# Oil & Natural Gas Technology

**DOE Award No.: DE-FC26-06NT15569**

## Quarterly Progress Report
### With Summaries of Center-sponsored Research
### (October – December 2007)

# UTAH HEAVY OIL PROGRAM

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Prepared for:
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National Energy Technology Laboratory

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**Office of Fossil Energy**

Quarterly Progress Report
**Utah Heavy Oil Program**
University of Utah
DE-FC26-06NT15569
Quarter Ended December 31, 2007

Philip J. Smith, Principal Investigator
Project Period June 21, 2006 through October 21, 2008

## EXECUTIVE SUMMARY

The mission of the Utah Heavy Oil Program is to provide research support to federal and state constituents for addressing the wide-ranging issues surrounding the creation of an industry for unconventional oil production in the United States. In this reporting period, approximately 500 copies of the update report on North American unconventional oil resources, “A Technical, Economic, and Legal Assessment of North American Heavy Oil, Oil Sands, and Oil Shale Resources,” were sent to individuals and organizations who requested them (Task 1.6). Additionally, a PDF version of the report was posted on the Department of Energy’s web site at http://www.fe.doe.gov/programs/oilgas/publications/oilshale/HeavyOilLowRes.pdf.

Work continued in this quarter on the five UHOP-sponsored research projects; updates of those projects are provided below. Additionally, progress was made relative to the on-line repository for informtion, data, and software relating to unconventional oil resources in North America. Finally, a revised budget was sumbitted and approved.

## PROJECT MILESTONES/PROGRESS PERFORMANCE

### A. Progress in Program-Sponsored Projects

UHOP selected five Program-sponsored research projects in the previous quarter. Brief summaries of the ongoing work in each project are provided below.

1. **Detailed Study of Shale Pyrolysis for Oil Production**

   Milind Deo, Eric Eddings, Terry Ring

**Shale Oil Pyrolysis Experiments**: The experimental system for shale pyrolysis was built in this quarter. The system consists of three different reactors, including a high-pressure (3000 psia) reactor. Other components include a series of band heaters with appropriate controls and a two-stage separation system for collecting the product. The system is being tested for leaks, temperature programming, and product collection and analysis. Additionally, gas chromatographic analyses protocols for shale liquids were put in place and simulated distillation methods were established. Samples of shale liquid from Mountain West Energy (our industry partner) were tested. Residual fractions of

~30% were measured, indicating that these particular shale oils are of good quality. Hence, only a moderate level of upgrading is required.

**Modeling of Oil Shale Extraction**: We are proceeding using a multi-physics approach. Initial 3D modeling work was inhibited by computer memory limitations, so we have focused on 2D modeling. We are modeling three types of heating; conduction, radio frequency heating and resistive heating. We have made significant progress on conduction heating with hot holes and some preliminary results are available with radio frequency heating and resistive heating. Flow in the deposit is modeled by D'Arcy's law with temperature dependent viscosity and density of the oil. The pressure that drives D'Arcy's law results from the creation of gas due to oil shale decomposition/pyrolysis which produces gas modeled as methane. As the oil shale decomposes, the void fraction of the deposit increases. The thermal decomposition of oil shale is modeled by simplified kinetics where the kerogen component decomposes to bitumen which subsequently decomposes to gas (methane); oil and carbon follow the kinetics developed by Braun and Rothman[1] and Allred[2]. With this multi-physics model, we have run into numerical problems (a stiff system) using the full kinetic mechanism with a one step having very fast kinetics. As a result of the long heating times (2 years) we believe that the fast reaction may be modeled with chemical equilibrium and are in the process of implementing that concept at this time. We hope that this will be successful and allow us to proceed with other types of heating and with 3D modeling as there are smaller memory requirements with this chemical equilibrium approach.

## 2. New Approaches to Treat Produced Water and to Perform Water Availability Impact Assessments for Oil Shale Development

Steve Burian, Ramesh Goel, Andy Hong

***Project Objectives:***

- Create a digital geospatial database of water, geology, energy, natural resources, and other pertinent data for the Uinta and Piceance Basins
- Quantify past, current, and future water use requirements for oil shale development in the Uinta and Piceance Basins
- Develop a methodology to assess water availability using a water budget analysis approach
- Advance and develop new technologies for bitumen extraction and process water treatment to limit future impacts on water availability and quality
- Develop an integrated treatment scheme for produced water.

