Potential for Geologic Storage of CO_2 in Western Maryland – Phase I Studies

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Abstract

The Maryland Geological Survey, Power Plant Research Program and Maryland Energy Administration are initiating geologic studies that will support the sustained use of coal for power generation coupled with the environmentally beneficial practice of decreasing greenhouse gas emissions through geologic sequestration. Maryland has recently joined the US Department of Energy funded Midwest Regional Carbon Sequestration Partnership. These studies will provide fundamental subsurface geological information, allowing a region-wide assessment of the suitability of geologic reservoirs for carbon dioxide (CO_2) sequestration.

The current investigation focuses on Western Maryland depleted or nearly depleted natural gas reservoirs and unminable coal seams in Garrett and Allegany counties. The western portion of the state has demonstrable potential for geologic storage of CO_2 as evidenced from its history of natural gas exploration and production; hosts several large coal-fired power plants representing potential sources of injectable CO2; anticipates future siting of clean-coal fired power plants which would employ carbon capture and sequestration technologies; and is on the eastern edge of the Central Appalachian coal producing region. Opportunities on the Eastern Shore Coastal Plain where saline aquifers have been encountered at depths greater than 2,500 feet will also be evaluated. Ongoing work involves evaluating, organizing, and cataloging data at the Survey and will lead to the development of ArcGIS maps for each reservoir type showing aerial extent, depth, thickness and structural features. When completed, results will be delivered to the Partnership and loaded onto the Survey website for easy access by Federal, State, and County agencies, as well as the public and private industry.

Introduction

The Maryland Geological Survey, Power Plant Research Program, and Maryland Energy Administration are conducting geologic studies that will support the sustained use of coal for power generation and will utilize the environmentally beneficial practice of decreasing greenhouse gas emissions through geologic sequestration. Electric power generation is responsible for a large portion of the CO_2 emitted in Maryland. Further, Maryland relies on coal-fired power plants to provide a significant portion (59%) of the State's electricity production (Figure 1). Because coal is anticipated to remain the dominant fuel source for electricity production in the future, it is important that carbon capture and storage technologies be employed to reduce greenhouse gas emissions. Especially if we enter into a carbon-constrained economy, it is expected that geologic sequestration would play a significant role in reducing these greenhouse gases.

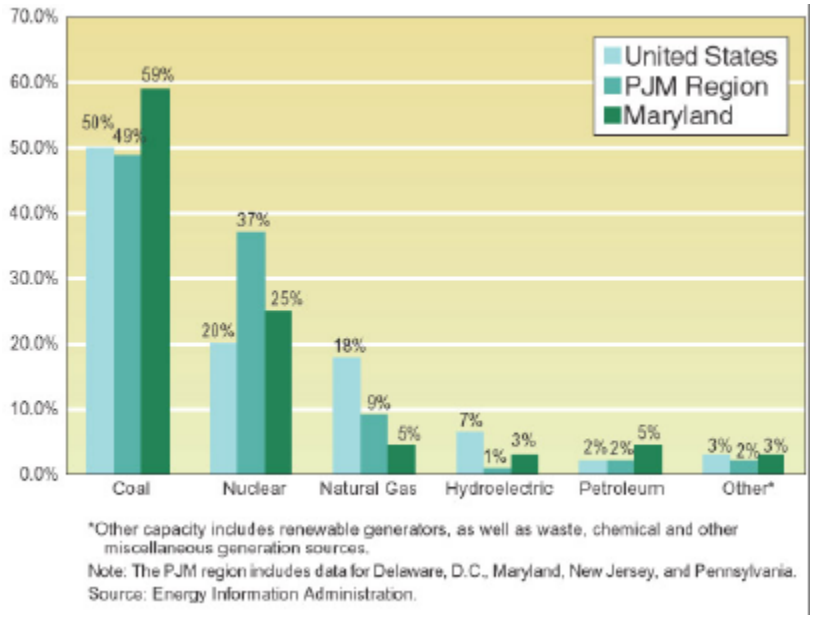

Figure 1. Electricity Production by Fuel Type for the U.S., the PJM region, and Maryland (2002)
Source: Energy Information Administration

Background - State partners

Three primary organizations within the State of Maryland have teamed together to conduct this investigation. Each organization will provide input on research direction, evaluate data collected, and contribute to the generation of end products. A brief description of each group is provided below.

