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Work Flow Procedures for Deploying Prediction and Verification Techniques for Two CO_2 Enhanced Oil Recovery Projects

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If geological storage of CO_2 is to become reality, it will be critical to choose sites that have a high likelihood of successful long-term containment. This fundamental criteria is achieved through diligent characterization of the subsurface using the myriad of techniques developed over the last century for oil and gas exploration and production activities. While much has been learned about injecting and removing fluids from the subsurface, there is still a significant knowledge gap when it comes to predicting the long-term fate of stored CO_2. Currently, questions arise regarding the condition of existing wellbores, the integrity of the cap rock, effects of impurities, and plume dispersion within a reservoir when considering the injection of CO_2 as a technique to mitigate the current trend of venting to the atmosphere. In an effort to build confidence and propose protocols that will facilitate the completion of a 99% accurate material balance and subsequent accreditation, it will be necessary to obtain a thorough understanding of the mechanisms by which storage in a reservoir will take place. It will also be critical to develop and implement site-specific characterization and risk assessment activities with regard to the possible mechanisms for leakage and mitigation techniques that can be deployed should leakage occur.

To assess these challenges, two ongoing CO_2 enhanced oil recovery (EOR) projects are currently being conducted by the Plains CO_2 Reduction (PCOR) Partnership as part of the U.S. Department of Energy's (DOE's) Regional Carbon Sequestration Partnership (RCSP) Program. Since its inception in 2003, the PCOR Partnership has brought together over 85 public and private-sector groups working to lay the groundwork for practical and environmentally sound CO_2 storage projects in the heartland of North America. The PCOR Partnership includes nine states and four Canadian provinces (Figure 1). The program partners contribute time, resources, and expertise in an effort to determine the best solutions to the safe, effective, and efficient management of CO_2 emissions.

This paper will present both projects as case studies in the optimization of work flow for selecting appropriate prediction and verification techniques, as part of an overall monitoring, verification, and accounting (MVA) plan for use at sites with ongoing oil production activities. In an effort to design and maintain a cost-effective approach to MVA, the following philosophy has been employed in the design of both projects:

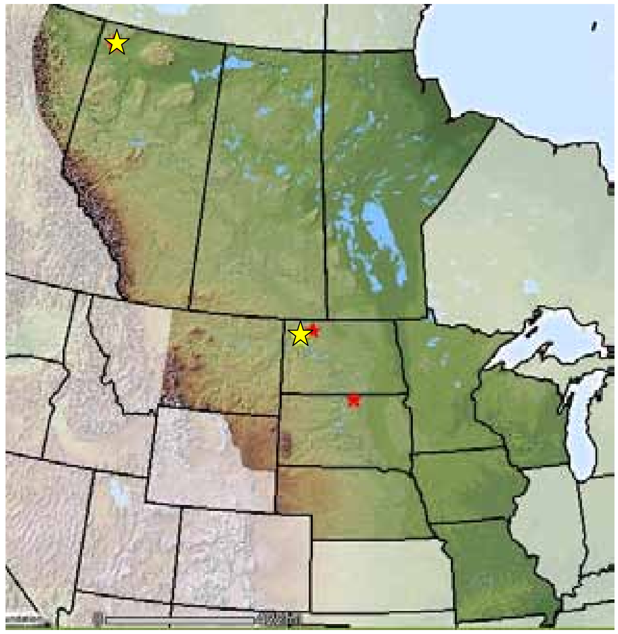

Figure 1. The PCOR Partnership covers an area greater than 1.4 million square miles, with representation from nine U.S. states and four Canadian provinces. The locations of the case studies presented in this paper are highlighted in yellow.

1. The use of existing data sets should be maximized in an effort to characterize the baseline conditions of the site.

2. The use of invasive or disruptive technologies to acquire new data will be minimized.

3. MVA data acquisitions will be coordinated with routinely scheduled operation activities.

4. The monitoring operations will be as transparent as possible to the day-to-day field operations.

The first case presented will focus on the design and implementation of prediction and verification activities at the Zama Acid Gas EOR, CO_2 Storage, and Monitoring Project. Since October 2005, the Zama Oil Field in northwestern Alberta, Canada, has been the site of acid gas (approximately 70% CO_2 and 30% H_2S) injection for the simultaneous purpose of EOR, H_2S disposal, and storage of CO_2. The Zama project has been designed to address the issue of monitoring CO_2 storage at EOR sites utilizing H_2S-rich acid gas as the sweep mechanism in a cost-effective and reliable manner. The primary issues that have been addressed include 1) cap rock leakage, 2) long-term fate prediction of injected acid gas, and 3) generation of data sets that will support the development and monetization of carbon credits. To address these issues, research activities have been conducted at multiple scales of investigation in an effort to fully understand the ultimate fate of the injected gas. Geological, geomechanical, geochemical, and engineering work has been used to fully describe the injection zone and adjacent strata in an effort to predict the long-term storage potential of this site.

The second case presents activities in the northwest MacGregor oil field in North Dakota, which has been designed to evaluate the potential for CO_2 storage and EOR in a carbonate formation deeper than 8000 feet. The overall project will focus on a variety of activities to 1) determine the baseline geological characteristics of the injection site and surrounding areas, 2) inject CO_2 into the target oil reservoir using a "huff and puff" approach, and 3) evaluate the effect that injected CO_2 has on the ability of the oil reservoir to storage injected CO_2 and produce incremental oil. Specific key prediction and verification elements of the MVA plan include the deployment and use of 1) the reservoir saturation tool, which will provide data on near-wellbore gas/fluid saturation, and 2) vertical seismic profiling, which will generate data on the lithology and gas/fluid saturation away from the wellbore up to 1000 feet away from the point of injection. Both of these techniques will be applied to the site before injection commences, immediately after injection ceases, and several weeks after the well is put back on production and the reservoir has reached equilibrium.

When considering the injection and storage of CO_2 into the subsurface as a means of mitigating the current trend of emitting to the atmosphere, it must first be recognized that each site will be unique and that one prescriptive approach will not be satisfactory. The work outlined here provides key work flow procedures to effectively screen technologies to apply the most appropriate prediction and verification techniques available. The techniques and work flows employed in these two projects are cost-effective and widely accepted means of providing critical data that can be used by site operators so that the CO_2 storage can be validated and the site can be accredited as injection commences.