

Summary of DOE/PERF Water Program Review

November 1–4, 2005

Annapolis, Maryland

prepared by
Environmental Science Division
Argonne National Laboratory

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for
U.S. Department of Energy
National Energy Technology Laboratory

by
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Contents

Introduction..... 1
 Purpose..... 1
 Participants..... 1
 Agenda 2
 What Did We Learn and Where Do We Go from Here? 2
 Acknowledgments..... 3

Summary of Day One – Wednesday, November 2, 2005 4
 Day-One Overview 4
 DOE-Funded Research Projects 4
 Regulatory, Permitting, and Information Tools..... 4
 Impact Characterization and Assessment 5
 Technology Development..... 6
 Produced Water Management and Beneficial Use 7
 WERF Session 8
 Open Discussion 9

Summary of Day Two – Thursday, November 3, 2005 10
 Day-Two Overview 10
 Federal Government Agencies..... 10
 Organizations and Associations..... 11
 Oil and Gas Companies 12
 Contractor and Consultant Companies 12
 Upstream Breakout Group 13
 Downstream Breakout Group 14

Summary of Day Three – Friday, November 4, 2005 16
 Day-Three Overview 16
 Research Gaps and Needs..... 16

Appendix A – Program Review Participants 18
 Appendix B – Detailed Agenda 24

TABLE

1 Participants in DOE/PERF Water Program Review..... 2

Introduction

For many years, the U.S. Department of Energy (DOE) has supported and sponsored various types of water research relating to the oil and gas industry through its Office of Fossil Energy and its National Energy Technology Laboratory (NETL). In early 2005, the Petroleum Environmental Research Forum (PERF) submitted a proposal to DOE for funding an upcoming PERF meeting that would feature water research in the petroleum industry. PERF is a nonprofit organization created in 1986 to provide a stimulus to and a forum for the collection, exchange, and analysis of research information related to the development of technology concerning the petroleum industry, and a mechanism for establishing joint research projects in that field. Additional information on PERF can be accessed at <http://www.perf.org>.

DOE agreed to provide funding to hold a review of its water research program in conjunction with the fall 2005 PERF meeting. Argonne National Laboratory (Argonne) was asked to coordinate and host the meeting, which was referred to as the DOE/PERF Water Program Review. The program review was held on November 1–4, 2005, in Annapolis, Maryland, at the Historic Inns of Annapolis.

Purpose

The purpose of the program review was to provide a forum for sharing information, reviewing current programs (especially recent unpublished research), and reviewing industry and regulatory needs regarding water use and reuse issues. PERF and DOE/NETL can use this information to plan for future water-related research projects. The water program review provided a unique opportunity in several ways. First, DOE was able to have all of the contractors currently receiving DOE funds for water research present in one room at the same time. Each contractor described his or her research and was able to learn about the research being conducted by the other researchers. Second, this forum allowed representatives of many large oil and gas companies to hear about the DOE research projects and offer their reactions to DOE and the researchers. Third, most oil and gas meetings focus on either upstream (the exploration and production sector) or downstream (the refining sector) issues. Typically, there is little overlap in content between the two industry sectors. At the program review, attendees with upstream and downstream orientations were able to spend much of their time in joint sessions and could learn more about the other sector.

Participants

Eighty-two persons attended one or more of the days of the program review. A list of all participants, including their contact information, is included in Appendix A. Table 1 shows the breakout of participants by type of organization.

Table 1 Participants in DOE/PERF Water Program Review

<i>Participant's Organization</i>	<i>Number of Participants</i>
DOE	12
Other federal agency	4
National laboratory	7
University	10
Oil and gas company	19
Association	12
Consultant or other	18

Agenda

The full agenda for the program review is included as Appendix B. Prior to the start of the organized program review, the PERF Board met on November 1, 2005. At the end of the program review, PERF held its business meeting. Because both of these activities are associated solely with PERF and not with DOE, neither is summarized in this document.

The program review consisted of two and one-half days of sessions structured in different ways. Day one included presentations from contractors who had received DOE funds for upstream water projects and a separate, parallel downstream session. Day two included presentations from government officials, representatives from national technical organizations, industry and trade associations, industry, and consultants who described key water issues and research topics that affect the industry. At the end of the day-two presentations, the participants broke up into upstream and downstream discussion groups. On day three, all participants held an open discussion of the significance of ongoing research, gaps in current research, and areas in which government or industry might conduct more research.

The subsequent sections of this report provide summaries of each of the program review sessions. Copies of all presentations made during the program review can be viewed and downloaded at http://www.perf.org/index.php?act=meeting_2005-11_overview.

What Did We Learn and Where Do We Go from Here?

Feedback from the participants indicated that they found the program review to be valuable. This was an unusual opportunity for major oil and gas companies to meet with several federal agencies and researchers from universities, national laboratories, and other contractors. Nearly all of DOE's water research program focuses on onshore produced water or coal bed natural gas (CBNG) water issues. The DOE water research presented during the program review did not reflect the direct interests of the most of the major oil and gas companies that work primarily in offshore areas and internationally, or of the downstream sector. In addition, the industry group that is most likely to benefit from DOE's water research program — the small and medium U.S. independent producers — were not represented at all at the program review, although the

program review and PERF meeting were open to the attendance of such entities. It would be interesting to learn the opinions of that group about the value and content of DOE's research.

