# Southeast Regional Carbon Sequestration Partnership (SECARB)

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## Disclaimer

## Abstract

The Southeast Regional Carbon Sequestration Partnership (SECARB) is on schedule and within budget projections for the work completed during the first 18-months of its two year program.

Work during the semiannual period (fifth and sixth project quarters) of the project (October 1, 2004 – March 31, 2005) was conducted within a "Task Responsibility Matrix." Under Task 1.0 Define Geographic Boundaries of the Region, no changes occurred during the fifth or sixth quarters of the project. Under Task 2.0 Characterize the Region, refinements have been made to the general mapping and screening of sources and sinks. Integration and geographical information systems (GIS) mapping is ongoing. Characterization during this period was focused on smaller areas having high sequestration potential. Under Task 3.0 Identify and Address Issues for Technology Deployment, SECARB continues to expand upon its assessment of safety, regulatory, permitting, and accounting frameworks within the region to allow for wide-scale deployment of promising terrestrial and geologic sequestration approaches. Under Task 4.0 Develop Public Involvement and Education Mechanisms, SECARB has used results of a survey and focus group meeting to refine approaches that are being taken to educate and involve the public.

Under Task 5.0 Identify the Most Promising Capture, Sequestration, and Transport Options, SECARB has evaluated findings from work performed during the first 18-months. The focus of the project team has shifted from region-wide mapping and characterization to a more detailed screening approach designed to identify the most promising opportunities. Under Task 6.0 Prepare Action Plans for Implementation and Technology Validation Activity, the SECARB team is developing an integrated approach to implementing the most promising opportunities and in setting up measurement, monitoring and verification (MMV) programs for the most promising opportunities.

Milestones completed during the fifth and sixth project quarters included:

- Q1-FY05 – Assess safety, regulatory and permitting issues.
- Q2-FY05 – Finalize inventory of major sources/sinks and refine GIS algorithms.

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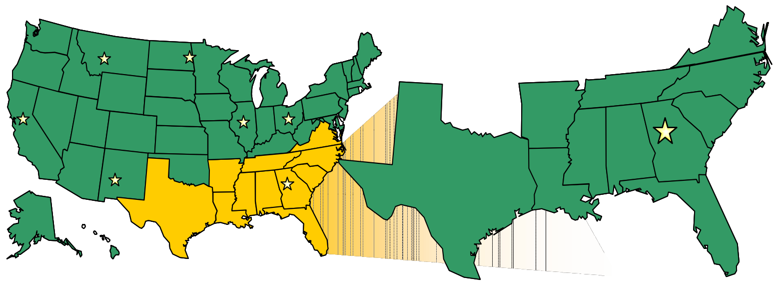
## Introduction

On November 21, 2002, Energy Secretary Spencer Abraham announced a new phase of the United States Department of Energy (DOE) research program solely devoted to the development and deployment of viable carbon sequestration technologies. Less than one month later, the Department issued Phase I of a solicitation aimed at creating a nationwide network of regional carbon sequestration partnerships (RCSPs).



**The SECARB region includes eleven states: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas and Virginia.**
*Map courtesy of the U.S. DOE/NETL.*

Given the Southern States Energy Board's (SSEB) existing carbon management initiative, the SSEB immediately began facilitating discussions with state and federal agencies, policy makers, industry representatives, research entities and other non-governmental organizations to determine a regional response to the solicitation. On August 16, 2003, the Department announced the winners of the Phase I solicitation. The result is a network of seven regional carbon sequestration partnerships, including the Southern States Energy Board's Southeast Regional Carbon Sequestration Partnership.

SECARB work is managed and administered by the Southern States Energy Board. SSEB is the only interstate compact in the United States that is constituted by both federal and state laws, that has governors, state legislators and a Presidential appointee comprising its board of directors and is empowered by its charter to address energy and environmental issues. Among the Technical Team partners are: SSEB; Electric Power Research Institute (EPRI); a Mississippi State University (MSU) team led by the Diagnostic Instrumental Analysis Laboratory (DIAL); Augusta Systems, Inc.; Massachusetts Institute of Technology (MIT); the University of Texas at Austin, Bureau of Economic Geology (TX BEG); the Virginia Polytechnic Institute and State University (Virginia Tech); Winrock International; Geological Survey of Alabama; Advanced Resources International (ARI); Applied Geo Technologies, Inc., a business of the Mississippi Band of Choctaw Indians; the Tennessee Valley Authority (TVA); RMS Strategies; and The Phillips Group.

SECARB is a collaboration covering eleven U.S. states under a DOE initiative to develop regional approaches to carbon sequestration in support of President George W. Bush's Global Climate Change Initiative. The SECARB will evaluate options and potential opportunities for regional carbon sequestration, promote the development of a framework and infrastructure necessary for the validation and deployment of carbon sequestration technologies and produce implementation plans for pilot-scale projects to test and validate approaches and technologies. In addition, the Partnership will focus on engaging stakeholders from diverse constituencies in the planning and implementation of SECARB activities to ensure that all constituencies are well represented in this collaboration.

## Executive Summary

The SECARB region has a diverse partnership composition that encompasses state executive and legislative leadership; electric utilities and associations; sequestration and GIS research centers; energy producers and associations; and natural resource advocates. Also, the region has a diverse portfolio of carbon dioxide ($CO_2$) sources, potential $CO_2$ transport networks and sequestration options.

Work during the semiannual period (fifth and sixth quarter) of the project (October 1, 2004 – March 31, 2005) was conducted within a "Task Responsibility Matrix." Under Task 1.0 Define Geographic Boundaries of the Region, Texas and Virginia were added during the second quarter of the project and no geographical changes occurred during the fifth or sixth quarter of the project. Under Task 2.0 Characterize the Region, general mapping and screening of sources and sinks have been completed, with integration and GIS mapping ongoing. Characterization has focused on smaller areas having high sequestration potential. Under Task 3.0 Identify and Address Issues for Technology Deployment, SECARB continues to expand upon its assessment of safety, regulatory, permitting and accounting frameworks within the region to allow for wide-scale deployment of promising terrestrial and geologic sequestration approaches. Under Task 4.0 Develop Public Involvement and Education Mechanisms, SECARB is using results of a survey and focus group meeting to refine approaches to educate and involve the public. SECARB technical team members are participating in the U.S. Department of Energy/National Energy Technology Laboratory (NETL) Communications Workshop Series. In addition, the SECARB website is operating and is a work in progress. The website address is www.secarbon.org.

SECARB Technical Team and Technology Coalition Members

Lead: Southern States Energy Board (SSEB)
Electric Power Research Institute (EPRI)
Mississippi State University (MSU) Diagnostic Instrumentation and Analysis Laboratory (DIAL)
Massachusetts Institute of Technology (MIT)
Winrock International
Augusta Systems, Inc.
AGL Resources
American Electric Power
Arkansas Oil and Gas Commission
BP America
$CO_2$ Capture Project
Center for Energy and Economic Development
ChevronTexaco Corporation
Clean Energy Systems, Inc.
Composite Technology Corporation
Dominion
Duke Power
Edison Electric Institute
Entergy Services
Florida Power & Light Company
Geological Survey of Alabama
Georgia Environmental Facilities Authority
Georgia Forestry Commission
Gulf Coast & Carbon Center, University of Texas at Austin
Interstate Oil and Gas Compact Commission
Louisiana Department of Environmental Quality
Marshall Miller & Associates
North American Coal Corporation, The
North Carolina State Energy Office
Nuclear Energy Institute
Oak Ridge National Laboratory
Old Dominion Electric Cooperative
Progress Energy
SCANA Corporation
South Carolina Public Service Authority/Santee Cooper
Southern Company
Tampa Electric Company
Tennessee Valley Authority (TVA)
Virginia Center for Coal and Energy Research, Virginia Polytechnic Institute and State University

SECARB's Geologic Sequestration Working Group (GSWG) established a logical step-wise process to collect data and information to characterize the region, identify the potential target areas for sequestration and define the most promising targets for Phase II project work. The first step focused on characterization at the macro level for the region. Subsequent characterization steps focused on refining the initial data, identifying gaps in the data and narrowing the field investigation to smaller areas having high sequestration potential.

Initial, minimum data sets were established to include geographical parameters to aid in locating the potential sinks. From public databases, the smallest geographical entity most consistently available for establishing data location was the county name, so initial maps were developed on a county basis.

Data gaps were apparent across the 11-state region, and research during this period has enabled the Partnership to better define most promising areas. However, there may be suitable geologic formations that can not be characterized sufficiently due to lack of data. While these areas could be promising sites, the lack of data introduces uncertainty and risk. Therefore, the Partnership has concentrated its Phase I efforts on portions of the SECARB region that are "data-rich" as well as having suitable attributes for geologic sequestration.

These areas and their associated geologic formations comprised the targets for geologic data-mining. Three primary data sets were developed from public data, each set focusing on one of the main types of geologic sinks for sequestration, namely saline formations, coal seams and oil and gas reservoirs.

Thousands of data records have been collected to date, and data continue to be gathered, refined and synthesized in an attempt to acquire the most-relevant datasets possible. The data have been and continue to be incorporated into a GIS database for use in identification of priority areas for conducting Phase II activities.

State geological surveys continue to provide additional data, but data gaps remain. Some areas, for example, have not been adequately studied and, therefore, little or no data are available. The expectation, however, is that the data will be adequate to focus detailed evaluation efforts on a number of areas within the region. Figure ES-1, for example, shows a map of saline formations in the SECARB region and relative suitability for geologic sequestration. Figure ES-2 illustrates the region's value-added storage opportunities for enhanced oil recovery (EOR). Figure ES-3 shows the mineable and unmineable coal formations within the region.

**Figure ES–1.** Inventory of Selected Prospects.

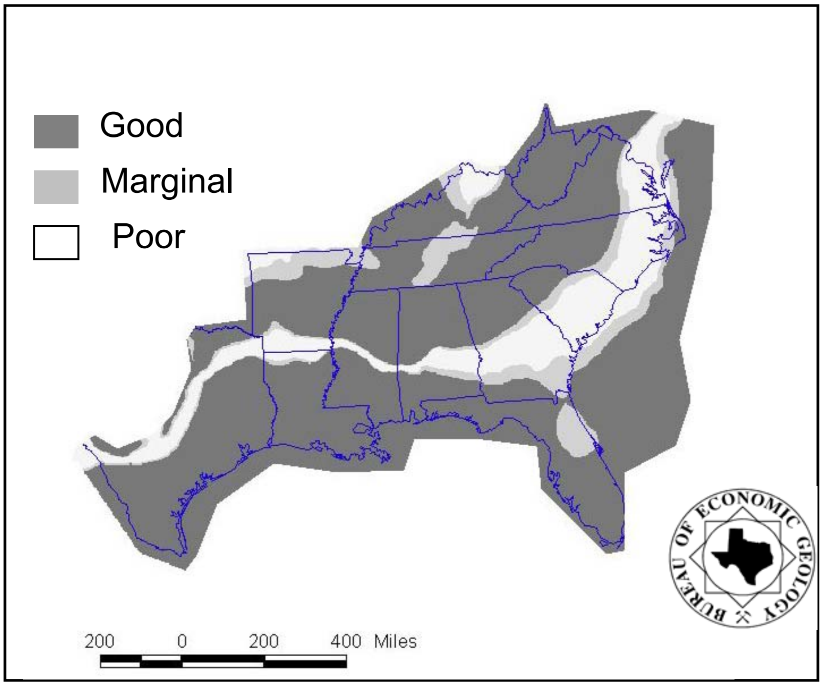



**Figure ES–2.** Value-added Storage Opportunities for Enhanced Oil Recovery (EOR).

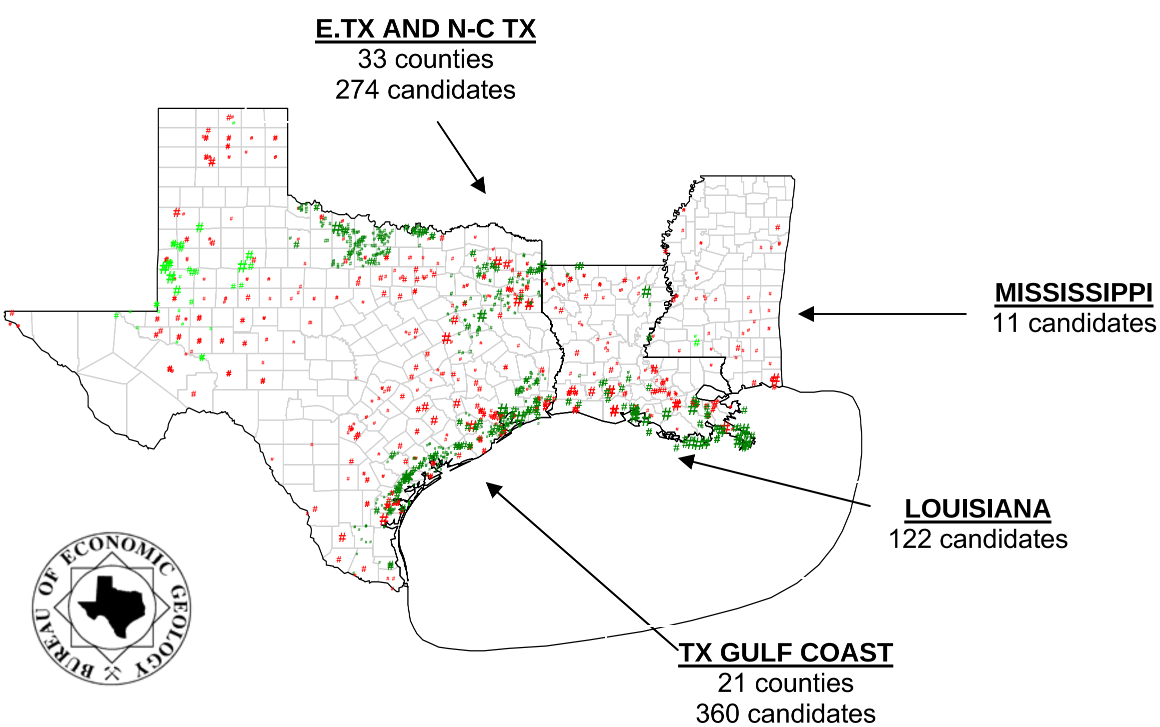
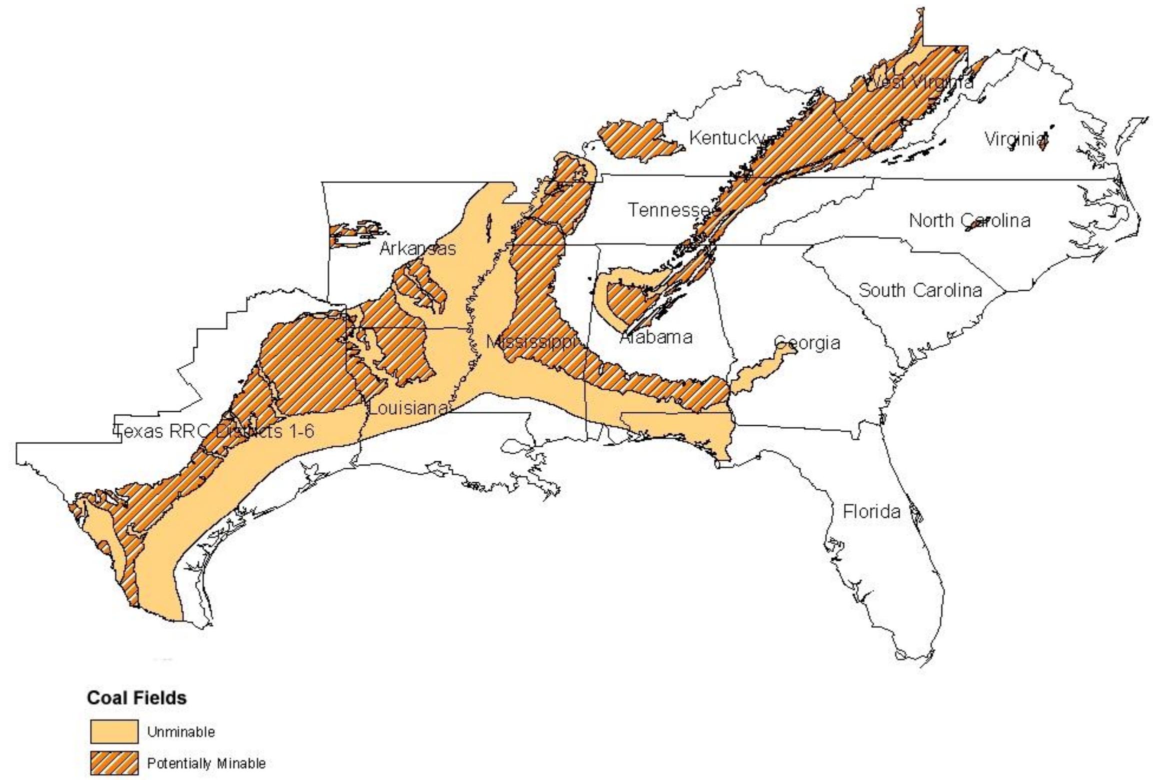


**Figure ES–3.** Mineable and Unmineable Coal Formations in the SECARB Region.




***Source: Massachusetts Institute of Technology***

The SECARB region is a very large region to characterize on the whole at the same precision necessary for selection of specific sequestration targets. Thus, the stepwise approach to narrow the focus to areas warranting further investigation is a more practical approach. During this semiannual report period, SECARB narrowed its range of opportunity locations by eliminating risk-prone locations that lacked data or demonstrated attributes that would make carbon sequestration unlikely (e.g. poor caps, lacking volume below 2400 feet, etc.).

The geologic characterization of coal seams is conducted in a joint effort by the Virginia Center for Coal and Energy Research, Virginia Tech and the Geological Survey of Alabama. Ongoing analyses of areas with sufficient data indicate that coal beds in Southwest Virginia have significant potential for carbon sequestration, particularly in Buchanan, Dickenson and Wise counties. Figure ES-4 provides regional coal bed methane (CBM) gas content. Similar potential exists in the Black Warrior Basin of Alabama shown in Figure ES-5. Geologic mapping of the Alabama and Southwest Virginia coalfields have focused on high carbon sequestration potential counties.

**Figure ES–4.** Regional Coal Bed Methane Gas Content.

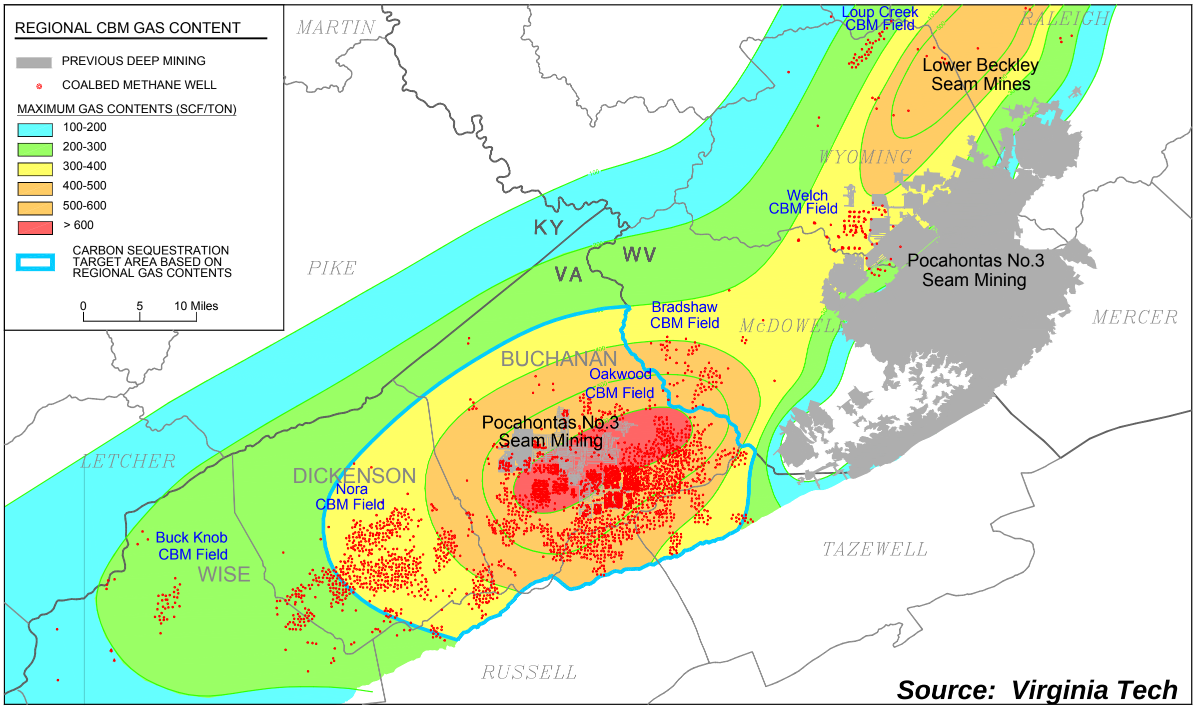
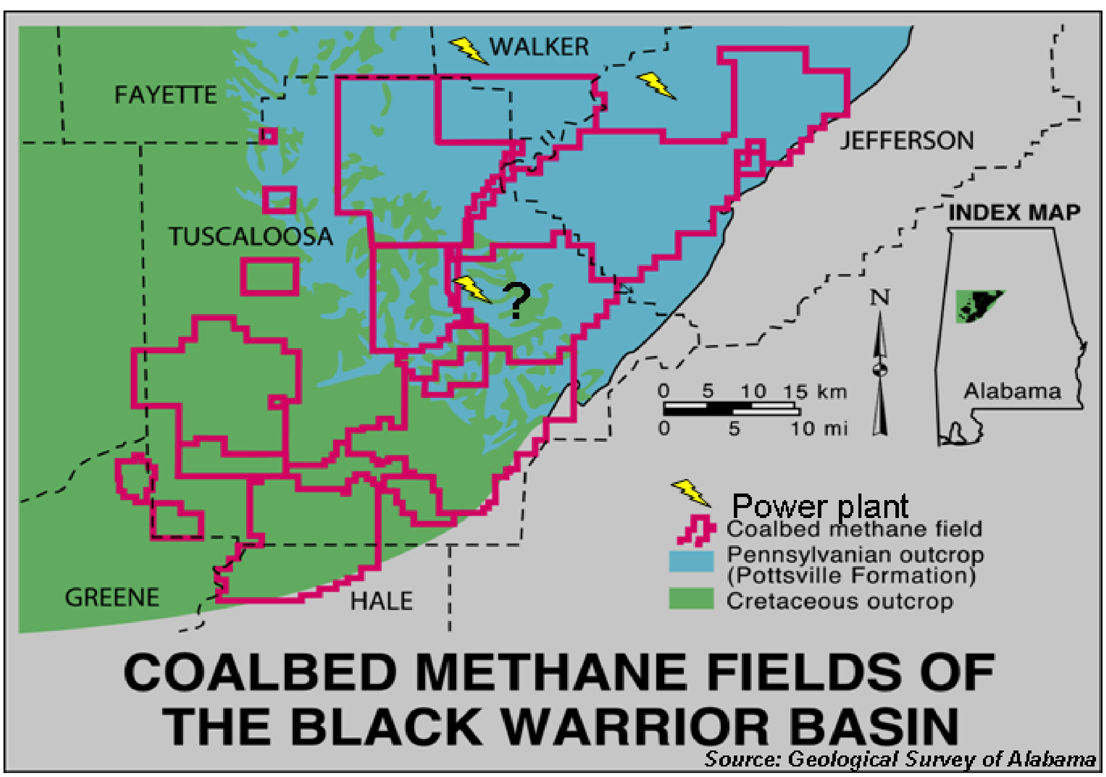



**Figure ES–5.** The Black Warrior Basin Coal Bed Methane Fields.



The Texas Bureau of Economic Geology has completed activities in fulfillment of its scope and tasks during this semiannual period. These activities supported the SECARB's work in completing the DOE objectives focusing on exploring solutions for the capture, transport and storage of anthropogenic fossil fuel carbon dioxide emissions in the Southeast region**.** Major efforts completed during this semiannual period have been the further geologic characterization of Texas oil and gas reservoirs and additional characterization of reservoirs in Louisiana and Mississippi (Figure ES-2). These have been created as GIS data layers to add to the previously created brine formation data layers. Continued progress is expected in the next quarter in terms of finalizing the data from the Louisiana Geological Survey (LGS) and Mississippi Mineral Resource Institute (MMRI). Participation in SECARB and DOE activities such as meetings and national $CO_2$ sequestration forums will continue during the remainder of the program.

