

Big Sky Carbon Sequestration Partnership

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ABSTRACT

The Big Sky Carbon Sequestration Partnership, led by Montana State University, is comprised of research institutions, public entities and private sectors organizations, and the Confederated Salish and Kootenai Tribes and the Nez Perce Tribe. Efforts under this Partnership fall into four areas: evaluation of sources and carbon sequestration sinks; development of GIS-based reporting framework; designing an integrated suite of monitoring, measuring, and verification technologies; and initiating a comprehensive education and outreach program. At the first two Partnership meetings the groundwork was put in place to provide an assessment of capture and storage capabilities for CO₂ utilizing the resources found in the Partnership region (both geological and terrestrial sinks), that would complement the ongoing DOE research. During the third quarter, planning efforts are underway for the next Partnership meeting which will showcase the architecture of the GIS framework and initial results for sources and sinks, discuss the methods and analysis underway for assessing geological and terrestrial sequestration potentials. The meeting will conclude with an ASME workshop (see attached agenda).

The region has a diverse array of geological formations that could provide storage options for carbon in one or more of its three states. Likewise, initial estimates of terrestrial sinks indicate a vast potential for increasing and maintaining soil C on forested, agricultural, and reclaimed lands. Both options include the potential for offsetting economic benefits to industry and society. Steps have been taken to assure that the GIS-based framework is consistent among types of sinks within the Big Sky Partnership area and with the efforts of other western DOE partnerships. Efforts are also being made to find funding to include Wyoming in the coverage areas for both geological and terrestrial sinks and sources.

The Partnership recognizes the critical importance of measurement, monitoring, and verification technologies to support not only carbon trading but all policies and programs that DOE and other agencies may want to pursue in support of GHG mitigation. The efforts begun in developing and implementing MMV technologies for geological sequestration reflect this concern. Research is also underway to identify and validate best management practices for soil C in the Partnership region, and to design a risk/cost effectiveness framework to make comparative assessments of each viable sink, taking into account economic costs, offsetting benefits, scale of sequestration opportunities, spatial and time dimensions, environmental risks, and long-term viability. Scientifically sound information on MMV is critical for public acceptance of these technologies.

Two key deliverables were completed in the second quarter—a literature review/database to assess the soil carbon on rangelands, and the draft protocols, contracting options for soil carbon trading. The protocols developed for soil carbon trading are unique and provide a key component of the mechanisms that might be used to efficiently sequester GHG and reduce CO₂ concentrations. While no key deliverables were due during the third quarter, progress on other deliverables is noted in the PowerPoint presentations and in this report. A series of meetings held during the second and third quarters have laid the foundations for assessing the issues surrounding carbon sequestration in this region, the need for a holistic approach to meeting energy demands and economic development potential, and the implementation of government programs or a market-based setting for soil C credits. These meetings provide a connection to stakeholders in the region and a basis on which to draw for the DOE PEIS hearings.

In the fourth quarter, three deliverables have been completed, some in draft form to be revised and updated to include Wyoming. This is due primarily to some delays in funding to LANL and INEEL and the approval of a supplemental proposal to include Wyoming in much of the GIS data sets, analysis, and related materials. (See Appendix for the Supplemental request and modified timelines.) The deliverables are discussed in the following sections and greater details are provided in the materials that are attached to this report. In August 2004, a presentation was made to Pioneer Hi-Bred, discussing the Partnership and the synergies with terrestrial sequestration, agricultural industries, and ongoing, complimentary USDA efforts. The Partnership organized a Carbon session at the INRA 2004 Environmental and Subsurface Science Symposium in September 2004; also in September, a presentation was made to the Wyoming Carbon Sequestration Advisory Committee, followed up with a roundtable discussion. Members of the committee are interested in being part of the Partnership, contributing their expertise on carbon sequestration potential on Wyoming cropland, rangeland, and forestlands, as well as contributing to the public outreach and education throughout WY. Substantial progress is being made on the decision support tools for assessing the participation of producers and landowners in terrestrial sequestration. South Dakota School of Mines and Technology have developed a working version of C-Lock to be used in pilot trades, and National Carbon Offset Coalition is working with Chicago climate exchange on background analysis and mechanisms for pilot trades. A third Partnership meeting was held in August, 2004 followed by an AMSE symposium on carbon sequestration (see Appendix for agendas).

The Partnership has nearly completed state-level greenhouse gas (GHG) emission inventories for South Dakota, Montana and Idaho. Per-capita emissions are lower than the national average in Montana, but higher in South Dakota and Idaho. Montana hosts the largest number of industrial point sources, while South Dakota has the highest livestock-related emissions of GHGs. Major point sources are being located within the project GIS in order to help assess source-sink spatial relationships. The data and methodology to conduct an assessment of agricultural GHG sources and sink potential are being finalized. In addition, the C-Lock team has begun to develop a pilot soil carbon sale on the Cheyenne River Sioux Reservation, to serve as a proof-of-concept for the C-Lock system.

Possible rangeland terrestrial sinks throughout the Big Sky project area have been identified and a literature review to support decisions for increasing carbon sequestration for areas identified as having potential as carbon sinks has been completed. Climatic potential, MLRA, and land tenure were selected to spatially stratify rangeland cover types into easily identifiable areas where sequestration programs could potentially be initiated. Climatic potential for carbon sequestration was classified into four categories based on annual precipitation: no potential - less than 130 mm; low potential – 130 to 230 mm; moderate potential – 230 to 460 mm; and high potential – greater than 460 mm. Since programs will not likely be implemented on Federal lands, only Indian reservations and private or other non-federal lands are discussed. For each of the Big Sky states (Idaho, South Dakota, and Montana) non-federal land areas and Indian reservations classified as rangeland have been identified according to their potential for carbon sequestration. This information can be used to target areas that will likely have the greatest return on investments in rangeland carbon sequestration projects.

The education and outreach efforts have resulted in a comprehensive plan which serves as a guide for implementing the outreach activities under Phase I. The public website is established (www.bigskyco2.org), along with a Partnership logo. We have made presentations to stakeholders and policy makers including participation in the June PEIS meeting in Bozeman, connections to other federal and state agencies concerned with GHG emissions, climate change, and efficient and environmentally-friendly energy production. In addition, the Partnership has plans for integration of our outreach efforts with the students, especially at the tribal colleges and at the universities involved in our Partnership. This includes collaboration with the film and media arts departments at MSU and with the U.S.-Norway Summer School, extended outreach efforts at LANL and INEEL, and with the student section of the ASME. Finally, the Big Sky Partnership was involved in two key forums: the NETL Carbon Sequestration Conference (May 04) and a special session sponsored by the Western Governors' Association at the annual Western Governors' meeting on carbon sequestration. The session was chaired by Governor Rounds from South Dakota. Presentations are posted on our website. The Partnership also was involved in the planning and kickoff meeting for the U.S.-Norway bilaterals held in May in New Orleans in an effort to facilitate an exchange of research and students/faculty. This resulted in the US-Norway Summer School on carbon sequestration organized by Pam Tomski which was held in August 2004. At the Big Sky Partnership sponsored meeting in August 2004 and at the ASME Carbon Sequestration Symposium, the public was invited as well as the state agencies and other interested parties.

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Big Sky Carbon Sequestration Partnership Advisory Committee

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INEEL, Idaho Falls, ID

Agenda for ASME Carbon Sequestration Symposium, August 26, 2004, Idaho Falls, ID

Request for Supplemental DOE Support

Big Sky Regional Carbon Sequestration Partnership website

Deliverable 4 – Geologic Carbon Sequestration GIS Database Structure and Summary of
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Deliverable 9 – Terrestrial GIS Data

Agenda for INRA Symposium, September 21, 2004, Spokane, WA, and Abstracts of
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INTRODUCTION

The Big Sky Regional Carbon Sequestration Partnership was initially called the Northern Rockies and Great Plains Regional Carbon Sequestration Partnership. The proposed name change was initiated in December 2003, and has received DOE/NETL approval. The Big Sky Partnership, led by Montana State University, Bozeman, MT, seeks to: identify and catalogue CO₂ sources and promising geologic and terrestrial storage sites, develop a risk assessment and decision support framework to optimize the areas' carbon-storage portfolio, enhance market-based carbon-storage methods, identify and measure advanced greenhouse gas-measurement technologies to improve verification, support voluntary trading and stimulate economic development, call upon community leaders to define carbon-sequestration strategies, and create forums that involve the public. Idaho, Montana and South Dakota are currently served by this Partnership that is comprised of 13 organizations and the Confederated Salish and Kootenai Tribes and the Nez Perce Tribe. Additional collaboration is being sought with neighboring states and Canada, and with other private and non-profit entities. To date, we are in the process of discussions for Phase II input from Puget Sound Energy and University of Wyoming/State of Wyoming, Montana Dept of Environmental Quality, Ducks Unlimited, and Rural electric coops. Montana Tech-Montana Bureau of Mines and Geology and the Idaho Carbon Sequestration Advisory Committee/Idaho Soil Conservation Commission are new members of the Partnership. Inland Northwest Research Alliance (INRA) and Western Governors' Association (WGA) have provided support for our Partnership since the onset and are members of the Partnership.

Original Partners include

Montana State University
Boise State University
South Dakota School of Mines
and Technology
Texas A&M
University of Idaho
The Sampson Group
EnTech Strategies
Environmental Financial Products

Nez Perce Tribe
The Confederated Salish
and Kootenai Tribes
Idaho National Engineering and
Environmental Laboratory
Los Alamos National Laboratory
Montana Governor's Carbon
Sequestration Working Group
National Carbon Offset Coalition

New Partners include

Idaho Carbon Sequestration Advisory
Committee/Idaho Soil Conservation
Commission
Inland Northwest Research Alliance
Montana Tech-Montana Bureau of Mines
and Geology
Western Governors' Association
Wyoming Carbon Sequestration Advisory
Committee
Montana Department of Environmental Quality

New Partners (in progress) include

Puget Sound Energy

EXECUTIVE SUMMARY

For reporting purposes, the activities and results for the Big Sky Partnership are organized into four somewhat overlapping components or efforts, with the related tasks from the workplan noted by each:

- **Evaluation of sources and potential for carbon sequestration sinks:** Tasks 1,2,4,5,6,7
- **Development of GIS-based framework and carbon cyberinfrastructure:** Task 3
- **Advanced concepts for monitoring, measuring, and verification; implementation, carbon trading, and evaluation:** Tasks 9-20
- **Education and outreach efforts.** Tasks 8, 21-25

The Partnership held their first meeting in Bozeman in October, 2003; the agenda included a discussion of the roles and contributions of each partner, the process of creating continuity among the geological and terrestrial efforts to provide a comprehensive assessment of capture and storage capabilities, and the unique contributions and research that our Partnership could provide to the DOE efforts. The subsequent efforts during the first three months of the grant focused on startup activities in each of the four areas.

A second Partnership meeting was held on March 1-3, 2004 at Los Alamos National Lab. The agenda for the meeting included Partnership reports, evaluation of progress and assessment of coverage, Phase II strategic planning, LANL overview and collaborations, and seminar presentations. A copy of the agenda was included with the second quarter report.

The Big Sky Partnership has had Partnership recognition at two key meetings during the third quarter: the DOE/NETL Annual Carbon Sequestration conference in May, 2004, and the Western Governors' Annual Meeting in June 2004. Other presentations are listed with the materials for this third quarterly report.

In the fourth quarter, efforts via Tasks and deliverables relate primarily to data sets for sources, terrestrial and geological sinks and analysis. The draft deliverables are attached to this report. In September, 2004 a presentation was made to the Wyoming Carbon Sequestration Advisory Committee, followed up with a roundtable discussion. Substantial progress is being made on the decision support tools for assessing the participation of producers and landowners in terrestrial sequestration. South Dakota School of Mines and Technology have developed a working version of C-Lock to be used in pilot trades, and National Carbon Offset Coalition is working with Chicago climate exchange on background analysis and mechanisms for pilot trades. A third Partnership meeting was held in August, 2004 followed by an AMSE symposium on carbon sequestration. Agendas for both are attached. The Partnership also organized and sponsored a session at the INRA "Environmental and Subsurface Science Symposium 2004" in Spokane, ID, and made a presentation to Pioneer Hi-Bred Intl. in August 2004, Des Moines/Johnston, IA

Evaluation of sources and sinks (Tasks 1, 2, 4, 5, 6, 7). Activities during the fourth performance period were focused on the methodologies for characterizing the potential for

geological and terrestrial sequestration sinks, compilation of data, and identifying and cataloging industrial and agricultural GHG sources. The Partnership Geologic Sequestration and Geographical Information System (GIS) support has focused on the creation of a database structure for collection of geologic sequestration data and summarizing the types of infrastructure information that are being collected in Idaho, Montana, and contiguous geologic regions of Wyoming. The Partnership has developed a uniform strategy for assessing the mineralization trapping potential across rocks types. These capabilities are being used to determine the geologic sequestration potential in the Big Sky region. We have established a geological sink assessment approach and screening criteria, and nearing completion on compiling county-level data on tillage and land use for the terrestrial component. Both the geological and terrestrial component is resulting in data layers that will allow us to assess the suitability for carbon sequestration in the Big Sky Partnership region as well as the potential for locating future energy facilities in our region.

For geological sinks, the potential for subsurface formation of carbon dioxide sequestration focused on solubility and mineralization trapping, and examined the technical feasibility, the time frame until implementation, and offsetting economic benefits. For the terrestrial sinks, the methodologies have been focusing on both technical and economic feasibility. Increasing soil C levels are dependent upon both the technical capacity of the soils to sequester and utilize additional carbon, and the incentives provided for landowners to change land use management practices. Activities to identify sources and assessment of transportation infrastructure are currently focused on identifying the state and federal databases and agencies, and addressing uncertainties inherent in matching/combining data sources. (See Appendix to this fourth quarter report)

Task 1. The Partnership's and South Dakota School of Mines and Technology's responsibilities included the preparation of major GHG source inventories for SD, MT and ID. With the exception of terrestrial (land-use related) sources, this inventory is largely complete. We used EPA-EIIP inventory methodologies, with local supplementation where possible, to develop aggregate estimates of greenhouse gas (GHG) emissions over the 2000-2002 period for each state. Point-sources of CO₂, N₂O, CH₄ and trace GHGs included energy utilities, petroleum processing and other industrial facilities. We also developed sectoral estimates of energy-related emissions based on data from the DOE-EIA. Methane and N₂O emissions from agricultural activities, primarily livestock, were based on Census of Agriculture data on livestock populations. Estimates of emissions from forest land-use change were drawn from a US Forest Service report on forest carbon stocks. Estimates of net emissions due to agricultural land management changes, which will be derived from the CENTURY model, are under development. The same process will allow us to estimate terrestrial sink potential in this region.

Idaho, Montana and South Dakota emitted approximately 11.7, 3.0 and 10.1 MMTCE, respectively, in 2002, or 9, 3 and 13 MTCE per capita. Although Idaho and Montana had larger industrial emissions, these were offset by increases in forest C uptake. Because a large proportion of Idaho's energy is produced by hydroelectric power, its largest category of emissions is imported electricity; the same is true in South Dakota. In Montana, petroleum refining and other heavy industry constitutes the largest GHG source category. Livestock-related GHG emissions also comprise 15% of South Dakota's GHG emissions.

The Texas A&M University research team is contributing to the Big Sky Partnership by identifying possible rangeland terrestrial sinks throughout the Big Sky project area and providing a literature review to support decisions for increasing carbon sequestration for areas identified as having potential as carbon sinks. A library search was completed of over 800 references linked to over 150 selected articles relating to terrestrial carbon sequestration, land use change, vegetation change, restoration, remote sensing and modeling. Included in this search is a summary of Natural Resources Conservation Service (NRCS) data for each of the Major Land Resource Areas (MLRAs) in the Big Sky Partnership area.

Climatic potential, MLRA, and land tenure were selected to spatially stratify rangeland cover types into easily identifiable areas where sequestration programs could potentially be initiated. Climatic potential for carbon sequestration was classified into four categories based on annual precipitation: no potential - less than 130 mm; low potential – 130 to 230 mm; moderate potential – 230 to 460 mm; and high potential – greater than 460 mm. Since programs will not likely be implemented on Federal lands, only Indian reservations and private or other non-federal lands are discussed. For each of the Big Sky states (Idaho, South Dakota, and Montana) non-federal land areas and Indian reservations classified as rangeland have been identified according to their potential for carbon sequestration. This information can be used to target areas that will likely have the greatest return on investments in rangeland carbon sequestration projects.

The material presented in this report addresses problems in verifying changes in carbon stocks associated with the high cost and time involved with repeated sampling and analysis. The objective is to demonstrate the practicality of near infrared reflectance spectroscopy (NIR) as a technique for reducing the cost and time required for sample analysis. We demonstrate a technique that identifies spectrally unique samples for laboratory analysis and equation development, and compare the accuracy and cost between NIR techniques and standard laboratory procedures. Results of a general soil carbon equation built on a diverse assortment of soils collected throughout the country are presented as well as the prediction results for several carbon fractions.

GIS-based efforts (Task 3). The GIS activities have involved LANL and INEEL as well as the research universities, and are focusing on building a database to meet the immediate Big Sky modeling and analysis needs, and on planning for multi-partnership, NATCARB, DOE, and national coordination, in the context of the emerging national cyberinfrastructure. We also have a major effort to examine the potential for using GIS-based systems in both research and outreach/education efforts of the Partnership, and the development of complimentary efforts with the West and Southwest carbon sequestration partnerships. LANL GISLab team leader Paul Rich continues in the role of coordination of Big Sky GIS efforts, Randy Lee (INEEL) continues as lead for geologic data, and Maribeth Price (SDSMT) continues as lead for terrestrial data.

Advanced Concepts (Tasks 9-20). The Partnership recognizes the critical importance of measurement, monitoring, and verification technologies to support not only carbon trading but all policies and programs that DOE and other agencies may want to pursue in support of GHG mitigation. For terrestrial sequestration, research is validating best management practices for soil C in the Partnership region. A team of researchers from MSU have been working in the field to

obtain field scale carbon estimates for ground truthing simulation models and identifying BMPs. Results from this research will also be used to validate the potential of soils to store carbon, and validate the Century Model predictions for soil C sequestration rates. Results were presented at the August 04 Partnership meeting and at the INRA Symposium in September, 2004.

Monitoring and Measurement Verification (MMV) activities, as they pertain to geological (and terrestrial) sinks, include some initial assessment of the state of the art for technologies that have a high likelihood of being mature enough to be applicable in Phase II small scale applications, and designing a risk/cost effectiveness framework to make comparative assessments of each viable sink, taking into account economic costs, offsetting benefits, scale of sequestration opportunities, spatial and time dimensions, environmental risks, and long-term viability. In conjunction with the GIS efforts and ongoing research at LANL, MSU, SDSMT, and INEEL, the Partnership is developing a well-integrated ensemble of diagnostics for MMV at each potential geological sequestration site, and a protocol for the terrestrial sequestration areas.

Regulatory and compliance research is being coordinated with the State agencies and with the IOGCC. Susan Capalbo is part of the IOGCC task force and met in Chicago in late August, 2004. A final report of the task force is due in Nov 2004. Also, the Montana Department of Environmental Quality is partnering with the Big Sky Partnership to provide detailed information on the permitting process for power plants in Montana.

The National Carbon Offset Coalition (NCOC) continued to expand the number and diversity of participants in its landowner/emitter advisory committee. Meetings were held with National Governors Association Greenhouse Gas Working Group, the Intertribal Environmental Council, and the U.S. Environmental Protection Agency. NCOC contractors attended and participated in a carbon sequestration conference sponsored by the state of Wyoming. NCOC contractors and a representative of the NCOC Board of Directors met with the Congressional delegation of the states of Montana and Idaho. NCOC contractors assisted in the development of an additional state of Montana grant designed to bring the Montana Bureau of Mines into the Partnership and expand the Partnership's geologic sequestration portion efforts. NCOC contractors worked with the Intertribal Environmental Council to develop a USDA proposal to create a 1605B Clearing House, conduct Greenhouse Gas workshops nationally with the tribes, and create a national Tribal Forestry Portfolio. Also NCOC began discussions with a national carbon trading group to begin marketing of NCOC carbon sequestration portfolios in DOE Phase II on the Chicago Climate Exchange (CCX) and other emerging markets.

Draft planning forms, contracting options and a draft forestry portfolio were submitted to the Chicago Climate Exchange for review. After review by CCX and a follow-up conference call between CCX staff and NCOC contactors a second draft is now under development

The first meeting was held with a Montana based farmer/producer group to act as an advisory committee for the development of cropland/agricultural soils protocols planning standards and contracting options this reporting period. Work has begun on the Project Planning handbooks which will ultimately incorporate all deliverables.

During the fourth reporting period the National Carbon Offset Coalition (NCOC) continued to expand the number and diversity of participants in its landowner/emitter advisory committee. The draft NCOC Project Planning Handbook final draft was 95% completed and distributed to members of the Partnership and others for review. Draft affiliate agreements, listing agreements, and contracting documents were completed and made ready for review by the NCOC Board of directors, the IRS. An exclusive marketing contract was completed between the NCOC, and NatSource, New York, New York to market projects in the yet to be implemented pilot portfolio. Marketing began on the first scheduled tribal workshop, in Spokane, Washington and the first private lands workshop in Post Falls, Idaho, both the week of January 11, 2005. This reporting period the University of Nebraska agroforestry subcontractor Dr. Jim Brandle completed scheduled 2004 field works.

Education and Outreach (Tasks 8, 21-25). The primary goal of the Education and Outreach efforts is to increase awareness, understanding, and public acceptance of carbon sequestration while building support for the efforts of the Partnership. The activities to date include the completion of a comprehensive Education and Outreach Plan, a Partnership listserv, the development of an internal website, development of handout materials for many of the conferences, and planning and designing outreach and education materials in conjunction with the universities and other partners throughout the States. A third Partnership meeting was held in August, 2004 followed by an AMSE symposium on carbon sequestration. Materials from these meetings and symposium are posted on our website.

As part of the ongoing efforts to involve stakeholders and communities in the carbon sequestration efforts, we are developing the decision support framework for producers to assess the soil carbon sequestration potential of specific land areas. Currently, the C-Lock program is operational for South Dakota, with expanded coverage in progress for Montana, Idaho, and Wyoming.

Other progress/efforts include: design and production of posters and fact sheets (see Appendix A); meetings with environmental groups including the Greater Yellowstone Coalition; participation in monthly Outreach conference calls; participation in the Bozeman PEIS meetings and development of Partnership materials; and design of a student-oriented ASME workshop.

An advisory committee that includes representation from local constituencies has been formed, with the first meeting tentatively planned for December, 2004. The mission and the (unofficial) composition of this committee are included in Appendix B.

EXPERIMENTAL SECTION

Task 1: GHG sources

The US EPA's Emissions Inventory Improvement Program (EIIP VIII) (USEPA 1996a and 2003a) provided the primary inventory methodology. The most recent data sources were used for each category, ranging from 1997 (most recent Census of Agriculture data) to 2002. Therefore the aggregate emissions values may be regarded as composite estimates.

CO₂, CH₄ and N₂O emissions resulting from the use of fossil energy were estimated based on the Energy Information Administration's State Energy Annual 2002 reports (USDOE-EIA 2002a). These provide detailed state-level breakdowns of fuel consumption by sector (residential, commercial, industrial, utility and transportation) and fuel type. These reports do not provide estimates of exported electricity or bunker fuels, so these categories are not included in the inventory. Standard emission factors, as described in EIIP VIII, were applied to all fuels.

CH₄ emissions from oil production and transport were estimated based on state production statistics in the Petroleum Supply Annual (USDOE-EIA, 2002b). Only Montana has significant oil production, centered in its western oil fields, although a small amount is produced in South Dakota. Similarly, CH₄ emissions from natural gas production and transport were estimated based on processing information from the Natural Gas Annual (USDOE-EIA, 2002c) the Oil and Gas Journal (v.101(n.22-25), 2002) and pipeline statistics obtained from the Office of Pipeline Safety (USDOT-OPS 2002). Montana has 4333 gas wells and 5 gas processing facilities, South Dakota 68 wells and Idaho has none.

GHG emissions from industrial processes:

Facility-level information about industrial processes that emit CO₂ and non-CO₂ GHGs was essentially unavailable from state or corporate sources. However, process information collected from permitted entities was available for some facilities through the EPA's PCS permit database for water discharges (USEPA 2002), and the NAAQS National Emission Trends Inventory 1996 for air releases (USEPA 1996b). The South Dakota DENR made 2001 process data available for permitted industrial facilities in South Dakota; comparable data were not available from other states.

The largest industrial sources of non-energy GHGs in the region are cement and lime manufacture. According to USGS mine and processing plant location data, South Dakota has one cement plant, Montana has 2 and Idaho has one (USGS 1997). CO₂ emissions estimates were based on 1996 process data from the NAAQS and 2001 data from the SD DENR. An estimate of CO₂ emissions from lime calcination in the 8 lime kilns in our region was provided by Michael Miller of the USGS (personal communication).

CO₂, CH₄, N₂O and PFCs are generated during aluminum processing and manufacture. There is a single aluminum plant in the region, located in Montana. Production statistics were estimated based on information in the 2002 Aluminum Yearbook (Plunkert 2002).

N₂O is generated during nitric acid manufacture at a single facility in Idaho; emissions were estimated based on process data from the 1996 NAAQS database. CO₂ generated by soda ash consumption and CO₂ manufacture, HFCs and PFCs generated during semiconductor manufacture, and SF₆ released from electrical transmission and distribution equipment, were all estimated using national production statistics, state population numbers from the 2000 Census and default emission factors provided in the EIIP methodology. HCFC-22, adipic acid and SF₆ from magnesium production are not significant GHG sources in these states.

GHGs from municipal and industrial waste:

Municipal landfills that do not practice landfill gas recovery are significant aggregate sources of CH₄. Landfill emissions estimates were based on state population data since 1960, and state-level waste-in-place projections derived from default per-capita landfill waste data provided in the EIIP, along with default composition factors and fractions in large vs. small landfills were obtained from the EIIP. The EPA Landfill Methane Outreach Program (USEPA 2003b) provides data regarding participating landfills in each state. Very small amounts of landfill methane were flared or recovered in Idaho and Montana as of 2002, and none in South Dakota. The EIIP also provides emission factors for municipal waste incineration facilities, of which there are 4 listed by the NAAQS database in Montana and 3 in South Dakota.

Anaerobic decomposition in municipal and industrial wastewater can generate CH₄ and N₂O. Because of uneven discharge data availability, we estimated emissions from municipal wastewater based on 2002 state population data and default factors from the EIIP. The EIIP also provided regional average protein consumption estimates, necessary for N₂O estimation.

Limited facility-level industrial wastewater discharge data are available through the EPA Permit Compliance System database of NPDES permits (USEPA 2002.) The EIIP provides default emission factors for three major categories of industries that generate wastewater enriched in organic constituents: fruit and vegetable processing, meat and poultry, and the pulp and paper industry. Corn-based ethanol production is also an important industry in this region, particularly in South Dakota; however, the EPA has not derived default emission factors for ethanol production. Pending better guidance, we applied the default emission factors for pulp plants to those ethanol plants which had provided discharge data to the NPDES system.

GHGs from land management and livestock:

By far the most important source of GHGs in agriculture is livestock. In 2001 South Dakota and Montana ranked 6th and 9th, respectively, in overall cattle production among US states. Livestock-derived GHG emissions in South Dakota are exceeded only by emissions from the transportation sector. Enteric fermentation by ruminants is the largest source of agricultural CH₄, but anaerobic management of livestock and poultry manure also produces important amounts of CH₄ and N₂O.

We used county-level livestock population data from the 1997 Census of Agriculture (USDA-NASS 1997), projected to 2001, for the various livestock commodities (cattle, poultry, hogs). Census categories were adjusted to correspond to those used in the USDA annual reports referenced in the EIIP methodology, which provided management and emission factors. County-level estimates of CH₄ and N₂O emissions for cattle, hogs, poultry, horses, mules, goats and sheep were aggregated to the state level.

Large confined feeding operations (CAFOs) have been classified as point sources of water pollution and are significant CH₄ sources. Because of limited facility data availability, weighted EIIP regional emission factors, which account for feed quality and likely manure management systems among the different livestock categories, were used to estimate CH₄ and N₂O releases

from enteric fermentation and anaerobic manure management. None of the three Partnership states had any operational manure methane recovery systems in place as of 2003.

Burning of crop residues generates CO₂, CH₄ and N₂O; however, because the source is of recent biogenic origin, the CO₂ is not counted in the GHG source inventory. CH₄ and N₂O releases were estimated based on EIIP default factors and USDA crop production statistics for 2002 (USDA-NASS 2002).

Forests can be GHG sources or sinks depending on management. We used estimates of forest stock changes from 1992-1997 and the consequent GHG fluxes derived by Birdsey and Lewis (2002). This report provides state-level estimates of forest stock changes based on USFS FIA (Forest Inventory and Analysis) data and modeling. It also includes estimates of carbon storage in persistent wood products and landfills. Methods documented in the report are consistent with those outlined for the Stock Approach in the EIIP.

Changes in soil C due to agricultural management will be estimated using soil, crop and management data compiled for the C-Lock program. Climate, soil and management files necessary for CENTURY modeling have been developed preliminary to conducting statewide agricultural source/sink potential estimates for Idaho, Montana and South Dakota. Historical management questionnaires sent out to Montana FSA agents to help refine CENTURY management schedules have to date resulted in a 35% response rate. Reminders have been sent in an attempt to encourage a higher rate of response.

Uncertainty Estimation for Source Estimates:

The uncertainty inherent to the data on which our summary estimates are based was accounted for by direct Monte Carlo simulations incorporating the uncertainty ranges for major component emissions estimates. Because time and funding did not permit direct estimation of uncertainty for each emissions component, we used the DARS (Data Attribute Ranking System) scores provided by the EIIP (USEPA 1996a). DARS scores are developed by evaluating the reliability of eight components of the emissions estimates, related to the activity level and to the emission factor. Because in most cases we employed the EPA's default ("Preferred") methods for developing emissions estimates, these scores were applicable, where available.

At present there is no established functional relationship between the DARS score and statistical measures of uncertainty (such as standard deviation, SD, or coefficient of variation, CV). Therefore we established an arbitrary but conservative relationship as follows: the maximum possible DARS score is 1 (representing perfect certainty). We doubled the difference between 1 and the actual score, and used that to represent a theoretical CV from which a standard deviation could be estimated for each emission component for which DARS scores were available (representing approximately 85 percent of total emissions.)

Task 1 and 2: Geological sequestration

This section describes the research that has been initiated that supports the objectives of the Partnership under both Task 1 (1.2) and Task 2. Activities during the second, third, and fourth

performance periods continue with the development of the methodology for characterizing the potential of subsurface formation for carbon dioxide sequestration via solubility and mineralization trapping. As noted in the first quarterly report, the approach relies upon the use of bulk whole rock chemical analyses for formation geomechanics. (See references from the first report.)

The Big Sky Partnership is securing public domain information about potential geologic carbon sequestration sites, and working with industry representatives. For regional sources, we have completed the compilation of state-level aggregate data regarding emissions from fossil fuel consumption, using EIA state data. Facility-level data for energy utilities and selected industries have been compiled for South Dakota, and this will serve as a template for the other states in our Partnership. Data on CH₄ from stationary and mobile combustion sources, oil and gas production, enteric fermentation and manure management, burning of agricultural wastes, and wastewater treatment, as well as data on N₂O emissions from similar sources have been compiled for South Dakota. This information will be incorporated into the GIS database for the Big Sky Partnership.

During the third performance period the overall approach to conduct assessments of geologic carbon sequestration potential was further refined. We are using a two-phased approach for the assessment of regional geologic carbon dioxide sinks. The first phase is the identification of geologic ‘plays’¹ that are screened against carbon dioxide injectability and capacity criteria. The screening eliminates plays that do not meet minimum criteria. The remaining plays will be subjected to a detailed analysis to evaluate (using numerical hydrogeochemical modeling) their carbon dioxide trapping potential. In addition, an economic and regulatory feasibility analysis will be conducted. The results of the screening and analysis will be incorporated into a GIS database.

Also under the geological sequestration component of the Partnership work, we are reviewing geophysical methods for monitoring the pre-injection and injection (i.e., production) phases of subsurface carbon sequestration in deep reservoirs. We are reviewing methods that are applicable for (a) single-well testing as would occur with a pilot project of small scale and could occur in a larger production-scale project; (b) cross-hole testing including tomographic and time-lapse tomographic methods; and (c) passive and active surface seismic monitoring or testing that can track the presence and movement of supercritical carbon dioxide.

We are also continuing to review published information on basins in the Big Sky Carbon Sequestration Partnership region. As a first step in evaluation for a familiar basin, we have reviewed published information on the western Snake River Plain as a potential geologic province for carbon sequestration and we have determined that the patchy nature of both the fluvio-lacustrine environments and the potential cap rocks on them in the basin make this province quite risky for large-scale, deep-reservoir, geologic carbon sequestration.

¹ The fundamental geologic unit used in the 1995 National Oil and Gas Assessment was the ‘play’, which is defined as a set of known or postulated oil and or gas accumulations sharing similar geologic, geographic, and temporal properties, such as source rock, migration pathways, timing, trapping mechanism, and hydrocarbon type.

A meeting with researchers at Los Alamos National Laboratory (LANL) was held to discuss the availability of empirically-based reaction kinetics for carbon dioxide facilitated weathering of geologic material. This meeting resulted in a collaborative effort to advance the state of understanding regarding carbon dioxide enhanced weathering of geologic material in potential sequestration sites. The research group at Los Alamos has developed an experimental technique through which reaction kinetics can be derived for carbon dioxide facilitated weathering of geologic materials. The application of this data to field scale sequestration modeling effort currently in progress by the Big Sky Partnership could prove invaluable to a Phase II to field deployment.

As stated in the last quarterly report, efforts have been continued to identify sources and databases containing pertinent information for the characterization of each of the plays and information relative to the screening criteria. There are two primary databases containing much of the information needed for Wyoming and Montana, 1) The Wyoming Oil and Gas Conservation Commission web site and 2) Montana Board of Oil and Gas Conservation web site. Screening criteria parameters expected to be collected from these agencies include depth, pressure, temperature, fluid properties, unit thickness, salinity, pH, porosity, permeability, and gas content. Efforts have begun in extracting this information and organizing it into a GIS database that will show the spatial distribution of these characteristics. Other research activities are being conducted to gather the rock type and whole rock chemistry relative to each of the geologic formations within each of the plays.

During the fourth performance period, work has continued on collecting geologic properties and characteristics for the region and entering this information into an Access data base. We have discretized the Big Sky Partnership region (including Wyoming) into 10 provinces and 111 plays in accordance with the 1995 National Assessment of United States Oil and Gas Resources conducted by the U.S. Geological Survey. The effort has included incorporating data from: 1) State of Wyoming Oil & Gas Conservation Commission, 2) Montana Board of Oil & Gas Conservation, and 3) Montana Geological Society. The data existed both as electronic databases and hard copy information. All hard copy information was entered into the data base twice, by two different individuals, the resulting files compared, and any discrepancies identified and corrected. The resultant database includes properties that will be used to calculate the size of the various reservoirs and the potential volumes of carbon dioxide that could be contained. Our data collection activities are focused on ultimately developing a database management system coordinated with GIS capabilities to support more-detailed analysis of reservoir potential based on well, stratigraphic, engineering, and production information available from state agency sources and other sources. We have also refined our assessment approach to allow consideration of the role of ferrous iron on the mineral trapping carbon dioxide and applied our assessment approach to the volcanic basins in southwest Idaho.

We are reviewing geophysical methods for monitoring the pre-injection and injection (i.e., production) phases of subsurface carbon sequestration in deep reservoirs with an eye towards methods that are applicable for (a) single-well testing as would occur with a pilot project of small scale and could occur in a larger production-scale project; (b) cross-hole testing including tomographic and time-lapse tomographic methods; and (c) passive and active surface seismic monitoring or testing that can track the presence and movement of supercritical carbon dioxide.

Geographic information system (GIS) work performed during the last quarter included developing a method for extracting formation information from the geologic properties and characteristics captured in various oil and gas databases from Wyoming and Montana. The geologic group is in the midst of compiling well log information that contains formation names, depths, temperatures and associated water chemistry into one comprehensive database for each of the states covered by the Partnership. As mentioned previously, the region has been discretized into 111 plays. The challenge for the GIS group is to connect the formation and chemistry data with the appropriate plays since the individual state databases do not make that distinction.

The method for connecting this data was accomplished by developing point layers representing well locations for each formation (see Figure 1). The point layers are then used to develop surfaces via kriging. Polygons representing the different plays were then used to clip out intersecting areas from the formations. Once the plays and formations were joined, the associated data from the database for each well was joined with the appropriate play.

As the final database for each of the states is completed, the method described above will be applied and the resulting layers will be provided to the geologists for screening. Screening at the play level and not the field (fields are smaller regions within each play) level, the amount of information that has to be collected is reduced significantly. Once the plays of interest are screened out, more detailed information at the field level will be collected and a similar method for connecting and the data will be performed. A more in depth discussion of these plays are included in the Appendix to this report.

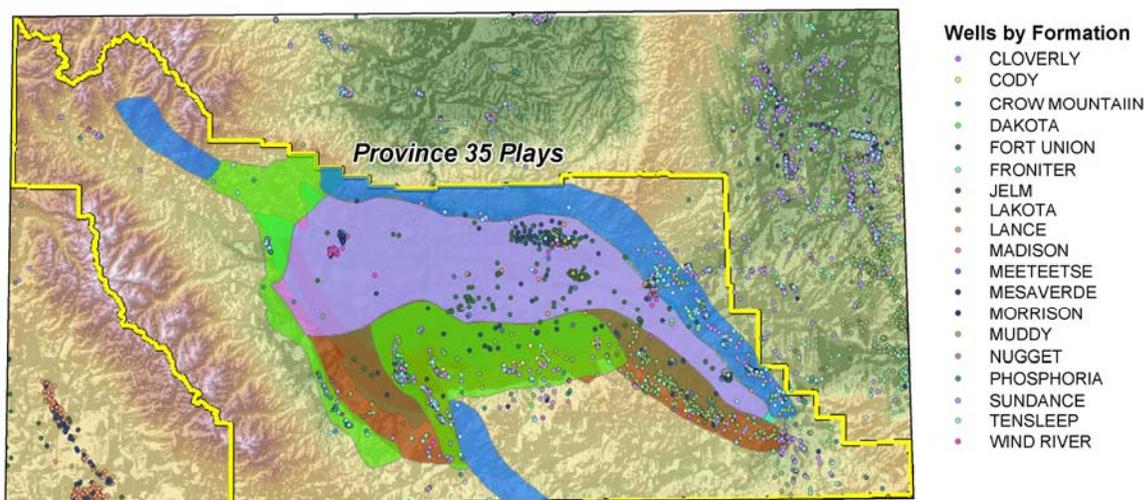


Figure 1. Well locations by formation

Tasks 4 and 5: Terrestrial sequestration

A third area of work has been to evaluate and verify the soil C potentials with the estimates forthcoming from the Century simulation model. During the second performance period, the results of the terrestrial sinks assessment for South Dakota has been completed using the

SSURGO soil texture grids and is being summarized; the evaluation of soil C potential on croplands in Montana is currently underway (see related material below). We have completed the SSURGO soil texture grids for Montana and Idaho; the CLIMATE data compilation is in progress.