The participants agreed that water research was valuable to the industry. The upstream and downstream breakout groups and the day-three facilitated discussion pointed out some of the research gaps and needs. Although no commitments were made to immediately pursue solutions to the research gaps, the discussions were useful in educating the participants on a wider range of issues and ideas and in stimulating future planning processes.

One fundamental issue concerns the source of future funding for water research. DOE has funded millions of dollars of oil- and gas-related water research but its research budget has diminished for FY06, and the future of its research program is unknown. Major oil and gas companies used to fund significant in-house research efforts; many such programs, however, have shrunk or disappeared. PERF can play a role in facilitating communication between the large oil and gas companies and other interested researchers, although some of the results of PERF projects are kept proprietary for several years after the projects have been completed. The Water Environment Research Foundation (WERF) funds a great deal of municipal and industrial wastewater treatment research. The focus is more closely aligned with downstream water concerns than with upstream ones. No clear solution to the future funding issue was identified. The participants encouraged greater communication and collaboration among researchers and users of the research. Other future gatherings like this program review may be helpful in benchmarking progress and enhancing communication.

Acknowledgments

The program review and Argonne's coordination and management efforts were sponsored by DOE's NETL under Contract W-31-109-Eng-38. Nancy Comstock was the NETL project officer at the time the program review was conceived and approved. Jesse Garcia was the NETL project officer at the time the program review took place. Their support was valuable in implementing the program review.

PERF sponsored the evening reception and dinner on day one. Jill Kerr of ExxonMobil was the PERF Chairperson during the program review. She and the other PERF Board members strongly encouraged and supported the program review. Virginie Vitiello of Total was the PERF Web site manager. Her efforts before and after the program review greatly aided in communicating information about the program review.

John Veil of Argonne was the meeting organizer and coordinator. He was assisted in planning and organizing the meeting agenda and content by Todd Ririe of Chevron and John Wilkinson of ExxonMobil. Patria Leath of Argonne provided invaluable assistance in planning and carrying out the meeting arrangements and logistics. Argonne's John Gasper, Markus Puder, and Patria Leath served as note takers throughout the meeting and contributed much of the content in this summary. The summary was edited by John Veil.

Summary of Day One – Wednesday, November 2, 2005

Day-One Overview

The primary focus of day one was to review the suite of research projects currently being funded by DOE relating to water issues and oil and natural gas. Fifteen different researchers gave short summaries of their projects, including details on the following:

- Project title, contractor name, and contact information;
- Partners/subcontractors;
- Project goal;
- Scope and approach;
- Current status;
- Schedule;
- Benefit to oil and gas industry;
- Transfer of knowledge, including any reports, publications, or significant presentations resulting from the project;
- Relationship to other DOE or non-DOE research; and
- Funding levels.

Some of the researchers described more than one project.

The projects reviewed on day one addressed produced water from both conventional oil and gas and CBNG. The projects can be grouped into four major categories, although aspects of several projects addressed more than one category. These categories include regulatory, permitting, and information tools; impact assessment and characterization; technology development; and produced water management/beneficial use. Presentations were made for completed, ongoing, and planned research.

All of the DOE-funded projects were related to water issues affecting exploration and production of oil and gas (upstream issues). To provide information more relevant to the attendees who work on refining (downstream) issues, a parallel session, organized by WERF, was held in the afternoon of day one in a separate room. At the end of the day, the DOE-funded speakers sat in front of the room for a round-table open discussion. The DOE-funded research is summarized first, followed by a summary of the WERF session and a summary of the open discussion.

DOE-Funded Research Projects

Regulatory, Permitting, and Information Tools

Four presenters reported on projects and programs related primarily to permitting and information tools. These programs addressed an array of issues ranging from development of

information for use in promulgation of regulation to creation of analytical tools for meeting permitting and reporting requirements.

John Veil of Argonne reported on development of a produced water White Paper for DOE. This White Paper, which was completed last year, is a compendium of information related to the production, regulation, and management of produced water. It has served as a guide to industry, regulators, and other stakeholders for understanding issues related to regulation and management of produced water. He further noted that he is providing regulatory and information support to two other projects involving a number of researchers. These projects are described below.

Mark Carl of the Interstate Oil and Gas Compact Commission (IOGCC) reported on a program to characterize current and emerging produced water management practices and to develop a geographical information system (GIS)-based watershed analysis tool, available through the Internet, to assist in water management planning and permitting decisions. A report on management practices is expected by December 2005, with the Internet tool to be completed by September 2006.

Dan Arthur of ALL Consulting summarized several projects that shared the objective of providing information needed to facilitate planning and permitting for CBNG. Two completed projects produced a primer and a handbook on environmental issues related to CBNG. Another ongoing study will provide guidance on siting, design, and construction of CBNG impoundments.

