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NOVEL CONCEPTS RESEARCH IN GEOLOGIC
STORAGE OF CO₂
PHASE III

THE OHIO RIVER VALLEY CO₂ STORAGE PROJECT

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ABSTRACT

As part of the Department of Energy's (DOE) initiative on developing new technologies for storage of carbon dioxide in geologic reservoirs, Battelle has been investigating the feasibility of CO₂ sequestration in the deep saline reservoirs in the Ohio River Valley region. In addition to the DOE, the project is being sponsored by American Electric Power (AEP), BP, The Ohio Coal Development Office (OCDO) of the Ohio Air Quality Development Authority, Schlumberger, and Battelle. The main objective of the project is to demonstrate that CO₂ sequestration in deep formations is feasible from engineering and economic perspectives, as well as being an inherently safe practice and one that will be acceptable to the public. In addition, the project is designed to evaluate the geology of deep formations in the Ohio River Valley region in general and in the vicinity of AEP's Mountaineer Power Plant in particular, in order to determine their potential use for conducting a long-term test of CO₂ disposal in deep saline formations.

The current technical progress report summarizes activities completed for the January-March 2006 period of the project. As discussed in the following report, the main accomplishments were analysis of Copper Ridge "B-zone" reservoir test results from the AEP #1 well and design and feasibility support tasks. Reservoir test results indicate injection potential in the Copper Ridge "B-zone" may be significantly higher than anticipated for the Mountaineer site. Work continued on development of injection well design options, engineering assessment of CO₂ capture systems, permitting, and assessment of monitoring technologies as they apply to the project site. In addition, organizational and scheduling issues were addressed to move the project toward an integrated carbon capture and storage system at the Mountaineer site. Overall, the current design feasibility phase project is proceeding according to plans.

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EXECUTIVE SUMMARY

This is a Quarterly Technical Progress Report for Contract DE-AC26-98FT40418. It has been prepared in accordance with the requirements of the National Energy Technology Laboratory (NETL). The reporting period for the current document is January to March 2006.

The purpose of this project is to evaluate the geology of deep formations in the Ohio River Valley region and to conduct a long-term test of carbon dioxide injection/storage in deep saline formations at an active power plant site. As discussed in the following report, the main accomplishments were analysis of Copper Ridge “B-zone” reservoir test results from the AEP #1 well and design and feasibility support tasks. Reservoir test results indicate injection potential in the Copper Ridge “B-zone” may be significantly higher than anticipated for the Mountaineer site. Work continued on development of injection well design options, engineering assessment of CO₂ capture systems, permitting, and assessment of monitoring technologies as they apply to the project site. In addition, organizational and scheduling issues were addressed to move the project toward an integrated carbon capture and storage system at the Mountaineer site. Overall, the current design feasibility phase project is proceeding according to plans.

1.0 INTRODUCTION

The main objective of this project is to evaluate the geology of deep formations in the Ohio River Valley region and if decided by the project sponsors conduct a long-term test of carbon dioxide injection/storage in deep saline formations at an active power plant site. This work supports the overall project objective of demonstrating that CO₂ sequestration in deep formations is feasible from engineering and economic perspectives, as well as being an inherently safe practice and one that will be acceptable to the public.

2.0 EXPERIMENTAL

The main experimental activities undertaken during the reporting period was analysis of Copper Ridge “B-zone” reservoir tests from fall 2005. Reservoir testing in the Copper Ridge formation was finished in fall 2005. Work continued on development of injection well design options, engineering assessment of CO₂ capture systems, reservoir simulations, work on a Class V Underground Injection Control permit, and assessment of monitoring technologies as they apply to the project site. Major accomplishments were related to the following topics:

