruling for December 2000.

Argonne National Laboratory (FEW3 49648/49658) developed an online Produced Water Management Information System (PWMIS) as a continuation of analysis of the impact of water and waste regulations. The web-based tool is designed to help assist oil and natural gas producers tackle produced water and environmental issues related to produced water disposal. The website provides an online resource for technical and regulatory information on practices for managing produced water. Resources include information on industry standard practices; how to determine which regulatory requirements that must be met; and how to select optimal management strategies for a given location and circumstances. Individual Fact Sheets provide an introduction to produced water; technology descriptions of current management practices; existing state and federal regulation that form the basis for produced water management practices. There is also an interactive tool to assist in determining the optimal management practices for a geographical or environmental setting. Information guides users to beneficial uses of produced water that allows producers to turn a costly waste product into a valuable resource. The project was funded by NETL and the website tool came online on ANL's website in June 2007.

Petroleum Environmental Research Forum

The **Petroleum Environmental Research Forum (PERF)** (DE-AP26-02NT20384) is a consortium that was funded by the DOE program and continues today which organized workshops to explore industry/government cooperation on produced water issues. PERF's role has been a facilitator between industry, scientific research organizations and State and Federal

regulatory agencies provided a medium of exchange for industry needs, opinions, new technology and new regulatory requirements.

The Interstate Oil and Gas Compact Commission

The Interstate Oil and Gas Compact Commission (IOGCC) has received a number of grants from DOE since the program began in 1991. A grant (DE-AF22-96BC14999) from DOE was used to review the requirements for the oil and gas industry and make recommendations to EPA. The petroleum industry was actively involved in IOGCC's effort to collect data and supported efforts to make information already reported by E&P operations more accessible to the public. IOGCC concluded that: 1) the public already had access to important environmental regulatory information for E&P operations, 2) environmental regulatory information collected at the state and local level is more immediately available from Federal sources, and 3) a cooperative effort should be developed between the states; industry, EPA and environmental organizations to provide easier access to existing data sources. IOGCC's participation with DOE yielded substantial cost avoidance for the petroleum industry.

Under IOGCC's Regulatory Streamlining project (DE-AP26-04NT40549) funded by DOE, two websites were established. The first was an expansion of on-line permitting to shorten the time and reduce the cost of regulatory permits for oil and gas operations. The Regulatory Streamlining project focused on eliminating duplicate and overlapping requirements of state and Federal programs, and educating current and future State and Federal policy makers on oil and gas issues. This site was particularly concerned with continuing to provide the public and EPA with a forum on waste disposal regulations to avoid ineffective regulations that burden the petroleum industry without improving environmental protection. The second website was a dedicated site – NORM Technology Connection – designed to provide information on identification, transportation and disposal methods of naturally occurring radioactive material (NORM). In addition, the NORM website included contact information for Federal agencies and a database of companies that provide services such as site characterization and remediation support.

Access to Federal Lands can also be enhanced by improving the amount and quality of information available for the public and operators. With this goal DOE funded IOGCC to develop guidelines on existing oil and gas leasing and development data necessary for the National Environmental Protection Agency (NEPA) processes (DE-FC26-04NT15541). Objectives of the project were to: assist with data gathering and information, develop a site management and research tool, provide documentation and evaluate existing government documentation, study environmental impacts, provide technology transfer, and perform a case study in Alaska.

The IOGCC (DE-FC26-06NT42937) goal for was to reduce onshore natural gas and oil exploration and production impacts. The objective was to conduct an evaluation of practices that are common and key to oil and gas exploration and production that will assist by identifying and minimizing impacts from the most notable issues delaying or curtailing E&P activities. The approach was to engage a broad-based stakeholder group including landowners, ranchers, farmers, and other concerned citizens, as well as State and Federal agencies and industry. The final goal was to determine practices that ultimately overcome impedances or delays in development of new energy resources. A wide range of documents and information sources related to environmental mitigation practices were reviewed and a number of public meetings held to discuss concepts with regulatory and industry personnel and the interested public.