Mike Nickolaus of the Ground Water Protection Council (GWPC) reported on three projects related to regulatory topics. The first of these was an examination of the U.S. Environmental Protection Agency (EPA's) primacy delegation limitations under the Safe Drinking Water Act that may lead to development of a partial primacy program in a state. Mike reported that the legal authority exists for granting partial primacy, and that efforts are ongoing to negotiate a Memorandum of Agreement (MOA) between EPA Region 8 and Montana to pursue a partial primacy program. Mike also reported on two upcoming studies. The first will examine the technical basis for and validity of calculations used in Area of Review determinations for siting injection wells. The second will develop a water quality data module for use with the Risk-Based Data Management System (RBDMS) data system that could facilitate electronic permitting and reporting.

Impact Characterization and Assessment

Four presenters reported on produced water characterization and/or assessment programs that examined fate, dispersion, and effect of the release of produced water to the environment. Two of the presented studies examined the distribution of brine contaminants in the environment. Seepage and salt scarring and impacts on the terrestrial and aquatic environment were the subjects of a study reported by Jonathan Fisher of Oklahoma State University. Field sites in Oklahoma that had experienced brine overflows in the past are being sampled to better understand the impacts of brine on biota and to validate testing protocols. The project began in January of 2005 with a completion date scheduled for fall of 2007.

Yousif Kharaka of the U.S. Geological Survey (USGS) reported on a study of another Oklahoma site where the goal is to examine the distribution and fate of contaminants from surface-discharged produced water and a petroleum storage pit. Chemical and isotopic compositions of source and ground waters were characterized, and plume boundaries were examined to determine the extent of subsurface penetration, of plume mixing, and of water-rock-bacterial interaction. Findings of the completed study indicate that 65 years after contaminants were released, organic and inorganic contaminant plumes remain distinct.

Terry Ackman of DOE's NETL reported on three studies related to reducing environmental impacts of oil and gas development in the Powder River Basin. The first developed a GIS-based screening tool to identify areas unsuitable for the construction of infiltration impoundments. Suitability was based on soil characteristics and the potential for contamination of surface and ground water. The approach was prototyped using the Juniper Draw area of Wyoming. The second and third studies, which also fall into the technology development category, evaluated emerging technologies for use in environmental characterization. These included the use of unmanned airborne vehicles for the detection of methane and carbon dioxide (CO₂) related to CBNG operations and helicopter-mounted electromagnetic sensing devices to detect and characterize water in subsurface fractures related to CBNG.

John Veil described a sampling program to estimate the contribution of offshore oil and gas produced water discharges to the nearshore hypoxic zone in the Gulf of Mexico. Fifty offshore platforms in the hypoxic zone were sampled for nutrient- and oxygen-demanding substances in their produced water discharges. The study also estimated loadings of those parameters from all the platforms in the hypoxic zone. The results indicate that pollutant loadings from the platforms are less than 1% of loadings from the Mississippi and Atchafalaya Rivers. Results of the study, which was completed in August 2005 to meet a permitting deadline, are being used by EPA in model development and evaluation.

Technology Development

Five presenters reviewed projects related to the development of technology for the characterization, treatment, and management of produced waters.

John Veil reported on a completed study that examined the feasibility of the use of downhole oil/water separation (DOWS) and downhole gas/water separation (DGWS) technologies to separate and reinject water from oil and gas production. The study characterized the regulatory, economic, and technical issues related to application and operation of downhole separation.

Reinjection was also the subject of a presentation by Mukul Sharma of the University of Texas who summarized components of an industry-funded water reinjection program that includes modeling, development, and testing of injection technology. A related DOE-funded program to develop fouling-resistant membranes for produced water purification is also a part of the program. The approach being taken in this ongoing DOE program is to modify the surface of commercial reverse osmosis (RO) membranes by grafting brushes or by coating with polymers to resist organic fouling and biofouling.

Treatment of produced water using membrane technology was the subject of presentations by two additional speakers. Robert Lee of the New Mexico Institute of Mining and Technology reviewed the status of a project to develop a new RO technology using inorganic molecular sieve zeolite membranes to treat CBNG produced water. In 2005, the study focused on understanding the mass transport behavior and operation parameters of zeolite membrane. Membrane improvement and testing will continue through 2007.

David Burnett of Texas A&M University summarized the desalination program at Texas A&M, reporting on desalination system design, testing, and evaluation activities. This included development of membrane pretreatment and cleanup technology, and evaluation of desalination applications at several test sites to provide water for enhanced recovery and beneficial use.

Lynn Katz of the University of Texas reported on development of a bioreactor system using a surfactant-modified zeolite sorption process with two-step vapor phase biodegradation. The goal is to develop a low-cost system for removal of organics in order to facilitate desalination for onsite use of produced water. The system, which has been designed and fabricated, is undergoing modification and optimization with testing at a field site to be completed by fall of 2007.

Produced Water Management and Beneficial Use

Four speakers reported on projects related to the management and/or beneficial use of produced water. All were systems analyses that identified and evaluated processes and technologies leading to beneficial use of produced water. Demonstration or pilot projects have been planned or completed for two of the projects.

Two of the projects included evaluation of beneficial uses for produced water from CBNG in the San Juan Basin. Mike Hightower of Sandia National Laboratories reported on a program to characterize produced water in both the San Juan and Raton Basins, and to develop and evaluate a process for produced water treatment. The characterization and process development tasks are complete. Pilot demonstrations are planned for FY06.

