Chapter 4
A Strategy for Designing an Optimal Characterization Study of the Premier Carbon Capture, Utilization and Storage Site in Wyoming

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Abstract The strategy adapted by the WY-CUSP team to accomplish their primary goal involved the following steps:

1. Inventory and prioritize the potential CO_2 storage reservoirs and storage sites in Wyoming, and select the storage reservoir(s) and site to be targeted.
2. Determine sources of available data for the targeted priority storage reservoir(s) and site.
3. Perform preliminary numerical simulations of a variety of CO_2 storage scenarios at the selected site, utilizing available data.
4. Design a new, robust data-acquisition program (3-D seismic survey and test well logging) that would provide the WY-CUSP team with the ability to attack the key barriers to accurate site characterization (pressure management and 3-D heterogeneity of petrophysical parameters of storage reservoirs and seals).
5. Develop a formation brine production and treatment program and facility that would result in required pressure management during commercial-scale CCUS on the selected site—a facility that functions as a profit center, not a punitive element, during commercial geologic CO_2 sequestration.
6. Simulate a variety of potential CO_2 storage scenarios on the selected site using realistic reservoir models that include, among other elements, the 3-D heterogeneity of petrophysical parameters, in order to provide significant uncertainty reduction in both performance assessment and risk analysis.
7. Accomplish the primary goal of the WY-CUSP program—to provide all essential information, data, interrelations, evaluations, and modeling results required by government regulations in order to permit construction of a commercial CO_2 storage facility on the RSU.

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4.1 The Wyoming Carbon Underground Storage Project (WY-CUSP)

When the CMI team decided to delineate outstanding geologic CO_2 storage sites in Wyoming, they had several tasks to complete before the characterization work could be initiated. Essentially, these initial tasks were: (1) to inventory and prioritize the potential CO_2 storage reservoirs and sites in Wyoming; (2) to determine sources of available data for the highest-priority sites; and (3) once the storage intervals and site were selected, to choose a study site suitable for characterization.

Early in this preliminary work it was demonstrated that the Paleozoic Madison Limestone and Weber/Tensleep Sandstone were the leading candidate stratigraphic storage intervals. This conclusion was founded on the volume of pore space, given the porosity (typically 5–10 %) and thicknesses (Madison Limestone, ~400 ft, 120 m; Weber Sandstone, ~700 ft, 210 m) of the potential storage intervals.

The Rock Springs Uplift and the Moxa Arch (La Barge Platform) were the two highest-priority storage sites. The Rock Springs Uplift was chosen because the reservoir intervals are closer to the surface (6000–12,000 ft (1800–3600 m) deep) on the uplift, whereas the reservoir interval on the Moxa Arch is ~18,000 ft deep (5500 m). Importantly, there is only a trace of hydrocarbons in the Paleozoic reservoir interval on the Rock Springs Uplift, whereas the Paleozoic rocks on the Moxa Arch contain substantial hydrocarbon accumulations and associated significant hydrocarbon production.

The Rock Springs Uplift is an elliptical structure, 50 mi (80 km) north–south and 35 mi (55 km) east–west, with four-way closure and ~10,000 ft (3000 m) of structural relief. In addition, the Rock Springs Uplift is a relatively recent structure; there is no topographic indication of its presence prior to 45 million years ago (Surdam and Jiao 2007).

This last aspect of the RSU is important because it explains why the formation fluids in both storage reservoirs are so saline (70,000–100,000 mg/L). The closest surface outcrops of these two Paleozoic stratigraphic units are 50–100 mi (80–160 km) away, so there has been no meteoric reflux into these units on the RSU. It bears repeating, because of the importance relative to the Paleozoic Madison and Weber formations as potential CO_2 storage reservoirs, that there is no chance that underground sources of drinking water (USDW, < 10,000 mg/L salinity) are within these formations on the RSU. The US Environmental Protection Agency will not allow CO_2 storage in rock/fluid storage systems containing USDW.

After surveying potential sites for a CCUS characterization study on the Rock Springs Uplift, the CMI team chose a state section on the east flank of the structure where the nearest Paleozoic hydrocarbon production, the Brady Unit, is 20 mi (30 km) away and separated from the RSU by a significant fault. The 2200-MW Jim Bridger Power Plant, the largest CO_2 emitter in the state (15 Mt/yr) is located about 2 mi (3 km) north of the study site. The Black Butte coal company has a network of well maintained haul roads in the area, so ready access to the study site is established. Finally, the topography in the area is relatively subdued, so acquisition of 3-D seismic information wouldn't be hampered by troublesome relief.