- Reservoir testing results from the Copper Ridge “b-zone” in the AEP #1 test well were analyzed to determine reservoir parameters. This latest field test program focused on detailed hydrologic characterization of the Cooper Ridge reservoir zone. Preliminary results indicate a moderately high reservoir transmissivity for this zone, and the existence of at least two potential candidate zones (i.e., the Rose Run and Copper Ridge) for carbon sequestration at AEP #1. Testing results were analyzed for hydraulic parameters necessary to support injection operation.
- STOMP-CO₂ reservoir simulations were developed for the Copper Ridge “b-zone” based on reservoir test results, wireline logs, and petrographic analysis. Scenario were defined for a “bulk” model which addresses total transmissivity across the entire “b-zone” and a layered model which addresses thin and discrete intervals of high permeability separately.
- A comprehensive review of CO₂ storage monitoring technologies was completed as they apply to the Mountaineer site. An objective survey of monitoring methods was completed for CO₂ storage sites around the world to see whether they would be applicable at the Mountaineer site given its specifications. A practical monitoring plan tailored for the site is under development.
- A gas well location was identified in northeastern Ohio for regional geologic framework exploration. Preliminary plans were developed to characterize this well to increase information on CO₂ storage potential in the NE Ohio/NW Pennsylvania/W New York area.
- Continued work on developing a draft Underground Injection Control injection permit under the assumption that a Class V experimental well status is viable, should it be decided to proceed to injection phase. Most sections of the permit document are complete, expect for the final injection and monitoring plans, which are in progress.

3.0 RESULTS AND DISCUSSION

The following sections summarize the major activities and their outcomes for the reporting period under each task of the project.

Task 1 – Geologic Data Assessment

Task 1 includes subsurface geologic assessment in the vicinity of the field site based on pre-existing information. All activities under Task 1 of the Statement of Work have been completed, and Battelle has developed a thorough understanding of the geologic framework for the site for deep saline reservoirs, caprock formations, and coal seams. An Interim Topical Report on the findings was submitted to NETL on August 3, 2003.

Task 2 – Seismic Survey

The main tasks related to the seismic survey have been completed including: design of a survey through injection well site, acquisition of 11 miles of seismic reflection data, processing of the data, interpretation of the results, analysis of the feasibility of seismic monitoring of CO₂ in the region, and reporting. Remaining elements of task 2 pursued during this quarter were continued evaluation of 4-D seismic monitoring costs and logistics. Discussions were held with Dr. Ernie Major, an expert on seismic monitoring at Lawrence Berkeley National Laboratory in March, to discuss the applicability of cross-well bore tomography, passive seismic, and VSP imaging at the Mountaineer site. The information from the site seismic and well log surveys was shared with him and his input on possible innovative options is anticipated during April.

Task 3 – Borehole Drilling and Testing

The main activity in this task involved analysis of the reservoir testing data from Copper Ridge (Figure 1). Data collected from the test was compiled and screened for examination. Data was analyzed to determine hydraulic parameters. Overall, this process was more challenging than expected due to some interference related to fluid density variations within the borehole. Preliminary results show that the injectivity in this zone may be many times higher than that in the Rose Run Sandstone. While this needs to be validated and proven through final data review and continued exploration in the region, it is a promising finding for the feasibility of large-scale sequestration in Appalachian Basin and other Midwestern basins that are dominated by carbonate rocks. A presentation on the comparison of data obtained and the area of investigation covered by various methods (coring, logging, slug/DST tests, and detailed reservoir tests) was given at the EPA/LBNL Symposium on Site Characterization for CO₂ sequestration in late March.

Figure 1. Copper Ridge “B-zone” Analysis Showing Predicted Impact of Linear No-Flow Boundary Distance on Pressure Recovery Derivative Response, Following Termination of a 2-Day Constant-Rate Pumping Test.

Neeraj Gupta and Frank Spane attended the International Symposium on Site Characterization for CO₂ Geological Storage (CO2SC 2006) in Berkeley, California, March 20-22. This conference focused on site testing and characterization technology. Dr. Gupta presented on regional fluid flow in deep basins and Mr. Spane presented on reservoir testing in the AEP#1 test well. This conference provided exposure for the project as well as an opportunity to review testing options.

