

Plains CO₂ Reduction (PCOR) Partnership

Fact Sheet

Practical, Environmentally Sound CO₂ Sequestration

Bell Creek Project – Enhanced Oil Recovery Resulting in Associated CO₂ Storage

The Plains CO₂ Reduction (PCOR) Partnership is studying associated carbon dioxide (CO₂) storage incidental to a commercial enhanced oil recovery (EOR) operation. The PCOR Partnership Phase III project is a collaborative effort with the operator of the Bell Creek oil field, Denbury Onshore LLC (Denbury), which began in 2010.

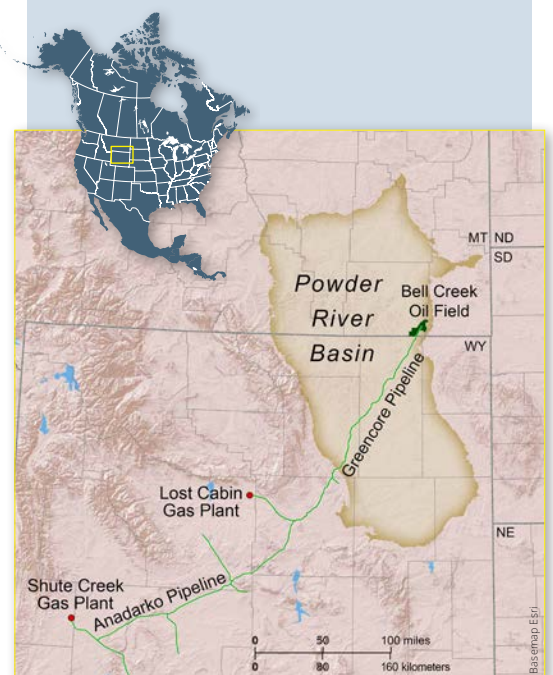
Objectives and Results to Date

The project is designed to 1) understand and predict the behavior of CO₂ in the reservoir, including how associated storage of CO₂ occurs during EOR; 2) validate that CO₂ can be effectively contained within oil-bearing sandstone formations; and 3) develop and demonstrate practical, cost-effective monitoring, verification, and accounting (MVA) techniques that can be adapted into commercially viable strategies for monitoring the performance of both EOR and associated CO₂ storage incidental to hydrocarbon recovery.

Notable achievements thus far include:

- A computer model of the geologic formations that make up the EOR complex (oil reservoir and cap rocks) based on data from rigorous geologic, geotechnical, and hydrogeologic characterization.
- Performance forecasts that use the geologic model to simulate the fluid and reservoir behavior under various CO₂ injection and operating scenarios.
- A research monitoring program that has demonstrated that associated CO₂ storage incidental to EOR is effective and safe.
- Integration of MVA techniques as part of an overall monitoring strategy that provides faster, more reliable, lower-cost, lower-impact, actionable results that inform operational decisions.
- A rigorously characterized test site, which has enabled the development of new, low-impact, near-real-time geophysical CO₂-monitoring techniques, such as Krauklis seismic wave (K-wave) and scalable, automated, semipermanent seismic array (SASSA).

Fast Facts



Project Type: CO₂ Enhanced Oil Recovery
Location: Southeast Montana, United States
Injection Zone: Lower Cretaceous Muddy (Newcastle) Formation
Depth: 4300–4500 feet (1300–1370 meters)
CO₂ Source: Gas-processing plants, Wyoming
CO₂ Injection Began: May 2013
Associated CO₂ Stored: 4.2 million tonnes (as of August 2017)
Partners: Denbury, PCOR Partnership, U.S. Department of Energy



MVA strategies developed at Bell Creek can be adapted to other operations injecting anthropogenic CO₂ and can help address the threat of climate change.

Approach

The Bell Creek oil field was discovered in 1967. Oil was produced during both primary production and a subsequent waterflood prior to the start of CO₂ injection for EOR in May 2013. The operational and production history of the field combined with preexisting geologic data served as the backbone for the project. Enhanced site characterization; comprehensive monitoring, modeling, and simulation activities; and development of verification and accounting strategies were integrated as part of the research project to understand associated CO₂ storage. These activities are undertaken in iterative phases that gather information, test techniques, assess results, and determine next steps.

