Senate Rural and Regional Affairs and Transport References Committee

Inquiry into the Management of the Murray-Darling Basin system

Additional Information provided by Produced Water Research Centre, Macquarie University

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Coal Bed Methane Primer: New Source of Natural Gas – Environmental Implications, Background and Development in the Rocky Mountain West, Prepared for US Department of Energy National Petroleum Technology Office, February 2004	71
Coalbed Methane Development in the Intermountain West: Primer, Gary Bryner, National Resources Law Center, University of Colorado School of Law, July 2002	50
New York State Department of Environmental Conservation, *Revised Draft, Supplemental Generic Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program: Well Permit Issuance for Horizontal Drilling and High-Volume Hydraulic Fracturing to Develop the Marcellus Shale and Other Low-Permeability Gas Reservoirs,* September 2011	1500
Contents pages *Development of a Knowledge Base on Desalination Concentrate and Salt Management, Revised Draft Final Report,* published by the WateReuse Research Foundation, Alexandria, VA, 2012 (in press)	18
National Academy of Sciences, *Management and Effects of Coal Bed Methane Produced Water in the Western United States, 2010*	4
First two pages, Andrew Moser and Kathryn Harris, *Realising the Potential for CSG Water Injection to Aquifers in the Surat and Southern Bowen Basins,* undated	2
National Centre of Excellence in Desalination, *National Desalination Research Roadmapping Workshop, Program and White Papers,* Fremantle, Western Australia, October 29-30, 2009	64

MACQUARIE UNIVERSITY

Outline of Proposed Reference Document on the Australian Brine Effluents, Including a White Paper for Identifying and Prioritising National Actions and Stimulating Investment in Innovative Management Solutions

Proposal by Produced Water Research Centre Presented at the Meeting Held on October 23, 2012 with The Rural Affairs and Transport References Committee

1. Detailed review of the situation (understanding of the issues)
   - Overseas experience
   - Salinity hazard risks, pollution risks, etc.
   - Legislative framework
   - Stakeholders views
   - Case studies

2. Definition of the context of management issues and opportunities
   - Definition of economic / environmental / community drivers
   - Total Resource Cost (TRC) study
   - Analysis of risks, liabilities and the short- and long-term value chains
   - Review of BATs (Best Available Technologies) and BMPs (Best Management Practices)
   - Identify investment incentives/opportunities

3. Provide a guidance framework for developing a national road map for technology base brine solutions
   - Guidance document
   - Workshops
   - Information screening
   - Website
   - Define framework for action plan (including national road mapping)

4. Study Report and White Paper

Handbook on Best Management Practices and Mitigation Strategies for Coal Bed Methane in the Montana Portion of the Powder River Basin

April 2002

LEAD RESEARCHER
ALL Consulting
Tulsa, Oklahoma

CO-RESEARCHER
Montana Board of
Oil & Gas Conservation
Billings, Montana

PREPARED FOR
U.S. Department of Energy
National Petroleum Technology Office
National Energy Technology Laboratory
Tulsa, Oklahoma

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INTRODUCTION

During the second half of the 1990's Coal Bed Methane (CBM) production increased dramatically nationwide to represent a significant new source of natural gas. In recent years, the exploration and development of CBM has been under intense scrutiny in many parts of the country. The heightened concern of environmental issues related to present-day production practices - including water production, hydraulic fracturing, pipeline construction, storage facilities, water impoundment and disposal facilities, underground injection activities, compressor station operations, etc. – increases the importance of using practices and mitigation strategies that facilitate resource development in an effective, timely, and environmentally sound manner. These issues have placed increased pressure on federal, state, and local regulatory agencies; land and resource managers; industry; landowners; and the general public to develop methodologies to accurately define specific areas of environmental risk along with defining Best Management Practices (BMPs) and mitigation strategies to aid in minimizing and alleviating these risks.

Sub-Bituminous coal from an outcrop in the Montana Powder River Basin

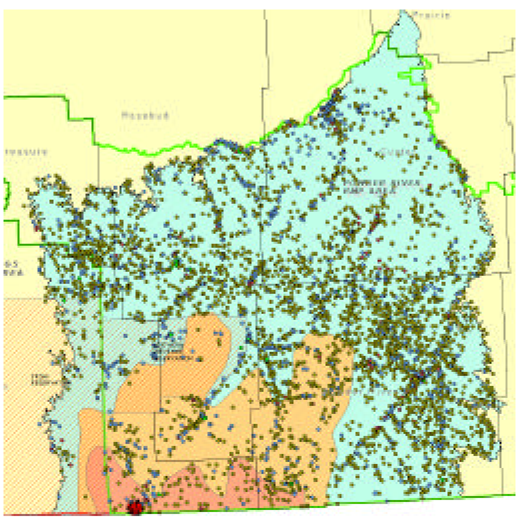
PURPOSE

This handbook is intended to serve as a resource to industry, regulators, land managers, and concerned citizens. The handbook presents background information on CBM activity in the Montana portion of the Powder River Basin (Study Area) while also presenting a number of Best Management Practices and Mitigation Strategies specific to CBM that have been successfully used throughout the United States. The handbook is not intended to be a prescriptive document that specifies required practices. Rather, it should be recognized that actual practices and mitigation measures used for a particular site or area will be largely dependant upon land and mineral ownership, geologic and hydrologic conditions (including depth of coal seams), soil types, local and regional wildlife issues, and other unique conditions.

OVERVIEW OF RESEARCH

This handbook aligns with research goals and objectives established by ALL Consulting and the Montana Board of Oil & Gas Conservation as approved by the U.S. Department of Energy for this project. Understanding the focus of the research will provide an increased level of understanding regarding findings and results presented in this handbook. Project research elements include this handbook and components that will serve as a supplement to this handbook as well as other data collection and research activities. An abbreviated summary of research activities associated with this project is presented below.

Montana/Wyoming Delegation CBM Field Trip



Montana Powder River Basin CBM Development Likelihood and Water Use

STUDY AREA

The research Study Area and focus of this manual is the Montana portion of the Powder River Basin. Currently, the only commercial production of CBM in the Montana Powder River Basin is located near Decker, Montana. During the field reconnaissance effort, the research team made several visits to the Study Area while also performing extensive analysis of existing data for the area.

DATA COLLECTION AND FIELD RECONNAISSANCE

Field reconnaissance and data collection activities performed as part of this project were broadly performed. Data collection included working with a variety of federal and state agencies and industry to obtain existing data from spatial data sets on a variety of resources in the area. The following list specifies many of the organizations that supported this research effort through the data collection and field reconnaissance effort:

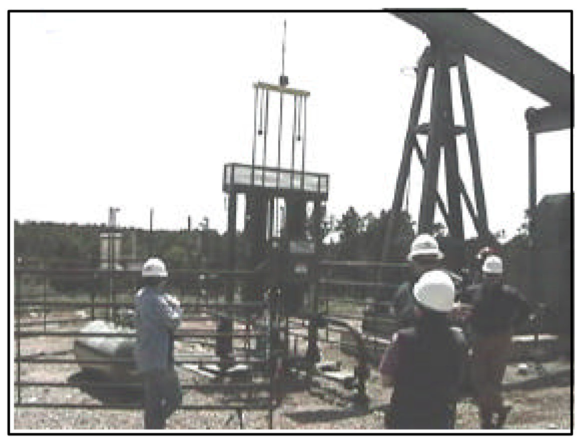
- Bureau of Land Management (Miles City Field Office, Montana State Office, Buffalo Field Office, New Mexico State Office, Durango Field Office);
- Montana Board of Oil & Gas Conservation;
- Montana Department of Environmental Quality;

- Montana Department of Natural Resources and Conservation;
- Montana State Library's Natural Resource Information System;
- Montana Bureau of Mines and Geology;
- United States Geological Survey;
- U.S. Department of Agriculture's Natural Resources Conservation Service;
- Alabama Oil & Gas Board;
- Arkansas Oil & Gas Commission;
- Kansas Corporation Commission;
- Oklahoma Corporation Commission;
- Utah Division of Oil, Gas and Mining;
- Ground Water Protection Council;
- Burlington Resources, Inc.
- Red Willow Production (Southern Ute Indians);
- Fidelity Exploration;
- Williams/Barrett Resources;
- BP America;
- Marathon/Pennaco; and
- J.M. Huber Corporation.

Field reconnaissance activities included visiting CBM development sites in several areas of the country. The researchers witnessed the application of numerous innovative practices that were used to address several issues, such as safety, noise, produced water disposal and beneficial use, water treatment, site development, compression, drilling, visual quality of an area, and several other practices used for the mitigation of environmental and safety concerns. Findings from the field reconnaissance effort have been used where applicable to operations in the Montana Powder River Basin.

BMP HANDBOOK PREPARATION

Preparation of a BMP handbook is designed to present an inventory of findings from field reconnaissance, data collection, and research. The research team has found a broad range of innovative and effective practices and mitigation strategies that are already being implemented throughout the United States. Some of these practices are in use in the Montana Powder River Basin. Other practices, being used elsewhere, show promise for use in the study area.



Hydraulic Pumping System
San Juan Basin, Colorado

GIS APPLICATION

In addition to the preparation of this handbook, the research team is also preparing an Internet-based GIS application that can be used to perform spatial analysis relative to conventional oil & gas and CBM exploration and development activities. The subject application will be interactive and include a variety of information in GIS and numeric formats. Visitors to the site will be able to perform spatial analysis for evaluation of environmental concerns, information relating to the types of mitigation strategies that could be considered, and statistical information for such things as preparing project and water management plans.

TECHNOLOGY TRANSFER

As part of the ongoing research, an aggressive technology transfer plan is ongoing. Researchers are currently planning to hold 2-3 workshops in Montana relative to the project's findings. One workshop has already been held in Houston, Texas (January 2002). In addition, researchers have already presented several technical papers concerning CBM development in the Powder River Basin, the ongoing Montana Environmental Impact Statement and Resource Management Plan Amendment, and the application of BMPs and mitigation strategies. Several more presentations are planned through the remainder of 2002.

BEST MANAGEMENT PRACTICES

Best Management Practices (BMPs) can be defined as a suite of techniques, procedures, measures, or practices which are site specific, economically feasible, and are used to guide, or may be applied to, management actions to aid in achieving desired outcomes. Measures or procedures that can be utilized within a BMP may include, but are not limited to, structural and nonstructural controls, operational procedures, and maintenance procedures. In this document, BMPs are presented as a procedure that is initiated by the identification of a specific CBM activity that is to be conducted, followed by an evaluation of the potential impact to the environment resulting from that activity, and concludes with the development and implementation of measures or procedures to mitigate the impact from that activity. This document does not provide an exhaustive list of BMPs. Additional measures may also be identified during CBM development or the MEPA/NEPA process for a specific activity.

ALL/MBOGC Research Team
Power River Basin - Montana

RESEARCHERS

Researchers involved in this project are ALL Consulting and the Montana Board of Oil & Gas Conservation. Individual researchers involved in the project are listed in Table 1, below:

TABLE 1

PROJECT RESEARCH TEAM

Dan Arthur, P.E. Petroleum/Environmental Engineer ALL Consulting 17 Years Experience	Bruce Langhus, Ph.D., CPG. Geologist/Hydrogeologist ALL Consulting 35 Years Experience
Tom Richmond Administrator/Petroleum Engineer Montana Board of Oil && Gas Conservation 25 Years Experience	Jim Halvorson State Petroleum Geologist Montana Board of Oil & &Gas Conservation 20 Years Experience
Dave Bockelmann, CPG Petroleum/Environmental Geologist ALL Consulting 20 Years Experience	David Epperly, Ph.D., P.E. Agriculture/Soils Engineer ALL Consulting 15 Years Experience
Brian Bohm Hydrologist/Sociologist ALL Consulting 5 Years Experience	Greg Casey, P.E. Drilling/Operations Engineer ALL Consulting 17 Years Experience
Parker Fleming Economist ALL Consulting 3 Years Experience	Jason Patton Geologist/Geography/GIS ALL Consulting 5 Years Experience
Jon Seekins Environmental Scientist ALL Consulting 15 Years Experience	David Winter Biologist/Wildlife ALL Consulting 5 Years Experience

DEPARTMENT OF ENERGY

The U.S. Department of Energy's (DOE's) National Petroleum Technology Office (NPTO) is the funding agency for this research effort. The NPTO is responsible for carrying out the National Petroleum Technology Program (NPTP). The **Mission** of the NPTP is to move the Nation toward a reliable, economic oil supply, enhance U.S. technological leadership, and protect the environment. Working together with their customers, the NPTO promotes key activities and policies that move our nation closer to its goal: to improve efficiency and environmental quality of domestic oil operations.

The **Vision** of the NPTP is to be a domestic oil resource at its fullest potential, contributing to the Nation's energy security, economic growth, environmental quality, and science and technological leadership. The United States leads the world in the advancement of oil technologies. A key-contributing factor in the success of the NPTP is the customer-driven approach to public-private partnerships, which contribute to the development of technologies, regulatory streamlining, and policies that support increased oil supplies.

SIGNIFICANCE OF CBM

Coal Bed Methane is a carbon-based gas that occurs naturally within the seams of un-mined coal beds. It is typically contained within the micro-pores of the coal and is retained in place due to the pressure created by the presence of water. During production, this water is pumped to the ground surface to lower the pressure in the coal bed reservoir and to stimulate the release of methane from the coal. Methane from un-mined coal beds has been produced on a minor scale since the early 1900s when a rancher in the Powder River Basin (Wyoming) drilled a water-well into a coal bed and started heating buildings with the produced gas. Until the 1980s, coal seams generally were not considered to be a reservoir target, even though producers often drilled through coal seams when going to deeper horizons.

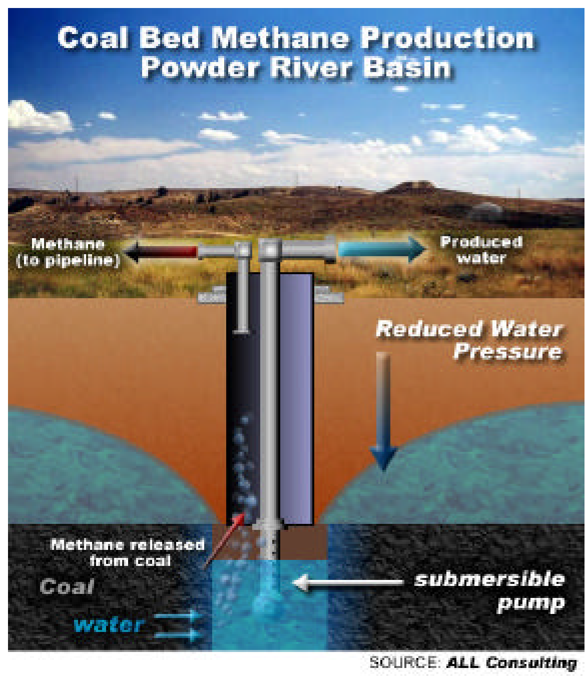
During the second half of the 1990s, Coal Bed Methane (CBM) production increased dramatically nationwide to represent a significant new source of natural gas to meet ever-growing energy demands. In Montana, oil and gas development began with the drilling of the first oil test wells in the late 19th century. Today, Montana's oil and gas industry exceeds 300 million dollars per year and is a significant aspect of the state's economic livelihood. Recent oil and gas exploration and development in the state has included a focus on CBM exploration and development. There are currently more than 200 commercially producing CBM wells in the state of Montana, all of which are located in the Powder River Basin near the town of Decker, Montana. CBM development in the Montana portion of the Powder River Basin (PRB) is, in part, the result of successful CBM development in the Wyoming portion of the basin where CBM activity started as early as 1993 (Flores et al, 2001).

CBM BACKGROUND AND STUDY AREA DETAILS

The Powder River Basin (PRB) of Montana comprises the Study Area and is where CBM exploration operations are currently being conducted in Montana. Future CBM development predictions for the state indicate that approximately 25,000 CBM wells could be drilled and completed during the next 10 to 20 years. The total Reasonable Foreseeable Development (RFD) scenario for CBM development in the State of Montana (including federal, Indian, state, and private mineral ownership) amounts to approximately 24,875 total CBM wells drilled. It is expected that about 10 percent of these wells will be dry holes. In considering the total RFD for the state, the majority of CBM development is expected to occur within the Montana PRB Study Area.

CBM has been produced in the Powder River Basin of Montana since April 1999, slightly behind production in Wyoming that began in the mid 1990's. The first Montana CBM exploration wells were drilled in both the Big Horn and Powder River Basins. The bulk of the producing data has, however, less history than that. In the CX Ranch Field located within the Montana Powder River Basin approximately 24 months of production data have been submitted to the Montana Board of Oil and Gas Conservation (MBOGC).

The schematic to the right shows the construction of a typical CBM well from the CX Ranch Field. Although there are variations in the drilling and completion methodology, the construction method shown is the most common for current practices. However, future practices could vary from this method depending on the depth of targeted coal seams, advances in drilling technologies, or changes in drilling philosophies. Potential changes could include, but may not be limited to, completing wells in more than one coal seam or drilling directional or horizontal wells.