As part of its mission, SECARB has a goal to develop action plans to overcome the issues identified in the preliminary assessment of safety, regulatory, permitting and accounting frameworks within the region. These action plans will allow for wide-scale deployment of promising terrestrial and geologic sequestration approaches, including specific capture, transport, injection and storage approaches. During the past 18 months, SECARB has worked to advance this goal and the overall mission.

Project team members have performed research and analysis of the relevant state and federal statutes and regulations applicable to sequestration regulatory, permitting and safety matters. This research involved direct examinations of applicable statutes and regulations related to both geologic and terrestrial sequestration applications, as well as interaction with state legislators and regulators responsible for enacting and implementing regulatory regimes. Also, SECARB team members are working with the Interstate Oil and Gas Compact Commission (IOGCC) Task Force on Geologic Carbon Sequestration to ensure that SECARB approaches will converge with recommended national approaches. In addition, the project team investigated emerging, potentially SECARB-applicable, greenhouse gas (GHG) accounting frameworks.

To meet the public outreach and education goals of SECARB, the Partnership's efforts sought to conduct a preliminary assessment of public perception regarding the SECARB effort. In addition, SECARB is formulating a follow-on plan focused on in-depth research that would serve to assist in the development of the formal action plans for public outreach and education.

Under Task 5.0 Identify the Most Promising Capture, Sequestration, and Transport Options, SECARB has evaluated findings from work performed during the first 18-months. The focus of the project team has shifted from region-wide mapping and characterization to a more detailed screening approach designed to identify the most promising opportunities. Under Task 6.0 Prepare Action Plans for Implementation and Technology Validation Activity, the SECARB team is developing an integrated approach to implementing the most promising opportunities and in setting up measurement, monitoring and verification (MMV) programs for the most promising opportunities.

## Experimental

Due to the nature of the project, no experimental methods, materials or equipment are necessary.

## Results and Discussion

The primary tasks in the Partnership's Phase I scope of work are: (1) Define the Geographic Boundaries; (2) Characterize the Region; (3) Identify and Address Issues for Technology Deployment; (4) Develop Public Involvement and Education Mechanisms; (5) Identify the Most Promising Capture, Sequestration and Transport Options; and (6) Prepare Action Plans for Implementation and Technology Validation Activity. A summary of the current status of each task is provided in this section of the report.

### Task 1: Define Geographic Boundaries

The geographic boundaries of SECARB were expanded by two states (Virginia and Texas) during the first semiannual reporting period. Special attention was given to the integration of Virginia and Texas activities into the overall SECARB region. The geographic boundaries currently include the states of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas and Virginia.

### Task 2: Characterize the Region

As part of the ***Regional Characterization Activities***, SECARB is reviewing its initial $CO_2$ emissions inventory and verifying the accuracy of source data added to the inventory. Identifying power plant sites on which the Partnership will concentrate is an immediate priority. SECARB continues to review pre-combustion, post-combustion and oxygen-fired technologies for separating and capturing $CO_2$ emissions.

The Massachusetts Institute of Technology continues to receive data and verify it locally. Source data on the MIT server has been linked to the DOE National Carbon Database (NATCARB), a national database covering all regional carbon sequestration partnerships.

The main work on ***transport options*** was completed during the last reporting period and is related to an EPRI project on $CO_2$ Test Centers.

SECARB has conducted an inventory of major $CO_2$ sources and sinks for the Partnership region. The information will reside on SECARB's database, and will be connected to the NATCARB database. The Partnership is refining GIS algorithms and tools for the geographic area, including:

- A tool for source/sink matching;
- A sink capacity tool; and

- Three costing algorithms for capture, transportation and injection.

SECARB continues to compile geologic data on ***potential sinks for $CO_2$***, including coal seams, gas and oil fields and deep saline formations. The process allows for an informed characterization of the region which then will allow the SECARB to identify the potential target areas that pose the optimum sequestration opportunities, as well as define the most promising target areas for potential field testing.

**Regional Sources**

This report summarizes the current status of the $CO_2$ database for the SECARB GIS. Eight major stationary source categories have been characterized and quantified for the project: power plants, oil and gas processing, refineries, ammonia plants, hydrogen production, ethylene and ethylene oxide plants, iron and steel plants and cement plants. SECARB has focused on the three most important sources for the Southeast region: power plants; refineries; and gas processing facilities. Table 1 provides a listing of data sources used to assess these facilities.

Data collected by ECOFYS was used as a preliminary dataset for the GIS database, except for power plants, which uses the 2002 U.S. Environmental Protection Agency (EPA) eGRID database. SECARB work focuses on replacing sections of this database with data sources that are more current and of higher detail. Many of the data sources used in the ECOFYS database were re-visited, including information from the Oil and Gas Journal Gas Processing Survey. In addition, information was collected from new sources, including the U.S. Geological Survey (USGS) Organic Geochemistry Database and the DOE Energy Information Agency (EIA).

**Table 1.** Summary of $CO_2$ Source, Data Sources and Status.

| $CO_2$ Source | Data Sources |
|---|---|
| Power plants | US Environmental Protection Agency<br>eGRID Database<br>http://www.epa.gov/cleanenergy/egrid/index.htm |
| Refineries | US Department of Energy – Energy Information Administration<br>http://www.eia.doe.gov/oil_gas/petroleum/data_publications/refinery_capacity_data/refcapacity.html |
| Gas processing facilities | Oil and Gas Journal Worldwide Gas Processing Survey (2003)<br>http://orc.pennnet.com/surveys/aboutsurveys.cfm<br>USGS Organic Geochemistry Database<br>http://energy.cr.usgs.gov/prov/og/ (well $CO_2$ levels) |
| Ammonia plants | ECOFYS Report – Building the Cost Curves of $CO_2$ Storage, Part 1: Sources of $CO_2$ (July 2002) |
| Hydrogen production | ECOFYS Report – Building the Cost Curves of $CO_2$ Storage, Part 1: Sources of $CO_2$ (July 2002) |
| Ethylene and ethylene oxide plants | ECOFYS Report – Building the Cost Curves of $CO_2$ Storage, Part 1: Sources of $CO_2$ (July 2002) |
| Iron and steel plants | ECOFYS Report – Building the Cost Curves of $CO_2$ Storage, Part 1: Sources of $CO_2$ (July 2002) |
| Cement plants | ECOFYS Report – Building the Cost Curves of $CO_2$ Storage, Part 1: Sources of $CO_2$ (July 2002) |

### *Power Plants*

Power plant locations were reported in the previous semiannual report. The current database uses 2002 EPA eGRID data for refinery capacities, locations and $CO_2$ emission rates. The EPA updates the eGRID database every two years; the last update (with 2002 data) was released May 2003. This data source is the best available for this category, and the database will be updated to 2004 data when available (expected spring 2005).

### *Oil and Gas Processing Facilities*

Oil and gas processing facilities were reported in the previous semiannual report. The ECOFYS database used data from the 2001 Oil and Gas Journal Worldwide Gas Processing Survey. In addition to gas processing capacity, the ECOFYS database lists latitude/longitude locations for most gas processing facilities. The locations were determined with the use of the USGS Geographic Names Information System (GNIS). This system was used to convert place names associated with each gas processing facility into latitude/longitude coordinates. The database for this project has been updated with the most recent (2003) Oil and Gas Journal Worldwide Gas Processing Survey, resulting in 298 gas processing facilities being identified for the region.

**Table 2.** 2003 Oil and Gas Journal Gas Processing Facilities Data.

| State | Number | Gas Capacity (MMCFD) | | | |
|---|---|---|---|---|---|
| | | Total Capacity by State (annualized, per day) | Total Throughput by State (annualized, per day) | Individual Facility Capacity | |
| | | | | Mean | Max |
| Alabama | 13 | 1377 | 670 | 106 | 600 |
| Arkansas | 5 | 876 | 519 | 175 | 850 |
| Florida | 1 | 90 | 17 | 90 | 90 |
| Georgia | 0 | | | | |
| Louisiana | 75 | 18811 | 11953 | 251 | 1850 |
| Mississippi | 9 | 1876 | 926 | 208 | 900 |
| North Carolina | 0 | | | | |
| South Carolina | 0 | | | | |
| Tennessee | 2 | 8 | 0 | 4 | 5 |
| Texas | 193 | 16686 | 11510 | 86 | 950 |
| Virginia | 0 | 0 | 0 | | |
| Total | 298 | 39724 | 25595 | 133 | 1850 |

The spatial coordinates of the gas processing facilities were determined by cross-referencing with data in the ECOFYS database. The location of 262 of the 298 gas processing facilities were located using this method. The remaining 36 facilities that were not located by cross-referencing the ECOFYS database will be located by using the USGS GNIS system.

### *Refineries*

The ECOFYS database uses data from the 1999 Oil and Gas Journal Worldwide Refinery Survey for Refining Capacity. ECOFYS database lists latitude/longitude locations for most gas processing facilities. The locations were determined with the use of the USGS GNIS. This system was used to convert place names associated with each gas processing facility into latitude/longitude coordinates. The GIS database was updated using 2004 DOE Energy Information Agency published data.

## Regional Sinks

### *Terrestrial Sequestration*

Winrock International currently is tasked by SECARB to extend the methods and lessons learned from the pilot region to the remaining states of Alabama, Florida, North Carolina, South Carolina and Tennessee in order to conduct an assessment of the terrestrial carbon sequestration opportunities across the region.

<u>Carbon Sequestration Potential on Agricultural Lands</u>

Two categories were developed for investigating the carbon storage potential of agricultural lands in the region: afforestation of marginal agriculture lands (including a separate component for grazing lands); and conversion to no-till land tenure systems. Marginal agriculture areas are prone to poor agriculture practices because they frequently flood, have a high slope or have other surface soil conditions that prohibit production. The amount of

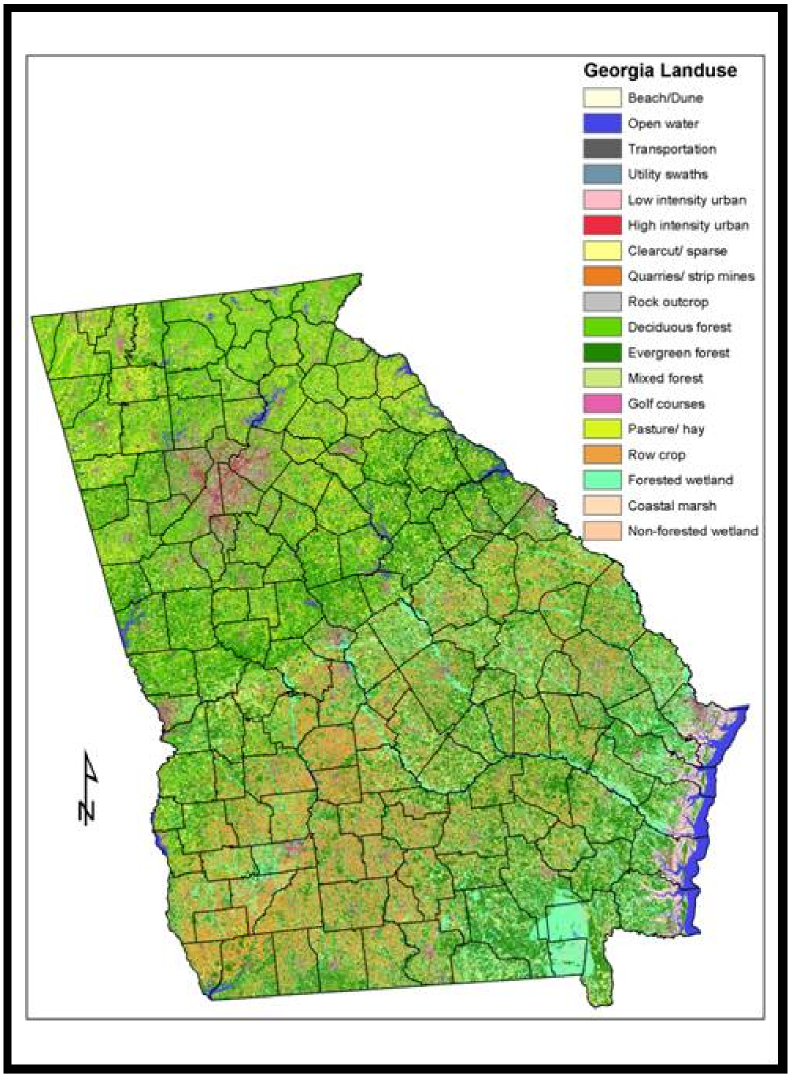



**Figure 1.** Map of Georgia Showing the Land-use/land-cover Classes for 1998 (from University of Georgia, NARSAL Classification).

carbon that can be expected to be sequestered on lands for 20, 40 and 80-year projects is calculated. The analysis of no till tenure systems identifies the amounts of carbon that could be sequestered if the crops of corn, soy and wheat were converted to a no till land tenure system.

Identification of Marginal Agricultural Lands

The analysis to identify marginal agricultural land uses a mosaic of National Land Cover Dataset (NLCD) tiles (Figure 1), which includes row crops, small grains, grasslands and pasture/hay land-use types. Lands that are prone to frequent and long-term flooding, slopes over a 10% incline and soils that are either rocky or have hardpan close to the surface have been identified and classified as ‘marginal’ because of their decreased productivity and/or need for more expensive land management.

The model that identifies marginal agricultural lands combines data from the State Soil Geographic (STATSGO) database for soil characteristics, flood frequency and duration, a digital elevation model (DEM) and a land cover map. The model selects areas with high rock content soils, shallow soil, high slopes (greater than 10%) and high frequency and duration of floods.

Quantifying Carbon Sequestration Potential

Figure 2 is an example of the quantification of costs per ton carbon for 40-year afforestation projects on agricultural and pasture lands in North Carolina and South Carolina.

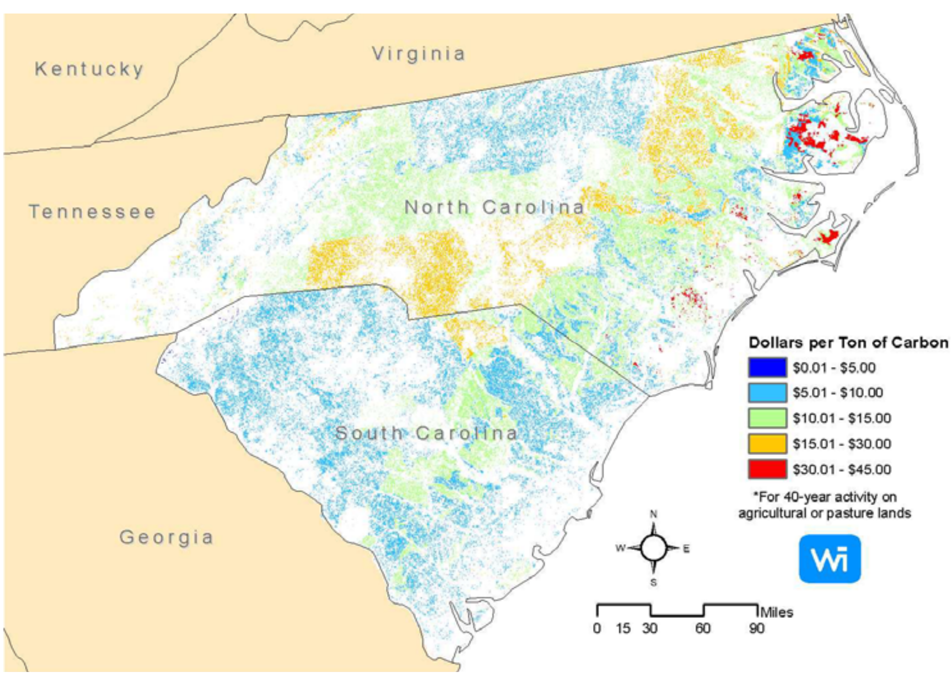



**Figure 2.** Costs per ton Carbon for 40-year Afforestation Projects on Agricultural or Pasture Land in North Carolina and South Carolina.

The cost per ton calculation includes opportunity costs for converting land from its current use (agriculture or grazing) to forest, conversion costs (clearing land and planting trees), maintenance costs (fertilizer, herbicides, thinning, fire management) and measurement and monitoring costs. These are combined with predicted productivity numbers for forest types matched to land classes drawn from data in the national forest inventory. The opportunity costs are determined using a complex set of calculations based on real land uses, crop productivity and prices drawn from current government data sources and averaged across regions.

Virginia Tech is developing results that are consistent and compatible with the terrestrial sequestration modeling protocol being used by Winrock International for the non-Virginia portion of the southeastern region. Efforts during the past quarter extended to completing the modeling of terrestrial carbon sequestration options using the Winrock method and the modified Winrock method. Final maps are being created that depict the spatial distribution of sequestration amounts while tabular results are being summarized within the Level III Mid-Atlantic ecological zones as described by the EPA. Currently, a manuscript is being prepared that documents those results (both spatial and tabular) for scientific publication.

Terrestrial carbon sequestration options are defined as land-resource management actions that have the potential to increase carbon storage, relative to a baseline no-change-in-management alternative. Carbon sequestration options are being evaluated using several different modeling procedures based on the principle of “additionality”, i.e., the increment of carbon storage that can be expected to occur as a result of a management action.

Potential sequestration rates and magnitudes are the major factors governing which options will be considered as “most promising.” Per-hectare rates and magnitudes are the primary factors considered. However, scale effects also should be considered by calculating state-wide totals and considering spatial distributions for each option. Issues of societal perceptions, ancillary benefits and economics also will be considered qualitatively in evaluation and interpretation of modeling results to derive conclusions regarding which are the “most promising” carbon sequestration options.

Carbon Sequestration Modeling Approaches

Project activities are being conducted through the application of several GIS modeling approaches. Modeling approaches are listed in order of priority in which resources will be applied to their application.

1. The Winrock Method: Procedure applied by Winrock International over the non-Virginia portions of the southeastern region. To the extent made possible by information provided by Winrock (Winrock International 2004), this procedure will be applied to generate results that are comparable to those being generated for other southeastern states. The major limitation on our ability to apply these

procedures in such manner is that certain portions of the Winrock method are considered proprietary.

2. Modified Winrock Method: the Winrock method modified to reflect local conditions using expertise of principal investigators:

   - Forests: Local specificity of forest types is increased using U.S. Forest Service Forest Inventory Analysis (FIA) data, and growth/sequestration rates associated with various forest types and age classes.
   - Soils: Application of STATSGO soils data to modeling procedures is refined.
   - Agricultural practices: Tillage assumptions are modified to reflect data on tillage practices in various Virginia counties.

3. The “Coarse Resolution” method: to be made up of 2 components:

   - Net primary productivity and carbon storage estimates associated with specific agricultural crop and forest types are adjusted based on MODIS satellite data. The results of this procedure are used to estimate effects of agriculture/forest conversions via a simple substitution algorithm based on neighborhood cells.
   - United Nations Food and Agriculture Organization (FAO) procedures are applied to model the effect of changing agricultural and forestry management practices.

4. Empirical approaches: Simple estimates derived from empirical calculations to develop crude estimates for land-management options that cannot be modeled using available data and within available budgets.

Land Management Options

*Tier 1*: To be evaluated on a state-wide basis using the Winrock, modified Winrock, (and possibly Coarse Resolution) methods:

- Afforestation of marginal agricultural land.

- Conversion of conventionally tilled agriculture to no-till or conservation till.

- Forest management changes, such as increasing the rotation age, improving forest nutrition and replanting to alter species composition.

*Tier 2*: Options to be evaluated via regional application of empirical methods:

- Reforestation of mined lands that are not in forest land use.

- Changing rate of urban (including transportation) land conversions. This option will be evaluated by comparing early-1990s and early-2000 land-use data coverages over areas of the state where comparable coverages representing these two time frames are available. Based on this analysis, the acreages of agricultural and forested lands converted to urban uses will be estimated, and the carbon-sequestration effect of growth management policies that slow urban conversions will be estimated.

*Tier 3*: Options to be evaluated via state-wide application of empirical methods:

- Afforestation of farmed wetlands: STATSGO/SSURGO soils data will be interpreted to produce a statewide grid that estimates the probability of hydric soils being present. This grid will be merged with a state-wide land-use coverage to estimate farmed wetland acreage and to estimate the amount of carbon that could be sequestered through afforestation of these acreages.

- Afforestation of riparian buffers: Hydrographic data that includes attributes to indicate stream size (either National Hydrographic Data or an alternative source) will be analyzed to determine the locations of riparian areas in locations with predominantly agricultural land use. For each stream size category and major state region, an appropriate riparian-buffer width assumption will be applied to estimate the riparian acreage available for afforestation and the potential for carbon sequestration though afforestation of these areas.

Analysis of Results

For each option evaluated using each modeling method, the following quantities will be compiled on a state-wide basis, and for each major state region:

- Total carbon sequestered.
- Sequestration rates (per hectare per year during some time period).

The investigators will derive conclusions regarding which options appear as “most promising” by considering modeling results and using professional judgment to consider issues of societal perceptions, ancillary benefits and economics.

For each land use option modeled using several approaches, results generated by individual modeling approaches will be compared. Investigators will evaluate these results and derive conclusions regarding the modeling approaches applied.

Terrestrial Carbon Pools in Southeast and South-Central United States: State Level Inventories, Potentials and Economic Impacts[(1)]

Inventories of regional carbon sources and sinks are essential for assessing the economic feasibility of various carbon sequestration options in mitigating the accumulation of $CO_2$ in the atmosphere and in preventing global warming. Such inventories are a prerequisite for the regional trading of $CO_2$ emissions. SECARB estimated terrestrial carbon pools in the Southeast and South-central United States at the state level and projected the potential for terrestrial carbon sequestration and its economic impacts on the region.

Results show that total terrestrial carbon pools in the Southeast and South-central United States (11 states) were estimated to be 21.1 Pg C (Figure 3). Texas has the highest total terrestrial carbon storage (5.6 Pg C), accounting for 26.6% of total terrestrial carbon pools in the region. Florida has the second highest terrestrial carbon storage (3.8 Pg C, 17.8% of total carbon storage in the region). Tennessee and Mississippi have the lowest terrestrial carbon storage (807-915 Tg C for each state), each accounting for about 4 % of the total terrestrial carbon storage in the region. We divided the terrestrial carbon into the four major carbon pools, which are soil organic carbon, forest biomass, agricultural crop biomass and grass biomass. Among these pools, soil organic matter is the biggest terrestrial carbon pool, totaling 16.54 Pg C and representing 78 % of the overall terrestrial carbon pools in the region, followed by forest biomass carbon pool (4.45 Pg C, or 21%). Carbon pools in agricultural crops and grass biomass are relatively small, totaling 113 Tg C and accounting for 0.53 % of total terrestrial carbon pools.