Low Impact Natural Gas and Oil

Low Impact Natural Gas and Oil (LINGO) was a new initiative in late 2005 under the Federal Lands Access program. The goal was to support environmentally responsible oil and gas exploration and production. The objective was to develop designs for onshore oil and gas exploration and production in the United States that integrated technologies and practices in ways that minimize adverse environmental impacts from oil and gas recovery over the life of the projects. Three specific goals were announced: to consider the whole operation of a project over its life, to creatively combine and apply current technologies and practices, and to develop new science, technologies and approaches. These projects are developing tools that will help small to medium size companies implement low-impact projects across the country. Three projects were conducted under this initiative by **Michigan Tech, University of Arkansas/Argonne National Laboratory, and IOGCC.**

The University of Arkansas (DE-FC26-06NT42930) and **Argonne National Laboratory** (FEW 49345) developed a probabilistic risk-based decision support tool for sensitive ecosystems. The web-based tool was designed for use by small and mid-sized oil and gas exploration and production companies, environmental regulators and others to proactively minimize adverse ecosystem impacts associated with production in sensitive areas of the Fayetteville Shale Play of central Arkansas. The decision tool allows operators to select locations within their leases and technologies that minimize environmental impact while still allowing production. The Fayetteville Shale play that requires fracturing to produce gas at an economic level, which in turn requires significant infrastructure and disposal of large volumes of produced water. The EFD program with the financial support of RPSEA is funding this initiative in a new phase that will include the development of a website for the Haynesville Shale that describes the natural gas resources available and their development and provides information about the state and federal regulatory requirements that developers must follow.

University of Alaska, Fairbanks

The **University of Alaska, Fairbanks** has been a recipient of funding from the Environmental Program and the Arctic Energy Office which was established in Fairbanks, Alaska in 2001 to oversee research projects concerned with environmental issues stemming from development of the oil and gas resources on the North Slope. Increased funding to the University of Alaska Fairbanks (DE-FC26-01NT41248) addressed a number of tasks to improve development of oil and gas resources on the North Slope while providing new technologies to protect the fragile Arctic tundra. One task looked at new technologies to explore and develop CBM resources in rural Alaska to provide fuel for remote villages and reduce the high cost and transportation of diesel fuel. A task on characterization of Alaskan North Slope lakes studied water withdrawal for use in building ice roads. The Alaska Department of Natural Resources (DNR) (DE-FC26-03NT41790) working with Anadarko Petroleum, ConocoPhillips Alaska, and the North Slope Borough facilitated a longer winter operation window on Alaska's North Slope. The project developed an ecological model accounting for the snow conditions and depth, soil character, permafrost depth and vegetation cover; and used the data to predict tundra resistance to oil field disturbance. Initial soil and vegetation samples were collected in 2003 and 2004 near Prudhoe Bay in both coastal and foothill regions and over a variety of soil and vegetative types. The device for consistent measurement of snow and frozen ground depth was a "slide hammer", a calibrated steel rod with a 15-pound sliding weight that is dropped rather than pounded to give a precise measure of the force needed to pierce a foot of soil. Tests ran several types of equipment (trucks, tracked vehicles and rollagons) over the test site at intervals during freeze-up to evaluate the impact.

This ecological model provides a better understanding of the tundra. Results showed that some restrictions could be lifted without compromising the health of the tundra plant community, allowing traffic on the winter tundra at an earlier date. DNR proposed replacing the old tundra travel standards. On September 25, 2004, Alaskan Governor Frank Murkowski announced that preliminary results indicated the tundra could be protected adequately if the rules were eased. DNR opened the Eastern Coastal area of the North Slope for tundra travel on December 10, and the Western Coastal area on December 16, 2004. In 2005, DNR opened the North Slope to tundra travel on December 6th, the earliest date since 1995. Extending the travel season by over two months has had a very positive impact on oil and gas development on the North Slope.

As a part of the EFD program, the U. of Alaska Fairbanks has participated in a study on Ecosystem and Biodiversity measurements and assessments on the North Slope. We believe there are many advances made in operations on the environmentally sensitive regions in Alaska that can be applied in the lower 48.