Typical Coal Bed Methane Well Construction Diagram for Wells in the Montana Powder River Basin

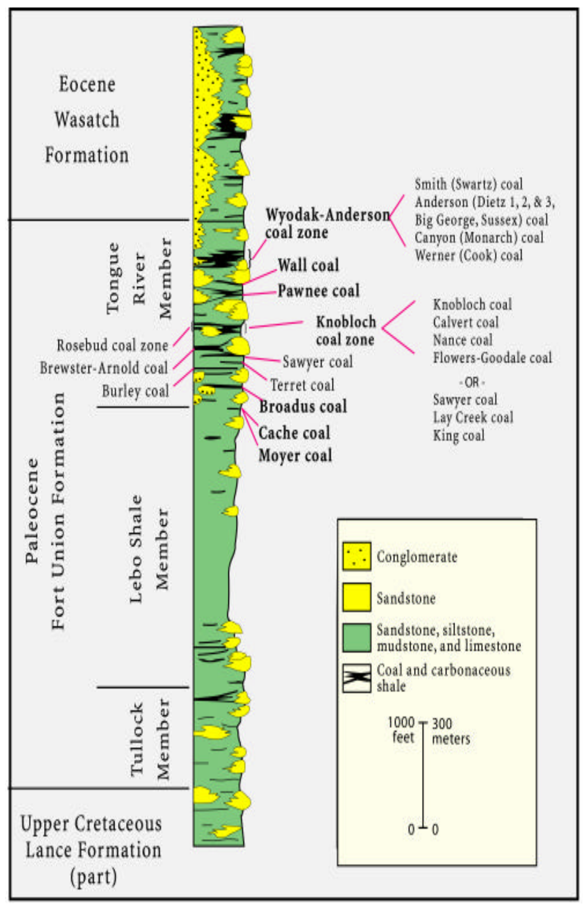
The exploration, development, and production of Coal Bed Methane (CBM) involves activities that have the potential to impact a number of resources/issues in the Powder River Basin Study Area. In pursuing CBM production, an evaluation of the specific CBM activities to be conducted would identify any potential impacts to these resources that might occur. This evaluation should include the identification of potential impacts from individual activities as well as the potential cumulative impacts resulting from multiple activities being carried-out concurrently or over the life of the production.

The development of a project plan is an integral aspect of CBM exploration, development, and production and is considered necessary for resource conservation. One aspect of the plan is to identity and describe potentially affected resources/issues that may be impacted by CBM efforts. Proper identification of each resource/issue can be useful in preventing accidental disruptions to local communities and in reducing the potential for future impacts that may significantly alter the surrounding environment.

GEOLOGY

Montana is the site of the juxtaposition of the Great Plains with the Rocky Mountains. Montana's basins have accumulated sediments that are up to several miles in thickness; these sands, shales, and limestones represent both the source rock and reservoirs of Montana's fossil energy reserves – crude oil, natural gas, coal, and Coal Bed Methane (CBM). In these basins, the accumulated sediments were buried to great depths where heating and increased pressure from overburden formed the fossil energy fuels from the raw plant materials trapped within the sediments as they were being deposited. These sedimentary basins also contain a significant portion of the water resources of the state; in the deep parts of these basins the water is generally salty while in the shallower parts of these basins the water is generally fresh.

With respect to CBM, it is important to recognize that this resource is directly associated with coal deposits. CBM gas is generated within the coal deposits under both thermogenic (heat-driven) and biogenic (microbe-driven) conditions. At the same time, the methane is trapped in the coal seams by the pressure of groundwater. Releasing the pressure of groundwater from the coal seams liberates the methane that is present, allowing it to be produced as an energy resource. The magnitude of the CBM resource is determined by coal type and volume; the location of CBM resources within the Montana PRB will coincide with the location of the coal seams.



Stratigraphic Column of Upper Cretaceous and Lower Tertiary Sediments in the Powder River Basin

The sedimentary strata at the surface within the Study Area consist of recent alluvium in stream valleys to surrounding outcrops that are largely Tertiary and Cretaceous in age. The stratigraphic column, on the previous page, depicts the sequence of Upper Cretaceous and Lower Tertiary sediments that are present within the Montana PRB. The stratigraphic column shows the continuous development of several thousand feet of sediments that include widespread sands, coals and fluvial, fine-grained sediments. Surface outcrops within the PRB consist largely of the several members of the Paleocene Fort Union Formation, as well as the overlying Wasatch Formation in a small corner of the basin (Rice et al. 2000).

The Fort Union forms most of the sedimentary fill within the Montana PRB. It consists of approximately 3,500 feet of non-marine silty and shaley clastics and coal beds whose individual thicknesses can be as much as 37 feet near the Decker mine (Roberts et al, 1999a). The Fort Union is split into three stratigraphic members: the lowest being the Tullock Member, overlain by the Lebo Shale Member, overlain by the Tongue River Member (McLellan et al. 1990). In the Montana PRB, the bulk of the coals are confined to the Tongue River Member, while the Lebo and Tullock Members are predominantly shale and shaley sand (McLellan et al. 1990). The Members are discussed in detail below:

THE TULLOCK MEMBER

This is the stratigraphically lowest part of the Fort Union, consisting of approximately 300 feet to more than 500 feet of interbedded sands and shales with minor coals near the base (Tudor 1975). The Tullock rests unconformably upon the Upper Cretaceous Hell Creek Formation and is overlain by the Lebo Member of the Fort Union Formation. While generally sandier, the Tullock is difficult to separate in outcrop and in the subsurface from the overlying Lebo Member.

THE LEBO MEMBER

This middle member of the Fort Union Formation ranges from 75 feet to more than 200 feet in thickness and consists of claystones, limestones, and mudstones with the Big Dirty coal (3 to 13 feet of thickness) at the very base (Tudor 1975). The Lebo Member is, in part, stratigraphically equivalent with the overlying Tongue River Member (McLellan 1990).

THE TONGUE RIVER MEMBER

The thickness of the Tongue River Member of the Fort Union Formation varies from 750 feet at the outcrop edge near the fringe of the basin to 3,000 feet near the axis of the basin (Williams 2001). Total coal thickness within the Tongue River Member ranges up to approximately 150 feet (Ellis et al. 1999). The Tongue River Member is divided into three units. The lower unit includes that portion below the Sawyer coal seam. The Middle unit includes the Sawyer through the Wall coal seam. The Upper unit consists of that portion above the Wall coal seam and includes the Wyodak-Anderson coal seam (Ellis et al. 1999).

HYDROLOGY

The Montana PRB Study Area includes many aquifers that represent different hydrologic flow regimes. The basin includes unconfined aquifers as well as confined, bedrock aquifers. Aquifers range from the unconfined Quaternary alluvium in the streambeds of rivers and creeks to the Mississippian Age Madison Formation in excess of 10,000 feet below the surface. The water quality within these aquifers ranges from less than 300 mg/L Total Dissolved Solids (TDS) to more than 30,000 mg/L TDS (Bergantino 1980). The aquifers also vary in depth from the basin center to the margin. Coal aquifers are also present and supply large numbers of water wells. Table 2 below provides a list of the major aquifers within the Montana PRB. Groundwater wells within the Montana PRB are almost exclusively completed in the shallow aquifers (< 500 ft depth) with the Tongue River Coals aquifer having the greatest number of wells. Wells completed in these major aquifers are limited in geographic distribution – alluvium wells are distributed along principle rivers and streams, coal wells are arrayed in two principal bands corresponding to two stratigraphic units, and Cretaceous sand wells are generally limited to the rim of the PRB.

TABLE 2

AQUIFERS AND WELLS IN THE MONTANA PRB STUDY AREA

AGE	AQUIFER	APPROXIMATE DEPTH	NUMBER OF WELLS IN THE MBMG DATABASE
Quaternary and Recent	Quaternary Alluvium	Surface to 90 feet	198
Tertiary	Wasatch	100 feet	6
	Tongue River Coals	50 to 400 feet	957
	Lebo/Tullock	100 to 400 feet	306
Cretaceous	Hell Creek/Fox Hills	100 to 500 feet	199
	Judith River	2500 feet	1
	Eagle	2700 to 5700 feet	0
	Dakota/Lakota	5600 to 8600 feet	0

Note: MBMG = Montana Bureau of Mines and Geology

Watersheds are an important factor in considering the development of CBM within the Montana PRB. Each watershed is ultimately drained by a single stream or river and each is bounded by a no-flow topographic boundary. Streams and rivers are influenced by their watersheds; in particular, water volume and water quality vary from base flow conditions to high-flow conditions under the control of runoff from land surfaces and recharge to rivers by aquifers. Table 3 shows the surface area of each watershed within the PRB that overlies known coal occurrences and the predicted number of CBM wells that would be drilled within each watershed. The areas with the highest potential for CBM development are located within the northern portion of the Upper Tongue River Watershed, the southern section of the Lower Tongue River Watershed, the western section of the Middle Powder River Watershed, and the eastern section of the Rosebud Watershed. Current CBM exploration operations in the Montana PRB consist of the CX Ranch Field located within the Upper Tongue River Watershed.

TABLE 3

WATERSHED ACREAGE AND FUTURE POTENTIAL CBM WELLS IN THE PRB STUDY AREA

WATERSHED	SURFACE ACREAGE OF WATERSHED	POTENTIAL NUMBER OF WELLS
Little Bighorn	87,000	1,050
Little Powder	29,500	278
Lower Bighorn	121,500	1,200
Lower Tongue	1,374,000	5,183
Lower Yellowstone-Sunday	687,500	2,568
Middle Powder	368,500	3,167
Mizpah	24,000	224
Rosebud	814,000	5,397
Upper Tongue	589,000	5,806
Total	**4,095,000**	**24,875**

CLIMATE

Montana is dry; therefore, it is neither oppressively hot nor oppressively cold. Average annual rainfall is 15 inches, varying from 9.69 to more than 100 inches. Average daytime temperatures vary from 28 degrees in January to 84.5 degrees in July. Montana's cold spells are frequently interrupted by Chinook winds.

AIR QUALITY

The air quality of any region is controlled primarily by the magnitude and distribution of pollutant emissions and the regional climate. The transport of pollutants from specific source areas is affected by local topography and meteorology. In the mountainous western United States, topography is particularly important in channeling pollutants along valleys, creating up slope and down slope circulations which may entrain airborne pollutants as well as blocking the flow of pollutants toward certain areas. In general, local effects are superimposed on the general weather regime, and are most important, when large-scale wind flow is weak.

Site-specific air quality monitoring was not conducted throughout most of the PRB Study Area, but air quality conditions are likely to be very good, as characterized by limited air pollution emission sources (few industrial facilities and residential emissions in the relatively small communities and isolated ranches) and good atmospheric dispersion conditions, resulting in relatively low air pollutant concentrations.

Air quality monitoring data collected throughout southeastern Montana and northeastern Wyoming was primarily conducted in urban or industrial areas and is considered to be the best available representation of background air pollutant concentrations through out the PRB Study Area.

Regulated air pollutants include: carbon monoxide (CO), nitrogen dioxide (NO_2; a portion of oxides of nitrogen, or NO_x), inhalable particulate matter less than 10 microns in effective diameter (PM-10), fine particulate matter less than 2.5 microns in effective diameter (PM-2.5), sulfur dioxide (SO_2), and volatile organic compounds (VOC).

The assumed background pollutant concentrations are below applicable National Ambient Air Quality Standards (NAAQS) and applicable Montana Ambient Air Quality Standards for most pollutants and averaging times, although hourly background concentrations of nitrogen dioxide, ozone, and sulfur dioxide are not available.

CULTURAL/PALEONTOLOGICAL RESOURCES

Cultural resources consist of the material remains of, or the locations of, past human activities including sites of traditional cultural importance to both past and contemporary Native American communities. Cultural resources within the Study Area represent human occupation throughout two broad periods: the prehistoric and the historic. The prehistoric period is separated into the Paleo-Indian Period (circa 10,000 B.C. to 5,500 B.C.), the Archaic Period (circa 5,500 B.C. to A.D. 500), the Late Prehistoric Period (circa A.D. 500 to 1750), and the Proto-historic Period (circa 1750 to 1805+). The prehistoric period began with the arrival of humans to the area around 12,000 years ago, and is generally considered to have ended in 1805 when the Lewis and Clark Expedition passed through the area. Cultural resources relating to the prehistoric period may consist of scatters of flaked and ground stone tools and debris, stone quarry locations, hearths and other camp debris, stone circles, wooden lodges and other evidence of domestic structures, occupied or utilized rock shelters and caves, game traps and kill sites, petroglyphs, pictographs, stone cairns and alignments, and other features associated with past human activities. Some of these sites contain cultural resource features that are in buried deposits.

Paleontological resources consist of fossil bearing rock formations containing information that can be interpreted to provide a further understanding about Montana’s past. Fossil-bearing rock units underlie the entire Study Area. While fossils are relatively rare in most rock layers, there are seven geologic rock units within the Study Area that do contain significant fossil material. Rock units that are known to contain fossils are the Tullock and Ludlow Members of the Fort Union Formation, the Judith River, Hell Creek, Morrison, Cloverly Formations, the Lakota Sandstone Formation, and the White River Group.

INDIAN TRUST ASSETS/ NATIVE AMERICAN ISSUES

Indian Trust Assets (ITAs) are official interests in assets held in trust by the federal government for Indian tribes or individuals. The U.S. Department of the Interior (DOI) Departmental Manual 303 DM 2 defines ITAs lands, natural resources, money, or other assets held by the federal government in trust or that are restricted against alienation for Indian tribes and individual Indians. Furthermore, DOI Departmental Manual 512 DM 2 requires all of its bureaus and offices to explicitly address anticipated effects on ITAs in planning, decision, and operating documents.

Land associated with a reservation or public domain allotments are examples of ITAs. Natural resources that exist within Indian reservations such as standing timber, minerals, and oil and gas are ITAs. Treaty rights, water rights, and hunting and fishing rights may also be ITAs. Other ITAs may consist of financial assets held in trust accounts or intangible items such as Indian cultural values. ITAs are a product of the unique history and relationship of the U.S. government with various American Indian tribes and remain within the purview of federal process. There is no similar relationship between the Montana State government agencies and sovereign independent Indian tribal nations (like the Northern Cheyenne and Crow Tribes).

Two Indian reservations are located within the PRB area: the Crow and Northern Cheyenne Tribes. The Crow Reservation is located in south-central Montana, and comprises nearly 2,296,000 acres. Access is via Interstate 90 or U.S. Highway 87. The reservation is bordered on the south by the State of Wyoming, on the east by the Northern Cheyenne Reservation, and on the northwest by the city of Billings, which is Montana's largest metropolitan area. The reservation encompasses the Little Big Horn Battlefield and approximately 3,600 square miles of rolling prairie and rugged foothills drained by the Bighorn River. The BIA Realty Office indicated that the tribe has some 455,719 surface acres and 405,888 acres of mineral rights. There are another 1,035,850 acres that have been individually allotted, and 824,427 acres of allotted mineral rights.

The Northern Cheyenne Indian Reservation occupies about 445,000 acres in eastern Big Horn and southern Rosebud Counties, Montana. Access to the reservation is provided via U.S. Highway 212. The reservation covers nearly 695 square miles and is bordered on the east by the Tongue River and on the west by the Crow Reservation. According to the BIA Realty Office, the tribe has 442,193 trust acres and 444,000 of surface and mineral estate lands. There are 138,211 individual allotted acres on the reservation.

LIVESTOCK GRAZING

Most livestock grazing allotments involve only one permittee; however, there are several multi-permittee allotments. There are no other rights or control of public lands granted by issuance of a livestock grazing permit. The length of grazing periods varies from seasonal to yearlong use. Most ranch operators using the allotments are cow-calf operations with sheep operations coming in second. Most allotments are predominantly private lands with scattered 40 to 80 acre tracts of federal lands. Occasionally a few larger blocks of 640 acres or more of federal lands are encountered. Most allotments have several range improvements such as fences, stock ponds, pipelines, springs, windmills, seedings, wells, and access roads for better control of livestock for management purposes (BLM 1992).

SOILS

The U.S. Department of Agriculture’s (USDA) Natural Resources Conservation Services (NRCS) has published a general soil association map for Montana in digital format. The State Soil Geographic Database (USDA NRCS 1996) provides a general overview of soils distribution and occurrences in the Study Area but is not sufficiently detailed to be suitable for site-specific evaluations. Soils in the PRB area are derived mainly from sedimentary bedrock and alluvium. The soils generally range from loams to clays, but are principally loams to silty clay loams. Detailed soil information in the PRB Study Area can be found in the *Soils Technical Report* (ALL 2001a).

Slope and K-factor are values that are used in the estimation of soil erosion potential. Slope values range up to greater than 40 percent; however, there are many soils that have slopes of zero to about 10 percent. Almost all of the soils in the Study Area have low K-factors (below 0.37). Easily eroded soils have a K-factor between 0.37 and 0.69, and resistant soils have a K-factor less than 0.37 (Jarrett 1995).

Soil salinity affects the suitability of a soil for crop production and the stability of the soil. Most of the soils within the Study Area have low salinity values. A factor of CBM produced water that can affect area soils is the Sodium Adsorption Ratio (SAR). SAR is a measure of the concentration of sodium in water relative to the concentration of calcium and magnesium. High SAR values adversely affect the soil structure by reducing its ability to allow water to infiltrate. Soil SAR values vary widely both statewide and within the Study Area. Based on the generally fine texture of the surface soils (clayey), much of the soil will likely be susceptible to increasing sodicity if irrigated with water having a high SAR value. The use of good water management practices, such as mixing high SAR water with better quality low SAR water, would allow for much of the soil within the study area to be irrigated. Permeability is the measure of vertical water movement within the soil (infiltration rate) when it is saturated. The soil structure, porosity, gradation, and texture all influence the permeability of the soil. Those soils with a coarser texture (sandy to loamy) and good internal drainage (higher permeability) will be the least susceptible to increasing sodicity and salinity.