Total annual terrestrial C sink in the region was estimated to be 189.1 Tg C/year (Figure 4). Texas is the leading state (38 Tg C/year), accounting for 20.1% of the total annual terrestrial C sink in the region, followed by Arkansas (31.4 Tg C/year, 16.6% of the total annual C sink in the region). South Carolina and Florida have the smallest total annual terrestrial C sink (6.4 Tg C/year, 3.4% of current annual terrestrial carbon storage in the region for each state). Most states have a total annual terrestrial C sink of between 16 and 20 Tg C/year.

Current annual forest carbon storage could compensate for 13% of the annual greenhouse gas emissions in the region (Figure 5). Annual forest carbon sinks in Mississippi could compensate for 31.2% of its total greenhouse gas emission, followed by North Carolina (24.8%), Georgia (24.6%), Tennessee (14.3%) and Virginia (18%). However, Texas has only 4.5% of its total greenhouse gas emissions offset by annual terrestrial carbon sinks, followed by Louisiana (8.7%) and Florida (9.7%).

Through implementation of policies and best management practices, the total potential of terrestrial carbon sequestration in the region was estimated to be 53.9 Tg C/year, indicating that an additional 9.3% of the total greenhouse gas emissions could be further offset by terrestrial sequestration (Figure 6). The potential for forestland, cropland and grassland was projected as 29.4, 15.1 and 9.4 Tg C/year, respectively (Figure 6). Texas has the largest annual carbon deficit (149 Tg C/year). Current and potential terrestrial carbon sequestration in the region would value $11.2 and $7.98 billion/year, respectively.

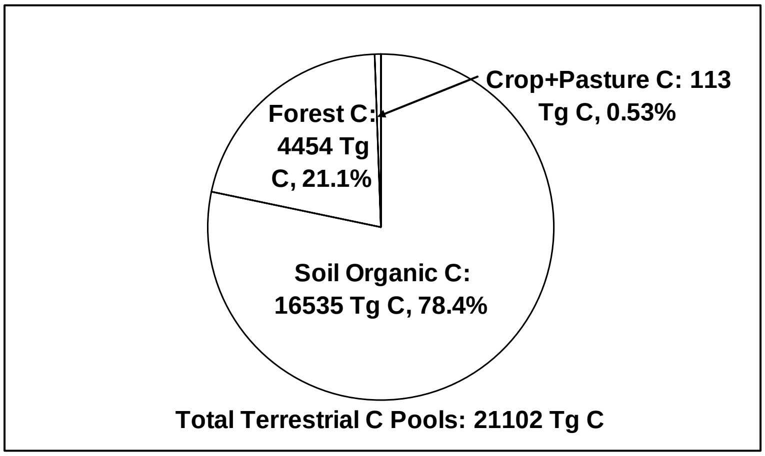



**Figure 3.** Total Terrestrial Carbon Pools in the Region.

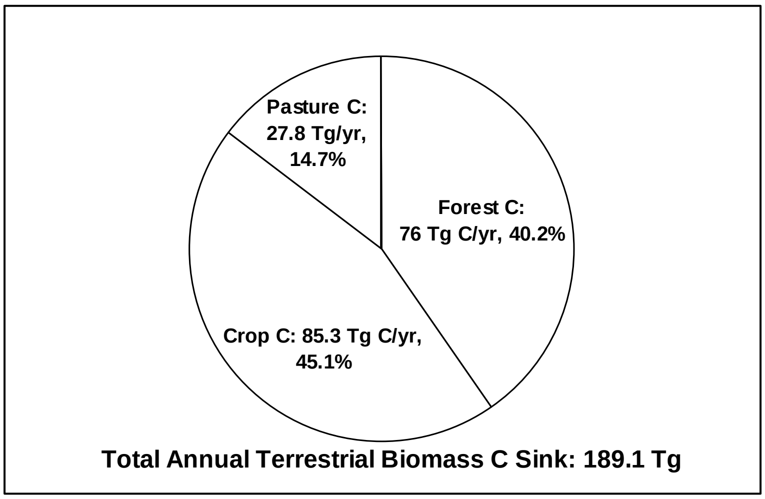



**Figure 4.** Current Annual Biomass Carbon Sink in the Region.

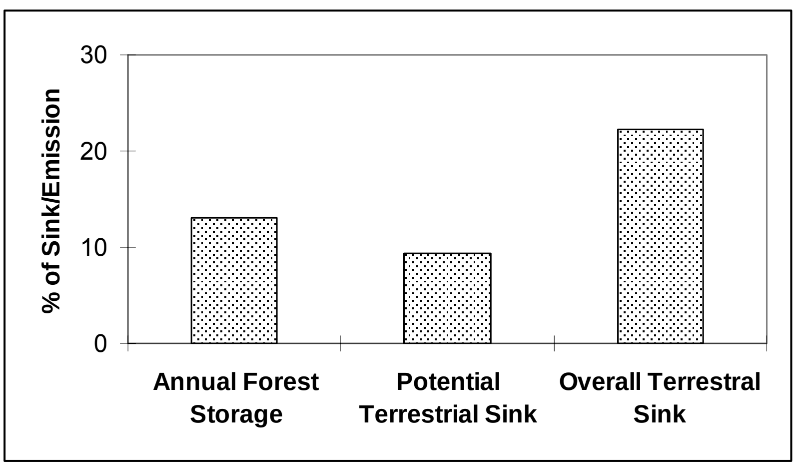



**Figure 5.** Percentages of Annual Biomass Carbon Storage in Forest, the Potential Terrestrial Carbon Storage and Overall Carbon Sinks Over the Total Greenhouse Gas Emissions in the Region. (Since total greenhouse gas emission in Arkansas and South Carolina are not available, the calculation excluded these two states).

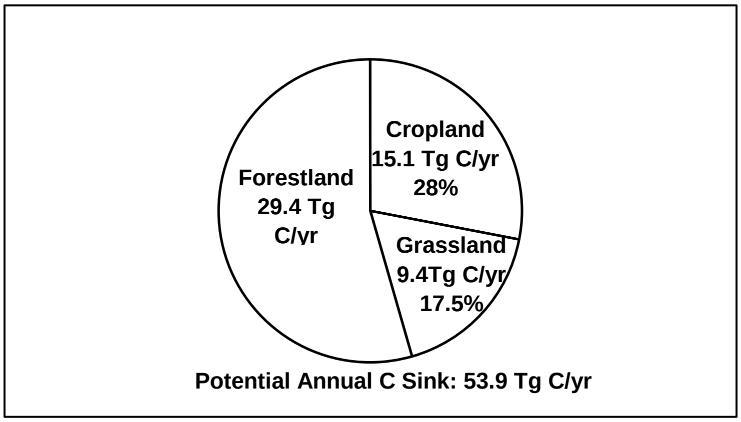



**Figure 6.** The Potential Terrestrial Carbon Sequestration in the Region.

<u>Progress to Date</u>

Modeling procedures have been precisely defined and documented for the Winrock method and preliminary model runs have been performed for Tier 1 of the land management options. Some interpretation of the methodology proposed by Winrock was necessary and led to the development of some modified Winrock methods. For example, in identifying marginal agricultural lands, the STATSGO data is interpreted to include a more quantifiable assessment of what is 'marginal'. In assessing sequestration rates for afforestation, the STATSGO data was used in combination with Forest Service empirical yield tables to expand the rates through the three time periods of 20, 40 and 80 years.

Model runs of the modified Winrock method and Tier 1, 2 and 3 land management options have been completed. Afforestation of riparian areas and farmed wetlands has been the focus of these tiers. A final report will be prepared during the next quarter showing all terrestrial work completed under this project.

***Geologic Sequestration***

SECARB took a macro-level, dimensional, geographic identification approach to identify areas and particular geologic formations with sequestration potential. Three primary data sets were developed from public data. Each set focused on one of the main types of geologic sinks for sequestration, namely saline formations, coal seams and oil and gas reservoirs. A minimum set of parameters were sought during this step, based at least in part on the information believed to be available. Additional data were collected simultaneously as the opportunity presented itself.

The minimum data sought initially included geographical parameters that would aid in locating the potential sinks (e.g.: state and county names; well location coordinates; oil, gas, or coal field names; formation names; etc.). Technical parameters included formation depth, thickness and porosity as being most essential. Permeability, fluid saturations, pressures, productive areas and area geology were placed at the next level of importance. Of equal importance to geological data were geographical parameters that would aid in locating the potential sinks.

Subsequent steps sought to refine the data from the first step by addressing data availability and quality with respect to potential sequestration targets. The data continue to be gathered, refined and synthesized to compile the most-relevant datasets possible. The data are being incorporated into a GIS database for prioritizing field test candidate areas with the best combination(s) of $CO_2$ sources, sinks and site attributes for constructing a sequestration test facility.

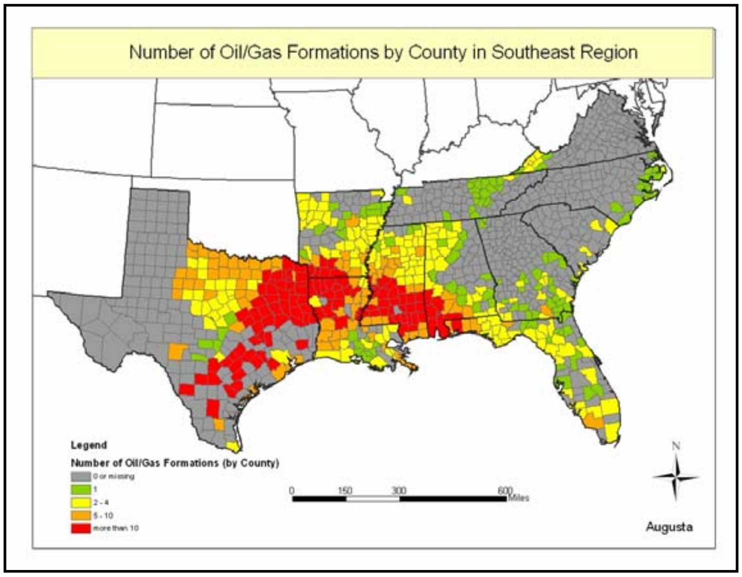



**Figure 7.** Number of Formations Penetrated by Producing or Exploratory Oil and Gas Wells, By County.

The initial datasets developed for the Southeast region were based on national public datasets that had been developed mainly for reasons other than sequestration, such as oil and gas exploration and production. Therefore, these national data sets, while containing a wealth of information, often contained only a minimum amount of information of direct value to the sequestration effort. The result was a substantial collection of data that could be used for a general characterization of the region but having numerous "holes" or missing data points. This was not unexpected and additional data were sought and are being obtained from other public and private sources. Figure 7 is a map constructed from the preliminary data indicating large areas in the region with multiple oil or gas producing formations present, clearly indicating areas that might be more suitable than others for geologic sequestration of $CO_2$. Primary data sources for the initial phase of geologic characterization included the United States Geological Survey's Assessment of National Oil and Gas Resources publications (1995 and 2001), supplemented by data from DOE's Gas Information System database (Version 2, 1999), reports from the USGS's National Coal Resource Assessment and publications obtained from the Texas Bureau of Economic Geology. Additionally, detailed information was sought from various state geological surveys and other cognizant state agencies.

Five of the 11 SECARB area states are embraced by state agencies participating directly in the SECARB effort: Texas, Louisiana, Mississippi, Alabama, and Virginia. The Florida Panhandle area also is being characterized by the Geological Survey of Alabama. Non-participating state agencies in North Carolina, South Carolina, Tennessee, Georgia, Arkansas and Florida were contacted to determine the availability of detailed data from those states. All states were found to be cooperative, but none had digitized information; few had much data on oil, gas, coal and especially salt water aquifers. In every case, the acquisition of information on underground rock formations would require manually searching through paper reports, paper and/or computer spreadsheets and state report forms for information. The agencies were very interested in the project and were willing to cooperate, but they typically recommended that any request for information be as specific as possible so that the correct information could be found quickly.

The USGS publication in 1995 of the "National Assessment of United States Oil and Gas Resources" identified all of the known major geologic oil and gas plays at that time and also identified hypothetical plays where oil and gas reserves were likely to occur, based on known geological characteristics and applied statistics. The geologic regions, provinces and individual stratigraphic plays provide a valuable system for general characterization of the large multi-state SECARB region. The states affiliated with the SECARB partnership are all included in USGS regions six and eight. Figure 8 shows the nine geologic provinces embraced, all or in part, by the characterization study.

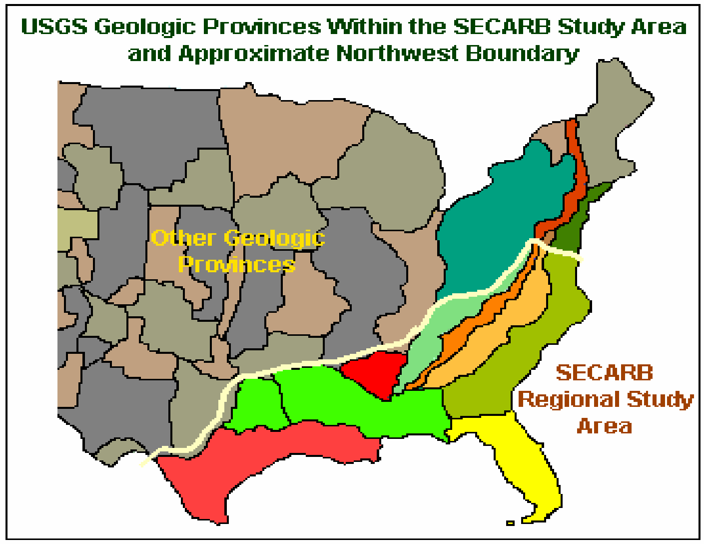



**Figure 8.** Nine Geologic Provinces Considered in the Characterization of the SECARB Region (After USGS).

In the northeastern area of the region (Virginia, North Carolina and Tennessee), the primary targets for sequestration will be unmineable coal seams and brine formations. Local opportunities for EOR may be available but will not be the primary targets. Large depleted gas fields and abandoned gas storage fields may also be future options in the northern area.

In the southeastern area of the region (South Carolina, Georgia and Florida), there are minimal opportunities for sequestration as part of the recovery of CBM, oil or gas, so the primary targets will be brine formations. The South Florida basin has a large potential for brine formations, especially in the Lower Cretaceous rocks (see Figure 9) that include the Dollar Bay and Sunniland formations, which also have potential for EOR. The South Florida basin contains a thick column of sediments with porous and permeable zones separated by impermeable anhydrites.

In the central and western parts of the region (Alabama, Mississippi, Louisiana, Texas and Arkansas) sequestration target options include coal, oil, gas and brine formations. The main targets, at least initially, will be oil reservoirs, which are particularly responsive to the injection of $CO_2$ to enhance oil recovery, with brine formations being the second choice. The exception to this rule may be in the northern parts of Alabama and Mississippi, where the Black Warrior Basin affords the opportunity for enhanced CBM production from unminable coals.

As more is learned about the potential for storage and/or enhanced CBM recovery from the large lignite deposits in the region, those resources may also be utilized in the future for storage of $CO_2$. Ample opportunities for EOR exist throughout the rest of the area and are more cost-effective than other forms of sequestration. In areas where EOR opportunities are not available, there is a high likelihood of brine formations being available for storing the $CO_2$.

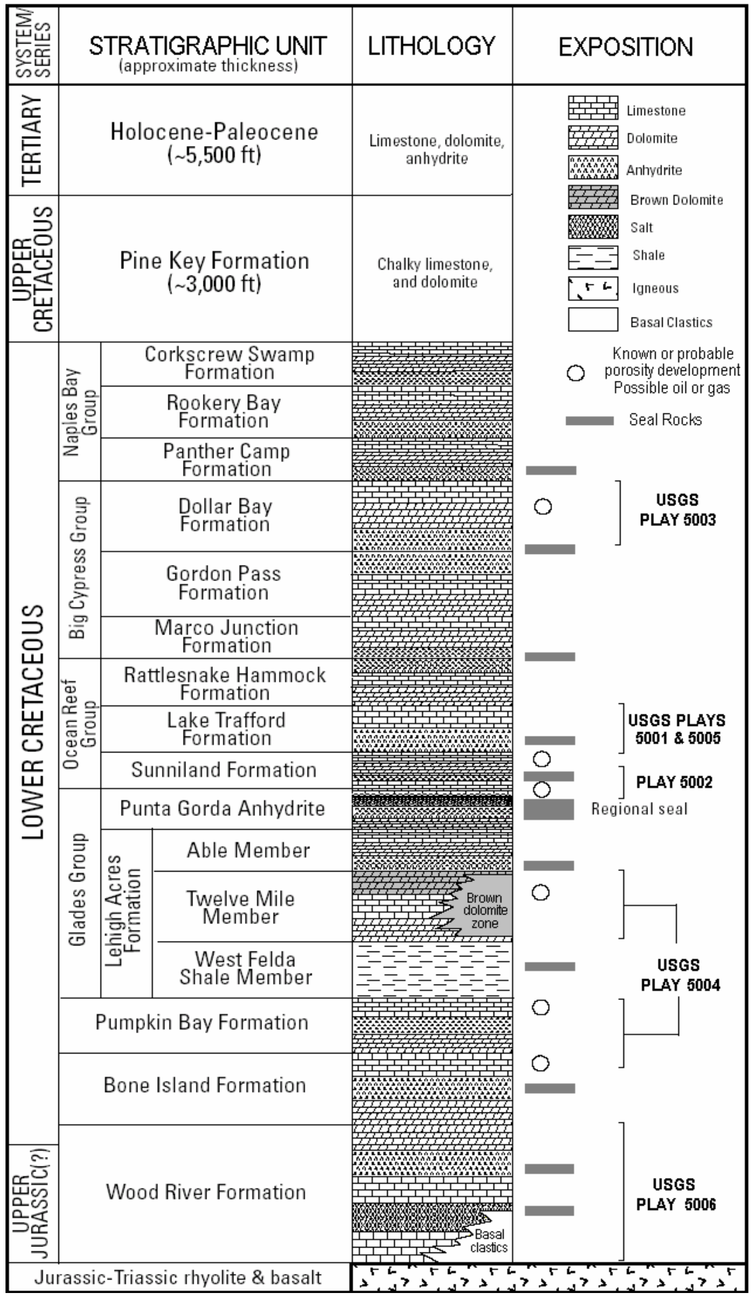



**Figure 9.** Stratigraphic Section of South Florida Basin Highlighting Positions of USGS Plays (After USGS).

Even though many "holes" were found to exist in the publicly-available information, there are enough data to differentiate between areas of good potential for geologic sequestration and areas that are less good. When these areas are paired with $CO_2$ sources in the region, it should be very obvious which potential sink areas warrant further investigation. Key data missing from the public data sets then will be derived from local sources such as oil and gas companies operating in the area or from State Geological Survey investigation reports performed in the area of question. GIS maps showing key formations and characteristics to be overlain by $CO_2$ sources and infrastructure considerations are being prepared to assist in the evaluation of potential geologic sequestration options. Upon narrowing the sequestration options to a priority group, these prospects will be pursued further to obtain specific information to complete the evaluation of those options. Surviving prospects will be evaluated to determine the best return on investment, based not only on cost but in terms of techniques tested, research goals and questions to be answered and the overall benefit to the sequestration effort.

### *Geological Sequestration (Appalachian Basin Coal Seams)*

The SECARB region has vast coal reserves and many additional coal resources that may not be economically recoverable (unmineable). Coal seams that are deep (generally below 2400 feet) and that have high gas content may be suitable for utilizing $CO_2$ to enhance the recovery of coal bed methane and for the long-term storage of $CO_2$.

Virginia Tech and Marshall Miller and Associates (MMA) have worked to characterize the Commonwealth of Virginia for potential carbon dioxide sinks, sources and transport options. The following sections outline the progress for this semiannual report ending March 2005.

Virginia Tech and MMA developed an approach to gather publicly-available geologic data from the Commonwealth of Virginia and to mesh this information with proprietary data, in order to characterize coal seams, oil and gas reservoirs and saline aquifers. Significant progress has been made in identifying and collecting the publicly-available data from the Virginia Division of Gas and Oil and the non-proprietary files of MMA. In order to protect confidentiality, in certain cases, final GIS data will be provided as contour lines without including individual point data.

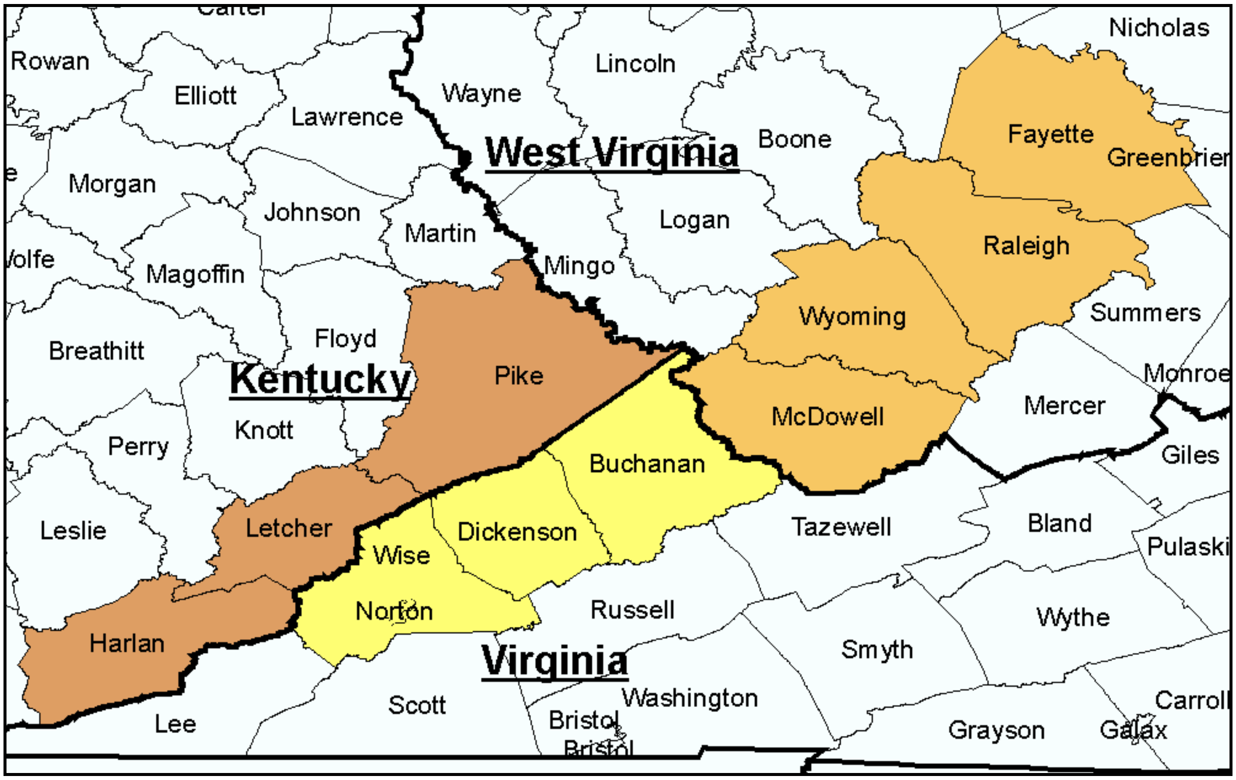



**Figure 10.** Carbon Sequestration Focus Areas for Regional Geologic Mapping.

From the detailed level assessment, a list of prospective coal beds for carbon sequestration was developed. The list includes the following seams in the Upper, Middle and Lower Lee formations and the Pocahontas formation:

*Upper Lee Formation*

- Jawbone
- Tiller
- Upper Seaboard
- Middle Seaboard
- Lower Seaboard

*Middle to Lower Lee Formation*

- Upper Horsepen
- Middle Horsepen
- C-Seam (P-10)
- War Creek (P-11)
- Lower Horsepen
- X-Seam

*Pocahontas Formation*

- Pocahontas No. 6
- Pocahontas No. 5
- Pocahontas No. 4
- Pocahontas No. 3

<u>Geologic Sequestration (Black Warrior Basin Coal Seams)</u>

Geologic sequestration is an attractive option for $CO_2$ sequestration because of the potential for injecting $CO_2$ into geologic formations to enhance the recovery of oil and coal bed methane. In addition to enhanced hydrocarbon recovery, significant sequestration capacity may exist in saline aquifers. A wide variety of potential geologic sinks exists in the southeastern United States, and these sinks are concentrated in the Black Warrior and Gulf of Mexico basins of Alabama, Mississippi and northwestern Florida.

