Plains CO_2 Reduction (PCOR) Partnership Monthly Update
December 1–31, 2015

PHASE III ACTIVITIES

Task 1 – Regional Characterization (Wesley D. Peck)

Highlights

- Attended the Science & Engineering Research Committee held December 14, 2015, in Ottawa, Ontario, Canada.
- Provided internal SQL training to two internal researchers for use in accessing data for ArcGIS applications.
- Continued development of criteria for the Inyan Kara Basin model.
- Continued compiling regional characterization data for the Mission Canyon Formation.
- Continued efforts to update Deliverable (D) 81, Regional Carbon Sequestration Atlas (update), due August 31, 2016. Concentrated efforts on the Aquistore section.
- Updated information and continued work on the partners-only Decision Support System (DSS) Web site:
  - Continued activities to update the content of the **PCOR Partnership general database**, including the following:
    - Updated North Dakota and Montana Petra projects with the latest general well information from each state's online resources: 135 new North Dakota wells and four new Montana wells added.
    - Updated North Dakota production data.
    - Updated South Dakota, Saskatchewan, and Manitoba projects.
  - Imported new LAS well files for 2015 wells from the North Dakota Industrial Commission (NDIC) Web site into the North Dakota project.
  - Continued database preventive maintenance of Petra projects.
  - Continued integrating current CO_2 storage calculations into the PCOR Partnership GIS (geographic information system).
- With regard to the **Williston Basin** CO_2 Storage Sink Relative Permeability Laboratory Characterization:
  - Continued work on the report.
  - Continued thin-section petrographic analyses.
  - Continued preparing the relative permeability system, including shakedown, brine recovery procedures, and troubleshooting and repairing a leak in the system.
  - Continued mercury injection capillary pressure (MICP) and x-ray diffraction (XRD) analyses and 3-D bulk volume measurements of the Broom Creek samples.
  - Completed XRF analyses of the Broom Creek samples.

  - Continued data reduction.
  - XRD data continue to be quality-checked.
- With regard to the **Aquistore** project's static modeling and dynamic predictive simulations effort:
  - Held an internal monthly update meeting to discuss abstract/presentation topics for upcoming conferences.
  - Updated Aquistore simulation with new injection data gathered since the restart of operations in November 2015. Well injection performance has recently improved, and this has been challenging to match in the simulation. Additional analysis of the data is proceeding to help explain the relationship between injectivity, pressure, and temperature.
  - Continued to process and analyze daily injection data for inclusion in the simulation model.
  - Continued to update the JewelSuite model.
  - Continued history matching, with an attempt to correct injection rate to account for temperature effect.
  - Continued work on the draft simulation report.
  - Ran an updated simulation, and compared the differences of simulation results to field data.
  - Separated injection data before and after the recent well injection performance improvement.

Task 2 – Public Outreach and Education (Daniel J. Daly)

Highlights

- Continued work on the draft Phase II project fact sheets, including applying changes based on final internal review to the updated Phase II Northwest McGregor and Lignite fact sheets.
- Began updating the Phase II Zama fact sheet.
- Held the Outreach Working Group (OWG) monthly call on December 17, 2015, and continued review and revision on the U.S. Department of Energy (DOE) outreach best practices manual (BPM) for the OWG. Exchanged e-mails with the OWG lead regarding the work.
- Provided comments and updated a draft of an abstract on outreach to be submitted to the Greenhouse Gas Control Technologies (GHGT)-13 Conference to be held November 14–18, 2016, in collaboration with the Petroleum Technology Research Centre (PTRC).
- Began working on a draft questionnaire for Bell Creek Field landowners with PCOR Partnership monitoring, verification, and accounting (MVA) personnel. The draft questionnaire deals with landowner perception of water quality-monitoring activities, water quality information reports, and the quality of their interaction with EERC personnel.
- Continued efforts with regard to the public Web site (www.undeerc.org/pcor), including the following:
  - The updated (revised) pages for the PCOR Partnership public Web site, including a revised home page, went live December 1, 2015 (www.undeerc.org/PCOR/).
  - Released an e-mail blast announcing the addition of the Household Energy and Carbon Footprint Web pages (funded in part by the North Dakota Department of Commerce Office of Renewable Energy and Energy Efficiency) to the PCOR Partnership Web site on December 15, 2015 (www.undeerc.org/PCOR/household-energy/). The Web pages provide

