DOE–IEAGHG Study: CO_2 Storage Efficiency in Deep Saline Formations – Stage 2

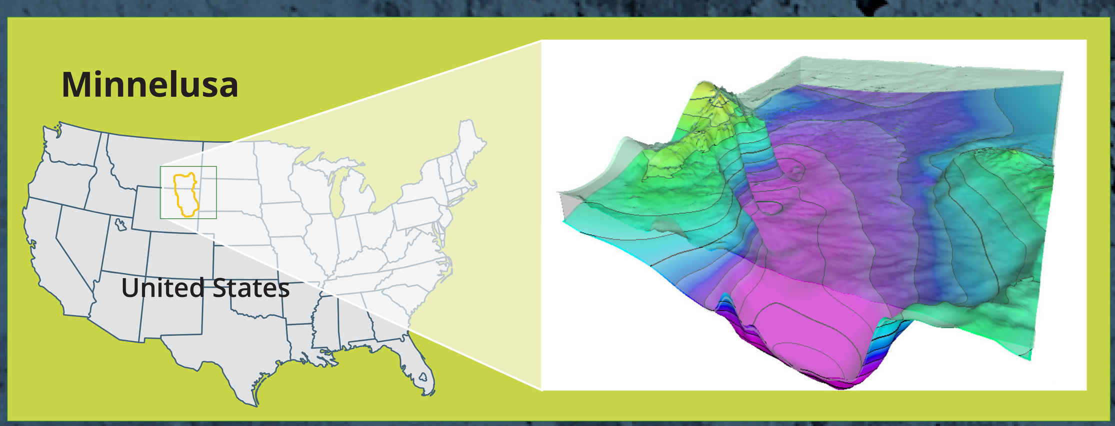
Lawrence Pekot, Nicholas Bosshart, Jun Ge, Neil Dotzenrod, Scott Ayash, Tao Jiang, Andrew Gorz, and Heidi Vettleson

ABSTRACT

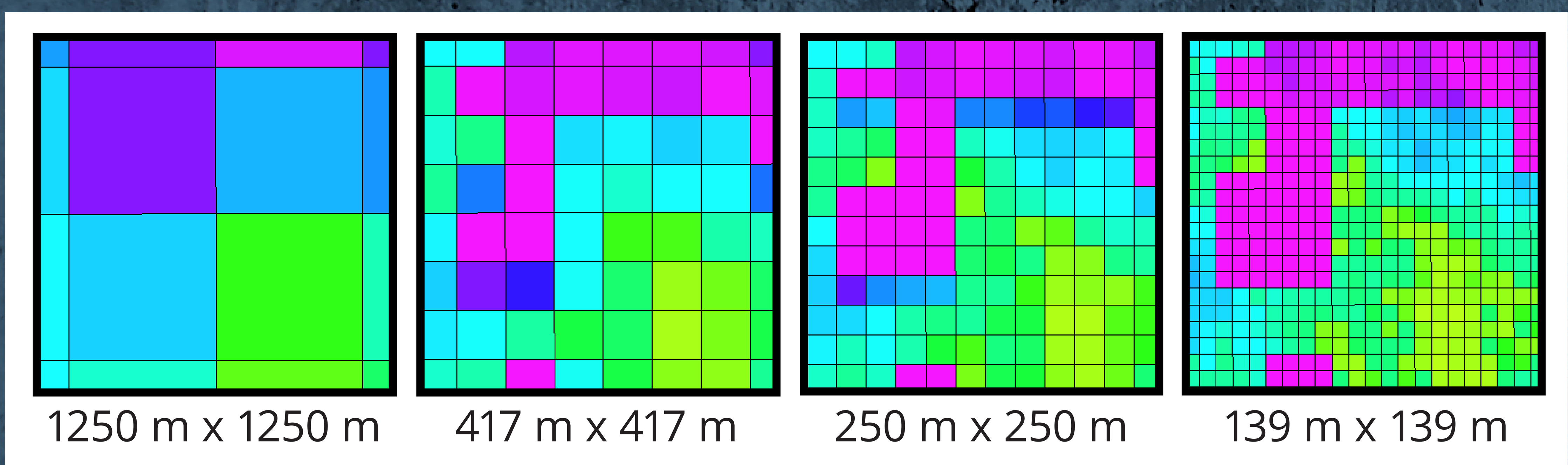
In an effort to mitigate the increase in atmospheric concentrations of carbon dioxide (CO_2) caused by emissions from large stationary sources, governmental/regulatory entities are pursuing geologic storage of CO_2 as one approach in a portfolio of greenhouse gas reduction strategies. Over the past decade, various CO_2 storage resource estimation methodologies have been developed for deep saline formations (DSFs, generally deeper than 800 m and with salinity greater than 10,000 mg/L), with the goal of providing reliable estimates of the potential CO_2 storage in these formations. Previous work has focused on estimating the effective CO_2 storage resource—resource that considers technical (geologic and engineering) constraints—to provide efficiency values for generic saline aquifers under a range of lithologies (clastics [sandstone], limestone, and dolomite [dolostone]) and an assumption of boundary conditions (i.e., open or closed hydrogeologic systems) (IEAGHG, 2009; U.S. Department of Energy, 2012; Peck and others, 2014). Recent investigations have focused on comparative analyses of volumetric (also referred to as static) and dynamic estimates of effective CO_2 storage resource and efficiency (IEAGHG, 2014; Gorecki and others, 2015). Dynamic estimates determined through numerical simulations have shown relatively good agreement with volumetric estimates; however, the numerical simulations indicate that it may take hundreds to thousands of years to reach the volumetrically estimated effective CO_2 storage resource for large-scale storage operations, which is beyond the practical time frame of interest for mitigating climate change in the next century (Bachu, 2015).

