Oil & Natural Gas Technology

DOE Award No.: DE-FC26-06NT15569

Quarterly Progress Report
With Summaries of Center-sponsored Research
(January – March 2009)

UTAH HEAVY OIL PROGRAM

Submitted by:
University OF Utah
Salt Lake City, UT

Prepared for:
United States Department of Energy
National Energy Technology Laboratory

May 1, 2009

Office of Fossil Energy

Utah Heavy Oil Program

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Quarterly Progress Report

January 2009 to March 2009

Submitted by:
Institute for Clean and Secure Energy
155 S. 1452 E. Room 380
Salt Lake City, UT 84112

Principal Investigator: Philip J. Smith
Project Period: June 21, 2006 to October 21, 2009

Prepared for:
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EXECUTIVE SUMMARY

The six tasks (five research projects and the repository) that comprise the Utah Heavy Oil Program (UHOP) are winding down. Three PIs are preparing final reports that will be submitted to DOE in May 2009. For the shale pyrolysis project, problems with numerical stability in their in-situ modeling work were resolved and final simulations involving RF heating of the deposit will be completed in the next quarter. Only one PI on the water management team has work to finish up. This work involves bacterial degradation of BTEX, naphthalene and MTBE. This quarter, experiments were conducted to determine whether hydroxyl radical is involved in electrolytic oxidation of naphthalene. A paper discussing the results is being prepared. For in situ production of oil sands, researchers demonstrated the use of a thermal simulator for simulating in-situ combustion in fractured media. Oil recovery rates were not significantly different for full- and half-length fractures. In the project that considers the effects of depositional heterogeneity in the Uinta Basin on shale oil production rates, the research team explored, both conceptually and with simulation, the idea of using a hybrid (pyrolysis-combustion) process for producing oil from oil shale. Once a sufficient amount of coke is formed during the pyrolysis phase of the process, combustion is performed to create the energy required for pyrolysis. Based on the scenario tested, the optimal switch time from pyrolysis to combustion is 1200 days. The legal team considering issues related to oil shale leasing continued its research and analysis of air and carbon issues and began working with an economist to evaluate the economic and socioeconomic issues associated with federal commercial oil shale leasing decisions. The new repository librarian has outline a protocol for all documents that are being considered for upload to the repository based on whether or not copyright permission can be obtained. During this quarter, over 400 documents were process through this protocol and most were uploaded to the repository in full-text form.

PROJECT MILESTONES/PROGRESS PERFORMANCE

A. Progress in Program-Sponsored Projects

During this reporting period, several UHOP-sponsored projects were completed. Final reports are in the editing/revision stage for “New Approaches to Treat Produced Water and to Perform Water Availability Impact Assessments for Oil Shale Development” and for “Detailed Study of Shale Pyrolysis for Oil Production.” Brief summaries are provided below for ongoing work in the other projects.

1. Detailed Study of Shale Pyrolysis for Oil Production

Experimental Results: Summarized in final report to be issued.

In-situ Oil Shale Recovery Modeling: At the beginning of this reporting period, we struggled with numerical stability of our multi-physics calculation of the in-situ heating and flow of gases and shale oil in oil shale deposits. With a new version of the software that allowed parallel processing in our quad processor machine and an improved solver, as well as some softening of abrupt boundary conditions, these numerical stability problems have been resolved. Our calculation is now stable simulating 5 years of in-situ production. With this success, we have started to look at various operating conditions and their impact on the rate and overall quantity of shale oil and gas produced from the deposit. In addition we have initiated other multiphysics calculations where the heating of the deposit is done by electrical resistive heating of the deposit. Long term calculation of the resistive heating of the deposit has been successful which shows interesting differences with the well based heating calculations that were perfected earlier of this month. Our next and last problem to be resolved is the RF heating of the deposit which will be the focus of the work next month.

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

Water Resources Sustainability: The water management team is preparing their final report.

Biological and Chemical Treatment of Produced Water: One question that has arisen in the course of this research is whether hydroxyl radical is involved in electrolytic oxidation of naphthalene. To examine this question, experiments involving the removal of naphthalene by electrolysis were performed for a range of concentrations of different hydroxyl radical scavengers (acetone, methanol, d6-acetone and d3-methanol). Results indicate that the oxidation of naphthalene is not hydroxyl-radical mediated, which was quite different that what other researcher have reported in the literature. A paper draft about these interesting results is in preparation and will be submitted to the Journal of Hazardous Materials.