The Maryland Geological Survey (MGS), founded in 1896, is currently a division within the Maryland Department of Natural Resources and is an applied scientific-investigative organization. The Environmental Geology and Mineral Resources Program conducts investigations and surveys of the geology of Maryland to assess economic and land resources, and environmental hazards. The Program, in partnership with the Center for Geographic Information Sciences at Towson University, utilizes state of the art GIS technology to produce maps related to a wealth of mineral, energy and other subsurface resource data. MGS will be responsible for collecting and analyzing data on Maryland's geologic carbon sequestration opportunities.

The second partner, the Power Plant Research Program (PPRP), also operates with the Maryland Department of Natural Resources, and provides a continuing program for evaluating electric generation issues and recommending and advocating responsible, long-term solutions. PPRP was established under the Power Plant Siting and Research Act of 1971 and functions to ensure that Maryland meets its electricity demands at reasonable costs while protecting the State's valuable natural resources. Emissions of greenhouse gases from power generation and transmission, in addition to carbon management options continues to be an active research area. PPRP supports studies related to terrestrial and geologic carbon sequestration opportunities, greenhouse gas emission reduction approaches and carbon capture technologies. In addition, PPRP coordinates research and licensing activities among various state agencies, the power industry and other stakeholders.

The mission of the third partner, the Maryland Energy Administration (MEA) is to maximize energy efficiency while promoting economic development, reducing reliance on foreign energy supplies, and improving the environment. MEA advises the Governor on directions, policies and changes in the various segments of the energy market. MEA has played a leading role in the development of a Maryland Greenhouse Gas Emissions Reduction Action Plant that features carbon sequestration as a strategy for reducing greenhouse gas emissions.

Power Generation and Greenhouse Gas Emissions in Maryland

Currently, greenhouse gas emissions within the State of Maryland are derived primarily from fossil fuel combustion. More than 90 percent of Maryland's greenhouse gas (GHG) emissions take the form of carbon dioxide emissions (CO_2) from fossil fuel combustion—about 76.3 million tons of CO_2 were emitted in 1999. The transportation and electric utility sectors respectively accounted for 37 and 38 percent of this sum. The industrial, residential, and commercial sectors accounted for 10, 9, and 6 percent, respectively.

Projected GHG emissions within Maryland are expected to increase. The National Energy Modeling System (NEMS) was used to forecast the energy use and GHG emissions in Maryland through the year 2020 (MEA). NEMS is the energy and economic model used by the U.S. Department of Energy's Energy Information Agency (EIA) in developing its Annual Energy Outlook (AEO), which forecasts energy supply, demand, and prices through 2025. CO_2 emissions are projected to increase by 49% by 2020, representing an annual average growth rate of 2.2%. This increase is divided almost equally among the different energy using sectors, as Figure 2 illustrates, with the utility and transportation sectors each maintaining between 35% and 40% share of the total State CO_2 emissions.