SOLID AND HAZARDOUS WASTE ISSUES

The hazardous materials program priorities are to protect the public health and safety; protect natural and environmental resources; comply with applicable federal and state laws and regulations; and minimize future hazardous substance risks, costs, and liabilities on public lands. BLM is responsible for all releases of hazardous materials on public lands and requires notification of all hazardous materials to be used or transported on public land.

Solid and hazardous wastes can be generated during oil and gas and CBM activity. These wastes are under the jurisdiction of the MDEQ for Resource Conservation and Recovery Act (RCRA) wastes; the MBOGC for RCRA-exempt wastes such as drilling wastes; and the EPA on tribal lands. At the present time, wastes generated from the wellhead through the production stream to and through the gas plant are exempt from regulation as a hazardous waste under RCRA's exploration and production exemption, but are covered by mineral leasing regulations on BLM lands. The exemption does not apply to natural gas as it leaves the gas plant for transportation to market. Releases must be reported in a timely manner to the National Response Center, the same as any release covered under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The MDEQ's Solid and Hazardous Waste Bureau is responsible for administering both the Montana Solid Waste

Management Act (75-10-201 *et. seq.*, Montana Code Annotated [MCA] and the Montana Hazardous Waste Act (75-10-401 *et seq.* MCA).

Montana's Department of Transportation (MDT) under CFR Parts 171-180 regulates the transportation of hazardous materials. These regulations pertain to packing, container handling, labeling, vehicle placarding, and other safety aspects. The transportation of all hazardous waste materials in Montana must comply with the applicable Federal Motor Carrier Safety Regulations.

VEGETATION

The Study Area includes six general land classes or vegetative communities: Agriculture/Urban Areas, Grassland, Shrub land, Forests, Riparian Areas, and Barren Lands. All of these habitats are important to a wide variety of wildlife species. Many federally listed threatened, endangered, or candidate species of special concern exist in the Study Area that are given special consideration under Section 7(c) of the Endangered Species Act of 1973 (ESA).

Although the word "noxious" means harmful or deleterious, in this context it is a legal term for species of plants that have been designated "noxious" by law. Noxious weeds are non-native species with the potential to spread rapidly—usually through superior reproductive capacity, competitive advantage mechanisms, and lack of natural enemies. Fourteen species have been defined as Category 1 noxious weeds for Montana; these are weeds that are currently established within the state.

VISUAL RESOURCE MANAGEMENT

Visual resources are visual features in the Montana landscape that include landforms, water, vegetation, color, adjacent scenery, unique or rare structures, and other man-made features. The Montana PRB contains a variety of landscapes and habitats, all with different visual qualities. There are four defined classes of visual resource management for federal lands; these are:

?? Class I—preserve the existing character of the landscape

?? Class II—retain the existing character of the landscape

?? Class III—partially retain the existing character of the landscape

?? Class IV—provide for management activities that require major modifications to the existing character of the landscape

Non-federal land is not under any visual resource management system although there are often visual quality concerns. Federally authorized projects, however, undergo a visual assessment to comply with aesthetic requirements. Typically, sensitive areas include residential areas, recreation sites, historical sites, significant landmarks or topographic features, or any areas where existing visual quality is valued.

WILDLIFE

The PRB Study Area contains substantial geographic and topographic variation that supports a wide variety of plant communities and wildlife habitat types. This combination of factors results in very diverse wildlife communities with some species having widespread occurrence throughout the Study Area and others being restricted to one or a few specialized habitats and locations. Many federally listed threatened, endangered, or candidate species of special concern exist within the Study Area that are given special consideration under Section 7(c) of the Endangered Species Act (ESA) of 1973.

PROJECT PLANNING ELEMENTS

The exploration and development of CBM within the Powder River Basin has many elements that are common to corresponding conventional oil and gas activities. As such, there are a number of existing industry practices, standards, laws, and regulations that apply to all oil and gas exploration and development activities, including CBM. However, there are also many aspects of CBM exploration and development that are unique and different from conventional oil and gas activities. With the development of the Statewide Draft Oil and Gas Environmental Impact Statement and Amendment of the Powder River and Billings Resource Management Plans (EIS) for CBM in Montana, there will be additional requirements identified and developed that will apply specifically to CBM operations within the state. Among those included in the EIS is the requirement for a Project Plan. The Project Plan will serve as an overall means for the CBM operator to specify how a particular area or field CBM operation will be conducted. The Project Plan would include such items as a Water Management Plan, Groundwater Monitoring Plan, and Wildlife Monitoring and Protection Plan as well as outline any provisions that are specific to the leasing arrangements or the siting of CBM facilities. Also included would be specific provisions for CBM operations that are conducted on lands or minerals that are owned or managed by the federal or state government or a tribal government. The Project Plan would also include a section on Best Management Practices (BMPs) that would be implemented by the operator to address site-specific issues such as the mitigation of potential impacts to area resources.

FEDERAL LANDS

Oil and gas activities, including CBM, conducted on federally owned or managed lands or minerals carry unique requirements. Federally owned oil, gas, and CBM resources are administered by the Bureau of Land Management (BLM) in cooperation with other Federal Surface Management Agencies (SMAs) or surface owners. The BLM has developed a guidance document entitled "Surface Operating Standards for Oil and Gas Exploration and Development" or, as it is more commonly referred to, the "Gold Book". The "Gold Book" provides guidance for oil and gas operations on federal lands and minerals that ranges from initial exploration activities through abandonment as well as presenting standards on surface land use and drilling programs. The standards and guidance that are contained in the "Gold Book" would also apply to CBM operations that are conducted on federal lands or minerals. The "Gold Book" also pertains to operations conducted on Indian Lands but those operations should incorporate early consultation with the BLM, the appropriate Bureau of Indian Affairs agency office, and local tribal government.

LEASE STIPULATIONS

Lease stipulations consist of specific measures that are incorporated into a mineral lease and are intended to avoid potential effects on resource values and land uses from oil and gas operations, including CBM. Lease stipulations can include provisions for, and constraints on, such things as site clearances, occupancy, and timing restrictions. Lease stipulations are applied before the lease is issued and, depending on the language of the stipulation, apply to all facets of exploration, production, and abandonment activities. The Federal government uses lease stipulations and site-specific mitigation measures determined at the development stage to protect various resources.

The Montana Board of Oil and Gas Conservation (MBOGC) implements restrictions that are analogous to lease stipulations through the issuance of field rules. Field rules are applied on a case-by-case basis to protect resources on state and privately owned land. The Montana Trust Land Management Division (TLMD) of the Montana Department of Natural Resources and Conservation (DNRC) also has lease stipulations for their minerals. The TLMD utilizes a set of standard stipulations on all oil and gas leases that is different from those used by BLM. In addition, the TLMD undertakes a site-specific review process for exploration and operating plan proposals. This review process generates site-specific stipulations for issues such as steep topography, wildlife, streams, wooded areas, and rivers or lakes. Additional stipulations can be placed on the use of MDNRC minerals on a case-by-case basis prior to their being leased. The success of these stipulations or field rules in avoiding a specified impact, in some instances, will require the collection of site-specific information regarding the resources to be protected relative to changes that occur from exploration, production, and abandonment activities.

CONTROLLED GROUNDWATER AREA

The technology involved in extracting Coal Bed Methane requires the withdrawal of groundwater from the coal seam aquifers to reduce water pressures allowing methane to be released. Because the Montana PRB will be a primary area of CBM development, it is anticipated that significant quantities of groundwater will be removed, resulting in an overall lowering of water levels within the Study Area. As such, the DNRC has adopted a Final Order creating a Controlled Groundwater Area within the Montana PRB. This Final Order designating the Montana PRB as a Controlled Groundwater Area contains specific provisions that include:

?? Applies only to CBM production and includes all formations above the Lebo member of the Fort Union Formation.
?? The setting of specific standards for permitting, drilling, and producing CBM wells.
?? Requirements for water source mitigation agreements.
?? The creation of a Technical Advisory Committee to review, oversee, and advise on scientific and technical aspects of the PRB Controlled Groundwater Area.
?? Requirements for reporting specific information on groundwater characterization and monitoring.
?? Requirements for the collection of specific data and sets procedures for notifications that will need to be made to appropriate state agencies and the public.

MONITORING PLANS

The EIS for CBM contains proposed provisions for the monitoring of changes that occur to groundwater and wildlife resources as a result of CBM exploration and development.

The Montana Department of Natural Resources and Conservation (DNRC) Technical Advisory Committee for the Powder River Basin Controlled Groundwater Area has proposed a groundwater monitoring plan for CBM development. The focus of this monitoring plan is to conduct an overall evaluation of the potential effects of CBM development and to track the changes that occur as CBM fields mature, and gas production declines and eventually ends. Monitoring performed by CBM operators, that is required by MBOGC or the U.S. EPA, will gradually be discontinued as portions, and eventually all, of the CBM fields are played out. Abandoned producing wells or monitoring wells within CBM fields could be incorporated into the regional monitoring program as fields mature in order to effectively monitor post-production groundwater recovery in affected areas. The need for detailed information and the cost of installing monitoring wells and monitoring ground water-levels and spring flows will need to be balanced to determine the ultimate spacing between monitoring sites.

The Bureau of Land Management (BLM), Fish and Wildlife Service (FWS), and the state have developed a draft outline for a Wildlife Monitoring and Protection Plan (WMPP). The goal of the WMPP is to avoid or minimize impacts to wildlife and serve as a communications tool to foster cooperative relationships among the CBM industry, landowners, and the various local, state, and federal agencies that will be involved in the regulation of CBM operations.

REGULATORY ENVIRONMENT

The identification of Federal, State, and Local regulations that are applicable to Coal Bed Methane (CBM) production will be a key element of the initial planning process. The provided information was obtained from the Montana Department of Environmental Quality (MDEQ) and is not considered all-inclusive since CBM related technologies and regulations are constantly being improved and/or revised. It is suggested that the Montana Department of Environmental Quality (MDEQ) as well as other relevant regulatory agencies be contacted prior to the performance for all CBM production activities. Additional guidance on the subject of regulations may be found at www.deq.state.us/coalbedmethane.

FEDERAL REGULATIONS

The Clean Water Act, as it relates to CBM activities, primarily regulates the discharge of dredged or fill material into the waters of the United States under section 404. The U.S. Army Corps of Engineers regulates all Montana water bodies, including wetlands and riverine systems, under this section. The discharge of water during CBM development and production activities may require a section 404 permit (Clean water Act, Section 404 regulations, 33 parts 320-330 and 404(b)(1).

Under the Federal Safe Drinking Water Act, the EPA Underground Injection Control (UIC) Program provides safeguards for endangerment of current and future drinking water sources. The EPA recognizes five classes of injection wells depending on the type of waste injected and where the waste is injected. The Montana Board of Oil and Gas Conservation (see below) regulates Type II wells, including injection of brines and other fluids associated with

CBM production. The EPA Region 8 office is responsible for the four well classes (42 U.S.C 300h et. seq.).

The National Environmental Policy Act of 1969 provides guidelines that are used to determine and assess the potential for environmental impacts on major federal projects. Under this Act, Environmental Impact Statements (EIS) are developed to consider project specific environmental impacts that may result from CBM development practices. Information evaluated in the EIS, including impact alternatives, is made available to the public prior to commencement of CBM activities (42 U.S.C 4321 et seq.).

STATE REGULATIONS

The Montana Board of Oil & Gas Conservation (MBOGC) is a quasi-judicial body that is attached to the Department of Natural Resources and Conservation (DNRC). The board's regulatory actions serve three primary purposes: (1) to prevent waste of oil and gas resources, (2) to conserve oil and gas by encouraging maximum efficient recovery of the resource, and (3) to protect the correlative rights of the mineral owners. The board also seeks to prevent oil and gas operations from harming nearby land or underground resources. It accomplishes these goals by establishing spacing units, issuing drilling permits, administering bonds, classifying wells, and adopting rules. The board has issued an order establishing the current CBM operating requirements.

The MBOGC has assumed the primary regulatory jurisdiction over the Underground Injection Control (UIC) Program for Class II injection or disposal wells. The purpose of this program is to protect underground sources of drinking water (USDWs). An oil and gas operator must apply for a permit to inject, providing specific data about the company and other required information (Administrative Rules of Montana (ARM) 32-22-101 through 1706).

Montana Water Quality Act & Rules classifies water quality standards and procedures for surface water and mixing zones. Under these standards Montana has implemented several permit requirements including water quality discharge, discharge elimination, and water quality pollution control. Discharged water resulting from CBM activities are regulated by these standards and are subject to permit approval prior to any discharge activity (ARM 17.30 and MCA 75-5).

The Montana Water Quality Act also requires 401 certification for the discharges of any dredged or fill materials. The certification process is defined and regulated by the Army Corps of Engineer’s 404 permit (MCA 75-5).

The Montana Water Use Act provides guidelines specific to controlled groundwater areas in the Powder River Basin and applies to wells designed and installed for the extraction of Coal Bed Methane. CBM development must follow the standards for drilling, completing, testing, and production of CBM wells as adopted by the MBOGC; CBM operators must offer water mitigation agreements to owners of water or natural springs within one-half mile of a CBM operation or within the area that the operator reasonably believes may be impacted by the CBM operation, whichever is greater. This area will automatically be extended one-half mile beyond any well adversely affected; and DNRC will designate a Technical Advisory Committee to oversee groundwater characteristics and monitoring, and reporting requirements (MCA 85-2-101 et. seq. and ARM 36.12.101 through 1212).

The Montana Clean Air Act governs activities with the potential to emit greater than 25 tons per year of any regulated pollutant. Such activities must obtain an air quality pre-construction permit prior to the construction or operation of the affected source.

The process of coal bed methane extraction requires the construction and operation of wells to access the gas and compressor stations to extract and convey the gas. The compressor stations consist of various pieces of equipment with the potential to emit pollutants at varying levels depending on equipment capacities. In addition, the facility may incorporate a Coal Bed Methane powered generator (well-head generator) located on top of the well to generate electricity. In these cases, the generator could also be a source of pollutant emissions.

A typical compressor station gathering CBM will incorporate from 1 to 3 compressor engines varying in power from 100 to 500 hp. Operation of these natural gas fired engines results in the emission of regulated air pollutants including CO, NOx, VOC, SOx, and PM_{10} (Montana Code Annotated (MCA) 75-2-204 and 211, ARM 17.8.705).

LOCAL REGULATIONS

The local Conservation District is responsible for administering 310 Permits for proposed work in Montana that may disrupt streams, lakes, and wetlands. The Montana Natural Streambed and Land Preservation Act establishes guidelines and mitigation measures to prevent degradation of natural water systems that might result from construction activities.

BEST MANAGEMENT PRACTICES AND MITIGATION MEASURES

EXPLORATION OF COAL BED METHANE

SITE LOCATION

The surface location of CBM wells is often constrained by regulatory requirements, lease stipulations, optimization for successful geologic testing, and other operational needs. Of equal importance is the selection of surface locations to minimize and mitigate surface conflicts and avoid unnecessary surface uses that will require additional reclamation, special operating procedures, or other restrictions that could be avoided. Consideration should be given to the proximity to schools, residences and other public areas, visual impacts, erosion potential, wildlife habit, and the improvements and structures of the landowner/surface lessee.

CBM Drilling Operations - Wyoming

Of particuar importance in populated areas or where individual residents are close by is the selection of an exploration site that takes maximum advantage of natural features and topography to minimize both audible disturbance and visual impairment of the local view shed. The well drilling operation in the photo is located in a valley between hills that act as barriers to both visual and noise impacts. The use of natural barriers may also benefit the operator by reducing potential vandalism and mitigating safety concerns that may occur if the exploration site is visible and accessible to the public. Topography and natural features may also be used to buffer areas where wildlife concerns such as breeding grounds or special habitats exist. These factors may be of substantially less importance in areas where no sensitive population is present. However, it is important to avoid “sky lining” of facilities even in remote areas to avoid unnecessary disruption of the vistas that travelers and residents have become accustomed to.

Operators should avoid steep slopes, unstable soils, and locations that block or restrict natural drainages. Care should be taken to disturb the minimum amount of native vegetation as possible, particularly in those areas where vegetation will be difficult to re-establish. Locations in areas with a potential for high surface run-off, with increased erosion potential or in the flood plain of surface drainages could dramatically increase maintenance costs and the ultimate restoration costs and create additional safety concerns. An exploration site that has a low slope, soils with low erosion potential, and that can be readily re-vegetated benefits the operator by reducing the costs of compliance with storm water discharge permits and associated well and road site remediation.

BASELINE STUDIES

Defining existing conditions prior to commencing exploration activities can be of considerable importance when the operator is faced with issues such as landowner mitigation agreements, future site reclamation/restoration activities, and public concern. Establishing existing conditions such as groundwater hydrologic characteristics and quality, surface water quality and flow, vegetation type and distribution, soil type, use and sensitivity, and the presence of local habitat will provide a basis for evaluating changes that may occur as a result of CBM exploration and development activities. Having background or existing conditions established will be a critical element in developing and choosing the types of practices to apply as well as the strategies for mitigation that will prove most effective.