4.2 Sources of Available Databases

Our search for existing data relative to the RSU yielded three primary databases. The Wyoming Oil and Gas Conservation Commission in Casper, Wyoming, possesses the most thorough Wyoming digitized database in existence. The Wyoming State Geologic Survey also has a valuable database on southwestern Wyoming, mainly in the form of maps and topical reports. The USGS Core Library in Denver contains several high-quality Weber and Madison cores from southwestern Wyoming.

4.3 Preliminary Modeling

One of the first tasks addressed by CMI after DOE funding had been secured was to build preliminary numerical simulations utilizing regional data derived from the literature and the Wyoming Oil and Gas Conservation Commission database (Stauffer et al. 2009; Surdam et al. 2009, 2010). The performance assessment produced by these early numerical simulations was fraught with geologic uncertainty. However, these early attempts were invaluable because they pointed out two crucial points.

First, the most critical problem with commercial-scale geologic CO_2 sequestration is the management of displaced fluids. The early simulations suggested that formation brines would have to be removed with injection of CO_2 in a one-to-one ratio. Our simulations of a variety of CO_2 injection scenarios showed that without pressure management through removal of formation fluids, pressures would quickly exceed fracture pressures during injection. The CMI team concluded early in the study that any CCUS strategy on the RSU had to integrate fluid production and water treatment with injection and storage of CO_2.

Second, it also was apparent from the preliminary numerical simulations that the greatest uncertainty in the performance assessment and modeling of CO_2 sequestration processes is the characterization of geologic heterogeneity in three dimensions. The objective of much of our subsequent research has been to significantly reduce that uncertainty.

4.4 Essential New Data

From these preliminary observations it was apparent that a more robust database was essential to achieving the WY-CUSP objectives. First, because the closest existing well penetrations of the Madison Limestone and Weber Sandstone on the RSU are approximately 18 mi (29 km) up-dip from the study area at the crest of the structure, and the closest outcrops are 50–100 mi (80–160 km) away, it was essential to drill a stratigraphic test well at the chosen study site. Second, to be able to project observations made at the well out into a realistic storage domain, it was essential to acquire a 3-D seismic survey of the study area. Thus, an integral part of the CMI plan was to reduce uncertainty in our RSU characterization project by integrating 3-D seismic techniques with stratigraphic test well observations. This approach has been absolutely crucial in reducing uncertainty in the RSU CO_2 injection/storage performance assessments. From the stratigraphic test well the project gained 900+ ft (270+ m) of high-quality core (rock samples) from the storage reservoirs and confining layers, a wide variety of well logs, fluid samples, DST's, injectivity measurements, VSPs, in situ temperature and pressure measurements, stress/strain properties, fracture gradients, and capillary properties, among other measures. This sample set, combined with a multitude of laboratory measurements, comprises a truly robust catalog of diverse databases. Combining these new robust databases with the seismic attribute volumes resulting from modern seismic analytical techniques has resulted in a new, powerful approach to evaluating 3-D spatial distributions of both reservoir and confining layer characteristic. The new data and this powerful evaluation approach to geologic CO_2 storage are described in detail in subsequent chapters.

4.5 Goals of WY-CUSP

The primary goal of the Wyoming Carbon Underground Storage Project (WY-CUSP) is to provide all essential information, data, interrelations, evaluations, and modeling results required by government regulations in order to permit construction of a commercial geologic CO_2 storage facility on the RSU. The modeling results should include injected CO_2 plume size and fluid-flow dynamics, area of review configuration (storage domain), performance assessments, and risk analyses for a spectrum of realistic CO_2 injection and storage configurations. With information provided by WY-CUSP, the potential operator of a commercial geologic CO_2 storage facility on the RSU should be able to proceed directly to the permitting phase of the project.

Secondary goals of the WY-CUSP program are to:

- Protect Wyoming's coal extraction and future coal-to-chemical industries (provide storage capacity for anthropogenic CO_2).
- Provide surge-tank storage of anthropogenic CO_2 for a 20–50 year state-wide enhanced oil recovery program. By way of comparison, using the CO_2 produced by the two gas processing plants in Wyoming, it would take 150–200 years to recover Wyoming's stranded oil. These comparisons were made by comparing the amount of CO_2 required to produce a barrel of oil with the amount of CO_2 produced by the two gas-processing plants.
- Retrieve reservoir information essential for expansion of natural gas storage in Wyoming.
- Establish a more robust database for two important hydrocarbon reservoirs in Wyoming, substantially reducing uncertainty for all dynamic models of Weber/Tensleep and Madison fluid-flow and rock/fluid systems.

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