information to homeowners and interested parties regarding the types of energy that come to households and, depending on how much households use, the ability to calculate their carbon footprint. The Web pages also contain information on actions individual homeowners can take to reduce household carbon footprint and what society as a whole can do.
  - Provided an interview for the EERC electronic newsletter concerning the addition of the North Dakota Department of Commerce Division of Community Services (DCS)-funded household energy and carbon footprint pages that are available from the PCOR Partnership Web site.
  - On December 17, 2015, attended a meeting with the Grand Forks, North Dakota, city government Green Committee to discuss the addition of the DCS-funded Household Energy and Carbon Footprint Web pages, ways they could publicize the Web pages, and ways the Web pages could be used.
  - Met with EERC PCOR Partnership senior management to review the new technical poster page, and began addressing their review comments.
  - Continued limited content development for the next round of updates for the public PCOR Partnership Web site.
  - Continued ongoing identification and repair of broken links.
- Continued collaborative efforts with Prairie Public Broadcasting (PPB), including the following:
  - Continued work on the coal documentary (D22), including organizing window dub, transcription, and preliminary storyline review.
  - Continued work on the Bell Creek (D21) documentary, including preparing a presentation and interview questions for D21 and reviewing B-roll and interview materials and schedules.
  - Continued budgeting discussions.

Task 3 – Permitting and NEPA (National Environmental Policy Act) Compliance (Charles D. Gorecki)

Highlights

- Attended a Webinar entitled "EPA's Proposed New Emission Rules and Impact on Oil & Gas Industry" presented December 8, 2015, by Jack Luellen, a partner with Fox Rothschild LLP, and hosted by the Association of Desk and Derrick Clubs (ADDC).
- Attended a Global CCS (carbon capture and storage) Institute Webinar entitled "Lessons Learned on CO_2 Storage from the Midwest Regional Carbon Sequestration Partnership Program," hosted by Battelle on December 8, 2015.
- Attended a presentation entitled "Smart Waterflood in Carbonates: A Promising IOR Method?," presented December 10, 2015, in Grand Forks, North Dakota, by Professor Hemanta Sarma, Oil and Gas Engineering, Department of Chemical & Petroleum Engineering, University of Calgary, Alberta, Canada.
- Continued work on D76 (once considered a value-added report) on rules, regulations, and statutes crosswalk and flowchart for various scenarios of CCS geologic storage and for CO_2 enhanced oil recovery (EOR) for each of the PCOR Partnership states and provinces. Began review of Missouri Oil and Gas regulations.

- Continue preparing the Wyoming injection well and underground injection control (UIC) permitting rules/regulations/statutes flowchart.
- Continued review of Alberta's permitting process.
- Began reviewing Wyoming's permitting process.
- Continued work on preparing descriptor language and flowcharts of North Dakota injection well-permitting requirements.

Task 4 – Site Characterization and Modeling (James A. Sorensen)

Highlights

- **Bell Creek** test site activities included the following:
  - Continued work on the PCOR Partnership site characterization BPM (D35).
  - Continued work on the construction of regional- and basin-scale Bell Creek Muddy Formation models.
  - Continued work on comparing pulsed-neutron logging (PNL) data to history match results for oil saturations and effective porosities.
  - Continued seismic horizon interpretation in the reprocessed baseline 3-D and repeat 4-D seismic surveys and linking the Hampson–Russell outputs with the geologic modeling software (Petrel).
  - Continued work on **geomechanical modeling**, including the following:
    - Continued updating the rock mechanical properties of the 3-D MEM, including the Young's Modulus, Poisson's Ratio, unconfined compressive strength, and in situ stresses, using log data (e.g., PNL, gamma ray [GR], density [RHOB], distributed transaction coordinator [DTC], and distributed temperature system [DTS]) and Petrel software.
    - Continued preparing for the geomechanical simulation work, including improving simulation efficiency and assessing the geomechanics simulation functionality of Computer Modelling Group, Ltd.'s (CMG's) GEM software.
    - Compared the geomechanical properties in the 3-D MEM to log data.