The aim of this study is to build upon and expand the work of the Stage 1 study (IEAGHG, 2014). The Stage 2 study begins the transition from effective storage resource assessment to practical storage capacity estimation by investigating the range of storage efficiency that is achievable within a more urgent time frame (50-year injection period) while also considering economics. To do this, the project is investigating two geologic formations that have been previously considered for CO_2 storage. The Minnelusa Formation of the North American Powder River Basin, which was investigated in the Stage 1 study, will be reexamined to provide continuity with the previous work and allow for direct comparison of the current work with previous efforts. The study will also investigate the Bunter Sandstone located in the United Kingdom sector of the Southern North Sea Basin to provide an offshore and European counterpoint to the continental setting of the Minnelusa.

The Minnelusa Formation

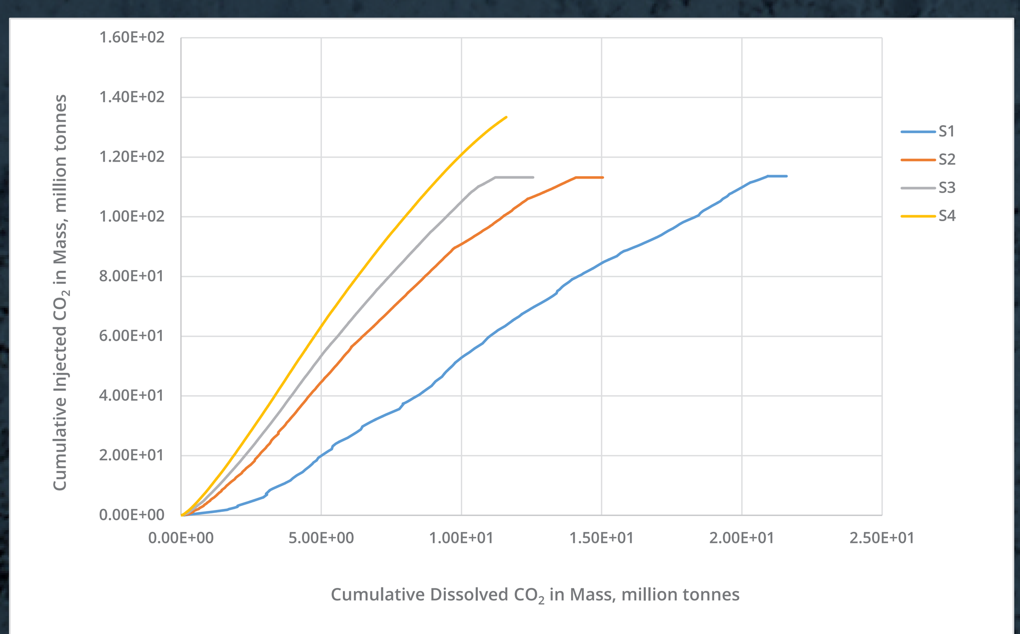


Simulation is used to investigate the accuracy of dissolved CO_2 calculations as a function of grid detail.