Colorado School of Mines

A multi-task, multi-performer study headed by the Colorado School of Mines (CSM) (DE-FC26-04NT15549) was designed to develop a portfolio of technologies to address produced water issues in a comprehensive manner. Produced water problems related to coalbed methane production in the Powder River Basin were the focus of the project with the assumption that successful management and treatment procedures can be transferred to other CBM basins. Because of the variability of produced water there is no single treatment or handling scenario. The group of subcontractors working on the project includes: **Argonne National Laboratory, Gas Technology Institute (GTI), University of Wyoming, Stanford University, Montana Technical University, Pennsylvania State University, and PVE, Inc.**

Another study related to this is by Rebecca Efroymson in conjunction with **Oak Ridge**. **Lawrence Livermore National Lab** and Oak Ridge data collection for GIS to manage ecological impacts was completed in 2001. *Ecological Assessments for Upstream Petroleum Sites* FEW 0054 **Project Goal:** The project goal is to provide research data for Petroleum environmental Research Forum (PERF) projects relating to the development of ecological risk evaluation (ERA) techniques at the population, community, or ecosystem level for upstream exploration and production sites. This includes supporting the development of early exit criteria for E&P sites, demonstrating that existing clean-up levels are protective of ecological receptors, and collecting and analyzing field data from existing E&P sites, as necessary. **Project Results:** LLNL participated in a multi-disciplinary team consisting of industry, government, National Laboratories, and private consulting firms to develop ecological assessment techniques for upstream E&P sites that are protective of ecological receptors at the population, community, or ecosystem level. That research was specifically designed to investigate the role of size and spatial distribution of small impacted or contaminated sites to the larger ecosystem or landscape. Under project FEW0067/FEAC321. Development of an ActiveX.dll will allow complex GIS functionality to be initiated directly from the website. The data can provide the range of population, plus a list of vegetation types present, sorted by area.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) was probably the second largest recipient of DOE environmental funding. They had a downhole separator project from 1997-2000; recycle of produced water downhole - Paul Taylor was the PI. Related was a centrifugal downhole separator - JF Walker and RL Cummins were listed at PI's. Another project was on ozone

treatment of soluble organics in produced water 2002, K. Thomas Klasson 865 576 8401. Related was D.T. Bostick characterization of soluble organics in produced water listed as the Chemical Technology Division. The EFD team visited ORNL and Joanna McFarlane has been our primary contact. One publication was the development of a model for produced water. Some of the ORNL work has an offshore focus. David DePaoli has an interesting project on Ionic liquids in produced water cleanup 2005 - COP, Shell, Chevron were co-sponsors. Lostas Tsouris had a project on CBM water cleanup using gas hydrates 865 241 3246.

ORNL in conjunction with **USGS and US Department of Agriculture** developed remote sensing to assess environmental impacts; David Reister was listed as the PI.

ORNL project (FEW FEAC308) was charged with establishing the ECAS on-line website and keeping the information updated. The on-line ECAS system was set up with a number of questions to guide operators to the type of information they needed to comply with regulations. Applicable cleanup methods, environmental and safety guidelines, specific state requirements, and information on how to obtain permits were the among the original data supplies. Information also included specific regulations for states and contact information for all states. DOE wanted to develop an Internet Web site to help operators understand and meet compliance issues. A study in 1990 by the First International Symposium of Oil and Gas Exploration and Production Waste Management Practices estimated the costs at $15 to $79 billion for initial industry-wide compliance with new environmental regulations. Annual costs for compliance were estimated to range from $2 to $7 billion as environmental regulations increased in the 1990s. DOE's objective in establishing ECAS was to simplify environmental regulations without compromising protection.

Pioneer Natural Resources

Pioneer Natural Resources conducted a project completed in 2000 on the beneficial use of drilling waste and wetland restoration; DE-FG22-97BC14849; Mike Jacobs was the PI. This project built upon work conducted by **Southeastern Louisiana University** and shows a beneficial and cost effective use of drill cuttings.

