Appendix A: Geologic Data Sources

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Broad ranges of geologic data are necessary to evaluate potential geologic CO_2 storage sites. The supplementary information in this appendix describes the types of data and various sources for obtaining these data. Many of the geologic data used for evaluating CO_2 storage are available at the Kentucky Geological Survey Web site: www.uky.edu/KGS/.

Geologic Data Sources

The principal data needed to calculate gross storage capacity for potential sequestration reservoirs are the porosity, thickness, area, temperature, and pressure of the reservoir, and salinity of interstitial fluids. The amount of irreducible water also needs to be considered, which is typically only estimated with numerical modeling. A similar calculation can be made for carbon storage in oil and gas reservoirs. It is important to note that these calculations provide a maximum theoretical capacity, and the practical capacity will be further reduced (Bachu and others, 2007). An example of an online calculator is provided through the NatCarb Web site: www.natcarb.org/Calculators/.

For large-scale, industrial geologic storage of carbon dioxide, storage rates of 1 million metric tons per year may be needed, which will require very large reservoirs (much larger than existing oil fields), or multiple smaller reservoirs. Exploring for these reservoirs will not be easy and will require different types of data. The primary source will come from wellbores used for oil and gas exploration. Seismic data will also be important for correlating units away from known oil and gas wells, or at depths greater than are penetrated by local oil and gas wells, and for determining if there are faults at depths that could serve as pathways for leakage of injected CO_2. Regulations have not been promulgated yet for large-scale storage of CO_2 in the United States, but the Environmental Protection Agency is in the process of writing them (U.S. EPA, 2008a, b). Until these regulations are written, the best estimates of the types of geologic data that will be needed to permit future storage projects are the permits for the current DOE phase II demonstration projects.

Oil and Gas Data

The type of data that might be generated during or after drilling of an oil and gas exploitation well include downhole geophysical logs (density, gamma ray, etc.) to determine rock type, rock unit correlations, depths, and porosity. In addition, samples of rock cuttings, and in some cases cores, are sometimes collected for evaluating rock mineralogy, porosity, and permeability. In some cases, reservoir tests are conducted, which include information about reservoir pressure. Also, fluid samples can be taken to determine hydrocarbon (gas, oil) composition and water composition (salinity, chemistry). A significant amount of oil and gas well data has been used to generate databases, maps, and summary reports for the phase I regional characterization studies of the DOE-sponsored MGSC (Frailey and others, 2005) and MRCSP (Wickstrom and others, 2005). Much of the data for the phase I report pertinent to Kentucky was obtained from the KGS Oil and Gas Database (kgsweb.uky.edu/DataSearching/oilsearch.asp).

More than 160,000 oil and gas wells have been drilled in Kentucky, although their locations are not evenly distributed around the state (Fig. A.1). These wells represent a wealth of subsurface data, although most of the wells are relatively shallow (less than 1,500 ft) and have limited usefulness for deep CO_2 storage research. For deeper analysis, 4,047 wells penetrate 4,000 feet or deeper (Fig. A.2). From a carbon storage perspective, this is both good and bad. Fewer wells mean fewer penetrations and therefore less information about potential storage and seal formations. Well penetrations, however, are one of the primary pathways for potential leakage of injected CO_2, so fewer penetrations reduce the risk of leakage. Documenting the number of well penetrations in the proposed area of influence was one of the criteria required in the FutureGen proposals, and will likely be required in any future CO_2 storage project.

Seismic Data

All of the phase II demonstration projects for the DOE-sponsored regional carbon sequestration partnerships have included seismic lines at their test sites as part of their applications for EPA Class V experimental injection permits. Seismic data are useful for correlations and depth projections of rock units in the deep subsurface. They are also useful for determining the dip of beds and the presence or absence of struc-