Kent Zammit of the Electric Power Research Institute (EPRI) reported on a project to evaluate the use of produced water in recirculating cooling systems at the San Juan Generating Station in New Mexico. The study included characterization of both produced water and blends of produced and process water, evaluation of transportation infrastructure and cooling system requirements, testing of treatment technology, and an implementation and cost-benefit analysis. The project is scheduled for completion in December 2005.

The use of Powder River Basin CBNG produced water was the subject of a systems analysis reviewed by Geoff Thyne of the Colorado Energy Research Institute at the Colorado School of Mines. This project, which began in April of 2005 and is scheduled to be completed two years later, will evaluate produced water characteristics, source reduction and treatment options, regulatory requirements, and traditional and innovative beneficial uses. The project involves a large team of researchers from several universities and research organizations.

Bob Liske of Aera Energy LLC described efforts to manage produced water from Aera's San Ardo field near King City, California, for beneficial reuse. The completed Phase I of the study evaluated potential uses (agriculture, mitigation of seawater intrusion, makeup water for industrial or utility processes), treatment technologies, and regulatory requirements. Aera considered discharging treated water to the Salinas River but concluded that it might be expected to continue supplying water even after its oil and gas production was completed. Phase II is currently underway and involves design and construction of a small-scale water treatment demonstration facility. Completion of Phase II is scheduled for July 2006.

WERF Session

The session began with an overview of WERF and the program-directed research methodology provided by Glen Reinhardt, the Executive Director of WERF. WERF is a not-for-profit organization seeking to promote the development and application of sound science to water quality issues. WERF subscribers include municipal and regional water and wastewater utilities, industrial corporations, environmental engineering firms, and others. WERF's primary funding comes from EPA and its members. WERF typically funds nearly \$10 million in new projects each year. Roughly 130 projects are active at present. All research conducted is peer-reviewed. WERF has a staff of roughly 30. Research projects are driven by subscribers.

Glen Reinhardt's introduction was followed by three presentations made by WERF-sponsored researchers, which are described below.

Movva Reddy of MPR Engineering Corporation outlined the best practices manual for correcting bottlenecks and improving performance at wastewater treatment plants. He presented the recommended systematic and collaborative approach for use by utilities, industries, and consultants for recovering treatment capacity through re-rating and plant optimization. His presentation included a case study on the water reclamation facility in Orange County, California.

Krishna Pagilla from the Illinois Institute of Technology provided background on the forms of nitrogen found in wastewater, along with an overview of current wastewater treatment technologies for nitrogen removal. He addressed the motivation provided by the 2001 USEPA Proposed Nutrient (N&P) Criteria and provided a review of the WERF 02-CTS-1 project, a field demonstration at the John Egan Water Reclamation Plant at the Metropolitan Water Reclamation District of Greater Chicago.

Charles Bott from the Virginia Military Institute (VMI) provided an update on a WERF project that focuses on biomass sensors to detect upsets to the biological processes. Detection of an upset to the biological processes may permit the development of rapid prevention/corrective action strategies. He provided an overview of two field studies conducted by VMI. Fundamental studies on source/cause/effect relationships may be found in WERF 00-CTS-2.

Open Discussion

At the end of the presentations on day one, an open discussion period was convened between the DOE-funded speakers and the other attendees. A wide range of topics were discussed; the key issues included:

- Increased communication and collaboration between researchers is important and should yield multiple benefits. Methods for improving future communication and collaboration were discussed.
- It is important to engage regulators in the planning and review of research.
- Research and development changes, along with improvements in operations and management, in the past 10 years have led to better control and management of produced water. Better knowledge of injection techniques and injection formations were identified as key advances. Regulatory requirements and increased sensitivity to injection costs were identified as key drivers for the changes.
- The discussion period culminated with a discussion of the opportunities and challenges of turning produced water from a liability into an asset.

Summary of Day Two – Thursday, November 3, 2005

Day-Two Overview

While day one followed a focused agenda of specific topics, the day-two agenda included a wider variety of themes. Many of the presentations were not specifically focused on oil and gas water issues but rather covered more generic water management and wastewater treatment topics. During the morning, speakers from four federal government agencies and several national technical organizations and industry associations described the range of water research activities that their agencies/organizations actually sponsored or in which they had an interest. During the first part of the afternoon, presentations were made by one oil and gas industry speaker followed by a series of presentations from industry contractors and consultants.

In mid-afternoon, the attendees split into two discussion groups, one on upstream issues and the other on downstream issues. Each of these groups of presentations as well as the two discussion groups are summarized below.

Federal Government Agencies

David Alleman directs oil and gas environmental research programs for DOE's NETL. The primary environmental areas in which NETL's Strategic Center for Oil and Gas is currently funding research are federal land access, produced water, and regulatory streamlining. While these programs face budget uncertainties, the big themes include produced water treatment technologies (in particular, improvements to RO treatment and membrane cleaning) and environmental impact minimization. DOE's mission includes ensuring a safe and cost-effective energy supply. The Low Impact Natural Gas and Oil (LINGO) is a new approach that considers the whole operation over its entire life, creatively combining and applying current technologies and practices and developing new science and technologies as necessary.