For forested lands, the USFS data on forest carbon stocks by state, by major species is available and ready to be incorporated into the GIS database. We have been compiling NLDC time series data to determine forest area change, for use in assessing forest sink potential.

We are integrating soil and climate databases with our econometric simulation models to estimate soil carbon trajectories at the MLRA level in Montana, and to test the impact of alternative management scenarios and carbon policy scenarios on the cost of sequestering soil C and on the size of the terrestrial sinks. During the second performance period we have developed a yield based framework for using US Ag census data to predict land use changes, soil carbon changes under alternative price and climate change scenarios. The third performance period focuses on modifying and validating these empirical results. Results were presented at the May DOE carbon sequestration meeting and will be presented at the INRA workshop in September 2004.

Rangelands comprise a sizeable portion of the land resources in our Partnership region and are of critical importance to our neighboring states. Preliminary estimates suggest that rangelands can store up to an additional 0.3 mg C/ha/yr and restores grasslands storing nearly twice that amount. Possible options that have been identified for rangeland carbon storage to date include juniper invasion control, mesquite invasion, and cheatgrass control. These options along with baseline estimates of soil C levels at the MLRA level are being compiled by Texas A&M colleagues for inclusion with the GIS terrestrial sink inventory.

In order to estimate areas of potential carbon sequestration or loss, data for use in a GIS is being acquired. This data includes 1990's Landsat TM data (30 m resolution) that identifies 21 classes of land cover types. For rangelands, land cover types designated as shrublands, grassland/herbaceous, and pasture/hay are being considered. These classes will be intersected with MLRAs to define acres within each MLRA and linked with other datasets such as STATSGO soil and MODIS net primary productivity.

The terrestrial research component for rangeland is nearly complete. A summary of Natural Resources Conservation Service (NRCS) data for each of the Major Land Resource Areas (MLRAs) in the Big Sky Partnership area is included. The experimental plan includes a data collection and literature review and an evaluation of the terrestrial sink potential. These are discussed below.

A general library and Internet search was conducted primarily using Current Contents and Google. Relevant articles were entered into an EndNote database. The complete bibliography was exported into a word document that is linked to selected PDF articles and recorded on a CD. NRCS data for landuse, potential vegetation, soil, water, elevation, precipitation, temperature, and irrigation for each MLRA in the Partnership were summarized in an Excel spreadsheet

The results of a literature search of over 1000 entries have already been submitted in an earlier report. A revised literature search containing over 800 references linked to over 150 selected articles is being mailed as a CD. Many of the less relevant articles were removed from the original search and selected articles were linked to the bibliography which acts as an index. A summary of NRCS data for each MLRA in the Partnership is presented in Appendix C. The results of this literature review can be used to support decisions for increasing carbon sequestration for areas identified as having potential as carbon sinks. (See <http://cubes.tamu.edu/bigsky>)

Climatic potential, MLRA, and land tenure were selected to spatially stratify rangeland cover types into easily identifiable areas where sequestration programs could potentially be initiated. Climatic potential for carbon sequestration was classified into four categories based on annual precipitation: no potential - less than 130 mm; low potential – 130 to 230 mm; moderate potential – 230 to 460 mm; and high potential – greater than 460 mm. Since programs will not likely be implemented on Federal lands, only Indian reservations and private or other non-federal lands are discussed. For each of the Big Sky states (Idaho, South Dakota, and Montana) non-federal land areas and Indian reservations classified as rangeland have been identified according to their potential for carbon sequestration. This information can be used to target areas that will likely have the greatest return on investments in rangeland carbon sequestration projects

A GIS approach was used to identify possible rangeland terrestrial sinks throughout the Big Sky project area. The objective was to spatially identify potential rangeland terrestrial sinks with respect to climatic potential, MLRA (as designated by the NRCS), and by land tenure (federal, private/non-federal, and Indian reservations).

Spatial cross-indexing was used to identify rangeland vegetation cover types that would have the potential for sequestration of carbon. Three major categories of cross-indexing were selected to spatially stratify rangeland cover types into easily identifiable areas where sequestration programs could be initiated. The categories of spatial cross-indexing selected included climatic potential, MLRA, and land tenure. Each of these categories and the associated spatial data used in the analysis will be described below. National land cover data from the early 1990's served as the basis for identifying rangeland land cover. This dataset and the rangeland cover types will also be described below.

Climatic Potential. To assess climatic potential for carbon sequestration, long-term precipitation was classified into the following categories:

- No Potential - Less than 130 mm (~5 inches) of annual precipitation
- Low potential – 130 to 230 mm (~5 to 9 inches) of annual precipitation
- Moderate potential – 230 to 460 mm (~9 to 18 inches) of annual precipitation
- High potential – Greater than 460 mm (18 inches) of annual precipitation

These categories were chosen in collaboration with Dr. Joel Brown of USDA/NRCS to reflect the climatic potential for carbon sequestration and/or interventions to promote carbon sequestration on rangelands. For the No Potential category, rainfall amounts of less than 130 mm would be inadequate for short-term (<10 years) sequestration goals and also inadequate for

interventions such as revegetation. The remaining categories represent increasing potential with areas having annual precipitation amounts greater than 460 mm having the greatest potential for carbon sequestration on rangelands.

The Parameter-elevation Regressions on Independent Slopes Model (PRISM) (<http://www.ocs.orst.edu/prism/>) long-term average annual (1970 to 2000) precipitation data (SCAS 2004) was used to spatially represent the climatic potential categories. The PRISM data is a gridded data set of total annual precipitation with a spatial resolution of approximately 4 km. PRISM is currently used by NRCS for their climate mapping (<http://www.nrcs.usda.gov/branch/gdb/products/climate/index.html>). Using the Spatial Analyst extension in ArcView 8.3, the gridded data were classified into the climatic categories described above and then converted to vector format (i.e., an ArcView shapefile). Converting the data to vector format allowed delineation of unique polygons of the climate potential categories. This was done for each of the 3 states (Idaho, Montana, and South Dakota) in the Big Sky study area ([Figure 1](#), [Figure 2](#), and [Figure 3](#), respectively). (These figures can be found in Appendix C.)

Major Land Resource Areas. The NRCS defines a Major Land Resource Areas (MLRA) as "a geographic area, usually several thousand acres in extent, that is characterized by a particular pattern of soils, climate, water resources, land uses, and type of farming" (<http://www.nrcs.usda.gov/technical/land/meta/m2147.html>). MLRA's form the basis of NRCS planning at national, state and regional levels. Since the NRCS will likely be a primary implementer of carbon sequestration strategies, stratification of rangelands by MLRA can provide a useful cross-index for identifying areas of high potential.

For this analysis, the MLRA boundary coverage was downloaded (ftp://fc.sc.egov.usda.gov/NHQ/pub/land/arc_export/us48mlra.e00.zip) and converted to an ArcView shapefile. Using the NRCS state boundary coverage, the MLRAs within Idaho, Montana, and South Dakota were clipped from the 48 state coverage using the clip algorithm in ArcView 8.3. The resulting state MLRA maps were saved as individual shapefiles and used in the spatial analysis ([Figure 4](#), [Figure 5](#), and [Figure 6](#), respectively). (See Appendix C.)

Land Tenure. Since private or non-federal land is where the majority of carbon sequestration programs are likely to be targeted, it will be important to identify the land tenure within the study area. This will assist in identifying areas that will have the greatest potential impact in carbon sequestration. To accomplish in the spatial analysis, the Federal Lands and Indian Reservations of the United States coverage was acquired (<http://nationalatlas.gov/fedlandsm.html>). As was done with the MLRA coverage, the individual states in the study area were extracted from the Federal Lands and Indian Reservations coverage using the clip algorithm in ArcView 8.3. The resulting map layers for Idaho, Montana, and South Dakota were saved as shapefiles and used in the spatial analysis ([Figure 7](#), [Figure 8](#), and [Figure 9](#), respectively). (See Appendix C.)

Rangeland Land Cover. The 1992 National Land Cover Data (NLCD) (Vogelmann et al. 2001) was used to identify land area as rangeland. The NLCD was derived from the early to mid-1990s Landsat Thematic Mapper satellite data. Using an unsupervised clustering algorithm, land areas were classified into a 21-class land cover scheme

(<http://landcover.usgs.gov/classes.asp>) applied consistently over the United States. The spatial resolution of the data is 30 meters. For this analysis, the following classes were selected as rangeland land cover types:

- Shrublands
- Grasslands/Herbaceous
- Pasture/Hay

National land cover data was distributed as TIFF images for each state. Using the Spatial Analyst extension in ArcView 8.3, the TIFF images were converted to GRID format. These grids were reclassified to extract the rangeland cover types described above. The resulting map layers for Idaho, Montana, and South Dakota ([Figure 10](#), [Figure 11](#), and [Figure 12](#), respectively) were then used in the cross-tabulation analysis. (See Appendix C.)

Spatial Cross Tabulation. Within the GIS, unique polygons of climatic potential, MLRA, and land tenure were generated by intersecting these layers for each of the states in the study area. The resulting map layers ([Figure 13](#), [Figure 14](#), and [Figure 15](#) – see Appendix C) were then used to cross-tabulate land area for each of the rangeland cover types by unique climatic potential, MLRA, and land tenure category. This was done using the Tabulate Areas algorithm in ArcView 3.3. For the purposes of this analysis, any land that did not have a classification of Federal or Indian reservations were given the class designation of private or other non-federal land tenure designation.

Tasks 16: Terrestrial sequestration, pilot sites and simulation models

Work is also proceeding on the terrestrial sink potential for croplands in the Big Sky region, using both pilot, field-scale methods and larger simulation type models for quantifying rates of change in soil C levels. Field-scale studies were established at six farm fields in the Golden Triangle in north central Montana, and researchers have been working on a weekly basis with producers in the study sites with field management and soil carbon sampling. The purpose of these studies is to determine the effect of cropping intensity (annual vs. alternate year) and tillage (conventional vs. no-till) on soil C levels across different soil types and terrains.

Efforts have focused on carbon measurements using the following experimental plan: At each farm, a field of 32 ha was divided into four strips (8 ha) representing the following cropping/tillage systems: traditional summer-fallow – wheat; no till chemical fallow – wheat; conventional tillage pea-wheat; and no till pea-wheat. Within each strip four sites were identified for sampling/monitoring of soil carbon changes over time. The sites (total of 16 per farm) were georeferenced via GPS. Soil samples are collected on a two-year time interval beginning with the initial background sampling in the Fall of 2002. A more detailed description of the experimental plan was included in the second quarterly report.

Field-scale studies were established at 6 farm fields in the Golden Triangle in north central Montana ([Figure 2](#)). The purpose of these studies is to determine the effect of cropping intensity (annual vs. alternate year) and tillage (conventional vs. no-till) on soil C levels across different soil types and terrains. At each farm, a field of 32 ha was divided into four strips (8 ha)

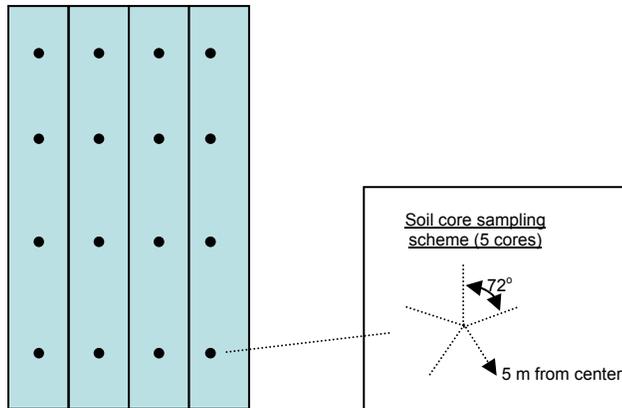


Figure 3. Hypothetical sampling scheme for long-term soil carbon studies.

Soil samples collected from this study were dried to 40° C then ground to pass through a 2 mm sieve. Subsamples were removed and ground to a fine powder using a ball mill. Total carbon analyses were performed using an automated dry combustion analyzer or Leco CNS-2000 analyzer (Leco Corporation, Saint Joseph, MI). The inorganic carbon fraction was determined using the procedure of Sherrod et al. (2002). Organic carbon was then calculated by difference, i.e. organic C = total C – inorganic C. Nitrous oxide samples were collected using vented chamber techniques (Hutchinson and Mosier, 1981) (Figure 4). Vented soil chambers covering a 1000 cm² area and with a 10 cm head-space were inserted between the crop rows. The protocol used for collecting and processing the gas samples was similar to one described by Lemke et al. (1999). Nitrous oxide flux was estimated from the concentration change in the chamber headspace over a predetermined collection period (e.g. 30 minutes to 1 hr). Samples were drawn from the headspace using a 20 to 30 mL syringe and then transferred to a pre-evacuated 13 ml extainer. The concentration of N₂O in the sample extainer was determined using a gas chromatograph equipped with an electron capture detector.

Intact core, crushed (< 2 mm), and ball-milled soil samples were scanned using an ASD “Fieldspec Pro FR” VNIR spectroradiometer (Analytical Spectral Devices, Boulder, CO). This spectroradiometer has a spectral range of 350-2500 nm, 2 nm sampling resolution and spectral resolution of 3 nm at 700 nm and 10 nm at 1400 and 2100 nm. Soils were scanned from below with a “mug lamp” foreoptic and white light source, a borosilicate bottom glass “puck” to hold samples and a Spectralon[®] panel for white referencing. Four and two composite scans (consisting of 10 internally averaged scans of 100 ms each) were obtained for the crushed and milled samples respectively, with a 90° rotation between each.



Figure 4. Nitrous oxide gas samples are collected using a vented chamber made of plexiglass. Without cover (left). With cover (right)

Efforts are nearing completion with the compilation of information relevant to point and terrestrial area sources of GHGs in MT and integration into a GIS framework as appropriate. INEEL/UI/BSU are coordinating efforts to collect spatially-referenced data for geological formations. The Partnership is assembling soil, climate, crop and land use databases and integrating these data with the C-Lock system developed by SDSMT and with economic data on land use practices and the economic frameworks developed at MSU for quantifying soil carbon sequestration potential. Furthermore, these efforts are being coordinated with the other Western partnerships.

Tasks 9-20: Advanced concepts

Task 9. Advanced concept activities this period include designing integrated measurement, monitoring, and verification for geological and terrestrial sinks, regulatory protocols, and risk assessment/tradeoff frameworks. Measurement, monitoring, and verification activities, and capture technologies, are complementing ongoing research at the labs and research institutions; to date we have assessed the focus and extent of these research efforts. The direction of the MMV research was discussed in detail the first quarterly report.

Some of the ongoing efforts at LANL on Advanced concepts include an initial examination of various mineralization concepts. These included:

- 1) Industrial Mineralization
- 2) In Situ Mineralization
- 3) Brine Mineralization
- 4) Carbonate Dissolution
- 5) Trona Carbonation

All these concepts fall into the category of advanced concepts and all were found to require considerable further research and development work before they could be implemented on a practical scale and/or their long-term storage capabilities could be fully understood.

The reaction rates for industrial mineralization of CO₂ are still too slow to prove to be an effective option. Although rates that can be obtained today are at the margins of becoming acceptable, achieving these rates still requires large (and costly) energy inputs that would prove uneconomical. New ideas and approaches are still being developed and pursued. It is believed that with further R&D, a viable approach can be found.

The reaction rates for in-situ mineralization tend to be even lower than in the industrial mineralization case as one has very limited or no ability to achieve the most favorable operating conditions. Nonetheless, given the virtually limitless source of resources available in the region, further examination of this approach is still warranted.

Brine mineralization is appealing from a conceptual point of view especially since huge quantities of brine are available deep underground. However, the brines tend to be dominated by non reactive salts and only a very small fraction of the dissolved minerals are likely to be able to be transformed into stable carbonates without the addition of other costly chemicals. The use of any reactive chemicals other than catalysts are likely to be ruled out when one considers the amount of CO₂ that must be disposed of. Isolated pockets of more favorable brines could nonetheless be found.

The dissolution of calcium carbonate (limestone) in carbonic acid to form a dissolved calcium bicarbonate solution that holds down additional CO₂ has been discussed in the literature. This is a process involved in the formation of limestone caves. However, the long-term fate of the temporarily dissolved CO₂ is still uncertain and vast amounts of water would be required unless one were able to maintain high CO₂ pressure throughout the duration of the sequestration period.

Trona carbonation is a sodium-based version of the above process and would allow one to store the CO₂ in the mineral form of solid sodium bicarbonate. It has the advantage of requiring far lower CO₂ pressures if the system were damp and concentrated, and no CO₂ pressure if kept dry. Extensive deposits of trona exist in Wyoming, which would allow extensive storage for the region. At the same time, the deposits are too small to provide a long-term national solution.

Measurement, Monitoring and Verification (MMV) are essential functions of a successful Carbon Sequestration Program. MMV involves the implementation and deployment of various integrated measurement diagnostics that monitor geological and terrestrial sequestration sites and verify the veracity of the site's performance. A successful MMV program will require an ensemble of integrated diagnostics that monitor all aspects of sequestration as well as verify the accuracy of the diagnostics employed.

We are in the process of completing a gap analysis that will compare and contrast the current state of likely MMV diagnostics with the likely levels of CO₂ that need to be monitored. The first step in this process is to estimate the concentration of CO₂ one needs to monitor giving a generic geological or terrestrial sequestration scenario. Secondly, one needs to identify the

ensemble of diagnostics that one could deploy to MMV the entire site and determine the current detection limits and sensitivity. The final step involves determining the gaps associated with the detection capabilities in the current state of the diagnostics as well as identify the technical gaps in the detection grid.

The first step involves determining the levels of CO₂ one needs to monitor given a generic geological or terrestrial sequestration site. Some performance goals for the FutureGen geological sequestration project have been published and this is a good place to start. The FutureGen Program seeks to build a plant that will use coal to generate electricity and hydrogen while the CO₂ produced is cleaned and permanently stored in a geological sequestration site. The goal is to annually store one million tons of CO₂ and maintain a leak rate of less than 0.01% annually. This results in a total leak rate from the entire sequestration reservoir of ~2μg/sec CO₂ at this maximum level. However, the CO₂ that leaks will likely come from several different fractures and will follow many different paths resulting in many different point sources of CO₂ at the surface. Emission from each of these point sources amounts to a small fractions of the total leak rate. The challenge is to deploy diagnostics that can detect these small point sources as the CO₂ travels from the fracture to the surface.

The second goal is to identify the likely diagnostics that will be deployed to MMV a sequestration site. Our efforts to identify these diagnostics have been divided into three subgroups including Sub-Surface, Surface and Atmospheric diagnostics. The following is a list of diagnostics that we believe need to be considered at this time.

Sub-Surface MMV:

- Rock Physics
- Subsurface
- Cross-well Seismic
- Microgravity
- Downhole Sampling for Leakage, Microdrilling
- Downhole Sampling for Leakage, Isotopes

Surface MMV:

- Laser Induced Breakdown Spectroscopy (LIBS)
- Microbial Indicators
- Isotopes
- Diffuse Reflectance Infrared Imaging

Atmospheric MMV:

- Isotopes
- LIDAR
- Airborne and Satellite Remote Sensing
 - Multispectral & Hyperspectral Imaging
- Tunable Diode Laser Spectroscopy

We have started to investigate and document the current state of these diagnostics. For example, Ebinger et al. has determined that the detection limit of their current LIBS diagnostic is 300mgC/kg sample. However, it is difficult to determine, at this time, how well this compares

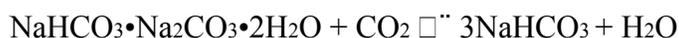
with the performance goals associated with terrestrial or geological sequestration. Some of the question that arise include the mechanism by which terrestrial sequestration converts atmospheric CO₂ into soil carbon or how well will LIBS detect increases in soil carbon that may be an indication of a geological sequestration leak.

Our current effort has focused on completing the gap analysis for the surface and atmospheric diagnostics first simply because we perceive them to be easier. We have started exploring the current state of the diagnostics that are commonly used here at LANL including LIBS, Microbial Indicators, Isotopes, and Tunable Diode Lasers. We also will begin reviewing LIDAR soon. A report that will provide the detailed results of the gap analysis is being prepared as the analysis of each diagnostic is complete.

Under Advanced Concepts, we are also exploring the possibility of coupling biomass based energy production with CO₂ separation and sequestration as a means of achieving net NEGATIVE CO₂ emissions for the Big Sky Partnership region. This possibility is attractive due to the large quantities of biomass resource available and the region's low average population density. The region's low population density and hence CO₂ production also opens the possibility of taking advantage of the large trona deposits available in Wyoming as a way to permanently sequester the CO₂ through a mineralization process. The Wyoming trona deposits are estimated to be in the 50 to 100 billion ton range, capable of sequestering 10 to 20 gigatons of CO₂, enough to account for all the region's emissions for some 100+ years. As the biomass being consumed has removed CO₂ from the atmosphere, the region would also have 10 to 20 gigatons of CO₂ credits to sell.

By using biomass, even if full CO₂ separation is not achieved during power generation, the CO₂ that escapes does not add to atmospheric CO₂ concentrations, as the biomass fuel is already carbon neutral. The proposed approach thus removes the need for very stringent performance requirements on the CO₂ separation step. Namely, any CO₂ that is not separated is not a penalty, rather it just reduces the amount of CO₂ credits that can be sold.

Trona is a hydrated sodium bicarbonate – sodium carbonate salt (Na₃H(CO₃)₂•2H₂O or NaHCO₃•Na₂CO₃•2H₂O) and is found as large evaporite deposits. When trona is reacted with CO₂, the “carbonate portion” of the trona is converted to a bicarbonate, thereby sequestering CO₂, i.e.



Doing this in an aqueous process will (depending on the dilution) result in precipitates, or in fully dissolved species. The resulting solution (perhaps with precipitates entrained) could be injected downhole forming a stable chemical system provided a very low CO₂ pressure (~1/1000 atmospheres). At higher CO₂ pressures it may be possible to fully carbonate the trona in place. Due to the mineralization of the trona, there is no concern about CO₂ leakage from the system.

We have obtained samples of natural trona and verified that it is readily soluble. We have examined the thermodynamics of the carbonation reaction and verified that it should move in a forward direction. The pH of the resulting solution has also been examined theoretically for equilibrium conditions and should yield nearly neutral solutions. This may impact the reaction

rate and is an issue we are currently exploring.

The main future work would be in the area of building a biomass fueled gasification plant with integral CO₂ separation, and testing the trona conversion at a large scale.

Tasks 11 and 15. Market-based carbon trading research and outreach

During the reporting period the National Carbon Offset Coalition (NCOC) continued to expand the number and diversity of participants in its landowner/emitter advisory committee. Meetings were held with National Governors Association Greenhouse Gas working Group, the Intertribal Environmental Council, and the U.S. Environmental Protection Agency. NCOC contractors attended and participated in a carbon sequestration conference sponsored by the state of Wyoming. NCOC contractors and a representative of the NCOC Board of Directors met with the Congressional delegation of the states of Montana, and Idaho. NCOC contractors assisted in the development of an additional state of Montana grant designed to bring the Montana Bureau of Mines into the Partnership and expand the Partnership's geologic sequestration portion efforts. NCOC contractors worked with the Intertribal Environmental Council to develop a USDA proposal to create a 1605B Clearinghouse, conduct Greenhouse Gas workshops nationally with the tribes, and create a national Tribal Forestry Portfolio. NCOC also began discussions with a national carbon trading group to begin marketing of NCOC carbon sequestration portfolios in DOE Phase II on the CCX and other emerging markets. During the third reporting period draft planning forms, contracting options and a draft forestry portfolio were submitted to the Chicago Climate Exchange for review. After review by CCX and a follow-up conference call between CCX staff and NCOC contractors a second draft is now under development.

Work on the Project Planning handbooks will ultimately incorporate all deliverables. The work being conducted for overall objective is design of proposed protocols planning standards, and contracting options based on input from specialists in the area greenhouse gas emission reduction policy, science and the carbon market. Dr. Brandle's work on overall objective 2, the development of volume tables relies on collection of field data from previously selected sites across Montana. Field data collection is accomplished through selecting representative samples for an identified number of key species. The field work involves actual cutting down measuring and weighing selected key species at each site. Field data is then compiled into volume tables for the selected species by using existing volume tables in the region.

Task 19. Assess available Measurement Instruments that can be used to Measure, Monitor and Verify Carbon Storage in Carbon Sequestration Projects

As part of Task 19, we address problems in verifying changes in carbon stocks associated with the high cost and time involved with repeated sampling and analysis. The objective is to demonstrate the practicality of near infrared reflectance spectroscopy (NIR) as a technique for reducing the cost and time required for sample analysis. We demonstrate a technique that identifies spectrally unique samples for laboratory analysis and equation development, and compare the accuracy and cost between NIR techniques and standard laboratory procedures. Results of a general soil carbon equation built on a diverse assortment of soils collected throughout the country are presented as well as the prediction results for several carbon fractions.

Study Site and Methods. This study was conducted on a 3000 hectare ranch in North Central Texas (Throckmorton County). Samples were collected in August 2002 and January 2003 from 175 locations distributed across the entire area of the ranch in order to capture the variance around the mean at this scale (Figure 19 - see Appendix C). For sampling protocols and NIR methodology please refer to our 2003 CASMGS report at <http://cnrit.tamu.edu/casmgs/>.

General Soil Equation and NIR Prediction of Carbon Fractions. We have been fortunate in having a number of collaborators who were willing to send archived soil samples analyzed for a range of constituents. The collection locations, labs and collaborators associated with the samples in the first carbon/nitrogen equation are listed in [Appendix II](#) (see Appendix C). Collaborators contributing samples with carbon fraction analysis are included in our general soils database [Appendix III](#) (see Appendix C). The carbon fractions for which NIRS equations were developed include glomalin, particulate organic matter (POM), amino sugar, β -glucosaminidase, and β -glucosidase. Additionally, an attempt was made to develop an equation for predicting bulk density. Details of equation development and sample selection can be found at <http://cnrit.tamu.edu/casmgs/>.

Time and Cost Comparisons: NIR vs. Conventional Laboratory. In order to estimate sampling costs, records were kept of the time required for each step in the sampling process (e.g. collecting samples, soil preparation, lab analysis, and NIR scanning steps). Estimates for conventional laboratory analysis per sample time were obtained from Cathleen McFadden from the University of Nebraska laboratory where our samples were analyzed. Because samples collected at Throckmorton Ranch contained carbonates, which require acid treatment between runs, two sample runs were included in our laboratory cost estimate.

Tasks 8, 21-24: Education and outreach

The education and outreach activities include the completion of the Education and Outreach Plan, which was revised in response to DOE and other outside review, a Partnership listserv, and the development of an internal and external website. A public website for the Big Sky Partnership was launched in the third quarter. The web site address is www.bigskyco2.org. In addition, enhanced collaboration with the University and research communities through visiting appointments, development of jointly sponsored summer schools and seminar series, presentations at international forums and at cross-departmental (USDA, EPA, DOE) conferences, and co-sponsored activities at professional meetings is underway.

RESULTS AND DISCUSSION

Task 3. GIS data compilation for Big Sky is being driven primarily by needs for analysis and modeling. Based on additional planning, the Big Sky GIS effort will focus primarily on planning and coordination, in particular 1) facilitation of GIS database implementation, 2) facilitation of multi-partner cyberinfrastructure development including links to NATCARB, 3) assistance with demonstration analyses and visualization using the database, and 4) assistance with multi-partner outreach efforts. Specific GIS planning activities to date include discussions/meeting with

NATCARB lead Tim Carr, planning sessions via teleconference involving Big Sky GIS personnel, and coordination with SW partnership and WGA;

Geographic Information System (GIS) data have been acquired for possible geological sink areas in the Big Sky Partnership geographic area. These data were defined during the 1995 National Assessment of United States Oil and Gas Resources conducted by the U.S. Geological Survey. The National Assessment identified oil and gas producing areas at a Province or Basin scale. In the Big Sky Carbon Sequestration Partnership ten Provinces were identified.

GIS layers at the next level of resolution, 'play', were also downloaded from the USGS National Oil and Gas Assessment website. Fully compliant Federal Geographic Data Committee (FGDC) Metadata for the two sets of GIS data layers were also downloaded. These GIS data layers will be used to perform an initial assessment to determine suitability for carbon sequestration.

Task 1. Results for identification of sources indicated that Idaho, Montana and South Dakota emitted approximately 11.7, 3.0 and 10.1 MMTCE, respectively, in 2002, or 9, 3 and 13 MTCE per capita. These values span the 6.6 MTCE estimated per capita gross emissions reported in the US EPA's Emissions Inventory for 2002 (USEPA 2004). Comparable analysis will be undertaken for Wyoming in the next two quarters.

Idaho and Montana benefited from increases in forest carbon storage that offset 22 and 56%, respectively, of their gross non-biogenic GHG emissions. Only 0.3 and 6%, respectively, of these offsets were attributable to land use change, however. In South Dakota, a decline in forest biomass meant that forests were net contributors to the GHG emissions total.

In Idaho, the largest proportion of gross emissions came from the Net Electricity Imports category (54%), followed by emissions from the transportation sector (17%). Fossil energy consumption accounted for 85% of gross emissions, while industrial non-energy emissions accounted for less than 1 percent. Utility emissions were very small (less than 0.01 percent), due to the importance of hydroelectric power in Idaho.

By contrast, Industrial energy emissions constitute the largest single category in the Montana inventory (36% of gross emissions), followed by utility emissions (30%) and transport emissions (14%). Montana is a net electricity exporter, so emissions associated with exported electricity, accounting for about 24 percent of gross emissions, were deducted from the net amount. Apart from Montana's energy production industries (coal mining and oil refining), the largest non-energy industrial emissions source is a single aluminum plant (2.6%).

In South Dakota, Net Electricity Imports again constituted the largest single category of GHG emissions (28%), followed by transportation (16.7%) and utility (10.5%) emissions. Agricultural emissions are more important in this state (15%) than in Idaho or Montana, due to the importance of the livestock industry. A single large cement plant accounts for the largest non-energy industrial emission (1.2%).

In addition to state-level inventory information, SDSMT is locating large point sources of GHGs within the Partnership GIS, in order to facilitate feasibility studies of carbon capture and

transport from major sources relative to potential geologic sinks. This process is complete for SD and underway for the other three states.

Our preliminary results for geological sinks suggest that mineral trapping for these basins will be rapid, with complete conversion of supercritical carbon dioxide to solid mineral carbonates within 400 years. This result has significant implications for the long-term containability and monitoring of a sequestration site because after a few hundred years the disposed CO₂ will be permanently tied up in solid phases.

Tasks 4 and 5. Preliminary results for terrestrial sequestration sinks indicate that the soils in our Partnership region have the capacity to store and productively utilize more soil C. However, the potential “size” of these sinks depends upon many biophysical and economic factors and the design of the policies and programs that are in place to sequester carbon.

We now report the results for assessment of the terrestrial sequestration on rangelands, by state. (See Appendix C.)

Idaho. The cross-tabulation analysis on the land cover classes for Idaho indicated that approximately 11 million acres could be classified as rangeland cover types. Of these, approximately 7.5 million hectares were shrublands, 2.8 million hectares were grassland/herbaceous, and 0.8 million were pasture/hay cover ([Table 1](#) - See Appendix C).

Of the land classified as rangeland types, approximately 7.1 million hectares fell under federal jurisdiction, 0.32 million were Indian Reservations, and 3.7 million hectares were private or other non-federal lands. With regard to climate potential, high climatic potential rangeland was 39% of the total rangeland area. Moderate climatic potential areas comprised 57% of the area and low climatic potential areas were only 4% of the rangeland area.

For the Major Land Resource Areas (MLRAs) within Idaho, the Northern Rocky Mountains MLRA had the greatest number of rangeland hectares at approximately 2.3 million ([Table 2](#) - See Appendix C). This was followed by the Owyhee High Plateau with 1.8 million hectares, the Eastern Idaho Plateaus with 1.2 million hectares, and the Lost River Valleys and Mountains MLRA with 1.1 million hectares. The remaining 10 MLRAs had area of rangeland types less than 1 million hectares ([Table 2](#)).

Using the combination of climatic potential, MLRA, and land tenure, areas within Idaho that could be potential targets for carbon sequestration programs were identified. Since programs will not likely be implemented on Federal lands, only Indian reservations and private or other non-federal lands will be discussed. Within the High Potential areas, Indian reservations in the Eastern Idaho Plateaus (75,061 ha), the Palouse and Nez Perce Prairies (58,544 ha) and the Northern Rocky Mountains (38,614 ha) MLRAs may be suitable areas for implementation of carbon sequestration programs ([Table 1](#)). On private or other non-federal land, the Eastern Idaho Plateaus (496,670 ha), Northern Rocky Mountains (310,872 ha) and the Upper Snake River Lava Plains and Hills (287,525 ha) MLRAs had the greatest area within the high climatic potential zones ([Table 1](#)).

Within the moderate potential zones, Indian Reservations within the Eastern Idaho Plateaus (54,189 ha), Owyhee High Plateau, (44,764 ha), and the Upper Snake River Plains (33,339 ha) MLRAs had the largest areas of land classified as rangeland types ([Table 1](#)). For private and other non-federal lands, the Upper Snake River Plains (370,495 ha) and the Central Snake River Plains (334,219 ha) MLRAs had the largest amount of rangeland when compared to the other MLRAs. It should be noted that rangeland area on Indian reservations is generally a much smaller percentage of the total area when compared to the private/non-federal lands ([Table 1](#)).

Low potential areas made up only a small percentage of the total rangeland area in Idaho ([Table 1](#)). It therefore should not be considered for carbon sequestration because of its low potential.

Montana. In Montana, the cross-tabulation analysis indicated that there was slightly over 21 million hectares of land that could be classified as rangeland ([Table 3](#) - See Appendix C). Of this land area, approximately 3.3 million hectares was classified as shrublands, slightly over 17 million hectares as grassland/herbaceous, and approximately 0.8 million hectares as pasture and hay land ([Table 3](#)). With regard to land tenure, private or other non-federal comprised approximately 14.5 million hectares of land classified as rangeland, federal land was approximately 4.8 million hectares and Indian reservations comprised approximately 2 million hectares of the rangeland land use types.

The majority of rangeland fell into the moderate climatic potential with 83% of the total rangeland area being in this class. High potential areas comprised 17% of the area, whereas low potential areas only made up 0.1% of the total rangeland area.

With regard the MLRAs within Montana, the Northern Rolling High Plains; Northern Part MLRA contained the largest area of rangeland types occupying approximately 8.6 million hectares ([Table 4](#) - See Appendix C). This was followed by the Northern Rocky Mountains and the Brown Glaciated Plain MLRAs with each having near 3 million hectares of rangeland. In all, Montana had 12 unique MLRAs.

An examination of the rangeland area within the high climate potential, MLRA, and land tenure classes revealed several areas that could be targeted for carbon sequestration efforts. For rangeland area categorized as Indian reservations, the Northern Rocky Mountain Foothills (174,495 ha) and the Northern Rocky Mountains (145,531 ha) had the largest areas ([Table 3](#)). For private and non-federal lands, the Northern Rocky Mountains (749,855 ha), Northern Rocky Mountain Foothills (530,763 ha) and the Northern Rocky Mountain Valleys (298,990 ha) MLRAs comprised the largest rangeland areas ([Table 3](#)) and would likely be excellent areas to target for carbon sequestration programs.

Within the moderate climatic potential areas, the Northern Rolling High Plains; Northern Part (506,158 ha) and the Brown Glaciated Plains (398,679 ha) MLRAs had the largest area of rangeland on Indian reservations ([Table 3](#)). For the private and non-federal land category, rangeland hectares were greatest for the Northern Rolling High Plains; Northern Part which comprised approximately 6.3 million acres. Although this MLRA has moderate climatic potential, development of a carbon sequestration program within this MLRA would impact approximately 30% of the rangeland in Montana. Other MLRAs that had substantial area

included the Brown Glaciated Plain (~1.7 million ha), the Northern Rocky Mountain Valleys (~1.1 million ha) and the Northern Rocky Mountain Foothills (1.1 million ha) MLRAs with each having greater than a million hectares of land classified as rangeland types ([Table 3](#)).

As with Idaho, the low climatic potential areas made up only a small percentage of the total rangeland area in Montana ([Table 3](#)) and therefore, should not be considered for carbon sequestration efforts.

South Dakota. The cross tabulation analysis for South Dakota indicated that approximately 12 million hectares of land in the state could be classified as rangeland vegetation ([Table 5](#) - See Appendix C). Grassland/herbaceous land cover occupied approximately 8.7 million hectares or 72% of the rangeland total. This was followed by the pasture/hay class with approximately 3 million hectares or 25% of the area classified as rangeland types ([Table 5](#)). Shrublands made up only about 3% of the total rangeland area.

Private or other non-federal land made up the largest portion of rangeland area in South Dakota with approximately 8.4 million hectares of land falling into this land tenure category. Indian reservations were the second with approximately 2.7 million hectares of rangeland. Federal land made up approximately 1 million hectares.

With regard to climatic potential class, rangelands falling within high climatic potential areas comprised 55% (6.7 million ha) of the total rangeland area. Rangelands falling into the moderate climatic potential category made up 45% of the total rangeland area. No land area in South Dakota fell into the low climatic potential category.

Two MLRAs had over 35% of all the rangeland in South Dakota within their boundaries. The Northern Rolling Pierre Shale Plains contained approximately 2.1 million hectares and the Pierre Shale Plains and Badlands contained approximately 2 million hectares of rangeland ([Table 6](#)). A total of 18 unique MLRAs occur in South Dakota.

The spatial cross-tabulation analysis identified several areas that could be targeted for carbon sequestration programs in South Dakota. In the high climatic potential regions, rangeland hectares were greatest for the Mixed Sandy and Silty Tableland (309,184 ha) and the Northern Rolling Pierre Shale Plains (238,655 ha) MLRAs within the borders of Indian reservations ([Table 5](#)). On Private and non-federal areas, the Southern Black Glaciated Plains (885,098 ha) and the Northern Rolling Pierre Shale Plains(801,423 ha) MLRAs made up the largest areas of rangelands. Three other MLRAs (Southern Dark Brown Glaciated Plains, Rolling Till Prairie and the Central Dark Brown Glaciated Plains) had approximately 500,000 hectares of rangeland within the high potential, private land category.

With regard to areas categorized as moderate climatic potential, the Rolling Soft Shale Plain (687,244 ha) and the Northern Rolling Pierre Shale Plains (387,962 ha) MLRAs had the greatest acreage with Indian reservations ([Table 5](#)). These two combine to total more than 1 million hectares. On areas categorized as private or non-federal land, two MLRAs, the Pierre Shale Plains and Badlands and the Northern Rolling High Plains; Eastern Part combine to total more than 2 million hectares of rangeland ([Table 5](#)).

Big Sky Region Rangeland Summary. Within the Big Sky Region study area, approximately 31.5 million hectares of rangeland occur on Indian reservations and private and other non-federal lands ([Table 7](#)). The majority of this rangeland occurs under moderate climatic potential (~21 million ha). However, approximately 10 million hectares of rangeland was classified as high climatic potential across the Big Sky region which equates to approximately 12% of the total land area in the study area. This would be a large area of impact for carbon sequestration on rangelands. Of the states within the study area, South Dakota had the largest total area of land classified as high climatic potential.