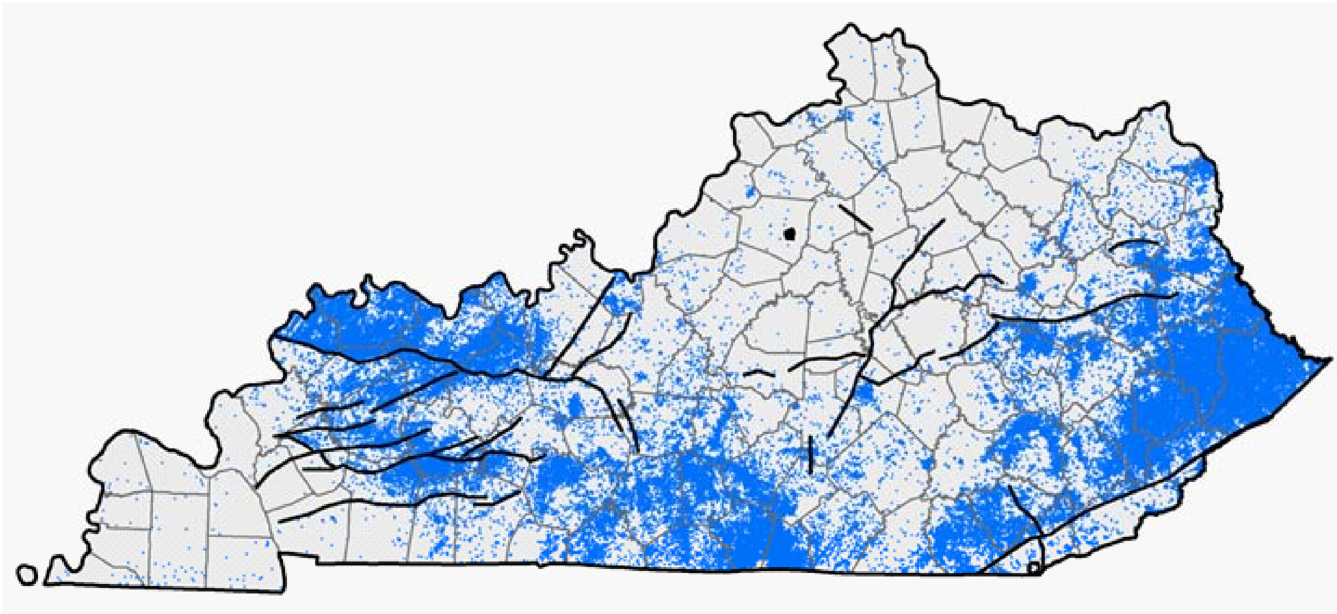

Figure A.1. Oil and gas wells in the Kentucky Geological Survey's Oil and Gas Database. Solid black lines represent major faults at the surface.