Carey Johnston works with the Effluent Limitations Guidelines program in the Office of Water at EPA. EPA does not fund specific oil and gas-related water research but develops regulations that can affect the oil and gas industry. EPA must review its Effluent Limitations Guidelines every few years. At present, the oil and gas industry sectors under review include offshore oil and gas extraction, CBNG, and liquefied natural gas import terminals. The major challenge is associated with a lack of knowledge about what exactly is being discharged. In light of concerns about more EPA regulations and less DOE research funding, the presentation emphasized that the review was a statutory obligation and that EPA was looking to make the process more efficient, for example, through electronic information exchange. For purposes of updating economic data, EPA looks at prior years as well as forecasts.

Mary Boatman works in the Environmental Assessment Branch of the Department of Interior's Minerals Management Service (MMS). Environmental studies programs conducted by MMS relate to:

- The hypoxic zone in the Gulf of Mexico,
- Effects of oil and gas operations at selected continental shelf sites in the Gulf of Mexico,
- Degradation of synthetics-based drilling muds and base fluids in Gulf of Mexico sediments,
- Barite solubility and release of trace components to the marine environment,
- Continuation of arctic nearshore impact monitoring in the development area, and
- Literature review of the environmental impacts of disinfection by-products formed during offshore regasification of liquefied natural gas.

Future projects may include synthetics-based muds and long-term effects studies. MMS maintains international channels for collaboration (e.g., deep spill research with Norway) short of full-fledged international consortia. The Energy Policy Act has given MMS a new regulatory role regarding renewable energy. The agency has nine months to develop a regulatory format. The Cape Wind Project now overseen by MMS will require a new environmental impact statement.

Yousif Kharaka is a scientist with the USGS. He gave an overview of USGS produced water research projects and initiatives. Many USGS researchers have conducted extensive investigations at the Osage-Skiatook Petroleum Environmental Research (OSPER) site in Oklahoma. USGS has compiled a detailed national produced water geochemical database. Other research includes produced water reclamation, investigation and characterization of organic and inorganic species in CBNG produced water, and oil spill behavior in groundwater.

Organizations and Associations

Roger Claff described the water-related research interests of the American Petroleum Institute (API). API acts as a coordinating forum, taking direction from industry and working with contractors. API's research projects include the following topics:

- Mercury chemistry, fate, toxicity, and wastewater treatment options,
- Occurrence and treatment of trace metals in petroleum industry wastewaters,
- Total Maximum Daily Load (TMDL) modeling,
- Nutrient criteria guidance,
- Analytical guidance for cyanide in petroleum industry wastewaters,
- Assimilative capacity for developing water-quality-based effluent limits,
- Water quality translators for mercury,
- Cooling water regulations and refinery operations,
- Alternative methods for establishing analytical detection/quantification limits,
- Whole effluent toxicity,
- Synthetics-based fluids and toxicity testing, and
- Oil spills.

Calvin Cobb spoke on behalf of the American Institute of Chemical Engineers (AIChE). The AIChE conducts research on water management and metrics in the context of sustainability

challenges. It provides ongoing support of a national, high-tech knowledge forum to counter the decline of engineering professionals in the oil and gas industry sector. AIChE's Institute of Sustainability brings together the Sustainable Energy Forum, the Center for Sustainable Technology Practices, and the Youth Council of Sustainable Science and Technology. A sustainability metrics index to evaluate progress should involve a cluster of themes — materials intensity (how much “raw” into “finished”), energy intensity, water consumption (60–90 gallons per barrel), solid waste, toxics release pollutants effects, land use, and total cost methodologies. In the sustainability arena, one major challenge involves preventing duplication of research. But even in light of the panoply of efforts, each organization has a focal area of expertise. Awareness, coordination, and teaming are means to pool resources.

Chris Flood spoke on behalf of WERF. He presented the same information that had been given by Glen Reinhardt on day one because the earlier presentation had been heard by only a small subset of the total attendees.

Oil and Gas Companies

Andy Glickman of Chevron presented a global perspective on the regulatory requirements and technology needs for managing produced water and drill cuttings. He surveyed a range of country and regional approaches. OSPAR (Convention for the Protection of the Marine Environment of the North-East Atlantic) countries in the North Sea also have their own regulations. Nigeria has the strictest offshore regulations in the world. The International Finance Corporation has developed its own global standards. At times, developing countries tend to “cut and paste” from regulations applicable in the United States and the North Sea. More recent requirements tend toward a greater emphasis on management of treatment chemicals and monitoring of receiving waters. The presentation encouraged DOE and PERF to facilitate partnerships and technology transfers with developing countries. Partnerships could emerge through exchange programs and various actors, including operators, non-governmental organizations (NGOs), and universities. Technology transfers (especially in the areas of wastewater treatment, environmental chemistry, and environmental assessment) should focus on technologies that are inexpensive, reliable, and easy to operate. In terms of United Nations involvement, some United Nations Environment Programme (UNEP) funding is available for training of local scientists.