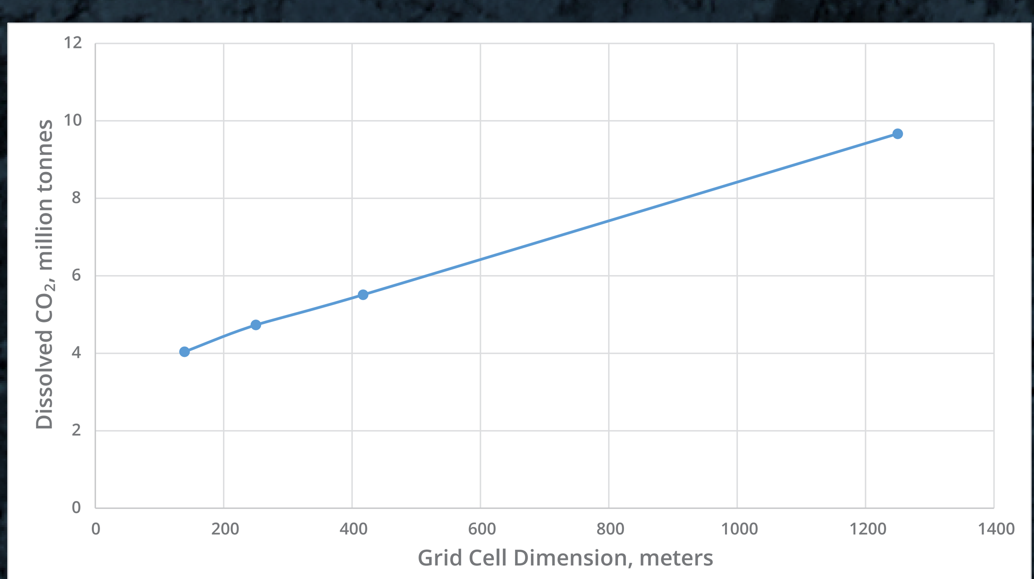


PROJECT GOALS

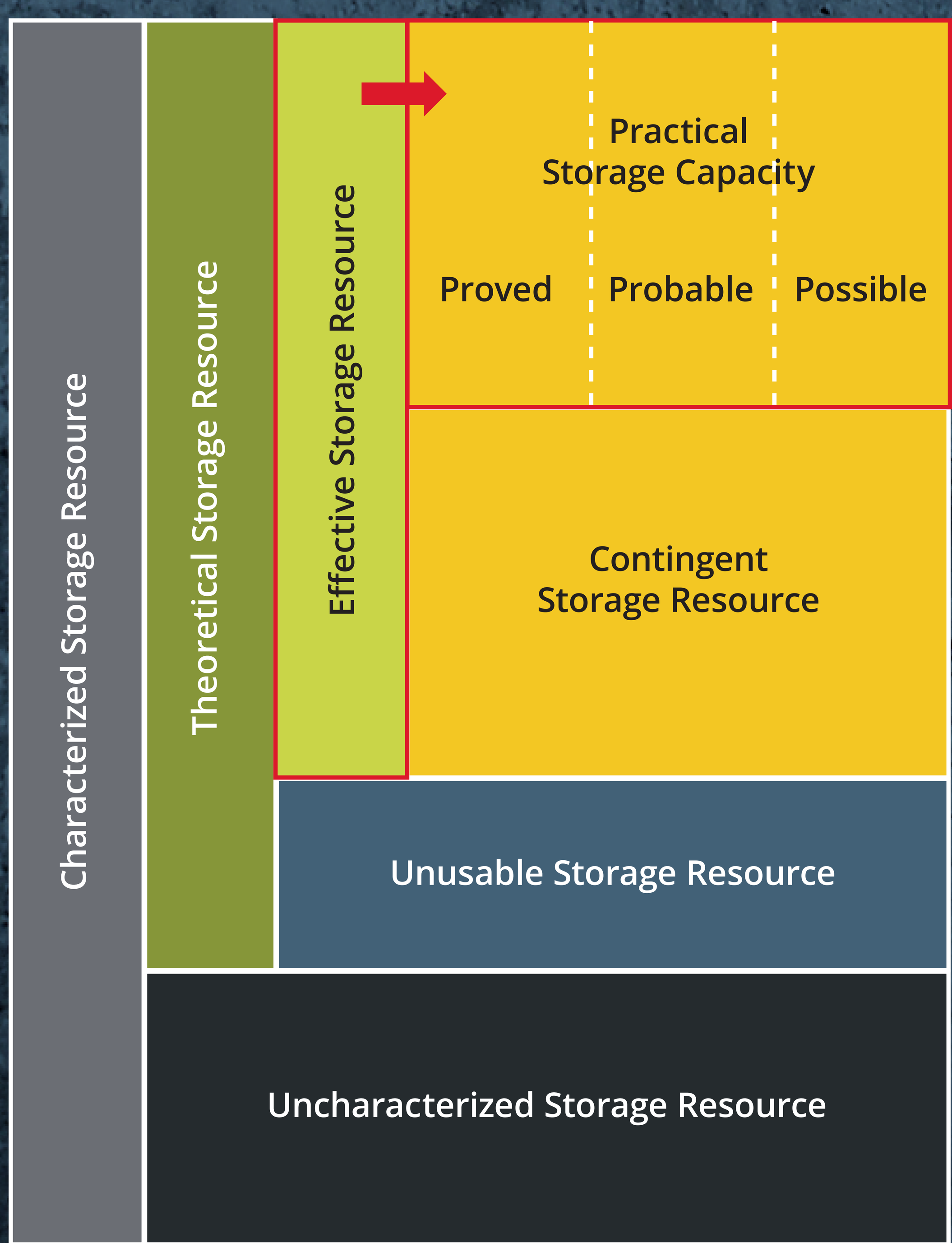
This project builds upon the framework established through the Stage 1 project work (IEAGHG, 2014). Stage 1 efforts focused on comparing volumetrically and dynamically derived CO_2 storage efficiency factors for basin-scale models while achieving ultimate storage capacity (hundreds to thousands of years). The goal of this Stage 2 work is to improve the understanding of potential CO_2 storage resource and efficiency by 1) focusing on a subbasin setting, 2) employing a temporal constraint of 50 years, 3) varying well densities, 4) weighing economic factors, and 5) considering different cell sizes to investigate the effects of cell size on simulated dissolved CO_2. These Stage 2 efforts were designed to reflect the timing and realities of potential commercial-scale carbon capture and storage projects.