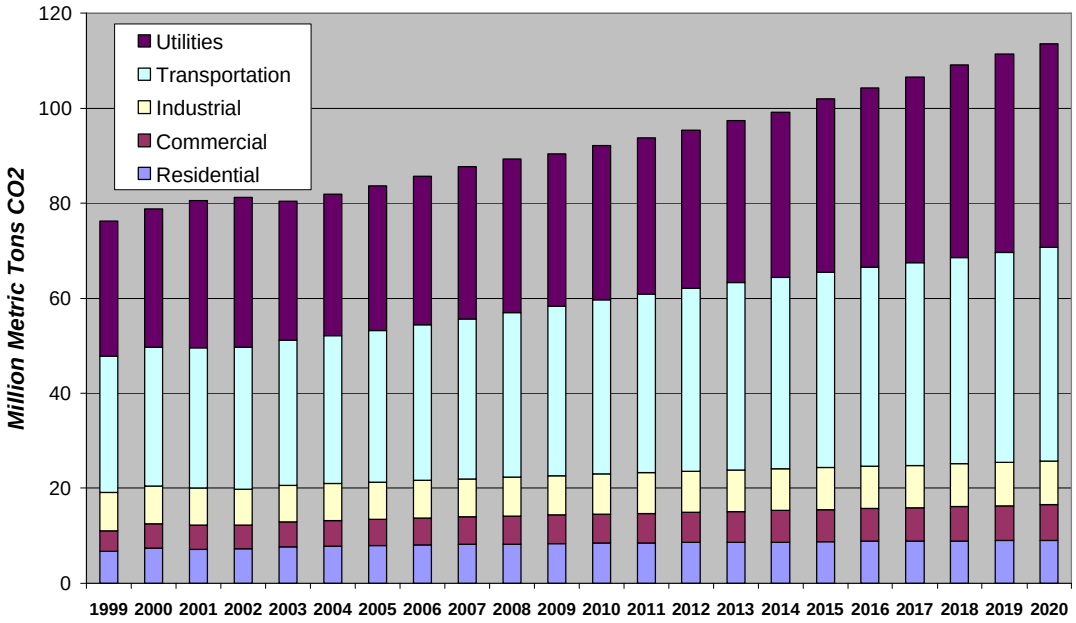

Figure 2. Maryland Projected CO_2 Emissions, 1999 through 2020
Source: SAIC forecast

US Department of Energy (DOE) Midwest Regional Carbon Sequestration Partnership (MRCSP)

In an effort to share in opportunities to reduce projected future greenhouse gas emissions, the State of Maryland has recently joined the US Department of Energy funded Midwest Regional Carbon Sequestration Partnership. Existing partnership states include Ohio, Indiana, Illinois, Kentucky, West Virginia and Pennsylvania. Michigan is also joining the MRCSP (Figure 3).

Figure 3. States Belonging to the Midwest Regional Carbon Sequestration Partnership

The MRCSP, led by Batelle Memorial Institute, will identify greenhouse gas sources in its region and determine the technical feasibility and cost of capturing and sequestering these emissions in deep geologic formations and agricultural forests and degraded land systems. These studies conducted through the Maryland Geologic Survey, the Maryland Power Plant Research Program and the Maryland Energy Administration will provide fundamental subsurface geological information, allowing a region-wide assessment of the suitability of geologic reservoirs for carbon dioxide (CO_2) sequestration.

Maryland has also partnered with several industries in this effort. These partners include AES Warrior Run, Constellation Energy Group, Alliance Resource Partners, L.P. and the Center for Energy and Economic Development. These industry partners have pledged financial and in-kind resources to support the Partnership. A brief description of each industry follows:

AES Warrior Run – In 2000, Maryland's AES Warrior Run plant in Cumberland became one of the first plants in the United States to begin voluntary, commercial scale capture of CO_2 from flue gases. AES's power plant uses more than 600,000 metric tons of Maryland coal every year to generate 180 megawatts of net capacity. In addition to revenue from sales of its electricity, the Warrior Run plant also sells CO_2 which is captured from the plant's flue gas.

Constellation Energy Group (CEG) – CEG owns and operates power plants throughout the United States, markets energy throughout North America, and also delivers electricity and natural gas through our regulated utility in Central Maryland, the Baltimore Gas and Electric Company (BGE). Constellation Energy's goal is to deliver cost-effective, flexible energy solutions that will help reduce the potential problems associated with climate change, and will support the continuation of a research program to help understand the science of global climate change.

Alliance Resource Partners, L.P. (ARLP) – ARLP is the nation's only publicly traded master limited partnership involved in the production and marketing of coal, with operations in Maryland (Mettiki Coal, LLC). ARLP will also assist these studies by providing additional coal exploration and distribution data.

Center for Energy and Economic Development (CEED) - CEED is a non-profit group dedicated to protecting the viability of coal-based electricity. CEED was a supporter of the MRCSP prior to Maryland's joining the partnership but is very supportive of Maryland research in this area. CEED has offered to assist in the Maryland research efforts by encouraging member companies to share their information and resources.

Preliminary Assessment of Maryland's Geologic Sequestration Opportunities

The current investigation focuses on Western Maryland's depleted or nearly depleted natural gas reservoirs and unminable coal seams in Garrett and Allegany counties (Figure 4), both of which provide excellent receptor sites for geologic sequestration. The western portion of the state has demonstrable potential for geologic storage of CO_2 as evidenced from its history of natural gas exploration and production and extensive coal deposits. Additionally, Western Maryland is on the eastern edge of the

Central Appalachian coal producing region and hosts several large coal-fired power plants representing potential sources of injectable CO_2 (Figure 5). It is anticipated that the future siting of clean-coal fired power plants which would employ carbon capture and sequestration technologies would be located in this region.