Task 16: We also provide some preliminary results from the pilot sites and analysis on terrestrial carbon in Montana's Golden triangle area. Many of the planned activities, including soil carbon analysis, assessment of diffuse reflectance infrared spectroscopy; nitrous oxide emission losses are still in progress. All farmer research partners remain actively engaged in this project and we will meet in late February to review field protocols for 2004. All farmers were interviewed in November to obtain detailed economic data about the costs and returns associated with each cropping system. This information will be used to assess net greenhouse gas emissions for each cropping system and determine cost-benefit relationships for adopting alternative cropping systems. During 2004, nitrous oxide flux measurements were collected at two field sites. Highest flux measurements were observed during May (Figure 5), and were associated with wet soil moisture conditions during this month. Results from these studies reveal that nitrous oxide emission moderate during the later part of June, and typically remain low or near background levels through the summer. If we assume a constant nitrous flux equivalent to 20 ug N/m^2 (greater than the majority of our observations), this would equate to only $0.14 \text{ kg of N ha}^{-1}$. Hence, the losses of nitrous oxide at our field sites appear nominal. Preliminary results suggest that adequate soil C estimations can be made using VNIR diffuse reflectance spectroscopy, provided 20% of a given sample set is submitted for regular laboratory analysis for model calibration (Figure 6). To date, these models have not proven very robust, a problem we are addressing through different modeling approaches and sample pre-treatments.

Baseline soil carbon values (Table 1) show greater variability than soil texture and pH values (data not shown). Statistical analysis of carbon data has not been done for we are interested in the change in soil carbon values as a function of the management treatments applied to the plots; therefore, analysis of carbon change will occur once the 2004 soil samples have been analyzed for SOC. No statistically significant differences in crop biomass were seen between treatments in 2003 (Table 2). In addition to changes in soil carbon, the agronomic effects of the treatments are also being investigated. Total biomass was measured at the same locations that soil carbon is measured. Significant differences between sites, tillage treatments, and cropping intensities were seen during the 2004 growing season (Tables 3 and 4). These differences are likely attributable to soil water status differences between treatments. Differences in crop yield and quality will also be investigated; samples have yet to be threshed for yield calculation. The amount of C and N returned to the soil will be calculated for each sampling location. Economic evaluation of the 4 cropping systems at each site will be completed after farm management data have been collected in November.

Preliminary results suggest that adequate soil C estimations can be made using VNIR diffuse reflectance spectroscopy, provided 20% of a given sample set is submitted for regular laboratory analysis for model calibration. To date, these models have not proven very robust, a problem we are addressing through different modeling approaches and sample pre-treatments.

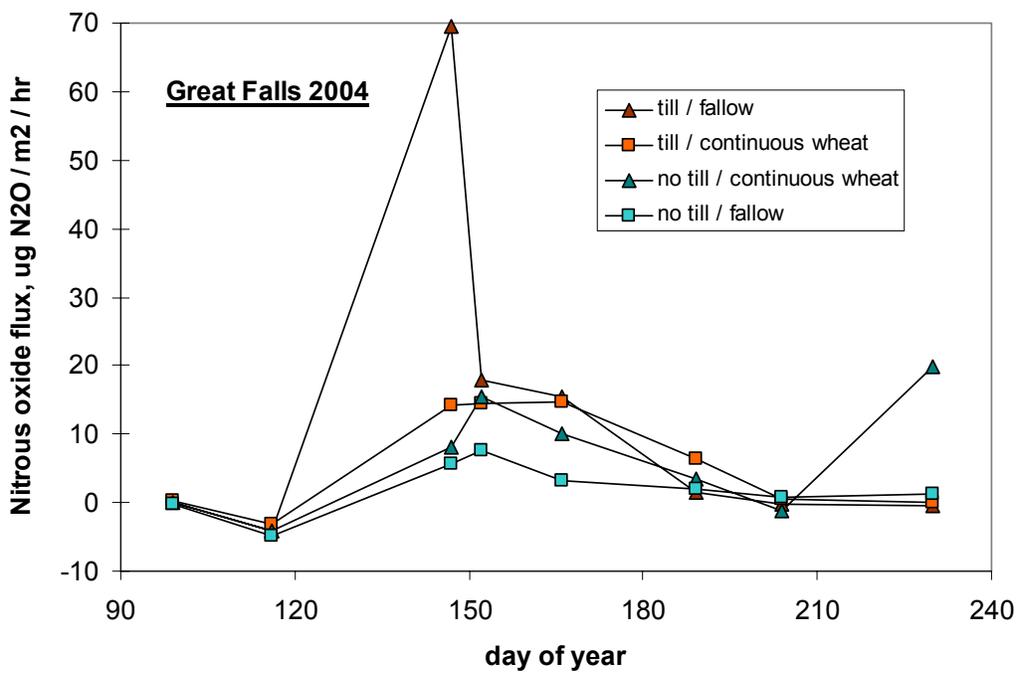
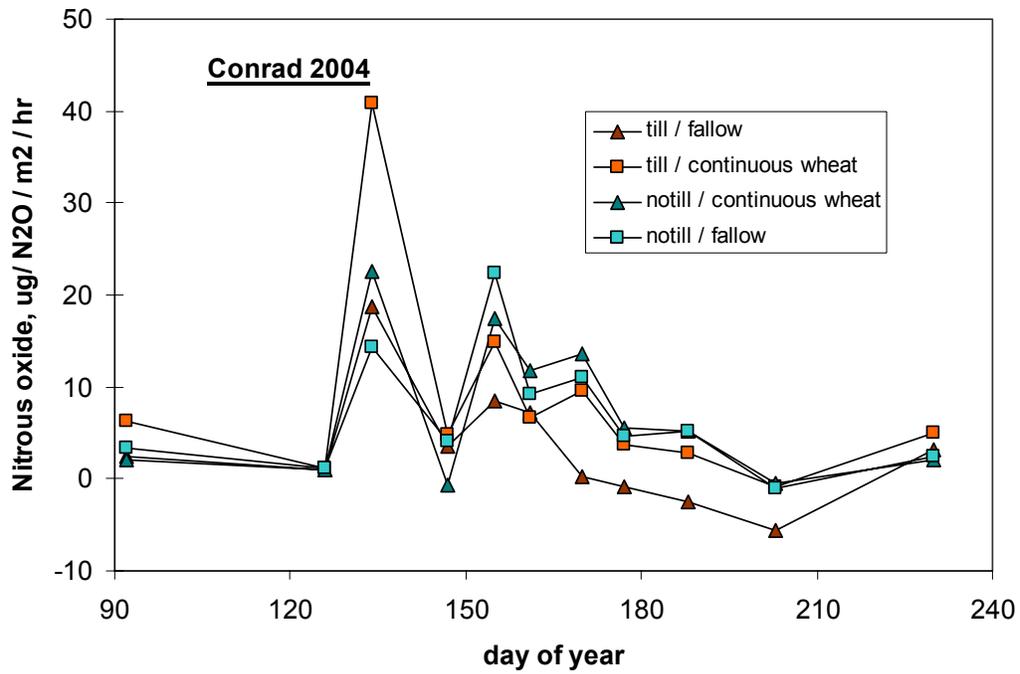


Figure 5. Seasonal distribution of N₂O emissions from Conrad and Great Falls farm sites in north central Montana.

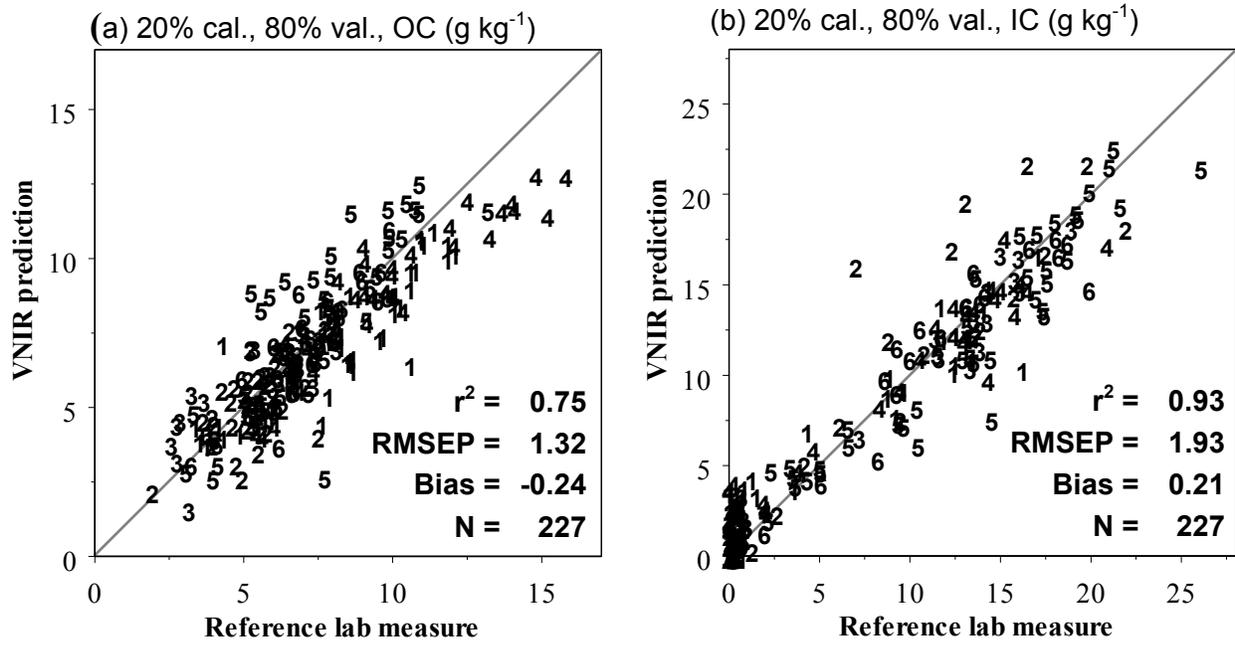


Figure 6. Predicted organic carbon (OC) and inorganic carbon (IC) using VNIR diffuse reflectance spectroscopy.

Table 1. Soil organic carbon ($t\ ha^{-1}$) by depth for each plot at Chester, Collins, Conrad, Great Falls, Kremlin, and Power, Sept. – Oct., 2002.

Crop System	Chester	Collins	Conrad	Great Falls	Kremlin	Power
----- 0-10 cm -----						
Tilled F-W	10.8	12.5	15.5	17.9	10.1	15.5
No-till F-W	10.3	10.8	12.0	15.1	9.3	17.1
Tilled W-L	10.2	11.8	13.3	14.7	8.3	14.1
No-till W-L	9.9	10.7	13.3	18.5	10.8	11.8
SE	0.3	0.6	0.7	1.1	0.4	0.9
----- 10-20 cm -----						
Tilled F-W	10.7	8.6	12.2	11.2	7.7	12.6
No-till F-W	10.7	11.0	11.3	11.6	7.2	12.3
Tilled W-L	10.1	8.8	11.4	11.8	7.8	11.7
No-till W-L	10.2	10.3	11.6	11.8	6.9	13.6
SE	1.0	0.6	0.6	0.4	0.2	0.5
----- 20-50 cm -----						
Tilled F-W	7.9	7.4	9.6	9.0	7.8	7.2
No-till F-W	6.3	6.9	10.1	9.0	7.1	7.6
Tilled W-L	7.6	8.2	9.3	8.4	7.5	10.7*
No-till W-L	8.1	8.2	9.5	8.6	6.7	8.7
SE	0.6	0.4	0.5	0.5	0.3	1.3
----- 50-100 cm -----						
Tilled F-W	6.9	6.5	8.4	7.4	4.8	5.5
No-till F-W	6.6	6.3	7.8	7.3	3.5*	5.6
Tilled W-L	6.8	5.8	8.2	7.1	ND	5.6
No-till W-L	8.3	6.1	8.7	6.5	5.9	4.1
SE	0.5	0.2	0.7	1.2	0.5	1.2

ND = no data, samples were not able to be collected at that depth due to soil conditions.

- Values that are under review.

Table 2. Crop biomass ($t\ ha^{-1}$) for each plot at Chester, Collins, Conrad, Great Falls, Kremlin and Power, 2003

Crop System	Location and crop					
	Chester peas	Collins peas	Conrad lentils	Great Falls pea/barley	Kremlin peas	Power pea/barley
Tilled W-L	1.5	1.7	0.8	4.1	2.3	2.2
No-till W-L	1.8	1.8	0.7	4.1	2.5	1.6
Tilled F-W	----	----	----	----	----	----
No-till F-W	----	----	----	----	----	----

Table 3. Crop biomass ($t\ ha^{-1}$) for each plot at Chester, Collins, Conrad, Great Falls, Kremlin and Power, 2004

Crop System	Location and crop					
	Chester wheat	Collins wheat	Conrad wheat	Great Falls wheat	Kremlin wheat	Power wheat
Tilled W-L	5.3	4.0	7.1	8.1	6.2	4.2
No-till W-L	5.1	4.5	7.1	9.6	6.0	5.3
Tilled F-W	8.1	6.9	9.3	12.2	8.5	3.8
No-till F-W	7.5	8.4	9.3	12.9	7.8	6.5

NT = no-till; T = tilled; F-W = fallow wheat rotation; L-W – lentil wheat rotation

Table 4. ANOVA results for total wheat biomass, 2004

Source	df	Prob>F	Effect
Site	5	<0.0001	
Tillage	1	0.0019	NT>T
Intensity	1	<0.0001	Fallow > Recrop
SxT	5	0.0001	Sites 1,2, and 5 significantly different
SxI	5	<0.0001	Sites 1,3,4,5, and 6, significantly different
TxI	1	0.6484	
SxTxI	5	0.2479	

1) Collins, 2) Power, 3) Chester, 4) Conrad, 5) Great Falls, and 6) Kremlin.

TASK 19. Assess Available Measurement Instruments that can be used to Measure, Monitor and Verify Carbon Storage in Carbon Sequestration Projects

Throckmorton NIRS Sample Selection and Equation Performance. Of the 460 samples that were scanned, 107 samples (23.2%) were identified as being spectrally unique representatives of the population and were used for equation development (Figure 17 – see Appendix C), these samples along with an additional 25 randomly selected samples for validation, and 10 replicate samples for estimating the lab error were analyzed at the University of Nebraska for total carbon (TC), inorganic carbon (IC), organic carbon (OC), and total nitrogen (TN) determination. An equation for all four constituents was developed based on the 107 selected samples and used to predict the validation set of 25 samples randomly selected from the rest of the population. The validation set was then combined with the calibration set in order to increase sample number and a new equation was developed. The validation prediction results as well as the combined cross validation results are presented in Table 8 (see Appendix C).

Lab and NIR Error Comparison. A standard error of the difference (SED) analysis was used to compare lab error to NIR prediction error. This process is done by comparing the standard error of the difference between replicate lab samples (n=10) and NIRS cross validation error. The SED for the lab for organic carbon was 0.301 (percent basis) and the standard error of cross validation (SECV) for NIRS was 0.313 which is 1.03 times that of the lab error. According to

NIRS forage industry standards (WinISI handbook) NIRS predictions should be within 1.5 times that of the lab error. These results are within those limits.

In order to increase the robustness of the equation, 68 samples from a separate study on this ranch, were added to the calibration set and a final equation was developed. Since this calibration had similar RSQ and SECV values, it was used to predict the remaining 328 samples and the SECV for this equation of 0.251 was used as an estimate of the prediction error for the unanalyzed samples (Table 9 – see Appendix C).

General Soil Equation and NIR Prediction of Carbon Fractions. Two general soil carbon equations were developed based on diverse sets of samples collected throughout the country (Appendix III). The first equation presented here uses 661 samples for organic carbon and 502 samples for total nitrogen. The RSQ and SECV for organic carbon are 0.92, 0.204 and for nitrogen 0.92, 0.019 (Figure 18 and Figure 19, respectively). The locations, labs and collaborators associated with the samples in the above carbon and nitrogen equations are listed in Appendix II.

In the first equation samples with carbon or nitrogen lab value which deviated more than 1.5 standard deviations from the NIR prediction were eliminated from the equation. The results of a second equation with additional samples collected from Konza Prairie (in cooperation with Kansas State University) and using a less strict criteria (2.5 standard deviations) for removing outliers is presented in Table 10. As the number of samples in a general equation becomes very large, statistical procedures other than Partial Least Squares (PLS) regression, such as neural networks or Winisi local predictions, may become more effective for predicting unknown samples. In any case, it will always be essential that the prediction equation include samples that are spectrally similar to the samples being predicted and that the laboratory determinations of the samples used for equation development are accurate.

Carbon Fractions and Bulk Density. We are looking at carbon fractions as possible early indicators of carbon sequestration, while acknowledging that their high variability may render many of these properties inappropriate as early indicators. Results are presented for glomalin, particulate organic matter (POM), amino sugar, β -glucosaminidase, and β -glucosidase (Table 11). It is not known whether the relatively high error of prediction and low R^2 is due to limited data range, poorly defined constituents, lab techniques, or NIR limitations. Further work is needed in this area.

The problem of reliable estimates of bulk density as well as rock content has not been well addressed. However, as suggested by Smith (2001), this error can be greatly reduced when measurements are focused on changes in soil carbon, rather than absolute stock – by treating rock content and bulk density as constants. Accordingly, we would recommend that until improved field measurements methods are developed for estimating rock content in rocky soils, a best possible initial estimate be made for bulk density and rock content and that this same estimate be used in subsequent samplings. The primary source could be standard published soil survey data from NRCS.

Currently we have an NIR equation for predicting bulk density at Throckmorton with an SECV of 0.119 and R^2 of 0.57. Clearly more work is needed on reliable in-field methods for estimating bulk density as well as for organic carbon.

Time and Cost Comparison NIR vs. Conventional Laboratory. A breakdown of time per sample for collecting and preparing samples for analysis including bulk density and rock component determinations is summarized below:

Collecting and processing	min./sample
Collecting samples	10
Separating into depth increments	8
Bulk density/moisture determination	3
Grinding and sieving	8
Calculating rock component	8
Total	37

Until in-field NIR methods are developed, the time and cost for both NIR and conventional soil collecting and preparation are identical. Here, we are concerned with comparing time per sample for conventional vs. NIR analysis. Estimates for conventional per sample time were obtained from Cathleen McFadden at the University of Nebraska laboratory. This estimate is for samples containing carbonates which require acid treatment and two sample runs.

Process Lab NIR	minutes
Sample run time (1)	61.4
Calibration time	10.1 (7 minutes/day)
Instrument maintenance	(change lamp – 6-8 months)
Sample packing (total carbon)	32
Treatment for organic C	30
Sample packing (organic C)	30
Sample run time (2)	60
Total	233.6

Considering that there are now analyzers on the market that can do both total and organic/inorganic carbon in about 4-5 minutes and that there are also automated samplers for NIR instruments, other time estimates are possible for future analyses. For the present evaluation, we used the estimates based on the Throckmorton samples which have a difference of about 19 minutes per sample. Based on an equal labor costs (\$10.00/hr.) this would be a difference of about \$3.17/sample. Likely the labor cost per hour would also be less for the NIR operator because the NIR instrument can be run by a student worker with only a few minutes of instruction, where as an elemental analyzer requires a trained laboratory technician.

Tasks 8, 23, 25: Outreach and education.

A series of meetings held since the Partnership's inception has laid the foundations for assessing the issues surrounding the implementation of a market-based setting for soil C credits. These include the impact of existing local, state, and federal permitting issues for terrestrial based carbon sequestration projects, consistency of final protocols and planning standards with national

requirements, and alignments of carbon sequestration projects with existing federal and state cost-share programs. These meetings provide a connection to stakeholders in the region.

The education and outreach efforts have resulted in a comprehensive plan which serves as a guide for implementing the outreach activities under Phase I. The primary goal of this plan is to increase awareness, understanding, and public acceptance of sequestration efforts and to build support for a constituent-based network which includes the initial Big Sky Partnership and other local and regional businesses and entities. Presentations about the Partnership have been made at the Western Governors' Annual meeting (June 04), the Western Energy Summit (April 04), the NETL/DOE carbon sequestration meeting (May 04), Pioneer Hi-Bred in August 04, the INRA science symposiums (Sept 04) and the American Society of Mechanical Engineers (ASME) (August 04) and in meetings with industry representatives. Fact sheets and posters were developed for these presentations (see Appendix A). PowerPoint presentations are posted on our website (www.bigskyco2.org).

The public website makes available many of the presentations to stakeholders and policy makers, provides a connection to other federal and state agencies concerned with GHG emissions, climate change, and efficient and environmentally-friendly energy production. In addition, we have laid plans for integration of our outreach efforts with the students through the ASME workshop, the film and media arts departments at MSU, and with outreach efforts at LANL. Finally, both Pam Tomski, outreach coordinator, and Susan Capalbo, PI for the Big Sky Partnership are involved in U.S.-Norway bilaterals in an effort to provide for an exchange of research and students/faculty. In related efforts, Pam Tomski organized the first U.S./Norway Summer School held at LANL in August 2004. This will be an annual event, rotating between the U.S. and Norway.

CONCLUSIONS

The Big Sky Partnership undertakes activities in four areas: evaluation of sources and carbon sequestration sinks; development of GIS-based reporting framework; designing an integrated suite of monitoring, measuring, and verification technologies; and initiating a comprehensive education and outreach program. The groundwork is in place to provide a comprehensive assessment of capture and storage capabilities for CO₂ utilizing the resources found in the Partnership region (both geological and terrestrial sinks). Steps have been taken to assure that the GIS-based framework is consistent among types of sinks within the Big Sky Partnership area and with the efforts of other western DOE partnerships. The Partnership secured supplemental funding to include Wyoming in the coverage areas for both geological and terrestrial sinks and sources. This extended coverage will be the focus of the efforts in the next six months on the sources and carbon sinks.

These activities are putting in place a map-based integrated information management system for our Partnership, with transferability to the national carbon sequestration efforts. This framework will also be critically important to the evaluation of future sequestration technologies, which by necessity must utilize simulation modeling and other related techniques for assessing environmental impacts and cost effectiveness.

The Partnership recognizes the critical importance of measurement, monitoring, and verification technologies to support not only carbon trading but all policies and programs that DOE and other agencies may want to pursue in support of GHG mitigation. The efforts begun in developing and implementing MMV technologies for geological sequestration reflect this concern. Research is also underway to identify and validate best management practices for soil C in the Partnership region, and to design a risk/cost effectiveness framework to make comparative assessments of each viable sink, taking into account economic costs, offsetting benefits, scale of sequestration opportunities, spatial and time dimensions, environmental risks, and long term viability. Scientifically sound information on MMV is critical for public acceptance of these technologies.

Results of research testing the feasibility of NIR technology were presented. Two general soil carbon equations demonstrate that NIR can be used to estimate soil carbon over a diverse array of soil types collected from a wide geographic area. Also, our time/cost comparisons illustrates the economic advantage of NIR technology over standard analytical methods. While NIR estimates are not as accurate as dry combustion determinations, NIR has a growing potential for in-field estimates using light-weight portable instruments. This would greatly facilitate the ease of taking larger sample numbers at more frequent intervals, which in turn, could actually improve landscape estimates of carbon stocks over traditional methods.

Finally, the education and outreach efforts have resulted in a comprehensive plan which serves as a guide for implementing the outreach activities under Phase I. The primary goal of this plan is to increase awareness, understanding, and public acceptance of sequestration efforts and to build support for a constituent-based network which includes the initial Big Sky Partnership and other local and regional businesses and entities. Presentations about the Partnership have been made at the Western Governors' Annual meeting (June 04), the Western Energy Summit (April 04), the NETL/DOE carbon sequestration meeting (May 04), Pioneer Hi-Bred (August 04), the INRA science symposiums (Sept 04) and the American Society of Mechanical Engineers (ASME) (August 04) and in meetings with industry representatives. The website makes available many of the presentations to stakeholders and policy makers, provides a connection to other federal and state agencies concerned with GHG emissions, climate change, and efficient and environmentally-friendly energy production.

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APPENDICES

APPENDICES

- A. Fact Sheet for Big Sky Carbon Sequestration Partnership, June 2004
- B. Big Sky Carbon Sequestration Partnership Advisory Committee
- C. Supplementary Tables and Figures
- D. Agenda for Big Sky Regional Carbon Sequestration Partnership meeting, August 24-26, 2004, INEEL, Idaho Falls, ID
- E. Agenda for ASME Carbon Sequestration Symposium, August 26, 2004, Idaho Falls, ID
- F. Request for Supplemental DOE Support
- G. Big Sky Regional Carbon Sequestration Partnership website
- H. Deliverable 4 – Geologic Carbon Sequestration GIS Database Structure and Summary of Infrastructure Data Compilation and Analysis Inputs
Deliverable 9 – Terrestrial GIS Data
- I. Agenda for INRA Symposium, September 21, 2004, Spokane, WA, and Abstracts of presentations given at INRA Symposium
- J. National Carbon Offset Coalition brochures for January 2005 workshops (drafts)
- K. News article on Carbon Cropping, Post Register, Idaho Falls, ID, August 30, 2004
- L. Patent Clearance document

Appendix 1. The Northern Rockies and Great Plains Regional Carbon Sequestration Partnership MLRAs

Appendix 2. Lists of locations, sample numbers, laboratories, and contributing scientists for samples used in the first general carbon equation

Appendix 3. Soils database – listing collection locations, labs, constituents of interest and collaborators

FIGURES

- Figure 1. Spatial classification of climatic potential for Idaho. Areas classified as High Potential have greater than 460mm of precipitation per year. Areas classified as Moderate Potential have between 230 and 460 mm of precipitation per year. Areas classified as Low Potential have between 130 and 230 mm of precipitation per year.
- Figure 2. Spatial classification of climatic potential for Montana. Areas classified as High Potential have greater than 460mm of precipitation per year. Areas classified as Moderate Potential have between 230 and 460 mm of precipitation per year. Areas classified as Low Potential have between 130 and 230 mm of precipitation per year.
- Figure 3. Spatial classification of climatic potential for South Dakota. Areas classified as High Potential have greater than 460mm of precipitation per year. Areas classified as Moderate Potential have between 230 and 460 mm of precipitation per year.
- Figure 4. Major land resource areas (MLRAs) within the state of Idaho.
- Figure 5. Major land resource areas (MLRAs) within the state of Montana.
- Figure 6. Major land resource areas (MLRAs) within the state of South Dakota
- Figure 7. Federal lands and Indian reservations within the state of Idaho.
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- Figure 9. Federal lands and Indian reservations within the state of South Dakota
- Figure 10. Rangeland cover types for the state of Idaho as classified by the National Land Cover Database.
- Figure 11. Rangeland cover types for the state of Montana as classified by the National Land Cover Database.
- Figure 12. Rangeland cover types for the state of South Dakota as classified by the National Land Cover Database.
- Figure 13. Sampling units (red lines) used in the spatial cross tabulation for the state of Idaho. The sampling units represent the intersection of the Major Land Resource Areas, climatic potential, and Federal Lands and Indian Reservations map coverage that were used in the spatial cross-tabulation analysis of the National Land Cover Database to determine area coverage of rangeland land cover classes (shrublands, grassland/herbaceous, and pasture/hay).
- Figure 14. Sampling units (red lines) used in the spatial cross tabulation for the state of Montana. The sampling units represent the intersection of the Major Land Resource Areas, climatic potential, and Federal Lands and Indian Reservations map coverage that were used in the spatial cross-tabulation analysis of the National Land Cover Database to determine area coverage of rangeland land cover classes (shrublands, grassland/herbaceous, and pasture/hay).
- Figure 15. Sampling units (red lines) used in the spatial cross tabulation for the state of South Dakota. The sampling units represent the intersection of the Major Land Resource Areas, climatic potential, and Federal Lands and Indian Reservations map coverage that were used in the spatial cross-tabulation analysis of the National Land Cover Database to determine area coverage of rangeland land cover classes (shrublands, grassland/herbaceous, and pasture/hay).
- Figure 16. Distribution of sample points for Throckmorton Ranch placed over soil map and pasture boundaries.
- Figure 17. Selection of spectrally unique samples used to reduce laboratory costs and to choose samples that represent the range of population variance for equation development. From a total of 460 samples (left box) this procedure identified 107 spectrally unique samples (right box).
- Figure 18. NIR cross validation prediction results for organic carbon using soils diverse locations. (n = 661)
- Figure 19. NIR cross validation prediction results for total nitrogen using soils diverse locations (n = 502)

TABLES

- Table 1. Rangeland (ha) by land cover class and sums of the classes for Major Land Resource Area (MLRA) and land tenure class grouped according to Climatic Potential for carbon sequestration in Idaho. Percent of total reflects the percent of total rangeland occupied by the MLRA and Land Tenure class within the climatic potential grouping.
- Table 2. Total hectares of rangeland cover types identified in Major Land Resource Areas (MLRA) in Idaho.
- Table 3. Rangeland (ha) by land cover class and sums of the classes for Major Land Resource Area (MLRA) and land tenure class grouped according to Climatic Potential for carbon sequestration in Montana. Percent of total reflects the percent of total

rangeland occupied by the MLRA and Land Tenure class within the climatic potential grouping.

Table 4. Total hectares of rangeland cover types identified in Major Land Resource Areas (MLRA) in Montana.

Table 5. Rangeland (ha) by land cover class and sums of the classes for Major Land Resource Area (MLRA) and land tenure class grouped according to Climatic Potential for carbon sequestration in South Dakota. Percent of total reflects the percent of total rangeland occupied by the MLRA and Land Tenure class within the Climatic Potential grouping.

Table 6. Total hectares of rangeland cover types identified in Major Land Resource Areas (MLRA) in South Dakota.

Table 7. Rangeland (ha) for each state in the Big Sky Project by climatic potential (annual precipitation) and land tenure class. Federal lands are not included since they will most likely not be included in carbon sequestration programs.

Table 8. Prediction statistics for the independent validation set predicted from the equation derived from the 107 analyzed samples and cross validation results obtained from combining the validation set with the calibration set. Values are percentages.

Table 9. Cross Validation Results for Final NIR Throckmorton Equation.

Table 10. Cross Validation Results for Second General Organic Carbon and Total Nitrogen Equation

Table 11. Cross validation predictions of selected carbon fractions.



A new energy future for Montana, Idaho, South Dakota and the nation.

Led by Montana State University, the **Big Sky Partnership** is one of the U.S. Department of Energy's seven regional partnerships. To date, the Partnership includes Montana, Idaho and South Dakota, as well as contiguous parts of neighboring states and Canada. The Partnership is developing a framework to reduce carbon dioxide emissions that contribute to climate change and is working with stakeholders to create the vision for a new, sustainable energy future that cleanly meets the region's energy needs.

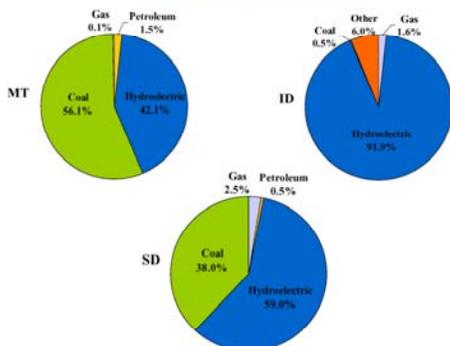


Because energy is not an optional commodity, carbon sequestration will play an important role.

What is CO₂ Sequestration?

Carbon dioxide, CO₂, is a major by-product of energy use. Abundant coal and hydropower offer Montana, Idaho and South Dakota some of the lowest cost electricity in the nation. However, burning fossil fuels for transportation, electricity generation and manufacturing emits greenhouse gases (GHG) that may impact regional and global climate. "Carbon sequestration" is a family of methods for capturing and permanently isolating gases that otherwise could contribute to global climate change. Affordable and environmentally safe sequestration approaches could offer a way to stabilize atmospheric levels of carbon dioxide.

Electricity Generation & GHG Emissions in the Big Sky Region



Two Approaches To Carbon Sequestration

The **Big Sky Partnership** is researching two major types of carbon sequestration projects: **geologic** and **terrestrial**.



Geologic sequestration involves storing carbon dioxide in geologic formations including oil and gas reservoirs, deep saline reservoirs and coal seams. These are structures that have stored crude oil, natural gas, brine and CO₂ for over millions of years. Many power plants and other large emitters of CO₂ are located near geologic formations that are amenable to CO₂ storage. In many cases the injection of CO₂ into a geologic formation can enhance the recovery of hydrocarbons, providing value-added by-products that can offset the cost of CO₂ capture and sequestration.

Terrestrial sequestration relies on management practices of agricultural lands, rangelands, forests and wetlands to remove CO₂ from the atmosphere via photosynthesis and at the same time reduce CO₂ emissions. No-till or reduced till methods, increased crop rotation intensity, the use of higher residue crops, cover crops or conservation measures are all means of increasing carbon storage in agricultural soils.



Terrestrial sequestration reduces emissions while improving land and water quality, thus making soils healthier, more productive and less susceptible to large-scale CO₂ release. Enhancing the natural processes that remove CO₂ from the atmosphere is thought to be one of the most cost-effective means of reducing atmospheric levels of CO₂.

Regional Sequestration Opportunities

The objectives of the **Big Sky Partnership** fall into four areas:

- Evaluation of sources and carbon sequestration sinks with the goal of identifying viable projects;
- Development of GIS-based reporting framework;
- Designing an integrated suite of measuring, monitoring and verification technologies;
- Initiating a comprehensive education and outreach program aimed at connecting with communities and organizations within the region

The region has a diverse array of geologic formations that could provide storage options for carbon in one or more of its three states. Likewise, initial estimates of terrestrial sinks indicate a vast potential for increasing and maintaining soil C on forested, agricultural and reclaimed lands. Both options include the potential for offsetting economic benefits to industry and society.

Complementary to the efforts on evaluation of sources and sinks is the development of the **Big Sky Partnership Carbon Cyberinfrastructure (BSP - CC)** and a GIS Road Map for the Partnership. These efforts are putting in place a map-based integrated information management system or carbon atlas for our Partnership with transferability to the national carbon sequestration effort.

Measurement and Verification

The **Big Sky Partnership** recognizes the critical importance of measurement, monitoring and verification technologies to support not only carbon trading, but other policies and programs the DOE and other agencies may want to pursue in support of GHG mitigation. The efforts begun in developing and implementing MMV (measurement, monitoring and verification) technologies for geologic sequestration reflect this concern. Research is also underway to identify and validate best management practices for soil C in the Big Sky region, and to design a risk/cost effectiveness framework to make comparative assessments of each viable sink, taking into account economic costs, offsetting benefits, scale of sequestration opportunities, spatial and temporal dimensions, environmental risks and long term viability.



For More Information

Please visit our website: www.bigskyco2.org or contact:

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Marketing Carbon Credits

The **Big Sky Partnership** is assessing the issues surrounding the implementation of a market-based setting for soil C credits. These include the impact of existing local, state and federal permitting issues for terrestrial-based carbon sequestration projects, consistency of final protocols and planning standards with national requirements, and alignments of carbon sequestration projects with existing federal and state cost-share programs.

Connecting with the Communities and Industry

The education and outreach efforts have resulted in a comprehensive plan whose primary goal is to increase awareness, understanding, and public acceptance of sequestration efforts and build support for a constituent-based network, which includes the initial **Big Sky Partnership** and other local and regional businesses and entities.

The Big Sky Partnership Team

- ❖ Montana State University
- ❖ Boise State University
- ❖ EnTech Strategies, LLC
- ❖ National Carbon Offset Coalition
- ❖ South Dakota School of Mines & Technology
- ❖ Texas A & M University
- ❖ University of Idaho
- ❖ Idaho National Engineering and Environmental Laboratory (INEEL)
- ❖ Los Alamos National Laboratory (LANL)
- ❖ Inland Northwest Research Alliance (INRA)
- ❖ U.S. Department of Energy
- ❖ Montana Governor's Carbon Sequestration Working Group
- ❖ The Confederated Salish and Kootenai Tribes
- ❖ Nez Perce Tribe
- ❖ The Sampson Group
- ❖ Environmental Financial Products, LLC
- ❖ Idaho Carbon Sequestration Advisory Committee (ICSAC) / Idaho Soil Conservation Committee
- ❖ Montana Bureau of Mines and Geology



Appendix B

Big Sky Partnership External Advisory Committee

Mission:

The External Advisory Committee will:

- (i) provide input on the direction and progress of the Big Sky Partnership toward meeting the goals of the Phase I efforts (Oct 03-Sept 05);
- (ii) facilitate transfer of ideas and research between the Big Sky partnership and its constituencies; and
- (iii) provide advice and direction to the Big Sky Partnership with respect to a Phase II proposal and work plan.

To the extent possible the Advisory Committee will meet via videoconferencing or conference calls. A progress meeting and Phase II planning workshop is tentatively planned for Spring 05. Travel expenses for the Advisory Committee will be covered by the Big Sky Partnership.

Members:

Confirmed:

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Mr. Ned Leonard
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(703) 684-4748
ned@westernfuels.org

Invited:

Dr. David Wendt, Director of Jackson Hole Center for Global Affairs

Dr. Maurice J. Mausbach, Deputy Chief
Soil Survey and Resource Assessment
Natural Resources Conservation Service, USDA

Mr. Michael Jones, Puget Sound Energy, Seattle, WA

Robert Harriss
Director of the Societal Impacts group
National Center for Atmospheric Research, Boulder, Colorado

Bruce McCulloch, Sempra Energy Systems

Big Sky Partnership

The Northern Rockies and Great Plains Regional Carbon Sequestration Partnership_MLRAs

Appendix 1

Summary of MLRA Attributes for Montana, Idaho, and South Dakota

% of region	MLRA	NAME	Area km²	Area mi²	States
	10	Upper Snake River Lava Plains and Hills (10A proposed)	44,870	17,330	Idaho and Oregon
	11	Snake River Plains (11A and 11B proposed)	35,250	13,610	Idaho and Oregon
	12	Lost River Valleys and Mountains	16,380	6,320	Idaho
	13	Eastern Idaho Plateaus	21,010	8,110	Idaho
	43	Northern Rocky Mountains	282,650	109,130	Idaho, Montana, Oregon, Washington, and Wyoming
	44	Northern Rocky Mountain Valleys	32,320	12,480	Idaho, Montana, and Washington
1/2 north	46	Northern Rocky Mountain Foothills	52,070	20,110	Montana and Wyoming
	52	Brown Glaciated Plain	52,110	20,120	Montana
2/3 west	53 A	Northern Dark Brown Glaciated Plains	30,740	11,870	Montana and North Dakota
1/3 south	53 B	Central Dark Brown Glaciated Plains	44,980	17,370	North Dakota and South Dakota
	53 C	Southern Dark Brown Glaciated Plains	13,870	5,350	South Dakota
1/3 south	54	Rolling Soft Shale Plain	58,100	22,430	Montana, North Dakota, and South Dakota
	55 C	Southern Black Glaciated Plains	20,240	7,810	South Dakota
	58 A	Northern Rolling High Plains; Northern Part	105,620	40,780	Montana and Wyoming
1/2 south	58 D	Northern Rolling High Plains; Eastern Part	10,000	3,860	North Dakota and South Dakota
	60 A	Pierre Shale Plains and Badlands	23,600	9,110	Nebraska, South Dakota, and Wyoming
	60 B	Pierre Shale Plains; Northern Part	5,600	2,160	Montana
	61	Black Hills Foot Slopes	8,400	3,240	South Dakota and Wyoming
	62	Black Hills (home of Rocky Racoon)	9,200	3,550	South Dakota and Wyoming
	63 A	Northern Rolling Pierre Shale Plains	29,610	11,430	South Dakota
1/2 north	64	Mixed Sandy and Silty Tableland	28,400	10,970	Nebraska, South Dakota, and Wyoming
1/3 north	66	Dakota-Nebraska Eroded Tableland	12,400	4,800	Nebraska and South Dakota
1/2 west	102 A	Rolling Till Prairie	38,600	14,900	Minnesota and South Dakota
	102 B	Till Plains	43,790	16,910	Iowa, Minnesota, South Dakota, and Nebraska

Land use

3/5 federal, 90% range, 5% (along streams) irrigated for potatoes, small grains, pasture

1/2 federal - mostly range, annual grasses have invaded much of the rangeland, 1/4 irrigated potatoes

mostly all federal, high mountain slopes are forested, grass - shrubs on slopes and valleys are grazed

1/4 federal, 1/2 range, 1/4 dryfarm - wheat, ~10% irrigated -alfalfa, ~10% forested mt. slopes

Nearly all this area is federally owned, less than 2% cropped, Mostly forest -lumbering and mining

farms and ranches. 1/2-1/3 native range (grass-shrub) , 1/3 irrigated - Potatoes, sugar beets, and peas

1/5 federal, 1/2 range of short and mid grass, 1/5 dryfarm (northeast side) wheat

Most of the land in the east is in range/ one-half of the total area is cropped (west) spring wheat

1/2+ dryland farm mostly spring wheat / sloping soils are in native grass range

1/2+ is dryfarmed -.winter wheat chief cash crop. Corn, grain, sorghum, oats, and alfalfa also grown sloping soils are in range.