Since the production of CBM involves the inherent production of groundwater resources, the research team noted it to be relatively common for producers to proactively take steps to establish pre-development environmental conditions – especially with respect to groundwater. Establishing baseline environmental conditions may also be required for CBM development on federal or state lands. NEPA documents prepared in both Wyoming and Montana that pertain to CBM development include monitoring plans, including the collection of baseline data. However, the research team noted that in many areas of the country, baseline data is becoming more comprehensive.

Local Residents at a Public Meeting for CBM Exploration near Bozeman, Montana

Cattle Grazing near Bozeman Pass

One example pertaining to the emphasis that can be placed upon collection of baseline data was exhibited with respect to a proposed CBM exploration well near Bozeman, Montana. In this case, the proposed exploratory well was located in an area having residents opposed to CBM development. Local residents rallied against the proposed exploratory well and suggested extensive baseline studies be performed prior to proceeding with the drilling of the exploratory well. The local residents were concerned with a variety of issues, not limited to, but including potential degradation and/or contamination of area watersheds and groundwater. Although baseline studies were conducted in this area, it is important to recognize that performing baseline studies do offer benefits in many cases, including establishing actual (i.e., not perceived) background characteristics.

Baseline data may involve characterization of produced water, groundwater, and surface water. The presence and number of cattle in a specific area may, for instance, drive the volume of water that may be used for stock watering. It may also include an evaluation of area soils, cultural and paleontological resources, wildlife, and other environmental concerns. Baseline data collection may also pertain to issues that are not environmentally related. If there are potential concerns relating to property values then the collection of this and other data and information may prove valuable as development proceeds. The actual extent of baseline studies will certainly be driven by local conditions and concerns that may be unique to a specific area. An evaluation of the type and extent of baseline conditions should likely be done early in the planning process.

HEALTH AND SAFETY

Many of the health and safety risks associated with gas and oil production are not commonly present at CBM sites. Nevertheless, there are important health and safety considerations at CBM sites that need to be taken into consideration. Health and Standards established by OSHA's Construction Standard (29 CFR 1926.1101), the State of Montana's Accident Prevention Regulations (1967), and DOE's Environmental Health and Safety Handbook, prepared for the Montana Oil and Gas Exploration and Production Industry (1998), are regulatory guidance not only circulated for worker and employee protection, but also for the local populace not directly involved in CBM activities.

Often times, CBM project sites must be accessed by driving on small rural highway systems that are not designed to accommodate large volumes of traffic. The research team, during the field investigation, recognized the importance of car-pooling to help minimize construction traffic and reduce the potential for vehicular accidents. Training, including defensive driving courses, has also been shown to help reduce work related traffic accidents. The team also noted that in some cases construction traffic and school buses share the same roads. It became evident that careful planning by the project staff was necessary to create a safe environment for the children. Planning work hours around the schedule of school bus pick-ups and drop-offs is a practical solution to achieve a safe highway environment.

Another safety issue common to CBM sites is fire control. The Powder River Basin is geographically located in an arid section of Montana and Wyoming and is therefore susceptible to outbreaks of uncontrolled fires. The conservation and protection of local habitat, including mature small grass prairies and endangered and threatened species habitat, often times could depend on a successful fire control plan. Fire safety is a concern not only for operators but local communities as well. The researchers noted in other regions where CBM development is occurring that notification of the local fire department and having on-site fire protection services often helps alleviate some of the concern. Implementing spark prevention programs, methods for properly disposing of cigarette butts, training in the proper use of fire extinguishers, and having emergency information accessible to employees are also important elements of fire control plans that were observed by the field team.

Lastly, the field team found that the development and utilization of a functional Health and Safety Plan allows for a successful working environment for on-site personnel. A Health and

Safety Plan allows employees to determine site-specific training requirements, activity specific Personal Protection Equipment (PPE) requirements, and other issues pertinent to CBM activities. A Health and Safety plan is intended to provide critical information to the employee, as well as the employer, to create a safe and responsible work environment that does not inhibit work efficiency. The research crew found the most effective plans were always easily accessible to all on-site personnel and in some cases, reward programs were implemented to recognize employee conformance with the plan.

DEVELOPMENT AND OPERATIONS OF CBM

WATER MANAGEMENT

Beneficial Use

The beneficial use of CBM produced water represents an opportunity for operators to provide themselves, the landowner, and nearby industry with water that does not result in the waste of this resource. The loss of groundwater resources that reside in the coal seam aquifers from which CBM is produced presents a significant concern to the regulatory community, and the residents of the Montana Powder River Basin. The ability of a CBM operator to provide produced water for beneficial uses by industry, landowners, or other parties, can provide unique and substantial benefits.

Dust Control

Dust is a noticeable nuisance, especially in arid regions of the country such as the Montana PRB Study Area. Dust from construction activities and standard travel of personnel and equipment over unpaved roads has the potential to impact air quality and create a nuisance to those traveling in these areas. The use of produced water for dust control offers multiple benefits from an environmental viewpoint, including the prevention of air quality concerns and the loss of surface soils. Based on available water quality data for water originating from underground coal seams in the Montana PRB, the application of produced water for dust control appears feasible. However, site-specific analysis may be necessary as well as gaining appropriate approvals from landowners and applicable governmental agencies.

Possible applications of produced water for dust control include use on lease roads, other unpaved roads in the development area, and various construction sites where surface disturbances due to CBM development exist. Water produced from CBM operations at the CX Ranch Field near Decker, Montana has been provided to nearby coalmines for industrial uses that include dust control.

The use of CBM produced water for dust suppression does present some concerns. Poor quality CBM water, generally associated with high sodium adsorption ratio (SAR) values, can create problems with native soils. Soils and crops have a particular sensitivity to sodium and its concentration relative to calcium and magnesium (referred to as the sodium adsorption ratio) in water. If operators continuously apply high SAR water to access routes and unpaved areas, future land reclamation and reseeding problems may arise. Further complications such as increased soil erosion could arise if the water is applied too frequently or at high rates. The fact that produced water has the potential of causing negative impacts to native soils throughout many portions of the Montana Powder River Basin necessitates careful evaluation of beneficial use applications, such as dust control, that involve applying produced water to the land surface.

Irrigation

The arid environment of the Montana PRB Study Area is not well suited for crop production. A majority of crop production within the area occurs either on high terraces above the valleys or in irrigated fields along the rivers and in stream valleys. There is less than one percent of the land within the Study Area currently being used for agricultural production. The use of produced water to provide area farmers with additional water for irrigation purposes could increase the lands available for agricultural production. Coordination between the CBM operator, local landowner, and local farming community could provide opportunities for supplying farmers with CBM water for irrigation. However, the quality of produced water would determine the extent to which the water could be used for irrigation. Irrigation uses have a defined range of acceptable water quality depending upon soil type and crop selection but some coal aquifers are reported to contain suitable water.

Spray Irrigation of CBM Produced Water

CBM produced waters with high sodium adsorption ratio (SAR) would likely be unfit for extended periods of irrigation in areas with certain soil types unless it was blended with higher quality water. However, decreased crop yields from poorer quality CBM water could be counter balanced by the availability of water for irrigation in areas where it is currently unavailable. If new cropland were made available for planting because of the availability of CBM water, the agricultural community may be able to use larger quantities of lesser quality CBM water to irrigate a greater number of acres and thus increase overall crop production even though the yield per acre may be reduced. Additional discussion of the relationship between SAR, soil type, and crop productivity can be found in the Soils Technical Report (ALL, 2001).

Livestock Watering

Recycled Tire Stock Tank

Throughout the PRB there is significant land that has no water that is easily accessible. The availability of produced water from CBM activities would allow some of this land to be used for grazing. The rancher would have to obtain the water rights for the use of the produced water for livestock watering through the Montana DNR. There are estimates that, on average, cattle can consume 11.5 gallons of water per day. The governmental standards for livestock water are less restrictive than potable water and would allow for the use of lesser quality CBM water for this purpose. Early coordination and cooperation between area CBM operators, landowners, and local ranchers on the potential uses of produced water could again prove beneficial to all parties. The CBM produced water provided to ranchers for use as livestock water in areas currently lacking water would increase the land area that ranchers have available for grazing. This practice is currently being implemented in portions of the PRB through the use of stock tanks made from old heavy equipment tires such as the one depicted in the photo here.

Industrial Use

In the Montana PRB, the researchers identified that certain industries, specifically coalmines, are often lacking water for activities such as dust control and the restoration of aquifers. The availability of CBM produced water to industries such as coal mines may assist in the restoration of aquifers impacted by mining activities as well as provide useable water for dust control, slurry mining, and slurry piping. Oil and gas and CBM development can require large quantities of water during drilling, completion, and the testing of wells and also for certain formation treatments such as water flushes. These activities could be performed using produced water. Other industries such as manufacturing and meat processing may have uses that are compatible with CBM produced water of sufficient quality.

Impoundments

Impoundments can provide a variety of beneficial use options for both the lease operator and landowners. Site-specific conditions may dictate which impoundment options are best suited for the area because of topography, soil conditions, clinker deposits, and the intended purpose of the impoundment. The CBM operator can coordinate with the landowner on the location of impoundments, future uses the landowner may have, whether to construct in-channel ponds or out-channel ponds, and

Landowner Requested Out Channel Pond

what size impoundments to construct. The out-channel pond in the picture was requested by the landowner and is currently stocked as a fishing pond. Impoundments could have a variety of uses including storage ponds, coal or shallow aquifer recharge (infiltration into clinker zones), fisheries, livestock and wildlife watering ponds.

Lined Pond

Surface ownership, purpose of the impoundment, and local topography may dictate the design of the impoundment. Surface ownership can determine what regulatory requirements govern impoundments as both the Bureau of Land Management (BLM) and Montana Department of Environmental Quality (MDEQ) have design and construction rules for impoundments. In some cases, such as the impoundment pictured here, impoundments are required to be lined with bentonite or synthetic liners to prevent infiltration through the bottom of the impoundment into shallow aquifers. In Montana, impoundments require Montana Board of Oil and Gas Conservation (MBOGC) permits that require the impoundment to have an impermeable liner if the water is in excess of 15,000 mg/l TDS (ARM 36.22.1227). If the water in an impoundment should seep into the shallow groundwater and that groundwater would later discharge into a surface water body, then such discharges require a general produced water discharge MPDES permit from the MDEQ (ARM 17.30.1341).

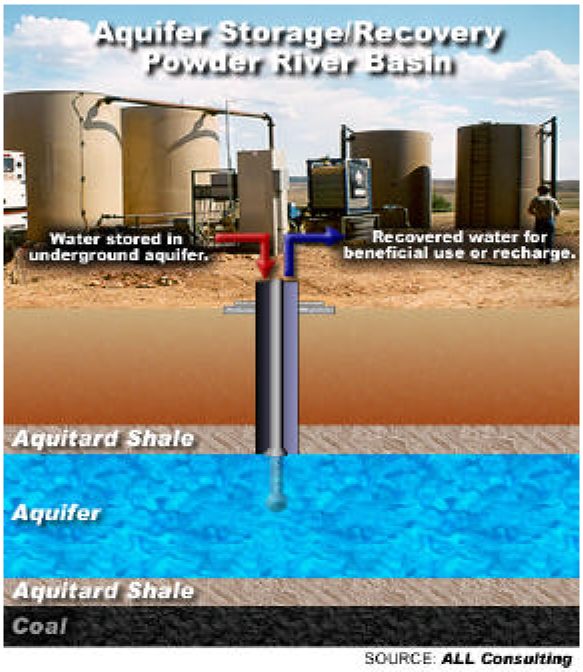
Landowner Use

The lack of water supplies in many areas of the PRB can limit the options many surface owners have for land uses. Produced water supplied to landowners creates additional options for their land use. In some instances the landowner may have some future use for the land that may benefit from the addition of produced water. The researchers have seen where cooperation between landowners and CBM producers in Wyoming has provided additional beneficial uses for produced water. The picture here shows a fishing pond that was constructed and supplied with produced water at the landowner's request. In one instance near Sheridan, Wyoming the researchers encountered a lease where the landowner requested that CBM operators create an out–channel pond around which the surface property would be subdivided and converted into a housing development. As CBM development continues, other options will likely be identified by landowners for the beneficial use of significant quantities of produced water that would otherwise require disposal.

Fishing Pond filled with CBM produced water, PRB Wyoming

Potable Water Use

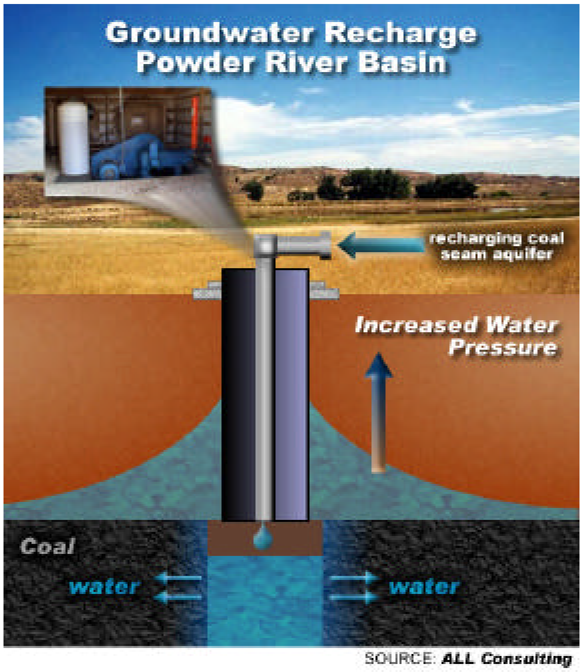
Potable water is a valued resource in the arid regions of the Montana PRB Study Area. Drinking water is often supplied from shallow surficial aquifers and coal seam aquifers. The water co-produced with methane is also a valuable commodity particularly when it is of drinking water quality. Although there is currently no regulation that requires produced water of drinking quality to be conserved, this water could be used to settle mitigation agreements and excess water could represent a saleable commodity. In populated areas, the water could be used to supplement water supplies during the dry seasons or drought years when there is a water deficit.



Aquifer Storage and Recovery
Well Schematic

Aquifer Storage and Recovery

In areas where there are distinct wet and dry seasons, during the wet seasons water is abundant in both surface streams and groundwater supplies. However, water supplies are often depleted during the dry seasons leaving a demand upon water supplies at this time. In these areas, water is captured from surface streams and other sources then stored in permeable aquifers for use during the dry season to ensure this resource is not wasted. Aquifer Storage and Recovery (ASR) is a proven technology for storing large volumes of water. ASR is a process in which underground aquifers are used as reservoirs to store water, which is later withdrawn for use. In the Study Area much of the recharge to alluvial aquifers occurs during the winter and spring when snowmelt from the mountains fills the streams. The production of water from CBM will be a year round activity and may occur for as long as 20 years in some production wells. Regulators and citizens are concerned that this valuable resource may be wasted. The storage of produced water for future use could be accomplished through the use of aquifer storage and recovery techniques. In the case of CBM, large quantities of produced water could be stored in depleted aquifers or coal seams where gas has been depleted. ASR provides water storage at lower costs than traditional surface storage methods while functioning in a similar manner as a traditional surface reservoir. Other benefits of ASR include eliminating evaporative losses and minimizing impacts to the environment, which can be of particular importance in instances where produced water is of drinking water quality.



Aquifer Recharge Well Schematic

Aquifer Recharge
In arid climates such as that of the Study Area, during dry seasons and droughts, shallow surficial aquifers can experience significant water level declines. The production of CBM will also result in the lowering of water levels in coal seam aquifers. Produced water of sufficient quality could be used to recharge surficial aquifers during drought years and recharge depleted coal seam aquifers. Impoundments could be constructed and produced water allowed to infiltrate into shallow alluvial aquifers. During infiltration some filtering of the water would likely occur and water quality may be improved in some instances. In other portions of the PRB, coal clinker deposits are exposed at the surface; these zones are depleted of methane gas because of their exposure to the atmosphere. These clinker zones could be used to replenish coal seams aquifers with produced water. CBM production activities are unlikely in areas near exposed coal and would not be impacted by pore pressure increases resulting from recharge efforts. The use of produced water to recharge shallow surficial aquifers and coal seam aquifers could also meet the requirements established in some mitigation agreements.

Other Use
The control of noxious and exotic plants in areas where surface disturbances have occurred is often a concern. These plants can be transported to other areas on vehicles and equipment that have come in contact with them. Exotics can have detrimental impacts to native plant populations by consuming nutrients that would otherwise be available for native plants and grasses. The construction of wash facilities which use produced water can minimize the spread of noxious and exotic plants within the Study Area. The facilities can be constructed so that both local landowners and producers can clean vehicles and equipment thus minimizing the spread of noxious plants.

Disposal
There are a number of options for the beneficial use of CBM produced water depending upon the quality of the water and the effectiveness of the various treatment options which could be applied to improve water quality. However, even with treatment, it is unlikely that all of the produced water can be beneficially used and some of the produced water will still require disposal. The disposal of produced water could be the only option available to some operators. Produced water quality may be so poor that beneficial use is not possible or treatment technologies cannot efficiently improve the water quality. If site specific conditions dictate that disposal is the preferred management option, there are a variety of disposal methods for CBM produced water including, deep well injection, direct discharge to

the land surface, direct discharge to surface water, and the use of impoundments for evaporation.