Figure 4. Counties of Maryland

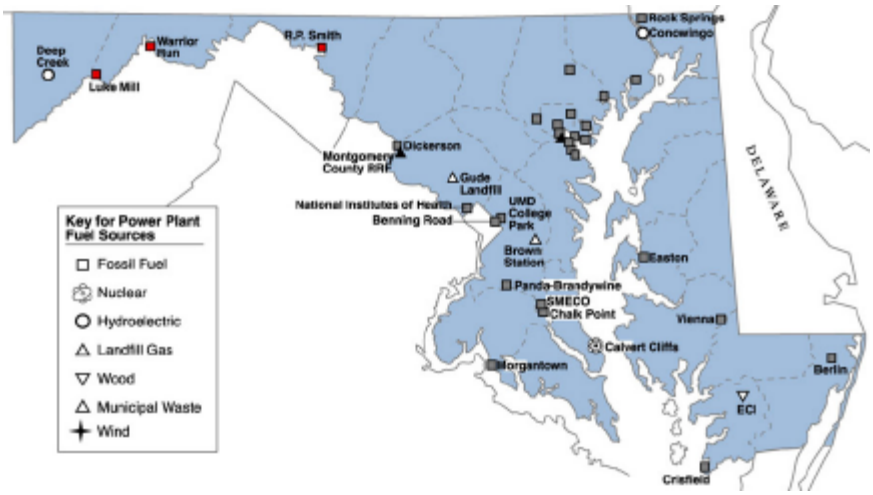

Figure 5. Power Plants in Maryland

Depleted Gas Reservoirs

The first exploration well in Maryland was drilled in 1888 in the Cumberland Narrows, northwest of the town of Cumberland. In 1944, the first evidence of natural gas was found in a well drilled on the Accident Dome in Garrett County. Salt water in the well made gas production difficult and the well was abandoned. Natural gas was later discovered in four fields in the Appalachian region of Maryland. The fields are: Mountain Lake Park, Accident, Negro Mountain, and Pennlands (Artemas). No petroleum has been found in Maryland. In 1995, a fifth field (Fox Curry #1) along the Allegheny structural front was discovered by the Fox Oil and Gas Inc., and is currently producing natural gas.

From 1951 to 1999, 48,591,883 million cubic feet (mcf) of natural gas were produced in Maryland. This figure provides a rough estimate for the capacity for CO_2 sequestration (Figure 6). In 1957, the maximum annual rate of production occurred with 4,543,058 mcf produced. This number declined to 16,506 mcf in 1999.

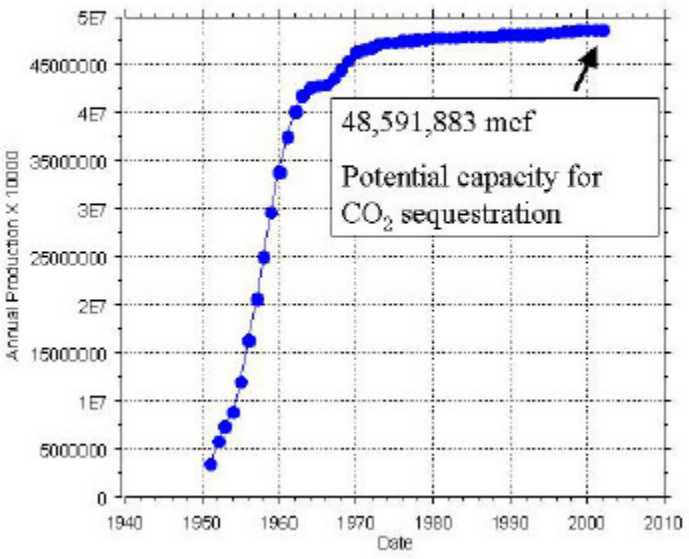

Figure 6. Cumulative Gas Production in Maryland in Million Cubic Feet

Depleted Gas Reservoirs as CO_2 Storage Option

Structural and stratigraphic reservoir features which trap hydrocarbons are also suitable for permanent geologic sequestration of CO_2. In Garrett County, structural features, such as anticlines and domes, trap hydrocarbons in the Oriskany sandstone formation (Figure 7). Natural gas production in stratigraphic fields also occurs in Maryland. The Fox Curry production well draws from the deeper Heldersburg sandstone formation, a stratrigraphic trap.