**Water Resources Sustainability**: We focused on improving our initial model of water requirements for oil shale development. We specifically initiated the development of a new approach to estimate producible oil shale in the Piceance-Uinta Basins and of a new technique to project urban growth associated with oil shale industry growth. Our water

[1] Braun, R.L. and Rothman, A.J., Fuel, 1975, Vol 54, April, p. 129-131.
[2] Allred, V.D., Chemical Engineering Progress, Vol. 62, no.8, August 1966, p. 55-60.

requirement estimation approach was adjusted to account for these two additions. A draft paper on the water estimation approach and the assessment of the impact on water resources of energy generation alternatives in 2050 was completed. Finally, the team devised a new regional approach to coupled water-energy sustainability that can rapidly assess and process choices of water use among urban growth, energy generation, and oil shale extraction.

**Water Treatment and Reuse**: We have continued the investigation of the treatment of produced water to render it amenable to recycle, reuse, or safe disposal. By applying ozonation via rapid, successive cycles of compression and decompression, we found:
1) Ozone degrades and converts dissolved hydrocarbons in the aqueous phase to organic acids. These highly dissolved organic acids are potentially more biologically accessible and treatable.
2) Pressure cycles are used advantageously for the conversion and removal of dispersed hydrocarbons in the aqueous phase, resulting in aggregates that can be readily removed by coarse filtration.
3) Pressure-assisted ozonation treatment accelerates the degradation of dissolved hydrocarbons in the aqueous phase by providing a reactive interfacial zone which attracts hydrophobic chemicals and concentrates them to the interfacial region across which ozone migrates.
4) Removal of dispersed oil and full degradation of dissolved oil with this technique prevents subsequent formation of oil sheen.

In addition, work was initiated on the enhanced extraction of bitumen from oil sands. A new method has been invented that improves on the conventional hot-water extraction method. The new method is particularly suited for Utah's oil-wet tar sands that would otherwise be challenging for the conventional hot-water method.

**Integrated Treatment Approach**: We obtained our fourth set of produced water samples from New Mexico Tech. The samples were analyzed using ICP-MS. Based on the results of four separate produced water data sets (total of 16-20 samples), we have developed a recipe for synthetic produced wastewater. We have faced challenges in developing analytical procedures for naphthalene and MTBE (our model organics) using GC/MS. Nevertheless, we have successfully developed a GC/MS method for naphthalene and are working on method development for MTBE. Culturing of bacteria capable of degrading naphthalene and MTBE is also in process. We have updated our laboratory with a new FID detector assembly on the GC/MS, a solid phase microextraction (SPME) unit and a vacuum extraction unit for micro analysis. These components were specifically added to accomplish the research goals that were proposed.

### 3. In Situ Production of Utah Oil Sands

Pete Rose, Royhan Gani, Jack Hamilton and Milind Deo

**Numerical Simulation Modeling of the Steam Assisted Gravity Drainage (SAGD) and Cyclic Steam Processes:** Initial numerical simulation models of the SAGD and cyclic steam production processes based upon the Whiterocks reservoir model were constructed and run using the STARS, the thermal compositional simulator developed by

Computer Modeling Group, Calgary, Canada. The 25 layers used in the simulation are shown in Figure 1.

| Layer | Category | Perm. | Por. | Sat. |
|---|---|---|---|---|
| 1 | r | 125 | 0.3 | 0.6 |
| 2 | l | 75 | 0.2 | 0.4 |
| 3 | r | 125 | 0.3 | 0.6 |
| 4 | b | 5 | 0.1 | 0 |
| 5 | l | 75 | 0.2 | 0.4 |
| 6 | b | 5 | 0.1 | 0 |
| 7 | l | 75 | 0.2 | 0.4 |
| 8 | b | 5 | 0.1 | 0 |
| 9 | v | 25 | 0.15 | 0.2 |
| 10 | l | 75 | 0.2 | 0.4 |
| 11 | v | 25 | 0.15 | 0.2 |
| 12 | b | 5 | 0.1 | 0 |
| 13 | l | 75 | 0.2 | 0.4 |
| 14 | b | 5 | 0.1 | 0 |
| 15 | v | 25 | 0.15 | 0.2 |
| 16 | b | 5 | 0.1 | 0 |
| 17 | v | 25 | 0.15 | 0.2 |
| 18 | b | 5 | 0.1 | 0 |
| 19 | l | 75 | 0.2 | 0.4 |
| 20 | r | 125 | 0.3 | 0.6 |
| 21 | v | 25 | 0.15 | 0.2 |
| 22 | r | 125 | 0.3 | 0.6 |
| 23 | b | 5 | 0.1 | 0 |
| 24 | l | 75 | 0.2 | 0.4 |
| 25 | b | 5 | 0.1 | 0 |

Figure 1: The 25 layers used in the simulation of cyclic and SAGD processes. The categories are rich, lean, very lean and barren.