Accordingly, the Geological Survey of Alabama is identifying and characterizing potential geologic sinks in these basins. This work is divided into three tasks, all of which are being performed. Subtask 2A, Geologic Reservoir Identification and Location, centers on identifying and delineating potential geologic sinks, as well as developing a regional geographic information system that incorporates relevant databases. Subtask 2B, entitled Oil, Gas, and Saline Aquifer Reservoir Property Characterization, focuses on geologic characterization of conventional hydrocarbon reservoirs and deep, saline aquifers that are potential sites for geologic sequestration. Subtask 2C, entitled Coal bed Fluid and Rock Property Assessment, focuses on the characterization of mature coal bed methane reservoirs in the Black Warrior basin and on the characterization of potential lignite sinks in the Gulf of Mexico basin.

*Progress*

The project is nearly complete, and our compilation of basic data for characterization of conventional oil and gas reservoirs, coal bed methane reservoirs and saline aquifers is now finished. We have completed a GIS of geologic sinks in Alabama, Mississippi and the Florida panhandle, and we are now beta testing an ArcView digital data product that will be submitted with the final report for this project during the upcoming quarter. The ArcView project features a unified front end that enables browsing of basic data and access to a series of GIS views that highlight specific types of sinks, as well as their proximity to anthropogenic $CO_2$ sources. A beta copy of the ArcView product was provided to MIT for incorporation to the NATCARB system.

As we were completing data collection, it became apparent that the published data available for characterizing $CO_2$ sinks in Mississippi are quite limited. However, a large volume of data can be collected from the open files and dockets of the Mississippi State Oil and Gas Board. TX BEG is considering funding an expansion of the SECARB database for Mississippi. Work on this initiative is expected to begin during the upcoming quarter.  When the data are compiled, they will be incorporated into the NATCARB GIS, and a revised version of our ArcView digital data product will be made available.

<u>Geological Sequestration (Oil & Gas Reservoirs)</u>

Oil and gas reservoirs have been characterized by TX BEG through digitally compiling in GIS the following: the *Atlas of Texas Major Oil Reservoirs* (Galloway and others, 1983) and the *Atlas of Texas Major Gas Reservoirs* (Kosters and others, 1989). Data from the Louisiana Geological Survey and the Mississippi Mineral Resources Institute are being compiled for the Gulf Coast region of Louisiana and Mississippi.  Utilizing $CO_2$ for enhanced oil recovery provides an economic driver that can offset the cost of developing $CO_2$ capture, transport and injection infrastructure.  Figure 11 shows EOR potential in Texas, Louisiana and Mississippi.

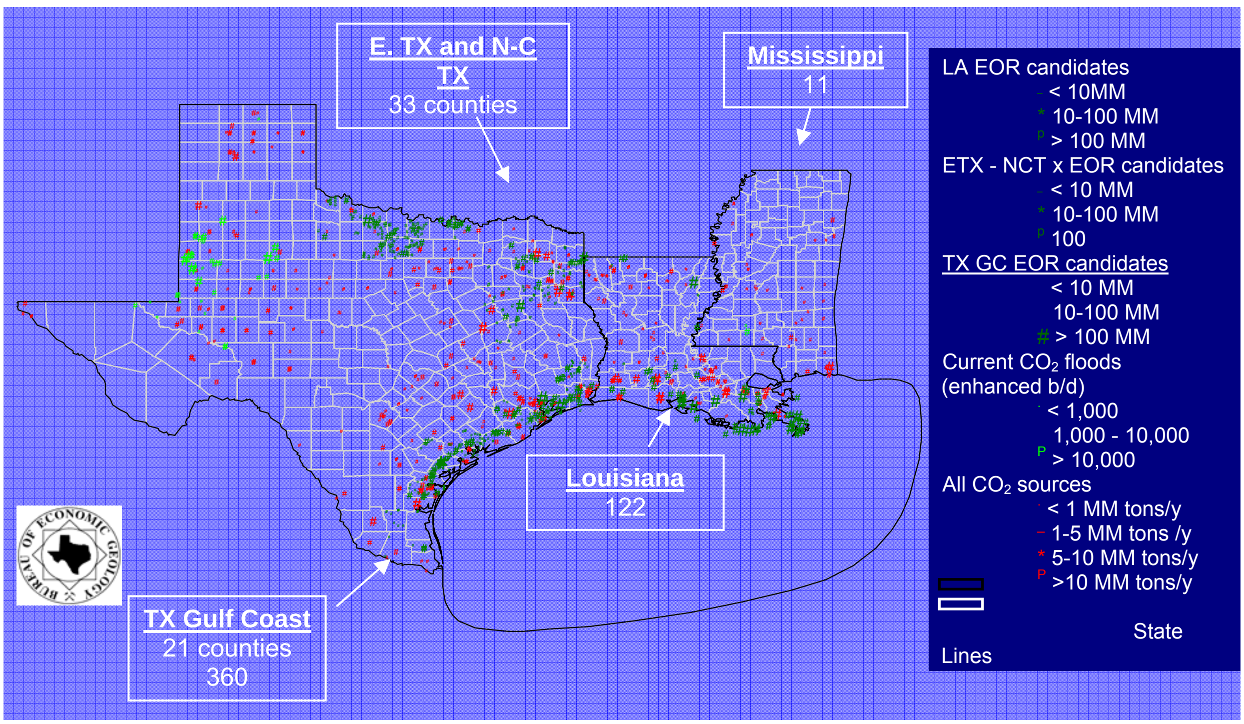



**Figure 11.**  Value-added Storage Opportunities for Enhanced Oil Recovery (EOR).

Extensive work by the TX BEG reveals that, within the South-central and southeastern areas of the SECARB region, opportunities exist for carbon sequestration with positive economic impacts.  This can result from the deployment of enhance oil recovery initiatives that utilize anthropogenic $CO_2$.  TX BEG noted that currently 2-billion cubic feet per day of $CO_2$ is injected for EOR in the United States.  Anthropogenic sources account for approximately 20% of the total.  Currently this represents 66 active projects with 205,877 barrels of oil per day (approximately 4% of U.S. production).  TX BEG estimates that sequestration volumes available in $CO_2$ – EOR (10% recovery) are 473 metric tons in Texas and 5763 metric tons in the United States.

ARI/Kuuskraa and others also have determined increases in the levels of $CO_2$ – EOR production in the United States. It is evident that significant successes in the Permian Basin have accounted for steady increases in daily oil recovery. TX BEG has noted that 50 of the 66 active $CO_2$ – EOR projects are located in the Permian Basin.

TX BEG has determined that opportunities exist for expanding $CO_2$ – EOR into East central and Southeast Texas. Based upon the characteristics of reservoirs in the area designated by Denbury as the “Eastern Gulf Coast”, SECARB has designated this area as having the most promising ppportunities for expanding the use of anthropogenic $CO_2$ for enhance oil recovery.

Geological Sequestration (Brine)

SECARB continues to work with state geologic surveys, universities and private companies to compile information on saline formations within the region. Figure 12 provides an overview of geologic provinces in the SECARB region. Figures 13 through 17 provide depictions of various formations within the SECARB region. The volume of formations available below approximately 2400 feet is extremely limited or poorly defined in the Atlantic Coastal Plain, Piedmont and Blue Ridge Thrust Belt. The Appalachian Basin has favorable characteristics at the northeastern edge of the region, deteriorates due to outcropping through Tennessee and improves near the Cincinnati Arch and Black Warrior Basin. The Gulf Coast Basin and Louisiana-Mississippi Salt Basins are characterized by the largest volumes of deep storage capacity. East Texas, Louisiana and Mississippi also have “stacked” oil and gas/saline reservoirs that can provide economic benefits to $CO_2$ storage.

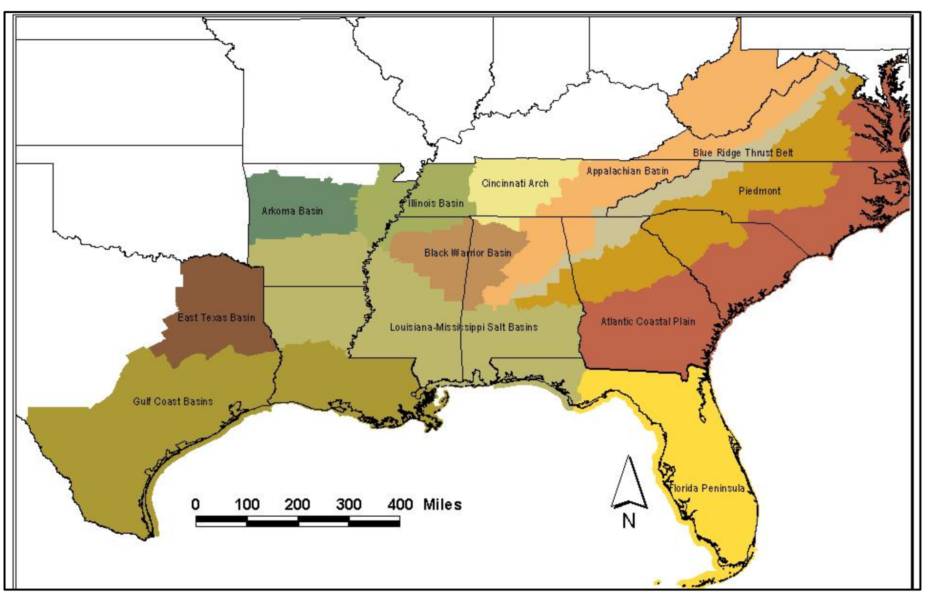



**Figure 12.** Geologic Provinces of the SECARB Region.

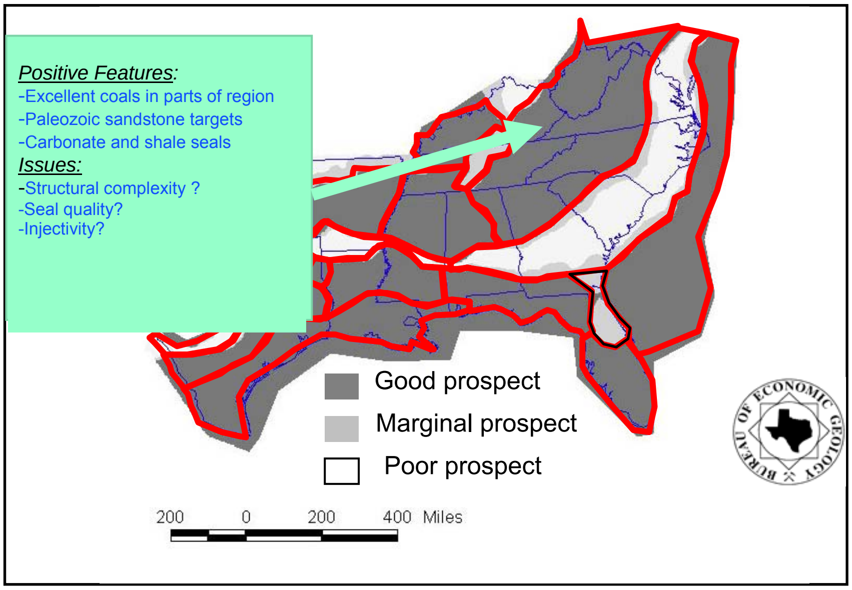



**Figure 13.** Inventory of Selected Prospects – Southern Appalachian Plateau and Basin.

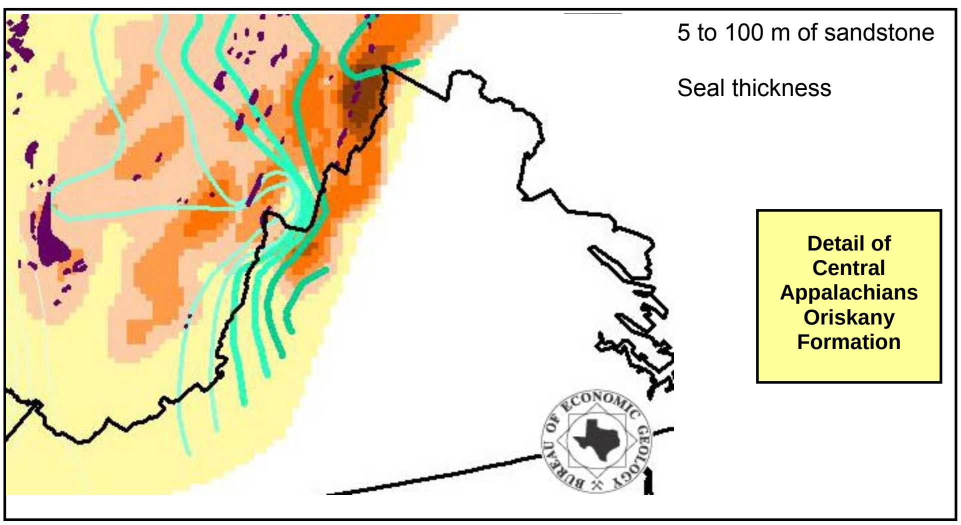



**Figure 14.** Inventory of Selected Prospects – Central Appalachians.

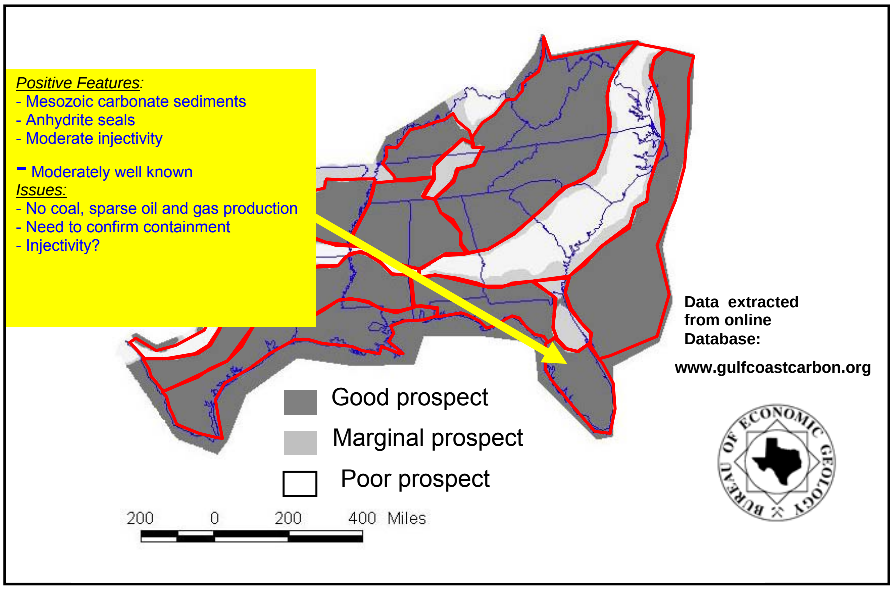



**Figure 15.** Inventory of Selected Prospects – South Florida Basin.

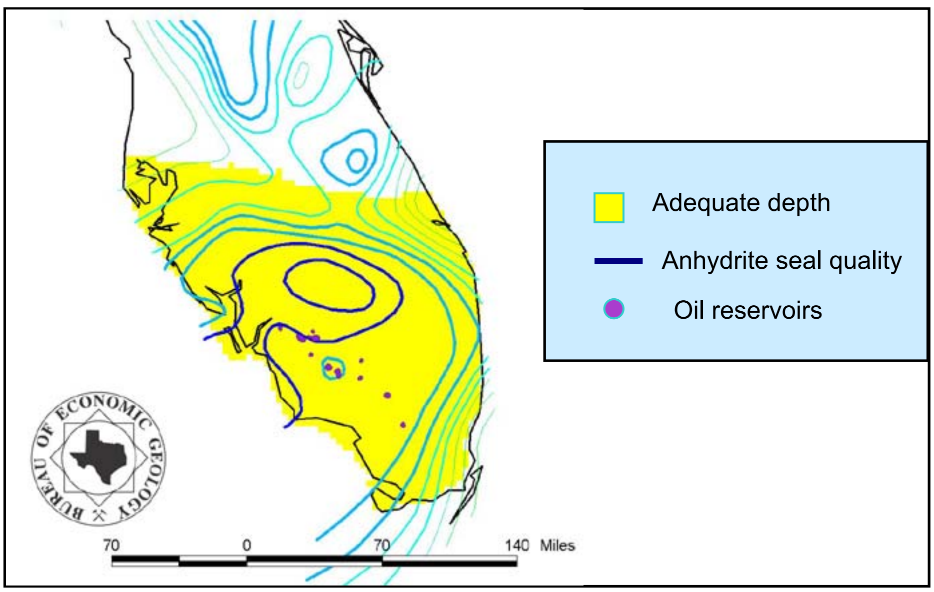
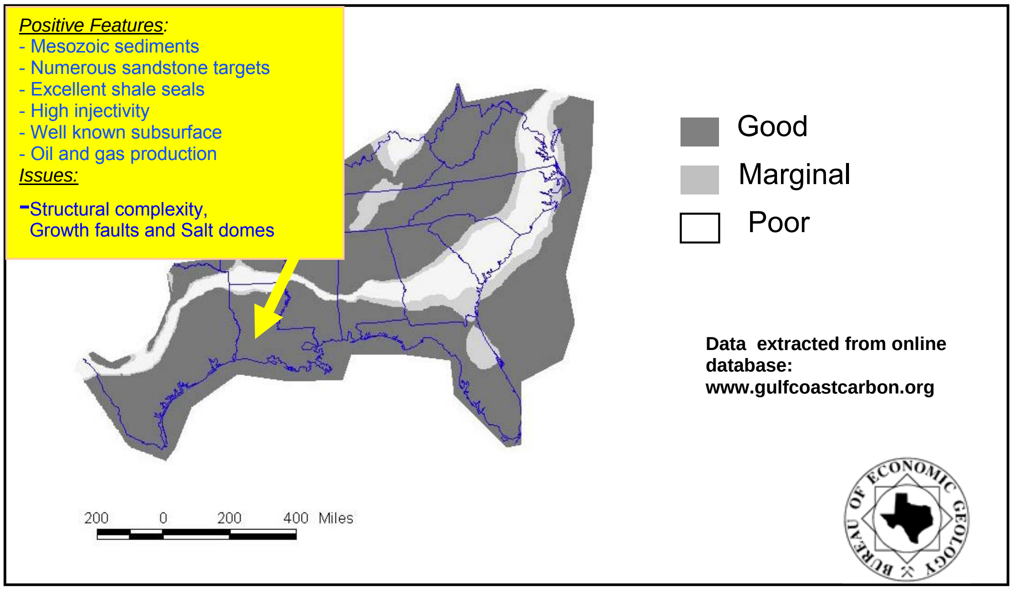



**Figure 16.** Inventory of Selected Prospects – Brine Targets in Florida.

**Figure 17.** Inventory of Selected Prospects – Gulf Coast Basin.



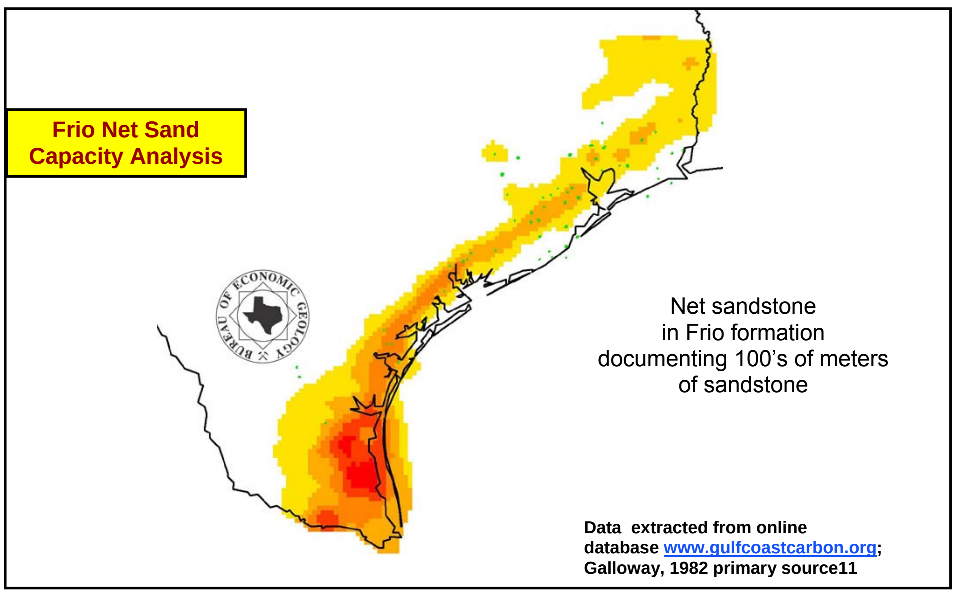
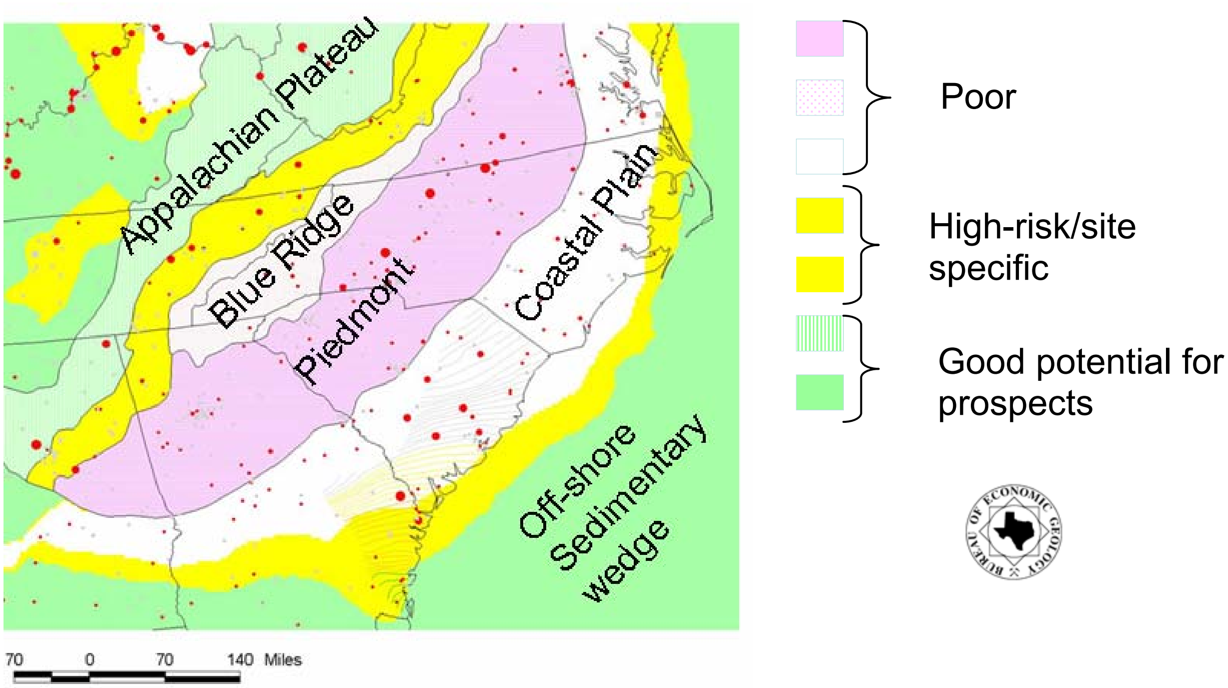



Figure 18 is an example of work performed by the TX BEG for SECARB to assist in depicting the nature and extent of sequestration potential in areas that lack data. These areas, while potentially suitable for long-term sequestration, are considered high-risk candidates for field demonstrations. In addition, the preliminary analysis supports the position that further characterization of the SECARB region is warranted. In some cases the additional analysis will be needed to substantiate and document the lack of suitability of particular areas.