University of Wyoming

University of Wyoming conducted several projects on produced water and CBM DE FC 2606NT15568 and CSM related project DE FC2605NT15549. In this project hydrologic modeling was performed by BLM, and the University of Wyoming. The project was to develop modeling tools to assist in streamlining analysis of the effects associated with energy development upon soil and water resources, and to improve the Application for Permit to Drill process in Wyoming. A test of the model and toolkit has been conducted in the Fortification Creek sub-basin of the Powder River Basin. The models can compute and show spatial distribution of runoff, erosion, and water quality to assist in resource management. Areas to be studied include the Powder River Basin, Atlantic Rim, and Pinedale area – all CBM development areas. The Atlantic Rim near Rawlins is of particular interest as it is the newest region of Wyoming for CBM exploration. The university is a part of the EFD program and is supporting an initiative to reduce the footprint from access roads.

Sandia National Lab

Managing CMB water David Borns was the PI and the project was completed in 2007. Other related Sandia Projects ultra filtration, and they did a plot desal test for COP Randy Everett was

listed as PI. Sandia and GTI conducted had a large project on gas leak detection - vapor imaging, while successful, it not related to EFD.

In the area of risk management the major recipient of DOE funding was **ICF.** Results were well published and not related to EFD.

Partnering with **ConocoPhillips (CP), Biosphere Environmental (BEST), New Mexico State University (NMSU), and the US Department of Agriculture (USDA), Sandia National Laboratories** conducted pilot studies at a coal bed natural gas pad site in the Four Corners Area near Navajo Dam, NM. The report covers the activities at the pilot site during 2007. In this project, the produced water from CBNG wells was reclaimed (desalinated) and used for a short term rangeland improvement study. Some of the grasses near the pad of the ConocoPhillips San Juan Unit (Well) 32-8 #237 A were watered with treated and untreated water. The technology applied to bring CBNG produced water to a suitable standard for rangeland and riparian improvement depends both on the TDS and organic content of the particular CBNG produced water. The technical challenge with respect to water treatment was to pre-treat the water for organic and other contaminants that will cause membrane fouling or scaling, as well as to remove coal fines prior to desalination. Membrane fouling and scaling can cause significant pressure increases and increase the amount of chemical cleaning required. The organic content of the produced water is designed to be lowered by membrane filtration. The pilot equipment was designed to remove coal fines by cyclone/centrifuge separators and a settling tank. After the pretreatment the salt content was lowered by reverse osmosis.

Lawrence Livermore National Laboratory

Because the Tallgrass Prairie offered an excellent field laboratory to study long term oil and brine spills and remediation of the soils and vegetation, DOE expanded research to test other remediation technologies. **Lawrence Livermore National Laboratory** (FEW 0054 and FEW 0067) began work on the site in 1999, and **Oakridge National Laboratory** (FEAC 321) and the **University of Tulsa** joined in the research efforts in 2000 (DE-AC22-01BC15332). The University of Tulsa and the National Labs under the Natural Gas and Oil Technology Partnership Program (NGOTP) developed a long term ecological model and analysis of the Tallgrass prairie ecosystem. Analysis of oil and brine impacts on soils, groundwater, vegetation and terrestrial vertebrates provided information on how to assess the impacts and how to develop remediation plans. Part of the NGOTP goals for the projects were to develop recommendations for EPA on how to regulate exploration and drilling sites in grassland communities. The University of Tulsa project developed a risk assessment and self-assessment guide for operators and land owners to determine the extent of soil and vegetation damage and determine the appropriate remediation steps. The University of Tulsa established a series of workshops and provided soil test kits and information to interested parties.

University of Tulsa

Between 2001 and 2005 a spill risk reduction project was funded for $1 MM with Kerry Sublette at the **University of Tulsa** as the PI. The project published a good amount of reports and presentations. The Tallgrass Prairie was the beginning of a new concept. The University employed a probabilistic risk assessment approach to data from well heads, pumps, gathering lines, oil-water separators, and tank batteries to develop guidelines for operators to model potential risks and determine remediation procedures.