Whiterocks is a steeply dipping reservoir ($75^0$). The model constructed in STARS is shown in Figure 2. It should be noted that if horizontal wells were used, they would cut across the bedding planes in almost a perpendicular manner.

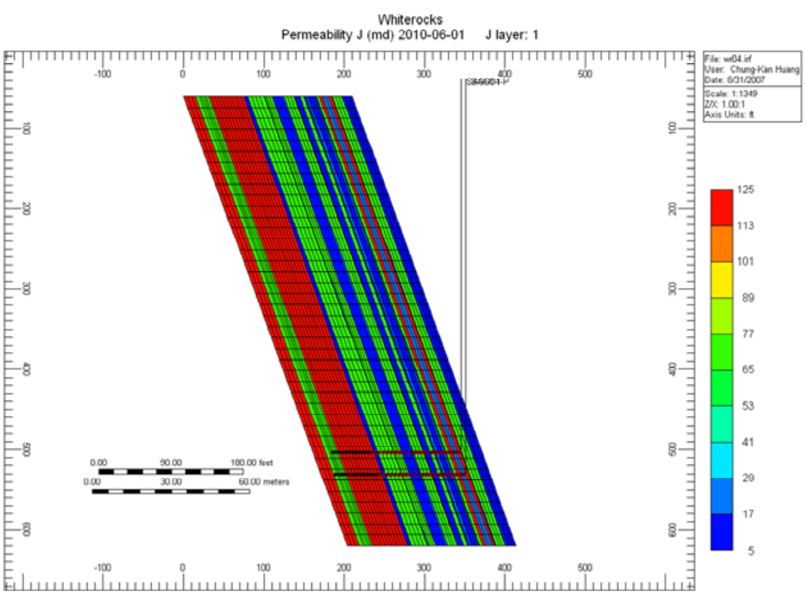

Figure 2: Model of the Whiterocks reservoir constructed in STARS.

The geometry and the well configurations used are shown in Figure 3. The wells were placed so that the steam chambers would be able to effectively drain oil from the reservoir. SAGD oil production is shown in Figure 4 and the cyclic oil production is shown in Figure 5.

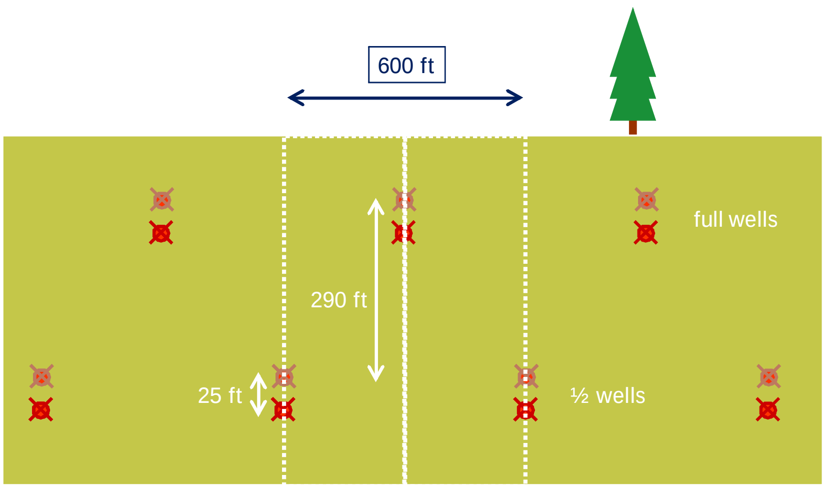


Figure 3: Geometry and well configuration used.