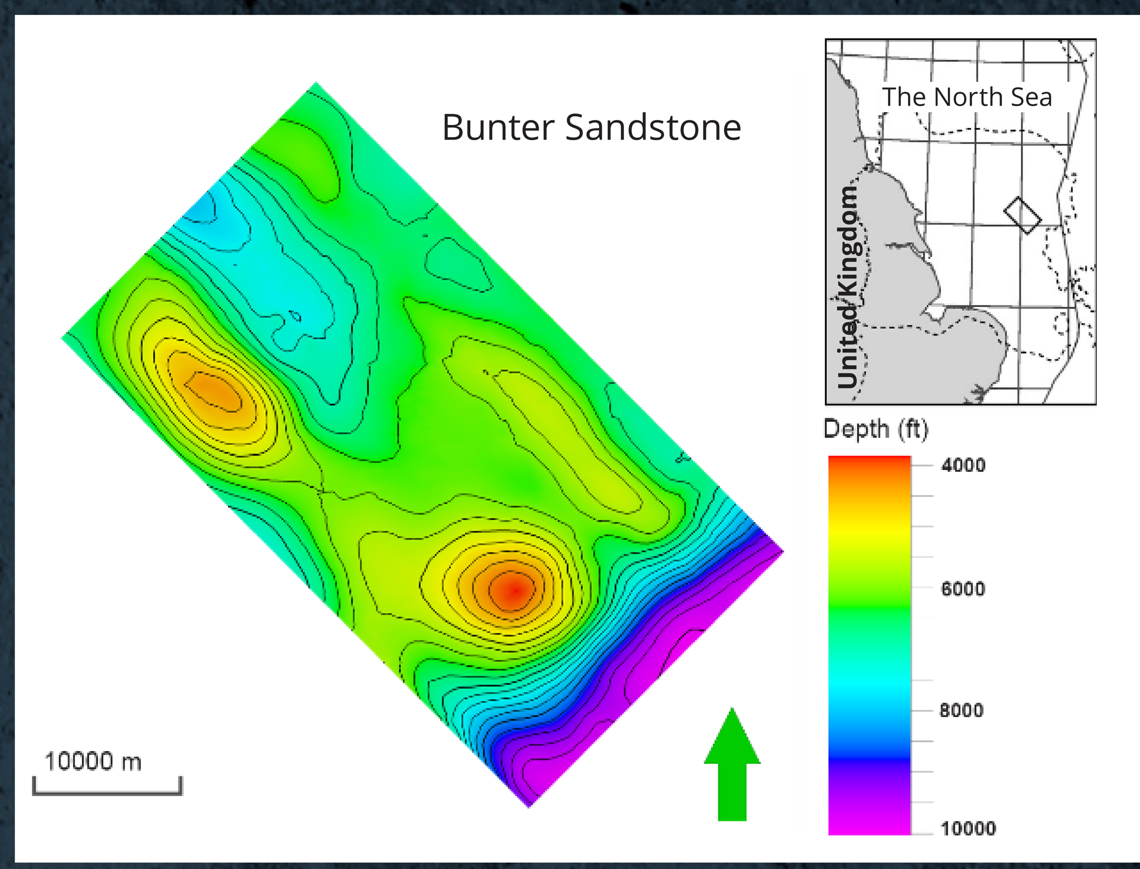
Plot 1 describes the change of dissolved CO_2 with the cumulative injected CO_2 for each of the cases (differing on the basis of grid cell size). From this plot, we can see that the dissolved CO_2 is increasing with an increase in the cell size for the same amount of CO_2 injected. This is more obvious in the second plot, which shows how the dissolved CO_2 changes with cell size for the same value of cumulative injection, 50 million tonnes.



Plot 2 describes the change of dissolved CO_2 with the cumulative injected CO_2 for each case (differing on the basis of grid cell size). From this plot, we can see that the dissolved CO_2 is increasing with an increase in the cell size at the same amount of CO_2 injected.

