The Importance of Redevelopment of Old, Mature Oil Fields in Wyoming
~David Mohrbacher, Director

Old, mature oil fields account for more than 80% of the world oil production (Halliburton, 2012), which is approximately 89 million barrels of oil per day (U.S. Energy Information Administration, 2013). Wyoming’s reliance on mature oil fields is similar. EORI estimates that more than 90% of Wyoming’s 2000+ oil fields are considered mature. Mature fields are defined in a variety of ways, but generally use the following criteria:

- The fields have produced for more than 25 years; many have produced for more than 60 years.
- The fields are currently operated with obsolete, aging facilities both above ground and below the surface.
- Produced water cuts are often greater than 95 percent.
- Maintenance of both surface and subsurface facilities was generally neglected between that late 1980s and current time.

Wyoming operators are increasing investments and their earnings in these old fields based on application of new technology and the increased price of oil. Risk associated with investment in mature reservoirs is substantially lower than exploration and development of new fields. Work in mature fields isn’t as glamorous as development of new unconventional oil reservoirs, but the work is potentially more financially rewarding (Denbury 2013).

The Size of the Prize in Wyoming

Wyoming’s mature oil fields have produced approximately 90 percent (6.3 billion BO) of all oil produced in the state since 1885, and still contain between 15 and 20 billion barrels of the original oil in place (OOIP). That’s a big target to evaluate for redevelopment.

More companies are positioning to reinvest in waterflood. Wyoming’s industry is still early in this process of identifying and initiating work.

EORI’s experience indicates reevaluation and optimization of mature fields, even those that
have been water flooded for decades, can result in increased oil production and booking of new reserves. This is true of both small and large oil reservoirs; in fact results in small reservoirs have been more impressive with regard to relative increases in production and addition of reserves. If oil recovery is increased by an average of 1 percent of Wyoming’s remaining OOIP in mature reservoirs, due to improved waterflooding, an additional 150 to 200 million barrels of oil can be recovered. A goal of recovering another 4 to 5 percent of stranded oil in Wyoming’s mature reservoirs is not unreasonable.

Once waterflood are optimized, opportunities to implement enhanced oil recovery provide another opportunity to boost production and reserves. Generally good EOR projects are preceded by implementation of good waterflood. Potential recovery of oil by EOR in Wyoming has already been conservatively estimated to range from 1 to 2 billion barrels of oil (EORI 2011).

**Types of Investment**
Operators of mature fields are beginning to invest in redevelopment of mature oil fields both in the U.S. and internationally. Typical investments include:

- Optimization of existing facility operations including subsurface lift systems, water injection facilities, and production facilities;
- Reinvestment in well work over programs on both production and injection wells, including casing integrity programs;
- Optimization of waterflood performance including improvement of vertical conformance, reevaluation of injection programs to improve horizontal conformance, well conversions, infill drilling, and step out programs; and
- Evaluation and implementation of EOR.

In larger fields, redevelopment programs may require more than a decade to complete based on reduced investments prevalent during the 1990s in mature oil fields (Chevron 2012).

**Early Returns on Oil Industry Investments**
Wyoming’s oil production has been steadily increasing since 2009, due in part to new improvements in mature fields. During 2009, Wyoming production dipped to approximately 51 million barrels of oil per year, compared to approximately 120 million barrels in the early 1980s.
Between 2009 and 2012, Wyoming oil production has increased each year to approximately 57 million barrels per year. More than 12 percent of the 2012 oil production resulted from implementation of improved oil recovery and application of enhanced oil recovery in Wyoming's mature oil fields. Increased production of natural gas liquids and development of unconventional oil reservoirs have also contributed to increased oil production in Wyoming since 2009.

**EORI Can Help**
It’s not too late to participate in the redevelopment of Wyoming’s mature oil fields. Please contact EORI to inquire about how we help you at 307-766-2791 or by email at uweori@uwyo.edu
You can also access our EORI website [http://www.uwyo.edu/eori/](http://www.uwyo.edu/eori/) for more information.

I will provide more detailed information regarding EORI’s programs to assist Wyoming operators with redevelopment of their mature oil fields in the next EORI newsletter to be published in December 2013.