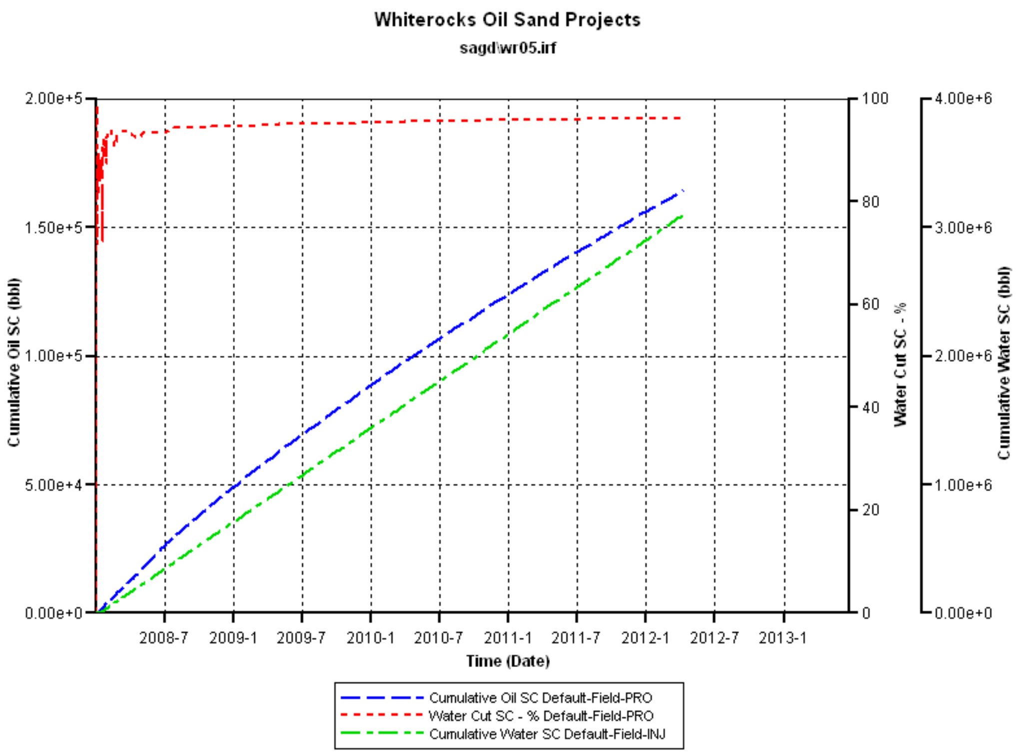


Figure 4: Oil production in Whiterocks SAGD simulations.

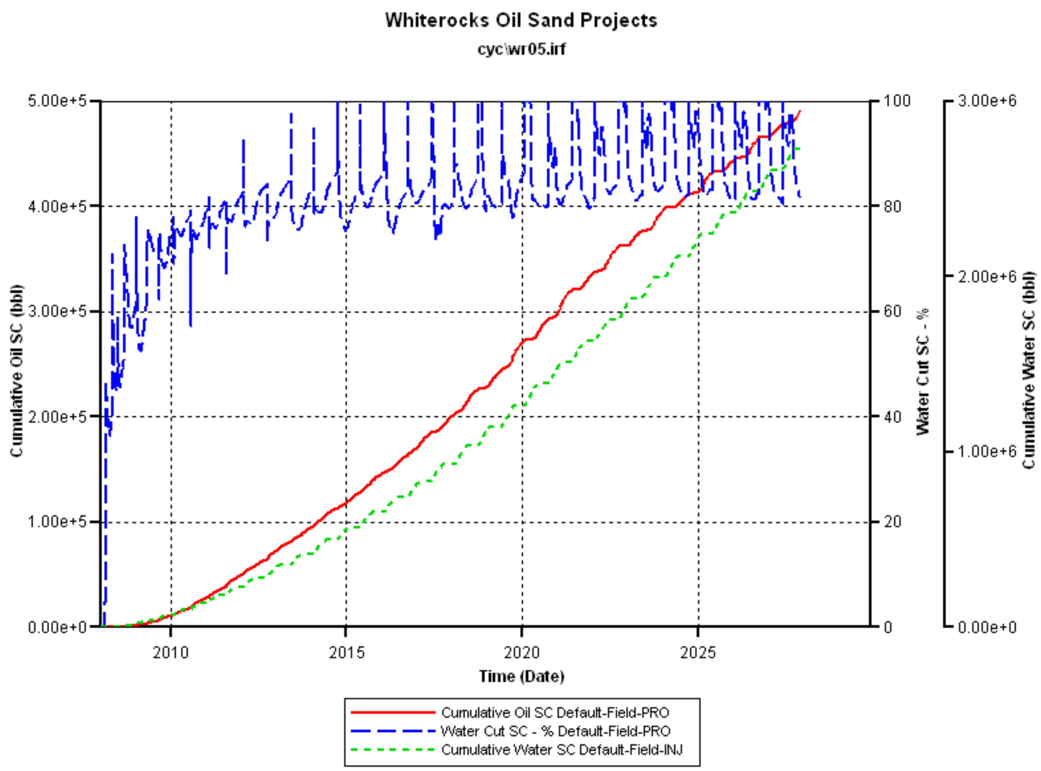


Figure 5: Oil production in Whiterocks cyclic simulations.