Contractor and Consultant Companies

Jan Dell of CH2M Hill spoke on the value of water and its scarcity. The driver for the presentation was the basic diagnosis that without water, there will be no oil. She therefore suggested a new approach for developing a value-chain perspective of water risks in the oil and gas industry. Water is scarce, especially in the light of increasing competition and wasteful practices. Less than 1% of freshwater is available. Innovative approaches should involve developing prioritization schemes in concert with suppliers and consumers, looking long-term beyond the fence line, and finding alternative water feeds.

Tom Sandy of CH2M Hill described a systematic approach to water reduction and reuse in the petroleum industry. Such an approach should be predicated on establishing leadership and commitment, framing problems, developing alternatives, selecting and implementing a course of action, and reviewing and updating the strategy. Approaches to tightening the water balance in the petroleum industry involve internal treatment and reuse, minimization of evaporative losses, and use of external sources.

John Woodhull of ENSR spoke on optimizing refinery wastewater management. Optimization meets multiple objectives, including the improvement of treatment performance, discharge reductions, freeing up of treatment capacity, and reduced energy costs. Process condensate, hydrotest water, washwater, once-through water, pump cooling water, and recovered groundwater have significant potential for reuse for utility and process operations. Stormwater flow presents a potential upset condition that needs to be addressed by the system design. Equalization offers a good control mechanism.

Bob Wenta of USFilter discussed how membrane technologies can be employed for wastewater reuse in downstream applications. Membranes have a lifespan of five to seven years. The impact on the membrane varies with the composition the wastewater.

Mark Delaurentis of USFilter, who was a last-minute substitute speaker, spoke on applications of activated carbon for treatment of volatile organic compounds in wastewater. His presentation overemphasized marketing material for his company, and consequently, the slides were not included with the other presentations on the PERF Web site as PERF is a joint research forum rather than a marketing organization.

Upstream Breakout Group

The upstream discussion group was led by Todd Ririe from Chevron. The meeting was primarily a brainstorming session among the attendees about the research topics or points of interest or concern. The key subjects discussed during the session are listed below:

- No single technology always works cost-effectively to clean up produced water. Numerous opportunities for research exist to better characterize performance and cost of treatment technologies.
- It would be helpful to better understand what effect surface actions have on downhole conditions.
- Some produced water management methods could create a liability for companies, particularly some of the beneficial reuse approaches.
 - Communities or property owners may become accustomed to having treated produced water available and could complain about the loss of a valuable resource in the future after the project shuts down.
 - End users may look to sue deep-pocket oil and gas companies that have provided treated water.
- Removal of dissolved organics can be difficult. Substances like BTEX, PAHs, and phenols are hard to remove to drinking water levels; they can foul the membranes.

- Water quality (e.g., high or low silica or ammonia) affects the process chosen to clean up the water.
- Water management has global implications.
- Better government guidance on “how clean is clean” would help in selecting water management methods.
- The cost of moving and treating water can be significant. Improved efficiency in these areas would be valuable.
- The full cost of managing produced water should include environmental costs (e.g., the environmental impact of drilling more wells).
- Techniques that minimize the volume of water handled in the well or at the surface can pay cost-reduction benefits. Examples include reservoir management techniques, water shutoff chemicals, downhole separation, and seabed treatment.
- Water rights may complicate onshore water management approaches.
- It would be helpful to have a guidance document on how to develop a produced water management strategy.
- A database that links producers with users (volume, chemical and physical characteristics, longevity of resource) could enhance beneficial reuse opportunities.

Downstream Breakout Group

The downstream discussion group was led by John Wilkinson of ExxonMobil. The session started with a presentation of a DOE-funded project followed by a discussion on future needs and opportunities for PERF downstream research projects. Ron Patun of Enersol Technologies presented information on the Plasma Energy Pyrolysis System (PEPS), which was designed to convert high-sulfur petroleum coke into synthetic gas. This project, which originated from an interest in clean fuels shared by DOE and the Department of Defense, presents an alternative approach for gasifying coal. The PEPS project, which has completed design engineering, presently seeks an industry partner for a pilot demonstration. The advantage of the “plasma torch” over “bed” technology involves energy savings and better process control. The footprint of the pilot unit would be small, some 5,000 to 10,000 ft². In the future, the project might be extended to include biomass.

After the Enersol presentation, several topics were discussed, including the following:

- The lack of standard measurement and best practices for water use limit the advancement of water and energy efficiency. The consensus was that water management benchmarking similar to others found in the Solomon index database of best practices would be very beneficial. Suggestions were made to approach AIChE about the development of such standards.
- The possible need for development and implementation of early warning upset systems, including new instrumentation. Is there interest in revisiting this topic that was the subject of an earlier PERF project?
- The status of existing or new PERF discussion groups. Topics included whether it may be time for the mercury discussion group to be reinvigorated based on EPA efforts to

promulgate emission standards, and whether creation of a gas-to-liquids discussion group might be appropriate.

- The need for additional research and development into filtration membranes for very dirty water such as desalter effluent.
- The need to better understand the impact of biomass, renewables, and sustainability issues on the downstream industry.
- The consensus was to invite a DOE Energy Efficiency Renewable Energy (EERE) speaker to the next PERF forum to discuss related DOE programs.