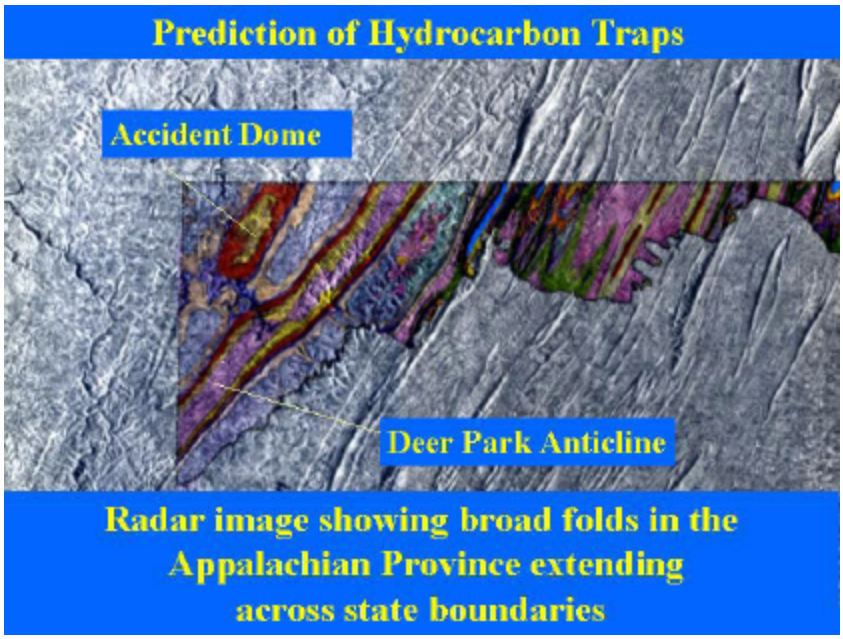

Figure 7. Prediction of Hydrocarbon Traps in Western Maryland

Coal deposits

The western part of the state intersects the Northern Appalachian Coal Basin and as a result has extensive coal formations. Coal from the Pittsburgh and Upper Freeport coal beds occurs in five elongated

structural basins (synclines) in Garrett and Allegany Counties (Figure 8). Maryland's coal reserves are estimated to exceed over 1 billion tons, and nearly 855 million tons of these reserves are regarded as recoverable (Table 1). Peak production of coal occurred in the early 1900s with approximately 5.5 millions tons produced annually. Current rates of coal production are about 3.5 million tons per year.

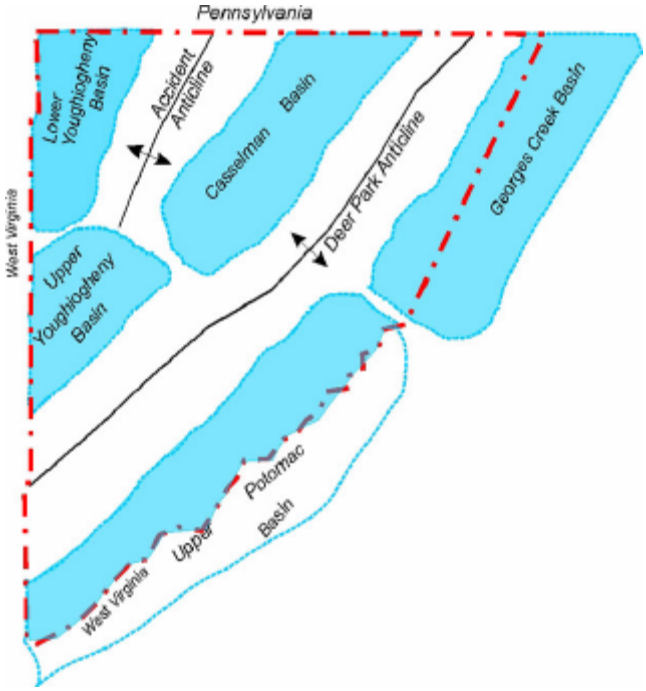

Figure 8. Garrett County Coal Fields

Basin	Recoverable Tons (Millions)
Georges Creek	354.1
Upper Potomac	223.5
Casselman (Castleman)	116.0
Lower Youghiogheny	107.0
Upper Youghiogheny	54.3
Total	**854.9**