Task 4 – Reservoir Simulations

All 2-dimensional scenarios for the Rose Run Sandstone injection have been completed and a draft of the modeling report section for these simulations has been prepared. During January several 3-dimensional scenarios were completed and their results were incorporated into the draft report. The draft report on relative permeability analysis of the Rose Run samples was received from BP and this is being used to evaluate sensitivity of the injection rates to these parameters. Overall, bine-CO₂ relative permeability curves from the Rose Run Sandstone are comparable to other Paleozoic sandstone rocks in North America. These scenarios are unlikely to significantly change the current conclusion that based on the field data and modeling results, large-scale injection (>100 ktonnes/year/well) is feasible in the Rose Run Sandstone.

A teleconference was held with Joel Sminchak, Mark Kelley, Frank Spane, and Diana Bacon to discuss the conceptual model for Copper Ridge simulations. A memo by William Rike and a report by geologist Thomas Wynn which discuss the high permeability “B zone” of the Copper Ridge formation were reviewed by Diana Bacon. Joel Sminchak transmitted to Diana Bacon an excel spreadsheet containing diagrams of two conceptual models of the Copper Ridge formation: one where the porosity and permeability of the upper portion are averaged, and another where there are three distinct high permeability layers within the dolomite (Figure 2). The three-layer model will be used as the basis for a

geostatistical realization of the Copper Ridge formation. Diana Bacon revised and had cleared for release an abstract of her oral presentation and paper for GHGT-8.

Geochemical simulation using the EQ3/EQ6 model to evaluate the potential reactions between formation fluids and injected CO₂ was started in December with an expected completion of the scenarios during March. These analyses incorporate the most recent chemistry from brine samples in AEP#1 test well.

Figure 2. Compiled Site Characterization Information from Copper Ridge “B-zone” used to Develop Reservoir Model Layout.

Task 5 – Design the Future Injection and Monitoring Facility and Prepare Regulatory Permits

The draft Environmental Assessment document for NEPA purpose for injection was reviewed by Lucy Swartz, a NEPA expert at Battelle. Final completion will be achieved once the design scenarios are finalized. A draft UIC permit document was prepared for the project, pending final design specifications. In January, Joel Sminchak attended the GroundWater Protection Council annual Underground Injection

Control meeting where CO₂ storage was the theme. This meeting helped understand regulatory atmosphere and other practical aspects of injection that may affect the Mountaineer project.

Battelle is continuing to work with Fluor on obtaining CO₂ capture system information. In addition, the confidentiality disclosure agreement with Mitsubishi Heavy Industry was finalized through discussions between Battelle and AEP. Battelle also plans to work with Trimeric, a Texas-based small business, on evaluating a potential improvement in the amine-based capture system design. Battelle met with Praxair during February to discuss potential concepts in capture system improvements and practical aspects of CO₂ handling.

Continued progress was made during to further develop the injection system design options and screen monitoring technologies. A detailed well design and drilling program was developed for a multi-horizon well completion and optional monitoring well. The design considers a vertical completion in the Copper Ridge and a lateral completion in the Rose Run; both from the existing borehole. A detailed cost analysis is underway for this and comparative options. The design is also being evaluated to determine if there are any UIC issues that would require modifications to the preliminary design and to help guide selection of materials. Analysis of monitoring options was completed for the Mountaineer site. A preliminary monitoring schedule (Figure 3) was prepared for the site to help define costs and make best use of monitoring methods given the geologic setting at the Mountaineer site for CO₂ storage.

Time (Months)	-12	-10	-8	-6	-4	-2	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	
Phase	Preinjection Baseline Monitoring						Active Injection																			Post-Injection
Capture System																										
Compression																										
Transport																										
Injection System																										
SCADA																										
Health and Safety																										
Mechanical Integrity Test						X							X						X							X
Well Workover													X						X							X
Passive Seismic																										
Groundwater Monitoring	X			X			X			X			X			X			X			X				X
Soil-gas	X			X			X			X			X			X			X			X				X
Atmospheric Flux				X			X						X						X							X
Wireline						X				X			X			X			X			X				X
VSP/X-well Sesimic						X							X						X							X
Tracer Testing																										
Reservoir Sampling						X							X						X							X
Well Indicator sensors																										

Figure 3. Example of Preliminary Monitoring Schedule Chart for Mountaineer CCS Project.