In both cases, substantial amount of oil from the reservoir can be produced. Since the initial water saturation in the reservoir is significant, large amounts of water are also produced. The simulation results are very sensitive to the relative permeability curves employed in the simulation.

### 4. Depositional heterogeneity and fluid flow modeling of the oil shale interval of the upper Green River Formation, eastern Uinta Basin, Utah

Royhan Gani and Milind Deo

**Subsurface Geology:** The Utah Geological Survey provided us scanned images of the gamma logs from available wells within the study area located at the eastern margin of the Uinta Basin. Student Beau Anderson has finished digitizing and producing industry standard las files of these gamma logs using Nueralog software and has loaded these digital log files onto a workstation.

**Reservoir Modeling:** A reservoir model was constructed using the log shown in the Figure 6. The section chosen for modeling, Mahogany, was the richest in this part of the Green River formation. Heating of the shale using a constant temperature source and its subsequent pyrolysis were studied. The recovery scheme employed is shown in Figure 7. The heaters and producers were located at distances of 25 feet. The central producer was later converted to a water injector to recover the remaining oil and to scavenge the heat. Several different production scenarios were investigated. A multiphase, compositional-thermal model was constructed in STARS. A sample result is presented in Figure 8. It is seen that as the bottom-hole production pressure is reduced, a "bump" in oil production is observed. It is also evident that waterflooding could successfully be applied to recover significant amounts of oil. However, the fraction of light oil recovered from this method may be less than that produced using pyrolysis only. Pros and cons of various process options and mechanisms of oil recovery from this rich resource were compiled.