**Figure 18.** Preliminary Prospects of Geological Storage.




## Database and GIS Tools

During the second quarter of FY2005, SECARB conducted an inventory of major $CO_2$ sources and sinks for the partnership region. The information resides on SECARB's database and will be connected to the NATCARB database. The Partnership is refining GIS algorithms and tools for the geographic area, including:

- A tool for source/sink matching;
- A sink capacity tool; and
- Three costing algorithms for capture, transportation and injection.

*Calculating $CO_2$ Storage Capacity*

The generic formula for calculating reservoir volume is:

$$Q = V * p * e * \rho_{CO_2}$$

where

| | |
|---|---|
| $Q$ | = storage capacity of the reservoir ($MtCO_2$) |
| $V$ | = total volume of reservoir ($km^3$) |
| $p$ | = reservoir porosity (%) |
| $e$ | = $CO_2$ storage efficiency (%) |
| $\rho_{CO_2}$ | = $CO_2$ density ($kg/m^3$) |

The reservoir volume and porosity are required inputs from the geologic datasets. The $CO_2$ density is calculated from the reservoir temperature and pressure (which are either obtained directly from geologic datasets or estimated from reservoir depth). The storage efficiency reflects the fact that $CO_2$ will flood only part of the reservoir. It has a typical range of between 2-30%. It can be obtained from detailed reservoir simulations. However, this is beyond the scope of our screening analysis, so default estimates will be obtained based on expert elicitations.

*Estimating $CO_2$ Injectivity and Injection Cost*

We have implemented a method into the GIS to calculate the injection costs. First, the $CO_2$ injectivity per well is calculated based on surface injection pressure, reservoir pressure, permeability, depth and thickness (based on the work of Law, D. and S. Bachu, "Hydrogeological and numerical analysis of $CO_2$ disposal in deep aquifers in the Alberta sedimentary basin," *Energy Convers. Mgmt*., **37**:6-8, pp. 1167-1174, 1996.). Reservoir permeability, depth and thickness are needed from the geologic data. Reservoir pressures can be obtained from the geologic data or estimated from depth. Injection pressure is set so as not to exceed the fracking pressure (or may be set by regulation in some cases). Second, using the $CO_2$ injectivity, the number of wells required for a given $CO_2$ flow rate is calculated. Finally, a set of capital and O&M cost factors are used to determine the cost based on well numbers. Details of this method can be found in: *Heddle, G., H. Herzog and M. Klett, "The Economics of $CO_2$ Storage," MIT LFEE 2003-003 RP, August (2003).* http://sequestration.mit.edu/pdf/lfee_2003-003_rp.pdf.

We recently have had discussions with Vello Kuuskraa and Scott Stevens of Advanced Resources International. We have decided to add an alternate methodology to Law and Bachu (1996) based on an ARI method. Both methods give similar results for initial injection rates. The advantage of the ARI model is that it reconciles the problem that $CO_2$ injectivity varies over time as the reservoir pressure rises due to the injection. The same reservoir parameters are used as input in both methods. Once implemented, we will provide further details on this methodology.

*Estimating $CO_2$ Pipeline Transportation Cost*

The transportation cost model takes the source-sink matching as a priori and estimates the $CO_2$ pipeline transportation cost at three levels: (1) one source to one sink; (2) many sources to one sink without route-sharing; and (3) many sources to one sink with route-sharing.

For the simplest case of one-source-to-one-sink connection, the estimation consists of three steps. First, the pipeline diameter is calculated based on the $CO_2$ flow rate. Second, the least-cost route is selected based on the relative cost factors assigned to various transportation obstacles for both economic and environmental concerns. The identified transportation obstacles include populated places, wetlands, national and state parks, waterways, railroads, and highways. Finally, the base case pipeline construction cost, additional obstacle crossing cost and O&M cost are assigned to estimate the levelized $CO_2$ transportation cost. More details are presented in Appendix K of this report. Note that we want to carry out some expert elicitations to better refine our cost parameters in the model.

*Matching $CO_2$ Sources and Sinks*

The source-sink matching analysis needs to take into account three factors: capacity, injection cost, and transportation cost (assuming $CO_2$ capture cost is source-specific and exogenous to the GIS system). We process our analysis by three levels: (1) starting from a particular source, search for the least-cost sink for this source; (2) starting from a targeted sink, search for a set of sources with the lowest overall cost to fill the sink's capacity; (3) for a set of multiple sources and multiple sinks in a study region, design a source-sink matching network to minimize the overall cost for $CO_2$ transportation and injection in the system.

**Task 3: Identify and Address Issues for Technology Deployment**

SECARB has a goal to develop action plans to overcome the issues identified in the preliminary assessment of safety, regulatory, permitting and accounting frameworks within the region. The action plan will allow for wide-scale deployment of promising terrestrial and geologic sequestration approaches, such as specific capture, transport, injection and storage approaches. Through the efforts of the SECARB team, SECARB has worked to advance this goal and the overall mission during the 18 months of the RCSP initiative. As a result of the unique structure of the SSEB, which is the Nation's only regionally-focused, federal-state energy compact, SECARB is well-positioned to research and develop regulatory, permitting and accounting frameworks for and associated multi-year action plans. During its first year and a half, Augusta Systems and the SSEB have worked to advance this goal and the overall mission.

Augusta Systems has performed research and analysis of the relevant state and federal statutes and regulations applicable to sequestration regulatory, permitting and safety matters. This research involved direct examinations of applicable statutes and regulations related to both geologic and terrestrial sequestration applications, as well as interaction with state legislators and regulators responsible for enacting and implementing regulatory regimes. This research and analysis concentrated on geologic sequestration related to direct carbon dioxide injection into geologic formations, enhanced hydrocarbon recovery using carbon dioxide and governance of the associated deep well injection classes. Also, Augusta Systems participated, on behalf of SECARB, with the Interstate Oil and Gas Compact Commission Geological $CO_2$ Sequestration Task Force to ensure that SECARB approaches would converge with recommended national approaches.

Key analysis regarding terrestrial sequestration focused on permitting and regulatory barriers and/or incentives to various field applications that could be implemented. This activity also used selected scholarly articles and papers related to regulatory and permitting issues for analogous practices.

In another effort to ensure that all RCSPs, including SECARB, engaged in regulatory, permitting, safety and accounting framework analysis and development activities with an appropriate base of background knowledge about regulatory and legal activities, NETL coordinated and managed RCSP Regulatory Compliance and Liability Issues Working Group meetings. As a result of these quarterly meetings and calls, as well as the IOGCC-led effort, SECARB and the other partnerships are working to ensure that common regulatory and accounting approaches are being developed throughout the RCSPs.

Further, Augusta Systems investigated emerging GHG accounting frameworks. As no universally-accepted accounting standard exists for GHG emissions and emissions reduction accounting, this research focused on tracking the methodologies and protocols presently in practice internationally and nationally. This study included the current requirements of and contemplated amendments to the DOE Voluntary Reporting of Greenhouse Gases Program, established under Section 1605(b) of the Energy Policy Act of 1992. SECARB also examined methodologies and protocols under various international efforts.

Appendix A of this semiannual report documents the efforts of the SECARB regulatory and accounting team during the initial year and a half of the Phase I SECARB activities. Completion of this task and the resulting report accomplishes SECARB's first quarter milestone for FY2005 (October 1 through December 31, 2004).

***Measurement, Monitoring and Verification***

Previous efforts in the area of measurement, monitoring and verification have centered on assessing the state of current technologies. The goal was to analyze existing programs and data and attempt to establish whether additional efforts/resources were needed to improve MM&V and permit reduction in associated sequestration costs. The analysis has indicated that a considerable number of measurements rely on sampling followed by laboratory quantification. Furthermore, the work indicated that the most appropriate measurements will focus on relieving the interference of standard $CO_2$ on isotopic compositions. The isotopic composition of $CO_2$ will depend on the originating source.

Related efforts that have been on-going in these laboratories for the past 3 years include the development of cavity ringdown spectroscopy (CRDS). The technique has been applied to the determination of isotopic constituents of spent nuclear waste, the determination of acetone in breath (a precursor/indicator of diabetes) and the quantification of water in gas feeds employed in the semi-conductor industry. The method is molecular specific, requires no external calibration and can achieve detection limits on the order of parts per trillion. As discussed below, the technology has all of the qualities needed for application to carbon sequestration; moreover, recent work indicates that through novel optical configurations, local measurements of pressure and temperature are possible. This invites the direct application of CRDS to quantification of pressure and temperature gradients within a reservoir. Such information is expected to be extremely valuable in evaluating the behavior of $CO_2$ sequestered in close proximity to a fault or seam.

Development of a Real-Time Portable $CO_2$ Monitor

The objective of this effort is to explore a new technology to develop a real-time portable $CO_2$ monitor, which will detect $CO_2$ leakage, monitor the long-term stability of $CO_2$ storage and provide rapid response to help mitigation of damage to the ecosystem in the unlikely event that a leak should occur. The new protocol also will be capable of being deployed in an aircraft to conduct geological surveys of atmospheric $CO_2$ at the regional and global levels, as well as tracking $CO_2$ migration in the atmosphere. With the capability to measure multiple species, the new protocol can also be used for monitoring other GHG emissions.

The $CO_2$ monitor is based on an ultra-sensitive and highly selective spectroscopic technique known as cavity ringdown spectroscopy[1] which is capable of measuring small-scale variations in $CO_2$ concentrations over the high concentrations of $CO_2$ in the atmosphere. Based on the spectral calculations using HITRAN 96, a single temperature controlled semiconductor diode laser operating around 1650 nm was selected to cover some of the spectral fingerprints of $CH_4$, $CO_2$, and $H_2O$ in the near-IR spectral region[2]. Ringdown spectra of atmospheric $CH_4$, $CO_2$, and $H_2O$ were obtained with inexpensive ringdown mirrors under vacuum free conditions. A near IR laser diode

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[1] A. O'Keefe and D. A. G. Deacon, "Cavity ring-down optical spectrometer for absorption measurements using pulsed laser sources," Rev. Sci. Instrum. 59, 2544 (1988).

[2] Wang, Chuji; Scherrer, Susan. T.; and Winstead C. B. "A simple method and device for control of cavity energy buildup and shutoff in cw-cavity ringdown spectroscopy: application for ringdown measurements of atmospheric $CH_4$, $CO_2$, and $H_2O$ at 1.65 μm". (to be published).

was selected as the light source, which provided narrow linewidth, tunable, single mode laser output at ~ 1650 nm. Figure 19 shows the laboratory-level CRDS-based spectrometer.

(a) Front view (b) Rear view

**Figure 19.** A Standalone Unit for Atmospheric $CH_4$, $CO_2$, and $H_2O$

The absorption spectrum of atmospheric $CO_2$, $CH_4$ and $H_2O$, measured with this CRDS-based spectrometer, is shown in Figure 20. The atmospheric concentrations of $CH_4$, $CO_2$, and $H_2O$ in a laboratory at Diagnostic Instrumentation and Analysis Laboratory were determined to be 1.8, 350, and 11000 ppm, respectively, from the recorded spectra. Results were compared with those from the theoretical simulations. The measured atmospheric concentrations of these molecules are in good agreement with the documented values in the literature, except for $H_2O$ whose concentrations varied daily during the one-month measuring period (13000, 12500 and 11000 ppm on April $21^{st}$, $25^{th}$ and $29^{th}$ respectively). With these relatively inexpensive mirrors and a cavity length of 60 cm, the detection limits of methane and $CO_2$ at this wavelength are ~ 7 ppb and 50 ppb, respectively. The measurement accuracy is ~ 5%. This work demonstrates that an inexpensive ringdown analyzer utilizing a single near-IR semiconductor diode laser can be developed for simultaneously monitoring atmospheric $CH_4$, $CO_2$ and $H_2O$. It should be noted that this laser diode was originally selected to demonstrate measurement of atmospheric methane. If another diode laser with wavelength output at ~ 1572 nm is selected, the detection sensitivity of $CO_2$ can be expected to improve by several orders of magnitude.

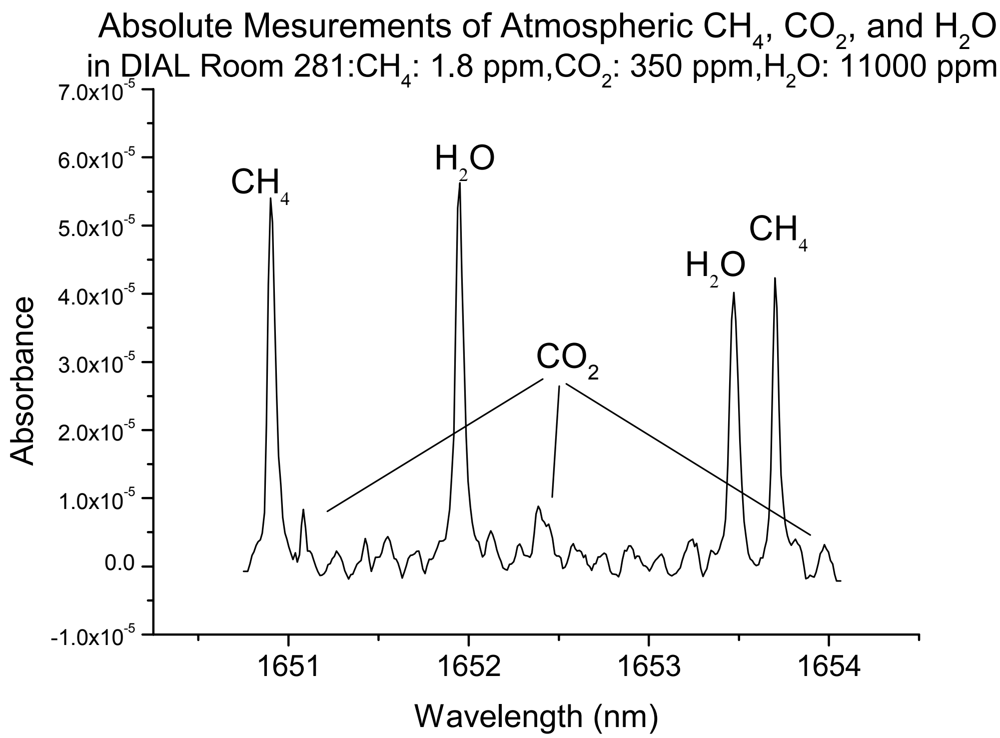


**Figure 20.** Ringdown Measurements of Atmospheric $CH_4$, $CO_2$, and $H_2O$ using a NIR laser diode at ~ 1650 nm.

This work demonstrates that emission monitors for GHGs can be developed using the CRDS technique. Potential applications include leak detection of $CO_2$, long-term stability monitoring of $CO_2$ storage and rapid response to $CO_2$ leakage for mitigation means. The research can be furthered to determine isotopic ratios of carbon in $CH_4$ and $CO_2$ in the atmosphere to track the migration of greenhouse gases or to monitor gas emissions in methane-and carbon dioxide-related sites.

Development of Fiber Pressure Sensors

Implementation of effective controls in oceanic and geological carbon sequestration will require monitoring the condition of the injection well, such as well-head pressures and formation pressures. A rugged, deployable and cost-effective pressure sensor is needed. In addition, if the sensor has the ability to measure down-hole, then additional validation of reservoir models and of the ability to verify that injected $CO_2$ is not subject to lateral or vertical migration can be demonstrated.

During the past twenty years, fiber optical pressure sensor technology has progressed rapidly - outperforming conventional pressure sensors with their high sensitivity, fast response, low cost, light weight, as well as immunity to electromagnetic interference. Currently, the most popular fiber pressure sensors are mainly based on fiber Fabry-Perot interferences (FFPI) or fiber Bragg gratings (FBGs). We have developed a technique for fiber pressure sensor development using conceptually new approach -- fiber loop ring-down[3, 4].

This method is modeled after the ringdown concept; however, a conceptually new approach, which eliminates the dependence on an ultra-high reflectivity cavity, is used. This new fiber ringdown technique utilizes an optical resonator, an optical fiber loop, as the ringdown “cavity.” Light radiation is coupled into the fiber loop. When the light source is rapidly shutoff, the resultant light rings inside the fiber loop for many round trips. In each round trip, a small fraction of light leaks into a photodetector through a fiber coupler. The rest of the light rings in the fiber experiencing internal fiber transmission losses. The signal intensity observed by the detector follows an exponential decay. The lower are the losses of the light in the fiber, the longer is the decay time constant (ringdown time). This type of fiber ringdown technique, functionally, resembles the standard high reflectivity cavity righdown for absorbance measurements but without the requirements of high reflectivity components.

The fiber ringdown device consists of two identical 2×1 fiber couplers, two sections of fused silica single mode fiber (Corning SMF 28), a temperature controlled diode laser at 1650 nm (the use of the diode laser wavelength is not particularly selected just based on availability of the laser diode in the laboratory) and a photodetector. The quoted tap ratio in the 2-leg end of the fiber couplers is 1: 99. The two 1-leg ends and the two 99% legs of the two couplers are spliced together, respectively, to form a fiber loop. The light from the single mode fiber of the pig-tailed laser diode is coupled into the fiber loop through the 1% leg with FC/APC fiber connectors, and the 1% leg of the second coupler is coupled to the photodetector. The total length of the loop is 61 meters. The quoted insertion loss of each coupler is less than 0.2 dB. The absorption loss rate of the fiber is 0.3 dB/km at 1550 nm and slightly higher at 1650 nm.

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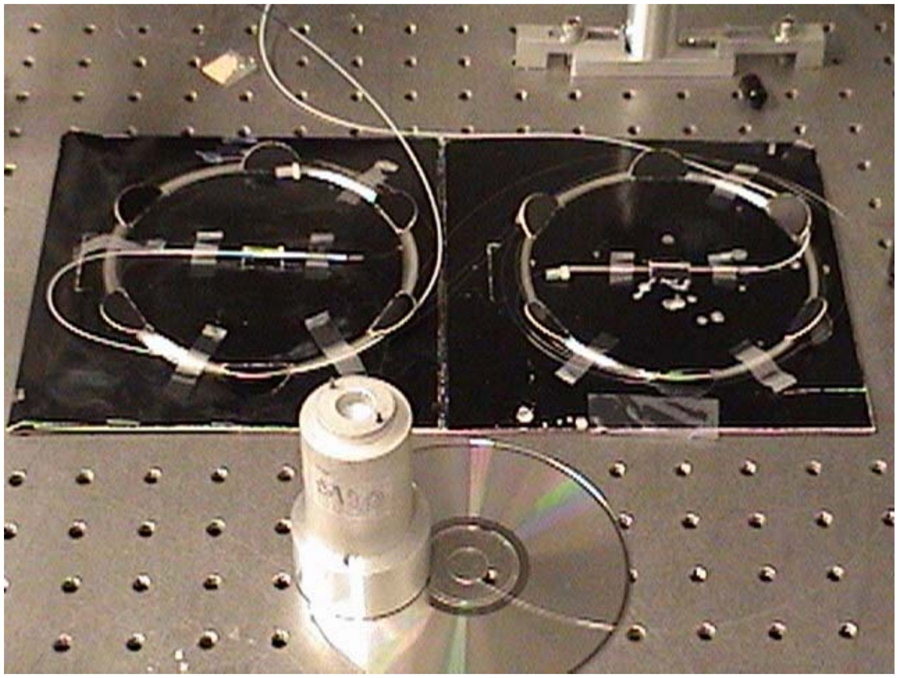
[3] Wang, Chuji; Scherrer, Susan T. "Fiber ringdown pressure sensors," Opt. Lett. 29(4), 352 (2004)

[4] Wang, Chuji; Scherrer, Susan T. "Fiber loop ringdown for physical sensor development: pressure sensor,"



A typical fiber ringdown pressure sensor unit

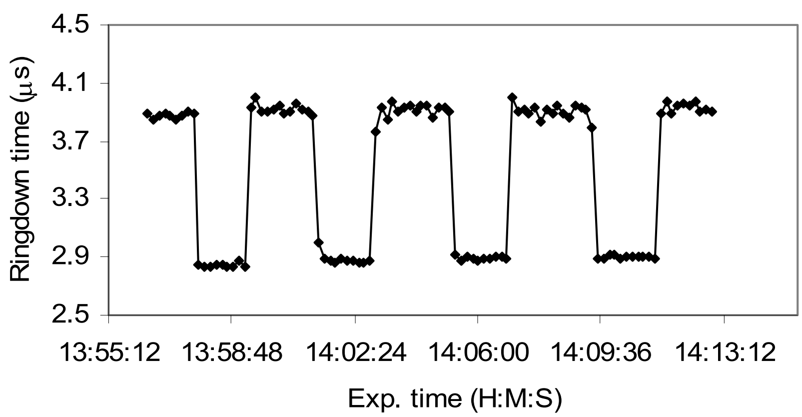



**Figure 21.** Fiber Ringdown Pressure/force Sensor Demonstrates a Rapid Response and Very Good Repeatability. The applied force is 237 grams, corresponding to ~ 338 psi.

Figure 21 shows the ringdown response to a 237 grams force loaded and unloaded on the pressure sensor. One section the fiber loop lies on the clean surface of the stainless optical table with the fiber jacket removed from this area. A separate piece of fiber, which is independent of the fiber loop but with the same fiber material, is similarly prepared with the fiber jacket removed and placed parallel to the section fiber loop on the optical table. A light aluminum plate (~ 1 gram) of a rectangular shape sits on the top of these two sections of fibers to form a Π shape-platform. The contacted area is the fiber cladding layer, and the contacted length of each section of the fiber to the rectangular aluminum plate is 8 mm. In this way, the real force applied to the sensor is approximately half of the forces loaded on the Π shape-platform. Therefore, when 474 grams force, comprised of six identical aluminum plates, circular in shape and each weighing 79 grams, is loaded on the Π shape-platform, the 237 grams force is applied to the sensor. Since the diameter of the fiber cladding layer is 125 μm, the 237 grams force approximately corresponds to 338 psi pressure, determined using the equation P=F/S. Each of the data points in Figure 21 comes from an average of 100 ringdown events. The curve shows that the fiber ringdown pressure sensor not only has a rapid response to pressure but also shows very good repeatability.

Figure 22 shows a typical testing curve obtained for measured ringdown times vs. applied forces. The applied forces are in the range of 0 - 418 grams, which approximately corresponds to pressures in the range of 0 - 595 psi, also based on the equation P=F/S. The measured ringdown times decrease from 3.94 μs at 0 psi to 2.38 μs at 595 psi. A linear fit of the measured ringdown time vs. force shows a good linearity.