Ozonation of Produced Water: The ozonation team is preparing their final report.

3. In Situ Production of Utah Oil Sands

In previous quarterly reports, development of a thermal simulator suitable for many process applications was described. We then examined the steam assisted gravity drainage (SAGD) process for the production of oil from oil sands. In this report, we demonstrate the use of the thermal simulator for simulating in-situ combustion in oil sand reservoirs.

In-situ combustion is considered a highly complicated enhanced oil recovery (EOR) process from both the practical and modeling points of view. In practice, the interplay between the geological heterogeneity of the reservoir and the distribution of the hydrocarbons increases the difficulty of process control. In modeling, the combination of the significantly different chemical reaction rates and phase equilibrium, along with complicated rock-fluid interactions, makes numerical stability a challenge. The addition of fractures in in-situ combustion modeling increases the numerical difficulty since multi-scale flow regions exist in the problem. In this report, we discuss results of modeling in-situ combustion in fractured media.

Injecting air in oil sand reservoirs for in-situ combustion requires reasonable permeability. Hydraulic fracturing is a logical method of creating this permeability. Before introducing fracturing, the in-situ combustion algorithms were tested with dry (no-water) combustion and with wet combustion, where different amounts of water were co-injected with air. The temperature profiles along the injection path (dimensionless) are shown in Figure 1. With wet combustion, the high-temperature plateau is wider due to the effect of water evaporation and re-condensation at the front. This wide plateau results in better heat utilization and distribution.

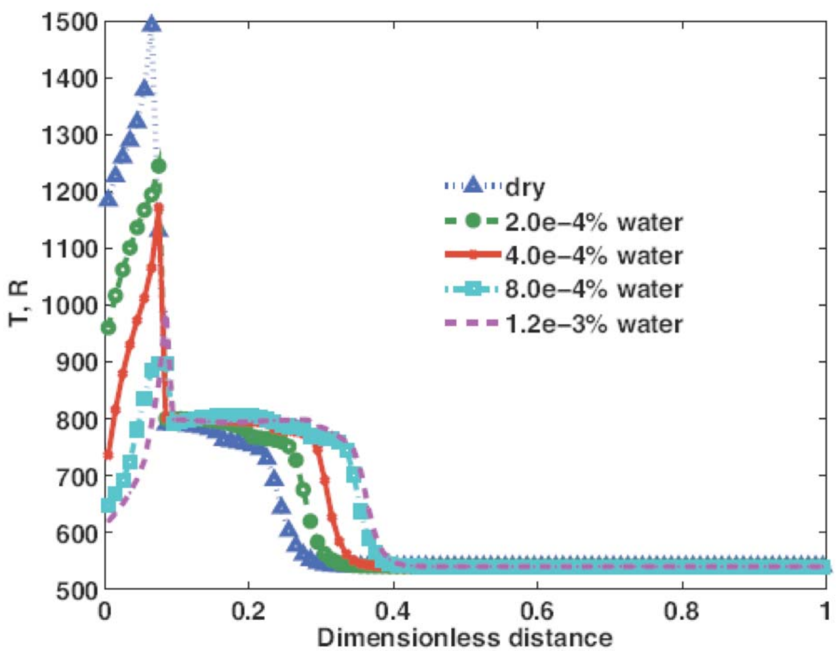


Figure 1: Comparison of temperatures profiles along the injection path with dry and wet combustion.

Next, the team studied the near-well displacement in a hydraulically-fractured in-situ combustion process. They used a discrete fracture model, which is an ideal discretization method for providing a better understanding of flow phenomena in this type of application. The hydraulic fracture is one of reservoir remedy options to improve the injectivity (or sometimes productivity) and sweep efficiency. The actual effect of the hydraulic fracture depends on its dimension, orientation and system of complexity

The domain used for this study, including a five-spot pattern, is shown in Figure 2. In the figure, the blue sphere represents the injector and the red sphere represents the producer. FA is the full length fracture, and FB is the half length fracture. The yellow square shows the boundary of the simulation domain (symmetry).