Los Alamos National Laboratory

Los Alamos National Laboratory has conducted several studies on produced water - Enid Sullivan was the PI. The majority of this work was around a surfactant modified zeolite vapor phase bio- reactor. Later in the program they worked with New Mexico Tech and U. of Texas who also had related work programs on this project. They have also worked with Texas A&M and the EFD program.

Lawrence Berkeley National Laboratory

Several projects with **Lawrence Berkeley National Laboratory** have been in the air emissions area and the lab was the recipient of millions from this program. Air quality impacts (modeling) – Nancy Brown was the PI, **and Lawrence Livermore National Laboratory** began in 1999 and 2000, that studied a variety of impacts on air quality in the West with specific studies in Wyoming and California. Projects with LBNL included: FEW EE1483, FEW EE1490, FEW EE1557, P-210, P-51, and FEW EE1682. Projects with LLNL included: P-74, FEW 00027, and FEW 0043. **Lawrence Livermore Lab** has conducted several related studies - Membrane for removal of organic impurities in produced water – John Reynolds was the PI, a report in 2005 indicated Shell was a co-sponsor. Ecological Assessments of Petroleum Sites was an interesting project - Tina Carlsen completed in 2004. Goal was ecological risk evaluation techniques. And related was ecological framework to evaluate impacts (**Scorecard related**).

The focus on air quality in 1999 addressed six topics: visibility, SO_2 concentration, ozone, acid deposition, new particulate matter standards (PM-10 and PM-2.5), and carbon monoxide (CO). Varying levels of concern for these issues were ranked in different regions: the Gulf Coast, Alaskan North Slope, California's San Joaquin Valley, the Rocky Mountain region and the California coast. Visibility was a serious concern in the San Joaquin Valley and in the Rocky Mountains, and less so in all the other regions. The SO_2 levels were an issue in the Rocky Mountains. Ozone levels were considered serious in the Gulf Coast, and the San Joaquin Valley and less so in the Rocky Mountains and along the California coast. Acid deposition was a new concern in the Rocky Mountain region. Meeting new EPA Particulate Matter standards was a serious problem in the San Joaquin Valley, a concern in the Gulf coast region and potentially an issue in both the Rocky Mountains and the California coast. The problem of carbon monoxide build-up is specific to very cold climates, and could be a health hazard on the North Slope.

Studies at LBNL and LLNL contributed to the understanding of how air quality is impacted by various pollution constituents and assisted EPA in setting standards for emissions of allowable toxics in the air. Modeling efforts on ozone looked at NO_x and VOC emissions and concentrations and provided tools for objective analysis of these constituents in the air. Particulate matter standards were addressed through a series of tests, measuring concentrations both indoors and outdoors to determine the effects of leaks and cracks in buildings on the infiltration rate of chemical pollutants from the outside entering houses and buildings. A project on visibility issues in National Wilderness areas set up a series of monitoring sites in Wyoming. Wyoming served as a prototype for the EPA's new regional haze regulations. Overall, the air pollution studies established methods and new technologies to measure the various types of pollutions, made observations on the timing of natural absorption and cleansing, and determined safety levels.

One project specifically addressed the use of plasma-assisted catalysis for NOx emission control. Efficient reduction of NOx was demonstrated with plasma assisted catalysis when propane was used as the reducing agent. LLNL also investigated several other types of catalysts to determine optimum combinations with the plasma.

Produced Water

Produced water has been a major initiative for the DOE environmental program. Beneficial use of produced water for rural areas and agriculture in Texas and New Mexico was a motivation for the projects at **Texas A&M, the University of Texas, Austin and New Mexico PRRC**. The arid north, west and south Texas regions, where aquifers have become depleted, need water for crops and grazing, and for municipal use in small communities. The shale gas production in the Barnett shale play near created enormous volumes of produced water that required treatment to make it useable which was the reason the DOE solicitation was initiated.