Site Characterization

Characterization efforts incorporated preexisting data and knowledge, including well logs, drilling reports, pressure and injectivity tests, and production histories. Data gaps were identified, and understanding was enhanced through additional data collection and expanded characterization efforts. Well locations and elevation data were corrected using a lidar survey. Several vintage 2-D seismic and vertical seismic profile (VSP) data sets were reprocessed, and baseline pulsed-neutron logs (PNLs) were collected to improve petrophysical and structural interpretation of the reservoir and overlying zones.¹ 3-D seismic data improved structural interpretation of the injection zone and overlying seals. This work provided a foundation for understanding how fluids, including injected CO₂, move and interact in the subsurface.

Monitoring

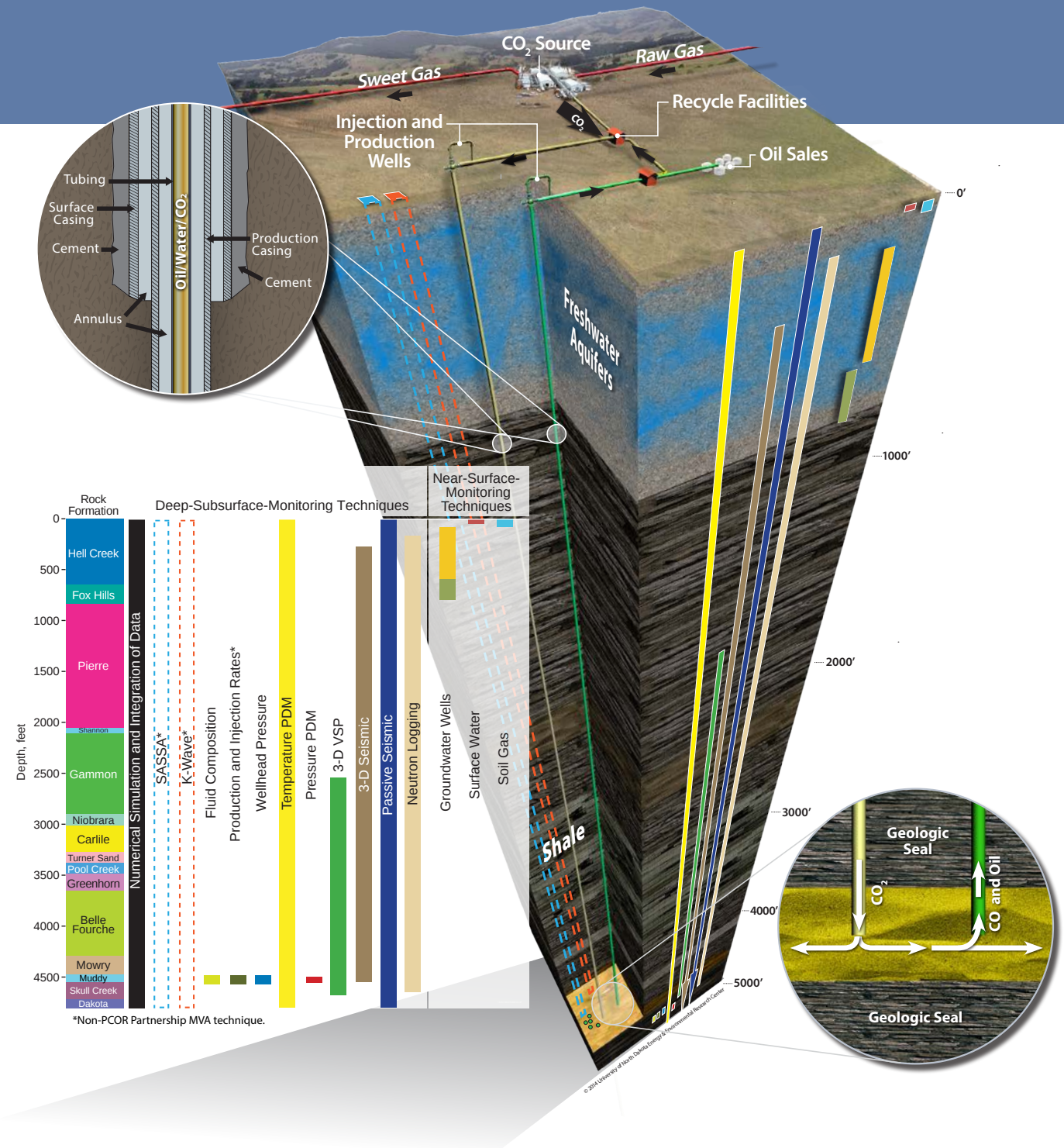
A variety of monitoring techniques were used to collect baseline data to establish the natural variability of soil gas and water chemistry in the near-surface environment; track CO₂ movement within the EOR complex; and demonstrate safe, effective associated CO₂ storage. Monitoring of surface water, groundwater, and soil gas chemistries provides data that can be used to both show that these environments are not adversely impacted by injection of CO₂ and understand anomalies and natural variability in the system should they occur.² Subsurface monitoring focuses on fluid behavior in the EOR complex using the techniques listed in the illustration at right. Injected and produced fluid rates, pressures, and compositions are monitored to understand performance and calibrate the geologic and forecast models. Information from MVA techniques is used to inform operational decisions and could be used in a similar way for dedicated storage projects in non-EOR sites.