Table 1. Recoverable coal reserves in Maryland

Unminable Coal Seams as CO_2 Storage Option

Coal beds, particularly those that are deep and unminable, are suitable for CO_2 sequestration. CO_2 injected into coal beds displaces methane (CH_4) and becomes chemically bonded to the coal. A co-benefit to this technology is the enhanced recovery of coal bed methane, which may partially offset the costs of sequestration.

This study initially focuses on characterizing the suitability of the Pittsburgh and Upper Freeport coal seams for CO_2 sequestration. These seams are widespread and are of minable thickness throughout the MRSCP region. However, there are several other coals in Maryland that are not of commercial thickness or areal extent, but may prove to be excellent storage sites for permanent CO_2 storage.

Power Plant Location Relative to Gas Production Fields

In evaluating the potential for geologic sequestration in Maryland, it is also important to consider the location of sources of CO_2. Several existing and potential sources of CO_2 occur within the Western Maryland region that could be used for test injections and future whole-scale capture and sequestration. Three existing power plants, Warrior Run, R. Paul Smith, and Luke Mill (Figure 9), are located from 7.5 miles, at the closest, to 86 miles, at the furthest, from known gas producing formations in Western Maryland.

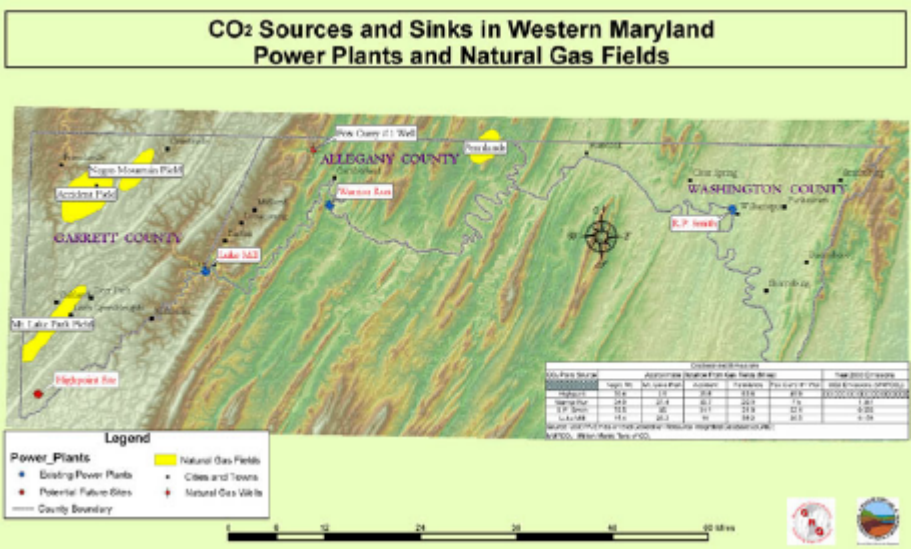

Figure 9. CO_2 Sources and Sinks in Western Maryland

Of these three existing power plants, Warrior Run, owned by AES Corporation, rates highest in terms of amounts of CO_2 emissions. This plant currently captures approximately 10% of its CO_2 emissions in a process that utilizes steam to make food grade carbon dioxide. Upgrades to capture more of the emitted CO_2 are technologically feasible and could be used to produce a source of concentrated CO_2 for geologic sequestration studies.

The R. Paul Smith power station, owned by Allegheny Energy Supply, is one of the oldest coal-fired power plants in Maryland, starting operations in 1909. In 2003, this power station began hosting demonstration projects to evaluate the performance and emissions reductions, particularly CO_2, of composite coal/biomass fuel. The R. Paul Smith power station would make an excellent candidate for future research and development projects designed to capture, sequester and reduce total emissions of CO_2.

Luke Mill is owned and operated by Westvaco for the purpose of meeting its electricity and steam requirements for pulp and paper processing. Energy production is fueled partially (38 %) by biomass, a renewable energy source. Although Luke Mill emits the least amount of CO_2 regionally, it is favorably located to several potential CO_2 reservoirs.