Summary of Day Three – Friday, November 4, 2005

Day-Three Overview

Day 3 started with summary presentations from the two breakout groups from the previous afternoon. The full group then had a facilitated discussion on the water research gaps and needs for the oil and gas industry. The day's event as well as the entire meeting finished with a PERF business meeting, including a review of PERF projects and new proposals. The facilitated discussion is summarized below. The PERF business meeting is outside the scope of the water program review and is not summarized here. Information on the PERF activities can be found on the PERF Web Site.

Research Gaps and Needs

The discussion attempted to identify gaps in water-related information of interest to PERF and DOE that might require additional research and how that research might be funded and conducted. Probably the leading challenge for the oil and gas industry is how to turn produced water from a cost into an asset. Information and analysis that would help meet this challenge include:

- Formation- or well-specific data on produced water quality and quantity;
- Inventory of water quality and quantity requirements of potential beneficial water users; and
- Definition of structure and mechanisms for water-credit trading systems, especially those that incorporate water use hierarchies.

Another item that received much discussion was how to prevent an oil and gas company that undertakes beneficial reuse of its produced water from being subjected to liability from an end user of the water. Anecdotal information was shared of an oil company that intentionally discharged water that was clean enough for reuse because it did not want to face future liability from a user believing he or she had become ill or harmed by using that water. Other comments were made on issues such as creating an artificial wetlands using produced water. If an endangered species becomes established in the wetlands, the company may not be able to stop operating the wetlands at the end of the production period and could be expected to maintain the wetlands indefinitely. Although liability is an important concern and potential barrier against beneficial reuse, it is not a scientific research issue, and so it is unlikely that DOE or PERF will have scientific research projects dealing with it.

The program review gave a good picture of DOE's current water research portfolio. With one exception (the hypoxic zone study), all the research currently being funded relates to onshore projects, with a particular emphasis on CBNG water projects. DOE noted that its FY06 oil and gas environmental budget was uncertain at that time (it has since been finalized and is smaller than in the past few years). DOE hopes to continue funding water research, but at this time it cannot make long-term commitments.

A consensus was reached that while this meeting had been successful at presenting DOE-funded produced water research, a better understanding of related work sponsored by industry would be beneficial to both PERF and DOE research programs. Many major oil and gas companies used to operate in-house research programs and facilities. Few such dedicated research programs or facilities remain in the industry. Some of the industry representatives at the meeting expressed their opinion that large companies were not likely to reinstate major environmental research efforts or facilities. Another commenter opined that much of the environmental research being done by the majors is focused on greenhouse gases. Some participants felt that produced water is a low priority for the majors, though each major doubtless has its own position on the matter. Research is most likely to be undertaken in response to a specific technical problem, a regulatory barrier, or new regulatory uncertainty, as was done in the case of synthetic drilling fluids and produced water discharges to the Gulf of Mexico hypoxic zone.

Most oil and gas companies outside of the majors are not conducting environmental research. Those independent companies usually rely on leveraging technology from other government and industry sources; this trend is likely to continue.

Related to greenhouse gas control, USGS representatives pointed out that one of their major concerns with carbon sequestration is the potential for leaking and contamination to result during CO₂ injection due to unidentified or improperly closed wells connected to the injection formations.

It was suggested that the water treatment and supply industry may be an excellent source of information on the potential for treatment and reuse of produced water. That industry developed the RO technology currently in use for produced water treatment and is currently sponsoring a significant amount of research that could be applied to produced water management. It was suggested that DOE and PERF need to explore means of accelerating technology transfer and collaborate on research and development with the water treatment and supply industry.

Related to produced water research planning, it was noted that a compilation or prioritization of needs is lacking, especially for the intermediate future. It was suggested that PERF or a partnership of DOE and PERF should consider development of a research roadmap to address this need.

Finally, there was consensus that the program review had been a success, especially in terms of creating a better understanding of the range of produced water research currently being funded by DOE.

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Appendix B – Detailed Agenda



DOE/PERF WATER PROGRAM REVIEW AGENDA

Program for Tuesday, November 1st (Board Member only)

5:00 PM	PERF Board of Directors Meeting	Historic Inns of Annapolis
7:30 PM	PERF Board Dinner	Maryland Inn, Crown and Crab Room

Program for Wednesday, November 2nd - REVIEW OF DOE WATER PROJECTS

8:00 AM	Opening Remarks	Todd Ririe, Chevron
8:10 AM	Welcome to Annapolis, Review of Logistics	John Veil, Argonne.
8:20 AM	Introduction of Participants	All
8:30 AM	Produced Water White Paper/Downhole Separation	John Veil, Argonne
8:50 AM	Field validation of toxicity tests to evaluate the potential or beneficial use of produced water	Jonathan Fisher, Oklahoma State Univ
9:10 AM	Recovery of more oil-in-place at lower production costs while creating a beneficial water resource	Robert Liske, AERA Energy LLC.
9:30 AM	Development of Fouling-Resistant Desalination Membranes for Treating Oilfield Waters	Mukul Sharma, Univ of Texas at Austin
9:50 AM	Treatment of produced water using a surfactant modified zeolite/vapor phase bioreactor system	Lynn Katz, Univ of Texas at Austin
10:10 AM	Break	
10:30 AM	Treating coal-bed methane produced water for beneficial use of MFI zeolite membranes	Robert Lee, New Mexico Institute of Mining and Technology
10:50 AM	Membrane filtration technology for cost effective recovery of freshwater from oil & gas produced brine/ Novel cleanup agents for membrane filters	David Burnett, Texas A&M
11:10 AM	Produced water management and beneficial use	Geoff Thyne, Colorado School of Mines
11:30 AM	Managing CBM produced water for beneficial uses	Mike Hightower, Sandia National Labs
11:50 AM	Use of produced water for power plant cooling	Kent Zammit, EPRI
12:10 AM	Lunch	