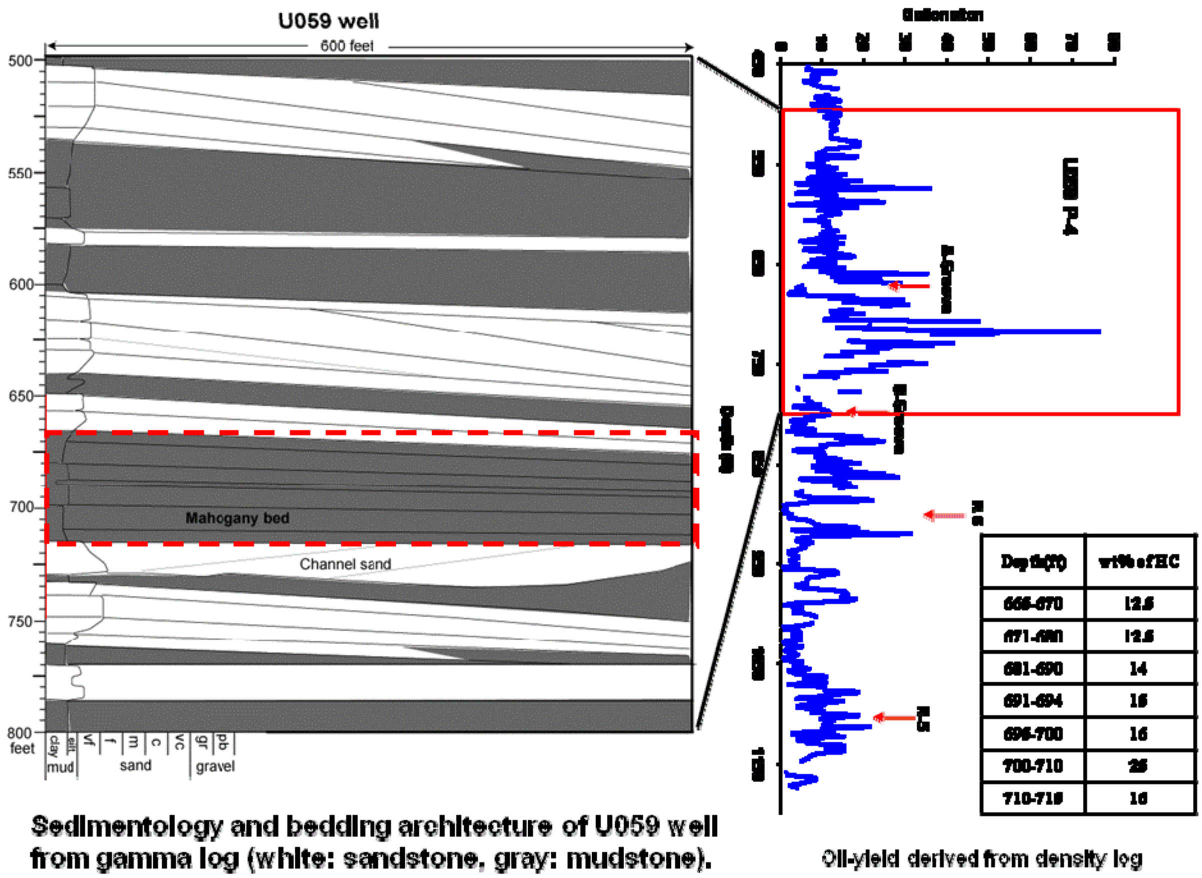


Figure 6: Figure showing the cross-section of the zone modeled and the Fischer Assay yields at corresponding depths.

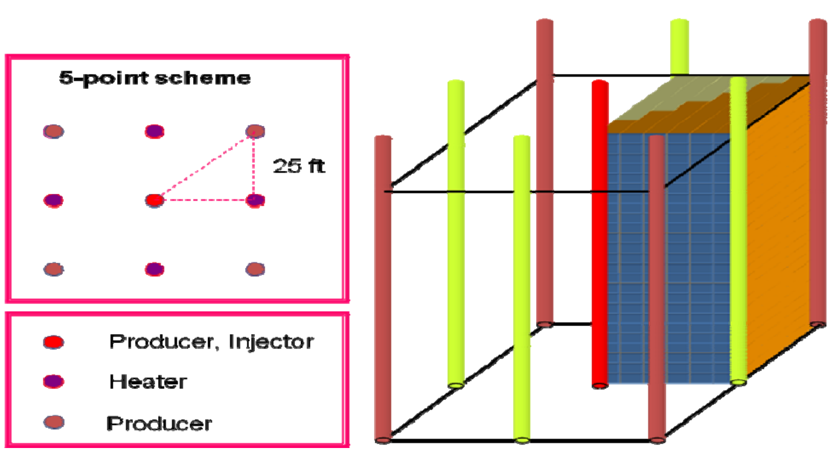

Figure 7: Pyrolysis scheme employed in heating the shale and recovering the oil.

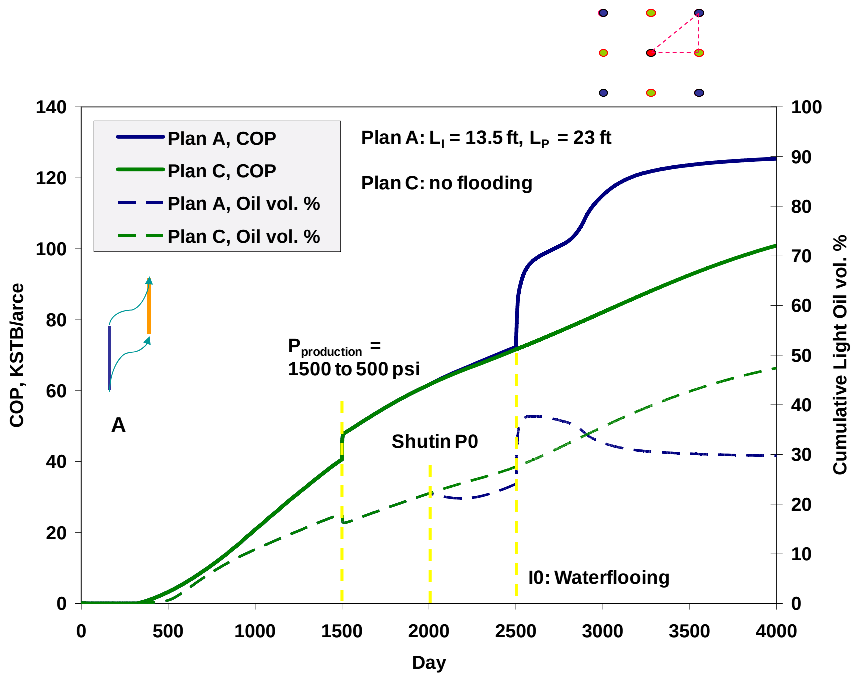


Figure 8: Cumulative oil production (COP) and cumulative light oil production for various production options.