The surface- and near-surface-monitoring program characterized natural CO₂ variability in the near-surface environment.

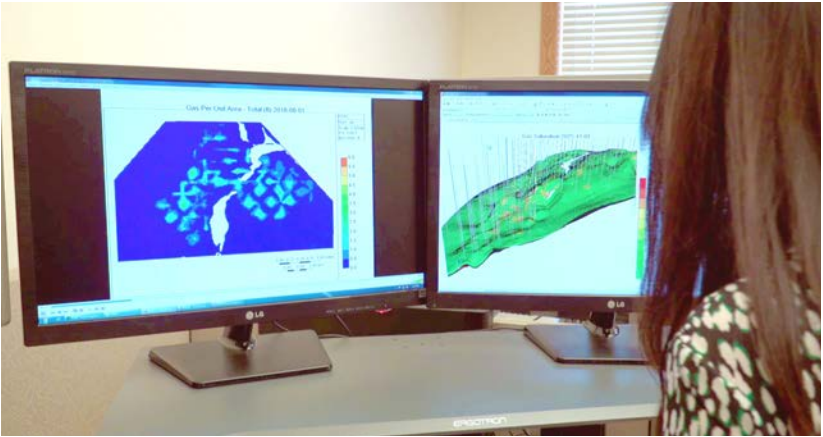
Monitoring and Injection Activities

The research-monitoring program leverages 1.5 years of preinjection and over 4 years of operational monitoring data to validate individual MVA tools as well as to investigate, develop, demonstrate, and validate MVA strategies broadly applicable to EOR and understanding associated CO₂ storage incidental to EOR.



Path Forward

Project activities at Bell Creek have transitioned from validating applications for individual MVA tools to focusing on developing cost-effective MVA strategies that combine appropriate high-value techniques to yield a more commercially viable long-term MVA approach.



Computer Modeling and Simulation

Preexisting characterization data (well log, core, and fluid data) were used to develop a first-generation model of the geology and fluids in the EOR complex. The model was then validated using available injection and production data and newly acquired MVA data. As new data became available, the model was further refined, eliminating inconsistencies between predictions and real-world observations. As a result, the simulations of the second- and third-generation models are more accurate in predicting how the CO₂ will behave over time based on a given injection scenario. Improved forecasts provide the ability to better evaluate the relationship between oil recovery and associated CO₂ storage; plan when, where, and how to effectively apply monitoring techniques; and provide feedback on the performance of monitoring techniques. The calibrated forecast models also provide the ability to predict performance under several operational scenarios in order to determine how the project can be operated to tune performance.

Monitoring, Verification, and Accounting

Initial monitoring efforts comprised preinjection and documenting the first million tonnes of associated CO₂ storage. This effort focused on understanding the viability of individual monitoring techniques applicable to commercial-scale CO₂ injection projects (i.e., >1,000,000 tonnes per year of CO₂ injected).³ Subsequent monitoring work focuses on developing, validating, and demonstrating MVA strategies (how groups of monitoring techniques can be combined to cost-effectively meet several monitoring objectives) applicable to commercial-scale projects. Data acquired through the MVA program are used to calibrate and refine the accuracy of simulation predictions. This integrated process generates more accurate predictions that, in turn, are used to target future MVA strategies.