**OUTREACH**
**Conferences and Workshops**
The Outreach team has been busy the past several months. Conferences, workshops and media events have given EORI a chance to be known around the state and the nation. EORI continues to expand its outreach, develop its partnerships and build relationships with more and more industry folks. Below is a recap of the past few months’ outreach activities.

- The 7th Annual Wyoming CO₂ Conference was held July 8th & 9th at the Casper Events Center. This year’s conference hosted a record 285 attendees. Speakers presented on topics ranging from economic scoping, CO₂ flooding case studies, regulatory updates, hydrocarbon conversion, polymer flooding and a well-attended update on the Grieve Field developments being managed by Denbury Resources. The Wyoming CO₂ Conference
continues to build upon its reputation as the premier CO$_2$ conferences in the rocky mountain region. Copies of all presentations are available on the EORI website. [http://www.uwyo.edu/eori/conferences/CO2/2013-agenda-CO2.html](http://www.uwyo.edu/eori/conferences/CO2/2013-agenda-CO2.html)

The Wyoming CO$_2$ Conference continues to grow because of our generous sponsors who continue to support this conference and the work of the Enhanced Oil Recovery Institute.

SAVE-THE-DATE: 2014 CO$_2$ CONFERENCE - JULY 9-10, CASPER EVENTS CENTER

- The final of three workshops hosted by EORI, *ROZ and CO$_2$ in the Bighorn Basin, Tensleep*, was held in Casper prior to the CO$_2$ Conference. The reservoir specific workshops have focused on introductory waterflooding concepts and general IOR/EOR applications. The final workshop focused on residual oil zone (ROZ) and CO$_2$ Flooding. The agenda consisted primarily of real-world case studies demonstrating identified concepts. These series of workshops were well attended by operators with investments in the Bighorn basin. Copies of presentations are available on the EORI website. [http://www.uwyo.edu/eori/technology-transfer/workshops/tensleep%20iii%20workshop.html](http://www.uwyo.edu/eori/technology-transfer/workshops/tensleep%20iii%20workshop.html)

**EORI in the News**

EORI has seen a lot of press time the past few months. Check out the following links to press releases and radio interviews.

- University News Service: [http://www.uwyo.edu/uw/news/2013/08/uw-enhanced-oil-recovery-research-lab-targets-stranded-reserves.html](http://www.uwyo.edu/uw/news/2013/08/uw-enhanced-oil-recovery-research-lab-targets-stranded-reserves.html)
- Laramie Boomerang
• Other news sources picking up EORI related press releases.

**EOR COMMISSION UPDATE**
The Enhanced Oil Recovery Commission met in July and again in September. Copies of the agenda and previous commission meeting minutes are available to the public at [http://eorc.wy.gov/](http://eorc.wy.gov/).

**TECHNICAL ADVISORY BOARD MEETING**
The Enhanced Oil Recovery Technical Advisory Board (TAB) met in mid-July in Laramie. EORI Staff and affiliated professors gave updates to the TAB members on recent accomplishments. Topics included reservoir modeling, special core and chemical EOR blends, design and development. The TAB consists of leading experts from universities and energy companies in the United States. The TAB will meet again in January 2014.

**DATABASE DEVELOPMENT & GIS**
*Screening and Scoping*
~Glen Murrell, Associate Director~
The Database and Screening and Scoping group consists of Glen Murrell, Vandy Jones and Nick Jones. The database consists of information about Wyoming oil fields and reservoirs gathered from WGA, NETL and Wyoming Oil and Gas Conservation Commission. Data screening requests can be run on the database to answer questions companies have about various fields and reservoirs in Wyoming and whether their enhanced oil recovery processes would be viable for use in those fields. The database provides the most up-to-date, complete and accurate Wyoming reservoir information to meet the data needs of internal and external stakeholders. Housing the database in Microsoft Access lets EORI use a template system for querying, extracting, and reporting data, as well as provide the data for export and use in assorted software applications. The EORI database ensures that data entry, updates and quality control is as error-proof, streamlined and efficient as possible.

EORI also has the capability to perform geospatial screening. ArcGIS offers enhanced decision making with better understanding of the special distribution of reservoir characteristics and, potentially, their origin. The software is also useful in identifying spatially related entities (data mining). ArcGIS shows the proximity to required resources, sinks, infrastructure, utilities, and other reservoirs with matching characteristics or potential enhanced oil recovery methods.