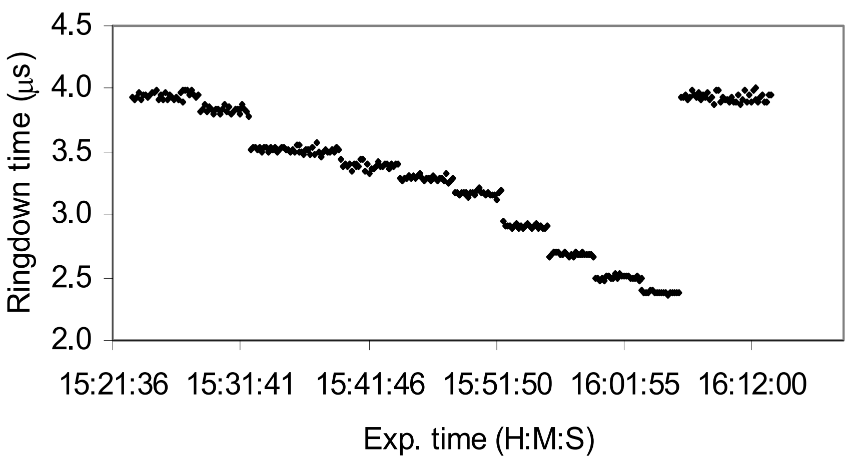



**Figure 22.** Ringdown Time Responses to Forces Applied on the Sensor. Each distinctive step corresponds to a different applied force. From the left to the right, the applied forces are 0, 40, 79, 158, 198, 237, 281, 339, 378, 418 and 0 grams.

Another issue to be addressed is the relation of detection sensitivity vs. the length of the fiber in contact with the applied force. It is found that for a given fiber ringdown device, the longer the fiber section that is used as the sensor "head," the more sensitive is the sensor. In our experiments, the absolute value of the slope increases from 0.0037 to 0.0072 when the fiber length in the sensor head increases from 8 mm to 16 mm. Similarly, the slope decreases from 0.0037 to 0.0031 when the length decreases from 8 mm to 6 mm. The variation of the slope is approximately proportional to the variation of the fiber length used in the sensor head. This result indicates that sensors could be designed and fabricated with selected areas to yield design-specified detection sensitivities.

Another experiment was conducted to examine the dynamic measuring range of the sensor. It was found that when force was applied to the fiber with the plastic fiber jacket intact, the detection sensitivity decreased. However, the fiber jacket served as a buffer and greatly increases the upper limit of the measuring range. With the same fiber-pressure interaction length, 8 mm, the measurable force was up to 750 grams, or 1068 psi. The force damage threshold was not tested in order to protect the sensor. This test suggests that if the specifically designed sensor head is adopted, e.g., using a protection layer or a buffer layer outside the fiber, FRP sensors will be suitable for pressure sensing in high measuring ranges.

**Task 4: Public Involvement**

As part of its mission, SECARB has a goal to develop public involvement and education mechanisms and plans to raise public awareness of sequestration opportunities in the region and provide interested stakeholders with information about technology deployment efforts. Through the efforts of the SECARB team, SECARB has worked to advance this goal and the overall mission during the second year of the RCSP initiative. As a result of the unique structure of the SSEB, SECARB is well positioned to obtain input from a broad cross-section of stakeholders and develop public involvement and education mechanisms and associated multi-year action plans to assist in the wide-scale deployment of carbon sequestration technologies and approaches.

To meet the public outreach and education goals of SECARB, year two efforts have included an assessment of public perception regarding the SECARB program through the undertaking of in-depth research. This research will assist in the development of the formal action plans for public outreach and education required for successful completion of the Phase I activities.

To serve the needs of public perception assessment, the SECARB team utilized various communications to engage and inform opinion leaders and stakeholders in the Southeast and beyond on SECARB and its goals. Information about SECARB was disseminated through various communications and events, including presentations at the North American Power Markets Conference, the Energy and Mineral Law Foundation Winter Meeting, and the West Virginia Environmental Academy; an article in *Coal Leader*; the announcement of the incorporation of the Carbon Offset Opportunity Program into SECARB's outreach efforts and meetings of the SECARB Technical Team and Technology Coalition, among others.

In addition, the SECARB team continued its assessment of public perceptions to ascertain knowledge of and interest in carbon sequestration to facilitate and structure on-going education and outreach efforts. These efforts built upon the successful industry focus group discussion of the last quarter of the first year of SECARB activities. The focus was on the unique environmental histories of the states in the SECARB region and the public perceptions of carbon sequestration among environmental non-governmental organizations in the region.

Specifically, these assessments involved survey research methods conducted by RMS Strategies and The Phillips Group, with the assistance of Augusta Systems and SSEB.

Opinions of environmental non-governmental organization stakeholders were studied for the purposes of outreach message development to governmental representatives from states in the SECARB region. Understanding the unique environmental history of each state is important as it pertains to project permitting and historical public reaction to project development, for instance. Activities during the two quarters included completion of the report on findings from the industry focus group and development and implementation of the survey research efforts involving environmental non-governmental organization stakeholders and governmental representatives from states in the SECARB region. These efforts will be concluded during the next quarter.

**SECARB Integrated Outreach Strategy**

During the first and second quarters of FY2005, the Partnership team worked to implement the integrated outreach strategy developed during the previous year of activities. This strategy served as an initial action plan for the Phase I effort, as required by SECARB Subtask 3.2.

The objective of the SECARB Integrated Outreach Strategy is to implement an outreach and education program that connects the value of carbon sequestration technologies among multiple constituencies. The program incorporates both internal, which includes SECARB Technical Team and Technology Coalition partners, and external components with strategies targeted to respective audiences and their needs. It helps to create awareness and comprehension of the purpose of the SECARB as outlined by the objectives of DOE and NETL. It seeks to advance RCSPs through the distribution of ongoing analysis and findings relative to the activities of SECARB initiatives. As a result, the application of carbon sequestration technologies will be accepted as an economically and environmentally sound energy technology and approach.

The SECARB Integrated Outreach Strategy consists of four key elements: determination of stakeholders and needs; establishment of outreach goals; determination of outreach strategies; and initiation of outreach activities and on-going evaluation. The Strategy is further detailed below.

***Determination of Stakeholders and Needs***

To initiate the outreach program, the SECARB outreach team identified the appropriate SECARB partners and other stakeholders and moved forward to determine the needs of these stakeholders with reference to education and outreach through the use of communications and survey research activities. The SECARB partners included, among others, the SECARB Technical Team members, the SECARB Technology Coalition members, DOE and others as defined by the SECARB leadership. In addition, the other SECARB stakeholders included SECARB regional organizations from industry, environmental non-governmental organizations, the public, other special interest groups, academic and research institutions, government agencies and others, including stakeholders from beyond the SECARB region.

### *Establishment of Outreach Goals*

The SECARB outreach team also has worked to set outreach goals focused on both SECARB partners and external SECARB stakeholders. These goals support the objectives of DOE, NETL and SECARB in generating understanding and support for carbon sequestration technologies among stakeholders. These goals are based upon four factors, as follows:

- Background research and survey research activity analysis;
- Existing environmental history that could drive awareness, education and attitude needs of audience;
- Technology validation needs; and
- Potential barriers to acceptance of carbon sequestration technologies and approaches.

### *Determination of Outreach Strategies*

Utilizing the above steps, SECARB is working to determine outreach strategies. The outreach strategies will develop the infrastructure, mechanisms and implementation methodologies aligned with DOE, NETL and SECARB in terms of overall objectives and objectives of the Integrated Outreach Strategy. The outreach strategies, which will be targeted at both SECARB partners and other SECARB stakeholders following input from NETL, will include focuses on:

- Stakeholder Prioritization;
- Message Development;
- Identity Development;
- Technology and Approach Concept Training;
- Outreach Infrastructure Development (possibilities include SECARB Web page, e-mail lists, newsletter, letters, resource book, forums, brochures, fact sheets, maps, charts, background papers, SECARB fact sheets, background papers, maps, etc.); and
- Outreach Timeline Development (for outreach on findings, announcements, achievements, ongoing activities, results, etc.).

Under this element, SECARB will develop the Action Plan for Public Involvement, Education and Acceptance called for by Subtask 6.5 of the SECARB scope of work. As part of this overall plan, SECARB has embraced utilization of the NETL-supported Carbon Offset Opportunity Program as a tool to assist in facilitating collaborative carbon sequestration activities in the SECARB region.

### *Formal Initiation of Outreach and On-going Evaluation*

This initiation of outreach and on-going evaluation will center on the development and refinement of the Action Plan for Public Involvement, Education and Acceptance called for by Subtask 6.5 of the SECARB proposal. This element will include the action plan delivery and measurement of the infrastructure and strategies for SECARB outreach and education.

### Stakeholder Needs Analysis: In-Depth Survey Research Activities

As noted, the determination of stakeholder outreach and education needs element of the effort currently is being conducted. These activities have focused on two areas: (1) SECARB Regional Perceptions of Carbon Sequestration; and (2) SECARB Region Environmental History Research. Details on these areas follow.

#### *SECARB Regional Perceptions of Carbon Sequestration*

The objective of the SECARB regional perceptions of carbon sequestration research effort is to determine and evaluate the attitudes and perceptions of key opinion leaders, including most notably leaders of industry and environmental non-government organizations, regarding carbon sequestration issues. The primary goals of the study will be to: assess the awareness and understanding of carbon sequestration; identify any barriers to the carbon sequestration effort; and determine effective messages among the stakeholders. Thus, the results of this research can direct the outreach and education efforts for SECARB.

With the SSEB Annual Meeting in September 2004 providing a suitable platform for an industry focus group session in Richmond, Virginia, RMS Strategies led the focus group activities and conducted the planning and structuring of these activities with the assistance of Augusta Systems and the SSEB. Working closely with representatives from Augusta Systems and the SSEB, RMS Strategies designed a focus group discussion guide and worksheet and delivered a program that elicited unbiased responses to a host of question areas, including:

- General environmental perceptions;
- Climate change perceptions;
- Overall awareness of carbon sequestration efforts; and
- Messaging.

Initial documentation, such as an email invitation letter sent to SECARB industry focus group participants, the SECARB industry focus group agenda and the SECARB industry focus group discussion guide and worksheet were included in previous submissions.

To further ascertain perceptions from other SECARB constituencies, including national and regional environmental nongovernmental organizations, a list of similar questions was posed to a select group of identified SECARB environmental non-governmental organization stakeholders by RMS Strategies, with assistance from Augusta Systems and the SSEB, through a telephone-based in-depth interview process. A report of findings from these discussions will be completed in the third quarter of 2005.

### *SECARB Region Environmental History Research*

Clearly, the paths that have been tread before play an important role in determining what courses may be taken in the future. To support efforts to ascertain the appropriate outreach strategies and mechanisms that should be employed to assist with wide-scale carbon sequestration deployment in the SECARB region, The Phillips Group, with the assistance of Augusta Systems and the SSEB, undertook a research effort to determine the environmental history of states within the SECARB region. This research, taking the form of a telephone interview with state energy and environmental officials, is meant to assist the partnership with its outreach efforts. Through this survey, SECARB will gain knowledge of the environmental issues unique to each state in the SECARB region to better understand how these issues may relate to regional and national carbon sequestration efforts. A report of findings from these discussions will be completed in the third quarter of FY2005.

### Meetings and Presentations

SECARB project team members participated in the following events during this semiannual reporting period.

- "Geological Working Group Meeting" in Houston, Texas, on October 20, 2004
- "MIT Carbon Sequestration Forum V: Overcoming Barriers to CCS Implementation" in Cambridge, Massachusetts, on November 2-3, 2004
- NETL "Regional Carbon Sequestration Partnerships Annual Program Review Meeting" in Pittsburgh, Pennsylvania, on November 16-17, 2004
- SECARB Technical Team/Technology Coalition Meeting on Geologic Characterization, December 17, 2004
- SECARB Technical Team/Technology Coalition Meeting, January, 20, 2005
- SECARB Partnership Status Briefing to Southern Company Senior Management, January 2005
- "Southern States Energy Board Associate Members Meeting", February 28, 2005

## Task 5: Identify Most Promising Capture Sequestration and Transportation Options

SECARB will continue the characterization of the most promising regional options for $CO_2$ capture, transport and storage. Currently, source information has been completed and tools for developing regional options are complete. Much of the geologic characterization is complete but not all has been incorporated into the GIS system. The 18-month investigation has enabled SECARB to focus on the most promising geologic field options that promote a framework and infrastructure necessary for the validation and deployment of carbon sequestration technologies (see details below). In addition, SECARB will allocate significant effort in the final two quarters to the continued characterization of the region, validating technologies and identifying locations.

**Field Test Opportunity 1: Gulf Coast Stacked Storage**

This most promising opportunity leverages the economic benefits of enhanced oil recovery (EOR) to help offset the cost of infrastructure needed to capture, transport and store CO2 in geologic formations. The Gulf Coast has numerous opportunities for CO2 EOR, with depleted reservoirs that are stacked with saline aquifers at great depths. A thick sedimentary wedge of Tertiary and Quaternary rocks up to 12,000 ft (3,658m) defines the Gulf Coast subregion, the onshore area of which is 154,440 $mi^2$ (400,000 $km^2$). Internal structure and properties of the Gulf Coast wedge are well known because of extensive exploration for end production of hydrocarbons. Examination of regional maps and cross-section sets (Dodge and Posey, 1981; Galloway, 1982; Hosman, 1996) shows the maximum depth (where detailed regional data are available) is 14,000 ft (4,000 km); deeper potential exists but was not assessed. Fresh and brackish water protected as USDW extends relatively deep (2,000 to 3,500 ft [610 to 1067m]) in this region (Arthur and Taylor, 1990; LBG Guyton Associates, 2003, Brackish groundwater manual for Texas; Hovorka and others, 2004b). In order to give adequate protection to USDW, the SECARB team assumes potential storage can begin at 4,000 ft (1,219m), which will allow the injection zone to be overlain by several thick, extensive shale-seal barriers to migration and a buffer of permeable sandstones to assure high permanence of storage. Sandstone porosity and permeability are high in the relatively young sediments of the GC wedge, averaging 25% to 35% and .5 to 3 darcys. With respect to the national picture, the entire region is a target, so an average net sand value of 23% was used, based upon the evaluation of type logs (Dodge and Posey, 1981). Using lower Gulf Coast area of 240,000 $km^2$ with a stratigraphic thickness of 2.4 Km and the 23% porosity, GCCC calculated total brine-filled subsurface porosity capacity of 42000 $km^3$. Injection simulation in typical, geologically heterogeneous Gulf Coast sandstones (Hovorka and others, 2004a) has shown that capacity is a complex of multiple variables, including dissolution, two-phase trapping, buoyancy trapping, and complex migration paths. Additional experimentation, followed by modeling, is needed for realistic and defensible capacity assessment to be done. However, 1% of the large subsurface volume could hold 428 years of the region's entire current $CO_2$ production, which motivates continued research.

Half the generating capacity of the subregion is from coal and lignite-fired power plants; the other half is gas fired, providing a diverse suite of options for capture. Both refiners (Chevron Texaco and BP) and utilities (Entergy and NRG) have joined the GCCC and are actively engaged in seeking a viable carbon capture and storage project (CCS) in a geologic setting with an economic driver. Without an effective program to capture and store $CO_2$ emissions from the Gulf Coast, the national GHG intensity goals will be difficult to reach.

$CO_2$-EOR could generate significant potential revenue streams to offset or completely cover costs of transportation infrastructure. Stakeholders, $CO_2$ emitters, operators and communities, have shown strong interest in taking action to prolong production at fields with declining production through $CO_2$-EOR. Over the last year, GCCC, through collaboration and academic funding, has completed an assessment of geologic storage options in the Gulf Coast region. We inventoried 0.4 billion tons of $CO_2$ produced annually from 316 stationary sources in the region. Capture of $CO_2$ from these sources could supply a 680-mi (1,095-km) pipeline infrastructure that links the Gulf Coast region in a network extending from Alabama to Mexico. This area comprises 767 oil and natural gas reservoirs that could be used first for EOR and then for large-volume, long-term storage of $CO_2$ in nonproductive formations below the reservoir interval. Modest investments could provide economic incentives for the oil and gas industry to support expanded EOR programs that will yield potential storage sites. Within Texas alone, we estimate that outside the traditional area of $CO_2$-EOR in the Permian Basin, an additional 5.7 billion barrels (Bbbl) of oil could be produced by using $CO_2$-EOR. By way of comparison, annual U.S. oil production is currently 3.2 Bbbl. This EOR activity could also lead to the storage of more than 700 million tons (0.7 gigaton) of $CO_2$—only a small part of the positive impact. The true prize will be that EOR could enable construction of a $CO_2$ pipeline infrastructure that could allow cost-effective storage of Gulf Coast power plant, refinery, and chemical plant emissions from fossil-fuel combustion for the next 50 years or more.

**Field Test Opportunity 2: Coal Seam Sequestration**

The Black Warrior Basin and adjacent parts of the Appalachian thrust belt contain a diverse assemblage of potential carbon sinks, including coal, mature oil and gas reservoirs, and saline aquifers (Pashin and Payton, in review). Among these potential sinks, coal is especially promising because of the potential to sequester large volumes of greenhouse gas while enhancing CBM production (Pashin et al., 2001, 2004). Two coal-fired power plants adjacent to the Black Warrior coal bed methane fields emit more than 31 megatons of $CO_2$ a year, and the proximity of these plants to the CBM fields makes validation of sequestration and ECBM potential a major priority. Additional capacity exists in CBM reservoirs in the Appalachian thrust belt, but this capacity has yet to be assessed. These reservoirs are close to a third coal-fired power plant that emits nearly 14 megatons of $CO_2$ annually, thus the potential of coal in the Appalachian thrust belt of Alabama will be assessed during the Phase II program.

Several coal-fired electrical power generation facilities operate in the region surrounding the proposed Central Appalachian pilot, which could provide a large source of $CO_2$ that, if not captured for sequestration, would be discharged to the atmosphere. The coal fields surrounding the generation facilities provide sequestration sinks for captured $CO_2$, the extent of which will be addressed in the SECARB project. An extensive natural gas pipeline infrastructure exists in the region, which provides pipeline rights-of-way to transport $CO_2$ from the facilities to injection locations within the coal fields.

In the Black Warrior coal bed methane fields, the storage capacity of coal locally exceeds 2 MMscm/acre, and the amount of gas left in place after primary CBM recovery is estimated to exceed 0.4 MMscm/acre in some areas (Pashin et al., 2004). Coal in the Black Warrior Basin may be used to sequester up to 1.2 Tscm of $CO_2$, which is equivalent to 35 years of $CO_2$ emissions from nearby coal-fired power plants at current rates (Pashin et al., 2001). Through ECBM, more than 14 MMscm of $CH_4$ may be recoverable from the established CBM fields in the Black Warrior basin, which could prolong the life of the CBM reservoirs substantially and result in a 20% expansion of CBM reserves in the basin (Pashin et al., 2004).

The area identified in the Central Appalachian Basin for carbon sequestration opportunities in coal seams encompasses portions of southwestern Virginia (Buchanan, Dickenson, and Wise Counties, southern West Virginia (Fayette, McDowell, Raleigh, and Wyoming Counties), and counties in eastern Kentucky (Harlan, Letcher, and Pike Counties). A total storage capacity of 0.86 Tscm has been estimated for the Middle to Lower Lee and Pocahontas Formations in Buchanan and Dickenson Counties, Virginia (Karmis, 2005). The technically feasible storage capacity estimate for these two counties, excluding mineable areas and areas not yet developed for CBM production, is 0.31 Tscm. $CO_2$ sequestration has the associated potential to recover an incremental 22.7 Bscm of enhanced coal bed methane. This region of Appalachia has been densely drilled for both conventional and CBM reservoirs; therefore, an extensive and mature natural gas pipeline infrastructure exists over the majority of the area defined for carbon sequestration potential. In addition to $CO_2$ sequestration, coal can be used as a natural separator for flue gas and may also sequester extremely large quantities of $SO_X$ and $NO_X$ emissions (Chickatamarla and Bustin, 2003). If proven, this breakthrough concept could revolutionize the possibilities for cost-effective $CO_2$ capture. Hence, coal may play a significant role in sequestering the full range of acid gases emitted by coal-fired power plants and may be pivotal to the development of novel technologies for acid gas mitigation. The proposed injection tests for $CO_2$ constitute an early step in realizing the acid-gas sequestration potential of coal. Modeling efforts during this study also will explore the possibility of sequestering multiple acid gases in coal. Advanced Resources work on Burlington Resources' $CO_2$-ECBM pilot in the San Juan Basin demonstrates the practicability of $CO_2$ storage in coal seams as well as the value-added benefits of such a project. The prospect of enhancing CBM production while proving that carbon sequestration in coal seams is feasible in the southeastern United States will represent significant progress in limiting GHGs in our region.

### Field Test Opportunity 3: Mississippi Salt Basin

The site is located along the southern boundary of the Mississippi Interior Salt Dome Province above the most significant structure of the local geology, the Wiggins Arch. The Wiggins Arch separates the Mississippi Salt Basin from the Gulf Coast Salt Basin. The Mississippi Salt Basin subsurface in the region is characterized by numerous salt related structures especially salt domes. Other salt related structures in the area include ridges and anticlines. These structures developed as a result of ascension of the Jurassic-age Luann Salt caused by sediment loading. South of the site area, sediments dip into the Gulf of Mexico where they are also punctuated by salt piercement domes of Jurassic-age Louann Salt. The site is located on Quaternary-age sediments. The stratigraphic section in the area (above the Paleozoic-age basement) contains over 20,000 feet of Jurassic through Tertiary-age sediments. The stratigraphic section in the area thins northward and thickens southward toward the Gulf Coast, except over salt structures and basement structures. Regional dip is to the southwest. Tertiary-age lithology consists of sand with interbedded shale and minor amount of limestone. The Createceous-age lithologies consist of interbedded sandstone, shale, and limestone with minor amounts of anhydrate. The Jurassic-age lithologies include salt, anhydrite, limestone, dolomite and sandstone. Deep confined aquifers for the site area include sandstones of the Cretaceous-age Eutaw, Tuscaloosa, Dantzler, Paluxy and Sligo formations and the Jurassic-age Cotton Valley and Norphlet formations. Where these sandstones are in fault blocks and truncate at the flanks of salt domes, some oil and gas may be trapped within these larger aquifer systems. These sandstone and carbonate aquifers and their associated confining units are part of the Gulf Coast Cenozoic to Mesozoic-age mixed siliciclastic carbonate wedge that attains a maximum thickness of over 23,000 feet and extends from northern Mississippi to deep into the Gulf of Mexico. This wedge of sediments and rocks thickens northwestward from the site area into the Mississippi Interior Salt Basin, thins over the Wiggens Arch, and then thickens again into the Gulf of Mexico. The Cretaceous-age Eutaw Formation reservoir is a marine shelf sandstone found at 8,000 feet near the major salt domes in the site area. Eutaw reservoir porosities range up to 30% with permeabilities up to 500 millidarcies. Eutaw Formation thickness is 500 feet containing 50% sandstone. The Cretaceous-age Tuscaloosa and Lower Tuscaloosa, Dantzler, and Paluxy reservoirs consist of fluvio-deltaic sandstone and are found at depths of 9,000 to 11,000 feet. Reservoir porosities range up to 30% with permeabilities as high as 1,000 millidarcies. The combined Tuscaloosa and Lower Tucscaloosa, Dantzler, and Paluxy formations are 3,000 thick and consist of 50% sandstone. The Sligo/Hosston reservoir is composed of deltaic and shelf deposits and is found at depths of 12,000 to 14,000 feet. Reservoir porosities range up to 15% with permeabilities up to 15 millidarcies. The combined Sligo/Hosston Formation thickness is 2,500 feet consisting of 65% sandstone. The Jurassic-age Cotton Valley Formation is a deltaic to slope-fan deposit found at 15,000 feet of depth. Cotton Valley reservoir porosity ranges up to 15% with permeabilities up to 15 millidarcies. Cotton Valley Formation thickness is 1,500 feet containing 90% sandstone. The Jurassic-age Norphlet Formation is an eolian deposit at a depth of 22,000 feet. Reservoir porosities range up to 12% with permeabilities of less than 5 millidarcies with a thickness of 200 feet (Kuuskraa, 2004).