2/3 dryland Spring wheat is the chief crop / flax, oats, barley, and alfalfa also grown / more sloping soil in native grass range

1/3 dry farmed wheat/ 3/5 native grass and shrub grazed /

70% dryland farm.- Corn, small grains, and alfalfa main crops / 1/4 native range and tame pasture along steeper slopes

Most in native grasses and shrubs grazed by cattle and sheep / rest dryland farming in wheat / sugar beets, alfalfa along river

4/5 ranches in native grasses and shrubs grazed by cattle and sheep 10-15% dryland wheat and alfalfa

Most of it is in native grasses and is used for grazing livestock / Badlands National Monument is a large tourist attraction.

Most of it is rangeland used for grazing livestock

Native grass is used mainly for livestock grazing. / the less sloping parts are farmed mainly to alfalfa and small grains

Black Hills National Forest used for mining, recreation, and hunting./Some timber / summer grazing

area is used mainly for livestock production and cash-grain farming / Dry-farming soils not suited to cultivation is destroying the native grassland

3/5 rangeland cattle / 1/3 crop cash grain and winter wheat / corn and sugar beets are irrigated crops

Most of this area is in native grasses that are grazed by cattle

70 % is cropland Corn, soybeans, alfalfa, flax, spring wheat, and oats are the principal crops /

70% cropland Corn, soybeans, grain sorghum, alfalfa, and oats are the principal crops./ Urban development is expanding

Elevation	Precipitation	Temperature	Freeze free days
400 to 2,000 m	250 to 500 mm.	4 to 13 C	60 to 165 days
600 to 1,700 m	175 to 325 mm	5 to 11 C	90 to 170
1,400 m valleys to 3,100 m mt.crests.	175 to 275 mm valleys 625 mm mountains	3 to 7 C valleys	80 to 110 days valleys
1,400 to 2, 000 m plains and plateaus	300 to 625 mm	4 to 7 C	50 to 120
400 to 2,400 m	625 to 1,525 mm	2 to 7 C	45 to 120 days
600 to as much as 2,100 m	300 to 400 mm in most of the area	4 to 8 C	100 to 120 days
1,100 to 1,800 m in north	300 to 500 mm	6 to 7 C	90 to 125 days
600 to 1,400 m	250 to 375 mm	3 to 7 C	100 to 130
600 to 900 m	300 to 350 mm	3 to 5 C	110 to 125 days
400 to 700 m	425 to 475 mm	7 to 9 C	130 to 150 days
500 to 600 m	350 to 425 mm	1 to 7 C	110 to 130 days
500 to 1100 east to west	325 to 450	4 to 7 C	110 to 135
400 to 600	50 to 525 mm	7 to 9 C	130 to 155 days
900 to 1,800 m east to west	300 to 500 mm	4 to 7 C.	120 to 140 days
700 to 1,000 m east to west	325 to 375 mm	4 to 7 C	120 to 130 days.
800 to 1,100 m	300 to 400 mm	7 to 9 C	130 to 150 days
900 to 1,000 m on uplands	300 to 350 mm	4 to 7 C.	110 to 125 days
900 to 1,200 m	375 to 450 mm	6 to 9 C	110 to 140 days
1,100 to 2,000 m	450 to 650 mm	3 to 7 C	80 to 130 days
400 to 500 m bottom 500 to 900 m upland	375 to 475 mm	7 to 9 C	130 to 160 days
900 to 1,200 m	375 to 450 mm	7 to 9 C	~140 days.
600 to 900 m	450 to 550 mm	8 to 10 C	130 to 160 days
300 to 400 m lowlands 400 to 500 m uplands	500 to 600 mm	6 to 9 C	120 to 140 days
300 to 400 m bottpm 400 to 500 m uplands	500 to 650 mm	9 to 11 C	135 to 165 days

Water

supplies small mostly untapped - low to moderate precipitation is adequate for dryfarming
Ground water is plentiful around major rivers - scarce on sites far from the major rivers
moderate precipitation for grass/shrubs on slopes, valleys depend on the streamflow
limited amount precip. for dryfarming and grazing
Moderate precipitation and many perennial streams and lakes provide ample water
Perennial streams principle source.
Precipitation too low for crops in some parts/ adequate for grain and forage in others
Most of the area depends on precipitation for water for range and crop
mostly moisture is inadequate for good crop production /
Most years, moisture is inadequate for maximum crop production.
most years moisture is inadequate for maximum crop production
most years moisture is inadequate for maximum crop production
most years precipitation is inadequate for maximum crop production
low and erratic precipitation is the principal source of water for agriculture.
low and erratic precipitation is the principal source of water for agriculture
limited precipitation, production of cultivated crops is marginal.
limited precipitation, the growing of cultivated crops is marginal
Most of the soils suitable for cultivation are dry during much of the growing season.
Precipitation, perennial streams, springs, and shallow wells provide adequate water for domestic use
In most years precipitation is inadequate for maximum plant growth
Most of the area depends on the rather low and erratic precipitation for water
limited precipitation makes farming a risk
In many years precipitation is inadequate for maximum production
Precipitation is the principal source of moisture for crops some year it is inadequate

Irrigation

Streams provide enough irrigation water along the major valleys
ground water around major rivers is used extensively for irrigation
about 1% mostly for hay and pasture
Ground water is scarce except near the large streams
Streams and reservoirs supply water to adjoining MLRA's for irrigation
Ground water is abundant some used for irrigation
1-2% irrigated (valleys) major rivers provide most water for irrigation
The Milk River provides irrigation water to its flood plains
only a small acreage is irrigated by the Missouri river
irrigated cropland is mostly along a narrow band of the Missouri river
only a small acreage is irrigated around the Missouri river
irrigation is available in quantity only from the Missouri River
Water from reservoirs on the Missouri River is used for irrigation
Strips along the Yellowstone River and main tributaries are irrigated.
no irrigation some wells provide water for stock
Few places have shallow-water wells for domestic use.
Water for livestock comes mainly from runoff that flows into dams
Domestic water mostly from streams, shallow wells, and springs.
moisture is adequate for normal plant growth. No irrigation
reservoirs on the Missouri River are on the eastern border
Ground water is scarce and of poor quality in most of the area
The Niobrara River is the only perennial stream.
Shallow wells and small ponds principle water supply for livestock
irrigation is increasingly along major rivers

Dominant soil

Xerolls and Argids moderately fine textured to fine textured
Orthids, Argids, and Orthens
Orthids, Orthents, Aquolls, and Xerolls (valleys)
Xerolls and Borolls
Ochrepts and Andepts
Orthids, Borolls, and Argids medium to fine textured
Borolls, Orthents, and Fluvents medium to fine textured
Borolls, Orthents, Argids, and Fluvents medium to fine textured
Borolls. deep, well drained, and medium textured
Ustolls. They are deep, well drained, and medium textured
Borolls. They are deep, well drained, and medium textured
Borolls. moderately deep - deep, loamy and clayey
Ustolls. deep, well to moderately well drained, sandy to clayey.
Orthents, Orthids, Argids, Borolls, and Fluvents. medium to fine textured, shallow to deep
Orthents, Orthids, Argids, and Borolls. They are medium to fine textured and well drained
Orthids. They are moderately deep and deep and fine textured
Orthids and Orthents. They are moderately deep and deep and fine textured
Orthents. They are deep to shallow and fine textured to medium textured
Borolls. They have a frigid or cryic temperature regime
Ustolls and Orthents fine textured and very fine textured
Ustolls. They are medium textured and formed in loess or in alluvium
Ustolls. moderately deep, medium and moderately coarse textured
Borolls. They are deep and loamy and silty
Ustolls. They are deep and silty and lo

Vegetation type

shrub-grass association
shrub-grass vegetation
desert shrub, shrub-grass, and forest vegetation
grass-shrub vegetation
conifer forests
conifer forests and grassland vegetation
grass valleys/foothills, forest higher elevations
grass land vegetation
natural prairie vegetation
grassland vegetation
mixed prairie vegetation
natural mixed prairie vegetation
natural mixed prairie vegetation
open grassland, forest, and savanna vegetation
open to dense forest vegetation
transition between mixed and true prairie vegetation.
mixture of short, mid, and tall grasses
mixed prairie vegetation
true prairie vegetation
true prairie vegetation

Potential Vegetation

Big sagebrush and bluebunch wheatgrass are dominant on moderate to deep soils

Big sagebrush, winterfat, shadscale, Indian ricegrass, needleandthread, Thurber needlegrass, and Sandberg bluegrass grow on the lower Snake River Plains

Indian ricegrass, needleandthread, shadscale, Gardner saltbush, and scarlet globemallow are major species in the valleys

Bluebunch wheatgrass and big sagebrush are dominant.

Western white pine, ponderosa pine, lodgepole pine, western redcedar, western larch, hemlock, Douglas-fir, subalpine fir, and spruce are common

Bluebunch wheatgrass, rough fescue, Idaho fescue, and bearded wheatgrass are the major species of the grassland

Bluebunch wheatgrass, rough fescue, Idaho fescue, and western wheatgrass are the major grass species /Ponderosa pine, Rocky Mountain juniper higher up

Bluebunch wheatgrass, needleandthread, western wheatgrass, green needlegrass, and basin wildrye are dominant species.

Western wheatgrass, needleandthread, green needlegrass, and blue grama. Little bluestem / important species on sloping and thin soils

Western wheatgrass, blue grama, needleandthread, and green needlegrass are dominant species

Western wheatgrass, needleandthread, green needlegrass, and blue grama Little bluestem important on sloping thin soils

Western wheatgrass, blue grama, needleandthread, and green needlegrass are dominant species / Prairie sandreed and little bluestem on shallow soils

Western wheatgrass, green needlegrass, needleandthread, and porcupinegrass. Big bluestem is an important species on soil with restricted drainage

Western wheatgrass, bluebunch wheatgrass, green needlegrass, and needleandthread are dominant species /in east littlebluestem replaces bluebunch wheatgrass

Western wheatgrass, green needlegrass, blue grama, and buffalograss /Little bluestem and sideoats grama grow on shallow soils

Western wheatgrass, green needlegrass, blue grama, and buffalograss /Little bluestem and sideoats grama grow on shallow soils

Western wheatgrass, green needlegrass, and blue grama. Little bluestem and sideoats grama grow on shallow soils.

Little and big bluestem, green needlegrass, western wheatgrass, and needleandthread / Bur oak grows throughout the area

Black Hills spruce grows at higher elevations // Kentucky bluegrass, poverty oatgrass, Richardson needlegrass, and Canada wildrye are common under story grasses

Green needlegrass, western wheatgrass, needleandthread, porcupinegrass, little bluestem, and big bluestem are the major species

Blue grama, western wheatgrass, threadleaf sedge, sideoats grama, little bluestem, prairie sandreed, switchgrass, sand bluestem, and needleandthread are the major species

Little bluestem, prairie sandreed, green needlegrass, and needleandthread are dominant species / Sideoats grama and plains muhly are important on shallow soils.

Big and little bluestem, porcupinegrass and green needlegrass / Needleandthread and prairie dropseed are important species on the steeper soils

Big and little bluestem, indiangrass, porcupinegrass, and green needlegrass. Needleandthread and prairie dropseed are important species on the steeper soils

Appendix II. List of locations, sample numbers, laboratories, and contributing scientists for samples used in the first general carbon equation.

Location	No. Samples	Labs	Scientist
Akron, CO	12	USDA, Lincoln NE	Brian Wienhold
Argentina	14	Texas A&M Univ.	Wylie Harris
Blackland Prairies, TX	24	Texas A&M Univ.	R. Blaisdell
Brookings, SD	11	USDA, Lincoln NE	Brian Wienhold
Bushland, TX	22	USDA, Lincoln NE	Brian Wienhold
Fargo, ND	13	USDA, Lincoln NE	Brian Wienhold
Las Cruces, NM	24	USDA, Las Cruces, NM	Jeff Herrick
Mandan, ND	17	USDA, Lincoln NE	Brian Wienhold
Mead, NE	32	USDA, Lincoln NE	Brian Wienhold
Nebraska	138	Univ. Nebraska Lincoln	Achim Doberman
Ohio	37	Ohio State Univ.	Warren Dick
Sidney, MT	3	USDA, Lincoln NE	Brian Wienhold
Swift Current, Canada	21	USDA, Lincoln NE	Brian Wienhold
Throckmorton, TX	104	Univ. Nebraska	R. Blaisdell
Throckmorton, TX	64	Colorado State Univ.	Richard Teague and Cindy Cambardella
Vernon, TX	59	Colorado State Univ.	Richard Teague and Cindy Cambardella
Wyoming	66	Univ. of Wyoming	Jerry Schuman
Total	661	7	8

Appendix III. Soils database – listing collection locations, labs, constituents of interest and collaborators.

Location	n	Lab	Constituents of Interest	Collaborators
Big Brown Mine Fairfield, Texas	170	Univ. Delaware (FAME)	FAME	Allen Peach David Zuberer
Blackland Prairie, Central Texas	269	Texas A&M Univ. Univ. Delaware	OC, TN, IN, FAME (n=40)	Robert Blaisdell Steve Whisenant David Zuberer
Utah	26	USDA Lincoln, NE	Glomalin	Jayne Belnap
Ohio	200	Univ. Ohio	OC, enzymes	Warren Dick
Nebraska	147	Univ. Nebraska	OC, TN	Achim Doberman
Oklahoma	261	Oklahoma State Univ.	NO ₃ , P, K OC	Sam Fuhlendorf
Argentina	16	Texas A&M Univ.	OC, TN, C13, N15	Wylie Harris
Las Cruces New Mexico	36	USDA Beltsville USDA Las Cruces	Glomalin OC, TN	Jeff Herrick
Kansas - Colorado	33	Colorado State Univ.	OC, TN, FAME	Rebecca McCulley
Wyoming	108	Univ. Wyoming	OC, TN	Jerry Schuman
Vernon, Texas	71	Colorado State Univ.	OC, IC, TN, POM	Richard Teague Cindy Cambardella
Bushland, Texas	24	USDA Lincoln, NE	OC (whole soil) glomalin (particle size)	Brian Wienhold
Fargo, North Dakota	24	USDA Lincoln, NE	OC (whole soil) glomalin (particle size)	Brian Wienhold
Mead, Kansas	44	USDA Lincoln, NE	OC (whole soil) glomalin (particle size)	Brian Wienhold
Swift Current, Canada	36	USDA Lincoln, NE	OC (whole soil) glomalin (particle size)	Brian Wienhold
Bushland, Texas	17	USDA Lincoln, NE	OC, TN, POM	Brian Wienhold
Fargo, North Dakota	20	USDA Lincoln, NE	OC, TN, POM	Brian Wienhold
Mandan, North Dakota	25	USDA Lincoln, NE	OC, TN, POM	Brian Wienhold
Mead, Nebraska	28	USDA Lincoln, NE	OC, TN, POM	Brian Wienhold
Sidney, Montana	22	USDA Lincoln, NE	OC, TN, POM	Brian Wienhold
Swift Current, Canada	18	USDA Lincoln, NE	OC, TN, POM	Brian Wienhold
Akron, Colorado	12	USDA Lincoln, NE	OC, TN, POM	Brian Wienhold
Brookings, South Dakota	18	USDA Lincoln, NE	OC, TN, POM	Brian Wienhold
Throckmorton, TX	460	Univ. Nebraska (n =132) 328 predicted by NIRS	OC, IC, TN	Robert Blaisdell Jerry Stuth
Manhattan, Kansas Konza	~390	Kansas State Univ.	OC, TN	Chuck Rice Mickey Ransom Kevin Price Matt Ramspott
sum	2085	10		18

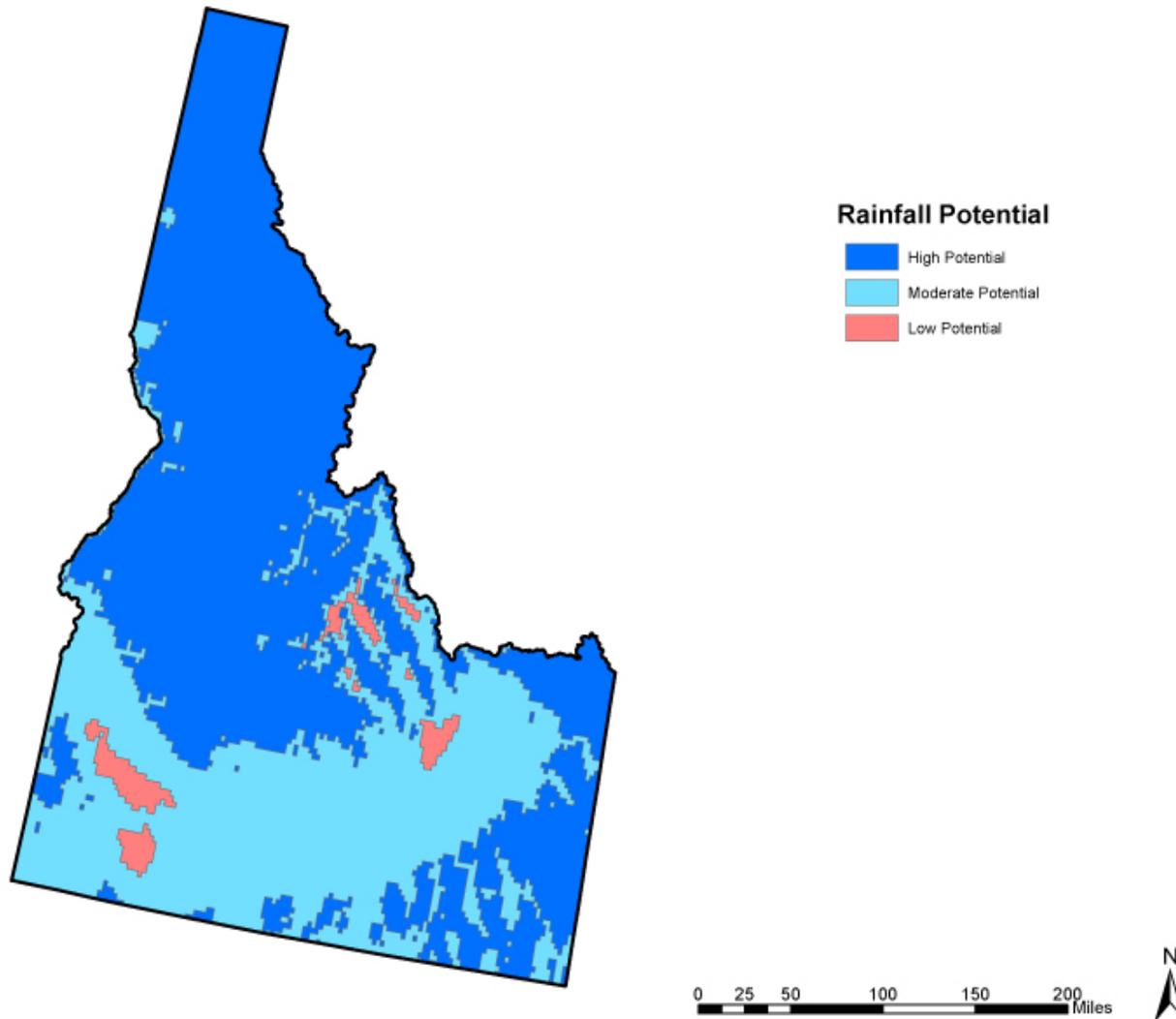


Figure 1. Spatial classification of climatic potential for Idaho. Areas classified as High Potential have greater than 460mm of precipitation per year. Areas classified as Moderate Potential have between 230 and 460 mm of precipitation per year. Areas classified as Low Potential have between 130 and 230 mm of precipitation per year.

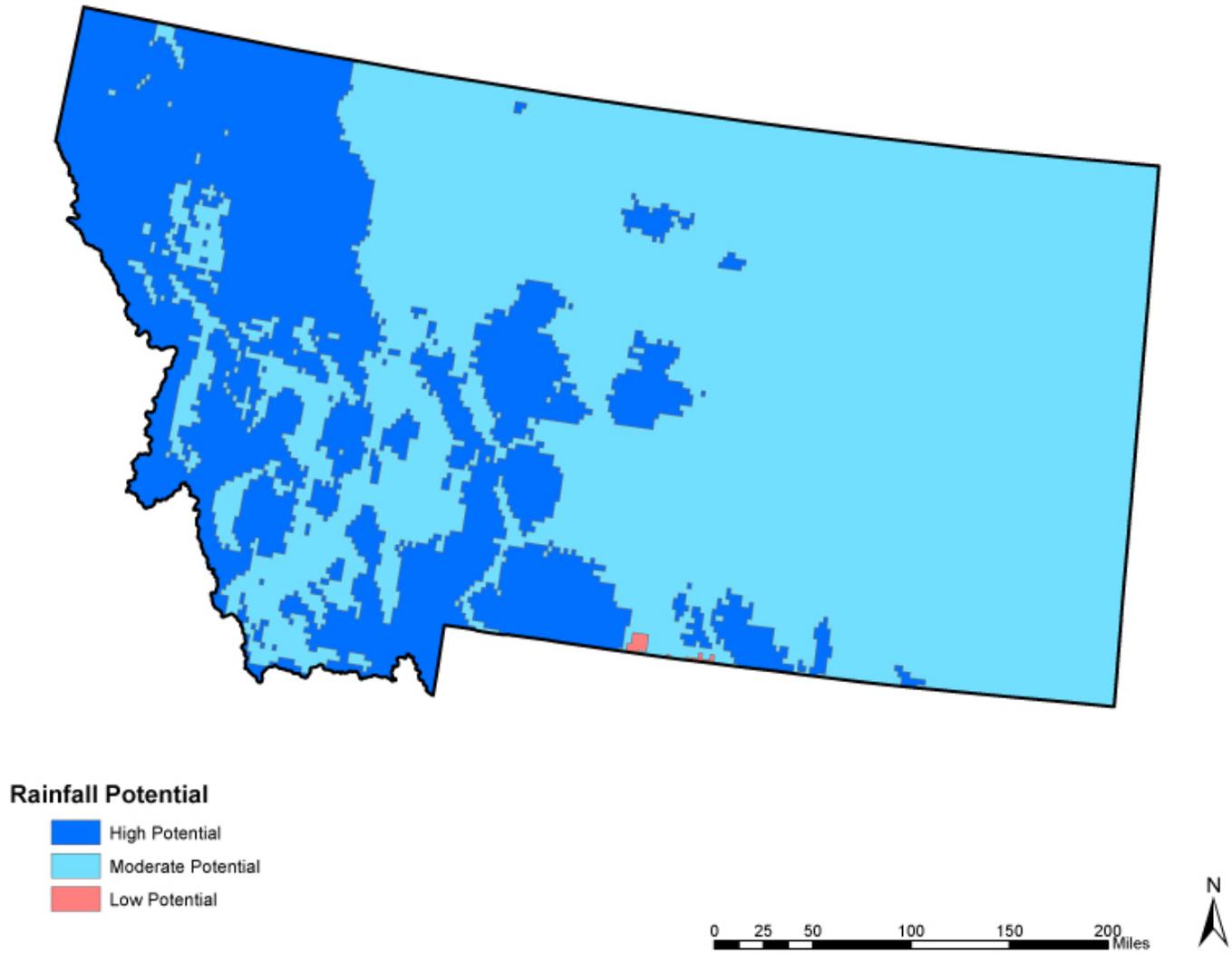


Figure 2. Spatial classification of climatic potential for Montana. Areas classified as High Potential have greater than 460mm of precipitation per year. Areas classified as Moderate Potential have between 230 and 460 mm of precipitation per year. Areas classified as Low Potential have between 130 and 230 mm of precipitation per year.

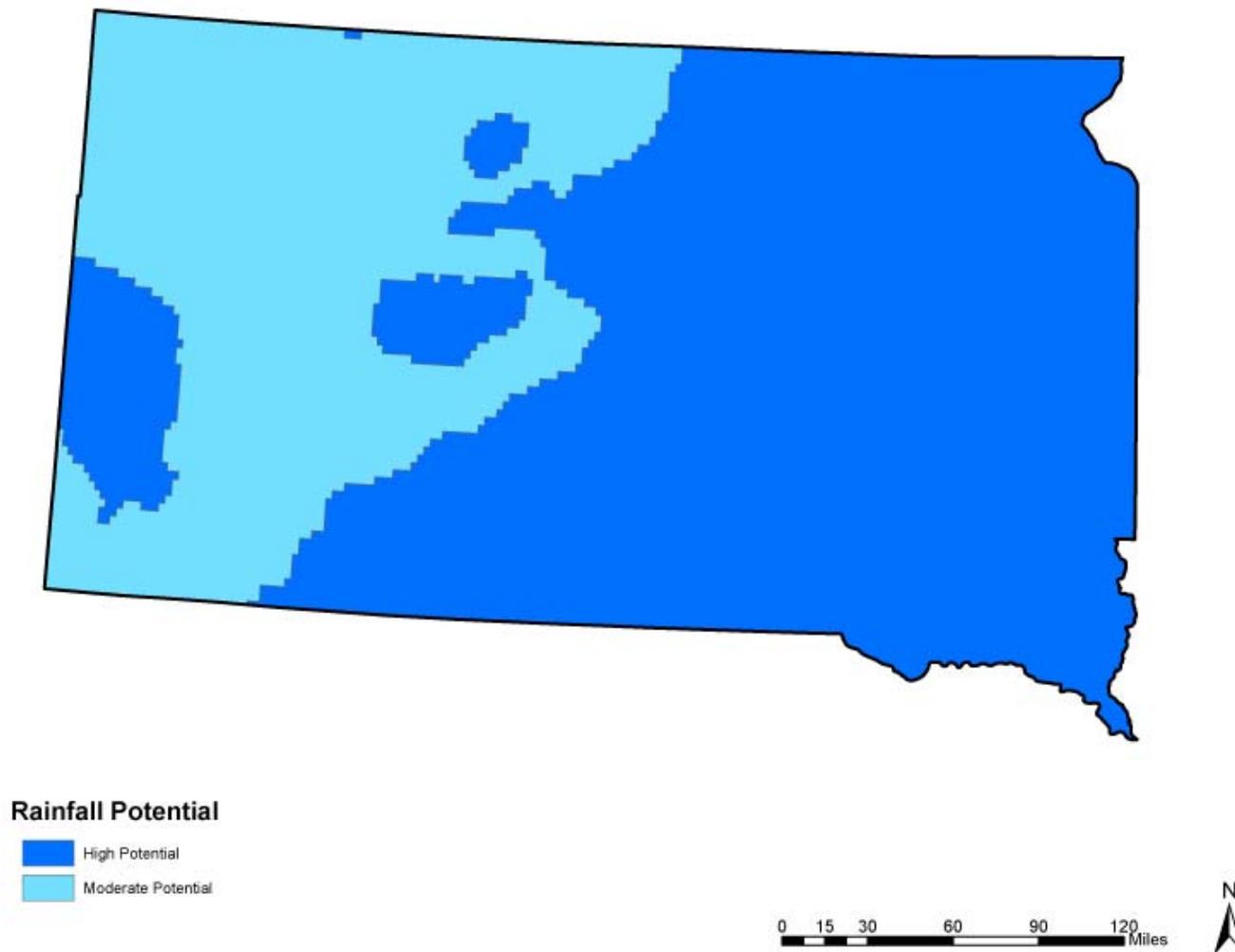


Figure 3. Spatial classification of climatic potential for South Dakota. Areas classified as High Potential have greater than 460mm of precipitation per year. Areas classified as Moderate Potential have between 230 and 460 mm of precipitation per year.

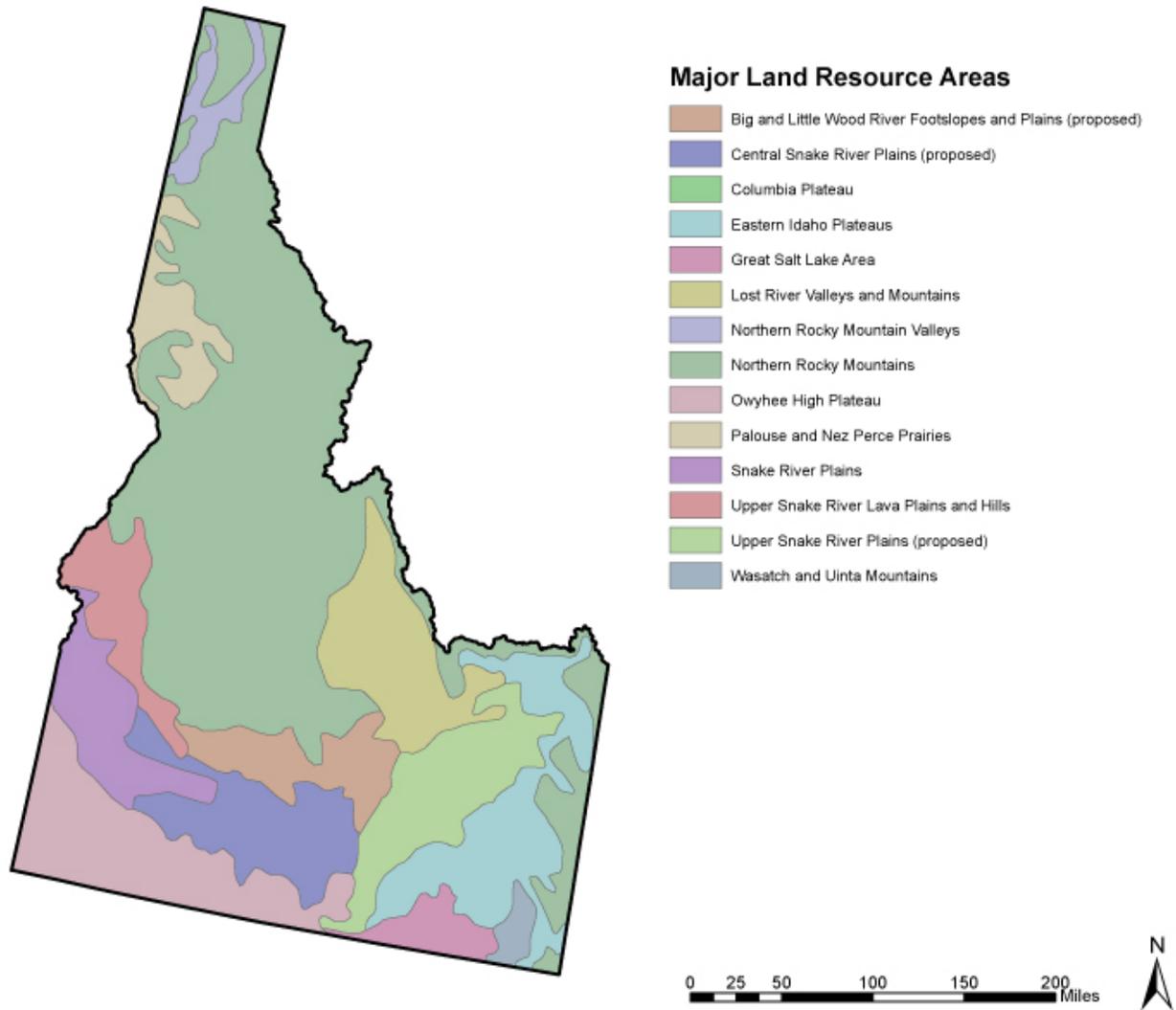


Figure 4. Major land resource areas (MLRAs) within the state of Idaho.

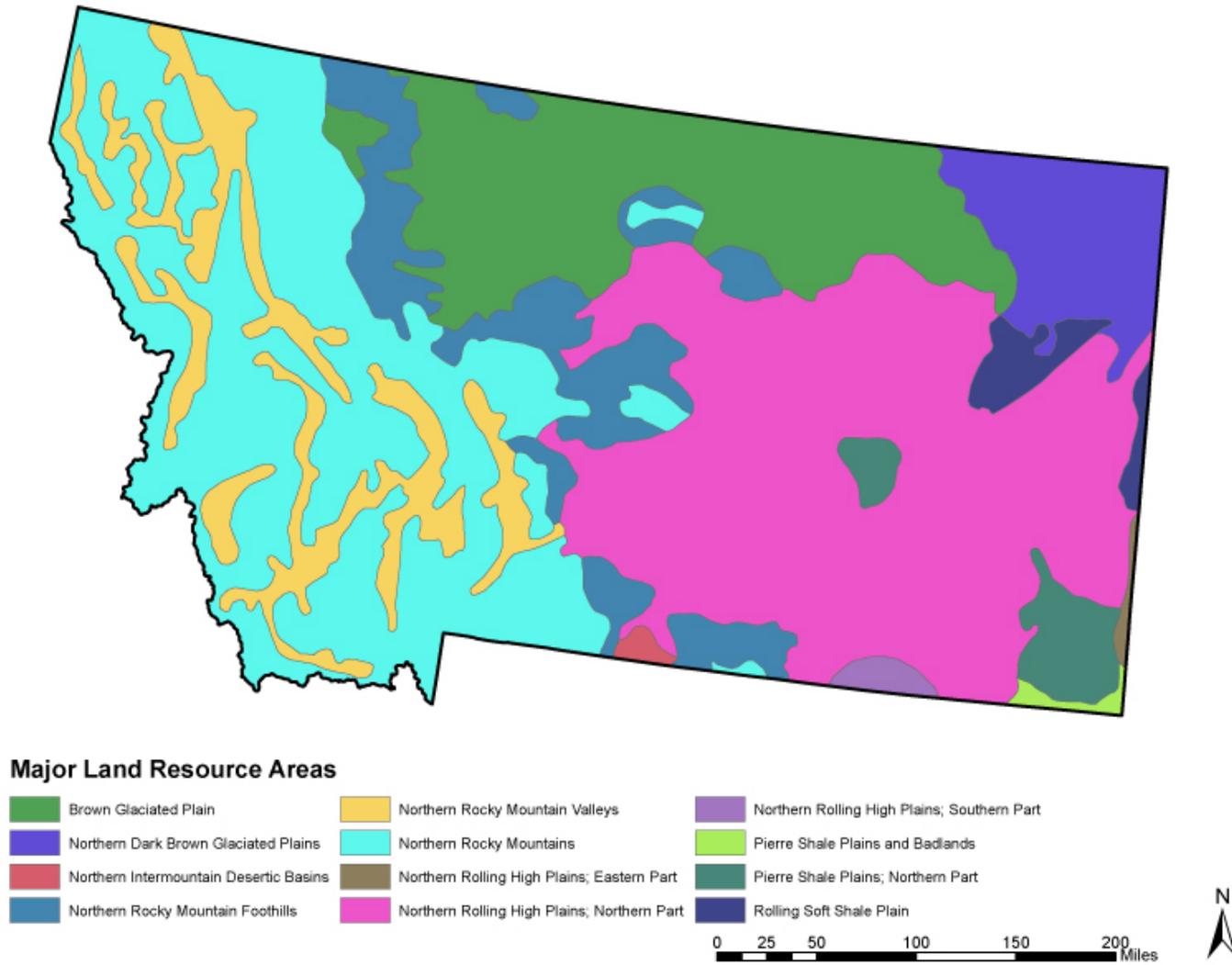


Figure 5. Major land resource areas (MLRAs) within the state of Montana.