From this produced water funding initiative the Mobile Advanced Membrane Filtration Technology at Texas A&M (DE-FC26-03NT15427 and DE-FC26-04NT15543) developed a trailer functional as a mobile desalination unit capable of processing up to 10,000 gallons of produced water per day. The goals of the projects were to develop improved reverse osmosis membrane filtration technology for treating waste-water produced during oil and gas operations, and to improve the lifetime and operating efficiency of the membrane filters. Objectives of the first project were to evaluate new pre-treatment technologies using combinations of liquid-liquid centrifuges, organo-clay absorbents and microfiltration and modification of oil-resistant trans-membrane pressure and recycling ratios to permit optimization of the desalination unit. The object of the follow-up project was to develop innovative and novel cleaning agents that would remove fouling materials and restore the microfilters and enhance reverse osmosis of the membrane used in the desalination unit. The challenge was to modify the reverse osmosis process to treat oilfield produced water and make the system cost-effective. The key to cost-effective RO desalination is the pre-treatment of the water to remove particulate matter and heavy minerals and to reduce the saline content. The process relies on improved filters and new methods to clean the filters on a daily basis.

University of Texas at Austin

The University of Texas at Austin (DE-FC26-04NT15547) took a somewhat different approach to analysis of membranes for reverse osmosis processes to clean produced water. The goal was to provide new alternatives to purify produced water with emulsified oil, particulate matter, and dissolved solids for beneficial use. They performed extensive laboratory studies on new fouling-resistant polymer membranes. New membrane coating and grafting techniques were developed and applied to ultrafiltration, nanofiltration and traditional reserve osmosis membranes. Two methods were investigated: surface coating of the commercial RO membranes with UV treated polymerized hydrogels (grafting) and direct chemical surface modification of the commercial RO membrane. Report reference #'s FEW 02 FE20, FEW 04FE 10-5 and FEW 15546. The University of Texas – novel cleanup of membrane filters for produced water. Report published in 2007 Benny Dean Freeman.

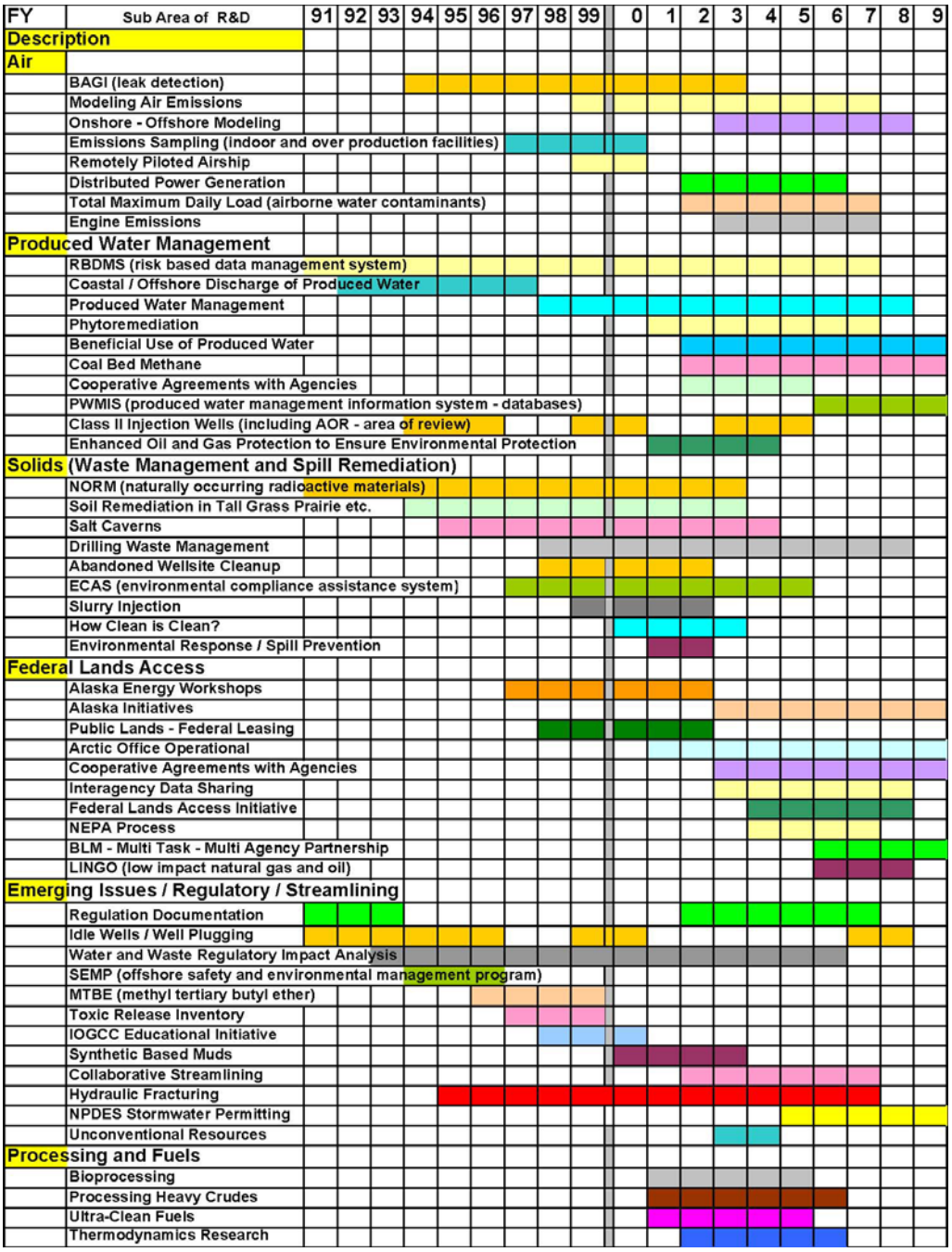
New Mexico Institute of Mining and Technology, and the Petroleum Recovery Research Center