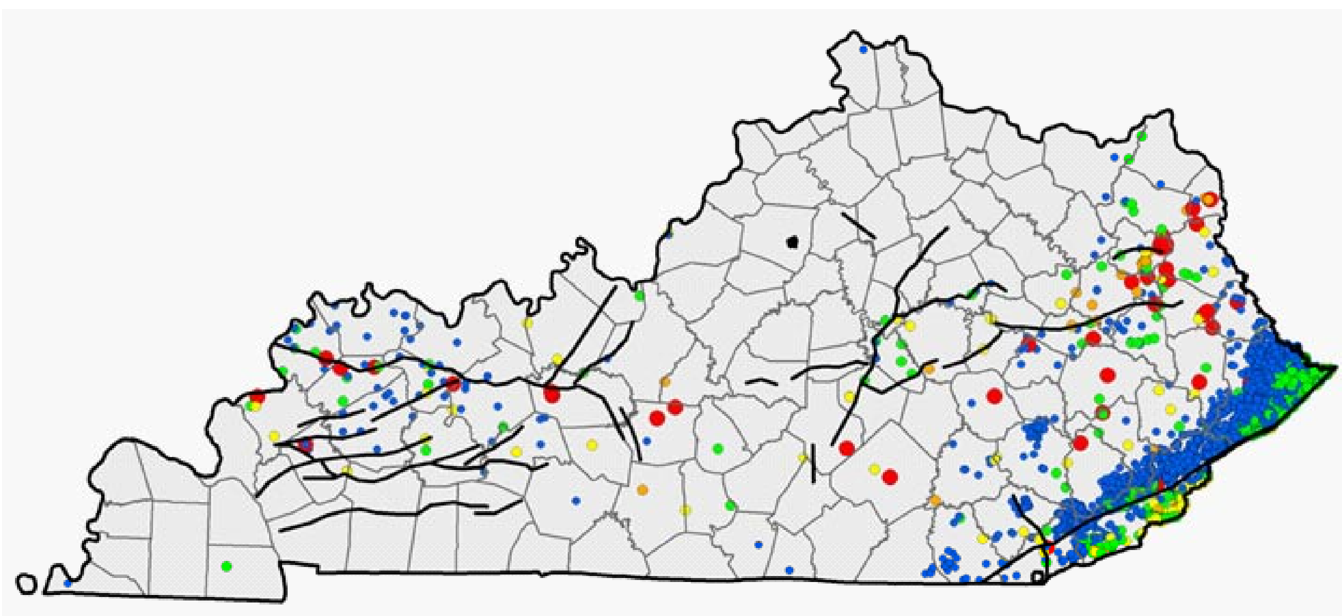

Figure A.2. Locations of wells more than 4,000 ft deep. Blue = 4,000 to 5,000 ft. Green = 5,000 to 6,000 ft. Yellow = 6,000 to 7,000 ft. Orange = 7,000 to 8,000 ft. Red = more than 8,000 ft. Solid black lines represent major faults at the surface.

tures such as folds or faults. Confirming the absence of faults in potential reservoirs and confining intervals that could act as pathways for vertical migration of injected CO_2 will likely be important for obtaining EPA permits for underground injection. Prior to and after injection, high-resolution seismic data have also been used to image and therefore document the fate of a CO_2 plume in the reservoir (White and others, 2002; Arts and others, 2004; National Energy Technology Laboratory, 2008).

Seismic data map

To help with planning for future sequestration projects, the Kentucky Geological Survey compiled a map (Plate A.1) of the locations of available seismic data in the state. Most of these seismic data is privately held, and available for sale. The map was compiled to provide users with a quick visual reference that will allow them to determine the particular areas of the state that have seismic data and the data owner or primary source for the specific data. All other information concerning the seismic data are within the purview of and available from the data owners, primary providers, or vendors, as the case may be.

Subsurface Pressure Data

The chief source of downhole pressure data is oil and gas well records. Logs in the immediate vicinity of any test site, or at the proposed horizon of injection should be checked to determine if any pressure data are included. In the absence of measured data, the hydrostatic gradient can be used to estimate a downhole pressure (Frailey and others, 2005; Wickstrom and others, 2005). The formula is:

hydrostatic gradient minimum = 0.433 psi/ft = 9.795 kPa/m.

Relative to downhole pressure and injection, it is also important to know the fracture gradient, or maximum hydrostatic gradient. This is the pressure that should not be exceeded in a subsurface reservoir, because it is the pressure at which the rock breaks or fractures, potentially resulting in leakage of injected gases or fluids. The EPA doesn't have a specific maximum injection pressure for Class I industrial waste injection, Class II oil and gas injection, or Class V experimental injection wells. However, the regulations state that the injection pressure cannot fracture the confining zone directly above the injection zone. Step-rate tests are usually used to calculate site-specific maximum injection pressures. In Indiana and Illinois (states with primacy), the maximum allowable injection pressure in injection wells is 0.8 psi/ft. A slightly more conservative value, 0.75 psi/ft, is sometimes applied in Kentucky:

fracture gradient minimum = 0.75 psi/ft = 16.966 kPa/m.

Subsurface Temperature Data

The chief source of downhole temperature data is oil and gas well records. Well logs in the immediate vicinity of any test site, or at the proposed horizon of injection, should be checked to determine if any temperature data are included. Unfortunately, downhole temperature is not a standard measurement in most wells. In the absence of measured data, the average geothermal gradient can be used to estimate a downhole temperature (Frailey and others, 2005; Wickstrom and others, 2005). The formula is:

geothermal gradient = 0.015°F/ft = 0.027°C/m.

When calculating downhole temperature, it is important to remember to start with the surface temperature and add the gradient. In Kentucky, the average surface temperature is approximately 55°F.