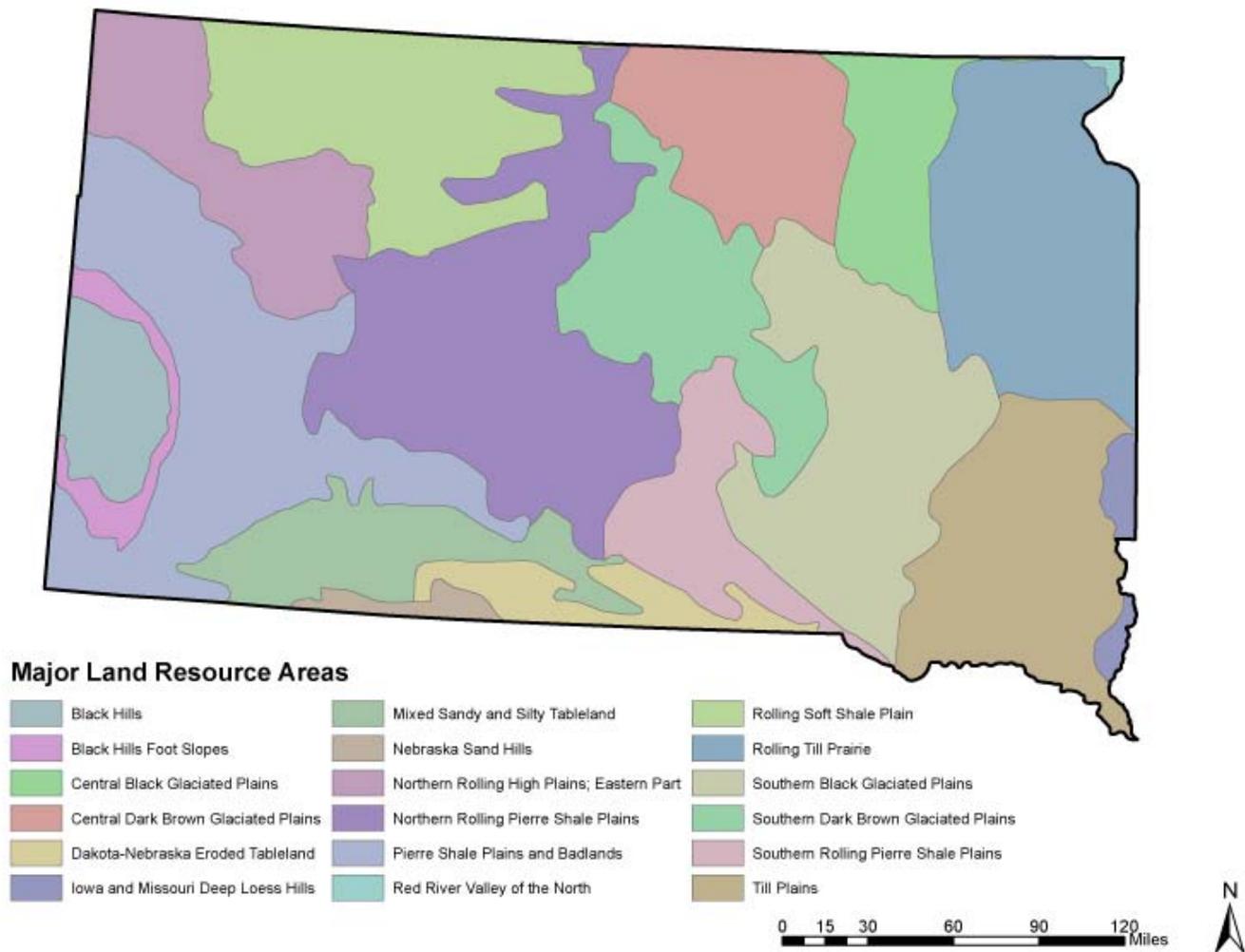


Figure 6. Major land resource areas (MLRAs) within the state of South Dakota

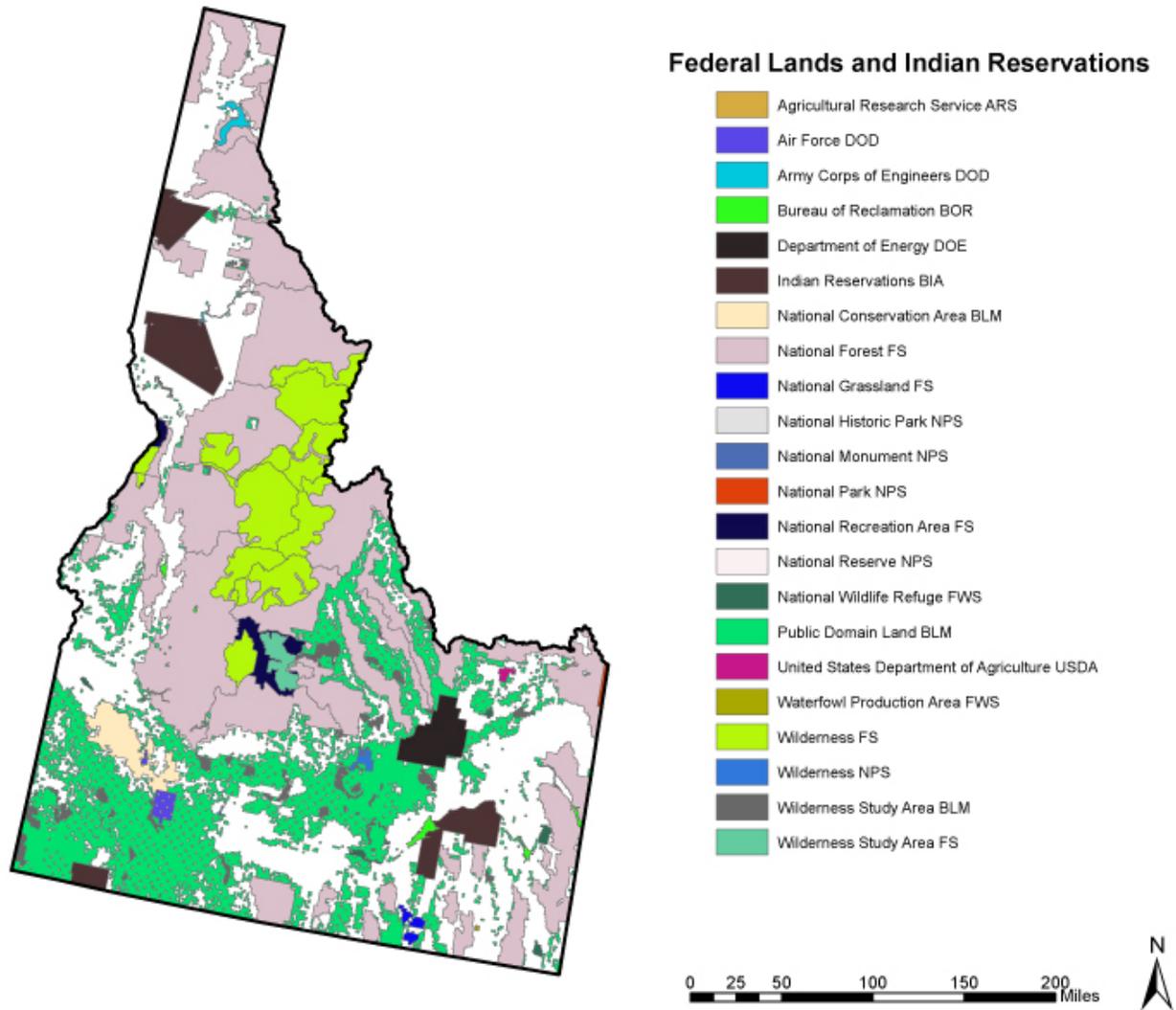


Figure 7. Federal lands and Indian reservations within the state of Idaho.

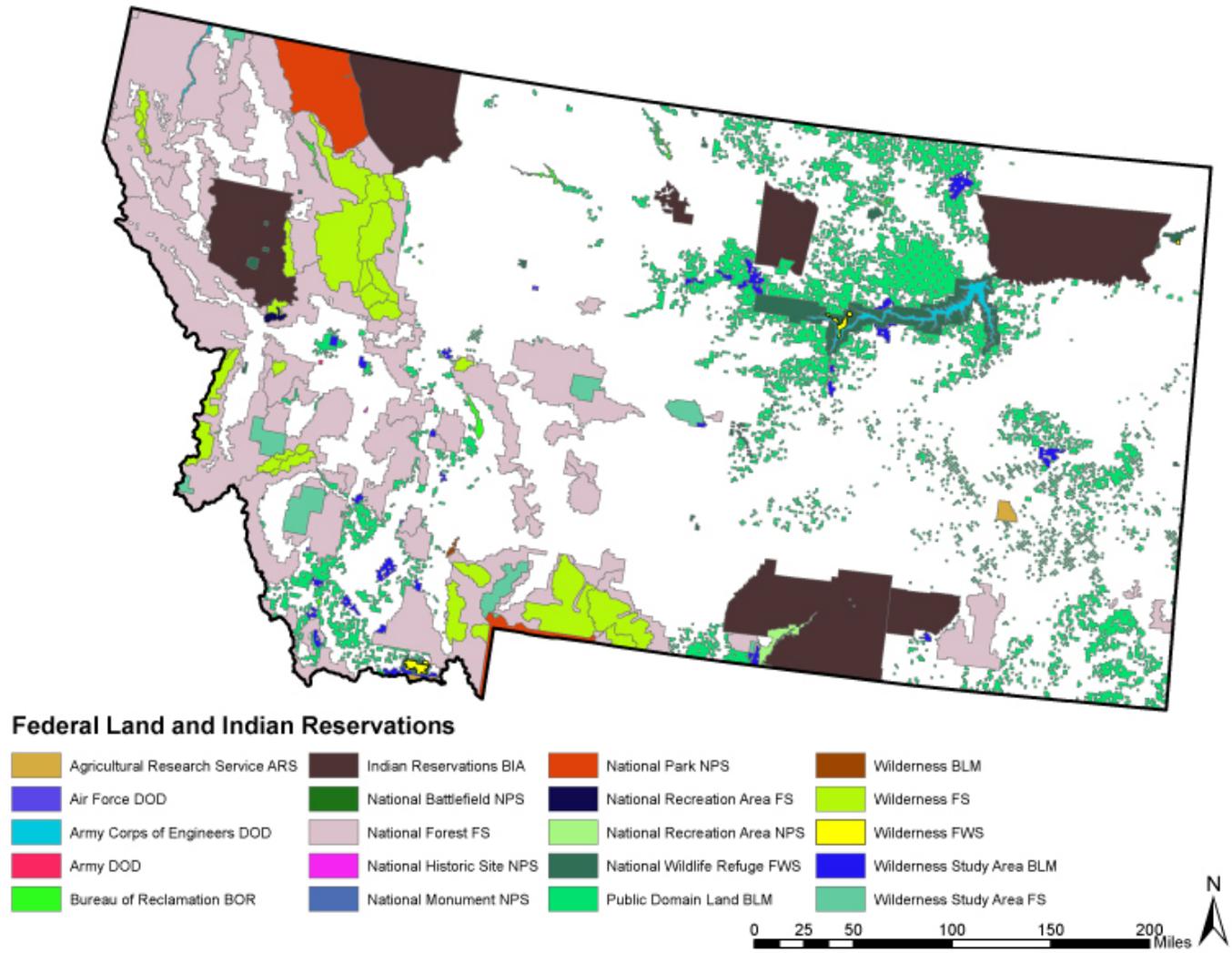


Figure 8. Federal lands and Indian reservations within the state of Montana.

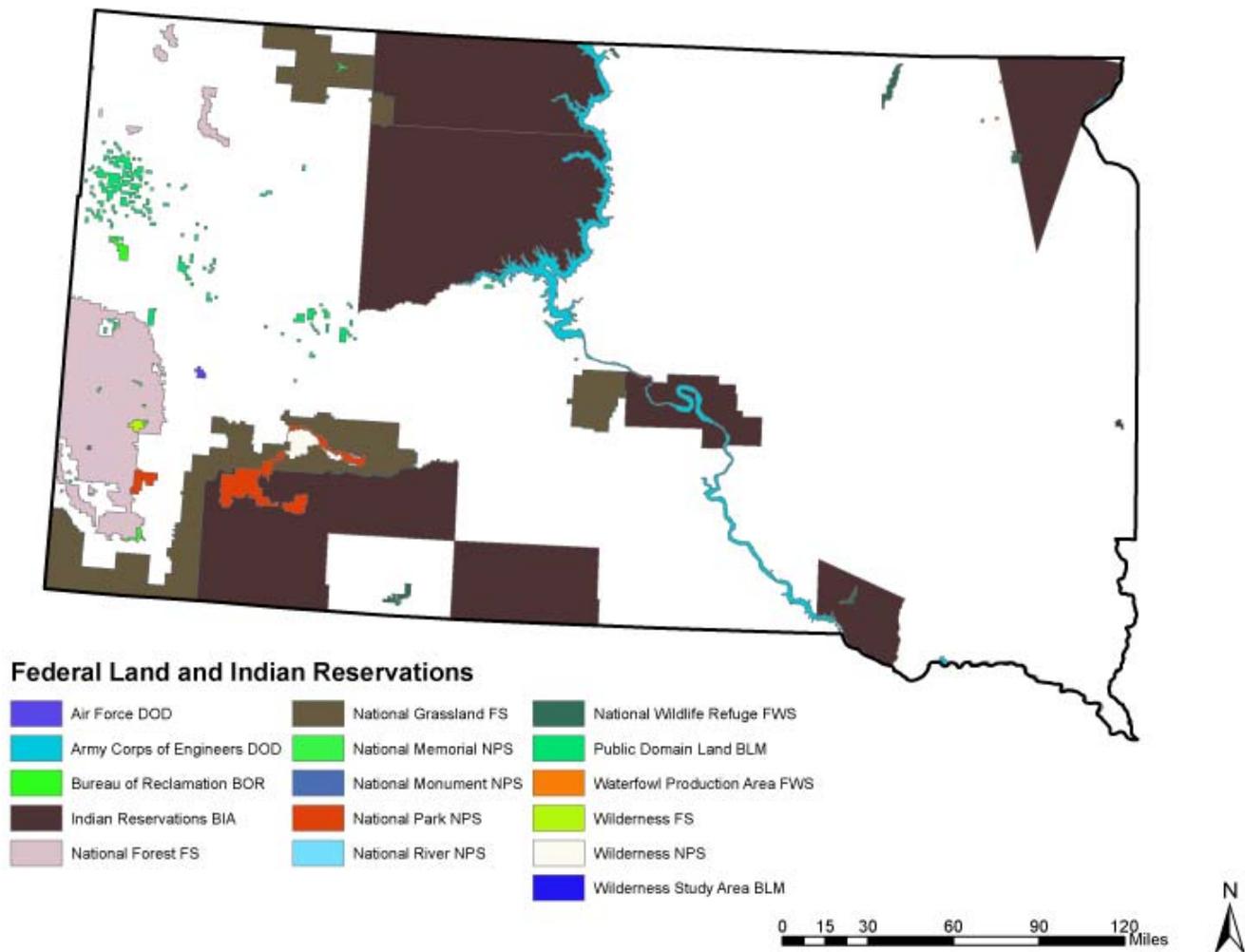


Figure 9. Federal lands and Indian reservations within the state of South Dakota

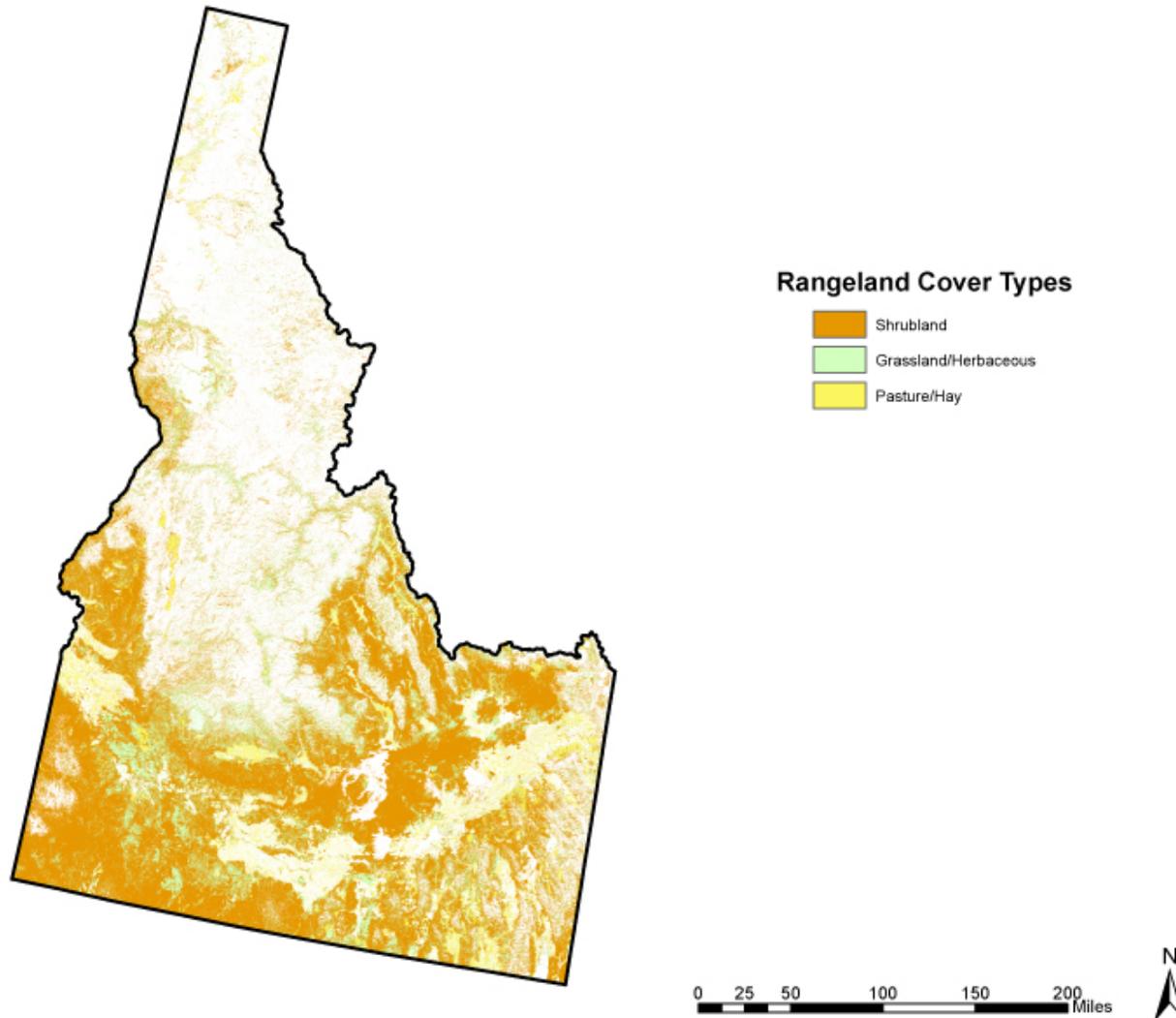


Figure10. Rangeland cover types for the state of Idaho as classified by the National Land Cover Database.

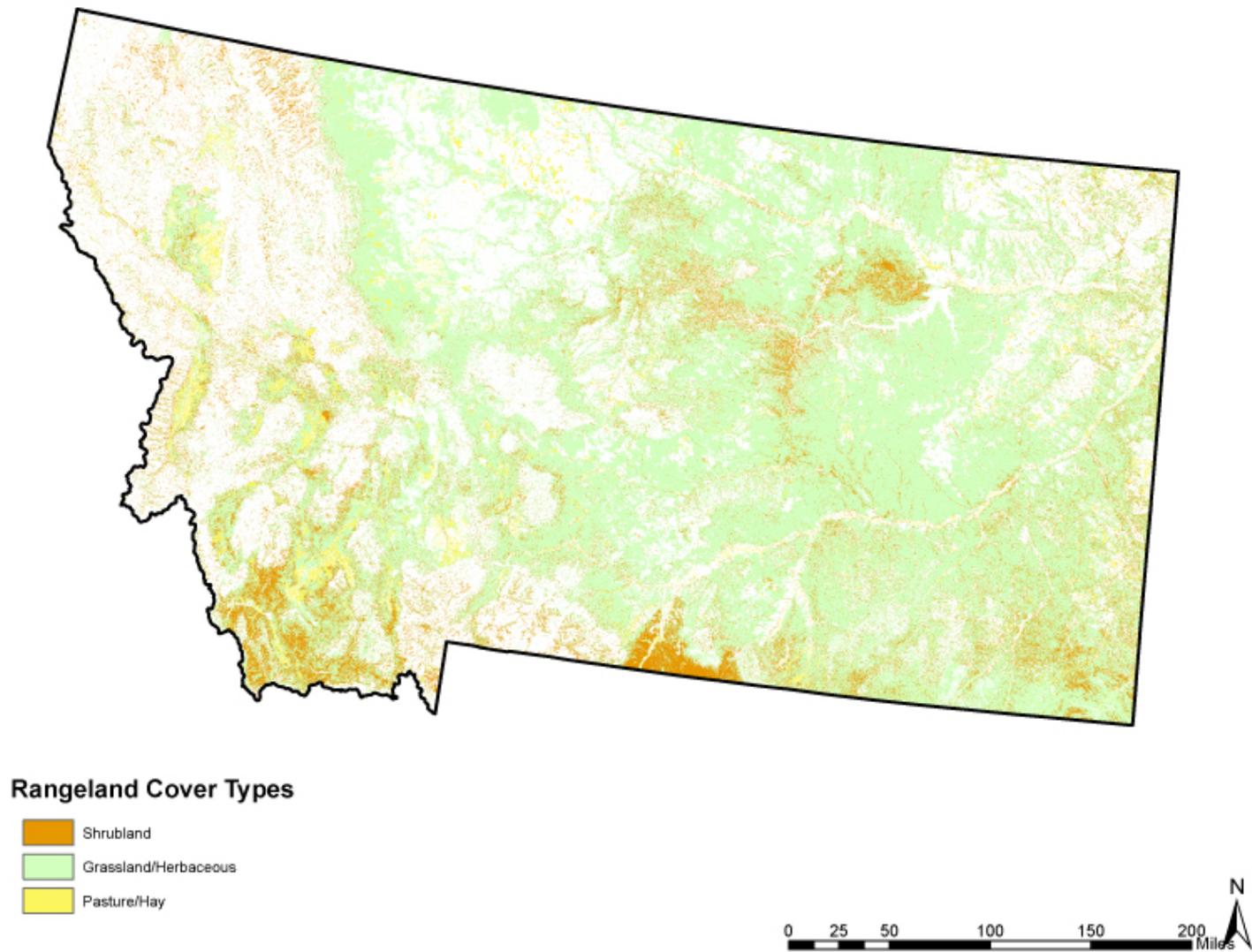
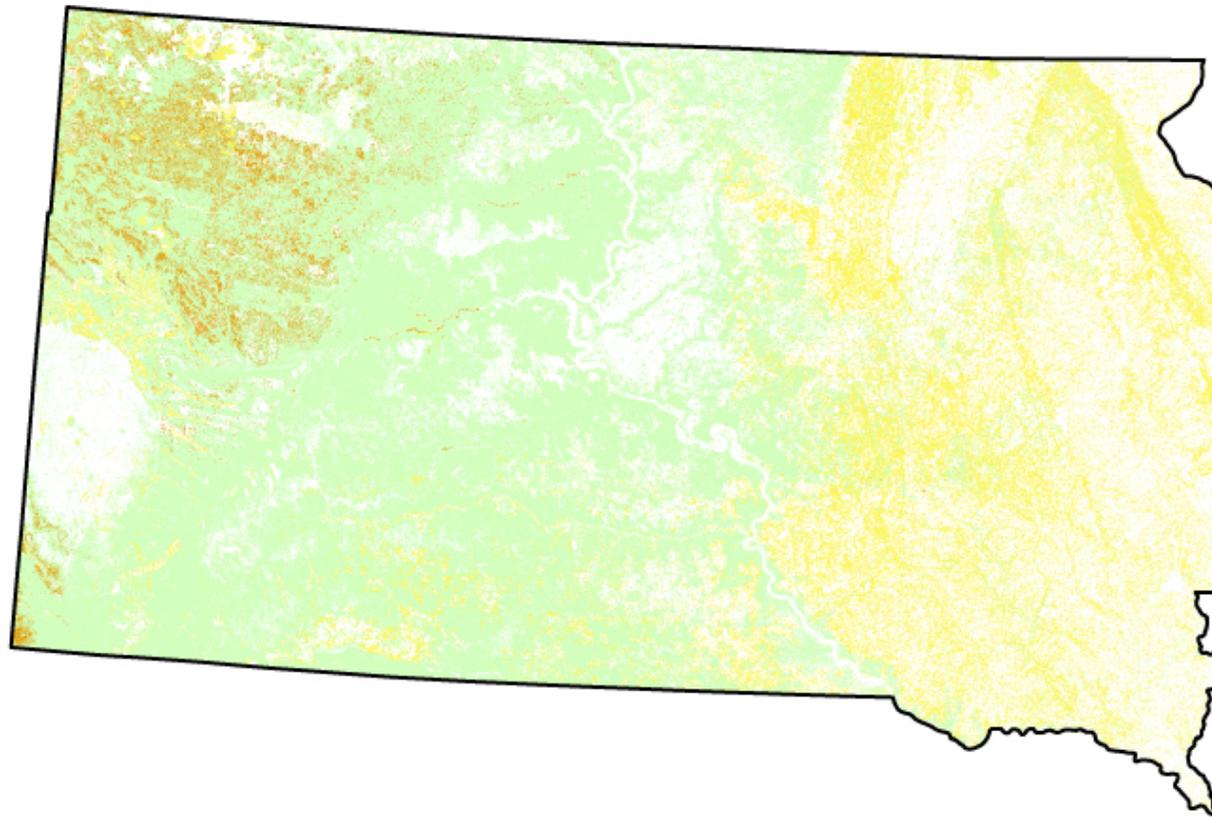


Figure 11. Rangeland cover types for the state of Montana as classified by the National Land Cover Database.



Rangeland Land Cover Types

-  Shrubland
-  Grassland/Herbaceous
-  Pasture/Hay

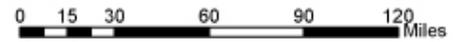


Figure 12. Rangeland cover types for the state of South Dakota as classified by the National Land Cover Database.

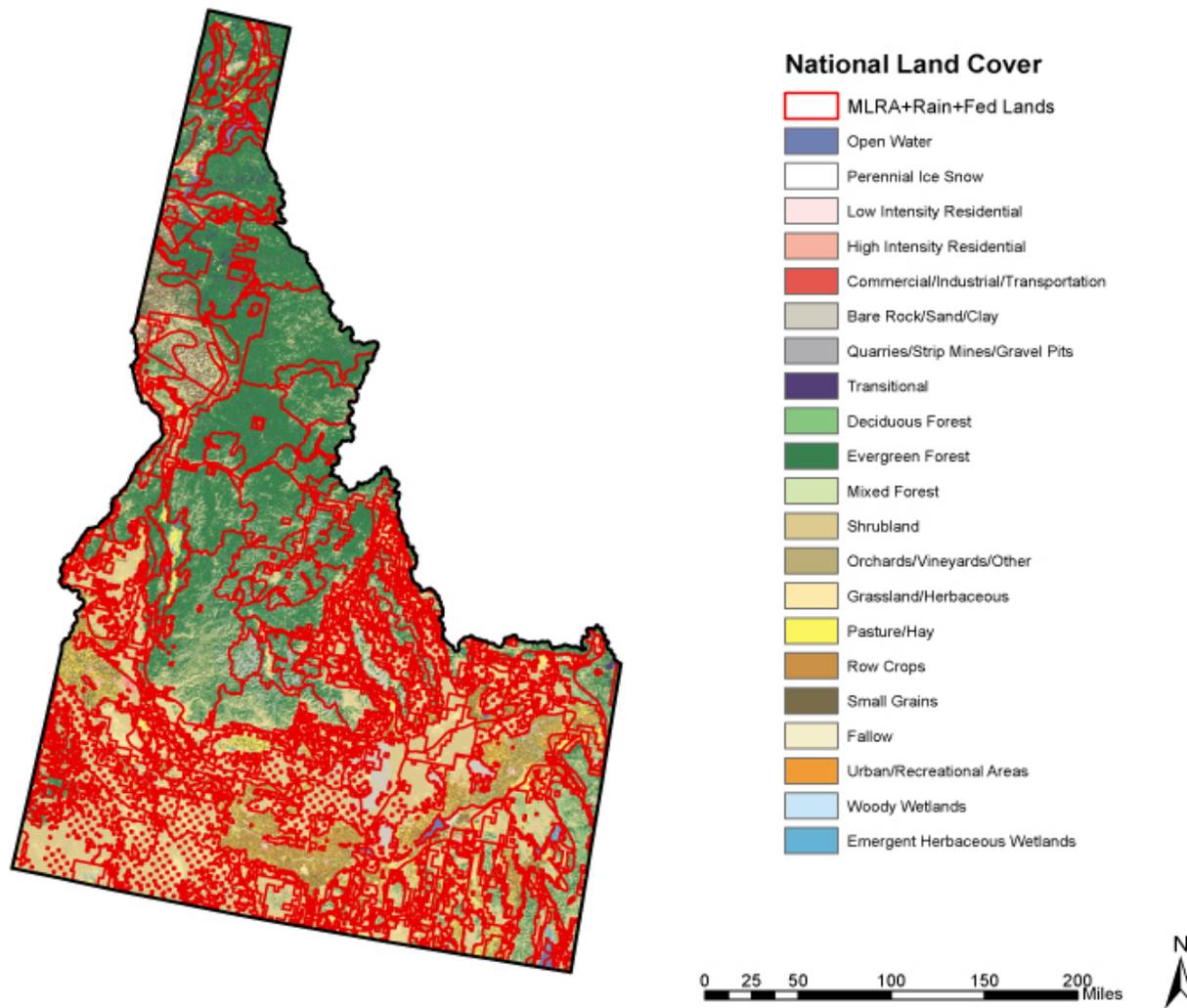
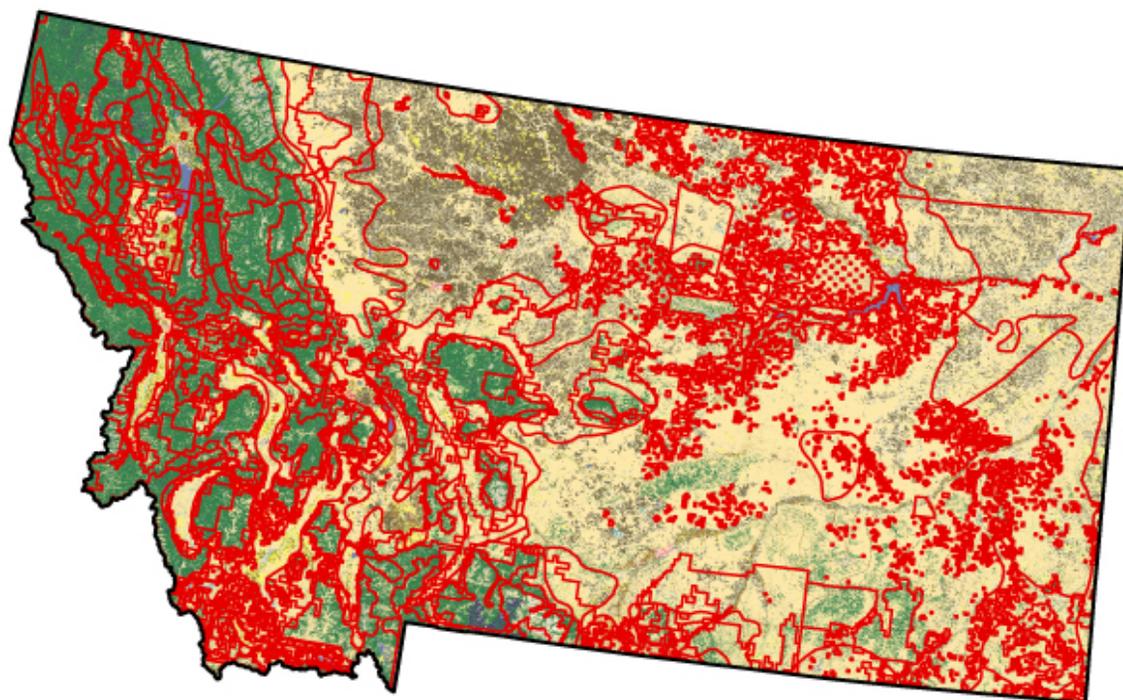


Figure 13. Sampling units (red lines) used in the spatial cross tabulation for the state of Idaho. The sampling units represent the intersection of the Major Land Resource Areas, climatic potential, and Federal Lands and Indian Reservations map coverage that were used in the spatial cross-tabulation analysis of the National Land Cover Database to determine area coverage of rangeland land cover classes (shrublands, grassland/herbaceous, and pasture/hay).



National Land Cover

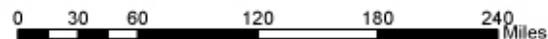


Figure 14. Sampling units (red lines) used in the spatial cross tabulation for the state of Montana. The sampling units represent the intersection of the Major Land Resource Areas, climatic potential, and Federal Lands and Indian Reservations map coverage that were used in the spatial cross-tabulation analysis of the National Land Cover Database to determine area coverage of rangeland land cover classes (shrublands, grassland/herbaceous, and pasture/hay).

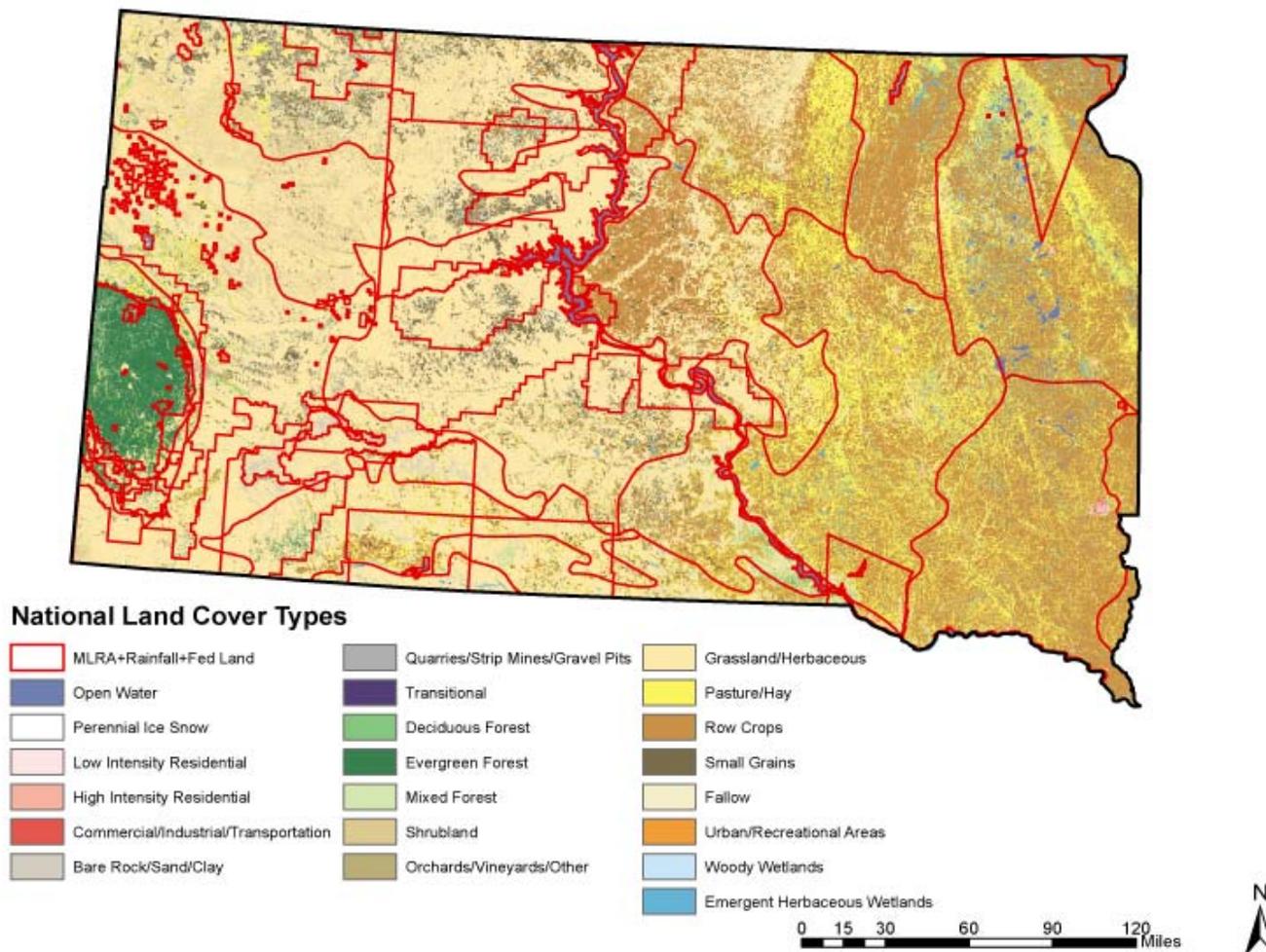


Figure 15. Sampling units (red lines) used in the spatial cross tabulation for the state of South Dakota. The sampling units represent the intersection of the Major Land Resource Areas, climatic potential, and Federal Lands and Indian Reservations map coverage that were used in the spatial cross-tabulation analysis of the National Land Cover Database to determine area coverage of rangeland land cover classes (shrublands, grassland/herbaceous, and pasture/hay).

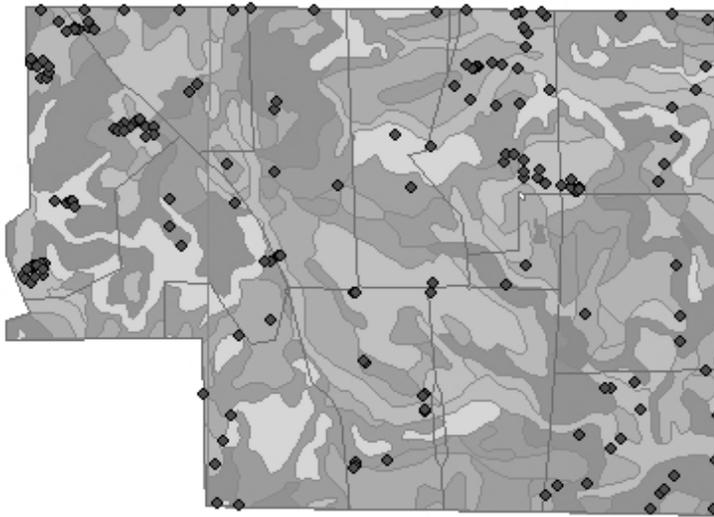


Figure 16. Distribution of sample points for Throckmorton Ranch placed over soil map and pasture boundaries.

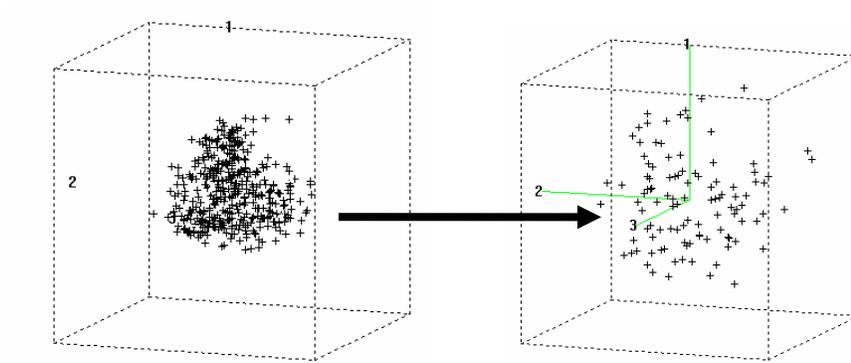


Figure 17. Selection of spectrally unique samples used to reduce laboratory costs and to choose samples that represent the range of population variance for equation development. From a total of 460 samples (left box) this procedure identified 107 spectrally unique samples (right box).