Task 5 – Well Drilling and Completion (John A. Hamling)

This task ended in Quarter 3 – Budget Period (BP) 4, Year 7 (June 2014).

Task 6 – Infrastructure Development (Melanie D. Jensen)

Highlights

- Continued work on an updated version of the CO_2 capture technologies report. Added summaries for several technologies that were not included in the first version of the capture technology overview. Information for the technologies was found in the presentations from the 2014 and 2015 DOE National Energy Technology Laboratory (NETL) capture technology meetings.
- Researched the CCS CO_2 tax credit for a partner who inquired.
- Met with an Energy & Environmental Research Center (EERC) researcher to discuss surface facilities at oil fields that are used during recycling the CO_2.

Task 7 – CO_2 Procurement (John A. Harju)

This task ended in Quarter 4 – BP4, Year 6 (September 2013).

Task 8 – Transportation and Injection Operations (Melanie D. Jensen)

Highlights
This task ended in Quarter 4 – BP4, Year 8 (September 2015).

Task 9 – Operational Monitoring and Modeling (John Hamling/Larry Pekot)

Highlights

- Attended the 2015 International Energy Agency Greenhouse Gas (IEAGHG) R&D Carbon Capture and Storage Summer School held December 6–12, 2015, in Perth, Australia.
- Attended the Global CCS Institute Webinar "Lessons Learned on CO_2 Storage from the Midwest Regional Carbon Sequestration Partnership Program," hosted by Battelle on December 8, 2015.
- Attended CO_2 Conference Week held December 8–11, 2015, in Midland, Texas, where we presented "Laboratory Studies of MMP (minimum miscibility pressure) and Hydrocarbon Mobilization in Conventional and Bakken Plays using CO_2, Methane, and Ethane" during Theme Session 3: "CO_2 Flooding Case Histories."
- With regard to DOE BPMs:
  - DOE BPM for MVA:
    - Reviewed and provided comments on draft Chapters 1 and 3.
    - Developed and submitted five PCOR Partnership call-out boxes to the Regional Carbon Sequestration Partnership (RCSP) group for consideration of inclusion in the BPM:
      - Pulsed-Neutron Log Use Within a Monitoring, Verification, and Accounting (MVA) Program
      - Using Near-Real-Time History Matching to Guide MVA Deployment
      - Designing an MVA Program to Reduce Risk and Meet Regulatory Requirements
      - PNL and Seismic Monitoring Integration for Risk Reduction
      - Periodic Surface 3-D Seismic Surveys
  - DOE Carbon Storage and Well Management Systems BPM:
    - The PCOR Partnership revised and submitted Chapter 5 – Injection Operations on December 31, 2015. Included were three PCOR Partnership-related call-out boxes entitled:
      - Formation Pressure Testing for Reservoir Analysis
      - Landowner Relations
      - Consideration of Wildlife During CCS Project Planning
- Began work on Milestone (M) 54 entitled "Initial Processing and Analysis of Historic InSAR Data Completed."
- Submitted M53 Entitled "Bell Creek Test Site – Expanded Baseline and Time-Lapse 3-D Surface Seismic Survey Completed" on December 17, 2015. Received DOE approval on December 18, 2015.