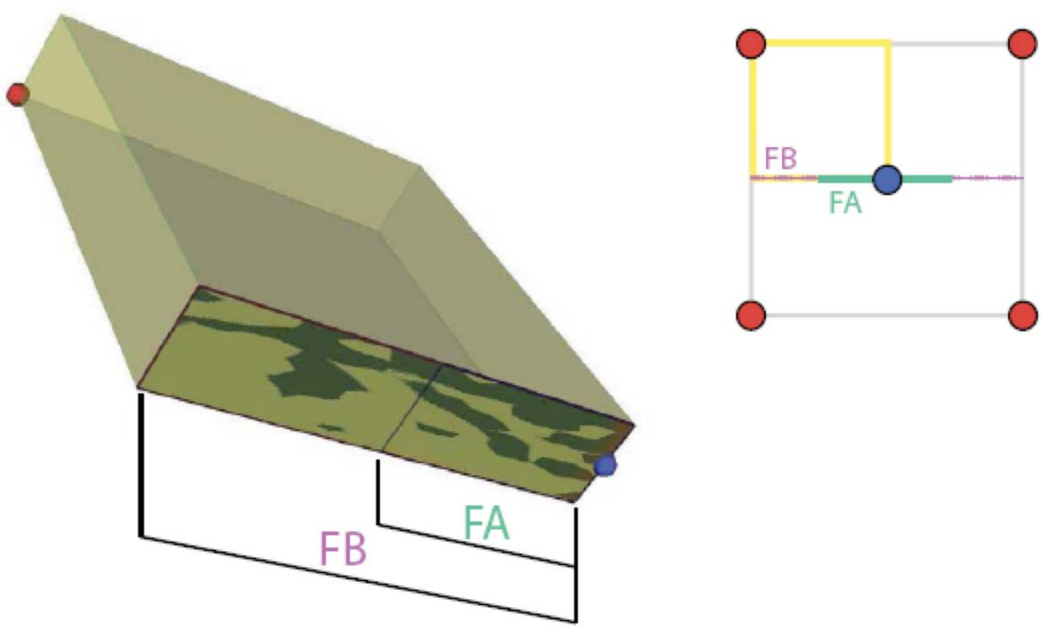
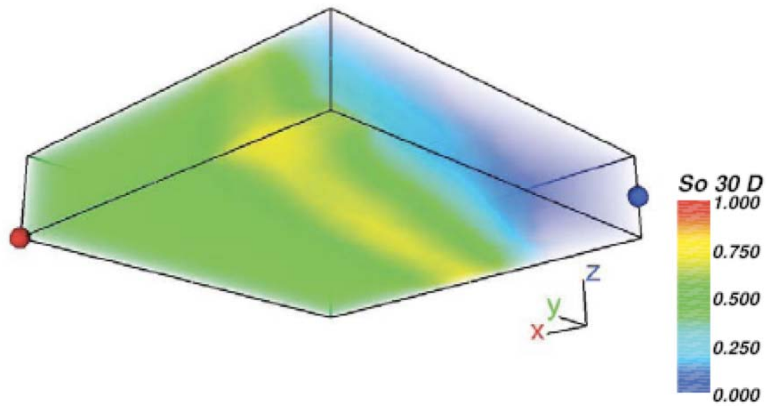
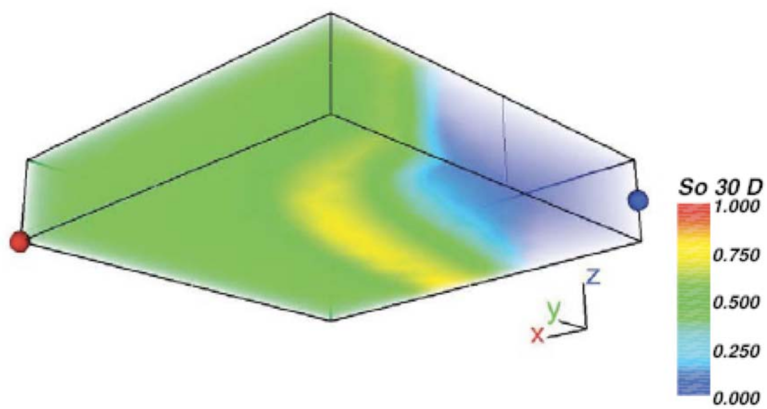


Figure 2: Domain with five-spot pattern used to study in-situ combustion in an oil sand reservoir with hydraulic fracture.

The oil saturation distributions with half and full length fractures are shown in Figure 3. It is seen that the full-length fracture creates a linear front compared to the radial front for the half-length system. The oil recoveries and rates are not significantly different.



(a) full length



(b) half length

Figure 3: In-situ combustion with hydraulic fracture – comparison of half length and full-length fractures.