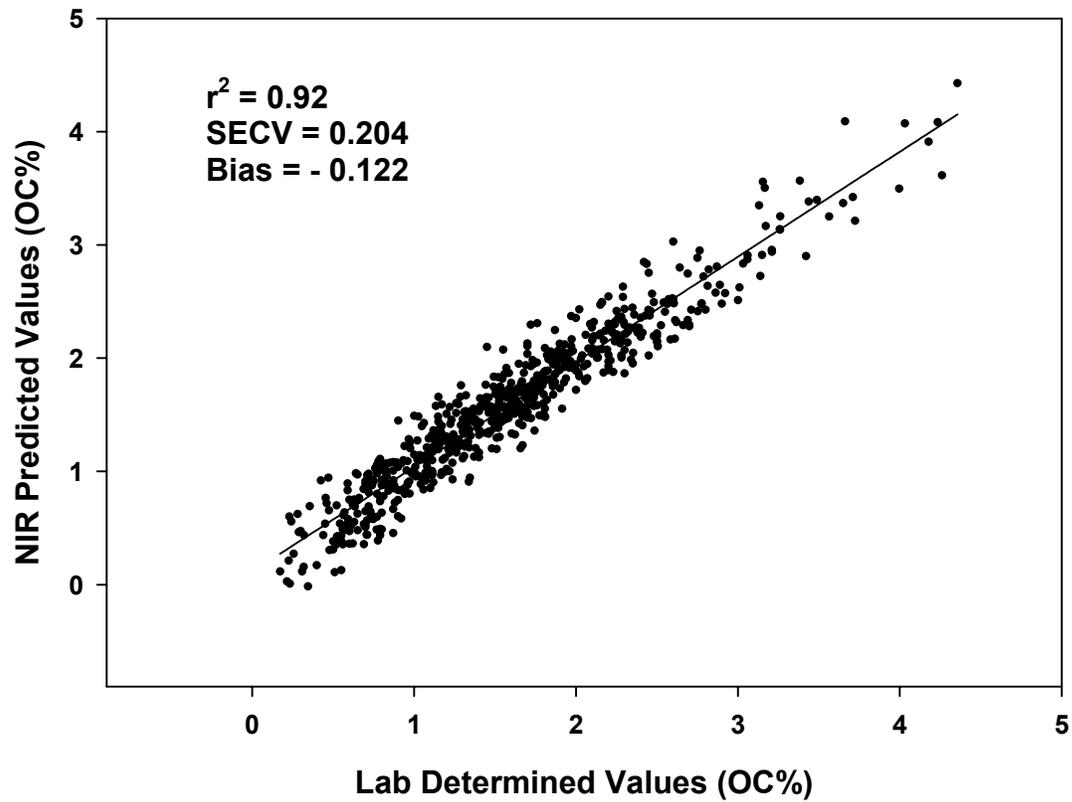


Figure 18. NIR cross validation prediction results for organic carbon using soils from diverse locations. (n = 661)

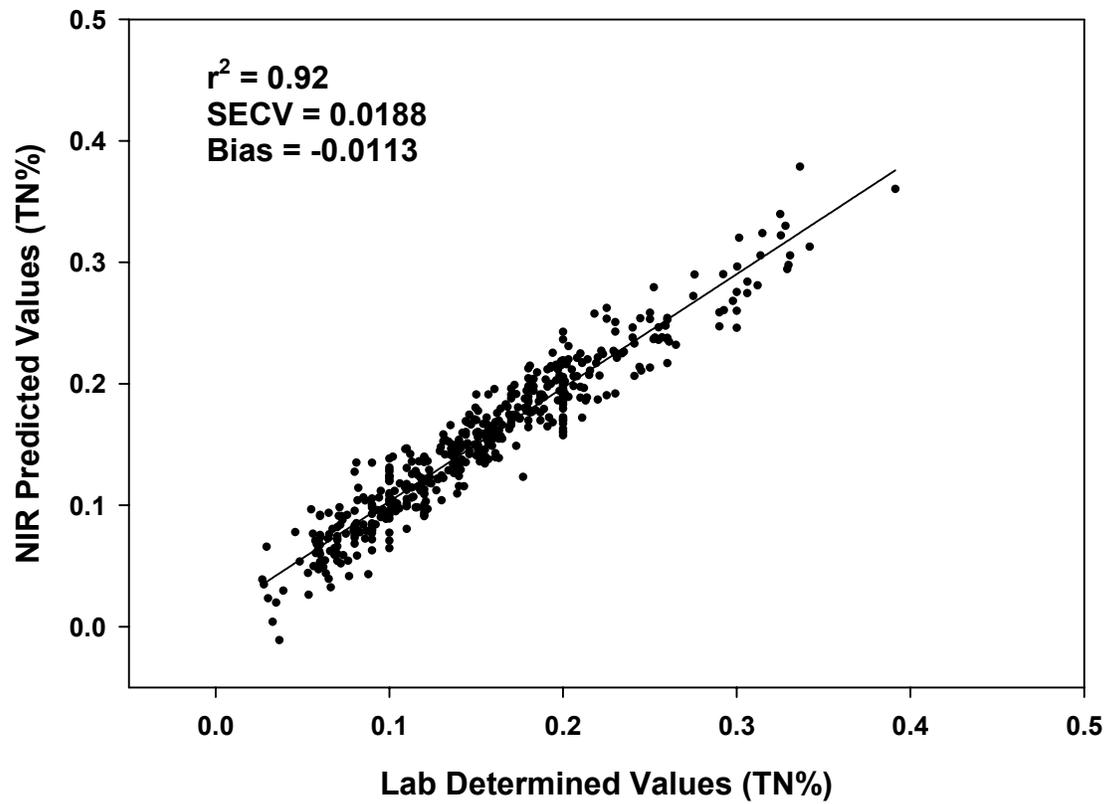


Figure 19. NIR cross validation prediction results for total nitrogen using soils from diverse locations (n = 502)

Table 1. Rangeland (ha) by land cover class and sums of the classes for Major Land Resource Area (MLRA) and land tenure class grouped according to Climatic Potential for carbon sequestration in Idaho. Percent of total reflects the percent of total rangeland occupied by the MLRA and Land Tenure class within the climatic potential grouping.

NRCS Major Land Resource Area	Land Tenure	Shrubland	Grasslands/ Herbaceous	Pasture/ Hay	Rangeland Totals	Percent of Total
High Climatic Potential (>460 mm)						
Big and Little Wood River Footslopes and Plains (proposed)	Federal	56,622	29,421	757	86,799	2.0
	Private or Non-Federal	27,243	15,017	92	42,352	1.0
Central Snake River Plains (proposed)	Federal	4,557	949	1	5,507	0.1
	Private or Non-Federal	829	336	41	1,207	0.0
Eastern Idaho Plateaus	Federal	193,563	63,495	3,173	260,231	6.0
	Indian Reservations	57,725	15,120	2,216	75,061	1.7
	Private or Non-Federal	314,950	105,948	75,772	496,670	11.4
Great Salt Lake Area	Federal	86,118	24,887	2,657	113,663	2.6
	Private or Non-Federal	44,230	20,983	23,323	88,536	2.0
Lost River Valleys and Mountains	Federal	164,767	82,669	261	247,697	5.7
	Private or Non-Federal	5,438	2,154	204	7,796	0.2
Northern Rocky Mountain Valleys	Federal	1,056	1,293	1,664	4,013	0.1
	Indian Reservations	0	0	0	0	0.0
	Private or Non-Federal	12,363	14,279	22,716	49,358	1.1
Northern Rocky Mountains	Federal	859,135	708,934	8,928	1,576,996	36.1
	Indian Reservations	18,552	16,882	3,180	38,614	0.9
	Private or Non-Federal	163,864	89,391	57,616	310,872	7.1
Owyhee High Plateau	Federal	136,813	21,248	85	158,146	3.6
	Indian Reservations	8,475	1,437	1	9,914	0.2
	Private or Non-Federal	68,598	7,731	665	76,994	1.8
Palouse and Nez Perce Prairies	Federal	2,418	1,595	6	4,019	0.1
	Indian Reservations	27,561	29,561	1,422	58,544	1.3
	Private or Non-Federal	27,529	21,288	1,764	50,581	1.2
Snake River Plains	Federal	3,687	68	0	3,756	0.1
	Private or Non-Federal	3,157	92	0	3,249	0.1
Upper Snake River Lava Plains and Hills	Federal	157,056	38,725	662	196,443	4.5
	Private or Non-Federal	226,480	47,414	13,631	287,525	6.6
	Federal	6,396	963	106	7,465	0.2
Upper Snake River Plains (proposed)	Indian Reservations	766	203	267	1,236	0.0
	Private or Non-Federal	7,107	2,884	4,075	14,066	0.3
Wasatch and Uinta Mountains	Federal	34,583	13,187	61	47,831	1.1
	Private or Non-Federal	25,893	8,698	5,444	40,035	0.9
	Sub Total	2,747,530	1,386,853	230,791	4,365,174	

NRCS Major Land Resource Area	Land Tenure	Shrubland	Grasslands/ Herbaceous	Pasture/ Hay	Rangeland Totals	Percent of Total
Moderate Climatic Potential (230 to 460 mm)						
Big and Little Wood River Footslopes and Plains (proposed)	Federal	360,770	39,236	1,796	401,803	6.3
	Private or Non-Federal	102,483	43,547	41,038	187,068	3.0
Central Snake River Plains (proposed)	Federal	454,674	173,426	5,770	633,870	10.0
	Private or Non-Federal	123,744	90,003	120,472	334,219	5.3
Columbia Plateau	Private or Non-Federal	254	161	0	415	0.0
Eastern Idaho Plateaus	Federal	51,017	9,328	2,619	62,963	1.0
	Indian Reservations	37,630	12,363	4,195	54,189	0.9
	Private or Non-Federal	140,491	57,646	79,381	277,519	4.4
Great Salt Lake Area	Federal	51,368	23,305	1,955	76,627	1.2
	Private or Non-Federal	22,751	14,359	28,563	65,674	1.0
Lost River Valleys and Mountains	Federal	447,226	100,518	6,059	553,802	8.7
	Private or Non-Federal	83,993	42,639	37,332	163,964	2.6
Northern Rocky Mountains	Federal	157,023	82,342	3,006	242,371	3.8
	Indian Reservations	173	23	0	195	0.0
	Private or Non-Federal	56,930	22,603	8,798	88,331	1.4
Owyhee High Plateau	Federal	1,032,573	160,837	3,007	1,196,417	18.9
	Indian Reservations	35,668	7,698	1,398	44,764	0.7
	Private or Non-Federal	194,881	33,059	13,933	241,873	3.8
Palouse and Nez Perce Prairies	Federal	1,780	624	0	2,404	0.0
	Indian Reservations	5,851	5,000	0	10,852	0.2
	Private or Non-Federal	22,538	10,783	0	33,321	0.5
Snake River Plains	Federal	250,264	95,717	3,502	349,483	5.5
	Private or Non-Federal	93,020	33,739	93,506	220,265	3.5
Upper Snake River Lava Plains and Hills	Federal	38,711	10,245	326	49,283	0.8
	Private or Non-Federal	115,130	26,065	11,503	152,698	2.4
Upper Snake River Plains (proposed)	Federal	394,244	82,842	2,973	480,059	7.6
	Indian Reservations	17,718	9,136	6,485	33,339	0.5
	Private or Non-Federal	162,794	85,580	122,121	370,495	5.8
Wasatch and Uinta Mountains	Federal	1,237	295	86	1,619	0.0
	Private or Non-Federal	5,737	2,328	3,317	11,382	0.2
	Sub Total	4,462,675	1,275,446	603,141	6,341,262	
Low Climatic Potential (130 to 230 mm)						
Central Snake River Plains (proposed)	Federal	8,437	2,317	6	10,759	2.3
	Private or Non-Federal	1,269	401	33	1,703	0.4
Lost River Valleys and	Federal	94,558	24,520	2,340	121,418	26.2

NRCS Major Land Resource Area	Land Tenure	Shrubland	Grasslands/ Herbaceous	Pasture/ Hay	Rangeland Totals	Percent of Total
Mountains	Private or Non-Federal	15,689	10,758	17,262	43,708	9.4
Northern Rocky Mountains	Federal	6,229	2,053	217	8,498	1.8
	Private or Non-Federal	1,129	506	395	2,030	0.4
Owyhee High Plateau	Federal	68,142	21,819	84	90,044	19.4
	Private or Non-Federal	3,705	1,029	1	4,735	1.0
Snake River Plains	Federal	81,218	46,044	3,122	130,384	28.1
	Private or Non-Federal	13,744	10,617	6,208	30,569	6.6
Upper Snake River Plains (proposed)	Federal	18,605	748	1	19,355	4.2
	Sub Total	312,724	120,809	29,670	463,203	
	Grand Total	7,522,930	2,783,108	863,602	11,169,640	

Table 2. Total hectares of rangeland cover types identified in Major Land Resource Areas (MLRA) in Idaho.

MLRA NAME	Rangeland (ha)
Northern Rocky Mountains	2267908
Owyhee High Plateau	1822887
Eastern Idaho Plateaus	1226633
Lost River Valleys and Mountains	1138385
Central Snake River Plains (proposed)	987265
Upper Snake River Plains (proposed)	926014
Snake River Plains	737706
Big and Little Wood River Footslopes and Plains (proposed)	718021
Upper Snake River Lava Plains and Hills	685948
Great Salt Lake Area	344500
Palouse and Nez Perce Prairies	159720
Wasatch and Uinta Mountains	100866
Northern Rocky Mountain Valleys	53371
Columbia Plateau	415

Table 3. Rangeland (ha) by land cover class and sums of the classes for Major Land Resource Area (MLRA) and land tenure class grouped according to Climatic Potential for carbon sequestration in Montana. Percent of total reflects the percent of total rangeland occupied by the MLRA and Land Tenure class within the climatic potential grouping.

NRCS Major Land Resource Area	Land Tenure	Shrubland	Grasslands/ Herbaceous	Pasture/Hay	Rangeland Totals	Percent of Total
High Climatic Potential (>460 mm)						
Brown Glaciated Plain	Indian Reservations	1,044	47,497	383	48,924	1.3
	Private or Non-Federal	154	6,993	59	7,206	0.2
Northern Intermountain Desertic Basins	Federal	1,798	2,606	0	4,404	0.1
	Private or Non-Federal	1,639	1,934	0	3,573	0.1
Northern Rocky Mountain Foothills	Federal	11,102	42,284	39	53,425	1.5
	Indian Reservations	30,045	138,512	5,937	174,495	4.8
	Private or Non-Federal	51,449	464,005	15,309	530,763	14.6
Northern Rocky Mountain Valleys	Federal	47,410	53,485	3,318	104,213	2.9
	Indian Reservations	3,492	15,622	2,129	21,243	0.6
	Private or Non-Federal	65,074	185,917	47,999	298,990	8.2
Northern Rocky Mountains	Federal	574,907	776,050	4,591	1,355,548	37.4
	Indian Reservations	30,912	107,895	6,724	145,531	4.0
	Private or Non-Federal	166,339	567,570	15,946	749,855	20.7
Northern Rolling High Plains; Northern Part	Federal	147	323	0	469	0.0
	Indian Reservations	11,539	72,612	1,957	86,108	2.4
	Private or Non-Federal	3,139	17,532	1,053	21,724	0.6
Northern Rolling High Plains; Southern Part	Federal	171	2,228	12	2,411	0.1
	Private or Non-Federal	1,359	15,404	299	17,062	0.5
	Sub Total	1,001,720	2,518,468	105,755	3,625,943	
Moderate Climatic Potential (230 to 460 mm)						
Brown Glaciated Plain	Federal	43,303	649,228	3,950	696,481	4.0
	Indian Reservations	16,450	374,909	7,319	398,679	2.3
	Private or Non-Federal	90,151	1,533,435	125,049	1,748,636	9.9
Northern Dark Brown Glaciated Plains	Federal	3,284	11,916	175	15,375	0.1
	Indian Reservations	32,783	173,152	3,429	209,364	1.2
	Private or Non-Federal	103,209	389,768	37,846	530,823	3.0
Northern Intermountain Desertic Basins	Federal	20,040	3,574	0	23,614	0.1
	Private or Non-Federal	24,763	6,049	1,423	32,235	0.2
Northern Rocky Mountain Foothills	Federal	31,919	57,980	172	90,071	0.5
	Indian Reservations	26,924	210,946	5,485	243,355	1.4
	Private or Non-Federal	72,222	983,168	58,110	1,113,500	6.3
Northern Rocky Mountain Valleys	Federal	51,065	84,188	4,337	139,590	0.8
	Indian Reservations	8,313	53,955	30,467	92,735	0.5
	Private or Non-Federal	177,486	728,161	222,278	1,127,925	6.4
Northern Rocky Mountains	Federal	146,928	189,265	2,490	338,683	1.9
	Indian Reservations	15,034	39,315	10,493	64,841	0.4

NRCS Major Land Resource Area	Land Tenure	Shrubland	Grasslands/ Herbaceous	Pasture/Hay	Rangeland Totals	Percent of Total
	Private or Non-Federal	199,634	654,437	54,658	908,728	5.2
Northern Rolling High Plains; Eastern Part	Federal	4,620	10,355	52	15,027	0.1
	Private or Non-Federal	11,434	35,177	2,490	49,102	0.3
Northern Rolling High Plains; Northern Part	Federal	310,851	1,340,477	3,688	1,655,017	9.4
	Indian Reservations	54,433	436,462	15,263	506,158	2.9
	Private or Non-Federal	648,515	5,506,180	145,777	6,300,471	35.8
Northern Rolling High Plains; Southern Part	Federal	2,479	10,565	45	13,090	0.1
	Indian Reservations	501	2,426	0	2,927	0.0
	Private or Non-Federal	25,141	104,513	1,723	131,377	0.7
Pierre Shale Plains and Badland	Federal	9,238	25,657	107	35,002	0.2
	Private or Non-Federal	6,909	65,461	2,117	74,487	0.4
Pierre Shale Plains; Northern Part	Federal	50,877	149,794	724	201,395	1.1
	Private or Non-Federal	86,067	449,058	10,616	545,740	3.1
Rolling Soft Shale Plain	Federal	227	2,763	138	3,128	0.0
	Private or Non-Federal	34,437	224,796	24,914	284,147	1.6
	Sub Total	2,309,237	14,507,129	775,335	17,591,700	
Low Climatic Potential (130 to 230 mm)						
Northern Intermountain Desertic Basins	Federal	9,260	535	20	9,815	33.5
	Private or Non-Federal	8,516	1,594	1,047	11,156	38.0
Northern Rocky Mountain Foothills	Federal	5,554	185	40	5,778	19.7
	Private or Non-Federal	471	7	0	478	1.6
Northern Rocky Mountains	Federal	1,780	254	0	2,034	6.9
	Indian Reservations	72	6	0	77	0.3
	Sub Total	25,652	2,581	1,106	29,339	
	Grand Total	3,336,609	17,028,178	882,196	21,246,983	

Table 4. Total hectares of rangeland cover types identified in Major Land Resource Areas (MLRA) in Montana.

MLRA NAME	Rangeland
Northern Rolling High Plains; Northern Part	8,569,948
Northern Rocky Mountains	3,565,297
Brown Glaciated Plain	2,899,925
Northern Rocky Mountain Foothills	2,211,864
Northern Rocky Mountain Valleys	1,784,696
Northern Dark Brown Glaciated Plains	755,562
Pierre Shale Plains; Northern Part	747,135
Rolling Soft Shale Plain	287,276
Northern Rolling High Plains; Southern Part	166,867
Pierre Shale Plains and Badlands	109,489
Northern Intermountain Desertic Basins	84,797
Northern Rolling High Plains; Eastern Part	64,128

Table 5. Rangeland (ha) by land cover class and sums of the classes for Major Land Resource Area (MLRA) and land tenure class grouped according to Climatic Potential for carbon sequestration in South Dakota. Percent of total reflects the percent of total rangeland occupied by the MLRA and Land Tenure class within the Climatic Potential grouping.

NRCS Major Land Resource Area	Land Tenure	Shrubland	Grasslands/ Herbaceous	Pasture/Hay	Rangeland Totals	Percent of Total
High Climatic Potential (>460 mm)						
Black Hills	Federal	126	63,784	11,469	75,379	1.1
	Private or Non-Federal	60	19,915	1,942	21,917	0.3
Black Hills Foot Slopes	Federal	19	10,776	689	11,483	0.2
	Private or Non-Federal	713	64,476	25,848	91,037	1.4
Central Black Glaciated Plains	Federal	0	278	1,638	1,916	0.0
	Indian Reservations	0	177	1,575	1,751	0.0
	Private or Non-Federal	45	40,388	171,125	211,558	3.2
Central Dark Brown Glaciated Plains	Private or Non-Federal	1,424	319,620	237,937	558,981	8.3
Dakota-Nebraska Eroded Tableland	Indian Reservations	0	152,108	19,518	171,626	2.6
	Private or Non-Federal	0	132,641	46,360	179,002	2.7
Iowa and Missouri Deep Loess Hills	Private or Non-Federal	1	1,618	31,220	32,839	0.5
Mixed Sandy and Silty Tableland	Federal	0	1,489	1,546	3,036	0.0
	Indian Reservations	0	264,652	44,531	309,184	4.6
	Private or Non-Federal	0	181,193	47,756	228,949	3.4
Nebraska Sand Hills	Federal	0	368	0	368	0.0
	Indian Reservations	0	43,193	1,426	44,618	0.7
	Private or Non-Federal	0	69,855	897	70,751	1.1
Northern Rolling Pierre Shale Plains	Federal	97	85,743	1,456	87,295	1.3
	Indian Reservations	1,556	235,250	1,848	238,655	3.6
	Private or Non-Federal	1,176	758,973	41,274	801,423	11.9
Pierre Shale Plains and Badlands	Federal	8	2,085	437	2,530	0.0
	Indian Reservations	0	77,028	8,188	85,216	1.3
	Private or Non-Federal	1,151	139,081	17,957	158,189	2.4
Red River Valley of the North	Federal	0	11	17	28	0.0
	Indian Reservations	0	3	1,620	1,624	0.0
	Private or Non-Federal	0	0	190	190	0.0
Rolling Soft Shale Plain	Indian Reservations	286	98,987	2,147	101,420	1.5
	Private or Non-Federal	0	796	416	1,213	0.0
Rolling Till Prairie	Federal	0	382	1,218	1,600	0.0
	Indian Reservations	1	21,170	113,190	134,360	2.0
	Private or Non-Federal	89	60,265	510,783	571,137	8.5
Southern Black Glaciated Plains	Federal	0	1,212	496	1,709	0.0
	Indian Reservations	0	15,080	54,100	69,180	1.0
	Private or Non-Federal	466	151,138	733,494	885,098	13.2
Southern Dark Brown Glaciated Plains	Federal	0	785	14	799	0.0
	Indian Reservations	30	15,325	161	15,516	0.2
	Private or Non-Federal	399	429,966	150,230	580,595	8.6

NRCS Major Land Resource Area	Land Tenure	Shrubland	Grasslands/ Herbaceous	Pasture/Hay	Rangeland Totals	Percent of Total
Southern Rolling Pierre Shale Plains	Federal	27	4,694	1,024	5,745	0.1
	Indian Reservations	75	86,247	11,763	98,085	1.5
	Private or Non-Federal	27	286,624	87,998	374,649	5.6
Till Plains	Federal	0	1,018	1,482	2,501	0.0
	Indian Reservations	0	371	822	1,193	0.0
	Private or Non-Federal	11	33,390	448,383	481,784	7.2
	Sub Total	7,788	3,872,157	2,836,184	6,716,129	
Moderate Climatic Potential (230 to 460 mm)						
Black Hills	Federal	303	2,524	53	2,881	0.1
	Private or Non-Federal	631	4,036	46	4,713	0.1
Black Hills Foot Slopes	Federal	878	34,954	686	36,518	0.7
	Private or Non-Federal	3,594	39,465	1,743	44,802	0.8
Central Dark Brown Glaciated Plains	Federal	0	17	0	17	0.0
	Private or Non-Federal	137	64,316	7,275	71,728	1.3
Mixed Sandy and Silty Tableland	Federal	0	10,346	64	10,410	0.2
	Indian Reservations	0	183,648	5,698	189,345	3.5
	Private or Non-Federal	0	9	5	15	0.0
Northern Rolling High Plains; Eastern Part	Federal	6,582	14,982	461	22,026	0.4
	Indian Reservations	399	13,283	0	13,681	0.3
	Private or Non-Federal	207,120	802,760	16,546	1,026,425	18.8
Northern Rolling Pierre Shale Plains	Federal	296	57,655	1,690	59,641	1.1
	Indian Reservations	3,225	383,905	833	387,962	7.1
	Private or Non-Federal	739	557,318	4,603	562,659	10.3
Pierre Shale Plains and Badlands	Federal	24,426	531,493	12,968	568,887	10.4
	Indian Reservations	0	154,950	3,880	158,830	2.9
	Private or Non-Federal	105,203	935,981	68,558	1,109,742	20.4
Rolling Soft Shale Plain	Federal	21,382	121,743	3,273	146,399	2.7
	Indian Reservations	27,392	653,331	6,522	687,244	12.6
	Private or Non-Federal	69,753	210,147	31,554	311,454	5.7
Southern Dark Brown Glaciated Plains	Federal	2	3,114	107	3,223	0.1
	Private or Non-Federal	10	27,258	2,694	29,962	0.5
	Sub Total	472,070	4,807,234	169,260	5,448,564	
	Grand Total	479,858	8,679,391	3,005,444	12,164,693	

Table 6. Total hectares of rangeland cover types identified in Major Land Resource Areas (MLRA) in South Dakota.

MLRA NAME	Rangeland
Northern Rolling Pierre Shale Plains	2,137,636
Pierre Shale Plains and Badlands	2,083,394
Rolling Soft Shale Plain	1,247,729
Northern Rolling High Plains; Eastern Part	1,062,133
Southern Black Glaciated Plains	955,986
Mixed Sandy and Silty Tableland	740,938
Rolling Till Prairie	707,097
Central Dark Brown Glaciated Plains	630,725
Southern Dark Brown Glaciated Plains	630,095
Till Plains	485,477
Southern Rolling Pierre Shale Plains	478,480
Dakota-Nebraska Eroded Tableland	350,628
Central Black Glaciated Plains	215,226
Black Hills Foot Slopes	183,841
Nebraska Sand Hills	115,738
Black Hills	104,890
Iowa and Missouri Deep Loess Hills	32,839
Red River Valley of the North	1,842

Table 7. Rangeland (ha) for each state in the Big Sky Project by climatic potential (annual precipitation) and land tenure class. Federal lands are not included since they will most likely not be included in carbon sequestration programs.

Land Tenure Class	Idaho	Montana	South Dakota	Big Sky Region Totals
High Climatic Potential (>460 mm)				
Indian Reservations	183,369	476,300	1,272,428	1,932,096
Private or Other Non-Federal	1,469,240	1,629,173	5,249,313	8,347,725
Moderate Climatic Potential (230 to 460 mm)				
Indian Reservations	143,339	1,518,059	1,437,063	3,098,461
Private or Other Non-Federal	2,147,225	12,847,170	3,161,500	18,155,895
Low Climatic Potential (130 to 230 mm)				
Indian Reservations	0	77	0	77
Private or Other Non-Federal	82,745	11,635	0	94,380
Totals	3,943,172	16,470,702	11,120,304	31,534,178

Table 8. Prediction statistics for the independent validation set predicted from the equation derived from the 107 analyzed samples and cross validation results obtained from combining the validation set with the calibration set. Values are percentages.

Property	Independent Validation				Cross Validation Combined Set				
	n	RSQ	SEP	BIAS	n	Mean	SD	SECV	RSQ
Inorganic Carbon	25	0.966	0.211	-0.060	120	1.85	2.11	0.279	0.98
Total Carbon	25	0.918	0.329	-0.016	120	3.46	1.90	0.313	0.97
Organic Carbon	25	0.859	0.278	0.090	120	1.63	0.73	0.266	0.87
Total Nitrogen	25	0.945	0.018	0.006	118	0.17	0.012	0.016	0.94

Table 9. Cross Validation Results for Final NIR Throckmorton Equation.

Property	n	Mean	SD	SECV	RSQ
IC	186	1.71	1.83	0.297	0.97
TC	188	3.32	1.75	0.323	0.97
OC	185	1.56	0.64	0.251	0.85
TN	118	0.17	0.012	0.016	0.94

Table 10. Cross Validation Results for Second General Organic Carbon and Total Nitrogen Equation

Property	n	Mean	SD	SECV	RSQ
Organic Carbon	1110	2.10	1.10	0.36	0.89
Total Nitrogen	951	0.20	0.093	0.034	0.86

Table 11. Cross validation predictions of selected carbon fractions.

Property	n	Mean*	SD	SECV	RSQ	Bias
Glomalin	111	0.51	0.36	0.122	0.89	-0.07
POM	142	0.95	1.02	0.556	0.71	-0.33
Amino sugar	131	201.54	71.26	33.26	0.78	19.96
B -glucosaminidase	138	26.32	18.61	10.73	0.67	-6.44
B- glucosidase	130	75.94	46.76	29.10	0.61	-17.46

*units for glomalin and POM are mg g⁻¹ and µg g⁻¹ for amino sugar, B -glucosaminidase and B- glucosidase.

August 16, 2004

The next Big Sky partnership meeting will be held August 24-26, 2004 in Idaho Falls. We will meet in the Riverside room (TAB 350) at the Center for Higher Education (CHE), where Bob Smith (208-282-7954) is located. There is a SUB in an adjacent building where drinks, snacks, etc. are available. There is no need for badges, but the participants will need parking passes (INEEL will take care of this).

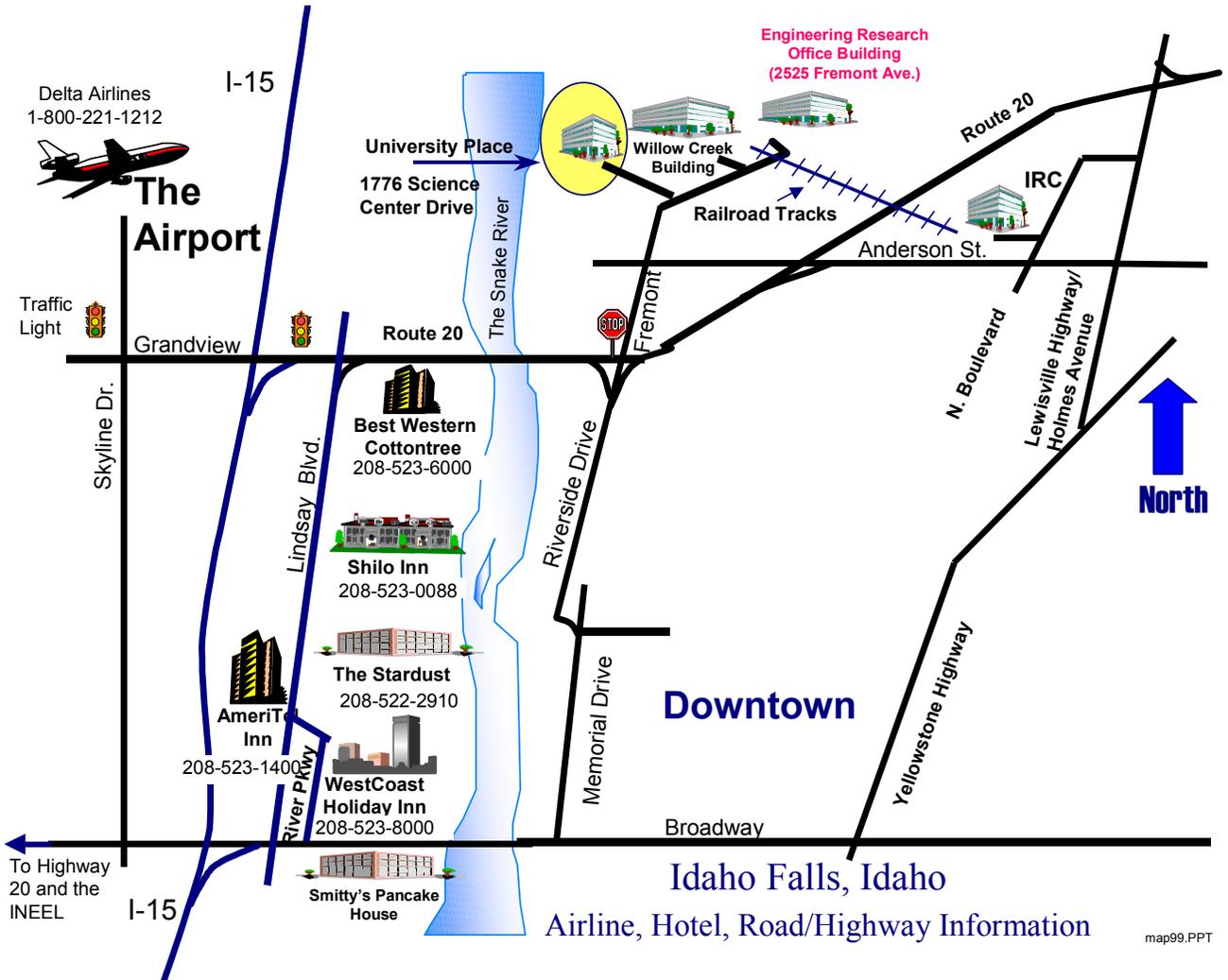
Working lunches will provide some flexibility in the presentation times.

Big Sky Carbon Sequestration Regional Partnership Agenda		
TAB 350 Conference Room at the Center for Higher Education		
Day 1 – Monday, August 23 (Travel Day)		
Day 2 –Tuesday, August 24		
Time	Topic	Presenters
7:45 – 8:00 AM	Coffee Reception	
8:00 – 8:30 AM	Welcome and INEEL R&D Overview	Paul Kearns PhD, Lab Director for INEEL
8:30 – 9:30 AM	NETL Program Office	John Litynski, DOE-HQ
9:30 – 10:00 AM	Review Agenda/Meeting goals	Susan Capalbo, Partnership PI
10:00 AM – 12:00	Progress Report (Geologic)	INEEL, U of I, BSU, LANL
12:00 – 1:00 PM	Working Lunch	
1:00 – 2:30 PM	Progress Reports (GIS)	INEEL, SDSMT, LANL
2:30 – 3:30 PM	Progress Reports (MMV, Adv. Technologies)	LANL
3:30 – 5:30 PM	INEEL IRC Lab tour/Geocentrifuge	INEEL/U of I
6:00 – 8:00 PM	Dinner	Jakers Restaurant (Lindsay Ave)
Day 3 –Wednesday, August 25		
Time	Topic	Presenters
8:00 – 8:45 AM	Progress Reports (Carbon trading)	Ted Dodge, NCOC
8:45 – 9:30 AM	Progress Reports (Public Outreach)	Pam Tomski, EnTech Strategies
9:30 – 11:00 AM	Progress Reports (Terrestrial)	MSU, SDSMT, Texas A&M
11:00 – 12:00	Progress Reports (Regulatory Compliance)	MSU, LANL
12:00 – 1:00 PM	Working Lunch	
1:00 – 2:00 PM	Phase 1 Action Item review	all
2:00 – 3:00 PM	Fossil Energy at INEEL (H ₂ , CO ₂ , etc.)	Bruce Reynolds, INEEL FE Dept.
3:00 – 5:30 PM	Partnership Advisory Committee/Partnership Housekeeping/SSI Presentations	INEEL/U of I
6:00 – 8:00 PM	Dinner	Sandpiper Restaurant (Lindsay)
Day 3 –Thursday, August 26		
Time	Topic	Presenters
8:00 – 9:30 AM	Discussions with Phase 2 participants	Wyoming, Idaho, others
9:30 AM – 11:30	Phase 2 Planning	All Phase 2 participants
11:30 AM – 12:00	Media Interviews	John, Susan, others..
12:00 – 1:00 PM	Working Lunch	
1:00 – 5:00 PM	ASME Carbon Sequestration Symposium held at the University Place Auditorium	Invited speakers, hosted by ASME (Separate agenda)

Additional details:

1. Local Idaho Falls map with CHE and building location, airport, and hotel locations in local area.

August 16, 2004



Idaho Falls, Idaho
Airline, Hotel, Road/Highway Information

map99.PPT

August 25, 2004

The American Society of Mechanical Engineers (ASME) Presents:

The Carbon Sequestration Symposium

August 26, 2004

1:00 pm to 5:00 pm

University Place Auditorium

1776 Science Center Drive

Idaho Falls ID

ASME Moderators: Karen Moore and David Shropshire

Introduction and Welcome by the Department of Energy

Invited Carbon Sequestration Speakers

Anhar Karimjee, EPA's Carbon Sequestration effort
John Litynski (DOE), Carbon Sequestration Program
Susan Capalbo (MSU), Big Sky Partnership
Ross Bricklemeyer (MSU), Terrestrial Sequestration
Robert Smith (U of I), Geologic Sequestration
Pamela Tomski (EnTech Strategies), Carbon Capture

Panel Discussion for Big Sky Region

David Ferguson (David Shropshire representing), Idaho Carbon
Sequestration Advisory Committee

George Vance, Wyoming Governor's Committee on Carbon Sequestration

Mark Lindberg, Montana Governor's Office

Pat Zimmerman (Pam Tomski representing), South Dakota School of
Mines & Technology

Ted Dodge, Indian Nation perspectives on carbon sequestration

No registration fee required

SUPPLEMENTAL REQUEST:

BIG SKY REGIONAL CARBON SEQUESTRATION PARTNERSHIP

DE-PS26-03NT41995

DE-FC26-03NT41995

Rationale:

Our supplemental request for additional funding is primarily to engage in GIS data analysis and research that will allow for coverage to Wyoming, both in terms of evaluation of geological and terrestrial sinks/sources and to build a more inclusive GIS-based data inventory for all sources and sinks in the Northern Rockies area. Wyoming would be brought into the Partnership through the Wyoming Governor's Carbon Sequestration Task Group, the University of Wyoming and other industry and government contacts.

More specifically we would:

- (a) The Big Sky Carbon Sequestration Partnership is using a two-phased approach for the assessment of regional geologic carbon dioxide sinks. The first phase is the identification of geologic 'plays'¹ and then they are screened against carbon dioxide injectability and capacity criteria. The screening eliminates plays that do not meet minimum criteria. The remaining plays will be subjected to a detailed analysis to evaluate (using numerical hydrogeochemical modeling) their carbon dioxide trapping potential. In addition, an economic and regulatory feasibility analysis will be conducted. The results of the screening and analysis will be incorporated into a GIS database.

The inclusion of Wyoming in the Big Sky partnership region would almost triple the number of plays (111 vs. 40) that will be evaluated. The geologic CO₂ sink screening approach is being developed with current funding, but new funds are needed to support the geologic and regulatory analysis for the additional 71 plays in Wyoming.

- (b) On the terrestrial side, the Big Sky partnership is examining both technical and economic feasibility. Currently, there are extensive land areas in Wyoming that are either in rangeland or cropland of some sort. These lands have the potential

¹ The fundamental geologic unit used in the 1995 National Oil and Gas Assessment was the 'play', which is defined as a set of known or postulated oil and or gas accumulations sharing similar geologic, geographic, and temporal properties, such as source rock, migration pathways, timing, trapping mechanism, and hydrocarbon type.

for terrestrial sequestration with perhaps minimal changes in land use/management options. Given the vast acreage involved, terrestrial sequestration could provide a win-win situation for producers and government or private carbon buyers. We would propose to expand the coverage of terrestrial sinks/sources to include Wyoming. The data and analysis would be incorporated into the GIS database. Eventually we would use this information from Wyoming to select some demonstration sites for measuring and monitoring carbon storage on rangeland.

Scope of Work:

The Partnership's objectives are: (i) identify and catalogue sources of CO₂ and promising geologic and terrestrial storage sites; (ii) develop a risk assessment and decision support framework to optimize the region's carbon storage portfolio; (iii) enhance market-based, voluntary approaches to carbon storage; (iv) identify and apply advanced GHG measurement technologies to improve verification protocols, support voluntary trading and stimulate economic development; (v) engage community leaders to define carbon sequestration implementation strategies and (vi) create forums to inform and secure input from the public. The project has four phases: geologic sequestration, terrestrial sequestration, advanced concepts, and outreach. The Big Sky Regional Carbon Sequestration Partnership initially consisted of the states of Montana, Idaho, and South Dakota. This supplemental request would provide the resources to expand the coverage of the partnership to include Wyoming.

Tasks under the Supplemental Proposal:

The supplemental proposal would modify the following Tasks to include coverage for Wyoming:

Task 1 – Regional GHG Source and Geologic Sequestration Characterization

Task 1.1 – Source Characterization

The project will survey both industrial and agricultural GHG (CO₂, CH₄ and N₂O) sources within three major categories: (1) fossil fuel power plants; (2) industrial plants including metals manufacturing, chemical processing and ethanol production and (3) agricultural sources (principally feedlots). Emissions will be estimated using standard guidelines and emissions factors recommended by EPA's Emission Inventory Improvement Program (EIIIP Document Series Vol. VIII, Estimating Greenhouse Gas Emissions) [2], supplemented with information from the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Reference Manual, and the Good Practice

Guidance and Uncertainty Management in National Greenhouse Gas Inventories [3]. Source data will be collected from cooperating state agencies and from national databases (EPA E-Grid, NEI facility data, DOE-EIA state energy data). Industrial facility and utility information will be derived where possible from air-quality permit data assembled by the respective state air quality agencies. Livestock inventories will be collected from the NASS county-level farm census data (through 2001) for each state. Other approaches for estimating GHG emissions may be used depending on the availability and quality of our sources of information.