The EORI screening group has completed over 50 evaluations for interested companies and has provided reports about the qualifying fields. Most recently, EORI has been contacted for screening work for two companies in the Rocky Mountain region. One is a steamflood company that wants to know if there are viable fields in Wyoming for their method of steamflooding. The other is looking for a general enhanced oil recovery screen to see what fields might be amenable to polymer flooding.
If you are a Wyoming based operator or a company working in Wyoming and need information from the EORI Database contact Glen Murrell at gmurrell@uwyo.edu.

**ECONOMICS**

*The Economic Impacts of CO₂-EOR in Wyoming*

~Laura Dalles/Outreach Coordinator

A tool to estimate the value of CO₂, its use in enhanced oil recovery and the economic impact of utilizing this naturally abundant resource is in its final phase of development and will soon be launched to Wyoming operators.

Using the CO₂Scope© offers Wyoming operators a quick economic evaluation of their CO₂ projects. Researchers at the University of Wyoming and the Enhanced Oil Recovery Institute (EORI) are in the final stages of offering Wyoming operators a unique scoping tool that help operators better understand the economic viability of CO₂ flooding in their legacy fields.

CO₂Scope© has been in development for several years. Ben Cook, Visiting Assistant Professor and Klaas van’t Veld, Associate Professor, in Economics and Finance at the University of Wyoming have finalized a one of a kind economic model. Initially starting as a resource for the Powder River Basin only – it has since evolved into an Excel based program that now covers all of Wyoming. CO₂Scope© has gone through several phases of development since its inception. A number of trials have been put into place with results coming out favorably. The evolution of CO₂Scope© has greatly enhanced its utility and has generated another use -- as a policy tool. "This is the only database of its type, states Glen Murrell, EORI Associate Director, it has raised the visibility of the Institute and Wyoming CO₂ EOR. Its development has also contributed heavily to our internal understanding of CO₂ supply."

EORI and Dr. Cook announced the release of the CO₂Scope© tool at the 7th Annual Wyoming CO₂ Conference held in early July. "We are anticipating a launch date of mid-October, says Ben Cook, program designer. "Wyoming operators will be able to download the model for free and begin to take advantage of its unique capabilities." Operators not working in Wyoming will be able to utilize the tool as well, for a small fee.

"Dr. Cook’s work evaluating the economic impact of growing Wyoming's CO₂ EOR capacity just makes sense", says David Mohrbacher, EORI Director. "The big benefits include extending the life of old Wyoming oil fields, and recovering a substantial portion of oil that is still stranded in those reservoirs. This is an opportunity to create jobs, increase state and county revenues, and do it with the existing infrastructure. Continued growth of CO₂ EOR will mean production of billions of barrels of additional oil in Wyoming over the next 20 to 40 years."

It is estimated that as a result of implementing CO₂ in enhance oil recovery an average of 1900 jobs per year may be supported by CO₂ operations in Wyoming, there is a potential of an increase in production of 0.7 to 1.09 more billion barrels of oil. Sixty two percent of that oil will come from the Bighorn Basin alone. One billion barrels of incremental oil produced in Wyoming with EOR would generate approximately $8 billion of ad valorem and severance taxes for state and county governments based on an average oil price of $70/barrel.
LABORATORY STUDIES

EORI Lab near completion
~Haifeng Jiang, Research Scientist/Lab Outreach
This is an exciting time for the EORI Lab team. They have been spending the summer unpacking crates and setting up new state-of-the-art lab equipment. Commissioning is just about complete. Core and oil samples are beginning to be prepared for testing and it won’t be long until they are up and running.

EORI is grateful to the many donors who contributed to the construction of the Energy Innovation Center and the EORI Lab and the University of Wyoming, School of Energy Resources. EORI is honored to be an SER Center of Excellence and looks forward to the research opportunities the future holds thanks in part to our new facilities.