The "Highpoint Site"

Western Maryland also hosts another site with great potential for implementing carbon capture and sequestration technologies. The Highpoint Site, located on the southernmost tip of Garrett County, has excellent development potential for a zero-emissions, clean-coal power plant outfitted with carbon capture and sequestration technologies. The features that make it an excellent candidate for carbon these technologies include:

- A 550 kva transmission line passes close to the Highpoint Site for convenient access to the Pennsylvania-New Jersey -Maryland power grid.

- Mine pools offer sources for major water use and deep mines below the water table could receive spent cooling water.
- The site is very close to potential CO_2 geologic sinks, being just 10 miles from Mountain Lake Park gas field.
- In addition to the existing highway and rail infrastructure, the Highpoint Site is adjacent to the Mettiki Coal Corporation's active mine mouth coal preparation plant and could share the use of existing coal separation and handling facilities as well as its modern wastewater treatment plant.
- Maryland's Governor Robert Ehrlich has expressed his support and enthusiasm for project development at this site to President Bush as a recommendation for the FutureGen project.

Data Collection and Methods

PPRP, MGS, and MEA have conducted significant initial research on geologic formations within the State of Maryland that have been identified as potential geologic sequestration receptors. As mentioned previously, these formations include the Oriskany Sandstone, the Pittsburgh Coal and the Upper Freeport Coal. Brief descriptions of the formations are included below.

Oriskany Formation

The Oriskany sandstone formation, which has proven to trap hydrocarbons, has been identified as a potential carbon sequestration site because of its ideal reservoir features, including its depth, porosity, and structural caprock. Based on the current data collected, the depth to the top of the Oriskany from the ground surface ranges from approximately 3,400 feet to nearly 8,900 feet. The thickness of the formation ranges from 34 feet to 289 feet.

Pittsburgh and Upper Freeport Coal Formations

The Pittsburgh and Upper Freeport coal formations also function as potential carbon sequestration receptor sites because of their widespread location and minable thickness. Based on the current data collected, the Pittsburgh Coal has a thickness ranging from 2.25 feet to 10 feet, and the Upper Freeport Coal ranges in thickness from less than 1 foot to 10 feet.

PPRP and MGS have developed a database of information collected from exploration and production wells in the Oriskany formation and coal bores from the Pittsburgh and Upper Freeport formations. The database includes summary information, such as depth, elevation, and formation thickness. Specifically, the database includes the following:

- Data from 178 exploration and production natural gas wells drilled into the Oriskany Sandstone. The information on these borings was obtained from two documents, MGS's Basic Data Report #11 titled "Garrett County Water-Well Records, Chemical Quality Data, Ground-Water Use, Coal Test Hole Data, and Surface Water Data" and Basic Data Report #5 titled "Deep Wells of Maryland."
- Data from 209 coal borings drilled into the Upper Freeport formation and 34 borings drilled into the Pittsburgh formation. Because data was incomplete for these borings, a topographic mapping software package was used to determine estimated ground surface elevation for each individual boring location.

These data points have been imported into GIS for mapping purposes. Figures 10 and 11 show the preliminary locations of the natural gas wells and the coal cores. As supplementary sources of data become identified and available, it is anticipated that all additional well and core data will be included in the database. It is also anticipated that data related to deep saline aquifers of Maryland's Coastal Plain will be included in the database.