Task 1.2 – Geological Sequestration Characterization

Evaluate the geologic sequestration potential of sedimentary and volcanic basins the region, which includes Idaho, Montana, South Dakota, Wyoming, and geologically contiguous areas in North Dakota. At a minimum, the following geologic formations will be assessed: deep saline aquifers, depleted oil/gas reservoirs, deep unmineable coal beds, and mafic/ultramafic rocks. Available characterization data will be issued to evaluate the potential for each formation to serve as a CO₂ sequestration reservoir against the following criteria: potential for hydrodynamic trapping; potential for solubility trapping; potential for mineralization trapping; technical feasibility and time frame for implication and offsetting economic benefits. Compilation of geologic data: e.g. prevalent geology, porosity, formation thickness, extent of formations. Coal properties such as coal rank, average pore-size distribution, surface area will be collected for coalbed methane reservoirs. Determination of storage capacity for oil/gas reservoirs, storage capacity would be evaluated in terms of volumetric capacities as well as capacity. For aquifers, the storage capacity would be mainly determined from solubility in water/brine. For coalbed methanes, storage capacity would be evaluated in terms of volumetric capacity as well as capacity resulting from displacement of methane by CO₂. Determination of long-term storage capability: Geologic and geophysical information would be carefully analyzed to determine whether adequate geologic barriers exist to trap CO₂ long term. The evaluation will result in each formations classification of either: 1) favorable and worthy of further consideration; 2) unfavorable; or 3) insufficient information to classify, unless a different ranking scheme is determined more appropriate during the project.

Task 2 – Infrastructure Characterization

Existing and infrastructure requirements will be evaluated within the region. Transportation information such as pipeline and rail infrastructure will be derived from siting boards and transportation departments, or other relevant information. In addition, assess the maturity of sequestration technologies and the availability of the necessary infrastructure for implementation. All the relevant infrastructure information for each sink would be evaluated and included in the database and GIS under Task 3. This will include number of active wells, surface facilities required for storage and processing of CO₂ as well as produced oil/gas/water, CO₂ pipeline and other transportation availability, proximity to major sources. Costs associated with developing the infrastructure necessary for large-scale sequestration would be determined. Technological and economical issues related to separation/capture and transportation of CO₂ would be identified and evaluated.

Task 3 – Incorporate Geologic, Infrastructure, and GHG Source Data into GIS

The results of the geologic sequestration, infrastructure, and GHG source characterization assessments will be embodied in a geospatial database that is integrated with the terrestrial sequestration assessment.

Task 4 – Data Collection and Literature Review for Terrestrial Sequestration

Conduct a literature review and collect data on terrestrial sequestration potentials in the region. The type of land uses the data will be collected for, at a minimum, will include croplands, grazing lands, and agroforestry, on private and public lands. Collection and preparation of forest inventory, growth and yield plots, biomass and productivity data and collection of soil data if necessary for the Partnership region. Collection of climate and disturbance data (such as fire, land use, harvesting). Other information may be collected depending on requirements to estimate terrestrial sequestration potential.

Task 5 – Evaluate all Terrestrial Sinks for GHG Emissions in Regional Ecosystems, Identify Infrastructure Requirements, and Prepare as Information Reports

Compilation of data analysis and management will be conducted. Integration of all possible data from Task 4 and derived during Task 5 into GIS map format. Preparation of TRIPLEX input data.

Task 6 – Overlay the Technical Terrestrial Sequestration Potential With Assessment of Opportunity Costs and Net Economic Benefits

Estimate carbon stocks and fluxes in the Partnership region including Wyoming. Perform comparative projective analysis under different assumed forest management practices, agricultural policies, as well as changing climate scenarios.

TimeLine and Deliverables:

(Assuming a start date of 10/1/04; end date of 9/30/05)

The deliverables for the supplemental will modify the relevant deliverables in the initial grant that pertain to the above tasks, expanded to include the coverage for Wyoming. These are as follows with the due dates reflecting the modifications to include Wyoming:

Deliverable 1 will reflect the inclusion of Wyoming in all reports stating with first quarter of the second year; deliverable 2 will be update to include Wyoming partners; deliverable 3 will reflect the expanded coverage to WY.

Geological Sources and Sinks:

Deliverable 4. Report on Infrastructure Data Compilation and Analysis (original July 04, modified to include Wyoming Jan 05)

Deliverable 5. Report on Technology Needs (original Nov 04, modified to include Wyoming by Mar 05)

Deliverable 6. Report and Action Plan for Geological Sinks (original July 04, modified to include Wyoming by Jan 05)

Terrestrial Sequestration:

Deliverable 7. Terrestrial Sequestration lit review and report (modified by Nov 04)

Deliverable 8. Terrestrial Sequestration, Action Plan and infrastructure needs (original July 04, modified by Jan 05)

Deliverable 9. Carbon Budgets and GIS database for terrestrial sinks (original Sept 04, modified by Mar 05)

Deliverable 11. Report on evaluation of terrestrial Sinks (original June 05, modification to include Wyoming on approximately the same time frame)

Responsibilities:

The GIS overall responsibility will be at LANL (Paul Rich), the terrestrial component at MSU (Susan Capalbo) and the geological component at INEEL (Randy Lee, David Shropshire). Susan Capalbo, PI for the Big Sky Partnership, will also oversee the management of the supplement, the travel/coordination with the Wyoming partners and entities, and the inclusion of Wyoming partners in all future meetings and workshops.

Big Sky Regional Carbon Sequestration Partnership website – www.bigskyco2.org

Big Sky Carbon Sequestration Partnership - Microsoft Internet Explorer

Address <http://www.bigskyco2.org>

Home | Partner Log-In | Contacts

A new energy future for Montana, Idaho, South Dakota and the nation

Big Sky Carbon Sequestration Partnership

The Big Sky Carbon Sequestration Partnership is building a new energy future for Montana, Idaho, South Dakota and the nation. Led by Montana State University, the Big Sky Partnership is one of the [U.S. Department of Energy's](#) (DOE) seven [regional partnerships](#). The Partnership is developing a framework to address carbon dioxide (CO₂) emissions that contribute to climate change and working with stakeholders to create the vision for a new, sustainable energy future that cleanly meets the region's energy needs. Because energy is not an options commodity, carbon sequestration will play an important role.

What's New

August 24–26, 2004 is the next Big Sky Carbon Sequestration Partnership Meeting, hosted by Idaho National Engineering and Environmental Laboratory (INEEL), Idaho Falls, Idaho.

[Inland Northwest Research Alliance Environmental and Subsurface Symposium](#) will be held September 20–22, 2004 in Spokane, Washington.

[Chairman of Shell Says We Urgently Need to Capture Emissions of the Greenhouse Gas Carbon Dioxide](#), Interview by David Adam, *The Guardian*, June 17, 2004.

start | 8:42 AM

Terrestrial GIS Data 1

Theme	Data set(s)	Description	Originator
agricultural	id_dairies	Dairies in Idaho	ID State Depts of Ag and Env. Qual.
civilian/political	id_all_cities	Towns and cities in Idaho	ID Dept. of Water Resources
civilian/political	id_townships_100k	Township and range lines for ID	ID Dept. of Water Resources
civilian/political	mt_townships_100k	Township and range lines for MT	Montana State Library
civilian/political	us_counties_100k	Detailed county boundaries consistent with tract and state data sets	ESRI
civilian/political	us_counties_gen	Generalized county boundaries	ESRI
civilian/political	us_states_100k	Detailed state boundaries consistent with tract and state data sets	ESRI
civilian/political	us_states_gen	Generalized state boundaries	ESRI
climate	id_ave_ann_precip_pol	ID average annual precipitation, 1961-90	Oregon State University
climate	mt_ave_ann_precip_lin	MT average annual precipitation, 1961-90	Oregon State University
climate	mt_ave_ann_precip_pol	MT average annual precipitation, 1961-90	Oregon State University
climate	us_clim_divs	Climate Divisions in the US	
climate	us_coop_sta	Cooperative weather stations in the US	

Terrestrial GIS Data 2

Theme	Data set(s)	Description	Originator
demographic	id_pop	Population of U.S. Census block centroids for Idaho	ESRI
demographic	id_urban_2000	Urbanized areas in Idaho, 2000	US Dept. of Commerce Bureau of Census
demographic	mt_pop	Population of U.S. Census block centroids for Montana	ESRI
demographic	mt_popden2000	MT 2000 population density	Montana State Library
demographic	sd_pop	Population of U.S. Census block centroids for South Dakota	ESRI
demographic	us_cities	Cities within U.S. with population of 10,000 or greater and state capitals	ESRI
demographic	us_msa	Metropolitan statistical areas	Geographic Data Technology, Inc.
demographic	us_urban	Boundaries for urban areas with a population greater than 50,000	Bureau of Transportation Statistics, ESRI
environmental	mt_fire_2000	Perimeters of Year 2000 fires, MT	Montana State Library
environmental	mtarea_fire_2003	Perimeters of Year 2003 fires, US Forest Service Northern Region	Northern Rockies Coordinating Group

Terrestrial GIS Data 3

Theme	Data set(s)	Description	Originator
Hydrologic	id_dams	Dams in Idaho	Sonny Hornbaker
Hydrologic	id_lakes_100k	Lakes in Idaho	Linda Davis, Sandra Thiel
hydrologic	id_rivers	Streams and rivers in Idaho	Geographic Data Technology, Inc., ESRI
hydrologic	id_streams_100k	Streams and rivers in Idaho at 1:100k	Linda Davis, Sandra Thiel
hydrologic	id_wetlands	Wetlands in Idaho	Landscape Dynamics Lab
hydrologic	mt_dams	Dams in Montana	MT Fish, Wildlife and Parks
hydrologic	mt_lakes_100k	Streams and lakes in MT from 1:100k US Census Bureau TIGER files	Montana State Library
hydrologic	mt_rivers	Streams and rivers in Montana	Geographic Data Technology, Inc., ESRI
hydrologic	mt_streams_100k	Streams and lake shorelines from 1:100k US Census Bureau TIGER files	Montana State Library
hydrologic	sd_rivers	Streams and rivers in South Dakota	Geographic Data Technology, Inc., ESRI
hydrologic	us_hydropoly	Water feature areas (bays, glaciers, lakes, and swamps)	National Atlas and USGS, ESRI

Terrestrial GIS Data 4

Theme	Data set(s)	Description	Originator
Hydrologic	id_dams	Dams in Idaho	Sonny Hornbaker
Hydrologic	id_lakes_100k	Lakes in Idaho	Linda Davis, Sandra Thiel
hydrologic	id_rivers	Streams and rivers in Idaho	Geographic Data Technology, Inc., ESRI
hydrologic	id_streams_100k	Streams and rivers in Idaho at 1:100k	Linda Davis, Sandra Thiel
hydrologic	id_wetlands	Wetlands in Idaho	Landscape Dynamics Lab
hydrologic	mt_dams	Dams in Montana	MT Fish, Wildlife and Parks
hydrologic	mt_lakes_100k	Streams and lakes in MT from 1:100k US Census Bureau TIGER files	Montana State Library
hydrologic	mt_rivers	Streams and rivers in Montana	Geographic Data Technology, Inc., ESRI
hydrologic	mt_streams_100k	Streams and lake shorelines from 1:100k US Census Bureau TIGER files	Montana State Library
hydrologic	sd_rivers	Streams and rivers in South Dakota	Geographic Data Technology, Inc., ESRI
hydrologic	us_hydropoly	Water feature areas (bays, glaciers, lakes, and swamps)	National Atlas and USGS, ESRI

Terrestrial GIS Data 5

Theme	Data set(s)	Description	Originator
Land management	ID, MT, SD tillage practices	Acreage data from the Conservation Technology Information Center (CTIC) by county and general crop type on tillage methods used in ID, MT, and SD	Conservation Technology Information Center
Land management	id_land_management	Special land management areas in Idaho	ID Dept. of Water Resources
Land management	id_land_ownership	Surface land ownership in Idaho	ID Dept. of Water Resources
Land management	id_nat_forests	National forests in Idaho	Interior Columbia Basin Eco. Mngt. Project
Land management	mt_fwplands	Montana Fish, Wildlife and Parks managed land	MT FWP and MT State Library
Land management	mt_indian_res	Montana Indian reservations	Montana State Library
Land management	mt_land_stewardship	Land ownership and manages areas in Montana	Montana Natural Heritage Program
Land management	mt_nat_forests	National forests and ranger districts in Montana	Montana Natural Heritage Program
Land management	mt_nps	National Park Service units in Montana	Montana Natural Heritage Program
Land management	mt_nwr	National Wildlife Refuges in Montana	Montana Natural Heritage Program
Land management	mt_wilderness_areas	Designated Wildernes Areas in Montana	Montana Natural Heritage Program
Land management	us_fedland	Federal and Indian-owned land areas	National Atlas and USGS, ESRI
Land management	us_parks	National Parks, National Forests, State and local parks and forests	ESRI, Geographic Data Technology, Inc

Terrestrial GIS Data 6

Theme	Data set(s)	Description	Originator
soils	ID county soils	Rasters of bulk density, clay percent, sand percent, and silt percent for each county in ID. For each county, SSURGO data are used where it is present. STATSGO data are used in areas where SSURGO data are not present	SDSMT
soils	id_statsgo	State soil geographic (STATSGO) data base for Idaho	USDA, NRCS
soils	id11buin	Raster of bulk density integer values corresponding to STATSGO map units	SDSMT
soils	id11clin	Raster of clay percent integer values corresponding to STATSGO map units	SDSMT
soils	id11sain	Raster of sand percent integer values corresponding to STATSGO map units	SDSMT
soils	id11siin	Raster of silt percent integer values corresponding to STATSGO map units	SDSMT
soils	id12buin	Raster of bulk density integer values corresponding to STATSGO map units	SDSMT
soils	id12clin	Raster of clay percent integer values corresponding to STATSGO map units	SDSMT
soils	id12sain	Raster of sand percent integer values corresponding to STATSGO map units	SDSMT
soils	id12siin	Raster of silt percent integer values corresponding to STATSGO map units	SDSMT
soils	MT county soils	Rasters of bulk density, clay percent, sand percent, and silt percent for each county in MT. For each county, SSURGO data are used where it is present. STATSGO data are used in areas where SSURGO data are not present	SDSMT
soils	mt_statsgo	State soil geographic (STATSGO) data base for Montana	USDA, NRCS
soils	mt11buin	Raster of bulk density integer values corresponding to STATSGO map units	SDSMT

Terrestrial GIS Data 7

Theme	Data set(s)	Description	Originator
soils	Mt11clin	Raster of clay percent integer values corresponding to STATSGO map units	SDSMT
soils	mt11sain	Raster of sand percent integer values corresponding to STATSGO map units	SDSMT
soils	mt11siin	Raster of silt percent integer values corresponding to STATSGO map units	SDSMT
soils	mt12buin	Raster of bulk density integer values corresponding to STATSGO map units	SDSMT
soils	mt12clin	Raster of clay percent integer values corresponding to STATSGO map units	SDSMT
soils	mt12sain	Raster of sand percent integer values corresponding to STATSGO map units	SDSMT
soils	mt12siin	Raster of silt percent integer values corresponding to STATSGO map units	SDSMT
soils	mt13buin	Raster of bulk density integer values corresponding to STATSGO map units	SDSMT
soils	mt13clin	Raster of clay percent integer values corresponding to STATSGO map units	SDSMT
soils	mt13sain	Raster of sand percent integer values corresponding to STATSGO map units	SDSMT
soils	mt13siin	Raster of silt percent integer values corresponding to STATSGO map units	SDSMT
soils	SD county soils	Rasters of bulk density, clay percent, sand percent, and silt percent for each county in SD. For each county, SSURGO data are used where it is present. STATSGO data are used in areas where SSURGO data are not present	SDSMT
soils	sd_statsgo	State soil geographic (STATSGO) data base for South Dakota	USDA, NRCS

Terrestrial GIS Data 8

Theme	Data set(s)	Description	Originator
transportation	id_majroads	Interstate, U.S. and state highways, and other major roads in Idaho	Geographic Data Technology, Inc., ESRI
transportation	mt_majroads	Interstate, U.S. and state highways, and other major roads in Montana	Geographic Data Technology, Inc., ESRI
transportation	mt_rail_100k	Montana railroads from the National Rail Network 1:100k	Fed. Railroad Admin., Bur. of Tran. Stat.
transportation	sd_majroads	Interstate, U.S. and state highways, and other major roads in South Dakota	Geographic Data Technology, Inc., ESRI
Added by KLU:			
emissions	99neiv2asciiaarea	1999 nationwide NEI (criteria and HAP) pollutant data	SDSMT
emissions	eGRID2002yr00	2000 nationwide CO2 emissions from utilities/energy producers	SDSMT
emissions	bysector_id	2001 emissions of CO2, CH4 and N2O from energy production/use	SDSMT
emissions	bysector_mt	2001 emissions of CO2, CH4 and N2O from energy production/use	SDSMT
emissions	bysector_sd	2001 emissions of CO2, CH4 and N2O from energy production/use	SDSMT
forestry	TablesForStateTotals	Data from GTRNE 298; forest C stocks/fluxes as of 19997	SDSMT
emissions	livestock	1997 cattle, hog, poultry, sheep, horse etc.. inventory data from Ag Census	SDSMT

Geologic Carbon Sequestration GIS Database Structure and Summary of Infrastructure Data Compilation and Analysis Inputs

The Idaho National Engineering and Environmental Laboratory (INEEL) is supporting the Big Sky Partnership by providing geologic carbon sequestration evaluations and geospatial data management. The region of interest includes Idaho, Montana, South Dakota, and geologically contiguous areas in North Dakota and Wyoming. The geologic sequestration potential is being assessed in sedimentary and volcanic basins including deep saline aquifers, depleted oil/gas reservoirs, deep unminable coal beds, and mafic/rock hosted fresh aquifers. During this first year of a two-year program, the INEEL Geologic Sequestration team has developed a Geographical Information System (GIS) database structure and identified the sources of data that will be populated in the database. During the next year, these data will be evaluated to determine the sequestration potential for geologic sites within the Big Sky region.

The INEEL is assessing the sequestration potential of the large traditional hydrocarbon basins located in Montana, Wyoming and South Dakota; and additionally has developed a procedure to evaluate the non-traditional volcanic basins plays found in southern Idaho. These non-traditional volcanic basins were first identified and classified by the U.S. Geologic Survey (USGS) in a 1995 report detailing the oil and gas potential of the United States (USGS 1995). These basins contain multiple plays¹ within the Eastern and Western Snake River Plains. Because these basins are of volcanic origin, they have not been explored for hydrocarbons and therefore, there is not the wealth of oil patch data available for them like there is for the oil and gas producing basins of Montana and Wyoming. As a result, data will be collected from a diversity of sources including but not limited to wells that have been drilled for geothermal exploration, and outcroppings of primary geologic features. Because the Eastern and Western Snake River Plains are unique volcanic basins, there are a large number of publications available that have described the water chemistry, mineralogy, and structure of the system. The data needed to populate the database will be extracted from the available sources, this process is more labor intensive, but will result in data comparable to the other basins.

During the performance period the overall approach to assess geologic carbon sequestration potential was developed (Figure 1). This assessment is based on the data collected and fed into a GIS based database. The database is structured to feed critical information into the geochemical and reservoir modeling activities. These modeling activities will then be used to characterization the suitability of each candidate site with respect to its carbon dioxide sequestration potential. The modeling approach is detailed in a report by Smith et al 2004 see attached. We are using a two-phased approach for the assessment of regional geologic carbon dioxide sinks found within the study area. The first phase is the identification of geologic ‘plays’ that are screened against carbon

¹ The fundamental geologic unit used in the 1995 National Oil and Gas Assessment was the ‘play’, which is defined as a set of known or postulated oil and or gas accumulations sharing similar geologic, geographic, and temporal properties, such as source rock, migration pathways, timing, trapping mechanism, and hydrocarbon type

The GIS database has been built using Environmental Systems Research Institute (ESRI) products to optimize compatibility across the user base. Geospatial information housed in the GIS complies with the Federal Geographic Data Committee's (FGDC) metadata standards for documenting source and lineage of geospatial data.

Geospatial information associated with geologic sequestration for the Big Sky Partnership has been and continues to be collected from a variety of sources. These sources include the Wyoming Oil and Gas Conservation Commission, US Geological Survey, Montana Geological Survey, Montana Board of Oil and Gas Conservation, Environmental Systems Research Institute, Wyoming Geographic Information Science Center, Idaho Department of Water Resources, and Montana Natural Resources Information System. All GIS data layers, associated data tables, and metadata have been placed in a directory structure that reflects the type of data one would expect to find by the name of each subdirectory.

<u>Data Structure for GIS and Tabular Data</u>	
Carbon Sequestration (top level directory)	
Boundaries	
	State boundaries
	National Parks/Reserves
	Indian Lands
	Counties
Geologic Feature	
	Snake River Plain
	Basalt flows
	Faults/Vents
Hydrography	
	Rivers/Streams
Land Use/Land Cover	
	USGS Land Use Land Cover Maps
	Cities/Towns
	Population
Oil and Gas Fields	
	Wyoming
	Provinces
	Montana
	Provinces
	Idaho
Plays	
	Provinces
	prov1
	prov2
	pr0100 (province boundary polygon)
	pr0101 (individual play polygon)
	...
Sources (carbon sources)	
	Power plants
	EPA – Clean Air Markets Division dataset (from NATCARB)
	EPA – EGRID dataset (from NATCARB)
	Other non-power producing sources
Topography	
	Digital Elevation Models (DEM)
	Shaded Relief

Data Structure for GIS and Tabular Data (cont.)

Transportation

Roads/trails

Wells

Wind River

Tensleep

Well information table

LONGITUDE (x coordinate)

LATITUDE (y coordinate)

API_NUMBER (unique field assigned to each well by formation)

TOWNSHIP (public land survey system)

RANGE (public land survey system)

SECTION (public land survey system)

SURVEYTYPE

QTR_QTR (quarter quarter section)

ALIUOT

WELL (name of well)

COMPANY (drilling company)

FIELD (associated oil field)

ELEVATION (land surface elevation)

SPUD_DATE (start of production)

TD (formation name)

WELL_CLASS (oil, injection, gas, etc.)

TD_FORM (target depth to formation)

STATUS (two letter code describing current status of well)

COMPLETED (date well was completed)

APPROVED (date of mineral rights)

SYMBOL

TOP1 (formation name)

DEPTH_TOP1 (depth below surface)

TOP2 (formation name)

DEPTH_TOP2 (depth below surface)

TOP3 (formation name)

DEPTH_TOP3 (depth below surface)

Water chemistry

Pressure

Phosphoria

Well information table

Water chemistry

Pressure

Frontier

...

Madison

...

Crow Mountain

...

Jelm

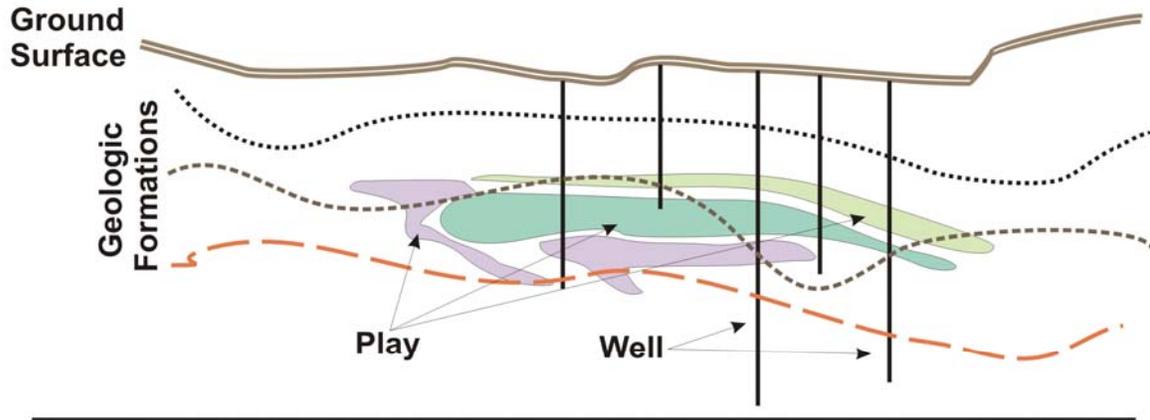
Well information table

Water chemistry

Pressure

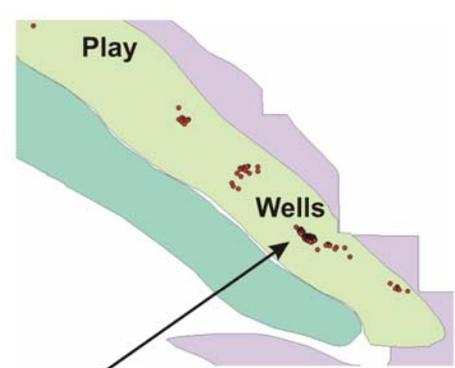
Most of the files that reside in the data structure are already in the form of a GIS layer; however, a number of tables including well information, water chemistry and pressure get linked to the appropriate play by geographic location and a key field called API_Number (see Figure 2).

Information collection to date for wells and geologic features has focused on Wyoming mainly due to the large amount of data available (**117,304** active wells). Montana also has adequate well (approximately **50,000** active wells) and oil field information, but Idaho is less rich in oil and gas well data. For Idaho, most well information will come from the USGS, Idaho Department of Water Resources, papers, reports, and books.



Well Information Table

LONGITUDE	LATITUDE	API_NUMBER	TOW	RANG	SEC	SUR	QTR	REAL	QUOT	WELL
-105.966670	41.444200	49-001-05148	17N	77W	13W	NE	SE	635	FNL 250 FWL	FREDERICK G HOLST 15
-105.976500	41.439600	49-001-20113	17N	76W	18W	SE	SW	200	FNL 1600 FWL	WILSON 12
-107.859200	44.246010	49-003-05217	49N	92W	11W	NV	SW	1590	FSL 660 FWL	FEDERAL 5
-107.931910	44.267420	49-003-05245	50N	92W	32W	NE	NE	660	FNL 660 FWL	MANDERSON UNIT F-41-32-P
-108.533590	44.794197	49-003-06209	56N	97W	33W	NW	NE	2040	FNL 660 FWL	CROSS GAS 7
-108.482440	44.782860	49-003-06268	56N	97W	25W	SE	SW	220	FNL 1542 FWL	STATE 2
-108.575470	44.800320	49-003-06278	56N	97W	30W	NE	SE	1580	FSL 1000 FWL	KINNEY COASTAL 14
-108.507420	44.825670	49-003-06418	56N	97W	14W	SW	SW	325	FSL 440 FWL	HOSKINS A 4
-107.977820	44.280390	49-003-06605	51N	93W	24W	SW	NE	1850	FNL 2000 FWL	TLMTU 24
-107.981170	44.405670	49-003-20178	51N	93W	12W	NE	NW	2121	FSL 2121 FWL	ANTICLINE UNIT 12
-108.544960	44.794140	49-003-20188	56N	97W	33W	NE	NW	200	FNL 1077 FWL	GEORGE EASTON 8
-108.550490	44.797310	49-003-20198	56N	97W	28W	SW	SW	400	FSL 425 FWL	P O SESSIONS 4
-108.536210	44.783780	49-003-20286	56N	97W	33W	SE	SE	535	FNL 925 FWL	VERNON SMITH 13
-108.543830	44.794630	49-003-20790	56N	97W	28W	SW	SW	513	FNL 1897 FWL	GEORGE EASTON 12
-108.534960	44.791070	49-003-20792	56N	97W	33W	SE	NE	625	FNL 659 FWL	YATES 5
-108.549490	44.795780	49-003-20842	56N	97W	33W	NE	NW	2953	FSL 1374 FWL	CROSS GAS 13
-108.577380	44.809620	49-003-20924	56N	97W	19W	SW	SE	361	FSL 1500 FWL	KINNEY COASTAL 100
-108.583230	44.808627	49-003-20925	56N	97W	30W	NE	NW	813	FNL 2171 FWL	KINNEY COASTAL 99
-108.577910	44.803490	49-003-20931	56N	97W	30W	SW	NE	1548	FNL 1638 FWL	UTAH SOUTHERN 72
-108.533200	44.869490	49-003-20973	56N	97W	4W	NW	NE	94	FNL 577 FWL	WELCH 4
-108.551820	44.794310	49-003-20977	56N	97W	32W	NE	NE	863	FNL 169 FWL	UTAH SOUTHERN 73
-108.536150	44.780230	49-003-20979	56N	97W	33W	SE	SE	1401	FNL 1387 FWL	VERNON SMITH 17
-108.536290	44.780230	49-003-20980	56N	97W	33W	SE	SE	1401	FNL 1412 FWL	VERNON SMITH 16
-107.953880	44.291560	49-003-20989	50N	92W	19W	SW	NE	1876	FNL 1511 FWL	MANDERSON UNIT 32-19
-107.955040	44.284150	49-003-20995	50N	92W	19W	SW	SE	687	FNL 1794 FWL	MANDERSON UNIT 34-19P
-108.609440	44.843500	49-003-21008	57N	71W	7W	NW	NE	330	FNL 2310 FWL	SAGE CREEK UNIT 23
-108.562001	44.797230	49-003-21025	56N	97W	29W	SE	SW	456	FSL 2437 FWL	UTAH SOUTHERN 71
-108.520000	44.829230	49-003-21044	56N	97W	15W	NE	SW	1590	FSL 1484 FWL	HOSKINS B 6
-108.524900	44.829230	49-003-21044	56N	97W	15W	NE	SW	1590	FSL 1484 FWL	HOSKINS B 8



X Y coordinates from table used to build Well Map

Formation Table

API_NUMBER	TD	WELL_CLASS	TD_FORM	STATUS	COMPLETED	APPROVED	SYMBOL	TOP1	DEPTH1	TOP2	DEPTH2
49-001-05148	DAKOTA	OIL	5511	PR	8/25/2000	3/11/948	11	TENSLEEP	5372		
49-001-20113	TENSLEEP	OIL	5555	PS	6/28/2002	12/13/2001	11	TENSLEEP	5318		
49-003-05217	TENSLEEP	OIL	6640	FL	7/7/1999	4/7/1990	11	TENSLEEP	5830	AMSDEN	5846
49-003-05245	PHOSPHORIA	OIL	7396	PA	3/29/1953	1/22/1952	61	TENSLEEP	5943	LEWIS	5262
49-003-06209	MADISON	GAS	4395	FL	7/1/1999	2/23/1950	12	TENSLEEP	3112	MADISON	3392
49-003-06268	EMBAR	DR	5488	DR	12/15/1946	9/27/1946	41	TENSLEEP	6790	AMSDEN	7092
49-003-06278	MADISON	OIL	4877	PR	4/8/1946	12/19/1945	11	TENSLEEP	4121	MADISON	4420
49-003-06418	TENSLEEP	INJECTOR	5758	AI	2/7/2003	8/28/1958	13	TENSLEEP	5138	AMSDEN	5395
49-003-06605	PT	OIL	3680	PR	7/21/2000	4/7/1996	11	TENSLEEP	3080		
49-003-20178	MADISON	OIL	4394	PR	6/22/1970	4/28/1970	11	TENSLEEP	3506	MADISON	3802
49-003-20188	MADISON	GAS	4590	FL	7/17/1998	8/25/1970	12	TENSLEEP	3120	MADISON-A	3520
49-003-20198	MADISON	OIL	4535	FL	1/29/1998	8/5/1971	11	TENSLEEP	3242	MADISON	3343
49-003-20286	MADISON	OIL	4540	FL	2/11/1971	10/29/1973	11	TENSLEEP	3454	AMSDEN	3604
49-003-20790	MADISON	OIL	4560	SI	8/14/1968	3/18/1967	21	TENSLEEP	3106	AMSDEN	3388
49-003-20792	DAKOTA	GAS	4505	SI	5/11/1998	7/16/1987	22	TENSLEEP	3180	DARWIN	3424
49-003-20842	MADISON	OIL	4569	DR	12/27/1988	10/29/1989	41	TENSLEEP	3200	AMSDEN	3325
49-003-20924	EMBAR	OIL	4755	PR	8/5/1997	12/13/1995	11	TENSLEEP	4202	AMSDEN	4307

Water Chemistry

API	Top	Base	Temp	RW	Pres	Formation	
049-007-20220	5662	5140	130	0	1584	Cloverly	
049-013-21202	3950	4050	130	2	1600	Dakota	
049-013-20113	5172	5220	132	0	1870	Dakota	
049-013-20783	4503	4523	0	5	2265	Dakota	
049-025-21678	4525	4620	148	0	6	2082	Dakota
049-025-21039	7366	7417	174	4.5	2796	Dakota	
049-025-21221	7210	7250	159	0	2226	Dakota	
049-025-20501	6375	6387	152	0	604	Dakota	
049-025-20006	7285	7314	0	0	0	Dakota	
049-009-21828	6830	6856	136	5	1086	Dakota	
049-009-20695	5680	5692	130	3.2	2552	Dakota	
049-009-20078	6341	6395	130	3.2	1985	Dakota	
049-009-21927	4720	4774	88	0	0	Dakota	
049-009-22231	5001	5021	112	42	1448	Dakota	
049-009-27895	5110	5148	114	1.7	2207	Dakota	
049-007-21458	6402	6436	0	2.8	161	Dakota	
049-001-20059	6331	6368	144	2	2327	Dakota	
049-001-20005	5850	5602	134	0	1803	Dakota	

Pressure Table

API Number	SODIUM	POTASH	LITHIUM	CALCIUM	MAGNESIUM	IRON	SULFATE	CHLORIDE	CARBONATE	BICARBONATE	HYDROXIDE	HYD SULFIDE	Other Solids	pH	Formation
049-025-05401	823.19	71	0.32	14	2.21	0.05	80.9	1250	0	0	0	0	2176.78	7.9	Cloverly
049-035-22239	1160	88.7	0	1700	3.18	0.09	93	3300	0	0	0	0	12100	7.8	Lance
049-035-22233	1590	33.1	0	34.8	0.38	4.83	63	140	0	0	0	0	4860	7.55	Lance
049-035-22286	761	0	0	499	0	0	194	1950	0	0	0	0	5720	6.96	Lance
049-035-21643	1380	88.7	0	2940	3.83	0	16	7000	0	0	0	0	12000	6.97	Lance
049-035-21549	3050	0	0	1.74	1.45	0	30.5	1220	0	0	0	0	4130	8.24	Lance
049-035-21697	190	78.8	0.74	736	3.4	0.83	8.09	97.3	0	0	0	0	4880	7.44	Lance
049-035-21942	932	0	0	0.85	0.39	0	220	913	0	0	0	0	3870	7.44	Lance
049-035-21764	1220	0	0	0.7	0.77	0	100	1020	0	0	0	0	4720	7.26	Lance
049-035-21241	1620	171	0	1460	17.02	0	126	4000	0	0	0	0	6540	7.83	Lance
049-035-21556	991	0	0	5.63	0.72	0	280	845	0	0	0	0	2870	8.07	Lance
049-035-21391	844	0	0	1.08	3.57	0	30.5	4970	0	0	0	0	2800	7.91	Lance
049-035-21595	215	0	0	0.15	0	0	19.28	103	0	0	0	0	1260	7.04	Lance
049-035-21918	264	0	0	3.45	0.56	0	196	362	0	0	0	0	1290	6.93	Lance
049-035-21665	295	9.71	0	897	0.32	0	4	2000	0	0	0	0	3500	7.19	Lance
049-035-21690	0	0	0	90.2	4.66	0	88	1870	0	0	0	0	3300	7.34	Lance
049-035-22065	3200	0	0	154	31.7	0	41.2	8000	0	0	0	0	13500	6.95	Lance

Figure 2 GIS Database Structure for Plays, Wells, and Geologic Formations.

References:

1. USGS - multiple authors, 1995, 1995 National Assessment of United States Oil and Gas Resources; U.S. Geological Survey Circular 1118, U.S. Government Printing Office, Washington, 1995.
2. Smith R.W., McLing T.L., Barrash W., Clement W.P., Erickson N.P., *Geologic Sequestration of CO₂: A Uniform Strategy for Assessing Mineralization Trapping Potential Across Rock Types*, Proceedings of the Third Annual Conference on Carbon Capture and Sequestration, Alexandria, VA, May 2004.