5. **Analysis of Environmental, Legal, Socioeconomic and Policy Issues Critical to the Development of Commercial Oil Shale Leasing on the Public Lands in Colorado, Utah, and Wyoming under the Mandates of the Energy Policy Act of 2005; Economic Evaluation of Bitumen Upgrading**

Robert Keiter, Kirsten Uchitel, Alan Isaacson

**Legal and Economic Analysis**: We secured a copy of the BLM's Programmatic Environmental Impact Statement (PEIS) on oil shale leasing and have begun reviewing and analyzing it. We also began collecting and analyzing demographic, economic, and employment statistics for the Uinta Basin in Utah and the Piceance Basin in Colorado. Additionally, we completed an outline for the final report and made tentative assignments for completing each section. We have also begun to review changes to the Energy Policy Act enacted as riders by the current Congress in its budget bill.

**B. On-line Repository**

We relocated the hardware for the on-line repository in this quarter and began the task of reviewing all the documents that had been uploaded to the repository for accuracy and copyright permission. During this review, it became clear that a specialist was needed to assist us with database and interface issues related to the Dspace software we have selected as our archiving software. We posted a part time job description and hired the most qualified candidate from the pool of applicants. We now hope to make rapid progress in reloading more accurate metadata for each of the 1200 documents currently in the repository. Once this metadata is complete, full text versions of each document will once again be available.

## CONCLUSIONS

We are pleased with the progress being made in each of the five UHOP-sponsored research projects and look forward to a more user-friendly and accurate repository in the next quarter.

## COST PLAN/STATUS

| **REVISED** Baseline Reporting Quarter | **Year 1** | **Start: 06/21/2006** | | **End: 06/30/2007** |
|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 |
| **Baseline Cost Plan (from SF-424A)** | | | | |
| Federal Share | $126,295 | $239,349 | $41,357 | $147,911 |
| Non-Federal Share | $31,574 | $34,342 | $25,969 | $38,387 |
| Total Planned (Federal and Non-Federal) | $157,869 | $273,691 | $67,326 | $186,298 |
| Cumulative Baseline Costs | $157,869 | $431,560 | $498,866 | $685,184 |
| **Actual Incurred Costs** | | | | |
| Federal Share | $126,295 | $239,349 | $41,357 | $164,491 |
| Non-Federal Share | $31,574 | $34,342 | $25,969 | $30,841 |
| Total Planned (Federal and Non-Federal) | $157,869 | $273,691 | $67,326 | $195,332 |
| Cumulative Baseline Costs | $157,869 | $431,560 | $498,866 | $694,218 |
| **Variance** | | | | |
| Federal Share | 0 | 0 | 0 | $16,580 |
| Non-Federal Share | 0 | 0 | 0 | $(7,546) |
| Total Planned (Federal and Non-Federal) | 0 | 0 | 0 | $9,034 |
| Cumulative Baseline Costs | 0 | 0 | 0 | $9,034 |

| **REVISED**<br>Baseline Reporting Quarter | **Year 2** Q5 | **Start: 07/01/2007** Q6 | **End: 06/30/2008** Q7 | Q8 |
| --- | --- | --- | --- | --- |
| **<u>Baseline Cost Plan (from SF-424A)</u>** | | | | |
| Federal Share | $147,911 | $147,911 | $147,911 | $147,911 |
| Non-Federal Share | $38,620 | $38,620 | $38,620 | $38,620 |
| Total Planned (Federal and Non-Federal) | $186,531 | $186,531 | $186,531 | $186,531 |
| Cumulative Baseline Costs | $871,715 | $1,058,246 | $1,244,777 | $1,431,308 |
| **<u>Actual Incurred Costs</u>** | | | | |
| Federal Share | 161,343 | 178,570 | | |
| Non-Federal Share | 29,299 | 10,038 | | |
| Total Planned (Federal and Non-Federal) | 190,642 | 188,608 | | |
| Cumulative Baseline Costs | 884,860 | 1,073,468 | | |
| **<u>Variance</u>** | | | | |
| Federal Share | $13,432 | $30,659 | | |
| Non-Federal Share | (9,321) | (28,582) | | |
| Total Planned (Federal and Non-Federal) | $4,111 | $2,077 | | |
| Cumulative Baseline Costs | $13,145 | $15,222 | | |