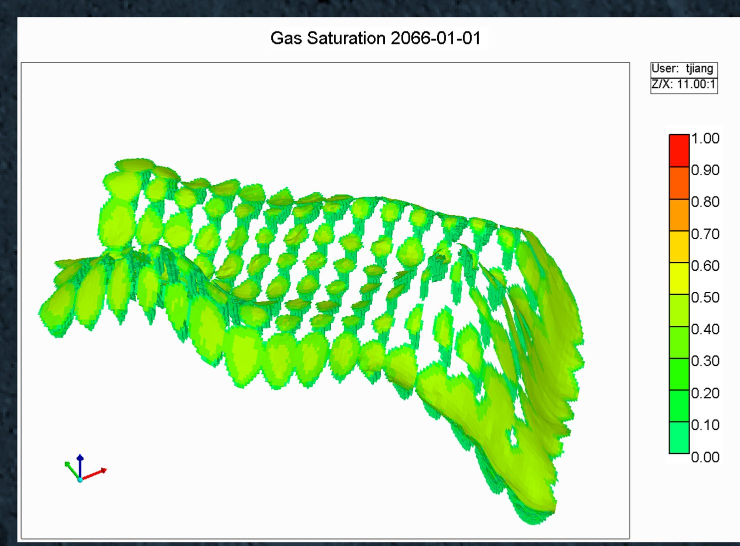


Describing the transition from effective to practical storage capacity.

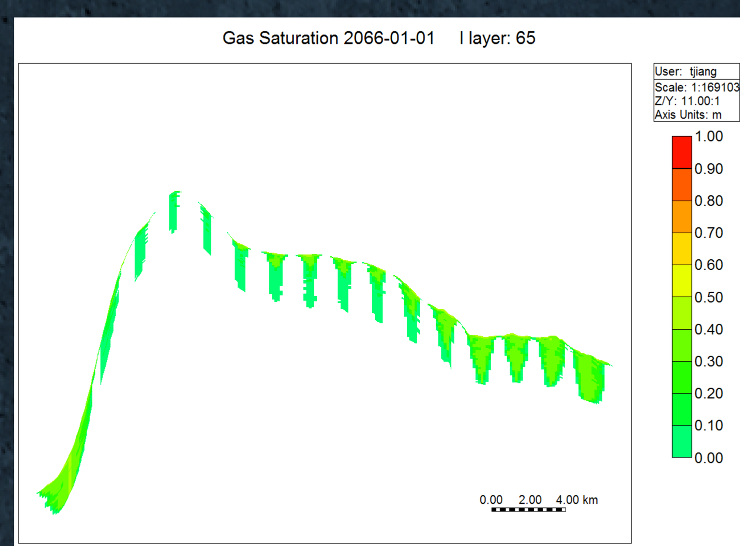


The Bunter Sandstone

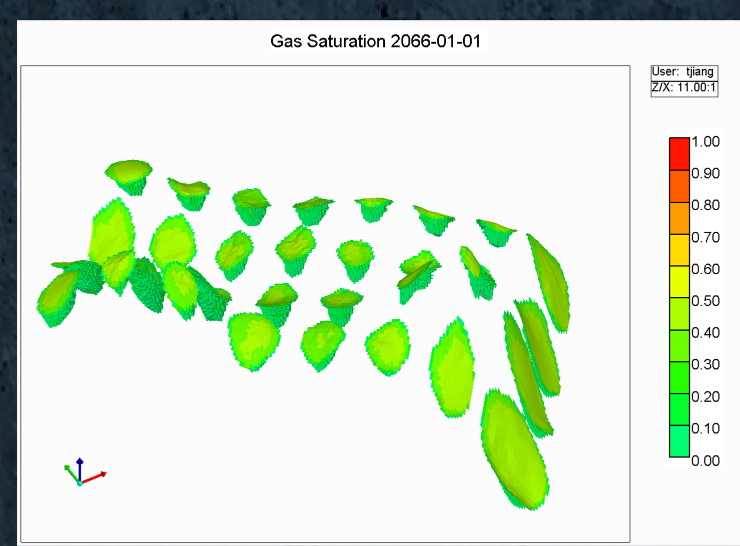
Each case was run with maximum injection well pressure = 1.5x initial pore and with a maximum allowed well rate = 2.9 million tonnes/year.



