The Role of Static and Dynamic Modeling in the Fort Nelson CCS Project

Energy & Environmental Research Center, University of North Dakota, Grand Forks, North Dakota

Abstract
Spectra Energy Transmission and the Energy & Environmental Research Center, through the Plains CO2 Reduction (PCOR) Partnership, are investigating potential commercial-scale carbon capture and storage (CCS) in a saline formation near Fort Nelson, British Columbia, Canada, by conducting detailed modeling and predictive simulations of injection at the Fort Nelson site. The results of the Fort Nelson modeling activities are providing insight regarding the movement of sour CO2, the potential effects that large-scale sour CO2 injection may have on neighboring natural gas production fields, and the deployment of selected monitoring, verification, and accounting (MVA) techniques.

Results of History Matching
A history-matching process was used to improve modeled output and to obtain a good match with historical data, which demonstrates the ability of the model to accurately predict reservoir conditions. A total of 92 wells were utilized, including 86 production wells and seven water disposal wells in the study area, primarily in the nearby gas fields. The goal of this step was to match gas and water production, water disposal, and well bottomhole pressure (BHP). Ultimately, by matching these parameters in the nearby gas pools, a more accurate geologic model with a current method distributed regional pressure profile could be used. After 494 history-matching simulation runs, an asymptotic convergence was achieved with a total of 92 wells matched. Upon convergence, the global objective function error between the simulation runs and the historical data was 3.91%. Correspondingly, a comparison of the historical and simulation data for cumulative gas production and cumulative water disposal is shown in the figures below. These history-matching results indicate a good match for gas and water production, water disposal, and BHP for all wells in the investigated area.

Methodology
The method used in this study is an integrated, iterative, risk-based approach for defining MVA strategies. Site characterization, modeling and simulation, risk assessment, and the development of a cost-effective MVA plan are the four key components iterated during the course of a CCS project. This approach will be applied through the feasibility, design, injection, closure, and postclosure periods of the project. Each iteration will improve the technical and cost-effectiveness of the MVA plan, while simultaneously reducing project risks.

Study Area

Results of Two Injection Scenarios
Initial simulations were run on three wells, including c6-1 (Track 1) at a rate of 120 MMscf/day for 25 years. An additional 75-year postinjection period was also modeled to allow for analysis of the postinjection gas and water pressure buildup. These simulations indicated that 120 MMscf/day could be injected for 25 years, although CO2 and elevated pressure may contact nearby gas pools within the 100-year simulation period. The simulation output was also utilized in a subsurface technical risk assessment, which indicated that CO2 contacting the gas pools may present an unacceptable risk. As a result, an alternative injection location was selected farther to the west (Track 2). In addition, new geologic data were collected, and the geologic model was updated with additional well and seismic information. The injection simulations were then run on both Track 1 and Track 2. While both injection scenarios indicate the formation can accept 120 MMscf/day for 25 years, the simulation for Track 2 indicates CO2 does not contact either gas pool in the 100-year simulation run. Additional characterization should be performed around both injection tracks to better understand the potential storage reserve of Fort Nelson.

Conclusion and Future Work
The static and dynamic modeling in the Fort Nelson CCS Project plays a crucial role in predicting the movement of sour CO2 in the reservoir, informing the risk assessment, and helping to define and develop the MVA plan. The proposed dynamic modeling workflow, along with the integrated approach to site characterization, modeling and simulation, and risk assessment, can lead to a more targeted, site-specific, and technically and economically feasible MVA plan and CCS project.

Both injection locations (Track 1 and Track 2) appear to have sufficient capacity to accommodate the target injection volumes. However, current knowledge suggests that Track 2 may be a better option compared to Track 1, because the injected sour CO2 has a lower carbon content and is less dense than the injection well BHP in Track 1. Overall, Track 2 has a lower risk profile; however, the collection of 3-D seismic data and the drilling of an additional well in the vicinity of Track 2 are necessary to determine whether or not the geology is suitable for the injection of 3.4 MMscf/day (120 MMscf/day) for 25 years.

Future work includes the development of an MVA plan for both Track 1 and Track 2 based on the results of site characterization, modeling, and simulation, and risk assessment. This MVA plan will be updated along with the modeling and simulation and risk assessment once additional site characterization activities are completed.

Reference
[1] EERC (Energy & Environmental Research Center), Colorado School of Mines, 2500 Fairview Avenue West, Golden, CO 80401, USA. 3D reservoir modeling, plot for the Fort Nelson viability study; Prepared by the Carbon Management Technology Laboratory, Institute for Energy Efficiency, University of South Carolina, and the U.S. Department of Energy.

Acknowledgments
This material is based upon work supported by the U.S. Department of Energy. National Energy Technology Laboratory through the Carbon Management Technology Laboratory. These authors acknowledge the intellectual property rights that the University of South Carolina, the U.S. Department of Energy, and the DOE’s Oak Ridge National Laboratory have to this work.