New Mexico Institute of Mining and Technology, and the Petroleum Recovery Research Center (PRRC) (DE-FC26-02NT15326 and DE-FC26-04NT15548) have been working with reverse osmosis and improvement membranes for purifying CBM produced water since 2000. The goal of the original project was to develop and fabricate a bentonite clay membrane (cheap and readily available) and a precipitator unit with a tubular clay ceramic membrane to provide a water treatment system to process produced water into reusable water. The bentonite

membranes did not prove successful for salt rejection, but new **zeolite membranes** were developed that were superior. Following the experiments of the first project the goals of the second project were to improve the understanding of reverse osmosis and use modified zeolite membranes to establish the optimal operating condition for water flux and ion rejection. The ultimate goal was evaluation of a technical and economic feasible long-term reverse osmosis operation. The objective has been to transform the high TDS produced water from CBM operations in the San Juan Basin and reduce them by 90%, leaving purified water available for beneficial use in agricultural and industrial applications. Experiments with other chemicals to modify the water flux were included in the report. New Mexico Tech has been the recipient of several other DOE projects including a PUMP project 2002-2005 that used a GIS database website for that region. (report DE FC2602NT15134). The PI was Robert Lee who may have retired and the Co-PI on some of these projects was Martha Cather (who helps with the PTTC).

Another NMT project was on modified reverse osmosis for treatment of produced water – Junghan Dong was PI. He was involved one a related project on beneficial uses of CBM water and another on the above mentioned use of MFI zeolite membranes.

Petroleum Environmental Solutions Program Timeline



CONCLUSIONS and OBESERVATIONS

The Department of Energy has played an important leadership role in improving environmental protection, improving the regulatory process and providing tools and data to inform the public, environmental organizations and policy makers. This effort initiated during the Bush (41) administration has accomplished a lot with a relative small Federal investment and it has done so with minimal financial support from most Administrations since it was initiated. DOE should be commended for their accomplishments. The concerns on our environment are perhaps as pressing today they were when the Environmental Research Program began in 1991. Since the

program was started a number of issues have been addressed, yet many of the same concerns, such as handling produced water, reducing our footprint, and maintaining air and water quality remain high priorities. While they are high priorities, and the environmental performance is significantly better than it was when this program began; many innovations and better practices from industry and researchers who benefited from the DOE program have made this possible. The challenges today highlight the need for programs like the Environmentally Friendly Drilling Program which would not be in existence today without the DOE funding.