**Task 6: Prepare Action Plans for Implementation and Technology Validation Activity**

Under Task 6, Prepare Action Plans for Implementation and Technology Validation Activity, SSEB and Hill will guide the SECARB team in developing an integrated approach to implementing the most promising opportunities and in setting up measurement, monitoring and verification programs for the most promising opportunities.

## Conclusion

During the last six months of SECARB's Phase I activities, the team will continue its work toward completing all remaining tasks to successfully accomplish the scope of work. Milestones for the upcoming quarters include:

3rd Quarter (April 1-June 30, 2005): Refine public involvement and education mechanisms in support of technology development options.

4th Quarter (July 1-September 30, 2005): Identify the most promising capture, sequestration and transport options; and prepare action plans.

## Problems Encountered

No unforeseen problems were encountered.

## Significant Accomplishments

SECARB achieved significant accomplishments during this semiannual reporting period, including completion of important scheduled milestones, identification of carbon sequestration field test opportunities and uploading additional SECARB data to NATCARB. A brief description of each accomplishment is provided below.

During the first quarter of federal FY2005, the Partnership completed a preliminary assessment of safety, regulatory, permitting and accounting frameworks within the region (Appendix A) to allow for wide-scale deployment of promising terrestrial and geologic sequestration approaches. Project team members performed research and analysis of the relevant state and federal statutes and regulations applicable to sequestration regulatory, permitting and safety matters. This research involved direct examinations of applicable statutes and regulations related to both geologic and terrestrial sequestration applications, as well as interaction with state legislators and regulators responsible for enacting and implementing regulatory regimes. Also, SECARB team members are working with the Interstate Oil and Gas Compact Commission (IOGCC) Task Force on Geologic Carbon Sequestration to ensure that SECARB approaches will converge with recommended national approaches. In addition, the project team investigated emerging, potentially SECARB-applicable, greenhouse gas accounting frameworks.

During the second quarter of federal FY2005, SECARB conducted an inventory of major $CO_2$ sources and sinks for the partnership region. The information resides on SECARB's database and will be connected to the NATCARB database. The Partnership is refining GIS algorithms and tools for the geographic area, including:

- A tool for source/sink matching;
- A sink capacity tool; and
- Three costing algorithms for capture, transportation and injection.

The most significant accomplishment during this period is the Partnership's identification of the region's most promising carbon sequestration field test opportunities. First, the Gulf Coast Stacked Storage field test opportunity leverages the economic benefits of enhanced oil recovery to help offset the cost of infrastructure needed to capture, transport and store $CO_2$ in geologic formations. Second, the Black Warrior Basin (Alabama) and Central Appalachian Basin (Virginia, West Virginia and Kentucky), coal seam sequestration is particularly promising because of its potential to sequester large volumes of greenhouse gases while enhancing CBM production. The third opportunity exists along the southern boundary of the Mississippi Interior Salt Dome Province above the Wiggins Arch. This site is located in a geological setting near numerous coal-fired power plants that could support significant storage of future $CO_2$ emissions in the region.

Lastly, SECARB uploaded additional SECARB data to the NATCARB database. This process will continue throughout the remainder of the program as additional data is collected.

## References

To assist the reader, the references are included as footnotes within the text of the document.

## List of Acronyms and Abbreviations

| | |
|---|---|
| ARI | Advanced Resources International |
| CBM | Coal Bed Methane |
| $CO_2$ | Carbon Dioxide |
| COOP | Carbon Offset Opportunity Program |
| CRDS | Cavity Ringdown Spectroscopy |
| DEM | Digital Elevation Model |
| Department | United States Department of Energy |
| DIAL | Diagnostic Instrumentation and Analysis Laboratory |
| DOE | United States Department of Energy |
| DOT | United States Department of Transportation |
| ECBM | Enhanced Coal Bed Methane |
| EGR | Enhanced Gas Recovery |
| EOR | Enhanced Oil Recovery |
| EPA | United States Environmental Protection Agency |
| EPRI | Electric Power Research Institute |
| GHG | Greenhouse Gas |
| GIS | Geographical Information System |
| GNIS | Geographic Names Information System |
| GSWG | Geologic Sequestration Working Group |
| IOGCC | Interstate Oil and Gas Compact Commission |
| LIBS | Lazer Induced Breakdown Spectroscopy |
| LGS | Louisiana Geological Survey |
| MIT | Massachusetts Institute of Technology |
| MMA | Marshall Miller and Associates |
| MMRI | Mississippi Mineral Resource Institute |
| MMV | Monitoring, Measurement and Verification |

| | |
|---|---|
| MSU | Mississippi State University |
| NARSAL | Natural Resources Spatial Analysis Laboratory |
| NATCARB | National Carbon Database |
| NETL | National Energy Technology Laboratory |
| NLCD | National Land Cover Dataset |
| NOAA | National Oceanic & Atmospheric Administration |
| NPP | Net Primary Productivity |
| $O_2$ | Oxygen (pure) |
| OPS | Office of Pipeline Safety |
| Partnership | Southeast Regional Carbon Sequestration Partnership |
| PEIS | Programmatic Environmental Impact Statement |
| PSI | Pounds Per Square Inch |
| RCSP | Regional Carbon Sequestration Partnership |
| R&D | Research and Development |
| SDWA | Safe Drinking Water Act |
| SECARB | Southeast Regional Carbon Sequestration Partnership |
| SLC | Southern Legislative Conference |
| SSEB | Southern States Energy Board |
| STATSGO | State Soil Geographic |
| TVA | Tennessee Valley Authority |
| TX BEG | Texas Bureau of Economic Geology |
| U.S. DOE | United States Department of Energy |
| U.S. | United States |
| UIC | Underground Injection Control |
| UNFCCC | United Nations Framework Convention on Climate Change |
| USDA | United States Department of Agriculture |
| USDOE | United States Department of Energy |
| USDOT | United States Department of Transportation |
| USDW | Underground Sources of Drinking Water |
| USEPA | United States Environmental Protection Agency |
| USGS | United States Geological Survey |
| UT-BEG | University of Texas Bureau of Economic Geology |
| VRGGP | Voluntary Reporting of Greenhouse Gases Program |
| WBCSD | World Business Council for Sustainable Development |
| WRI | World Resources Institute |

# Appendices

## Appendix A

### Regulatory, Permitting, and Safety Frameworks

Initial regulatory, permitting, and safety frameworks issues analysis focused on two key areas – geologic sequestration and terrestrial sequestration issues. Activities in both areas are discussed below.

***Geological Sequestration***

As terrestrial sequestration activities have been initiated and are beginning to emerge as a standard bearer for GHG emissions management projects, the relatively less well-known and less practiced domain of geologic carbon sequestration merits substantially more examination and analysis at this time to ensure that appropriate regulatory, permitting, and accounting frameworks emerge around the arena. To support this effort, USDOE NETL has provided funding support to the above-referenced the IOGCC Task Force, which was formed by IOGCC with funding support from USDOE and empowered with two primary objectives:

- Examine the technical, policy, and regulatory issues related to safe and effective storage of $CO_2$ in the subsurface (oil and natural gas fields, coal-beds and saline formations), whether for enhanced hydrocarbon recovery or long-term storage; and
- Produce of a final report containing (a) an assessment of the current regulatory framework likely applicable to geologic $CO_2$ sequestration, and (2) recommended regulatory guidelines and guidance documents. The Final Report and the documents contained therein will lay the essential groundwork for a state-regulated, but nationally consistent, system for geologic sequestration of $CO_2$ in conformance with national and international law.[5]

Per direction of USDOE, Augusta Systems, on behalf of SECARB, has worked to support the IOGCC effort through idea generation, analysis, drafting, and technical editing, and, when possible, worked to adopt its anticipated recommendations. Thus, in many instances, this report will cite the IOGCC Task Force's report as it potentially provides a common platform for geologic sequestration regulatory, permitting, and safety frameworks.

In an examination of geologic sequestration both under SECARB and the IOGCC effort, a clear question emerged regarding the future regulatory, permitting, and safety frameworks – How linked will geologic sequestration regulatory, permitting, and safety frameworks, especially with reference to the injection and long-term storage activities,

[5] Interstate Oil and Gas Compact Commission Geological $CO_2$ Sequestration Task Force, Final Report, March 2005.

be to the Federal Safe Drinking Water Act (SDWA) Underground Injection Control (UIC) program? More specifically, there are four sub-level questions:

- Will $CO_2$ be defined as a commodity, waste, or pollutant under Federal, state, or Federal and state laws and regulations, including UIC regulations?
- Will geologic carbon sequestration injection and storage activities be wholly subject to existing UIC regulations?
- Will new UIC classes or definitions emerge to facilitate geologic sequestration injection and storage activities?
- Will long-term geologic sequestration projects without enhanced hydrocarbon recovery components be subject to UIC at all?

Clearly, SECARB and even the IOGCC Task Force do not hold the final authority on this matter, or else the conclusions of this report could be more concrete. With the USEPA holding authority for UIC rules, regulations, and interpretations, it seems that the USEPA will be ultimate arbiter of these matters. To assist in defining the options for the SECARB region, and perhaps the nation, however, SECARB has produced this examination. A brief overview of the present regulatory, permitting, and safety environment for potential geologic sequestration activities follows.

<u>Natural Analogues</u>

It has been suggested that four analogues exist for regulatory guidance regarding geologic carbon sequestration – naturally occurring $CO_2$ contained in geologic formations; $CO_2$ enhanced oil recovery (EOR) operations, storage of natural gas in geologic formations, and the injection of hydrogen sulfide ($H_2S$) into underground formations.[6] In some states, and more specifically states with hydrocarbon production and/or storage activities, there is a rich legacy of regulatory, permitting, and safety regimes in place that would assist in wide-scale deployment of geologic carbon sequestration approaches and technologies.[7]

Of these analogues, perhaps the most significant are those of the naturally occurring $CO_2$, which shows the capabilities of geologic formations to retain vast quantities of $CO_2$ over time, and the EOR operations, which demonstrate the safe and well-regulated transport and injection of $CO_2$ into geologic formations.

Although $CO_2$ is a non-hazardous gas at normal atmospheric conditions, $CO_2$ can exist in three forms:

- As the above-referenced gaseous state;
- As a supercritical fluid that has physical properties between a liquid and a gas at pressures greater than 1073 pounds per square inch (psi) at less than 87.7 degrees Fahrenheit; and,

[6] Interstate Oil and Gas Compact Commission Geological $CO_2$ Sequestration Task Force, Final Report, March 2005.
[7] Interstate Oil and Gas Compact Commission Geological $CO_2$ Sequestration Task Force, Final Report, March 2005.

- As a solid form most commonly referred to as dry ice, at temperatures below 109 degrees Fahrenheit.[8]

Given a situation in which normal geologic pressure and temperatures would exist, it has been assumed that deep injection of $CO_2$ (i.e. greater than 2,500 feet below the surface) would result in the $CO_2$ existing as a supercritical fluid. In other instances related to geologic sequestration (i.e. capture, transport, injection, and shallow storage, if ever), it is likely that $CO_2$ would be in a gaseous form. Thus, geologic sequestration regulatory, permitting, and safety frameworks would relate to the gaseous and supercritical fluid states.

Options for geologic sequestration abound, but the geologic sinks with the highest potential geologic carbon sequestration include deep unmineable coal seams, depleted or nearly depleted sandstone/limestone oil and gas reserves, oil and gas bearing shales, active and abandoned storage fields, saline formations, salt caverns/beds, and hydrates. Thus, the focus on regulatory, permitting, and safety analysis for geologic sequestration would be focused on these areas.

Examination of Regulatory, Permitting, and Safety Issues

More specifically, the regulatory, permitting, and safety framework analysis and action plan development would principally focus on four key areas:

- Capture;
- Transport;
- Injection; and,
- Storage.[9]

*Capture*

Capture of $CO_2$ from anthropogenic, or man-made, sources is presently being performed in the SECARB region, and in some instances with processing activities to enhance purity, to feed EOR and enhanced gas recovery (EGR) projects and can be anticipated to increase in frequency as geologic sequestration becomes deployed on a more significant scale. At present, the existing regulations are likely of limited utilization for future geologic sequestration, which will include elements of capture and separation of $CO_2$ from flue gas streams and other point sources. Thus, it would seem that the future of capture regulations will rely upon the answer to whether $CO_2$ will be defined as a commodity, waste, or pollutant under Federal, state, or Federal and state laws and regulations, including UIC regulations.

*Transport*

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[8] Interstate Oil and Gas Compact Commission Geological $CO_2$ Sequestration Task Force, Final Report, March 2005.

[9] These key areas of analysis have been selected both for reasons of sound regulatory analysis and practical considerations. For reference, the IOGCC Task Force and the Carbon Sequestration Leadership Forum Legal, Regulatory, and Financial Issues Task Force have both selected similar breakdowns for their analysis efforts.

The arena of $CO_2$ transport is a little more complex today, but also more applicable to the future world of wide-scale geologic sequestration. Transport of $CO_2$ is currently conducted through pipelines, generally, and with the support of three primary mechanisms:

- High pressure, or supercritical phase (i.e. above 1180 psi);
- Lower pressure gas transmission; and,
- Refrigerated liquid transmission (also commonly used for rail and truck transport).

The SECARB region is fortunate, and perhaps unique as compared to a number of other RCSPs, because the region already has a functioning $CO_2$ transport infrastructure. $CO_2$ pipelines exist in Louisiana and Mississippi. Denbury Resources, Inc. (Denbury), is selling $CO_2$ commercially (primarily to the food and beverage industry), and currently seems to be expanding its supply. Denbury may also be a major consumer of $CO_2$ for enhanced oil recovery. Several SECARB Technology Coalition Members and others in the SECARB region have publicly expressed interest in the use of $CO_2$ for recovery of coal bed methane gas. The latter two are particularly important in the region because of the extensive oil production along the Gulf Coast, and the coal beds in Mississippi, Alabama, and Tennessee.

The $CO_2$ infrastructure in the region includes pipelines and other transportation infrastructure, separation and purification capabilities, and a network of equipment suppliers. These existing pipelines are regulated by the Office of Pipeline Safety (OPS) of the U.S. Department of Transportation (USDOT).[10] U.S. states may also be involved in the regulatory process for these $CO_2$ pipelines under partnership agreements with OPS. In most instances, regulatory responsibilities the smaller diameter gathering lines for the $CO_2$ tend to fall to the states. Moreover, rail and truck transportation tend to be regulated primarily by state entities.

While the existing SECARB infrastructure is robust, the opportunity to leverage this infrastructure may not be as significant. Presently, the $CO_2$ pipelines assets tend to be closely controlled, and without options for open access-based utilization.

*Injection and Storage*

Injection and storage, like transport, has a robust history, both in terms of practices and regulations, to rely upon for the future of sequestration. Due to the fact that the regulatory, permitting, and safety frameworks for injection and storage will likely be linked closely, these two topic areas will be discussed together.

In terms of practices, the American Petroleum Institute (API), American Gas Association (AGA), and the American Society for Testing and Materials (ASTM) have established materials selection standards for well casing and down hole equipment, wellhead

[10] 49 C.F.R. 195.

equipment, cement types and other relevant oilfield equipment and facilities that meet prevailing standards in states under UIC laws and regulations. Logically, these established practices and industry standards would adequately address materials standards for geologic carbon sequestration.

While clarity may exist with regard to industry standards for well construction, maintenance, and operation, less agreement is found regarding the rules and regulations for the potential geologic sinks. While present state regulations would generally permit injection of $CO_2$ into depleted oil and natural gas reservoirs, for EOR, EGR, and enhanced coal bed methane (ECBM) purposes, and into deep saline formations, the treatment of salt cavern utilization is less consistent. In fact, in some SECARB states, including Alabama, salt cavern storage would not be permitted by existing statutes.

Although the USEPA has indicated that $CO_2$ regulation is beyond its mandate under the Clean Air Act, the USEPA may play a significant role in voluntary GHG management programs as USEPA could have the primary authority for structuring geologic sequestration program requirements, and in some instances, applying them. This would be dependent upon whether geologic carbon sequestration is governed under the UIC Program of the SDWA. Based upon the IOGCC Task Force recommendations and the general consensus of other interested parties, it seems that at a minimum the USEPA will play this role, at least with respect to geologic sequestration activities related to enhanced hydrocarbon recovery. More details on the SDWA, the UIC Program, and their applicability to the arena of geologic sequestration follows.

The SDWA of 1974 requires that the USEPA determine the need for and to promulgate regulations sufficient to protect underground sources of drinking water (USDWs). A USDW is any aquifer that contains a volume of water such that it is a present, or viable future, source for a public water system, contains water with less than 10,000 parts per million total dissolved solids, and is not exempted.[11] Section 1421 of the SDWA mandates that the USEPA establish rules for UIC programs, which apply to certain types of wells for which five classes exist as shown in Figure 1 below.[12] Under SDWA Section 1423, states may, although need not, acquire primacy for enforcement.[13] The goal of the USEPA UIC Program is to protect public health through the protection of USDWs.[14] USEPA estimates indicate that the nation's most accessible freshwater is stored in geological formations, known as aquifers, which in many instances, USEPA estimates indicate that these resources are utilized to recharge 41 percent of streams and rivers and serve as resources for 89 percent of public water systems in the U.S.[15] Underground injection is the practice of placing fluids underground, in porous formations of rock, soils, or rock and soils, through wells.

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[11] United States Environmental Protection Agency (USEPA), Drinking Water Pocket Guide #2: Protecting Drinking Water Through Underground Injection Control, January 2002.
[12] SDWA § 1421; 42 U.S.C.A §300h.; 40 CFR Parts 144-148.
[13] SDWA § 1421; 42 U.S.C.A §300h-2; 40 CFR Parts 144-148.
[14] USEPA, "UIC Program Overview," Sequestration Workshop, February 2-3, 2004.
[15] USEPA, "USEPA's Program to Regulate the Placement of Waste Water and other Fluids Underground, December 1999.

Figure 1. Summary of UIC Well Class Applicability.

| UIC CLASS | SUMMARIZED APPLICATION |
|---|---|
| Class I | Deep disposal of hazardous and non-hazardous fluids (including industrial and municipal wastes) beneath the lowermost USDW and are further regulated under the Resource, Conservation, and Recovery Act (RCRA) |
| Class II | Injection of brines and other fluids associated with oil and gas production, including crude oil (storage), drilling fluids, and drilling muds |
| Class III | Injection of fluids associated with solution mining of minerals with fresh water (salt), sodium bicarbonate (uranium), or steam (sulfur) |
| Class IV | Injection of hazardous or radioactive wastes into or above a USDW (which have been banned except as part of authorized clean up activities) |
| Class V | All underground injection not included in Classes I-IV, which generally inject non-hazardous fluids or above a USDW and are on-site disposal systems, such as storm water runoff, industrial wastewater, car wash water, sanitary waste, agricultural waste, and aquifer recharge, as well as experimental wells |

Source: USEPA, "USEPA's Program to Regulate the Placement of Waste Water and other Fluids Underground, December 1999.

All injection wells are not waste disposal wells – some Class V wells inject surface water to replenish depleted aquifers or to prevent salt water intrusion.[16] Some Class II wells inject fluids for enhanced recovery of oil and natural gas (i.e. EOR and EGR), and others inject liquid hydrocarbons that constitute the nation's strategic fuel reserves, including the Strategic Petroleum Reserve.[17]

Of these five classes, only three are potentially applicable to the arena of geologic carbon sequestration – Class II, in cases of enhanced hydrocarbon recovery, and potentially Classes V and I, which are both invoked under the Frio Injection Project presently being conducted by the University of Texas, Bureau of Economic Geology invokes both approaches, which is explained in greater depth in this same section.

Responsibility for UIC regulation is divided between the Federal government, as represented by the USEPA, and state governments. The USEPA roles include setting UIC Program requirements and national standards, approving and overseeing U.S. state delegations, providing assistance to state entities administering UIC activities, overseeing direct implementation programs in certain states, and supporting and

[16] USEPA, "USEPA's Program to Regulate the Placement of Waste Water and other Fluids Underground, December 1999.

[17] USEPA, "USEPA's Program to Regulate the Placement of Waste Water and other Fluids Underground, December 1999.

advancing sound science. U.S. state and tribal roles for the 33 states, Guam, Commonwealth of the Mariana Islands, and Puerto Rico, that have primacy authority for all or part of the UIC program, which includes responsibility for application, review, authorization, and monitoring.[18] In seven other states, including SECARB state Florida, primacy is shared between the states and the USEPA. In addition, the USEPA administers UIC programs for the remaining 10 states, including SECARB states of Tennessee and Virginia, and all other Federal jurisdictions and Tribal lands.[19] Most of the minimum requirements that affect the siting of the injection well, the construction, operation, maintenance, monitoring, testing, and, finally, the closure of the well, are designed to address USDW functions. A detailed listing of the regulatory relationship between the Federal government and the states in the SECARB region follows in Figure 2. For reference, it is these entities that will play a crucial role in the development and implementation of regulatory, permitting, and accounting frameworks in the SECARB region.

[18] USEPA, Drinking Water Pocket Guide #2: Protecting Drinking Water Through Underground Injection Control, January 2002.
[19] USEPA, "USEPA's Program to Regulate the Placement of Waste Water and other Fluids Underground, December 1999.

**Figure 2.** SECARB State Regulatory Primacy for UIC Program.

| SECARB STATE | PRIMACY | REGULATORS |
|---|---|---|
| Alabama | State | Classes I, III-V -- Alabama Department of Environmental Management<br>Class II -- Alabama State Oil and Gas Board |
| Arkansas | State | Classes I, III-V -- Arkansas Department of Environmental Quality<br>Class II -- Arkansas Oil and Gas Commission |
| Florida | Shared | Classes I, III-V -- Florida Department of Environmental Management<br>Class II -- EPA Region 4 |
| Georgia | State | Classes I-V -- Georgia Environmental Protection Division |
| Louisiana | State | Classes I, III-V -- Louisiana Department of Natural Resources<br>Class II -- Louisiana Office of Conservation |
| Mississippi | State | Classes I, III-V -- Mississippi Department of Environmental Quality<br>Class II -- Mississippi Oil and Gas Board |
| North Carolina | State | Classes I-V -- North Carolina Department of Environment and Natural Resources |
| South Carolina | State | Classes I-V -- South Carolina Department of Natural Resources |
| Tennessee | Federal | Classes I-V -- USEPA Region 4 |
| Texas | State | Classes I, III-V -- Texas Natural Resource Conservation Commission<br>Class II -- Texas Railroad Commission |
| Virginia | Federal | Classes I-V -- USEPA Region 3 |
| Tribal Lands in SECARB | Federal | Classes I-V -- USEPA Region 4 or 6 (in Arkansas, Louisiana, and Texas) (*Note: No Tribal Lands Region 3 SECARB state, Virginia) |

Source: USEPA, Drinking Water Pocket Guide #2: Protecting Drinking Water Through Underground Injection Control, January 2002.

According to recent USEPA estimates, there are between UIC 650,000 to 850,000 wells in the U.S. as of February 2004. For reference, approximate UIC well counts by SECARB state follows in Figure 3.

Figure 3. UIC Well Numbers by SECARB State.

| SECARB STATE | NUMBER OF UIC WELLS |
|---|---|
| Alabama | 797 |
| Arkansas | 1,247 |
| Florida | 75,674 |
| Georgia | 780 |
| Louisiana | 3,990 |
| Mississippi | 5,377 |
| North Carolina | 4,489 |
| South Carolina | 6,314 |
| Tennessee | 4,747 |
| Texas | 59,246 |
| Virginia | 16,267 |

Source: USEPA, "UIC Program Overview," Sequestration Workshop, February 2-3, 2004.