INRA 2003 Subsurface Science Symposium Agenda

Sunday, October 5, 2003		
5:30 - 7:30 pm	Registration Desk Open	Salt Palace
6:00 - 8:00 pm	Welcome Reception	Salt Palace - Room 251D

Monday, October 6, 2003		
7:30 am - 4:30 pm	Registration Desk Open	Salt Palace
8:30 - 9:20 am 8:30 am 8:35 am 8:40 am 8:55 am 9:10 am	Welcome and Overview <ul style="list-style-type: none"> • Welcome & Symposium Information - Gautam Pillay, Executive Director, INRA • Welcome - Kermit Hall, INRA Vice President, Utah State Univ. President • INRA Overview - Gautam Pillay, Executive Director, INRA • INEEL Overview - Paul Kearns, Deputy Director, Idaho National Engineering and Environmental Laboratory • DOE-ID Overview - Linda McCoy, Chief Scientist, U.S. Department of Energy Idaho Operations 	Salt Palace - Room 251D
9:20 - 9:30 am	Subsurface Science Initiative - P. Michael Wright , Director, Subsurface Science Initiative, INEEL, <i>"Advancing the Subsurface Science Research Agenda – A Call to Action"</i>	Salt Palace - Room 251D
9:30 - 10:15 am	Keynote Address - Dr. Harrison (Jack) Schmitt , Former New Mexico Senator and Apollo 17 Astronaut, <i>"Field Exploration on the Moon"</i> Click here for Dr. Schmitt's biography.	Salt Palace - Room 251D
10:15 - 10:30 am	Break, <i>continental breakfast provided</i>	Salt Palace - Landing
10:30 - 11:05 am	Plenary Address - Dr. Terry Hazen , Lawrence Berkeley National Laboratory, <i>"Natural Attenuation and Bioremediation: Critical Biogeochemistry in Treatment Trains"</i> Click here for Dr. Hazen's biography.	Salt Palace - Room 251D
11:05 - 11:40 am	Plenary Address - Dr. Rosemary Knight , Stanford University, <i>"Geophysical Images of the Near-Surface: What are we really seeing?"</i> Click here for Dr. Knight's biography.	Salt Palace - Room 251D
11:40 am - 1:00 pm	Lunch Break	on own

1:00 - 5:00 pm	TECHNICAL SESSIONS Environmental Policy and Management <i>Role of Stakeholders in Determining Environmental Policy</i> (Chair: Gautam Pillay, INRA)	Salt Palace - Room 250A
LEAD 1:00 - 1:35 pm	Topic/Session: Environmental Policy and Management <i>Author - J.D. Wulfhorst</i> , Department of Agricultural Economics & Rural Sociology, University of Idaho	Salt Palace - Room 250A
1:35 - 2:00 pm	Probabilistic Risk Assessment and Multi-Criteria Decision Analysis for the Management of Contaminated Subsurface <i>Author - Ibrahim M. Khadam</i> , Utah Water Research Laboratory, Utah State University Jagath J. Kaluarachchi, Utah Water Research Laboratory, Utah State University	Salt Palace - Room 250A
2:00 - 2:50 pm	Panel Discussion of "Role of Stakeholders in Determining Environmental Policy" - Organized by <i>Gautam Pillay</i> Presentations by: <ul style="list-style-type: none"> • J.D. Wulfhorst, University of Idaho • Fred Wagner, Utah State University • Ron Sims, Utah State University (invited) • Phil Bandy, Idaho Department of Environmental Quality (invited) • Roy Mink, U.S. Department of Energy (invited) • Julia Gustafson, Counsel, Rep. Dennis Rehberg (R-MT) (invited) • Ryan Thomas, Staff Member, U.S. Senate Subcommittee on Interior Appropriations (invited) 	Salt Palace - Room 250A
		Salt Palace -

2:50 - 3:20 pm	Break, refreshments provided	Room 251D
3:20 - 5:00 pm	CONTINUED: Panel Discussion of "Role of Stakeholders in Determining Environmental Policy" - Organized by Gautam Pillay	Salt Palace - Room 250A
6:00 - 8:00 pm	Poster Session & Catered Reception All technical posters will be on display; student posters will be judged. Complimentary hors d'oeuvres and cash bar will be provided for all attendees. To view poster titles and authors, click here .	Salt Palace - Room 251D

1:00 - 4:10 pm	TECHNICAL SESSIONS Geophysics (Chair: Russ Hertzog, INEEL)	Salt Palace - Room 250D
LEAD 1:00 - 1:35 pm	Spectral Analysis of Visual Images for Characterizing Hydraulic Conductivity Fields <i>Author - Greg A. Oldenborger, Boise State University</i> Robert A. Schincariol and Lalu Mansinha, University of Western Ontario, London, Ontario, CAN	Salt Palace - Room 250D
1:35 - 2:00 pm	Nuclear Probes to Determine the Contents of Buried Waste <i>Author - Ray Keegan, Idaho National Engineering and Environmental Laboratory</i> Woo Yoon, Russell Hertzog, Chris McGrath, Idaho National Engineering and Environmental Laboratory, Jeffrey Schweitzer, University of Connecticut, Storrs, CT Donald Steinman, Integrated Physics Measurements, Houston, TX George Schneider, US Department of Energy, Idaho Falls, ID	Salt Palace - Room 250D
2:00 - 2:25 pm	Fresnel Volume Attenuation Difference Inversion of Borehole Georadar Data <i>Author - Timothy C. Johnson, Boise State University</i> Michael D. Knoll and Warren Barrash, Boise State University	Salt Palace - Room 250D
2:25 - 2:50 pm	Wave Propagation Studies Through Sediments at In Situ Conditions <i>Author - Manika Prasad, Stanford University, Stanford California</i> Sandra Vega and Traci Bryar, Stanford University, Stanford California	Salt Palace - Room 250D
2:50 - 3:20 pm	Break, refreshments provided	Salt Palace - Room 251D
3:20 - 3:45 pm	Appraisal Analysis in Geophysical Inversion: A Practical Tool for Image Interpretation <i>Authors - Partha S. Routh and Michael D. Knoll, Dept of Geosciences, Boise State University</i>	Salt Palace - Room 250D
3:45 - 4:10 pm	A Novel Optical Method for Measuring Strain in Coal as a Function of Pore Pressure <i>Author - Eric P. Robertson, Idaho National Engineering and Environmental Laboratory and Colorado School of Mines</i> Richard L. Christiansen, Colorado School of Mines	Salt Palace - Room 250D
6:00 - 8:00 pm	Poster Session & Catered Reception All technical posters will be on display; student posters will be judged. Complimentary hors d'oeuvres and cash bar will be provided for all attendees. To view poster titles and authors, click here .	Salt Palace - Room 251D

1:00 - 5:00 pm	TECHNICAL SESSIONS Multi-Discipline Panel Discussion (Chair: Paul Wichlacz, INEEL)	Salt Palace - Room 251A
1:00 - 2:50 pm	Panel Discussion of "A Conceptual Model of Flow and Contaminant Transport at the INEEL" - Organized by Paul Wichlacz Presentations by: <ul style="list-style-type: none"> • Michael Wright, Idaho National Engineering and Environmental Laboratory • Joseph Rousseau, US Geological Survey • Thomas Wood, Idaho National Engineering and Environmental Laboratory • Brennon Orr, North Wind, Inc. • Robert Starr, Idaho National Engineering and Environmental Laboratory 	Salt Palace - Room 251A
2:50 - 3:20 pm	Break, refreshments provided	Salt Palace - Room 251D
3:20 - 5:00 pm	CONTINUED: Panel Discussion of "A Conceptual Model of Flow and Contaminant Transport at the INEEL" - Organized by Paul Wichlacz	Salt Palace - Room 251A
6:00 - 8:00 pm	Poster Session & Catered Reception All technical posters will be on display; student posters will be judged. Complimentary hors d'oeuvres and cash bar will be provided for all attendees. To view poster titles and authors, click here .	Salt Palace - Room 251

Tuesday, October 7, 2003		
7:30 am - 4:30 pm	Registration Desk Open	Salt Palace
7:30 - 8:00 am	Continental Breakfast	Salt Palace - Room 251D
9:50 - 10:20 am	Break, <i>refreshments provided</i>	Salt Palace - Room 251D
12:00 - 1:30 pm	Lunch Break	on own
3:20 - 3:50 pm	Break, <i>refreshments provided</i>	Salt Palace - Room 251D
6:00 - 8:00 pm	Poster Session & Catered Reception All technical posters will be on display; student posters will be judged. Complimentary hors d'oeuvres and cash bar will be provided for all attendees. To view poster titles and authors, click here .	Salt Palace - Room 251D

8:00 am - 12:00 pm	TECHNICAL SESSIONS Bioremediation <i>Microbial Remediation</i> (Chair: Rick Colwell, INEEL)	Salt Palace - Room 250A
LEAD 8:00 - 8:35 am	Mineral Surface-Associated Microbial Community Structure at a Subsurface Uranium Contaminated Site <i>Author - Gill Geesey</i> , Montana State University Catherine Reardon, Montana State University David Cummings, Idaho National Engineering and Environmental Laboratory Brent Peyton, Washington State University David Watson and Barry Kinsall, Oak Ridge National Laboratory	Salt Palace - Room 250A
8:35 - 9:00 am	Iron (III) Minerals Can Impact the Microbial Reduction of 2,4,6-Trinitrotoluene <i>Author - Thomas Borch</i> , Montana State University Alfred B. Cunningham and Robin Gerlach, Montana State University	Salt Palace - Room 250A
9:00 - 9:25 am	Influence of Adsorbates on Microbial Interaction with Mineral Surfaces <i>Author Allison E. Ray</i> , Idaho State University Timothy S. Magnuson, Idaho State University David E. Cummings, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 250A
9:25 - 9:50 am	Cr (VI) Reduction by Cellulomonas: Multi-Scale Flow-Cell Experiments <i>Author - Brent M. Peyton</i> , Washington State University Sridhar Viamajala and Vaidee Sivaswamy, Washington State University William A. Apel, Idaho National Engineering and Environmental Laboratory Robin Gerlach and Alfred B. Cunningham, Montana State University	Salt Palace - Room 250A
9:50 - 10:20 am	Break, <i>refreshments provided</i>	Salt Palace - Room 251D
10:20 - 10:45 am	Genomic Analysis of a Microbial Community by Microarray Comparative Genomic Hybridization <i>Author - Ronald L. Crawford</i> , University of Idaho Jonathan L. Sebat, Cold Spring Harbor Laboratory, Cold Spring Harbor, NY Frederick S. Colwell, Idaho National Engineering & Environmental Laboratory	Salt Palace - Room 250A
10:45 - 11:10 am	Influence of Electron Shuttling Compounds on the Reduction of Metals and Organics <i>Author - Robin Gerlach</i> , Montana State University Thomas Borch, Al B. Cunningham, Montana State University Sridhar Viamajala, Brent M. Peyton, Washington State University William A. Apel, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 250A
11:10 - 11:35 am	Microbial Diversity of Mineral-Associated Biofilms Collected from a Uranium-Contaminated Aquifer <i>Author- Catherine Reardon</i> , Montana State University Gill Geesey, Montana State University David Cummings, Lynn Petzke, Idaho National Engineering and Environmental Laboratory David Watson, Barry Kinsall, Oak Ridge National Laboratory	Salt Palace - Room 250A

11:35am - 12:00pm	Bioremediation of Cr(VI) Contaminated Soil and Groundwater: Column Experiments <i>Author - Mahbub Alam</i> , Washington State University David Yonge, Brent Peyton, and James Petersen, Washington State University Akram Hossain, Washington State University, Tri-Cities campus, Richland, WA	Salt Palace - Room 250A
12:00 - 1:30 pm	Lunch Break	on own

8:00am - 12:00pm	TECHNICAL SESSIONS Geochemistry <i>Geochemistry Tools and Aqueous-Phase Studies</i> (Chair: George Redden, INEEL)	Salt Palace - Room 250D
LEAD 8:00 - 8:35 am	Field Portable Electrochemical Sensors for Heavy Metals <i>Author - J.M. Scaggs</i> , Boise State University D.D. Russell, W.B. Knowlton, L.R. Warner, R.L. Meyer, and D. Kiri, Boise State University W. Bauer, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 250D
8:35 - 9:00 am	Effects of Wetting and Drying Cycles on Metal Mobility <i>Author - Karen E. Wright</i> , Idaho National Engineering and Environmental Laboratory D. Craig Cooper, William F. Bauer, and George D. Redden, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 250D
9:00 - 9:25 am	A Benzene Selective Electrode <i>Author - L. R. Warner</i> , Boise State University D. D. Russell, Boise State University	Salt Palace - Room 250D
9:25 - 9:50 am	Mineral Surface Reactivity Using Isotopic Oxygen Exchange with Secondary Ion Mass Spectrometry <i>Author - Recep Avci</i> , Montana State University Cem Karahan and Jan Sunner, Montana State University Anita Gianotto, and Gary Groenewold, Idaho National Engineering and Environmental Laboratory Senay Yalcin, Bahcesehir University, Istanbul, Turkey	Salt Palace - Room 250D
9:50 - 10:20 am	Break, refreshments provided	Salt Palace - Room 251D
10:20 - 10:45 am	Study of Mesoporous Sorption Phenomena Using a SiO₂ Soil Simulant <i>Author - Diana Washington</i> , Washington State University David Yonge, Brent Peyton, and Reid Miller, Washington State University Gary Groenewold, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 250D
10:45 - 11:10 am	Applications and Technological Spin-offs of Electron LINACS to Sub-Surface and other Environmental Sciences <i>Author - Doug Wells</i> , Idaho State University F. A. Selim, J. Kwofie, F. J. Harmon, Idaho State University G. Erickson, Boise State University J.L. Jones, T. White, T. Roney, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 250D
11:10 - 11:35 am	Fabrication of ChemFETS for Uranium Detection in Geological Subsurface Groundwater <i>Author - William Knowlton</i> , Boise State University Dale Russell, Dorian Kiri, Jonathan Scaggs, Lisa Warner, and Ryan Meyer, Boise State University	Salt Palace - Room 250D
11:35am - 12:00pm	The Effect of Co-Solvents in Modified Fenton's Reagent <i>Author - Brant A. Smith</i> , Washington State University Richard J. Watts, Washington State University David A. Atkinson, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 250D
12:00 - 1:30 pm	Lunch Break	on own

8:00am - 12:00pm	TECHNICAL SESSIONS Modeling <i>Modeling Methods</i> (Chair: Akram Alshawabkeh, Northeastern University)	Salt Palace - Room 251A
LEAD 8:00 - 8:35 am	Time Domain Forward Computational Modeling of Complex Dispersive Media for Underground Sensing Applications <i>Author - Carey Rappaport</i> , Northeastern University, Boston, MA	Salt Palace - Room 251A

	Akram Alshawabkeh, Northeastern University, Boston, MA	
8:35 - 9:00 am	Optimal Collocation Solution of Steady-State Convection-Diffusion Equations <i>Author - Stephen H. Brill</i> , Boise State University	Salt Palace - Room 251A
9:00 - 9:25 am	The Use of a Physical Test Cell to Evaluate Assumptions Made in Fate and Transport Modeling <i>Author - Daniel B. Shrum</i> , Envirocare of Utah, Inc. Timothy L. Orton, Envirocare of Utah, Inc.	Salt Palace - Room 251A
9:25 - 9:50 am	Simulation of Colloidal Transport via the Lattice Boltzmann Method <i>Authors - Hakan Basagaoglu and Paul Meakin</i> , Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 251A
9:50 - 10:20 am	Break, refreshments provided	Salt Palace - Room 251D
10:20 - 10:45 am	A Mixing-Cell Model for Assessment of Water Flow and Solute Transport in the Unsaturated Zone <i>Author - Arthur S. Road</i> , Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 251A
10:45 - 11:10 am	Modeling 2D Water Flow in Heterogeneous Unsaturated Media at INTEC: Uncertainty Analysis <i>Author - Joan Q. Wu</i> , Washington State University Richard Rossi and Limin Yang, Washington State University Annette L. Schafer and Larry C. Hull, Idaho National Engineering and Environmental	Salt Palace - Room 251A
11:10 - 11:35 am	Electrical and Petrophysical Parameter Modeling and Inversion of Ferron Sandstone Data <i>Author - Robert B. Szerbiak</i> , Boise State University George A. McMechan, The University of Texas, Dallas, TX Craig B. Forster and Stephen H. Snelgrove, University of Utah	Salt Palace - Room 251A
11:35am - 12:00pm	Geoenvironmental Research at the INEEL Geocentrifuge Laboratory <i>Author - Alan T. Stadler</i> , Director, INEEL Geocentrifuge Research Laboratory	Salt Palace - Room 251A
12:00 - 1:30 pm	Lunch Break	on own

1:30 - 5:05 pm	TECHNICAL SESSIONS Bioremediation <i>Remediation Techniques</i> (Chair: Al Cunningham, Montana State University)	Salt Palace - Room 250A
LEAD 1:30 - 2:05 pm	Controlled Cultivation: Strategies for Improving our Understanding of the Biology behind Bioremediation <i>Author - Yuri Gorby</i> , Pacific Northwest National Laboratory	Salt Palace - Room 250A
2:05 - 2:30 pm	Applying Enzyme Activity Probes to Evaluate a TCE Contaminated Aquifer <i>Author - Scott R. Clingenpeel</i> , Idaho State University Michelle H. Howard-Jones, and Mary E. Watwood, Idaho State University William K. Keener, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 250A
2:30 - 2:55 pm	Remediation of Metal Contaminants by Microbially Mediated Calcite Precipitation <i>Author - Robert W. Smith</i> , D.M. Cosgrove, J.L. Taylor, University of Idaho Y. Fujita, F.S. Colwell, T.L. McLing, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 250A
2:55 - 3:20 pm	Potential for Enhancement of In Situ Bioremediation by Electrochemical Methods <i>Author - Akram N. Alshawabkeh</i> , Dept of Civil and Environmental Engineering, NE University, Boston, MA Xingzhi Wu and James Wang, Dept of Civil and Environmental Engineering, NE University, Boston, MA David B. Gent, Environmental Lab, US Army Engineering Research & Development Center, Vicksburg, MS	Salt Palace - Room 250A
3:20 - 3:50 pm	Break, refreshments provided	Salt Palace - Room 251D
3:50 - 4:15 pm	Subsurface Biofilm Barriers for Containment and Remediation of Contaminated Groundwater <i>Author - Alfred B. Cunningham</i> , Montana State University Robert R. Sharp and Margo Adgie, Manhattan College, Riverdale NY Randy Hiebert and Garth James, MSE Technology Applications, Butte MT	Salt Palace - Room 250A

4:15 - 4:40 pm	Vadose Zone Bioremediation: Gene Probes, Intermediates, and Binding for PAHs <i>Author - Ronald C. Sims</i> , Utah State University Kevin A. Hall, Yanna Liang, Karl Nieman, and Charles Miller, Utah State University	Salt Palace - Room 250A
4:40 - 5:05 pm	Environmental Factors Affecting Natural Attenuation/Bioremediation of MTBE at a Full-Scale Site <i>Author - Aaron E. Swank</i> , Utah State University, Utah Water Research Laboratory Mark H. Greenwood and Ronald C. Sims, Utah State University, Utah Water Research Laboratory	Salt Palace - Room 250A
6:00 - 8:00 pm	Poster Session & Catered Reception All technical posters will be on display; student posters will be judged. Complimentary hors d'oeuvres and cash bar will be provided for all attendees. To view poster titles and authors, click here .	Salt Palace - Room 251D

1:30 - 5:30 pm	TECHNICAL SESSIONS Technology Transfer <i>The University-Industry Relationship</i> (Chair: Steven Billingsley, INRA)	Salt Palace - Room 250D
1:30 - 3:20 pm	Panel Discussion of the University-Industry Relationship – Organized by Steven Billingsley Presentations by: <ul style="list-style-type: none"> • Bradley B. Bertoch, President, Wayne Brown Institute (invited) • Richard Clayton, President, T2M (Technology to Market) • Norris F. Krueger, Faculty of Entrepreneurship, Idaho Small Business Development Center, Boise State University • Dale S. Richards, Wayne Brown Institute (invited) • William Ruud, Professor, Department of Management, Boise State University • Mel Ustad, Associate Dean of Research, University of South Dakota 	Salt Palace - Room 250D
3:20 - 3:50 pm	Break, <i>refreshments provided</i>	Salt Palace - Room 251D
3:50 - 5:30	CONTINUED: Panel Discussion of the University-Industry Relationship – Organized by Steven Billingsley	Salt Palace - Room 250D
6:00 - 8:00 pm	Poster Session & Catered Reception All technical posters will be on display; student posters will be judged. Complimentary hors d'oeuvres and cash bar will be provided for all attendees. To view poster titles and authors, click here .	Salt Palace - Room 251D

1:30 - 5:30 pm	TECHNICAL SESSIONS Hydrology (Chair: Ingrid Padilla, University of Puerto Rico)	Salt Palace - Room 251A
LEAD 1:30 - 2:05 pm	Emission from DNAPL Source Zones with Complex Entrapment Architecture <i>Author – Tissa H. Illangasekare</i> , Colorado School of Mines Satawat Saenton, Elena Moreno-Barbero, Colorado School of Mines	Salt Palace - Room 251A
2:05 - 2:30 pm	Simulation of Episodic Flood Events at the Idaho National Engineering and Environmental Laboratory (INEEL) Vadose Zone Research Park <i>Author - Kristine Baker</i> , Idaho National Engineering and Environmental Laboratory Larry Hull, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 251A
2:30 - 2:55 pm	Integrated Bayesian Network for Watershed Information Management <i>Author - Ahmed Said</i> , Civil and Environmental Department, Utah State University David K. Stevens, Civil and Environmental Department, Utah State University Gerald Sehlke, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 251A
2:55 - 3:20 pm	Estimating Transmissivity from Pumping Data using the Sensitivity Matrix Eigenvectors <i>Author – Tom Clemo</i> , Boise State University Paul Michaels, Boise State University R. Michael Lehman, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 251A
3:20 - 3:50 pm	Break, <i>refreshments provided</i>	Salt Palace - Room 251D

3:50 - 4:15 pm	Rate-Limited Mass Transfer of Volatile Organic Compounds in Unsaturated Porous Media <i>Autor - Ingrid Y. Padilla, Ph.D.</i> , Dept of Civil Engineering and Surveying, University of Puerto Rico, Mayagüez	Salt Palace - Room 251A
4:15 - 4:40 pm	NMR Imaging of Microbial Transport in Porous Media <i>Author - Justin P. Gage</i> , Montana State University, Bozeman Joseph D. Seymour, Sarah L. Codd, Robin Gerlach, and Alfred B. Cunningham, Montana State University	Salt Palace - Room 251A
4:40 - 5:05 pm	Use of Support Vector Machines in Groundwater Monitoring Network Design <i>Authors – Tirusew Asefa and Mariush Kemblowski</i> , Utah State University	Salt Palace - Room 251A
5:05 - 5:30 pm	Comparisons Between the Water Quality Index and the Biotic Indicators <i>Author - Ahmed Said</i> , Civil and Environmental Department, Utah State University David K. Stevens, Civil and Environmental Department, Utah State University Wayne G. Minshall, Stream Ecology Center – Department of Biological Sciences, Idaho State University Ron Rope, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 251A
6:00 - 8:00 pm	Poster Session & Catered Reception All technical posters will be on display; student posters will be judged. Complimentary hors d'oeuvres and cash bar will be provided for all attendees. To view poster titles and authors, click here .	Salt Palace - Room 251D

Wednesday, October 8, 2003

7:30 am - 1:00 pm	Registration Desk Open	Salt Palace
7:30 - 8:30 am	Continental Breakfast	Salt Palace - Room 251D
8:00 - 8:30 am	Student Poster Awards Presentation To view poster titles and authors, click here .	Salt Palace - Room 251D
10:20 - 10:50 am	Break and Poster Clean Up, <i>refreshments provided</i>	Salt Palace - Room 251D
12:30 pm	Lunch Break / End of Conference	on own

8:30am - 12:05pm	TECHNICAL SESSIONS Geochemistry <i>Geochemistry Applied to Nuclear Waste Treatment</i> (Chair: Bob Smith, UI)	Salt Palace - Room 250A
LEAD 8:30 - 9:05 am	SIMS Characterization of Soils Leached Using Sequential Aqueous Extractions <i>Co-Author - Gary Groenewold</i> , Idaho National Engineering and Environmental Laboratory <i>Co-Author - Recep Avci</i> , Montana State University Marnie Cortez and Anita Gianotto, Idaho National Engineering and Environmental Laboratory Cem Karahan, Montana State University	Salt Palace - Room 250A
9:05 - 9:30 am	Sorption of Gadolinium onto Nontronite and Goethite as a Function of pH and Ionic Strength <i>Authors - Scott A. Wood and Alexander F. Redkin</i> , University of Idaho George Redden and Larry C. Hull, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 250A
9:30 - 9:55 am	Evidence for the Occurrence of Microbial Iron Reduction in Bulk Aerobic Unsaturated Sediments <i>Author - D. Craig Cooper</i> , Idaho National Engineering and Environmental Laboratory William A. Smith, Don T. Fox, Mitchell A. Plummer, and Larry C. Hull, Idaho National Engineering and Environmental Laboratory Ravi K. Kukkadapu, Pacific Northwest National Laboratory	Salt Palace - Room 250A
9:55 - 10:20 am	Stability of Colloidal Material from the Hanford Sediments <i>Author – S. Czigány</i> , Markus Flury, Jeffrey Boyle, and James B. Harsh, Washington State University	Salt Palace - Room 250A
10:20 - 10:50 am	Break and Poster Clean Up, <i>refreshments provided</i>	Salt Palace - Room 251D

10:50 - 11:15 am	Degradation of Chlorinated Solvents in the Vadose Zone at a Radioactive Waste Subsurface Disposal Area <i>Author - Larry C. Hull</i> , Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 250A
11:15 - 11:40 am	Incorporation and Adsorption of Cesium in Zeolitic Minerals <i>Author - James B. Harsh</i> , Washington State University Youjun Deng, Markus Flury, and Jeffrey Boyle, Washington State University James Young and Joseph Ford, Pacific Northwest National Laboratory, Richland, WA	Salt Palace - Room 250A
11:40am - 12:05pm	The Partitioning of Plutonium to INEEL Soils and Sediments <i>Author - Rosara Payne</i> , Washington State University Myung Ho Lee, Sue Clark, Washington State University Dean Peterman, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 250A
12:30 pm	Lunch Break / End of Conference	on own

8:30am - 12:30pm	TECHNICAL SESSIONS Modeling Modeling Environments (Chair: Jeff Sondrup, INEEL)	Salt Palace - Room 250D
LEAD 8:30 - 9:05 am	Particle-Based Modeling of Multiphase Flow <i>Author - Paul Meakin</i> , Idaho National Engineering and Environmental Laboratory Alexandre Tartakovsky, Hakan Basagoaglu and Hai Huang, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 250D
9:05 - 9:30 am	Determination of Soil Hydraulic Properties using a Geocentrifuge <i>Author - H. Nakajima</i> , Idaho National Engineering and Environmental Laboratory J.R. Lord, M.G. Gifford, E.D. Mattson, A.T. Stadler, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 250D
9:30 - 9:55 am	Nonlinear Advective Contaminant Transport in Clay Under Consolidation <i>Author - Akram. N. Alshawabkeh</i> , Dept of Civil & Environmental Engineering, NE University, Boston, MA Nima Rahbar, Dept of Civil & Environmental Engineering, NE University, Boston, MA	Salt Palace - Room 250D
9:55 - 10:20 am	Methanogen Biomass in Hydrate-Bearing Sediments <i>Author - S. Boyd</i> , Idaho National Engineering and Environmental Laboratory F.S. Colwell, D. Reed, and M.E. Delwiche, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 250D
10:20 - 10:50 am	Break and Poster Clean Up, <i>refreshments provided</i>	Salt Palace - Room 251D
10:50 - 11:15 am	Application of Ensemble Kalman Filter to Unsaturated - Saturated Groundwater Model <i>Qiang Shu and Mariush Kemblowski</i> , Utah State University	Salt Palace - Room 250D
11:15 - 11:40 am	Modeling Non-Drainable (Residual) NAPL in the Vadose Zone <i>Author - RJ Lenhard</i> , Idaho National Engineering and Environmental Laboratory M Ostrom and MD White, PNNL, Richland, WA JH Dane, Auburn University	Salt Palace - Room 250D
11:40am - 12:05pm	Amplitude and Frequency Experimental Field Measurements of a Rotating-Imbalance Seismic Source Associated with Changes in Lithology Surrounding a Borehole <i>Author - Stephen R. Novascone</i> , Idaho National Engineering and Environmental Laboratory Michael J. Anderson, University of Idaho David M. Weinberg, Idaho National Engineering and Environmental Laboratory Jack H. Cole, University of Arkansas, Fayetteville, AR, USA	Salt Palace - Room 250D
12:05 - 12:30 pm	Prediction of Immiscible Displacement on Different Scales <i>Author - Alexandre Tartakovsky</i> , Idaho National Engineering and Environmental Laboratory Hai Huang, Idaho National Engineering and Environmental Laboratory	Salt Palace - Room 250D
12:30 pm	Lunch Break / End of Conference	on own

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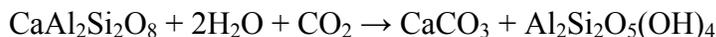
This site was last updated: 08/02/2004

CARBON SEQUESTRATION POTENTIAL OF BASINS OF SOUTHERN IDAHO: BIG SKY CARBON SEQUESTRATION PARTNERSHIP

Robert W. Smith, Nathan P. Ericson, University of Idaho, Idaho Falls, ID 83402
Travis L. McLing, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID 83415
Warren Barrash, William P. Clement, Boise State University, Boise, ID 83725
John P. Kaszuba, Los Alamos National Laboratory, Los Alamos, NM 87545

Carbon sequestration is one approach to stabilize or reduce the levels of potentially climate-changing greenhouse gasses in the earth atmosphere. Geologic sequestration is the storage or entombment of carbon dioxide in naturally occurring subsurface geologic formations. Because approximately one third of the carbon dioxide emitted annually in the United States is from point sources, source capture coupled with geologic entombment has high potential to limit emissions. Geologic sequestration of CO₂ occurs via three interrelated processes. Hydrodynamic trapping dominates in short time frames where a distinct supercritical CO₂ rich fluid fills pore space within subsurface media. In the medium-term, solubility trapping becomes important in which the supercritical CO₂ dissolves into subsurface fluids (e.g., formation waters). Mineral trapping can become the dominate sequestration process at longer time-scales where CO₂ reacts with subsurface media to form solid-phase carbonates. The permanence of sequestration by the three trapping processes is the inverse of their trapping time scale. Mineralization trapping offers the most permanent sequestration, hydrodynamic trapping the least. In an ideal sequestration site CO₂ would be permanently stored utilizing multiple trapping mechanisms.

As part of the U.S. Department of Energy funded Big Sky Carbon Sequestration Partnership, we are assessing the potential of northern Rocky Mountain and Great Plain geologic formations for long-term carbon sequestration. Of particular interest are the mafic volcanic rock and volcanic bounded basins of southern Idaho because they serve as an example of the inherent potential for permanent mineral trapping of large amounts of CO₂ in the abundant basalts of the northwestern U.S. Carbon dioxide injected into the subsurface dissolves in pore-water to form carbonic acid that is neutralized by the weathering of host-rock minerals to produce carbonate and bicarbonate ions (alkalinity) and/or mineral carbonates. For example, the weathering of the calcic component of plagioclase feldspar (a common basalt mineral phase) to calcite and a clay mineral can be written as



The thermodynamics for this reaction indicate that for any CO₂ pressure important for sequestration, the reaction will proceed as written, entombing the introduced CO₂ as solid calcium carbonate. Mineralization potential will be highest in rocks with abundant Ca-, Mg-, and Fe-silicates such as basalt and lowest in rocks poor in these phases (e.g., sandstone). The time frame and extent of mineralization for a given subsurface environment (and hence its mineralization potential) are functions of the weathering rates

and the abundance of silicate phases. We are conducting a preliminary assessment of the CO₂ sequestration potential of volcanic rocks and volcanic hosted basins in southern Idaho using The Geochemist's Workbench computer code and a generalized mineral dissolution rate law that we have developed. Simulation results suggest that more than 20 kg carbon m⁻³ of rock can be sequestered in typical basalt. Furthermore, mineral trapping becomes the dominant form of sequestration after approximately 300 years. In addition to considering direct trapping in basalts, we are also considering the potential of basalt as an impermeable cap rock. The simulations indicate that mineralization processes can result in a significant decrease in porosity (and by inference permeability), suggesting that the cap rock seal may become more robust with time in some subsurface environments. Overall, our preliminary assessments based on mineral reactivity indicate that mafic volcanic rocks and volcanic bounded sedimentary basins of southern Idaho have significant potential for the permanent sequestration of CO₂.

Presentation Type Requested: ORAL

Topical Area: Energy Production, Carbon Sequestration

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SENSITIVITY OF CARBON SEQUESTRATION COSTS TO ECONOMIC AND BIOLOGICAL UNCERTAINTIES

Susan M. Capalbo and John M. Antle
Montana State University
Bozeman, Montana, USA

Siân Mooney
University of Wyoming
Laramie, Wyoming, USA

Keith Paustian
Colorado State University
Fort Collins, Colorado, USA

INRA Presentation Abstract Topical Area: (carbon sequestration session) monitoring, risk assessment, and policy; social science and environmental policy issues; critical parameters for predictive monitoring

Modifying current agricultural management practices as a means of sequestering carbon has been shown to be a relatively low cost way to offset greenhouse gas emissions. In this presentation, we examine the sensitivity of the estimates of the amount of soil carbon sequestered and the costs of sequestering carbon to uncertainties in the underlying economic and biological parameters of the modeling framework and to scale of analysis. We present a brief overview of the economic versus technical potential for terrestrial sequestration in the northern Rockies, and a description of the economic-biophysical simulation model. An application is made to the dryland grain production systems of the U.S. Northern Plains under a per-hectare carbon payment policy. We show that the resulting changes in the marginal costs and corresponding quantities of soil carbon sequestered are a nonlinear function of the changes in the soil carbon rates, yields, or economic parameters, and depend upon the spatial heterogeneity of the area. The analysis of changes in yields supports the argument that sequestering soil C could be a long-term win-win situation for producers and society. In the short run, providing incentives to producers to switch production practices in order to sequester soil C could lead to higher productivity in the long run that would induce farmers to maintain these practices without further incentives.

SOIL ORGANIC CARBON SEQUESTRATION POTENTIAL IN NORTH CENTRAL MONTANA

Ross S. Bricklemyer and Perry R. Miller
Montana State University
Bozeman, Montana, USA

INRA Presentation Abstract Topical Area: carbon sequestration (special session); monitoring, risk assessment, and policy; sensors/monitoring; subsurface experiments and research

Continuing interest in terrestrial carbon sequestration in agricultural soils as a greenhouse gas mitigation strategy has led to the desire to estimate mitigation potential of various management practices across the United States. North central Montana is primarily dryland small grain production with a long history of tillage based management. In an across-the-fence comparison of no-till (6+yrs) versus conventional tillage (30+yrs) management, no-till had significantly higher SOC content at 5 of 6 sites in north central Montana. Annual SOC gains due to no-till ranged from 0.13 to 0.4 t ha⁻¹, with an average of 0.28 t ha⁻¹. Increasing C inputs to the soil and reducing oxidation of soil organic carbon (SOC) are keys to sequestering C in soil. Many factors influence soil carbon dynamics including soil disturbance, soil texture, cropping intensity and diversity, and soil inputs such as nitrogen fertilizer.



The National Carbon Offset Coalition provides an opportunity for landowners and tribal, state, and local governments to participate in a market-based conservation program which provides a marketable commodity while helping to offset the environmental impacts of carbon dioxide emissions.

The sequestration of carbon through natural resource-based programs can reverse soil, water, and air degradation.

The program offers buyers a cost-effective way to achieve their carbon dioxide emission reduction goals.

NATIONAL CARBON OFFSET COALITION
305 WEST MERCURY
ROOM 408
BUTTE, MONTANA 59701

*National Carbon Offset Coalition
Idaho Governor's Carbon
Sequestration Working Group*

Big Sky DOE Regional Partnership

FORESTRY & AGRICULTURE CARBON SEQUESTRATION WORKSHOP

**January 13 & 14, 2005
Red Lion Templins Hotel
Post Falls, Idaho**

FORESTRY & AGRICULTURE CARBON SEQUESTRATION WORKSHOP

The National Carbon Offset Coalition working in partnership with the Idaho Governor's Carbon



Sequestration Working Group and the Big Sky DOE Regional Partnership is offering a workshop specifically designed to instruct attendees about the carbon sequestration trading opportunities available on private, state, and tribal lands. The goal of this workshop is to create a national portfolio capable of meeting the trading requirements of the emerging markets as part of a DOE grant.

AGENDA

Thursday, January 13, 2005

- 7:30 am Registration
- 8:30 am Introductions
- 8:45 am Overview—Workshop
- 9:00 am Carbon Sequestration Science
- 10:00 am Break
- 10:15 am Carbon Sequestration Policy & Ancillary Benefits
- 11:15 am NCOC Organization -- Operating Policies, Relationship Between the Landowner, Aggregator, Broker, & Buyers
- 12:00 Lunch — Big Sky Regional Partnership
- 1:00 pm The Market
- 2:15 pm Initial Proposal (Planning the Proposal)
- 3:00 pm Break
- 3:15 pm *continuation of* Initial Proposal (Planning the Proposal)
- 5:00 pm Adjourn for the day

Friday, January 14, 2005

- 8:00 am Questions & Review of Previous Day Discussions
- 9:00 am Submission of Initial Proposal, Contracts, Marketing & Fund Disbursement
- 10:00 am Break
- 10:15 am Monitoring & Verification During Contract
- 11:30 am Work on Individual Projects
- 12:00 Lunch
- 1:00 pm *continuation of* Work on Individual Projects
- 2:30 to 3:00 pm Follow-up Questions & Adjourn

REGISTRATION

Name

Address

City, State

Phone

Email

A block of rooms have been set aside under the name of NCOC.

Hotel Rates: \$64.00/sgl
*plus sales tax 8.5%

Red Lion Templins Hotel
(800) 733-5466

Deadline to receive this rate is December 13, 2004



Method of Payment

Check payable to: NCOC

**NATIONAL
CARBON OFFSET
COALITION**

305 West Mercury
Room 408
Butte, Montana 59701
(406-723-6262
Email: info@ncoc.us
www.ncoc.us

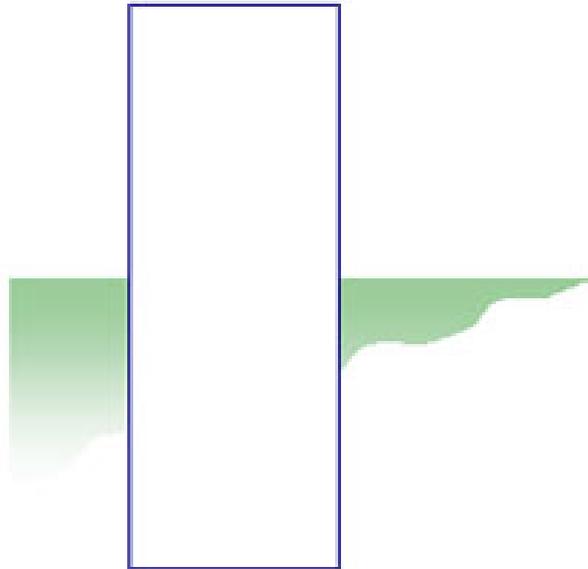


National Carbon Offset Coalition

The National Carbon Offset Coalition provides an opportunity for landowners and tribal, state, and local governments to participate in a market-based conservation program that provides a marketable commodity while helping to offset the environmental impacts of carbon dioxide emissions.

The sequestration of carbon through natural resource-based programs can reverse soil, water, and air degradation.

The program offers buyers a cost-effective way to achieve their carbon dioxide emission reduction goals.



National Carbon Offset Coalition
305 West Mercury
Room 408
Butte, Montana 59701



Tribal Carbon Sequestration Forestry Portfolio



January 11 thru 12, 2005
Red Lion Inn— Spokane, Washington

Tribal Carbon Sequestration Forestry Portfolio Workshop

The National

Carbon Offset

Coalition working



in partnership with the Nez Perce

Tribe and the National Tribal

Environmental Council is offering a

workshop specifically designed to

instruct attendees about the carbon

sequestration trading opportunities

available on tribal lands. The goal of

this workshop is to create a national

tribal forestry portfolio capable of

meeting the trading requirements

of the emerging markets.

Agenda

Tuesday, January 11, 2005

- 7:30 am Registration
- 8:30 am Introductions
- 8:45 am Overview—Workshop, Past Tribal Efforts, Project Types & Tribal Forestry Portfolio
- 9:15 am Carbon Sequestration Science, Policy, Market, & Ancillary Benefits
- 10:15 am Break
- 10:30 am NCOC Organization – Operating Policies, Relationship Between the Landowner, Aggregator, Broker, & Buyers
- 11:15 am Big Sky Partnership Outlook
- 12:00 Lunch (hosted)
- 1:00 pm The Market
- 2:00 pm Break
- 2:15 to 5:00 pm Initial Proposal (Planning the Proposal)

Wednesday, January 12, 2005

- 8:00 am Questions & Review of Previous Day Discussions
- 9:00 am Submission of Initial Proposal, Contracts, Marketing & Fund Disbursement
- 10:00 am Break
- 10:15 am BIA Policies
- 10:45 am Monitoring & Verification During Contract
- 12:00 Lunch (hosted)
- 1:00 pm Work on Individual Projects
- 2:30 to 3:30 pm Follow-up Questions & Adjourn

Registration

Name _____

Address _____

City, State _____

Phone _____

Email _____

A block of rooms has been set aside under the name of NCOC.

Hotel Rates: \$63.00/sgl
\$73.00/dbl
*plus a sales tax 10.1%

Call Red Lion Inn for reservations
(800) 733-5466

Deadline to secure these rates is
December 11, 2004

\$90.00

Method of Payment

Check payable to: NCOC

National Carbon Offset Coalition

305 West Mercury
Room 408
Butte, Montana 59701

Phone: 406-723-6262

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