4. Depositional Heterogeneity and Fluid Flow Modeling of the Oil Shale Interval of the Upper Green River Formation, Eastern Uinta Basin, Utah

In this quarter, researchers explored the idea of using a hybrid (pyrolysis-combustion) process for producing oil from oil shale. The idea of the hybrid process, shown in Figure 4, is to minimize energy consumption in the pyrolysis process. First, pyrolysis is carried out. The pyrolysis process yields oil, coke and gas. Once a sufficient amount of coke is formed, combustion is performed to create the energy required for in-situ pyrolysis. Researchers have examined both the conceptual idea and its implementation.

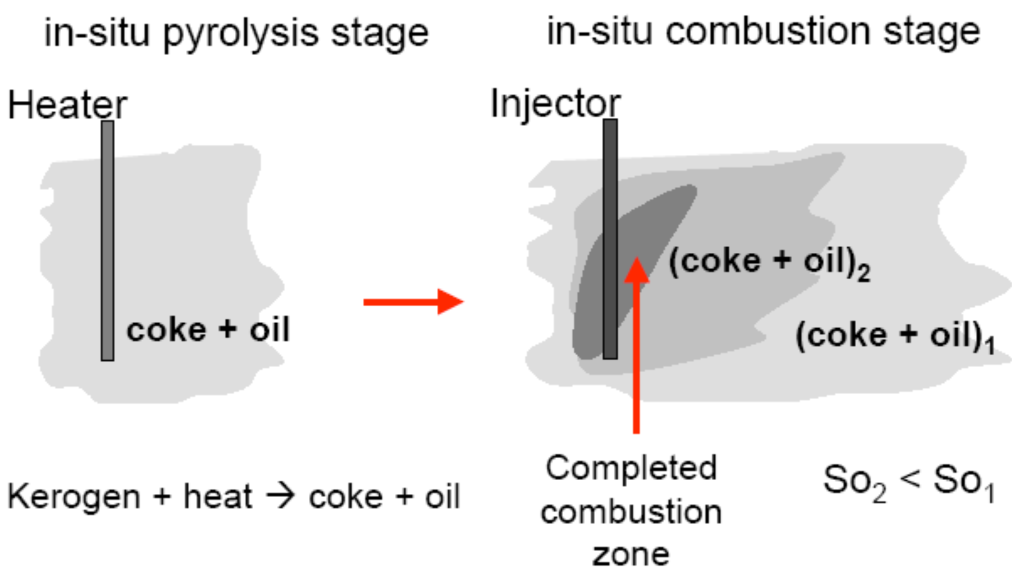


Figure 4: In situ pyrolysis followed by the combustion of coke to minimize energy consumption in the pyrolysis process.

Numerical simulations were performed using the thermal simulator SATRS (Computer Modelling Group, Inc.). The hypothetical chemical reaction models shown below, including three combustion reactions and one pyrolysis reaction, were integrated into the reservoir model.

<u>Kerogen burning</u>

1.0 Kerogen + 60.55 O_2 $\rightarrow$ 28.34 H_2O + 51.53 InertGas + 1.2525E7 (Btu/lbmol)

<u>Oil burning</u>

1.0 Oil + 14.06 O_2 $\rightarrow$ 6.58 H_2O + 11.96 InertGas + 2.9075E6 (Btu/lbmol)

<u>Coke burning</u>

1.0 Coke + 1.18 O_2 $\rightarrow$ 0.55 H_2O + 1.0 InertGas + 2.25E5 (BTU/lbmol)

<u>Kerogen pyrolysis (50/50 mass basis)</u>

1.0 Kerogen + 3.5E4 (Btu/lbmol) $\rightarrow$ 2.154 Oil + 25.96 Coke

Molecular weight (lb/lbmol)

Kerogen = 675, Coke = 13, Oil = 156.7, Inert Gas = 40.8

The domain used, an 88x88x88 cube, is shown in Figure 5.