The EORI laboratory has been offering assistance to local Wyoming producers for many years. The current laboratory group consists of two petroleum engineers, one geochemist, and two chemists; with the existing and newly acquired state-of-the-art equipment, the EORI laboratory offers a wide range of capabilities from sample analysis (core, water, oil, and gas) to phase behavior studies and coreflood experiments at Wyoming reservoir conditions. These lab services are available to Wyoming operators. Please see detailed list of lab capabilities below:

1. Petrology analysis
   a. Whole core description
   b. Mineralogy studies (thin section, XRD and SEM studies)

2. Core analysis
   a. Routine core analysis (porosity, permeability, saturation)
   b. Advanced core analysis (coreflooding, unsteady state relative permeability)
   i. HT coreflood studies – high temperature coreflood line for water flooding, low salinity water flooding, and chemical EOR (Polymer, Surfactant, ASP etc.) coreflood studies.
   ii. HPHT coreflood studies – higher pressure up to 10,000 psi, high temperature coreflood line for miscible gas injection, foam injection, and water alternating gas (WAG) injection studies with live oil capability.
   iii. Spontaneous imbibition studies

3. Reservoir fluids analysis (services)
   a. Recombination of live oil samples – restore oil samples to reservoir conditions by recombining solution gas and stock tank oil
   b. Gas Chromatography (GC) Studies– compositional analysis of gas and stock tank oil samples.
c. PVT studies
   i. Slim tube test to determine minimum miscibility pressure (MMP) up to 10,000 psi.
   ii. Bubble and dew point pressure measurements
   iii. Swelling tests up to 10,000 psi
   iv. GOR (GWR) measurements
   v. Viscosity measurement of reservoir fluids up to 10,000 psi

d. Visual cell studies – visual observation of fluids at reservoir conditions.

e. HPHT surface tension (ST) and interfacial tension (IFT) measurements.

f. Molecular weight and density studies of reservoir fluids.

g. Dissolved solid analysis and geochemical simulations of reservoir brines.

If you are a Wyoming operator or a company working in Wyoming and are interested in contributing samples to the lab group, or have a need for some advanced research needs that could be done in the EORI lab, contact Glen Murrell by email at uweori@uwyo.edu

RESERVOIR SIMULATION

Seismic interpretation of Little Mitchell Creek
~Shuqian Li, Research Scientist & Shaochang Wo, Sr. Research Scientist, Reservoir Simulation Team

The EORI Reservoir Simulation team has recently completed a seismic interpretation of Little Mitchell Creek, located in the Powder River Basin.

The analysis of the 3D seismic data of Little Mitchell Creek contributed highly valuable insights to the sand body distribution in the reservoir. Several attributes were analyzed and each led to a further refinement of the model, including highly accurate delineation of the sand body in 2D, identification of channel features and qualitative identification of ‘good’ versus ‘bad’ reservoir. These insights are being passed through to the reservoirs simulation phase of the project and will help us to define flow units better, re-evaluate OOIP, and identify flow barriers and areas of un-swept reservoir and ultimately more accurate options for development and exploitation.

Reservoir modeling and simulation has become a routine tool for exploration and reservoir management in major oil companies, primarily because they can test hypothesis that cannot be tested in any other way. Simulation is the only way to describe quantitatively the flow of multiple phases in a heterogeneous reservoir. Adding on EORI’s existing strength in the fields of geology, petrophysics and laboratory tests, the advance of EORI’s simulation capability allows us to provide an integrated technical support to the independent oil and gas producers in the state of Wyoming. Reservoir simulation models are used in the development of new fields where production forecasts are needed to help operators make investment decisions. For new fields, models may help in development by identifying the number of wells required, the optimal completion of wells, the present and future needs for artificial lift, and the expected production of oil, water and gas.

This work is supported in part by Schlumberger who provides Petrel, Eclipse and Blueview software and support and ESRI who provides ArcGIS through the University of Wyoming.
RESERVOIR CHARACTERIZATION

Reservoir Characterization Project
~Nick Jones/Senior Geologist

EORI and Wyoming based Sunshine Valley Petroleum Corporation - Osage Partners, LLC are working together to characterize the Newcastle Formation in the north-eastern portion of the Powder River Basin. The focus of this work is to perform clay analysis for the petroleum bearing sands within the reservoir. This analysis will allow the operator to avoid wellbore damage due to water sensitivity to clay.