Deep Injection

The injection of water waste into deep reservoirs is a standard practice of disposal in the conventional oil and gas industry. Injection wells and injection technology is an established industry regulated by state agencies and the US Environmental Protection Agency. The MBOGC currently regulates the Class II UIC rules for the state of Montana as established under 36.22.1400 of the Administrative Rules of Montana. The rule establishes guidelines for the permitting requirements for Class II injection wells including their construction, installation, and monitoring and requirements for the receiving formation. These regulations have been adjusted to include the use of all Class II injection wells for the CBM industry. Deep injection could also require a permit from the US EPA if Indian Tribal Land is involved.

Deep Injection Facility for the Disposal CBM Produced Water, Wyoming

The injection of CBM produced water into deep subsurface formations provides an alternative for disposal that would not require the treatment of water, or result in the degradation of surface water, groundwater, or further erosion of the surface soils. Operators could inject produced water into deeper reservoirs that are not classified as Underground Sources of Drinking Water (USDWs). The PRB contains several reservoirs scattered across the Study Area that could be used for injection disposal. Injection facilities are currently operating in the Wyoming PRB for the disposal of CBM produced water.

Direct Discharge to Land Surface

The direct discharge of water to the land surface can be a viable disposal practice. Factors such as the quality of produced water, the existing land use and landowners future plans for use, soil type, vegetative cover, and other site-specific conditions can affect surface disposal. The potential impacts and benefits from direct surface discharge can be discussed with the landowner to determine if direct land surface discharge is advantageous to the landowner and operator.

Direct Surface Discharge Location

The image above shows direct discharge to the land surface as it is currently being practiced in the PRB. The operator has placed rocks around the base of the discharge point to help prevent erosion of the soil. The use of rocks helps reduce the physical impacts that can cause erosion, however, other impacts to the soil can still occur depending on the quality of the water being discharged. The direct surface discharge of produced water with a high SAR on certain soil types could result in undesired impacts to the soil. Specifically, high SAR water can result in a reduction in the infiltration characteristics of certain types of soils. Further discussion of the relationship between SAR and soil type can be found in the Soils and Water Technical Reports (ALL, 2001a and 2001b).

Direct Surface Water Discharge

The discharge of CBM produced water to surface water can provide another disposal alternative for operators. Produced water can be discharged to waters of the state of Montana with an appropriate permit from the MDEQ. New discharges are subject to Montana's Non-Degradation Rules (ARM 17.30.700). The MDEQ is currently working to adopt Total Maximum Daily Loads (TMDLs) relating to CBM produced water discharge, in particular, they are evaluating rules to regulate Electrical Conductivity (EC), SAR, and bicarbonate values for select waterways in Montana.

Direct Discharge to the Surface Waters of the Tongue River

Lease operators could consider various discharge scenarios based on the quantity and quality of the produced water and the receiving water. The image to the left shows direct discharge to the surface waters of the Tongue River; note how the discharge point is over a rocky surface to minimize erosion of the stream bank. Discharge options such as flow based discharge, rate based discharge, or other discharge options may be appropriate depending on site-specific conditions. Flow based discharge can be used to control the quantity of poor quality CBM produced water discharged to receiving streams during times of low flow in streams and rivers when the potential for degradation of surface water quality is greatest.

Flow based discharge is designed to maximize the dilution potential of the receiving stream by controlling the volume of water discharged relative to the flow rate of the receiving stream. This is done by storing produced water during times of low flow in the receiving stream when the dilution potential is lowest; in the Study Area this would be during the dry summer months. Stored water is then discharged when flow in the receiving streams has been increased in the Study Area; this usually results from precipitation and/or snowmelt. Flow based discharge requires more management than rate based discharge including the continuous monitoring of produced water and the receiving stream.

Rate based discharge typically establishes a single rate at which discharge is allowed year round and is often based on a worse case discharge scenario. Rate based discharge can be more restrictive of the total volume of produced water an operator can discharge. However, because rate based discharge permits typically have one rate of discharge they are easier to manage and require less monitoring.

Impoundments

Impoundments can provide a variety of disposal options and benefits to both the lease operator and landowners depending on site-specific conditions. The quality of produced water, soil type, current and future land use, and terrain are factors that should be considered when constructing an impoundment. The owner of the mineral lease could also affect the design of impoundments as BLM and the State of Montana have different requirements for the design and construction of impoundments on their mineral leases. Additionally, in Montana impoundments require MBOGC permits and, if the water is in excess of 15,000 mg/l TDS, the pond or impoundment must be lined with an impermeable liner (ARM 36.22.1227). In the case where produced water would be discharged to surface waters, a Montana Pollution Discharge Elimination System (MPDES) permit from the MDEQ (ARM 17.30.1341) is required. Impoundments built for the disposal of produced water could include evaporation ponds, storage ponds with discharge to surface waters, and constructed wetlands treatments.

Evaporation/infiltration ponds can be constructed for the disposal of produced water. These ponds would utilize natural conditions to allow produced water to infiltrate back into the alluvium and eventually back into the water table while also allowing evaporation to occur at the surface. The construction and operation of an infiltration pond can be impacted by the local water table as high water tables prevent the natural filtration of water. A high water table could present regulatory concerns if the groundwater was in contact with a surface stream. Infiltration ponds constructed in areas where produced water infiltrates into the groundwater and is subsequently discharged to a stream or river would require a MPDES permit. Evaporation/infiltration ponds are currently being used in the PRB for disposal of produced water.

Treatment

During the production of Coal Bed Methane, groundwater is extracted from coal seam aquifers to facilitate the release of methane gas trapped under hydrostatic pressure. Development of new CBM fields will require the production of more water from areas where hydrostatic pressure within the coal seam aquifer has not already been reduced. Over the life of a CBM well the rate at which groundwater will need to be withdrawn is expected to decrease while methane gas continues to be produced. The quality of the water that is extracted during CBM development may determine how this water can be managed. In some instances, high quality CBM produced water can be used for a variety of beneficial uses or disposed in a variety of manners. Discussions regarding the types of beneficial uses and disposal options are included in other sections of this chapter. However, it is also expected that poor quality water will be produced during CBM operations, which may limit potential beneficial uses and limit disposal options. CBM water may be considered poor quality for a variety of reasons depending on the intended beneficial use or disposal practice being considered. For instance, water that is below drinking water quality standards may be considered poor for mitigation requirements, but may be of sufficient quality for livestock watering. Another example would include water that has a high SAR value, which would be unsuitable for irrigation practices, but still meets drinking water standards. It is important to consider that some of the produced water may require treatment prior to its beneficial use or disposal. Presented below are a variety of treatment technologies that could be used to treat produced water. Treatment technologies including freeze/thaw/evaporation, atomization, reverse osmosis, UV, chlorination, wetlands treatment, and other technologies that could be used depending on the ultimate intended use of the produced water.

Freeze/Thaw/Evaporation
The Study Area experiences seasonal changes that may benefit operators in treating some of the produced water. During the summer, the region is warm and dry with high evaporation rates, in the winter, the area typically reaches freezing temperatures for several consecutive months. These seasonal changes can be applied to reasonably simple treatment technologies to reduce the amount of produced water that must be managed. Freeze/Thaw/Evaporation treatments are currently being practiced in Alaska, Colorado and Wyoming to reduce the concentration of Total Dissolved Solids (TDS) in CBM produced water. The produced water is allowed to freeze naturally and as the water freezes, the dissolved solids and other constituents are concentrated in the unfrozen liquid. The ice that is formed is higher quality water than the produced water from which it was derived. The ice can be collected and thawed providing a source of high quality water with more management options or simply allowed to evaporate. This process can be repeated until the more concentrated effluent is of a manageable volume. The smaller volume of effluent, though more concentrated, can be more easily disposed.

Frozen CBM Produced Water from a Freeze/Thaw/ Evaporation Treatment (picture from Ogbe, 2000)

Atomization
The Study Area is an arid region with annual average evaporation rates between 38 and 40 inches. The high evaporation rates in the area create another natural condition that can be used for treatment of produced water. The evaporation of water results in a decrease in the volume of poor quality water that must be managed. Atomization is a process whereby water particles are separated into small droplets and dispersed; in warm dry climates these droplets are more easily evaporated than water stored in impoundments.

Reverse Osmosis

Reverse Osmosis (RO) is a proven technology for the treatment of water and the removal of TDS and other constituents. RO involves the removal of water from a solution containing dissolved solids by passing the water through a semi-permeable membrane. As pressure is applied, the semi-permeable membrane allows water to pass while the membrane retains the dissolved solids. The membranes are often cleaned by a cross flow which removes the molecules retained on the surface, these molecules are then collected and concentrated to be disposed. RO systems can be used to treat produced water and concentrate constituents into an effluent that is smaller in volume and more easily disposed.

Ultra-Violet Sterilization

Ultra-violet sterilization (UV) is a proven technology for the treatment of water and the removal of unwanted free-floating constituents. Although UV will not remove the dissolved constituents which present water quality problems for CBM produced water, it will remove microscopic organic contaminants that can prevent some uses of produced water. It is required that water that has been exposed at the surface be sterilized before it can be re-injected into an aquifer. The use of UV sterilization would achieve this requirement. Produced water which will be used for groundwater restoration, aquifer storage and recovery, or aquifer recharge should be sterilized prior to re-injection.

Ultra-Violet Sterilization Treatment
Of CBM Produced Water

Wetlands Treatment

Constructed Wetland for the Treatment
of Produced Water in Wyoming

The treatment of produced water can also be achieved by natural biologic reactions in a constructed wetland. Wetland plants can remove some dissolved constituents from water, reducing the concentration levels in the water and binding the constituents within the plant structure. Wetlands have been constructed in a variety of different environments and used to reduce the concentrations of constituents including dissolved sodium, and other metals. Currently in Wyoming, CBM operators are using constructed wetlands to reduce the level of some constituents before discharging the produced water to surface streams. The photo above shows a wetland constructed as a flow through treatment for produced water. The wetlands are able to reduce the concentrations of some constituents within the water prior to its being discharged.

Chlorination

Water that will be used for human consumption is often chlorinated before distribution. Chlorination effectively removes disease-causing bacteria, nuisance bacteria, parasites and other organisms, and can be used to oxidize iron, manganese, and hydrogen sulfide so these minerals can be filtered from the water. In instances where produced water could be used for beneficial human consumption, storage, or injection into aquifers, it may be necessary to chlorinate the water.

FACILITIES

The planning of CBM operation facilities prior to construction can be beneficial in minimizing impacts to resources. Throughout the course of this project, researchers have been informed of concerns regarding the impacts CBM will have by landowners, citizens groups, and the regulatory community. Well-developed Project Plans will aid operators in reducing concerns from the regulatory community, landowners, and citizens groups. Planning principals that are designed to minimize surface disturbances, view shed impacts, noise levels, emissions, and erosion can be implemented to address these concerns and reduce impacts.

Surface Disturbances

The impacts to both the present and future land uses of areas that will be developed for CBM operations represents concerns for surface landowners. The disruption of the land for the construction of roads, utility corridors, CBM operation facilities, and wells can result in significant impacts to soils, land use, wildlife, and surface drainages. The planning of operation facilities can benefit both the operator and surface landowner and reduce these impacts. Surface disturbances can be minimized by a variety of planning activities including, using existing roads and utilities, constructing wells in pods, centrally locating compressor stations, and the use of utility corridors. Operators must also consider minimizing the footprint of operation facilities as well as the number of operational disturbances. The state of Montana requires a storm water discharge permit for construction activity which results in the disturbance of more than 5 acres or more than one acre if located within 100 ft of a lake, stream or river (ARM 16.20.1314).

CBM Wells Constructed as Part of a Well Pod in Montana

In portions of the Study Area there are multiple coal seams that are expected to have CBM production potential. Operators who have leases with multiple gas producing coal seams can reduce surface disturbances by completing multiple wells in the different coal seams, called well pods. Well pods can utilize the same operation resources such as access roads, compressors, and utility corridors. The picture on the previous page shows a well pod in Montana in which three wells are currently sharing operation equipment. Each well produces from a separate coal seam so spacing requirements are met. The centralizing of operations equipment around well pods helps to minimize the footprint that is created for operations equipment since fewer compressor stations and tank batteries must be constructed.

Another planning element that can be developed to reduce surface disturbances is the use of existing roads and utilities, and the construction of one-way-in/one-way-out roads. The construction of lease roads creates additional surface disturbances that may impact wildlife habitat, create additional air quality problems from dust, increase erosion potential and result in noxious weed infestations. The design of CBM facilities to minimize the construction of new roads and utility corridors while utilizing the existing network of roads would help to minimize these impacts. Operators should coordinate with surface owners when planning road construction to identify future land uses and other planning concerns that the landowner may have. In some instances, the landowner may request operators to construct roads in areas for the landowner's future use. When new roads must be constructed, the construction of one-way-in/out roads to access facilities and wells would minimize impacts. More information on the requirements and engineering practices for road construction can be found in the Gold Book (BLM, 1989).

Underground Utilities for CBM Facilities
Connected to Existing Power Lines

In situations where road construction and utility placement are both necessary, surface disturbance can be minimized by placing utilities and road construction within the same corridor. Underground utilities such as electricity, discharge water, and gas transport lines could be placed in the same trench along roadways with the safety precautions to ensure that electrical shorts do not result in gas fires. In instances where utility placement is separate from road construction, placement of utilities underground would allow for the restoration of surface disturbances once the utilities are in place.

Aesthetics

During the field research activities, many landowners and citizen groups expressed concern for the aesthetic impacts CBM operations may have in their area. CBM operators have been able to alleviate some of these concerns by minimizing impacts from equipment noise and to viewshed disturbances. CBM operators can use the local terrain, noise reduction technology, and camouflage to minimize impacts for both noise and visual impairments.

As was discussed in the exploration section, the landscape of a lease surface can act to buffer neighboring communities from view-shed and noise impacts during drilling activities. In the same manner, local terrain can be used to buffer local communities from operation facilities. Low lying areas and hills can be used to camouflage roadways, CBM facilities, and wells minimizing view-shed disturbances and creating natural sound barriers. In the image to the right, a production well is located behind a rock outcrop protecting the viewshed and acting as a natural barrier to noise generated by well pumps. The image also illustrates how paint can be used to camouflage the facilities as the light brown color blends with the color of the grasses and rocks. For much of the year within the Study Area the grasses have a brown color; using neutral paint tones for buildings allows them to be blended into the viewshed. Other line of site conditions can be used to minimize visual impacts. Using low profile equipment and building structures can also minimize viewshed impacts. In some cases, traditional pump jacks may be used for CBM production; rotating the pump jack to a position where the line of site is not a profile view of the pump jack can minimize visual impacts.

CBM Production Well Hidden Behind a Rock Outcrop

In areas where natural barriers do not exist, noise from pumps and compressor stations can be reduced through the use of sound barrier technology. There are several sound reduction technologies, which can be applied to reduce noise impacts to local communities including, mufflers, barrier walls, and insulation. Barrier walls are frequently constructed in urban regions to reduce highway noise; similar technology could be applied to reduce noise from CBM facilities. The walls are designed to disrupt sound waves reducing the level of noise that communities on the other side experience.

Member of the Project Team Posing with Noise Reducing Insulation

Another option for operators is to use noise-reducing insulation in the construction of buildings that house compressors, gas transmission equipment, and pumps. This insulation is designed to allow sound to resonate within the walls of the facility until a desired level is reached. The result is a reduced sound level outside the facility walls that dissipates before reaching neighboring communities. The use of insulation to reduce noise levels from compressors and pumps is currently being used in other CBM producing regions including the San Juan Basin. The image to the left shows a cut away of the noise reducing insulation used in constructing the walls around a CBM compressor.

Mufflers can also be utilized to reduce the noise from compressor engines and pump motors. The maintenance of these motors would make certain that mufflers are operational and efforts are made to ensure that, when the mufflers do wear out, they are replaced in a timely manner.

Noise generated from CBM facilities can also be reduced through the identification of alternative methods that can be used to power compressors and pumps. Diesel and gas powered engines produce more noise than electric or hydraulic motors. Operators in other producing areas have identified alternatives to diesel and gasoline powered engines including using electric and hydraulic pumps to extract groundwater in CBM wells. These pumps operate at a much lower noise level than the pumps powered by diesel or gasoline engines.

Emissions

Landowners and citizen groups have expressed concern regarding the impacts that CBM development will have on the air quality in the Study Area. Operators who find methods to reduce air emissions from compressors and pump motors can alleviate this concern. Besides providing noise reduction, mufflers on diesel and gas engines reduce emissions to the atmosphere. The use of electric and hydraulic motors to operate pumps and compressors could also be used to reduce emissions. Another option is to use produced methane to power pumps since its combustion results in fewer emissions than diesel or gasoline.

Pumps

In addition to the reduction of noise and emissions there are several other considerations when selecting pumps including, depth of the reservoir, extraction rate and volume, view-shed, noise generation, and power supply. The discussion of impacts for viewshed, noise and power supply/emissions, and how these affect pump selection was discussed earlier in this section. The other two main considerations for pumps are the depth of the reservoir and the extraction rate and volume. There are numerous options for pumps to extract water from CBM wells including diesel and gasoline powered pumps, electrical pumps, progressive cavity pumps, hydraulic pumps, and traditional pump jacks. Site-specific conditions are going to determine which pump is best for CBM production.