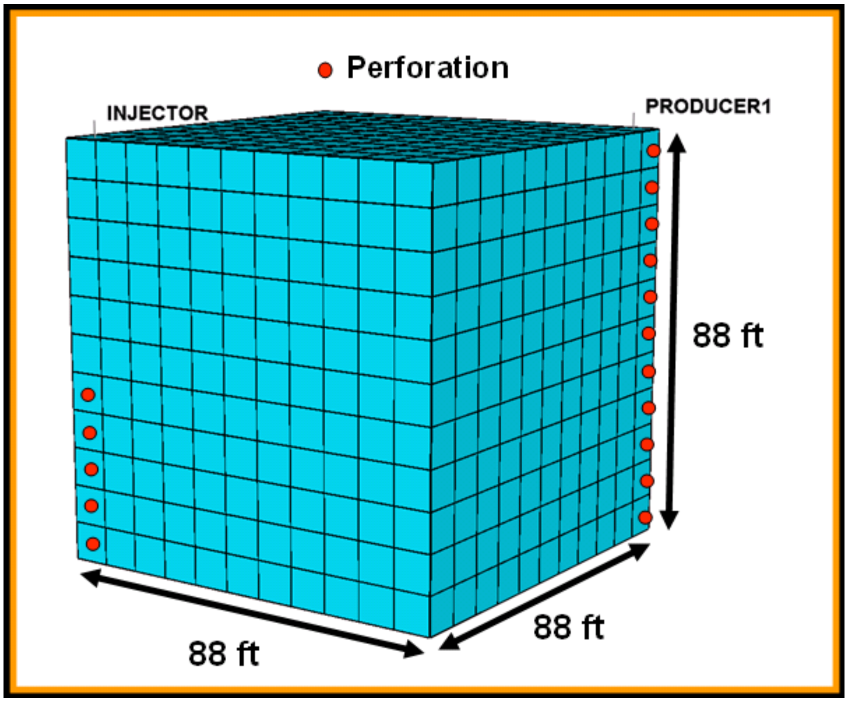


Figure 5: Domain used for the process simulation.

Researchers studied the impact of several operating parameters: time to switch the process from pyrolysis to combustion, the air injection rate, and the location of the producer. This report contains sample results for this hybrid process. Detailed results will be presented in the final report.

The oil rate increases once air injection begins. Air plays two roles; the first is to maintain the combustion reactions and the second is to sweep the product gases. Compared to the original in-situ pyrolysis simulations, more oil recovery was observed. A comparison of recoveries at different switching times (from pyrolysis to combustion) is shown in Figure 6. The 1200 day switch was considered optimal since oil recovery matched recoveries at later switching times with much less energy input.