- Prepared and submitted an abstract entitled "How Green Is My Oil? A Detailed Look at Carbon Accounting for CO_2 Enhanced Oil Recovery Sites (CO_2 EOR)" for the Carbon Capture, Utilization, and Storage (CCUS) Conference to be held June 14–15, 2016.
- Began preparing abstracts for GHGT-13 regarding PCOR Partnership seismic work, the impact of CO_2 impurity on MMP and oil recovery performance in the Bell Creek Field, and application of dimensionless groups in field-scale CO_2 flooding history matching.
- Began planning for meetings with Denbury in Plano, Texas, in early January 2016, including work on a surface time-lapse seismic presentation.
- Discussed internally options for publication of our MMP method and results in a journal article.
- Bell Creek injection-phase site activities included the following:
  - Continued reservoir pressure and distributed temperature monitoring of the 05-06 OW (observation well) from the permanent downhole monitoring (PDM) system using the casing–conveyed pressure–temperature gauges (PTGs) and fiber optic distributed temperature system (DTS):
    - Continuous operation since April 2012.
    - Successfully installed replacement PROMORE 05-06 OW PTG interrogator (part of the PDM system), which was necessary because of communication issues while downloading data. Will send the interrogator that was replaced back to PROMORE as an exchange, and they will download and send the data from the replaced unit.
  - Continued dynamic reservoir pressure and multiphase fluid flow simulation efforts:
    - Consistent progress since April 2011.
    - Began preparing a Phase 3–7 dynamic model (from Version [V] 2 full-field model) for predictive simulations.
  - Continued passive seismic monitoring of 04-03 OW using the borehole seismic array:
    - Continuous operation since May 22, 2013.
    - Remotely restarted the passive seismic monitoring system after a crash. System is currently up and running.
  - Completed analysis of the purchase and recycle gas stream samples collected on September 16–17, 2015 (Table 1). Four samples from the purchase gas stream and four samples from the recycle gas stream were collected to investigate short-term variability in the injected gas composition in order to provide improved gas composition estimates for calculating CO_2 storage volumes.
  - Continued working with Denbury personnel on oil and gas samples from three wells in Phase 1 and purchase/recycle gas sampling (timing/frequency).
  - Renewed a software license for COMSOL Multiphysics and Subsurface Flow module. This simulation software has multiple applications, one of which is simulation of fluid flow in the subsurface.

Table 1. Oil and CO_2 Gas Stream Sampling and Analyses

Stream(s)	Dates Sampled
Production: Oil and CO_2 Gas[1]	Sept 2014[2], Nov/Dec 2014, Jan 2014[3], March 2015, July 2015
Purchase/Recycle: CO_2 Gas[4]	May 2014[5], June 2014, July 2014, Sept 2014, Oct 2014, April 2015, July 2015, **Sept 2015**

[1] Wells 56-14R, 32-02, and 05-06 unless otherwise noted; [2] Wells 56-14R and 32-02 only; [3] Well 05-06 only; [4] Both purchase and recycle streams unless otherwise noted; [5] Purchase stream only.

- Matched the primary depletion history in Phase 3.
- Reviewed and processed PDM data and potential ways to revise the processing.
- Continued 4-D seismic analysis, including technical parameterization of fluid substitution modeling, seismic properties estimation, and crossplotting. Prepared a presentation for Denbury meetings in Plano, Texas, in January 2016.
- Continued matching production history in Phase 3 area for the primary depletion stage.
- Began work on the life cycle analysis of CO_2 EOR.
- Modified the reservoir properties in Phases 1 and 2 areas of the V3 geologic model update.
- Divided the large-scale field model into five regional-phase-scale models.
- Continued repeat analyses of miscible-phase sampling of mobilized hydrocarbons using methane, CO_2, and ethane at Bell Creek reservoir conditions.
- Proposed regridding Bell Creek Phases 3–6 model at 300-ft × 300-ft cell size. Requires additional investigations to ensure data export to CMG is accurate.
- Separated the Phase 3 simulation model area with the 100-ft × 100-ft grid. Model executes more quickly than the Phases 3–6 model, but gas production is not matched.
- Continued horizon interpretation and quality control for 4-D analysis.
- With regard to the November 2015 Bell Creek Field groundwater and soil gas sample event (October 26 – November 17):
  - Continued quality assurance/quality control on gas bag analyses.
  - Completed soil gas sample analyses on over 180 total gas bag samples.
    - Processing is under way.
  - Completed water field parameter measurements for 12 shallow groundwater and two Fox Hills Formation groundwater location sample analyses.
    - Processing is under way.
  - Conducted additional water parameter field measurements, and sampled the two Fox Hills Formation groundwater locations and one groundwater well.
    - Laboratory analysis is under way.
- With regard to the Bell Creek site visit November 16–20, 2015:
  - Submitted oil samples from 05-06 and 56-14 wells.
- Continued work on the Bell Creek Field landowner questionnaire with the Task 2 team.
- Used the most recent publicly available data to determine that cumulative total CO_2 gas injection is 3,848,446 metric tons through October 31, 2015. This value represents the total gas volume injected, which includes purchase and recycle streams and is NOT corrected for a gas composition of approximately 98% CO_2 (Table 2). It should be noted that there were two injection wells that had cumulative data added to the Montana Board of Oil and Gas (MBOG) database during the October 2015 injection updates for this monthly reporting period; these cumulative totals consequently updated previous months' (March 2014 until current) totals.
- As of October 31, 2015, the most recent month of record, 2.632 million tonnes of total gas (composition of approximately 98% CO_2) has been purchased for injection into the Bell Creek Field, equating to an estimated 2.582 million tonnes of CO_2 stored (Table 3). A separate methodology from that used to calculate total gas injected was used to cumulative associated CO_2 storage volume estimate by correcting the gas purchase volume (approximately 98% CO_2) obtained from Denbury's custody transfer meter with gas compositional data.