ABANDONMENT AND RESTORATION OF CBM FACILITIES

LAND SURFACE RECLAMATION

CBM development and operation practices will result in a disturbance of existing vegetation and plant communities that could eventually lead to the loss of overall grazing/wildlife forage productivity, erosion, and introduction of noxious weeds as well as adverse impacts to native plant and animal populations. For this reason, proper re-vegetation of the disturbed area is an important component of the reclamation process. A successful restoration program is designed to identify and re-introduce impacted native species where necessary, to re-establish a local distribution, and to plant selected species that are determined to be valuable and successful in the area being restored. In general, the success of a re-introduction program is measured by how closely the revitalized area resembles, in both appearance and functionality, its original state. Operators are commonly asked by landowners and surface management agencies to stockpile approximately 6 inches of topsoil for use in reclamation of constructed sites. Many CBM wells are drilled on minimally constructed drill pads that result in little topsoil removal, but care must be taken to preserve topsoil where construction activities expose the subsoil.

In-Channel Impoundments near Prairie Dog Creek, Wyoming

The benefits associated with restoring vegetation to an area include visual enhancement of the area as well as the re-establishment of local wildlife habitat and the stabilization and recovery of damaged soils. Depending on landowner agreements, re-seeding strategies may also be implemented to provide valuable resources for livestock. In most situations, previously disturbed areas are re-seeded according to BLM or State stipulations until vegetation is considered satisfactory. Often the local Natural Resources Conservation Service office can provide recommendations for suitable seed mixtures known to be successful in the area. In those instances where the disturbed property was under cultivation, the operator is usually asked to defer planting to the landowner or surface lessee, who will re-plant a suitable crop of his choice.

A successful reclamation program must also consider necessary corrections to the general topography of the local landscape. Surface preparations prior to re-seeding, such as ripping, contour furrowing, terracing, reducing steep slopes, etc. can help lead to a reduction of erosion and unwanted water runoff, avoid the dewatering of jurisdictional wetlands, and allow for the restoration of suitable habitat for area wildlife. Generally, as part of the reclamation process, regulatory agencies require that the land surface be returned to original grade as nearly as practical. This can involve the removal or burial of any remaining surfacing material such as gravel or scoria, the backfilling and leveling of any pits, and the spreading of recovered or stockpiled topsoil. In some cases, soil amendments or the application of fertilizers may be required to adequately restore the site. In the arid West, planting of upland grasses is usually done only in fall or early spring; multiple plantings may be required if there is inadequate moisture available.

Common field practices observed by the research team included aggressive visual monitoring for noxious weeds from the start of exploration activities through the production phase, reclamation of disturbed soil after the drilling and construction phases of the project, and full restoration upon abandonment. The researchers also noted that the restoration is dependent upon landowner priorities. In some cases, landowners may choose to leave roads, impoundments, and other disturbed areas for alternative purposes that do not relate to CBM development or production but fit the needs of the landowner for future land use plans.

WELL PLUGGING

The plugging of dry holes and wells that are taken out of productive service is regulated by the Montana Board of Oil and Gas Conservation (MBOGC) and by lease stipulations established by the mineral lease owners, especially for state and federally owned mineral rights. The primary purpose for abandonment and plugging of a well is to return the disturbed area to a safe and stable condition while preventing the migration of fluids from one subsurface formation to another. This migration of fluids is of particular concern when shallow groundwater resources are at risk.

Typically, wells that are determined to be dry holes are plugged on location by placing cement through the open-ended drill pipe. Successful plugging is usually accomplished by placement of cement plugs below the base of the surface casing and above the surface casing. Depending on lease stipulations, the casing can remain in place and is cutoff below ground level and marked with a dry hole marker.

Depending on mineral rights ownership of wells to be abandoned, additional plugging stipulations may be required prior to abandonment. Stipulations such as BLM's requirement for approval prior to well reclamation activities as described in the "Sundry Notices and Reports on Wells" is one example of additional requirements from lease stipulations. The sundry notice serves as an operator's Notice of Intention of Abandonment (NIA). In some cases, especially in older wells that have been produced for some time before being plugged and abandoned, BLM may require a reclamation plan to accompany the NIA. A representative of BLM may also be present on-site during the reclamation process to assure that bureau stipulations are satisfied and to act as a professional witness. Wells on State owned minerals rights and fee lands are required to be plugged and abandoned in accordance with regulations as set by the MBOGC or MDNR.

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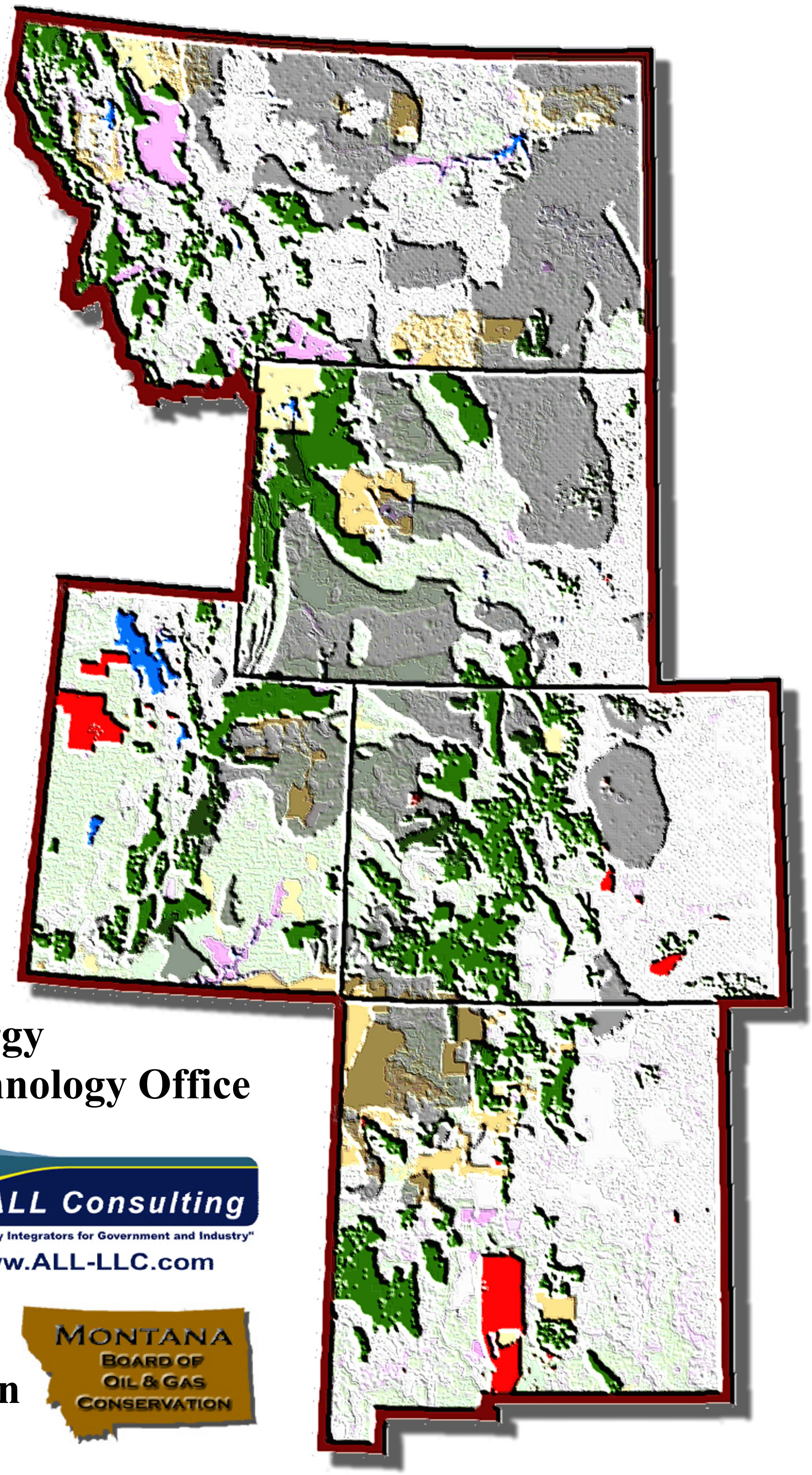
COAL BED METHANE PRIMER

New Source of Natural Gas–Environmental Implications

Background and Development in the Rocky Mountain West



February 2004

Prepared for:
U.S. Department of Energy
National Petroleum Technology Office

Prepared by:
ALL Consulting

"Technology Integrators for Government and Industry"
www.ALL-LLC.com

Montana Board of Oil and Gas Conservation

ACKNOWLEDGEMENTS

This project was funded by a U.S. Department of Energy (DOE) office of Fossil Energy Grant under the National Energy Technology Laboratory (NETL) program "*Development of Technologies and Capabilities for Developing Coal, Oil, and Gas Energy Resources*". The project was developed under the *Oil and Gas Environmental: Upstream* Area-of-Interest. This study was conducted by ALL Consulting (ALL), and the Montana Board of Oil and Gas Conservation (MBOGC). The contractor's effort was overseen by NETL's, National Petroleum Technology Office located in Tulsa Oklahoma. The National Petroleum Technology Office project manager for this effort was Mr. John Ford. The Department also wishes to extends its appreciation to those companies operating in the Powder River, San Juan, Raton and Unita basins, and staff of the Department of the Interior, Environmental Protection Agency, and the Colorado, New Mexico, Montana, Utah and Wyoming State agencies who provided the technical input and assistance that enable DOE to improve the scope and quality of the analysis. We also wish to thank Ms. Viola Schatzinger for her detailed editorial review, comments, and suggestions on this document.

DE-FG26-02NT15380

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ACRONYMS AND ABBREVIATIONS

ACEC	Area of Critical Environmental Concern
APD	Application for Permit to Drill
ARM	Administrative Rules of Montana
BACT	Best Available Control Technology
BCF	billion cubic feet
bgs	below ground surface
BIA	Bureau of Indian Affairs
BLM	U.S. Bureau of Land Management
BMP	Best Management Practice
BTU	British thermal unit
CAA	Clean Air Act
CBM	coal bed methane
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CFS	cubic feet per second
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
COA	Condition of Approval
CWA	Clean Water Act
DEIS	Draft Environmental Impact Statement
DOE	U.S. Department of Energy
EA	Environmental Assessment
EIS	Environmental Impact Statement
EO	Executive Order
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FEIS	Final Environmental Impact Statement
FERC	Federal Energy Regulatory Commission
FLM	Federal land managers
FLPMA	Federal Land Policy and Management Act
FR	Federal Register
FWS	Fish and Wildlife Service (USDI)
gpm	gallons per minute
MBOGC	Montana Board of Oil & Gas Conservation
MCA	Montana Code Annotated
MCF	thousand cubic feet
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act

ACRONYMS AND ABBREVIATIONS
(CONTINUED)

NO_2	nitrogen dioxide
NO_X	oxides of nitrogen
NOA	Notice of Availability
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service (USDI)
NRHP	National Register of Historic Places
NSO	no surface occupancy
POD	Plan of Development
RCRA	Resource Conservation and Recovery Act of 1976
RFFA	Reasonably Foreseeable Future Actions
RFD	Reasonably Foreseeable Development
RMP	Resource Management Plan
ROD	Record of Decision
ROW	right-of-way
SAR	Sodium Adsorption Ratio
SHPO	State Historic Preservation Office
SN	Sundary Notice
SO_2	sulfer dioxide
T&E	Threatened and Endangered
TCF	trillion cubic feet
TDS	total dissolved solids
UIC	underground injection control
U.S.	United States
U.S.C.	United States Code
USDI	U.S. Department of the Interior
USFS	U.S. Forest Service (USDA)
VRM	visual resource management
WMP	Water Management Plan
WQS	water quality standards
WSA	Wilderness Study Area

ATTACHMENTS

COAL BED METHANE PRIMER

New Source of Natural Gas - Environmental Implications

INTRODUCTION

During the second half of the 1990s Coal Bed Methane (CBM) production increased dramatically to represent a significant new source of natural gas for many Western states. Matching these soaring production rates during this period was a heightened public awareness of environmental concerns. These concerns have created a significant growth in public involvement, which has generated thousands of comments resulting in the inconsistent prioritization of concerns and resources protection efforts. The accelerating interest in CBM development coupled with growth in public involvement has prompted the creation of this CBM Primer.

> *"America must have an energy policy that plans for the future, but meets the needs of today.*
> *I believe we can develop our natural resources and protect our environment."*
>
> *-President George W. Bush*

The Primer is designed to serve as a summary document, which introduces and encapsulates information pertinent to the development of CBM. The discussions focus on coal deposits, methane as a naturally formed gas, split mineral ownership, development techniques, operational issues, producing methods, applicable regulatory frameworks, land and resource management, mitigation measures, preparation of project plans, data availability, Indian Trust issues and relevant environmental technologies.

An important aspect of this CBM Primer involves the sharing of information with a broad array of stakeholders, including land and mineral owners, regulators, conservationists, tribal governments, special interest groups, and numerous others that could be affected by the development of CBM within their vicinity. Perhaps the most crucial aspect of successfully developing CBM resources and instituting appropriate environmental protection measures is public awareness, information sharing, and acceptance.

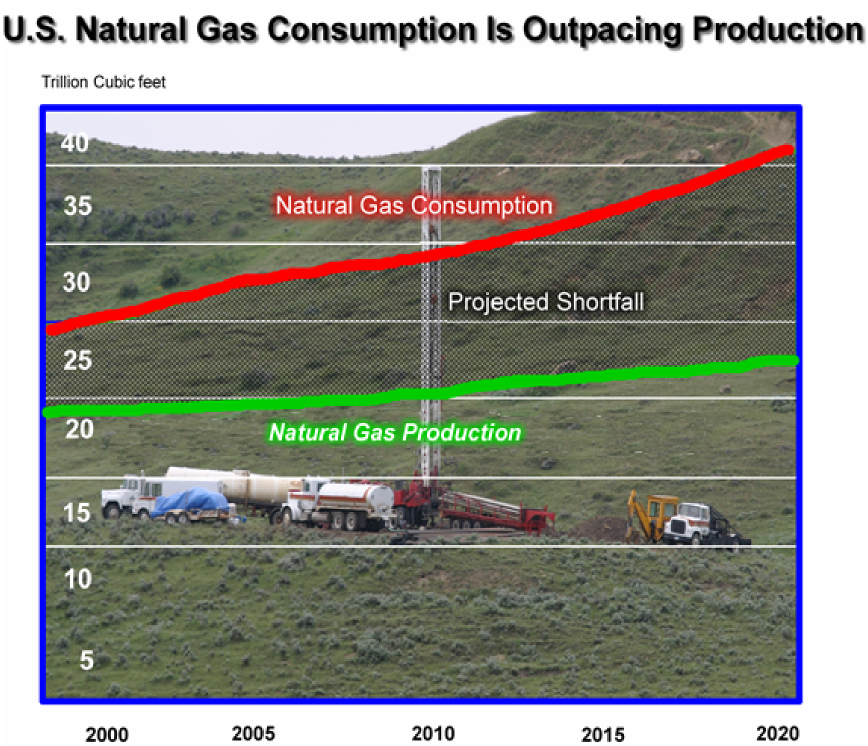
The current image of CBM that exists is dependent on the stakeholders' perspective of energy development versus environmental protection. There is significant diversity in the view points expressed by nearly all stakeholders, including industry, government, special interest groups, and land owners. The primer is designed to serve as an accessory to public discussions that will contribute to policy making decisions by examining the current CBM development practices throughout the Western U.S. and by discussing mitigation measures and more environmentally friendly development methods from various CBM areas.

The Primer sections focus on the following areas:

Section 1 – What is CBM? How is it formed? Where does it come from? How is it developed? This section provides the backdrop and circumstances for outlining the issues encompassing CBM formation and production, including coal seams and how they originate; the general location of CBM basins in the United States; the various development techniques, operational issues and production methods used based on regional conditions; and the position CBM serves in meeting our current and future national energy requirements.

Section 2 – Regulatory framework. This section addresses federal, state and local regulations governing the development of CBM across the west; analyzes existing regulations guiding CBM development, including regionally specific Plan of Development variances; identifies federal land and resource management practices, Indian Trust Issues, surface owner agreements and local land uses per region; and the state oil and gas programs including typical lease stipulations and field rules.

Section 3 – Best Management Practices and Mitigation. Section three identifies the typical environmental effects associated with CBM development in the west and the mitigation measures employed to address these effects. Focus is on the results of production and distribution affecting natural resources to local populations, and the tension between opposing land uses and land users. Vital to this discussion are the potential effects of CBM extraction on water quality and quantity, and the numerous mitigation measures employed to control and eliminate these effects.



Over the next 20 years, U.S. natural gas consumption will grow by 50 percent. At the same time, U.S. natural gas production will grow by only 14 percent, if it grows at the same rate of the last 10 years.

Coal bed methane is a clean-burning energy source well suited as a fuel for production of electricity, residential and commercial heating, and as a vehicle fuel. CBM currently supplies approximately eight percent of the nation's natural gas production, and is an important facet of the nation's energy mix. United States CBM production grew by 13 percent in 2001 to 1.562 Trillion cubic feet (Tcf). (EIA 2001). CBM will become more important as the demand for natural gas increases, and the focus on domestic production is heightened due to the deregulation of electricity and the tension over international energy supplies. As illustrated in the figure on the left, natural gas consumption is outpacing production. However, CBM production has the potential to significantly reduce this gap, if development can continue to increase at the rates observed between 1998 and 2001.