In order to more effectively integrate the modeling and simulation into the overall MVA strategy, a dynamic modeling workflow was developed (1). The workflow utilizes these techniques: 1) grid-size sensitivity analysis, used to create the coarsest grid resolution that will yield accurate results; 2) numerical tuning to speed up simulation run time and minimize material balance error; and 3) property parameter sensitivity analysis to identify the properties and parameters that have the greatest effect on the simulation results. The optimized model is then validated by history matching to obtain a reasonable match between simulated results and historical data before predictive CO2 simulations are run (1).

Methodology
The method used in this study is an integrated, iterative, risk-based approach for defining MVA strategies. Site characterization, modeling and simulation, risk assessment, and the development of a cost-effective MVA plan are the four key components iterated during the course of a CCS project. This approach will be applied through the feasibility, design, injection, closure, and postclosure periods of the project. Each iteration will improve the technical and cost-effectiveness of the MVA plan, while simultaneously reducing project risks.

Results of History Matching
A history-matching process was used to improve modeled output and to obtain a good match with historical data, which demonstrates the ability of the model to accurately predict reservoir conditions. A total of 92 wells were utilized, including 86 production wells and seven water disposal wells in the study area, primarily in the nearby gas fields. The goal of this step was to match gas and water production, water disposal, and well bottomhole pressure (BHP). Ultimately, by matching these parameters in the nearby gas pools, a more accurate geologic model with a current method distributed regional pressure profile could be used. After 494 history-matching simulation runs, an asymptotic convergence was achieved with a total of 92 wells matched. Upon convergence, the global objective function error between the simulation runs and the historical data was 3.91%. Correspondingly, a comparison of the historical and simulation data for cumulative gas production and cumulative water disposal is shown in the figures below. These history-matching results indicate a good match for gas and water production, water disposal, and BHP for all wells in the investigated area.

Results of Two Injection Scenarios
Initial simulations were run on three wells, including c6-1 (Track 1) at a rate of 120 MMscf/day for 25 years. An additional 75-year postinjection period was also modeled to allow for analysis of the postinjection gas and water pressure buildup. These simulations indicated that 120 MMscf/day could be injected for 25 years, although CO2 and elevated pressure may contact nearby gas pools within the 100-year simulation period. The simulation output was also utilized in a subsurface technical risk assessment, which indicated that CO2 contacting the gas pools may present an unacceptable risk. As a result, an alternative injection location was selected farther to the west (Track 2). In addition, new geologic data were collected, and the geologic model was updated with additional well and seismic information. The injection simulations were then run on both Track 1 and Track 2. While both injection scenarios indicate the formation can accept 120 MMscf/day for 25 years, the simulation for Track 2 indicates CO2 does not contact either gas pool in the 100-year simulation run. Additional characterization should be performed around both injection tracks to better understand the potential storage reserve of Fort Nelson.

Conclusion and Future Work
The static and dynamic modeling in the Fort Nelson CCS Project plays a crucial role in predicting the movement of sour CO2 in the reservoir, informing the risk assessment, and helping to define and develop the MVA plan. The proposed dynamic modeling workflow, along with the integrated approach to site characterization, modeling and simulation, and risk assessment, can lead to a more targeted, site-specific, and technically and economically feasible MVA plan and CCS project.

Both injection locations (Track 1 and Track 2) appear to have sufficient capacity to accommodate the target injection volumes. However, current knowledge suggests that Track 2 may be a better option compared to Track 1, because the injected sour CO2 has a lower carbon content and is less dense than the injection well BHP in Track 1. Overall, Track 2 has a lower risk profile; however, the collection of 3-D seismic data and the drilling of an additional well in the vicinity of Track 2 are necessary to determine whether or not the geology is suitable for the injection of 3.4 MMscf/day (120 MMscf/day) for 25 years.

Future work includes the development of an MVA plan for both Track 1 and Track 2 based on the results of site characterization, modeling, and simulation, and risk assessment. This MVA plan will be updated along with the modeling and simulation and risk assessment once additional site characterization activities are completed.

Reference
[1] EERC (Energy & Environmental Research Center), Colorado School of Mines, 2500 Fairview Avenue West, Golden, CO 80401, USA. 3D reservoir modeling, plot for the Fort Nelson viability study; Prepared by the Carbon Management Technology Laboratory, Institute for Energy Efficiency, University of South Carolina, and the U.S. Department of Energy.

Acknowledgments
This material is based upon work supported by the U.S. Department of Energy. National Energy Technology Laboratory through the Carbon Management Technology Laboratory. These authors acknowledge the intellectual property rights that the University of South Carolina, the U.S. Department of Energy, and the DOE’s Oak Ridge National Laboratory have to this work.

In order to more effectively integrate the modeling and simulation into the overall MVA strategy, a dynamic modeling workflow was developed (1). The workflow utilizes these techniques: 1) grid-size sensitivity analysis, used to create the coarsest grid resolution that will yield accurate results; 2) numerical tuning to speed up simulation run time and minimize material balance error; and 3) property parameter sensitivity analysis to identify the properties and parameters that have the greatest effect on the simulation results. The optimized model is then validated by history matching to obtain a reasonable match between simulated results and historical data before predictive CO2 simulations are run (1).