Subsurface Salinity Data

The chief source of downhole salinity data is water samples collected from oil and gas wells. Wells in the immediate vicinity of any test site, or at the proposed horizon of injection, should be checked to determine if samples were collected and analyzed. Unfortunately, sampling of deep wells for water has been fairly rare in Kentucky. Water salinity can also be estimated using the spontaneous-potential and/or formation-resistivity logs (see Schlumberger, 1997, charts SP-1 and Gen-9). Salinity and geochemical data for Kentucky are summarized in chapter 3 of this report.

Near-Surface Freshwater Data

An important aspect of future CO_2 injection projects will be protection of the freshwater (groundwater) zone from potential leakage. Wells will have to be cased through freshwater-bearing strata, and a satisfactory number of sealing strata will need to separate the potable water zones from the zone in which injection occurs. Current Class V experimental well permits being obtained from EPA for test injections of CO_2 are requiring monitoring of all wells and springs within a 1- to 2-mi radius of the test well. In some cases, extra monitoring wells may need to be drilled and sampled to ensure that potable water zones are not being influenced by the injected CO_2.

Static water well data are available through the Kentucky Geological Survey's Groundwater Data Repository (kgsweb.uky.edu/DataSearching/watersearch.asp). A tutorial explains how to compile available depths to groundwater in an area. KGS also provides online county groundwater resource reports for the entire state (www.uky.edu/KGS/water/library/webintro.htm). Each report is a compilation of information on the hydrology, geology, topography, and water supply and quality of the county, based on data collected from 1940 to 2000. These reports are digital updates of the USGS hydrologic atlases that cover multicounty regions. The hydrologic atlases for Kentucky have been scanned and are available online at www.uky.edu/KGS/water/library/USGSHA.html.

In general, the depth to groundwater in Kentucky is less than 300 ft; many areas have groundwater at less than 50 ft from the surface. The fresh–saline water interface is generally less than 1,000 ft beneath the surface and in many parts of Kentucky is only hundreds of feet beneath the surface (Hopkins, 1966).

Bedrock Geology

Permitting a CO_2 test well or large-scale injection project will require information on the bedrock geology of the well site and potential area of influence. Kentucky is fortunate to have detailed maps of bedrock geology at a scale of 1:24,000, which is the same scale as standard topographic maps. The geologic quadrangle maps each illustrate an area of 7.5 minutes of latitude and longitude, or approximately 7 X 10 mi. The geologic quadrangle maps are available in hard copy and as digital files online at the Kentucky Geological Survey GIS and Maps page, www.uky.edu/KGS/gis/. Each map illustrates the bedrock geology at the surface and near surface, and includes rock-unit descriptions, thicknesses, structural dips, known fault locations, and information about the economic geology of the area when it was mapped. Kentucky is one of only two states mapped at 1:24,000 scale, and the only state to provide those maps in digital form online.

KGS offers an online map service that allows users to create custom geologic maps and add data from various themes that relate to geology, land use, environmental protection, and economic development (kgsmap.uky.edu/website/KGSGeology/viewer.asp).

Seismic Hazard Data

Another type of geologic data that may be required for future carbon storage projects is seismic risk potential. The FutureGen RFP (request for proposals) required that proposed sites have peak ground acceleration of less than 30 percent g. This is a measurement of the relative strength of seismic shaking relative to the force of gravity. This limitation was for building a large energy plant with geologic sequestration, so geologic sequestration by itself may not have these guidelines. Estimates of peak ground acceleration in Kentucky can be found at the U.S. Geological Survey's Web site at earthquake.usgs.gov/research/hazmaps/.

In western Kentucky, a 30 percent g peak acceleration with a 2 percent chance of being exceeded in 50 yr is surpassed in counties west of a line from eastern Henderson to central Christian Counties (Fig. A.3). These counties are positioned within the New Madrid Seismic Zone. These estimates of peak ground acceleration are being reexamined, and this work suggests that magnitudes and peak exceedance might be overestimated (Olson and others 2005; Wang and others, 2007).