The extraordinarily dramatic growth of CBM development has created comprehensive challenges for communities

Agricultural irrigation in Wyoming

throughout the Rocky Mountain region. The development of CBM infrastructure including construction of utility right-of-ways, pipelines, new roads, compressor stations, water conveyance and storage systems, and other facilities have affected rural communities.

Another issue responsible for many disputes is split estates - land owners who hold only surface rights may have government agencies such as the BLM or State Trust Land departments leasing the subsurface mineral rights to one or many development companies. CBM development plans can be opposed by many farmers, ranchers, hunting and fishing outfitters, environmentalists, recreational users, homeowners, and others who use the land for their specific purposes. Increases in exhaust gases and noise levels have also created strife between residents and the CBM industry.

Beyond the land use disputes and affecting nearly all Rocky Mountain citizens are the concerns associated with produced water from CBM development. CBM produced water has the potential to affect groundwater quantity and quality. Coal seam aquifers may have competing water rights and be diminished as CBM production increases. Surface water quality could be altered by mineral-laden discharge, and agricultural productivity of soils could be reduced by irrigating with altered surface water. Riparian ecosystems may be negatively affected by the release of large quantities of produced water. Some produced water, on the other hand, has the potential to be a prized source of fresh water in many arid regions.

The development of CBM throughout the Rocky Mountain Region is a major issue facing citizens, special interest groups, federal land management agencies, state governments, Tribal governments, county commissions, and energy companies. The major challenge is obtaining a balance between the development of this important resource and environmental protection while maintaining the local culture. This can be done by sharing the responsibilities for governing the development by federal, state, Tribal and local governments. These governments have varying and often competing interests and responsibilities for regulating CBM production. The coordination between these agencies will be essential to the balance and will ultimately influence the pace of development.

It is envisioned the Primer will be used by a variety of stakeholders to present a consistent and complete synopsis of the key issues involved with CBM. This primer is intended to add focus to the public discussion and policy making for CBM development by offering a comprehensive, user-friendly overview that clarifies what CBM is and how it is produced, analyzes and evaluates the knowledge gained from various CBM developments throughout the Rocky Mountains, provides options for addressing conflicts, and improves policies that regulate CBM development. This primer also recognizes lessons-learned from different basins and various environmental groups and producers that could resolve similar challenges posed by development in other areas.

WHAT IS CBM?

How is it formed, where does it come from, and how is it developed?

CBM - THE BASICS

Coal Bed Methane (CBM) is an important facet of the nation's energy mix. While currently supplying approximately eight percent of the nation's natural gas, CBM is expected to increase in importance (EIA 2001). Natural gas is a clean-burning energy source well suited as a boiler fuel, vehicle fuel, and for heating residences as well as large structures. CBM is a non-conventional hydrocarbon resource that fundamentally differs in its accumulation processes and production technology when compared to conventional natural gas resources. The following paragraphs detail the formation of coal and CBM.

Coal Formation

Coal is a sedimentary rock that had its origin on the surface of the earth as an accumulation of inorganic and organic debris. Major coal basins across the United States are depicted in Figure 1 below. Coal is predominantly made up of organic plant material, in particular ancient wood, leaves, stems, twigs, seeds, spores, pollen, and other parts of aquatic and land plants. When the debris first begins to pile up it is termed peat; the earth's crust subsides, and more sediments are piled on top of the organic material, causing it to sink ever deeper into the sedimentary layer.

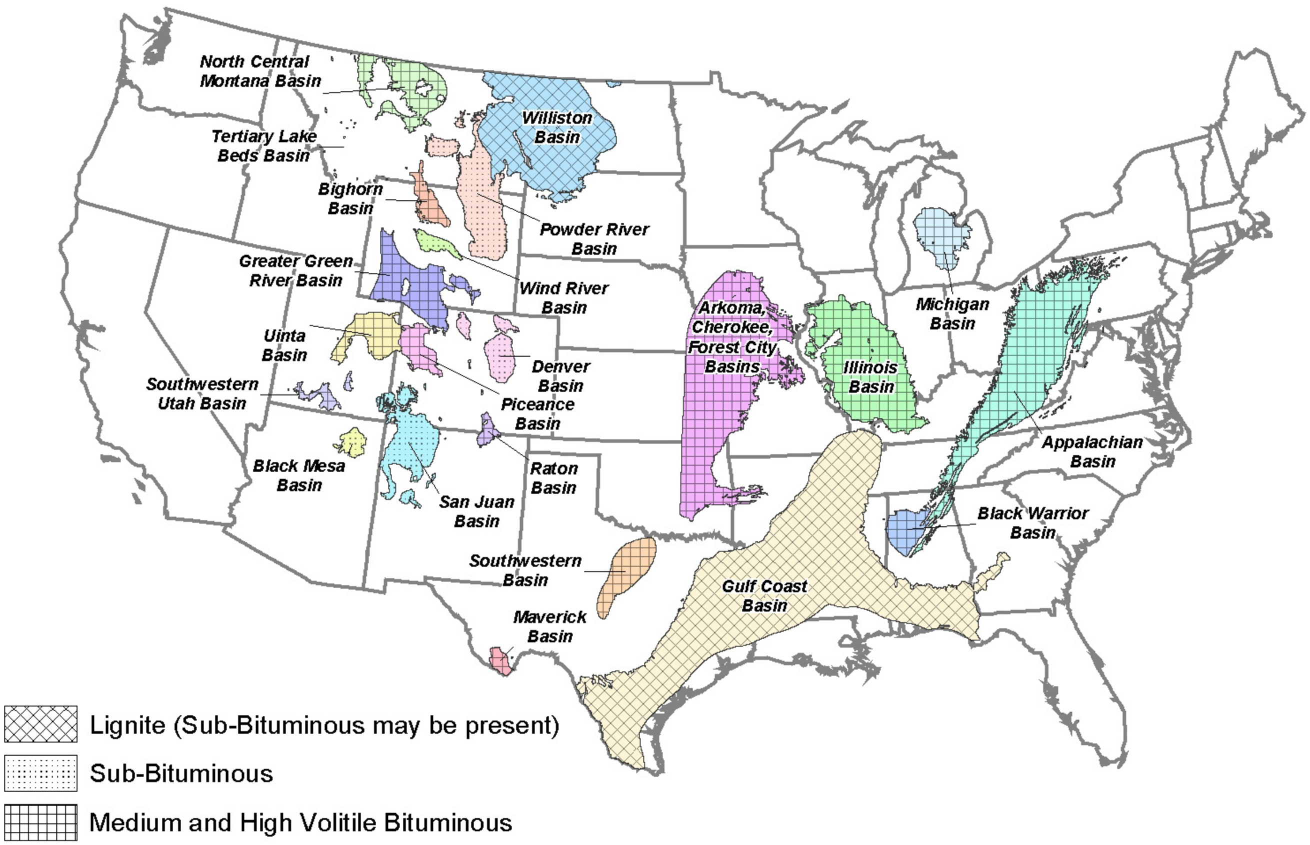


Figure 1
Major Coal Basins within the Contiguous United States by Coal Rank

Layers of peat may be separated by clay and sand deposited during times of flood or other breaks in the accumulation cycle. As the peat accumulates, organic processes begin to break the plant debris down, both physically and chemically.

Physically, small insects, worms, and fungi break the fragments into smaller pieces. As the peat solidifies, the small fragments formed are termed macerals, and can be identified microscopically as coming from plant products. At the same time, the peat is squeezed by overlying material, driving out its water content and compacting the plant debris into rock.

Chemically, the plant material is slowly converted into simpler organic compounds ever richer in carbon. These combined processes are called sedimentation, and are illustrated in Figure 2. After sedimentation, the peat is buried deeper while pressure and heat build up. It is the heat and pressure that slowly transforms the peat into coal through the process of maturation. To generate one foot of coal it took approximately five feet of raw organic material.

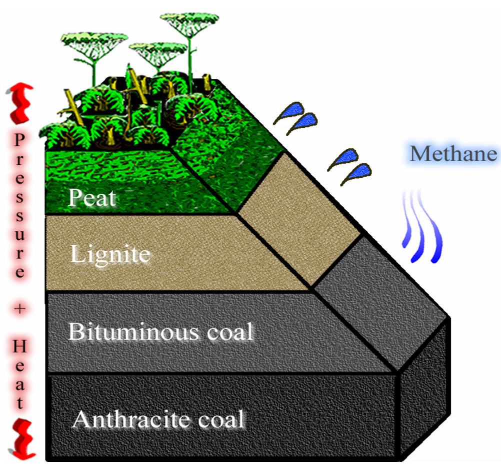


Figure 2
Sedimentation and the formation of coal

Coals are deposited over a narrow range of sedimentary environments, such as swamps or bogs. In all cases the fresh, organic plant material needs to be buried quickly and protected from oxidation. In order for the organic matter to be preserved, the plant debris must accumulate in a local area of restricted oxygen supply.

Coal Classification

There are two main recognized ways to classify coal – by rank or by grade. Coal rank is a measure of the degree of coalification or heat content and coal grade is a measure of the coal purity. For the purposes of the Primer, Rank will be used to describe coal and it's relationship to methane production.

Rank

The degree of coalification or metamorphosis undergone by a coal, as it matures from peat to anthracite, has a significant bearing on its physical and chemical characteristics, and is referred to as the 'rank' of the coal. The major ranks of coal from lowest to highest are lignite, sub-bituminous, bituminous, semi-anthracite and anthracite. The higher the coal rank the higher the temperature and pressure of coal formation. The higher coal ranks have a greater percent of carbon. As moisture and volatiles are driven off during coal maturation carbon is left behind. With an increase in carbon content there is also an increase in the heat content of the coal.

The earth's crust exhibits an average geothermal gradient of about 1.5° F for every 100 feet of burial depth. As coal seams are depressed ever-deeper into the earth under accumulating sediments, much of the water and volatile matter are driven away, leaving behind the fixed carbon as well as residual amounts of ash, sulfur, and tiny amounts of a few assorted trace elements. The extent of this *de-volatilization* varies according to the deepest depth of ultimate burial, resulting in a continuous series of coal grades according to the relative percentages of fixed carbon they contain.

Lignite is the lowest rank of coal and is characterized as browner and softer. Lignites have a high oxygen content (up to 30 percent), a relatively low fixed carbon content (20-35 percent), and a high moisture content (30-70 percent) (WCI). Lignite is found in great quantities in the United States in the Gulf Coast Basin and the Williston Basin. Lignite is not particularly efficient in producing energy per mass of fuel. These coals are also susceptible to spontaneous combustion.

Sub-bituminous coals usually appear dull black and waxy. Sub-bituminous coals have a fixed carbon content between 35 to 45 percent and a moisture content of up to 10 percent. These coals are frequently used for electrical generation and are found

throughout the west in the Black Mesa, Bighorn, Denver, Greater Green River, North Central Montana, Powder River, San Juan and Wind River basins (WCI).

Bituminous coals are dense black solids, frequently containing bands with brilliant colors. The carbon content of these coals ranges from 45 to 80 percent and the water content from 1.5 to 7 percent (WCI). Major deposits of bituminous coals are found in the central United States in the Appalachian, Arkoma, Black Warrior, Cherokee, Forest City, Illinois, Maverick, Michigan, Raton and Southwestern basins. The coals are well suited for the production of metallurgical coke, power generation, cement making, and to provide heat and steam in industry.

Because of their higher fixed carbon content and lower moisture content, bituminous coals contain more energy per pound than sub-bituminous coals, which in turn contain more energy than lignite coal. In the U.S., this heat energy is typically expressed as BTU's (British Thermal Units) per pound. A typical pound of bituminous coal will yield about 10,500 to 12,000 BTU's of energy. Figure 3 illustrates the composition changes associated with coal rank.

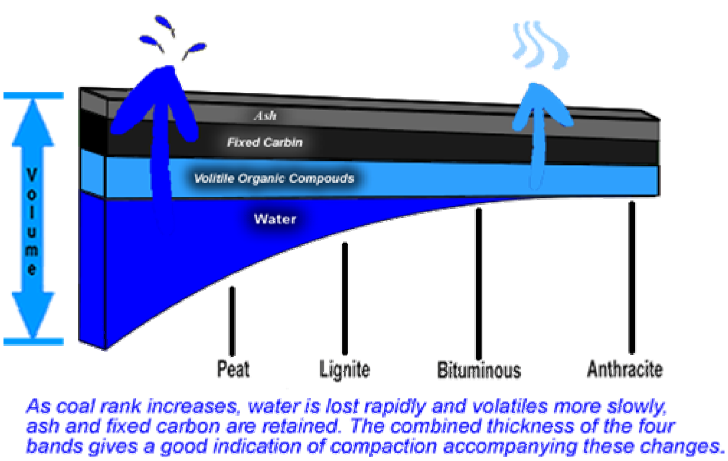


Figure 3
Composition Changes with Coal Rank

ALL Consulting

Anthracite is dense, hard and shiny and defined as having more than 86% fixed carbon and less than 14% volatile matter on a dry, mineral-matter-free basis. The rank is divided into semi-anthracite, anthracite, and meta-anthracite groups on the basis of increasing fixed carbon and decreasing volatile matter. Anthracite coals are relatively uncommon representing less than 1% of all world coal reserves. The high carbon and energy content coupled with being a relatively hard material and clean burning makes anthracite a desired product. The value-added anthracite products are used in carbon filtration water purification and space heating. Anthracite is also used as a reductant in metallurgical processing, pulverized coal injection for steel making, in cooking and heating briquettes, and as fuel used in the manufacture of cement and generation of electricity.

WHAT IS CBM?

Coal Bed Methane is naturally occurring methane (CH_4) with small amounts of other hydrocarbon and non-hydrocarbon gases contained in coal seams as a result of chemical and physical processes. It is often produced at shallow depths through a bore-hole that allows gas and large volumes of water with variable quality to be produced. Shallow aquifers, if present, need to be protected but in the Rocky Mountain Region, the producing coal bed is often a source of water for both livestock and human consumption. CBM resources represent valuable volumes of natural gas within and outside of areas of conventional oil & gas production. Many coal mining areas currently support CBM production; other areas containing coal resources are expected to produce significant volumes of natural gas in the near future.

CBM is intimately associated with coal seams that represent both the source and reservoir. Significant reserves of coal underlie approximately 13% of the U.S. landmass as shown in Figure 1. Coals have an immense amount of surface area and can hold enormous quantities of methane. Since coal seams have large internal surfaces, they can store on the order of six to seven times more gas than the equivalent volume of rock in a conventional gas reservoir (USGS 1997). CBM exists in the coal in three basic states: as free gas; as gas dissolved in the water in coal; and as gas "adsorped" on the solid surface of the coal.

Coal varies considerably in terms of its chemical composition, its permeability, and other characteristics. Some kinds of organic matter are more suited to produce CBM than are others. Permeability is a key characteristic, since the coal seam must allow the gas to move once the water pressure is reduced.

Gas molecules adhere to the surface of the coal. Most of the CBM is stored within the molecular structure of the coal; some is stored in the fractures or cleats of the coal or dissolved in the water trapped in the fractures. Methane attaches to the surface areas of coal and throughout fractures, and is held in place by water pressure as shown in Figure 4. When the water is released, the gas flows through the fractures into a well bore or migrates to the surface.

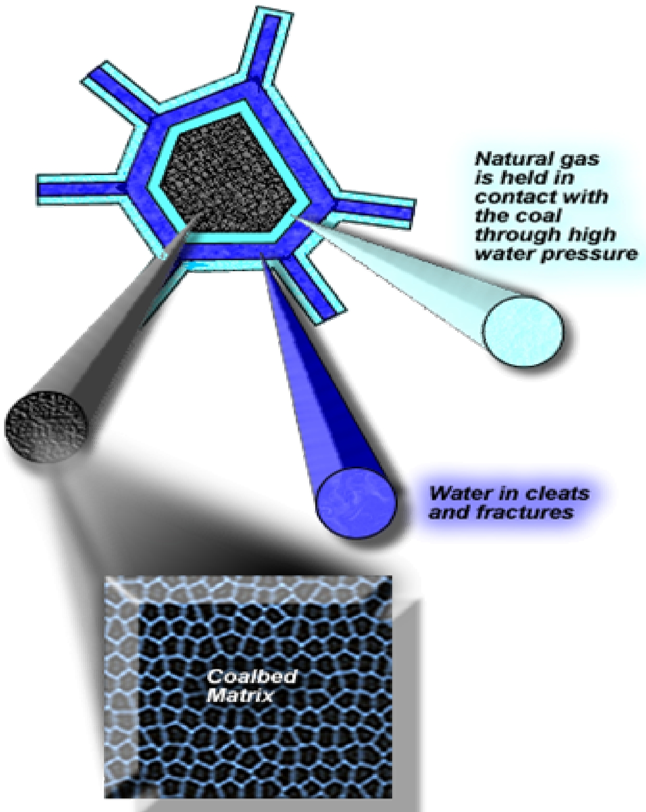


Figure 4
Coal Bed Matrix illustrating gas surrounding the coal bound by water and rock

Coals can generally generate more gas than they can absorb and store. Basins that contain between 500 to 600 standard cubic feet (SCF) of methane per ton are considered to be "very favorable for commercial production," as long as there is sufficient reservoir permeability and rate of desorption (Murry, 1993). Desorption is the process by which coals frees methane when the hydrostatic pressure is reduced. Some coals have generated more than 8,000 SCF of methane per ton of coal. The most productive coals are saturated with gas, fractured and highly permeable (Cook NRLC, 2002).