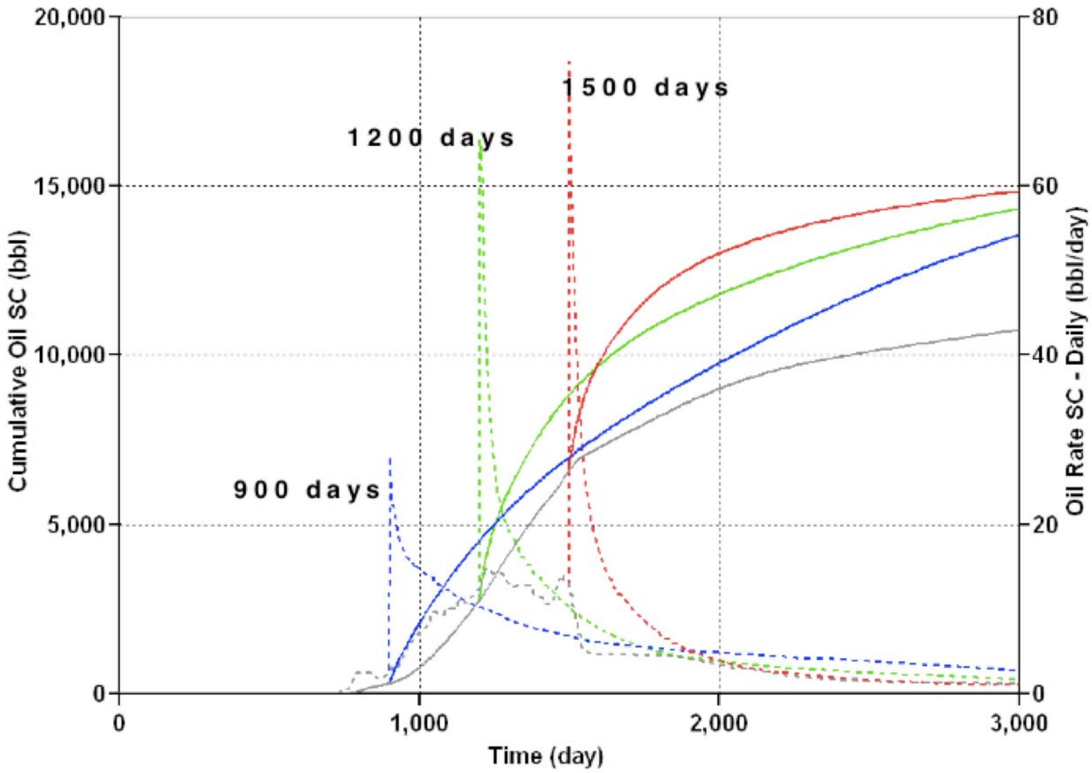


Figure 6: Sensitivity study of the hybrid process – time of switching between pyrolysis and combustion.

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**

The legal team continued its research and analysis of air and carbon issues relevant to oil shale development. The team also began research on federal commercial leasing issues presented by both state leasing decisions and the potential for additional federal RD&D oil shale leases. Michael Hogue, the economist working on the project, began economic impact analysis relevant to addressing the economic and socioeconomic issues associated with federal commercial oil shale leasing decisions.

B. On-line Repository

This project will be considered complete once the 1400 documents received from the Utah Geological Survey in 2006 have been verified for copyright permission and then, depending on the results of the copyright verification, been processed in one of three ways: (1) if copyright permission is received, the document will be uploaded to the repository, (2) if copyright permission is denied, only information allowed by copyright law will be uploaded to the repository, including title, author, publisher, etc. (3) if copyright permission is unclear due to age/source of the document, limited information will be uploaded to the repository until a more permanent decision is made. In the past quarter, approximately 400 full-text documents were processed following these guidelines. Work will continue through the summer until all 1400 documents have been processed.

CONCLUSIONS

Research work in the UHOP program must be completed in two more quarters, so work is progressing at an accelerated pace. The acquisition of equipment, development of research techniques, and modification of simulation tools has been accomplished, so researchers are focusing on completing their experimental matrices and simulation runs. Final reports on each project will be issued over the next few months.

COST STATUS

COST PLAN/STATUS

Baseline Reporting Quarter	Year 1							
	Q1		Q2		Q3		Q4	
	6/21/06 - 9/30/06		10/1/06 - 12/31/06		1/1/07 - 3/31/07		4/1/07 - 6/30/07	
	Q1	**Total**	Q2	**Total**	Q3	**Total**	Q4	**Total**
Baseline Cost Plan								
Federal Share	126,295	**126,295**	239,349	**365,644**	41,357	**407,001**	147,911	**554,912**
Non-Federal Share	31,574	**31,574**	34,342	**65,916**	25,969	**91,885**	38,387	**130,272**
Total Planned	157,869	**157,869**	273,691	**431,560**	67,326	**498,886**	186,298	**685,184**
Actual Incurred Cost								
Federal Share	126,295	**126,295**	239,349	**365,644**	41,357	**407,001**	164,491	**571,492**
Non-Federal Share	31,574	**31,574**	34,342	**65,916**	25,969	**91,885**	30,841	**122,726**
Total Incurred Costs	157,869	**157,869**	273,691	**431,560**	67,326	**498,886**	195,332	**694,218**
Variance								
Federal Share	0	**0**	0	**0**	0	**0**	16,580	**16,580**
Non-Federal Share	0	**0**	0	**0**	0	**0**	(7,546)	**(7,546)**
Total Variance	0	**0**	0	**0**	0	**0**	9,034	**9,034**

Baseline Reporting Quarter	Year 2							
	Q5		Q6		Q7		Q8	
	7/1/07 - 9/30/07		10/1/07 - 12/31/07		1/1/08 - 3/31/08		4/1/08 - 6/30/08	
	Q5	**Total**	Q6	**Total**	Q7	Total	Q8	Total
Baseline Cost Plan								
Federal Share	147,911	**702,823**	147,911	**850,734**	147,911	**998,645**	147,911	**1,146,556**
Non-Federal Share	38,620	**168,892**	38,620	**207,512**	38,620	**246,132**	38,620	**284,752**
Total Planned	186,531	**871,715**	186,531	**1,058,246**	186,531	**1,244,777**	186,531	**1,431,308**
Actual Incurred Cost								
Federal Share	161,343	**732,835**	178,570	**911,405**	165,243	**1,076,648**	114,429	**1,191,077**
Non-Federal Share	29,299	**152,025**	10,038	**162,063**	36,285	**198,348**	19,020	**217,368**
Total Incurred Costs	190,642	**884,860**	188,608	**1,073,468**	201,528	**1,274,996**	133,449	**1,408,445**
Variance								
Federal Share	13,432	**30,012**	30,659	**60,671**	17,332	**78,003**	(33,482)	**44,521**
Non-Federal Share	(9,321)	**(16,867)**	(28,582)	**(45,449)**	(2,335)	**(47,784)**	(19,600)	**(67,384)**
Total Variance	4,111	**13,145**	2,077	**15,222**	14,997	**30,219**	(53,082)	**(22,863)**