Public forums on carbon sequestration during phase I and phase II DOE-sponsored projects have shown that there is considerable public concern about the fate of injected CO_2 during an earthquake. Consequently, most phase II demonstration projects are located away from areas of potential seismic hazard to help alleviate those concerns. Because of public perceptions about the risk of an earthquake in the New Madrid Seismic Zone, there may be more concerns in western Kentucky than in other parts of the state. Aside from locating projects away from areas of known earthquakes, additional public confidence can be attained by noting the long history of drilling and injecting gases and fluids in seismic areas without harm to the public. Available technology and engineering have been designed for injection projects to prevent catastrophic releases of gases or fluids in the event of an earthquake (MRCSP, 2008).

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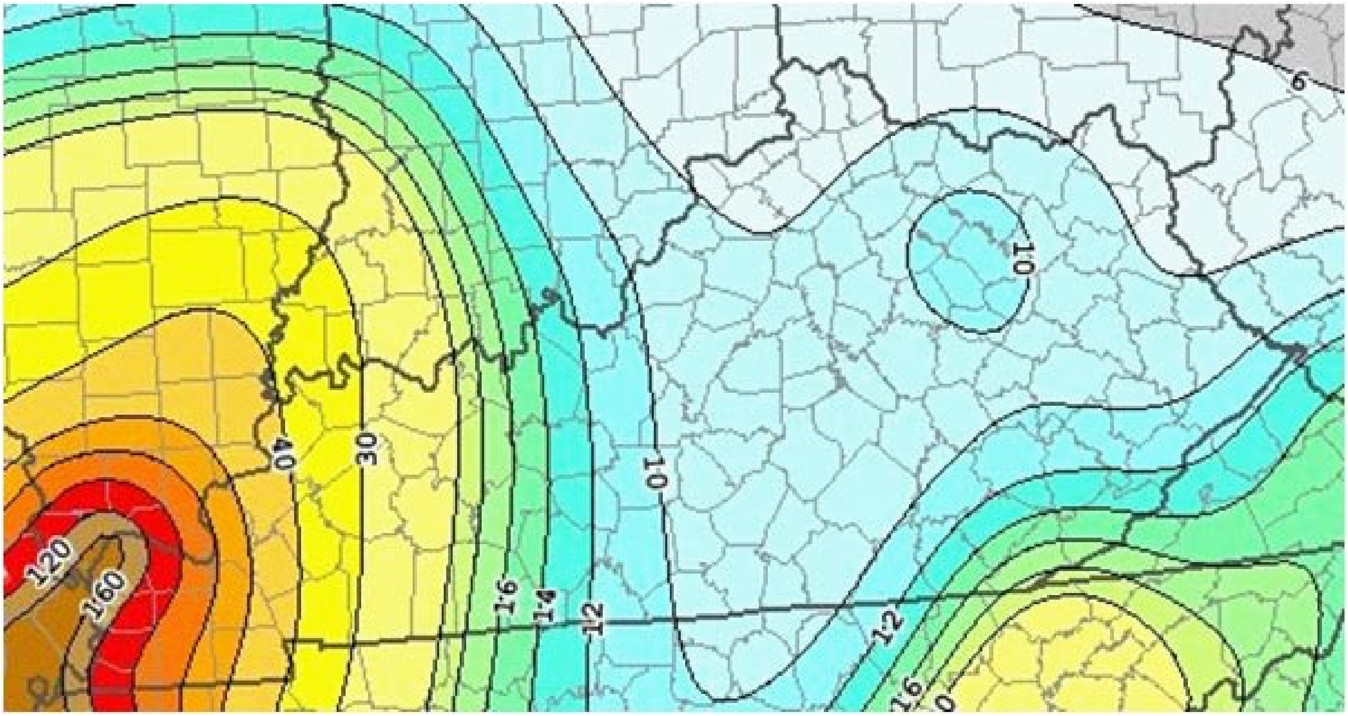

Figure A.3. Estimated peak horizontal acceleration (percent g) with 10 percent probability of being exceeded in 50 yr. From the U.S. Geological Survey National Seismic Hazards Map Viewer, gldims.cr.usgs.gov/nshmp2008/viewer.htm.

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