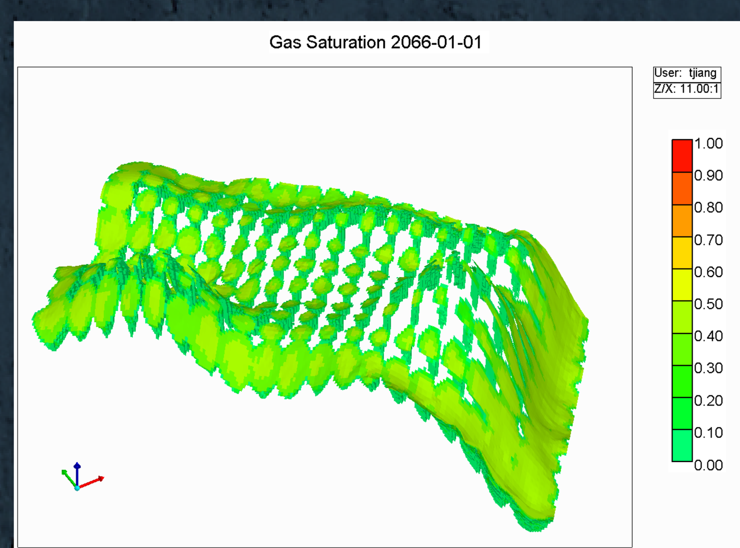
128 wells
Dynamic efficiency factor: 4.42%



128 wells
2-D cross section



32 wells
Dynamic efficiency factor: 3.39%



190 wells
Dynamic efficiency factor: 4.82%

The Bunter Sandstone Formation has excellent reservoir quality in comparison to other saline formations characterized for CO_2 storage. The Bunter modeling and simulation efforts conducted in this project were designed to assess dynamic storage potential for multiple cases (with varying well numbers and placements) over a 50-year injection interval. The results show that dynamic efficiency increases when introducing more wells; however, diminishing returns are experienced when well density is relatively high. A 2-D cross section shown above for a simulation case with 128 wells indicates the CO_2 buoyancy effect is significant, thus limiting the storage potential in the lower layers of the Bunter model.

Acknowledgments

This material is based upon work supported by the U.S. Department of Energy under Award Number DE-FE0024233. Nonfederal funding was provided by IEA Greenhouse Gas R&D Programme (IEAGHG).

The EERC would like to thank Schlumberger Carbon Services and Computer Modelling Group, Inc. (CMG) for their support of the project. All modeling and simulation work was performed using software packages from Schlumberger and CMG.

The EERC would also like to thank the Energy Technologies Institute (ETI). Information for the Bunter model was taken from the Strategic UK CCS Storage Appraisal Project, funded by DECC, commissioned by ETI, and delivered by Pale Blue Dot Energy, Axis Well Technology, and Costain. This information is copyrighted under an ETI Open License. Details on this license can be found here: http://www.eti.co.uk/wp-content/uploads/2016/04/ETI-licence-v2.1.pdf.

Bibliography

Bachu, S., 2015, Review of CO_2 storage efficiency in deep saline aquifers: International Journal of Greenhouse Gas Control, v. 40, p. 188–202.

Gorecki, C.D., Ayash, S.C., Liu, G., Braunberger, J.R., and Dotzenrod, N.W., 2015, A comparison of volumetric and dynamic CO_2 storage resource and efficiency in deep saline formations: International Journal of Greenhouse Gas Control, v. 42, p. 213–225.

IEAGHG (IEA Greenhouse Gas R&D Programme), 2009, Development of storage coefficients for CO_2 storage in deep saline formations: 2009/12, October.

IEAGHG (IEA Greenhouse Gas R&D Programme), 2014, CO_2 storage efficiency in deep saline formations—a comparison of volumetric and dynamic storage resource estimation methods: 2014/09, October.

Peck, W.A., Glazewski, K.A., Klenner, R.C.L., Gorecki, C.D., Steadman, E.N., and Harju, J.A., 2014, A workflow to determine CO_2 storage potential in deep saline formations: Energy Procedia, v. 63, p. 5231–5238.

U.S. Department of Energy, National Energy Technology Laboratory, 2012, Carbon sequestration atlas of the United States and Canada, 4th ed.

Energy & Environmental Research Center, University of North Dakota, 15 North 23rd Street, Stop 9018, Grand Forks, ND 58202-9018