Overall, the DOE program has been a success, resulting in increased production, reduced operating costs, reduced permitting time and increased efficiency; new technologies to address identification, monitoring, remediation and improvement of the quality of the Nation's air, water and soil; and improved access to Federal Lands and oil and gas resources. Technology transfer has been a major focus of the program, with a range of efforts under way to provide information to the oil and gas industry and the public.

Many people probably do not know about the Outer Continental Shelf Safety and Environmental Management Program (SEMP) research project that was funded by DOE in the mid 1990s in response to safety and environmental concerns by the Minerals Management Service (MMS). MMS and the American Petroleum Institute and the Offshore Operators Committee developed the RP75 guidelines (Recommended Practices for Development of a Safety and Environmental Management Program for Outer Continental Shelf Operations and Facilities) in May 1993. In 1994, MMS requested that industry voluntarily adopt the RP75 guidelines. The research was managed for DOE under BDM Petroleum Technologies (NIPER/BDM-0343) at the Bartlesville Project Office.

Under the SEMP program, offshore producers are responsible for identifying potential hazards in the design, construction, and operations of drilling and production rigs and developing specific approaches to reduce the occurrence of accidents on offshore locations. However, many small and midsized independent operators and producers raised questions over the costs and methods for implementing RP75. In cooperation with MMS, DOE determined that a prototype demonstration project performed by a smaller producer would answer these questions and provide other offshore operators with the understanding needed to comply with RP75 recommendations.

Specific concerns that the SEMP program addressed include: 1) Offshore operations have moved into deep water and farther offshore, 2) A large number of offshore platforms are aged and out of date, 3) Older facilities have not incorporated the newest sophisticated technologies for inspection and safety, and 4) An increasing number of smaller companies now own and operate facilities on the Outer Continental Shelf, and many of these companies lack the financial capability, experience and incentive to operate facilities in the manner historically enjoyed by the Major oil companies.

The cost to develop a Safety and Environmental Management Program depends on many factors, including the size of the company, financial capability, number of facilities it operates, offshore experience, development and use of operating practices, level of technical knowledge, and the safety attitude of management. In reviewing this report it was stated that "the cost of program implementation can be recovered by the prevention of one relatively minor accident or oil spill that would otherwise cause operations to shut down for repair and cleanup."

Through a competitive procurement Taylor Energy of New Orleans was selected to demonstrate SEMP development. Taylor Energy implemented SEMP procedures at five platforms in the Gulf

of Mexico over a 30-month period in 1994-1996. Engineering and support services were provided by Paragon Engineering. The objectives were to: 1) demonstrate the development and implementation of SEMP, 2) determine the cost and effort for Taylor Energy to successfully implement SEMP, and 3) develop measures of effectiveness that determined necessary improvement found as a result of the SEMP implementation.

The demonstration was designed to guide operators through the complexities of regulations, safety issues and other difficulties associated with SEMP implementation. The demonstration was geared to show how to perform tasks in accordance with SEMP and promote investment of the small and mid-sized operators in the necessary safety equipment and training.

Paragon Engineering assisted in the development and evaluation of SEMP, including hazard analysis, safety, and environmental information, management of changes, and establishment of safe work practices. Paragon evaluated Taylor Energy's success on resource recovery, profitability, safety and environmental protection. Experience and information developed through implementation of the SEMP was documented and technology transfer of the information to other small and midsized operators was conducted. Training programs for personnel were conducted at each platform that was included in the demonstration. Results of the demonstration were published in three operating manual and safety handbooks (1997): *Safe Operating Procedures Manual*, *Safe Drilling and Workover Practices Manual*, and *Safety Handbook* (BDM-0318, 1997, p. 405-405).

This was an important effort that has made operations safer and more environmentally protective, but unfortunately this initiative did not evolve adequately with government led leadership and funding to keep pace with the ever increasing challenges facing the OCS.