Based upon existing rules and regulations, it seems logical that geologic carbon sequestration projects, which function as EOR and EGR activities, would be permitted under UIC as Class II wells. It is less clear, however, how other long-term storage carbon sequestration projects would be permitted. Viewpoints range from the IOGCC preference for regulating and permitting these sites under natural gas storage laws to restating USEPA regulations regarding Class V well definitions or adding another UIC class.[20] Another less viable, and potentially more costly, option is the utilization of the Class I UIC definition, which appears to be preferred by another faction of geologic carbon sequestration scholars.[21] In fact, the Frio Injection Project presently being conducted by the University of Texas, Bureau of Economic Geology, as noted, invokes both approaches. While the project was permitted as a Class V UIC well due to its experimental nature, the consensus in Texas is that future, non-experimental long-term geologic carbon sequestration wells would be permitted under a UIC Class I regime.

In addition to the governing regime for the regulatory, permitting, and safety issues of geologic sequestration injection and storage, matters of long-term liability and stewardship exist which cannot be easily ignored. One approach to this matter could mirror the various state mine land restoration programs, which would require bonding or trust fund deposits to be posted with the relevant state regulatory agency to ensure that the long-term stewardship of geologic carbon sequestration sites would continue past the life of operating companies. Based upon early stakeholder input on this subject, it seems that this type of approach would address public concerns without undue harm to the economics of geologic sequestration, and, in doing so, serve as an asset to wide-scale geologic sequestration deployment.

[20] Interstate Oil and Gas Compact Commission Geological $CO_2$ Sequestration Task Force, Final Report, March 2005.
[21] Wilson, Elizabeth J., David W. Keith, and Malcolm Wilson, "Considerations for a Regulatory Framework or Large-Scale Geological Sequestration of Carbon Dioxide: A North American Perspective," Presented at Vancouver, BC, Canada, September 2004.

***Terrestrial Sequestration***

While the geologic sequestration regulatory, permitting, and safety frameworks will require substantial shepherding to ensure that the regulations protect the public interest and are at the same time not unduly burdensome on terrestrial sequestration project stakeholders, the arena of terrestrial sequestration regulatory, permitting, and safety frameworks is advancing without assistance from entities like SECARB. Witness, for example, the investments being made in the Lower Mississippi River Valley by power companies, including Entergy and American Electric Power, and nonprofit organizations, including the Conservation Fund, among others. This is not to say, however, that SECARB will not play a beneficial role in attempting to streamline various state enactments in this domain, as with its present mission, SECARB would do so.

In general, most laws and regulations related tangentially to terrestrial sequestration in the SECARB states provide limited guidance to regulatory, permitting, and safety practices, but instead focus on attempting to stimulate voluntary terrestrial sequestration activities. As a result, much of the guidance for terrestrial sequestration activities in the SECARB region results from state conservation policies or economic development enactments. As a result of the potential terrestrial sequestration options in the region, four areas that relate to potential terrestrial sequestration projects – mine reclamation, reforestation, farm practices, and brownfield restoration – were examined in greater depth.

Mine Land Reclamation

As a result of Federal mining laws, all SECARB states have required mining companies to submit reclamation plans to the state governments explaining the post- mining utility of lands that have been excavated for mineral resources. These plans typically explain the vegetative cover that will be planted in the land and the man-made structures that will conserve water and land resources. Some of the states such as Florida and Arkansas have regulations on the type of plants and trees to be used in the reclamation process and the manner in which vegetation is to be planted. As terrestrial sequestration can be additional value-add options for mine land reclamation projects, state focuses on encouraging this practice could be helpful to the goal of wide-scale terrestrial sequestration.

Reforestation and Afforestation

Similar value-add opportunities exist for terrestrial sequestration in the area of reforestation and afforestation to combat emerging problems with land erosion resulting, in some instances, from development and industrial processes. To augment this situation, many SECARB states have employed programs to diminish the costs associated with replanting trees and conserving land resources. Therefore, the SECARB states provide technical assistance services or provide cost-sharing grant opportunities to develop appropriate preliminary planning to implement reforestation and afforestation practices. For example, some SECARB states provide private land-owners with tree seedlings at cost of planting the trees. Many of the state governments maintain tree nurseries for the rational of diminishing the costs associated with developing immature trees. In addition, many SECARB states utilize the educational systems to develop reforestation technical assistance and site preparation. Further, these states provide, in some instances, technical assistance through “Stewardship Programs” for maintenance of forestry resources. This program is also used for information resources and networking for forest land owners to optimize the value of their resources.

Brownfield Restoration

SECARB states have also adopted a focus on brownfield restoration as a land management activity, which in some instances can positively impact terrestrial sequestration prospects. Most SECARB states, with North Carolina as a notable exception to the rule, have diminished the liability associated hazardous waste for future generations following the initial clean-up process, which could include for purposes of terrestrial sequestration.

The incentives associated with brownfield redevelopment do not always apply to terrestrial sequestration activities in the SECARB states. Often, in terms of terrestrial sequestration, these governmental incentives are dependent on the definition of “development”. Some of the states observe the creation of public parks as an activity worthy of these tax incentives. The development of public parks could sequester carbon, but the intention of these laws is often more focused on development of brownfields into commercial property, not necessarily GHG reduction projects. Thus, alterations to brownfield restoration laws could be required in order to allow this mechanism to become a more viable option for terrestrial sequestration.

Farm Practices

Moving to the domain of soil sequestration, select SECARB states have advanced programs that assist in on-farm, soil management-based terrestrial sequestration. While several SECARB states encourage agricultural management practices that enhance terrestrial sequestration, two SECARB states – Georgia and North Carolina – have provided incentives for farmers to employ conservation-oriented farm preparation activities, e.g. no-tillage farm practices, which can directly result in marketable, verifiable carbon sequestration achievements. For reference, the state governments provide capital equipment for farm owners using this form of site preparation. In addition, North Carolina state government also provides technical assistance for farmers that utilize no-tillage practices.

Other References to Terrestrial Sequestration

To date, SECARB state terrestrial sequestration enactments have focused on laws and regulations that provide opportunities for terrestrial sequestration, but that do not directly contemplate terrestrial sequestration. In limited instances, however, terrestrial sequestration projects are specifically referenced in state codes and forestry entities are empowered with the authority to assist private and public parties, in some instances, with terrestrial sequestration projects. For instance, the Arkansas Forestry Commission is endowed with these privileges under a recent enactment.[22] Other non-SECARB states, including Oklahoma, seem to have set the precedent for this approach with its "Carbon Sequestration Enhancement Act" from several years earlier.

While common approaches to terrestrial sequestration are developing, there remains a void in terms of a universal approach to terrestrial sequestration regulatory, permitting, and safety frameworks that would encourage such activities in the SECARB region.

### *Accounting Frameworks*

Related to regulatory, permitting, and safety frameworks are accounting frameworks for carbon sequestration which allow for adequate recording, documentation, and verification of the carbon sequestration activities, whether terrestrial or geologic in nature. Presently, GHG accounting comes in two forms – voluntary or mandatory. In the SECARB region, to-date, voluntary reporting has been the universally accepted form of accounting practices, although mandatory approaches must also be assessed for consistency in case mandatory measures should arise locally, on a state basis, or nationally. Regardless of the compliance mechanism approach, it appears that the most significant issues regarding carbon sequestration accounting center on a few key elements – baselines, minimum legal requirements, additionality, measurement, monitoring, and verification.

Voluntary reporting is valuable as it provides a way to present information about an enterprise's GHG emissions and/or emissions reduction activities to its customers or constituents, who are interested in GHG emissions. The communication of voluntary reports and achievements can be valuable in that it provides public information that may influence future GHG policy formulation, and more importantly, prompt enterprises to pursue GHG mitigation projects in the years to come, including those focused on terrestrial and geologic carbon sequestration.

Under this research phase, SECARB partner Augusta Systems analyzed Federal, state, and private sector accounting frameworks, including, most notably, the U.S. national voluntary GHG reporting program, the Voluntary Reporting of Greenhouse Gases Program (VRGGP) of the U.S. Department of Energy (USDOE), the new Georgia registry legislation, and the emerging Chicago Climate Exchange and "Greenhouse Gas Protocol" of the World Business Council for Sustainable Development and World Resources Institute. Details of each analysis follow.

[22] Code of Arkansas, §22-5-506 (2003).

USDOE 1605(b) Program

In 1992, the U.S. Congress established the VRGGP in order to meet U.S. commitments under the United Nations Framework Convention on Climate Change (UNFCCC). The VRGGP was established under Section 1605(b) of the 1992 Energy Policy Act, which has become known as the 1605(b) program. The 1605(b) program provides a mechanism for reporting GHG emissions and emissions reductions, including those produced from carbon sequestration projects. Presently, the 1605(b) program is being revised to better meet the emerging needs of the voluntary GHG trading market and the expanding role of carbon sequestration in the GHG emissions management arena. As this national program would, potentially, impact accounting frameworks within the SECARB region, a summary of the present 1605(b) program will be presented, as well as information on the proposed revisions made public to-date.

*Existing Program*

Under the enacting legislation for the 1605(b) program, the USDOE through its Energy Information Administration (EIA), and in collaboration with the U.S. Environmental Protection Agency (USEPA), was required to publish procedures for the accurate voluntary reporting of information on: (1) GHG emissions on an annual basis for the baseline period 1987 through 1990, and for subsequent calendar years; (2) annual reductions of GHG emissions achieved through any measure; and, (3) reductions in GHG emissions achieved voluntarily, including via carbon sequestration, or as a result of plant or facility closings, or as a result of Federal or individual state requirements.

Final guidelines and supporting materials were developed, with stakeholder input, for the six sectors identified by the 1605(b) program, which are: Electricity Supply; Residential and Commercial Buildings; Industrial; Transportation; Forestry; and, Agricultural. The initial guidelines provide reporting flexibility by allowing the participant to utilize existing GHG emissions and emissions reduction information, and to select appropriate quantification methods based upon the nature of their reduction or offset projects. To prompt action by participants, the support documents included examples of project analyses for the various sectors, appendices of conversion tables, and default emissions factors for various fuels and for electricity on a state-by-state basis.

Participants are encouraged to submit comprehensive reports, which can include information on GHG emissions levels and emissions reduction projects, including terrestrial and carbon sequestration projects. It is important to note that the present 1605(b) program definition of “carbon sequestration” is limited to terrestrial projects. Geologic sequestration projects are dealt with under another project type definition. For project reporting, every GHG emissions reduction project report must include specific information to assist in analyzing the benefits of the projects. For instance, it is required that every report provide an established reference case that serves as a basis for comparison with a specific project. Further, the report must provide identification of the effects of the project, and an estimation of the GHG emissions for both the reference case and the specific GHG emissions reduction or carbon sequestration project.

To aid in the development of these data sets, the 1605(b) program guidelines and supporting documents provide detailed information regarding the appropriate processes under which an entity should obtain data and define the methods for estimating a specific project's effect on GHG emissions reduction and carbon sequestration results. The guidelines outline the acceptance of three types of data – physical, default, and reporter-generated. Based on these three categories of data, the guidelines recognize two categories of projects: standard projects, which rely on physical and default data, and reporter-designed projects, which use relative default data and measured, or engineering data, developed by the entity. The GHG emissions reduction outcomes or sequestered carbon emissions of an entity's project must be determined and recorded. By requiring these elements, the report contains detailed information relative to the impact of the project, which can be reviewed by a third party to determine the validity of the emissions reduction effort.

In summary, the 1605(b) program provides enterprises with an opportunity to record their GHG emissions reduction and carbon sequestration achievements, and communicate these achievements to colleagues, customers, and the general public. By nature of its voluntary and uncomplicated structure, the 1605(b) program provides an unrestrictive opportunity to encourage enterprises to engage in GHG emissions reduction activities. However, the 1605(b) program was not without its detractors, as the program's reporting mechanisms did not, in the eyes of many, truly allow for detailed accounting procedures and did not adequately address geologic sequestration project reporting and accounting. The following section describes the on-going efforts of the USDOE, the U.S. Department of Agriculture (USDA), and the USEPA to improve the 1605(b) program.

*Emerging Changes to 1605(b) Program*

During 2002, USDOE, USDA, and USEPA initiated a series of actions to facilitate comments and suggestions for enhancements and improvements to the 1605(b) program from stakeholders. In July 2002, the three federal agencies initiated a call for public comments to improve the guidelines. In addition, the three Federal agencies conducted a series of workshops to enable interested persons to help improve the 1605(b) program guidelines. Following these activities, the Federal agencies moved forward to produce two levels of new proposed guidelines – Technical Guidelines and General Guidelines.[23]

The enhanced General Guidelines are intended to improve the accuracy and completeness of GHG emissions data in the national registry created by 1605(b). These enhanced General Guidelines were publicly released in draft form in 2004 and have recently been released in an interim final form in March 2005. The Technical Guidelines were released in draft form at the end of March 2005 and both of these

[23] United States Department of Energy (USDOE), USDOE 1650(b) Program Enhancements Website, Proposed Guidelines, General Guidelines, www.pi.energy.gov/enhancingGHGregistry/proposedguidelines/generalguidelines.html

Guidelines, when effective, will collectively modify and replace the current guidelines for the 1605(b) program. The Technical Guidelines will specify methods and factors to be used in measuring and estimating greenhouse gas emissions, emissions reductions, and carbon sequestration. Thus, these Technical Guidelines will play the most critical role of the two in the development of the accounting framework for SECARB.

Due to the fact that these General Guidelines will provide the structure for the more specific Technical Guidelines, these initial proposed revisions are significant to the SECARB accounting framework research. The remainder of this document summarizes key elements of the proposal on which USDOE will again solicit public comments on these specific issues at a later date. More specifically, these General Guidelines are summarized into sections examining entity reporting requirements, certification and verification, and reporting and registering emission reductions (including carbon sequestration).

With respect to entity reporting requirements, the General Guidelines feature two different mechanisms for differently sized entities. Large entities, i.e. those with average annual emissions over 10,000 tons of $CO_2$ equivalent ($CO_2e$), would be required to provide an inventory of total emissions and calculate net reductions associated with entity-wide efforts, as well as to demonstrate that the reported reductions represent an actual net decrease in entity-wide emissions, as calculated by one or more of the methods allowed by the General Guidelines. Meanwhile, smaller entities, i.e. those with average annual emissions of less than 10,000 tons of $CO_2e$, would be eligible to register emission reductions associated with specific activities without completing an entity-wide inventory or reduction assessment.[24]

As certification and verification standards of the 1605(b) program could impact SECARB accounting frameworks, the certification and verification recommendations for the new General Guidelines merit examination. Under the proposed new General Guidelines, an agency head, CEO, or other responsible official is required to certify that the reporting entity accurately follows the revised guidelines for determining emissions, emission reductions, and sequestration achievements with sufficient records maintained for at least three years to enable independent verification. In addition, entities are encouraged to obtain independent verification of the accuracy of their reports and compliance with USDOE Guidelines. It is also important to note that the required reports sent to EIA should be sufficiently detailed to enable EIA to review and confirm the final emission reduction calculations for each method and output measure utilized, and to review and confirm the rates of conversion used for each category of GHG covered and for electricity-related use or emissions avoidance, by region.[25]

With reference to reporting and registering emissions reductions, including those achieved via carbon sequestration, there are a number of significant points to consider,

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[24] USDOE, USDOE 1650(b) Program Enhancements Website, Proposed Guidelines, General Guidelines at www.pi.energy.gov/enhancingGHGregistry/proposedguidelines/generalguidelines.html

[25] USDOE, USDOE 1650(b) Program Enhancements Website, Proposed Guidelines, General Guidelines at www.pi.energy.gov/enhancingGHGregistry/proposedguidelines/generalguidelines.html

including legal rights and ownership, as well as emissions intensity metrics. Notably, as legal rights to sequestration opportunities or other emissions management activities may be in question given current laws, the proposed new General Guidelines state that owner of the facility, land, or vehicle that generated the emission reductions or sequestration is the entity presumed to have the right to report and register any emission reductions or sequestration. Also, entities are required to coordinate with other entities that share ownership of particular operations to ensure no double counting occurs and this no double counting must be certified. With reference to emissions intensity metrics, the proposed General Guidelines recommend the use of emission intensity indicators as the basis for determining emission reductions however, the USDOE Technical Guidelines will set procedures to calculate emission reductions, including lists of possible output indicators, calculation methods for determining reductions associated with terrestrial and geologic sequestration, methods and emission factors for calculating avoided emissions, and project-based methods. Also, it is important to note that, entities could report reduction in emissions intensity, absolute reductions in emissions, increased carbon storage, avoided emissions, and project emission reductions.[26] Analysis of the recently released draft Technical Guidelines is on-going.

State-Based Accounting

While the 1605(b) program has been in operation for a sufficient period to allow for the thoughtful consideration of enhancements and revisions, state voluntary reporting programs are only beginning to appear. While a number of states are moving forward to initiate and adopt voluntary GHG registries, including Georgia in the SECARB region, a smaller number (California, New Hampshire, and New Jersey) have active state voluntary GHG registries, which include opportunities for reporting and registering emissions reductions achievements, including those produced via carbon sequestration projects, both terrestrial and geologic. In the SECARB region, however, less activity has occurred and most existing state enactments tend to deal only with the technology and approaches presently enjoying expansion – terrestrial sequestration. For instance, the State of Georgia, under its recently enacted Senate Bill 356, established the Georgia Carbon Sequestration Registry Act, which supported the use of terrestrial sequestration, but is seemingly silent on geologic sequestration opportunities. The launch date for the Georgia Registry has not been established at this time.

Private Sector Initiatives

In addition to analysis on Federal and state reporting and registry mechanisms that could impact the SECARB accounting framework action plans, Augusta Systems also examined the requirements of reporting, registering, and accounting under the Chicago Climate Exchange, as well as the World Business Council for Sustainable Development and World Resources Institute (WBCSD/WRI) Greenhouse Gas Protocol. For reference, the WBCSD/WRI Greenhouse Gas Protocol may provide the most

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[26] USDOE, USDOE 1650(b) Program Enhancements Website, Proposed Guidelines, General Guidelines at www.pi.energy.gov/enhancingGHGregistry/proposedguidelines/generalguidelines.html

comprehensive method and process for GHG and carbon sequestration accounting activities produced to-date, and as such will serve as a vital resource for accounting framework developments by SECARB. In general, the most significant issues regarding carbon sequestration accounting for private sector initiatives tend to key on the same points as public sector initiatives – baselines, minimum legal requirements, additionality, measurement, monitoring, and verification.

Thus, it appears that while all existing reporting, registering, and accounting methodologies are still developing, there is some level of commonality among the existing accounting framework standards. Year 2 SECARB efforts are focusing on development action plan with accounting frameworks that meets the needs of stakeholders and duly defers to the existing and emerging Federal, state, and private sector practices.

### *Action Plan Development and Activities*

During the first year and a half of SECARB activities, SECARB regulatory and accounting team activities, the efforts focused on two major areas – early action plan activities and action plan development activities. More information on these areas follows.

<u>Early Action Plan Activities</u>

As a Federal-state energy compact, the SSEB hosts a number of activities for SSEB members during the course of a calendar year, including an SSEB Annual Meeting, an SSEB Chairman's Forum, and a meeting at the Southern Legislative Conference. As a significant benefit to SECARB, these meetings, as proposed in the SECARB proposal to NETL, have been utilized to facilitate early engagement of partners and stakeholders alike in SECARB, which will need to be involved in the final development of the SECARB regulatory, permitting, safety, and accounting frameworks and action plans.

During year one of SECARB Phase I, the SECARB team utilized the SSEB as a vehicle for engaging and informing opinion leaders and stakeholders in the southeast on SECARB and its goals. Information about SECARB was disseminated through various SSEB communications and events, including the SSEB Chairman's Forum, the SSEB Annual Meeting, the Southern Legislative Conference Annual Meeting, meetings of the SECARB Technical Team and Technology Coalition and the Carbon Sequestration PEIS public scoping meeting held in the SECARB region, among others.

The initial meeting of the SECARB Technical Team and Technology Coalition occurred in January 2004 in Atlanta, Georgia. The meeting served to report on the status of subcontracts for SECARB, the work effort accomplished following the NETL RCSP Kick-off Meeting in November 2003, and to solicit input from Technology Coalition stakeholders for the coming months of the activity. A copy of the agenda from the event is attached as Appendix A.

As a result of the decision of SSEB 2004 Chairman, West Virginia Governor Bob Wise, to host an SSEB Chairman's Forum focused on carbon management, entitled "Regional Meeting on Defining Priority Actions for Voluntary Carbon Management Activities in the South," SECARB had another opportunity to present to stakeholders the plans and initial efforts of SECARB. Speakers at the SSEB Chairman's Forum included representatives from USDOE, NETL, the United States Environmental Protection Agency, the United States Department of State, state governments, private industry, the SECARB Technology Coalition, and the SECARB Technical Team. A copy of the agenda from the SSEB Chairman's Forum is attached as Appendix B. Notably, this event featured an update on regulatory and accounting research activities for the Technical Team and Technology Coalition, which serves as a de-facto partnership advisory board for SECARB.

In August 2004, Augusta Systems and the SSEB, on behalf of SECARB, provided remarks to a meeting of the Southern Legislative Conference regarding the carbon sequestration issues of potential interest to legislators in SECARB and other southern states. A copy of a briefing document distributed along with a Power Point presentation delivered by Augusta Systems is attached as Appendix C. For reference, the oral presentation and Power Point Presentation included features on carbon management overview, SECARB regulatory and accounting research activities, voluntary and regulatory efforts at carbon management by U.S. states, and SECARB plans for action plan development and implementation, and a mechanism for feedback from SECARB and SSEB state legislative representatives.

In addition, the SSEB and SECARB provided comments during the NETL Carbon Sequestration PEIS public scoping meeting. A copy of these comments is provided for reference as Appendix D.

<u>Action Plan Development Activities</u>

During the initial two quarters of Year 2 SECARB activities, the SECARB regulatory and accounting team focused on performing initial Draft Action Plan development activities. Key questions integrated into the development of the Draft Action Plan include:

- Whether $CO_2$ be defined as a commodity, waste, or pollutant under Federal, state, or Federal and state laws and regulations, including UIC regulations?
- What Federal and/or state standards should be devised for measurement of $CO_2$ concentration at the point of capture to ascertain and verify the quality and purity of the $CO_2$?
- Whether the Federal and state entities with existing $CO_2$ pipelines continue business-as-usual with regulating, permitting, and enforcing safety as CO2 pipelines enjoy greater proliferation under wide-scale sequestration endeavors?
- Whether geologic carbon sequestration injection and storage activities be wholly subject to existing UIC regulations?

- Whether new UIC classes or definitions emerge to facilitate geologic sequestration injection and storage activities?
- Whether long-term geologic sequestration projects without enhanced hydrocarbon recovery components be subject to UIC at all?
- How will the existing Federal and state land management and restoration, timber management, and farm management legislation be augmented to include comprehensive plans to encourage terrestrial sequestration?
- How will the 1605(b) guideline enhancements, state registry activities, and private sector standards develop and allow for reconciliation to create reliable accounting frameworks?
- How quickly can effective measurement, monitoring, and verification technologies be developed that will provide reliable data to advance regulatory and accounting activities, both for terrestrial and geologic carbon sequestration activities?

Thus, the Year 2 SECARB activities for the regulatory, permitting, safety, and accounting framework activity efforts are focusing on developing frameworks that will incorporate available information to forge a flexible Action Plan that would allow for the integration of new findings and pronouncements during the course of a potential SECARB Phase II. Action Plan development is on-going.