1:20 PM	Osage Skiatook petroleum environmental research project	Yousif Kharaka , USGS-Support to produced water
1:40 PM	Produced water management practices for conventional oil and gas production operations	Mark Carl , IOGCC
2:00 PM	Handbooks for environmental plans and background development pertinent to CBM production/CBM Impoundments	Dan Arthur , ALL Consulting
2:20 PM	Cost-effective regulatory approach to produced water management.	Mike Nickolaus , GWPC
2:40 PM	Electromagnetic imaging of water movement from CBM impoundments.	Terry Ackman , NETL
3:00 PM	Break	
3:20 PM	Produced water discharges to Gulf of Mexico hypoxic zone/Regulatory support to other produced water projects.	John Veil , Argonne
3:40 PM	Open discussion of all presentations from the day	(all presenters sit at front of room and field questions from floor)
4:30 PM	Adjourn	
5:00 – 7:00 PM	Reception	Buddy's Crabs and Ribs

Concurrent Session-Hosted by WERF on Downstream Projects

1:20 PM	Overview of WERF programs	WERF 1, Glen Reinhardt , WERF Executive Director
1:50 PM	Recovering Treatment Capacity through Rerating and Optimization	WERF 2, Movva Reddy , MPR Engineering Corporation, Inc.
2:20 PM	Sustainable Technologies for Nitrogen Control	WERF 3, Krishna Pagilla , Illinois Institute of Technology
2:50 PM	Update on Early Upset Warning Systems and Evaluation and Measurement of Nitrification Inhibition Potential	WERF 4, Charles Bott , Virginia Military Institute
3:20 PM	Adjourn	
5:00 – 7:00 PM	Reception	Buddy's Crabs and Ribs



DOE/PERF WATER PROGRAM REVIEW AGENDA

Program for Thursday, November 3rd - REVIEW OF GOVERNMENT AND INDUSTRY WATER RESEARCH AND INDUSTRY WATER ISSUES

8:00AM	Opening Remarks	Todd Ririe, Chevron
8:10 AM	Water management and metrics for sustainability: Future Challenges	Calvin Cobb, AIChE
8:40 AM	Future plans for DOE oil and gas water research projects	David Alleman, DOE
9:10 AM	Oil and gas water research project	Carey Johnston, EPA
9:40 AM	Oil and gas water research projects	Mary Boatman, MMS
10:10 AM	Break	
10:30 AM	Overview of current and planned water research projects	Roger Claff, API
11:00 AM	Oil and gas water research projects	Yousif Kharaka, USGS
11:30 AM	Refinery water management optimization	John Woodhull, ENSR
12:00 PM	Lunch	
1:00 PM	Trends in Produced Water Regulations around the World	Andy Glickman, Chevron
1:30 PM	Overview of WERF programs	Chris Flood, WERF
2:00 PM	The use of membrane systems for wastewater reuse in downstream petroleum facilities	Robert Wenta, US Filter
2:30 PM	Water Risks in the Petroleum Value Chain and the "Beyond the Fenceline" Approach to addressing water issues	Jan Dell, CH2MHill
3:00 PM	Activated carbon for VOC control in wastewater treatment systems	Mark Delaurentis, US Filter
3:30 PM	Water Reduction and Reuse within a Refinery	Si Givens and Tom Sandy, CH2MHILL
4:00 PM	Break	
4:15 PM	UPSTREAM & DOWNSTREAM DISCUSSION GROUP	
	UPSTREAM Topic	Todd Ririe, Chevron
	DOWNSTREAM Topic	John Wilkinson, ExxonMobil
5:30 PM	Adjourn	



DOE/PERF WATER PROGRAM REVIEW AGENDA

Program for Friday, November 4th - REVIEW OF ONGOING RESEARCH, GAPS IN CURRENT RESEARCH AND AREAS IN WHICH MORE RESEARCH MIGHT BE CONDUCTED BY INDUSTRY OR GOVERNMENT

8:00 AM	Opening Remarks	Todd Ririe, Chevron
8:10 AM	Presentation and discussion of results of Upstream and Downstream discussion group highlights on future needs for water research	All
8:50 AM	Facilitated discussion of research gaps and need	John Veil Argonne National Laboratory
9:50 AM	Break	
10:10 AM	PERF business meeting (review of PERF activities, status of projects, treasurer report, new project proposals, etc.)	PERF board member, PERF
11:30 AM	Adjourn	