ZAMA ACID GAS EOR, CO_2 STORAGE, AND MONITORING PROJECT

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From October 2005 through September 2009, 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 purposes of enhanced oil recovery (EOR), H_2S disposal, and storage of CO_2. Injection takes place at a depth of approximately 4900 feet into a Devonian-aged pinnacle reef structure. There are currently five such structures (out of as many as 800) in the field undergoing acid gas EOR. Research activities are taking place on one pinnacle, the “F” pool, with the results being used to better understand the field-scale application of EOR and CO_2 storage. The Plains CO_2 Reduction (PCOR) Partnership, led by the University of North Dakota Energy & Environmental Research Center, has conducted monitoring, verification, and accounting (MVA) activities at the site throughout this period while Apache Canada Ltd. has undertaken the injection and hydrocarbon recovery processes. This project has been conducted as part of the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) Regional Partnership Program and has been recognized by the Carbon Sequestration Leadership Forum as being uniquely able to fill key technological gaps with regard to geological storage of CO_2.

The purpose of the MVA program is to 1) provide a set of baseline conditions upon which the effects of the project can be compared to data gathered during and after injection operations, 2) generate data sets that demonstrate the security of the injection program from the perspectives of containment and safety, and 3) establish a technical framework for the creation and ultimate monetization of carbon credits associated with reduction of emissions and the geological storage of CO_2 at Zama. MVA program activities that resulted in the determination of baseline conditions included geological and hydrogeological characterization at various scales, characterization of the F pool reservoir, determination of geomechanical and geochemical properties of key rocks in the reservoir/seal system, and evaluation of wellbore integrity issues. Field-based elements of the MVA program included the introduction of a tracer and data collection (i.e., formation fluid sampling and analysis, reservoir dynamics monitoring) from the injection, production, and monitoring wells. Other key elements of the MVA program included documentation of the permitting process and regulatory framework for the project, determination of material balance based on the collected field data, and a modeling-based study of historical and new reservoir pressure data in an effort to maximize the use of pressure data as a means of early identification of leakage. Generally speaking, monitoring activities were focused on the near-reservoir environment, including monitoring for leakage through cap rock, wellbore leakage, and spill point breach.

Geological investigation was focused on the reservoir, local, and regional (subbasinal) scales. Results of these investigations indicated that the likelihood of natural leakage from this system is unlikely and regional flow is extremely slow, on the order of thousands to hundreds of thousands of years to migrate out of the basin. The potential for leakage through existing wellbores was also evaluated and found to be very low. Geomechanical evaluations, including 3-

D modeling, were completed on the injection zone and adjacent stratigraphy. This series of tests confirms that the geological structures that are being utilized are excellent for storage. The cap rock is extremely stable, has extremely low permeability, and is not likely to fracture when subjected to injection pressures well beyond the maximum allowed. Geochemical modeling aids in the understanding of the long-term fate of acid gas injected into carbonate rocks. Evaluations of the Zama system indicate that the impact of mineralization on the overall storage capacity of the system is negligible and will occur very slowly over geological time scales.

Acid gas has been obtained as a by-product of oil production in the Zama Field and a subsequent fluid separation process at the on-site facilities. During the separation process, oil and gas are sent to market while acid gas is redirected back to the field for utilization in EOR operations. Previously, CO_2 was vented to the atmosphere, and sulfur was separated from the H_2S and stockpiled in solid form on-site for subsequent sale. This project has enabled the simultaneous beneficial use of each of these “waste” products and effective mitigation of two environmental concerns.

As of September 30, 2009, approximately 40,000 tons of acid gas had been injected into the pinnacle reef, of which approximately 25,000 tons were CO_2. Incremental oil production from the pinnacle reef over the course of the project as of September 30, 2009, was approximately 22,000 barrels. Results of the research activities at Zama indicate that the site will provide ample, secure storage for a project as large as 1 million tons injected per year. Combined with the added benefit of using acid gas for EOR, and in light of emerging carbon markets, the economics of CO_2 storage become tenable.

Overall, this project has been designed to address the issue of monitoring CO_2 storage at EOR sites in a cost-effective and reliable manner. The primary issues that were addressed include 1) determination of leakage, or lack thereof, from the pinnacle; 2) determination of the long-term fate of injected acid gas; and 3) generation of carbon credits associated with the geologic storage of CO_2 at the Zama oil field. To address these issues, a variety of research activities have been conducted at multiple scales of investigation, including geological, geomechanical, geochemical, and engineering work. These activities will provide the necessary confidence in the long-term containment of injected gas and validate stored volumes over the life of the project. While this project has been focused on one of the hundreds of pinnacles that exist in the Zama Field, many of the results obtained can be applied not only to additional pinnacles in the Alberta Basin but to similar structures throughout the world.