| **REVISED** Baseline Reporting Quarter | **Year 3** Q9 | **Start: 07/01/2008** Q10 | **End: 10/20/2008** | |
|---|---|---|---|---|
| **<u>Baseline Cost Plan (from SF-424A)</u>** | | | | |
| Federal Share | $147,911 | $147,909 | | |
| Non-Federal Share | $38,620 | $37,222 | | |
| Total Planned (Federal and Non-Federal) | $186,531 | $185,131 | | |
| Cumulative Baseline Costs | $1,619,839 | $1,802,970 | | |
| **<u>Actual Incurred Costs</u>** | | | | |
| Federal Share | | | | |
| Non-Federal Share | | | | |
| Total Planned (Federal and Non-Federal) | | | | |
| Cumulative Baseline Costs | | | | |
| **<u>Variance</u>** | | | | |
| Federal Share | | | | |
| Non-Federal Share | | | | |
| Total Planned (Federal and Non-Federal) | | | | |
| Cumulative Baseline Costs | | | | |

# MILESTONE COMPLETION CHART

| Task | Critical Path Project Milestone Description | Project Duration Start: End: | | | | | | | | | | Planned Start Date | Planned End Date | Actual Start Date | Actual End Date | Comments (notes, explanation of deviation from baseline) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Project Year 1 | | | | Project Year 2 | | | | Project Year 3 | | | | | | |
| | | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | | | | | |
| 1.1 | Identify resources on unconvention-al oil in North America | X | | | | | | | | | | June, 2006 | Sept., 2006 | June, 2006 | Sept., 2006 | |
| 1.2 | Prepare draft update report on domestic unconvention-al oil resources | X | X | | | | | | | | | June, 2006 | Sept., 2006 | June, 2006 | Feb. 2007 | Identifying personnel & surveying available sources took longer than expected. Added value from the report will be from analysis, which also takes more time. |
| 1.3 | Release draft update to public & request input from unconvention-al oil community | | X | | | | | | | | | Sept., 2006 | Sept., 2006 | Oct., 2006 | March 2007 | Preliminary draft was released on March 21, 2007 Release delayed by Task 1.2 delay and by problems with report quality from company hired to do page layout. |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.4 | Attend the CERI Oil Shale Symposium & provide a summary | | X | | | | X | | | | | Oct., 2006 | Oct., 2006 | Oct., 2006 | Oct., 2006 | |
| 1.5 | Develop on-line repository for all types of material pertaining to unconvention-al oil resources in North America | X | X | X | | | | | | | | June, 2006 | June, 2008 | June, 2006 | | Documents, data continue to be added to repository. |
| 1.6 | Update and release enhanced version of report developed under 1.3, integrating comments received | | | X | | | | | | | | Jan., 2007 | Aug., 2007 | April, 2007 | Sept., 2007 | |
| 1.7 | Release on-line repository to unconvention-al oil community | | | X | | | | | | | | Jan., 2007 | Jan., 2007 | Jan., 2007 | Feb, 2007 | Release date was Feb. 15, 2007. |
| 1.8 | Refine repository, incorporating information provided by user community | | | X | X | X | X | | | X | X | Jan., 2007 | Oct., 2008 | Jan., 2007 | | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.1 | Identify Center-sponsored research projects areas in consultation with DOE | X | | | | X | | | | | | Sept., 2006 | Sept., 2006 | Sept., 2006 | Oct., 2006 | |
| 2.2 | Issue internal RFP to support project areas identified in 2.1 | | X | | | X | | | | | | Sept., 2006 | Sept., 2006 | Oct., 2006 | Nov., 2006 | RFP was released on Nov. 20, 2006. Proposals were due Dec. 15, 2006. |
| 2.3 | Select 2-3 Center-sponsored research projects | | X | | | X | | | | | | Oct., 2006 | April, 2007 | Jan., 2007 | April, 2007 | Selection of research projects completed in March 2007. Researchers were not notified of project selection before end of quarter three. |
| 2.4 | Complete technical reports for Center-based research projects | | | | | X | | | | | | Oct., 2008 | Oct., 2008 | | | |
| 2.5 | Provide priority listing of research & demonstration needs for domestic production from unconventional oil resources | | | | X | X | | | | | | June, 2007 | Sept., 2007 | Nov. 2007 | | Will address this milestone in the first quarter of 2008 |

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