Baseline Reporting Quarter	Year 3							
	Q9		Q10		Q11		Q12	
	7/1/08 - 9/30/08		10/1/08 - 12/31/08		1/1/2009 - 3/31/09		4/1/09 - 6/30/09	
	Q9	Total	Q10	Total				
Baseline Cost Plan								
Federal Share	147,911	**1,294,467**	34,802	**1,329,269**	34,802	**1,364,071**	34,802	**1,398,873**
Non-Federal Share	38,620	**323,372**	8,758	**332,130**	8,758	**340,888**	8,758	**349,646**
Total Planned	186,531	**1,617,839**	43,560	**1,661,399**	43,560	**1,704,959**	43,560	**1,748,520**
Actual Incurred Cost								
Federal Share	144,808	**1,342,302**	31,909	**1,374,211**	72,324	**1,446,535**		
Non-Federal Share	37,868	**255,236**	4,266	**259,502**	45,111	**304,613**		
Total Incurred Costs	182,676	**1,597,538**	36,175	**1,633,713**	117,434	**1,751,147**		
Variance								
Federal Share	(3,103)	**47,835**	(2,893)	**44,942**	37,521	**82,463**		
Non-Federal Share	(752)	**(68,136)**	(4,492)	**(72,628)**	36,353	**(36,275)**		
Total Variance	(3,855)	**(20,301)**	(7,385)	**(27,686)**	73,874	**46,188**	0	**0**

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Note: The Cost Plan has been revised to reflect the agreement’s extension through 10/20/2009.

MILESTONE STATUS

Three project milestones have not been completed: Task 1.5, Develop on-line repository for all types of material pertaining to unconventional resources in North America; Task 1.8, Refine repository, incorporating information provided by user community; and Task 2.4, Complete technical report for Center-based research projects. During this quarter, 400 of the 1400 documents available were processed by the librarian. Hence, the completion of Tasks 1.5 and 1.8 will most likely take until the end of the project period. Final reports are in the review process with three PIs. It is anticipated that those reports will be sent to DOE in May 2009.

PROBLEMS OR DELAYS

The issuing of the first final reports has been delayed until May 2009 due to the heavy teaching loads of the PIs.

RECENT AND UPCOMING PRESENTATIONS/PUBLICATIONS

Milind Deo, "In Situ Production of Utah Oil Sands." Presentation given at the 2009 Western U.S. Oil Sands Conference, February 27, 2009, Salt Lake City, UT. (Note- this presentation was included in the CASE project quarterly report, but what was presented was actually from a UHOP-sponsored project)

Steve Burian, "Water Management for Oil Sand and Oil Shale Development in Utah: Challenges and Solutions." Presentation given at the 2009 Western U.S. Oil Sands Conference, Salt Lake City, UT, February 27, 2009. (Note- this presentation was included in the CASE project quarterly report, but what was presented was actually from a UHOP-sponsored project)

Andy Hong, Zhixiong Cha, Cheng-Fang Lin, and Angela Lin, "Pressure-Assisted Ozonation for Rehabilitation of Produced Water," 19th Annual AEHS Meeting & West Coast Conference on Soils, Sediments, and Water, March 9-12, 2009, San Diego, California.

Steven Burian, Eric Jones, Ramesh Goel, Andy Hong, Liang Li, Zhixiong Cha, Beth Dudley-Murphy, Greg Nash," Oil Shale Development in the Western United States:Water Resources Challenges, Impacts and Solutions," American Water Resources Association, May 4-6, 2009, Anchorage, Alaska.

REFERENCES

None

National Energy Technology Laboratory

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880

One West Third Street, Suite 1400
Tulsa, OK 74103-3519

1450 Queen Avenue SW
Albany, OR 97321-2198

2175 University Ave. South
Suite 201
Fairbanks, AK 99709

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