Table 2. Bell Creek CO_2 Gas Injection Totals for October 2015 (cumulative totals May 2013 to October 2015)*

	October 2015 Injection
Total, Mscf	3,720,906
Total, U.S. tons†	121,830
Total, metric tons†	193,264
Cumulative Total, Mscf ‡	74,094,137
Cumulative Total, U.S. tons†‡	4,238,068
Cumulative Total, metric tons†‡	3,848,446

Source: MBOG database.

* There has been a lag in posting of injection/production volumes to the MBOG database. Total gas injection volumes are ***NOT CORRECTED*** for gas composition and include the combined purchased and recycled gas streams.

† This was calculated utilizing a conversion of 17.483 Mscf/U.S. ton and 19.253 Mscf/metric ton.

‡ Cumulative totals are for the period from May 2013 to the month listed.

Table 3. Cumulative Total Gas Purchased and Estimated Associated CO_2 Storage Volumes for the Bell Creek Field[1]

	October 2015 Gas Volume
Monthly Total Gas Purchased, MMscf[2]	1671
Monthly Total Gas Purchased, million tons[2]	0.096
Monthly Total Gas Purchased, million tonnes[2]	0.087
Cumulative Total Gas Purchased, MMscf[2,3]	50,677
Cumulative Total Gas Purchased, million tons[2,3]	2.899
Cumulative Total Gas Purchased, million tonnes[2,3]	2.632
Cumulative Total CO_2 Stored, MMscf[3,4]	49,712
Cumulative Total CO_2 Stored, million tons[3,4]	2.843
Cumulative Total CO_2 Stored, million tonnes[3,4]	2.582

[1] Conversion factors of 17.483 Mscf/ton and 19.253 Mscf/tonne were used to calculate volumes.

[2] Total gas purchased volumes are ***NOT CORRECTED*** for gas composition.

[3] Cumulative totals are for the period from May 2013 to the month listed.

[4] Total gas CO_2 stored volumes are ***CORRECTED*** for gas composition.

- Continued injection-phase sampling work, including the following:
  - Traveled to Gillette, Wyoming, December 7–11, 2015, primarily for non-PCOR Partnership-related work. Borehole array computers were powered down, removed, dismantled, and cleaned, and a hardware issue was fixed. Computers were reinstalled and brought back online. New satellite provider was installed and remote access tested.

Task 10 – Site Closure (to be announced [TBA])

- This task is anticipated to be initiated in Quarter 3 – BP 5, Year 9 (April 2016).

Task 11 – Postinjection Monitoring and Modeling (TBA)

- This task is anticipated to be initiated in Quarter 3 – BP5, Year 9 (April 2016).

Task 12 – Project Assessment (Loreal V. Heebink)

Highlights

- Submitted D57 entitled "Annual Assessment Report" on December 31, 2015.