Building on the Bell Creek Project

Individual MVA techniques are being evaluated to provide insight into how they can be integrated as part of cost-effective monitoring strategies for nonoilfield commercial carbon storage projects. Insights from the Bell Creek project enabled the development of and provided an ideal environment to demonstrate two emerging geophysical techniques, referred to as K-wave and SASSA. These techniques show promise for providing more cost-efficient, lower-impact, near-real-time solutions for long-term monitoring. The results of the research at Bell Creek are expected to benefit both dedicated CO₂ storage—where eliminating emissions of anthropogenic CO₂ is the primary purpose of underground injection—and associated storage of either anthropogenic or geologic CO₂ that occurs as a natural part of CO₂ EOR operations.

CO₂ EOR and Associated Storage

Injecting CO₂ into an oil-producing zone is called CO₂ EOR or CO₂ flooding. When CO₂ comes into contact with oil, it dissolves into the oil, reducing the oil's viscosity and increasing the oil's mobility. Combined with restoring the original pressure drive in the reservoir, this increases oil production rates and extends the operational life of the oil field. Because CO₂ dissolves into the oil, some of the injected CO₂ will come to the surface with the oil. Oilfield operators separate that CO₂ and reinject it along with new CO₂. Over the years of an EOR operation, there are many cycles of CO₂ injection. With each cycle, another portion of injected CO₂ becomes permanently stored in the oil reservoir through a combination of several trapping mechanisms. At the end of the project, nearly all of the purchased CO₂ remains naturally trapped in the reservoir. This is called associated CO₂ storage.

CO₂ EOR and Carbon Footprint

When the carbon dioxide for CO₂ EOR comes from an anthropogenic or man-made source, the CO₂ EOR operation sequesters CO₂ that would otherwise be released to the atmosphere. The carbon content of the oil itself is not changed. But because all of the CO₂ is ultimately stored at the end of the project, the overall carbon footprint of the process is reduced.⁴ Oil with this reduced-life-cycle carbon footprint is called “greener.” The Bell Creek Field is one of a small number of CO₂ EOR floods using anthropogenic CO₂ and, as a result, produces oil with a lower overall carbon footprint.



Bell Creek has been a development and demonstration site for CO₂-monitoring technologies, which are validated using more conventional and proven monitoring.

References

- ¹ Hamling, J.A., Gorecki, C.D., Klapperich, R.J., Saini, D., and Steadman, E.N., 2013, Overview of the Bell Creek combined CO₂ storage and CO₂ enhanced oil recovery project: *Enegy Procedia*, v. 37, p. 6402–6411.
- ² Botnen, B.W., Kalenze, N.S., Leroux, K.M., Klapperich, R.J., Glazewski, K.A., Stepan, D.J., Hamling, J.A., and Gorecki, C.D., 2016, Bell Creek test site—development of a cost-effective, long-term monitoring strategy: Plains CO₂ Reduction (PCOR) Partnership Phase III draft Task 11 Deliverable D55 for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-05NT42592, Grand Forks, North Dakota, Energy & Environmental Research Center, September.
- ³ Gorecki, C.D., Hamling, J.A., Klapperich, R.J., Steadman, E.N., and Harju, J.A., 2012, Integrating CO₂ EOR and CO₂ storage in the Bell Creek oil field, in 2012 Carbon Management Technology Conference: Orlando, Florida, February 7–9, 2012, Proceedings, CMTC 151476.
- ⁴ Azzolina, N.A., Peck, W.D., Hamling, J.A., Gorecki, C.D., Ayash, S.C., Doll, T.E., Nakles, D.V., and Melzer, L.S., 2016, How green is my oil? A detailed look at greenhouse gas accounting for CO₂ enhanced oil recovery (CO₂ EOR) sites: *International Journal of Greenhouse Gas Control*, v. 51, p. 369–379.

The Plains CO₂ Reduction (PCOR) Partnership is a group of public and private sector stakeholders working together to better understand the technical and economic feasibility of storing CO₂ emissions from stationary sources in the central interior of North America. The PCOR Partnership is led by the Energy & Environmental Research Center (EERC) at the University of North Dakota and is one of seven regional partnerships under the U.S. Department of Energy's National Energy Technology Laboratory Regional Carbon Sequestration Partnership Initiative. To learn more, contact:

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