Task 6 – Risk Assessment and Stakeholder Interactions

Risk and consequence assessment for the Mountaineer geological sequestration project is ongoing, in a phase-wise fashion. Preparation of input file for the leakage risk analysis using STOMP- CO₂ simulations, which includes cap rock, the entire overburden (~7842 ft), and the vadose zone, was completed previously. This required analysis of both saturated and 2 phase (CO₂-water) hydrologic characteristics of the site, with approximately 150 different soil/rock types. Initial simulations using this conceptual model were completed during January with trouble-shooting related to numerical instabilities. The current results for an injection scenario with three years of injection and 20 years of post-injection period show the initial movement of CO₂ into the immediate overlying caprock followed by stabilization and shrinking of the plume after injection stops. This analysis will be completed during the next two months and the results will be documented in the report on modeling and risk analysis.

A systematic risk screening effort using *Features, Events, and Processes* database for geologic storage of CO₂ was prepared for presentation at Fifth Annual DOE Conference on Carbon Capture and Sequestration.

Task 7 – Project Briefings and Meetings

- Presented and discussed project status with Mike Mudd during a meeting at AEP on January 12.
- Presented project overview to ConocoPhillips representatives during their visit to Battelle.
- Presented and discussed project status and technology overview for Mountaineer and MRCSP efforts to a group of NGO representatives on February 14 in Washington DC
- Presented project overview to Praxair representatives during their visit to Battelle to discuss both Mountaineer and MRCSP projects
- Two papers accepted for the Annual CO₂ sequestration conference in Alexandria VA for oral presentation.
- Two presentations were made at the International Symposium on Site Characterization for CO₂ Geological Storage (CO2SC 2006) in Berkeley, California, March 20-22.
- Several papers on the Mountaineer project have been accepted for oral and poster presentation at the GHGT-8 conference to be held in Trondheim, Norway during June.

Task 8 –Building the Regional Geologic Framework

Battelle continues to monitor ongoing or planned drilling activity in the region for opportunities to fill gaps in geologic data for deeper formations with the long-term goal of building a geologic framework for potential storage and containment zones in the Ohio River Valley region. Battelle met with Knox Energy geologist to discuss their planned drilling activities and explore collaboration options. A planned gas well location in NE Ohio was identified for expanded exploration. Preliminary plans were developed to characterize this well to increase information on CO₂ storage potential in the NE Ohio/NW Pennsylvania/W New York area.

4.0 CONCLUSION

The project remains on track to complete all major tasks during 2006 calendar year. Overall, the project is proceeding to pilot demonstration phase, and a strong team has been assembled to accomplish this undertaking. During the reporting period substantial progress was made in the planning and design of a pilot-scale CO₂ capture and injection demonstration at the Mountaineer site. Reservoir testing and computer simulations intimate that injection potential may be substantially more than anticipated for the Mountaineer site. As a first-of-a-kind system, this work involves numerous challenges, but a diverse range of resources are being utilized to meet the challenges.

4.1 Future Activities

With the completion of the reservoir testing, the remaining focus of the project will shift to the capture and injection system design issues. During the next few months the following areas of emphasis are anticipated:

- Complete the next phase of capture system design development in collaboration with system vendors
- Complete reservoir testing data analysis and incorporate into the reservoir model for Copper Ridge Dolomite zone
- Continued development of injection well design and monitoring system options

- Complete reservoir simulations of injection in Copper Ridge dolomite
- Presentations on systematic risk analysis and integrated CCS aspects of Mountaineer project at DOE Carbon Capture and Sequestration Conference in May in Washington, D.C.,
- Design and feasibility overview presentation on the Mountaineer project at the GHGT 8 conference in June in Trondheim, Norway
- Complete simulations of injection in Copper Ridge and finalize results from Rose Run
- Extending the modeling effort to risk assessment task.

5.0 REFERENCES

No references cited