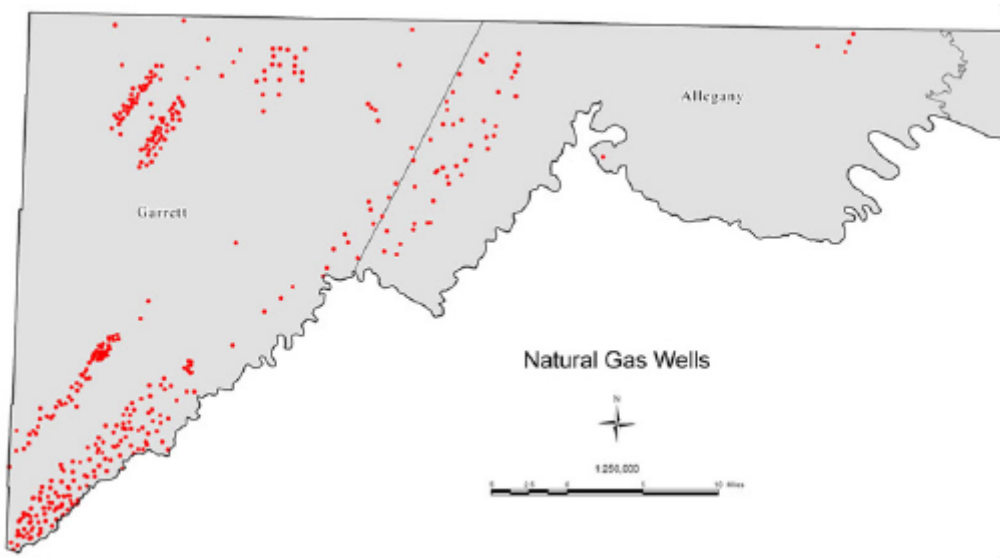

Figure 10. Preliminary Map of Natural Gas Wells in Garrett and Allegany Counties

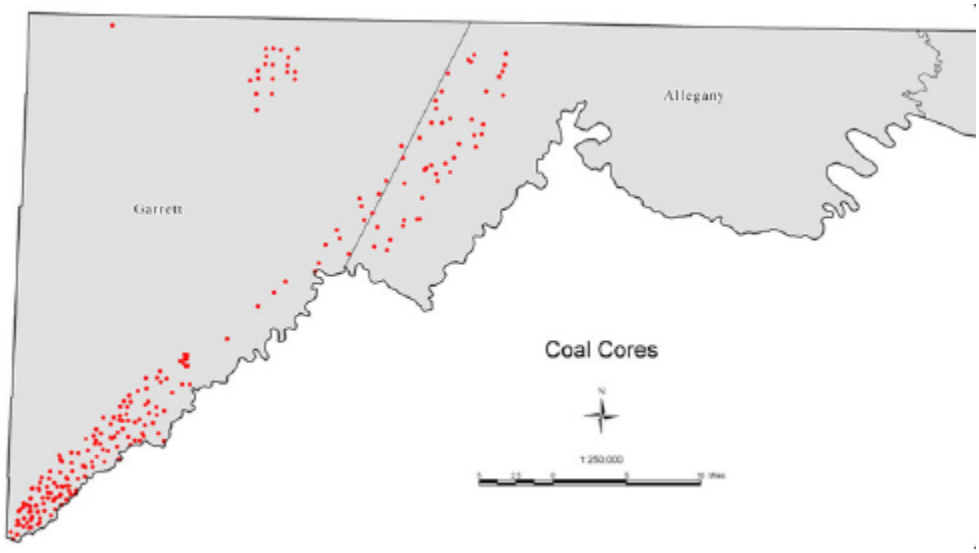

Figure 11. Preliminary Map of Coal Cores in Garret and Allegany Counties

Additional ongoing work involves evaluating, organizing, and cataloging data at MGS, which will lead to the development of ArcGIS maps for each reservoir type showing aerial extent, depth, thickness, and structural features. When completed, the results will be delivered to the Partnership and loaded onto the Survey website for easy access by Federal, State, and County agencies, as well as the public and private industry.

Conclusions and Next Steps

An initial review of available data on geologic sequestration opportunities in Western Maryland reveal that potential does exist, however many more studies will be required to evaluate the feasibility of permanent storage of CO_2 in deep geologic reservoirs. Detailed studies will need to address a variety of issues including physical and chemical reservoir characteristics influencing storage volumes and permanence, CO_2 interactions and behavior within target reservoirs, environmental risk analyses, infrastructure requirements and costs, regulatory concerns and stakeholder outreach.

For the MRCSP, Maryland will provide map and reservoir characterization data for selected gas fields, coals and saline aquifers. Data will be submitted in the form of integrated geographic information system

(GIS) files and associated digital data. For the remainder of 2004, tasks will focus on the following items:

- Continue gathering and mapping well and coal bore locations
- Evaluate coastal plain deep saline aquifer – "The Waste Gate Formation"
- Evaluate available porosity, permeability and other physical and chemical data
- Produce depth, thickness and structural maps, including any identifiable porosity and permeability gradients
- Evaluate carbon sequestration potential
- Produce GIS files and deliver to MRSCP

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