Core samples from four wells are being used to make thin sections for petrophysical analysis, X-Ray Diffraction (XRD), Scanning Electron Microscope (SEM), and Cat-Ion Exchange analysis (CEC). This work is currently being performed by EORI researchers. The purpose of this work is to determine options in regard to the design of a water or chemical flood that will minimize formation damage and improve oil recovery at the nearly 100 year old Osage oil field. Osage Partners, LLC acquired the field in 2012 and has since been working to improve operations and optimize production. Work on the EORI-Sunshine project began in July and is currently on schedule to be completed later this fall.

Clay Minerals and EOR
~Peigui Yin, Sr. Research Scientist/Reservoir Characterization

In order to make an enhanced oil recovery project successful, analysis of clay minerals in the reservoir rocks are very important. In the enhanced Oil Recovery Institute, we can qualitatively and quantitatively analyze clays through petrographic investigation, SEM observation, x-ray diffraction, and cation exchange capacity measurement. By working together with petroleum engineering professors, a comprehensive design for chemical and water flooding can be achieved to avoid clay damage in enhanced oil recovery performance.

It is well known that all the Cretaceous sandstone reservoirs rocks in Wyoming are rich in clay minerals, which include kaolinite, chlorite, smectite, illite, and mixed layers of illite/smectite or smectite/mica. These clay minerals occur as pore filling or grain coating, significantly reducing sandstone porosity and permeability. In addition, because the clay minerals are of small crystal size and loosely packed, they interact well with fluids injected into the reservoir. Without careful consideration of the clay effects on reservoirs, formations can be damaged by rate-sensitive mobile fines, water-sensitive clay swelling, and problematical precipitates. As a result, the enhanced oil recovery project can be less effective, or completely fail.

STAFF RECOGNITIONS

EORI would like to recognize a few staff members for their personal and professional growth and recognitions. A recent theory regarding Tertiary-age coal deposits in the Powder River Basin developed by Nick Jones – Senior Geologist, Enhanced Oil Recovery Institute, has recently been recognized and adopted by the U.S. Geological Survey. His work will be incorporated into a USGS Professional Paper about the coal resources of the Powder River Basin later this year. Nick’s significant contribution toward a better understanding of the geology of the coal resources in the PRB was completed and published in 2010 while working as the lead coal geologist at the Wyoming State Geological Survey. Nick’s theory challenges
conventional wisdom and is the first ever to identify and incorporate basement related faulting within the Powder River Basin in order to explain how and why coal deposits in excess of 100 feet thick developed. This new perspective developed by Nick was further substantiated through continuing work by the U.S. Geological Survey’s Coal Assessment Team as it was used to validate the results of the team’s subsurface mapping and correlation work.

**Glen Murrell, Associate Director** has been invited to be a guest speaker during this year’s CO2 Week being held in Midland, TX in December. His presentation will be on North American CO2 Supply Updates with Phil Dipietro from NETL. Glen has also been a guest lecture at UW and for the Powder River Basin Chapter of the Society of Petroleum Engineers. He has also been invited to contribute to the organization committee for the Rocky Mountain Minerals Law Foundation Sub Surface Issues Special Institute.

**Glen Murrell, Nick Jones** and **Laura Dalles** have been working on obtaining their Project Management Professional (PMP) certification. Both Glen and Nick participated in the online course – a 12 month self-paced course offered through the Project Management Institute [http://www.pmi.org/](http://www.pmi.org/). Glen completed the course and passed the certification exam in May and is now a certified project manager. Nick is in the last few months of coursework and plans to take the exam early next year. Laura attended a week long crash-course in August and is in the process of applying to take the exam early next year as well. Nick was recently selected to participate in the University of Wyoming Leadership Academy. This program is designed to develop and enhance the skills of current and future UW leaders. Laura recently attended the National Science Foundations (NSF), Becoming the Messenger workshop. She participated in a day long, intensive public relations training geared toward promoting science – learning how to take technical information and making it less technical for the general public, while maintaining the integrity of the science. Laura learned how to develop strong messages for the media as well as how to build powerful PowerPoint presentations, “tweet” and blog.

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If you are ever in the neighborhood – give us a call and we will proudly show you around the Energy Innovation Center.

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**Resources**

- [http://www.uwyo.edu/eori/](http://www.uwyo.edu/eori/)
- [http://www.uwyo.edu/ser/](http://www.uwyo.edu/ser/)

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