Task 13 – Project Management (Charles D. Gorecki)

Highlights

- Attended the Carbon Capture Sequestration and the Carbon Capture Utilization Working Group meeting held December 2, 2015, in Austin, Texas.
- Attended the Intelligent Monitoring Systems Project Kickoff Meeting, and provided an update on the PCOR Partnership Program on December 2–3, 2015, in Pittsburgh, Pennsylvania.
- Attended the PCOR Partnership continuation application meeting held December 4, 2015, in Morgantown, West Virginia.
- Attended CO_2 Conference Week held December 8–11, 2015, in Midland, Texas.
- Reviewed the DOE risk analysis BPM draft. Comments were provided to the BPM working group leads.
- Participated in the DOE BPM Synergy Webinar on December 10, 2015.
- Attended National Risk Assessment Partnership (NRAP) beta tool Webinar (Short-Term Seismic Forecasting Tool). We plan to test several of the beta tools and will be attending the corresponding Webinars.
- Attended the NRAP beta tool Webinar (IAM-CS and RROM-Gen tools) on December 7, 2015.
- Prepared and submitted an abstract entitled "The Plains CO_2 Reduction Partnership: Guiding CCS Deployment in Central North America" for the CCUS Conference, to be held June 14–16, 2016.
- Continued planning for the spring 2016 Technical Advisory Board (TAB) meeting to be held in New Orleans, Louisiana, on April 4–6, 2016.
- Began planning the 2016 PCOR Partnership Annual Membership Meeting, including choosing a location (Grand Forks, North Dakota) and prospective dates.
- Distributed a summary of the September 2015 PCOR Partnership TAB meeting held in Chicago, Illinois (in conjunction with the PCOR Partnership Annual Membership Meeting) to the members.
- Continued working on the PCOR Partnership BP5 continuation application, including the task budgets and proposed adjustments of milestones and deliverables. A plan was created to have the application submitted to DOE by January 15, 2016.
- Held a task leader meeting December 15, 2015. Topics discussed included the BP5 continuation application, abstracts for the upcoming CCUS and GHGT-13 conferences, Bell Creek and Aquistore project updates, upcoming meetings/conferences, and task leader updates.
- Completed deliverables and milestones in December:
  - November monthly update
  - Task 9: M53 – Bell Creek Test Site – Expanded Baseline and Time-Lapse 3-D Surface Seismic Survey Completed
  - Task 12: D57 – Annual Assessment Report

Task 14 – RCSP Water Working Group (WWG) Coordination (Ryan J. Klapperich)

Highlights

- Continued review of the articles for the special issue of *International Journal of Greenhouse Gas Control* (IJGGC) on the "Nexus of Water and Carbon Capture and Storage." Sent comments to authors.
- Held the November/December WWG monthly conference call on December 8, 2015, to discuss progress of IJGGC Special Issue and DOE BPM sidebars related to WWG.
- Distributed notes from the October and December conference calls.
- Began preparing for the January 2016 WWG monthly conference call.
- Continued draft development for DOE BPM water-related sidebars.

Task 15 – Further Characterization of the Zama Acid Gas EOR, CO_2 Storage, and Monitoring Project (Charles D. Gorecki)

This task ended in Quarter 2 – BP4, Year 7 (February 2014).

Task 16 – Characterization of the Basal Cambrian System (Wesley D. Peck)

This task ended in Quarter 2 – BP4, Year 7 (March 2014).

Travel/Meetings

- December 1–3, 2015: traveled to Austin, Texas, to attend the Carbon Capture Sequestration and the Carbon Capture Utilization Working Group meeting.
- December 1–4, 2015: traveled to Morgantown, West Virginia, to attend the PCOR Partnership continuation application meeting.
- December 6–12, 2015: traveled to Perth, Australia, to attend the 2015 IEAGHG R&D Carbon Capture and Storage Summer School.
- December 7–11, 2015: traveled to Gillette, Wyoming, to conduct maintenance on geophysics systems at the Bell Creek site.
- December 8–11, 2015: traveled to Midland, Texas, to attend CO_2 Conference Week.
- December 13–15, 2015: traveled to Ottawa, Ontario, Canada, to attend the Science & Engineering Research Committee meetings.

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