Worldwide, coal is present in most sedimentary basins that are Devonian to Tertiary in age. Coal deposits in the Eastern and Central U.S. are Paleozoic in age (Mississippian and Pennsylvanian) and in the Western U.S. and Gulf Coast the coals are younger (Cretaceous and Tertiary) in age. This diversity of age has given rise to two different types of CBM basins. The eastern hard coals are higher rank and thinner. They contain less water within the coal seam and require fracture enhancement to increase the productivity. The water contained within the coals is typically low quality, which does not lend itself to many beneficial uses. The western soft coals are lower in rank but very thick. These coals contain vast amounts of water that requires removal to initiate production. The produced water is typically high to medium quality water that lends itself to many beneficial uses. Table 1 provides a summary of the coal reserves across the U.S.

Table 1
Coal Reserves by State

State	Tons (billions)	Percent of U.S.
Montana	120	25.4
Illinois	78	16.5
Wyoming	68	14.4
West Virginia	37	8.0
Kentucky	30	6.3
Pennsylvania	29	6.1
Ohio	19	4.0
Colorado	17	3.6
Texas	13	2.7
Indiana	10	2.1
Other States	51	10.9
Total Coal Reserves	472	100.0

Source: *COAL: Ancient Gift Serving Modern Man*; American Coal Foundation, 2002

Where Does CBM Come from?

CBM is generated either through chemical reactions or bacterial action. Chemical action occurs over time as heat and pressure are applied to coal in a sedimentary basin. This is referred to as thermogenic production. Bacteria that obtain nutrition from coal produce methane as a by-product in a method referred to as biogenic. The gas in higher rank coals is a result of thermogenic production as heat and pressure transform organic material in the coal. Gas in lower rank coals results from the decomposition of organic matter by bacteria.

Typically, the deeper the coal bed, the less the volume of water in the fractures, but the more saline the water becomes. The volume of gas typically increases; with coal rank, how far underground the coal bed is located, and the reservoir pressure (USGS 2000). Natural desorption occurs when the fracture system releases water, the adsorptive capacity of the coal is exceeded, pressure falls, and the gas trapped in the coal matrix begins to desorb and move to the empty spaces in the fracture system. The gas remains stored in the fracture system or in nearby non-coal reservoirs until it is extracted.

As coals mature from peat to anthracite, the associated fluids transform as well. Low rank peat and lignite have high porosities, high water content, and produce low temperature biogenic methane and few other fluids. As coals mature into bituminous types, water is expelled, porosity decreases, and biogenic methane formation decreases, because temperatures rise above the most favorable range for bacteria. At the same time, heat breaks down complex organic compounds to release methane and heavier hydrocarbons (ethane and higher). Inorganic gases may also be generated by the thermal breakdown of coals.

As the coal matures to anthracite, less methane is generated and little porosity or water remains in the matrix. The chart below (Figure 5) lists the steps in the maturation of coal from peat to anthracite and the fluid generated and expelled during the maturation process. Peat, largely unaltered plant debris, and lignite ("brown coal") can give rise to biogenic methane, produced by methanogenic bacteria. Minor production of CBM has been reported from lignite in North Dakota and Louisiana. CBM production in most of the Western U.S. comes from sub-bituminous and bituminous coals. CBM in the Eastern U.S. originates in higher rank coals.

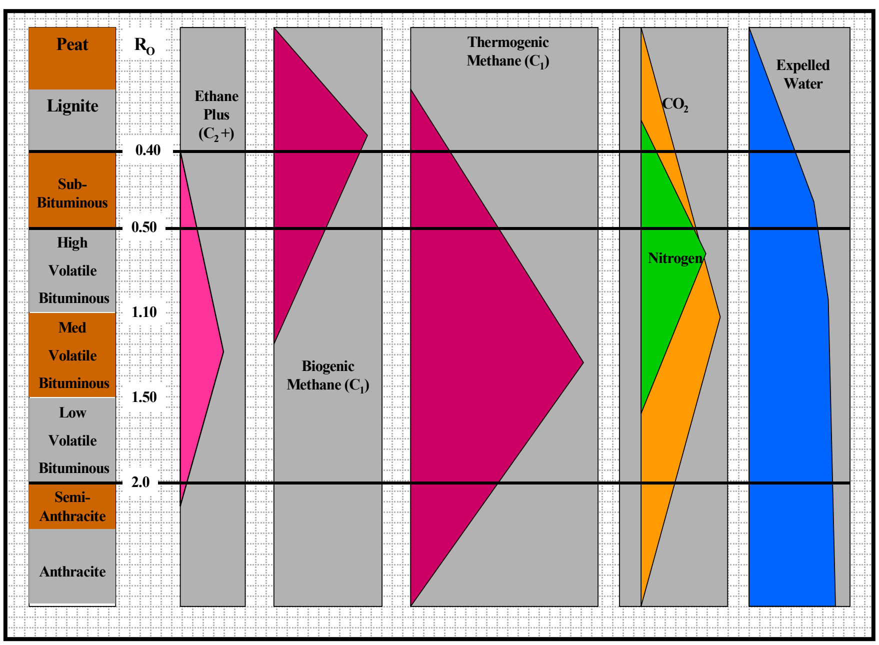


Figure 5
Coal Maturation Chart

What Controls CBM Production?

CBM production potential is a product of several factors that vary from basin to basin – fracture permeability, development, gas migration, coal maturation, coal distribution, geologic structure, CBM completion options, hydrostatic pressure and produced water management. In most areas, naturally developed fracture networks are the most sought after areas for CBM development. Areas where geologic structures and localized faulting have occurred tend to induce natural fracturing, which increases the production pathways within the coal seam. This natural fracturing reduces the cost of bringing the producing wells on line.

Most coals contain methane, but it cannot be economically produced without open fractures present to provide the pathways for the desorbed gas to migrate to the well. As long as the pressure exerted by the water table is greater than that of the coal the methane remains trapped in the coal bed matrix. Coal cleats and fractures are usually saturated with water, and therefore the hydrostatic pressure in the coal seam must be lowered before the gas will migrate.

Lowering the hydrostatic pressure in the coal seam accelerates the desorption process. CBM wells initially produce water primarily; gas production eventually increases, and as it does water production declines. Some wells do not produce any water and begin producing gas immediately, depending on the nature of the fracture system. Once the gas is released, it is usually free of any impurities; is of sufficient quality and can be easily prepared for pipeline delivery.

Some coals may never produce methane if the hydrostatic pressure cannot be efficiently lowered. Some coal seams may produce gas, but are too deep to economically drill. CBM wells are typically no more than 5000' in depth, although some deeper wells have been drilled. Figure 6 illustrates the relationship between hydrostatic pressure, coal seam depth and well location.

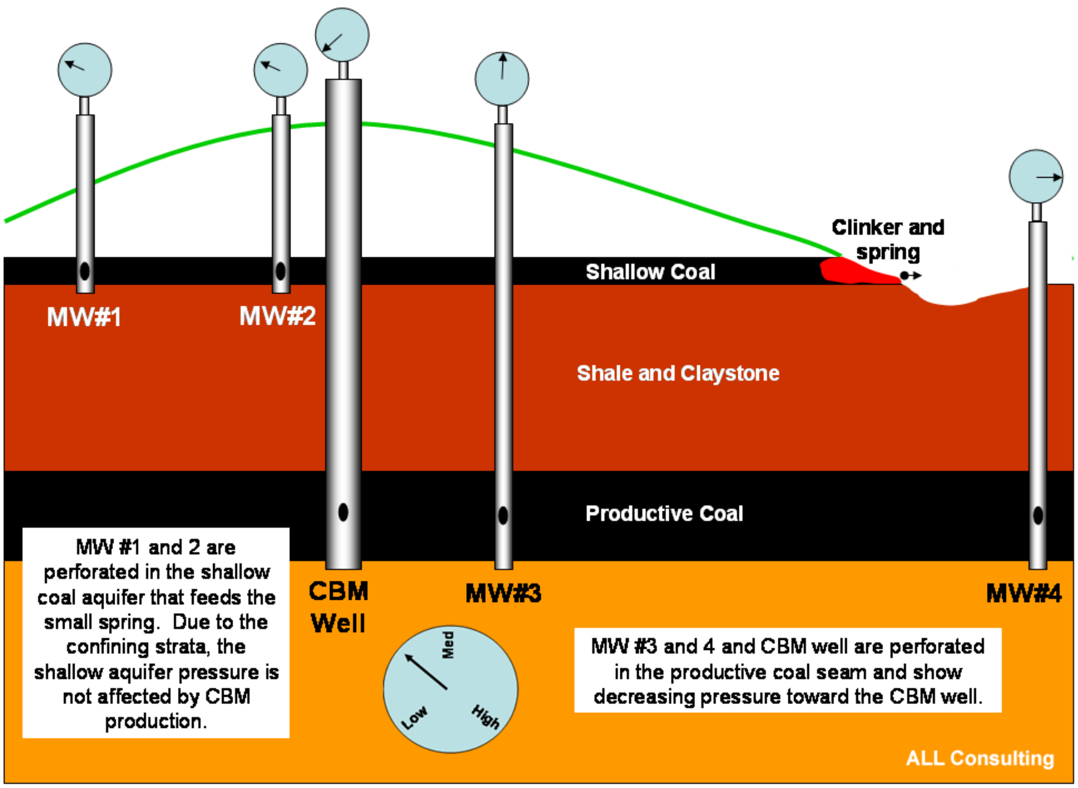


Figure 6
CBM Production Relationship to Hydrostatic Pressure

Cleat (Fracture) Development

Coal contains porosity but very little matrix permeability. In order for fluids to be produced out of coal seams into a well-bore, the coal must possess a system of secondary permeability such as fractures. Fractures allow water, and natural gas to migrate from matrix porosity toward the producing well. Cleat is the term used for the network of natural fractures that form in coal seams as part of the maturation of coal. Cleats form as the result of coal dehydration, local and regional stresses, and unloading of overburden. Cleats largely control the directional permeability of coals and therefore are highly important for CBM exploitation through well placement and spacing.

Two orthogonal sets of cleats develop in coals perpendicular to bedding. The face cleats are the dominant set that are more continuous and more laterally extensive; face cleats form parallel to maximum compressive stress and perpendicular to fold axes of the coal bed. The butt cleats are secondary and can be seen to terminate against face cleats. Butt cleats are strain-release fractures that form parallel to fold axes. Figure 7 shows the cleat orientation.

Cleat spacing is related to rank, bed thickness, maceral composition, and ash content. Coals with well-developed cleat sets are brittle reflecting fracture density. In general, cleats are more tightly spaced with increasing coal rank. Average cleat spacing values for three coal grades include: sub-bituminous (2-15 cm), high-volatile bituminous (0.3-2 cm), and medium-to low-volatile bituminous (<1 cm) (Cardott, 2001). Cleat spacing is tighter in thin coals, in vitrinite-rich coals, and in low-ash coals.

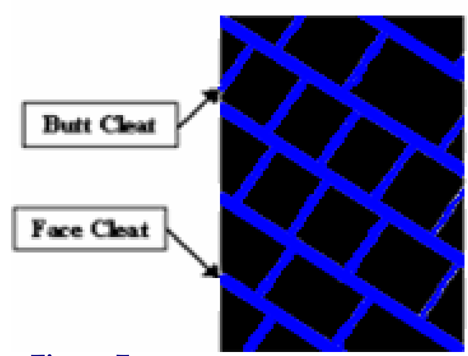


Figure 7
Coal Cleat Orientation

Natural Gas Migration

In coal seams, most gas is absorbed by the microscopic laminations and micropores within coal macerals. As hydrostatic pressure is decreased by water production, gas desorbs and moves into the cleat system where it begins to flow towards the producing well, as diagrammed in Figure 8.

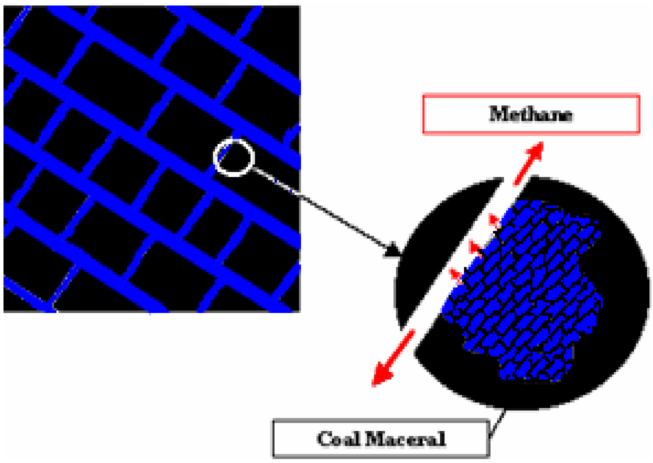


Figure 8
Methane Migration Pathways

Natural gas can also migrate through more wide-spread fracture sets related to faults and tectonic jointing. Faults can persist over several miles and are related to geologic movement and structure, and can enhance the migration pathways for the methane in the subsurface.

Coals can be analyzed for adsorbed gas content using standardized techniques that mechanically pulverize the core samples. The gas content figures range from several hundred standard cubic feet (scf) per ton to less than 50 scf per ton of coal. The test results cannot be directly equated with ultimate recoverable CBM reserves since not all the gas can be desorbed and produced from the coal. Methane content values in producing basins range from around 800 scf per ton in Oklahoma, to 450 scf per ton in the San Juan Basin, and to an average of 40 scf per ton in the Powder River Basin.

CBM Background

CBM development has its roots in the coal mining industry. Attempts to develop marketable CBM began in the United States in the 1970s, as a result of the U.S. Bureau of Mines' efforts to improve mine safety by extracting methane in advance of mining operations. As recently as 1982, CBM production in the United States was practically non-existent. In 1983, the Gas Research Institute commenced field investigations that motivated the expansion of CBM recovery. At the end of 1983, annual CBM production was nearly 6 Bcf (billion cubic feet) from about 165 wells. By 1994, it had grown to 85.1 Bcf from more than 6,000 wells, and by 1999, there were 14,000 wells producing roughly 1,252 Bcf.

In 1980, Congress enacted a tax credit to promote domestic production from alternative sources, including CBM. Known as the Section 29 tax credit (section 29 of the 1980 Crude Oil Windfall Profit Tax Act), the requirement has two limits: the gas needs to be sold to an unconnected group, and the tax credit can only be applied to wells brought on line before Dec 31, 1992. The credit, valued at $3 barrel of oil or Btu equivalent, ended on December 31, 2000, however the tax credit was modified and extended in both the House and Senate energy bills that the two chambers passed in 2001 and 2002, respectively. The greatest increase in development, however, didn't begin until approximately 1988. This was due to the 1980 tax incentives being put in place by the Congress coupled with improved production techniques.

Currently, there are thousands of CBM wells in the United States, and active exploration, development, and/or production is being carried out in Alabama, Alaska, Arkansas, Arizona, Colorado, Illinois, Indiana, Kansas, Kentucky, Louisiana, Montana, Nebraska, New York, North Dakota, Oklahoma, Pennsylvania, Texas, Utah, Virginia, Washington, West Virginia and Wyoming. To date almost 88 percent of the United States total CBM production is from the Rocky Mountain region encompassing Colorado, Montana, New Mexico, Utah and Wyoming (EIA 2001)

The San Juan Basin in Northern New Mexico and Southern Colorado has contributed the most to CBM production and is the most extensively developed basin in the region. Exploration and development began in the late 1980s and quickly grew throughout the 1990s. Production is nearing its peak in the basin, but companies are trying to maintain recovery with new production enhancement methods and reduced well spacing.

The Powder River Basin in eastern Wyoming and southeastern Montana is currently the fastest growing basin for CBM development. In 1997 there were 360 wells producing 54 million cubic feet (MMcf) of gas/day, by the end of 2002, 935 MMcf/day was being produced from 10,991 wells. During the past 12 months an additional 5400 Applications for Permit to Drill (APDs) have been submitted (http://wdogcc.state.wy.us April 2003). Significant CBM resources in the Rocky Mountains have also been identified in the Raton Basin in central Colorado, the Piceance Basin in northwestern Colorado, the Unita Basin in Eastern Utah, Kaiparowits Plateau Basin in Southern Utah, Hanna-Carbon Basin in south-central Wyoming and the Greater Green River Basin in southwestern Wyoming.

It has been estimated that the Rocky Mountain basins contain as much as 595 Trillion cubic feet (Tcf) of CBM, (GTI 2000). The technically recoverable amount may currently be less than one quarter of that volume, but with improved methods and enhanced recovery techniques CBM in the Rocky Mountains will remain an important source of natural gas.

CBM production continues to advance across North America as operators develop new techniques for drilling and producing coal seams of different rank and quality. It is anticipated that production will only increase as the demand for natural gas continues to increase.

How is CBM Produced?

CBM wells are completed in several ways, depending upon the type of coal in the basin and fluid content. Each type of coal (sub-bituminous to bituminous) offers production options that are different due to the inherent natural fracturing and competency of the coal seams. The sub-bituminous coals are softer and less competent than the higher rank low-volatile bituminous coals, and therefore are typically completed and produced using more conventional vertical well bores. The more competent higher rank coals lend themselves to completions using horizontal as well as vertical well bores.

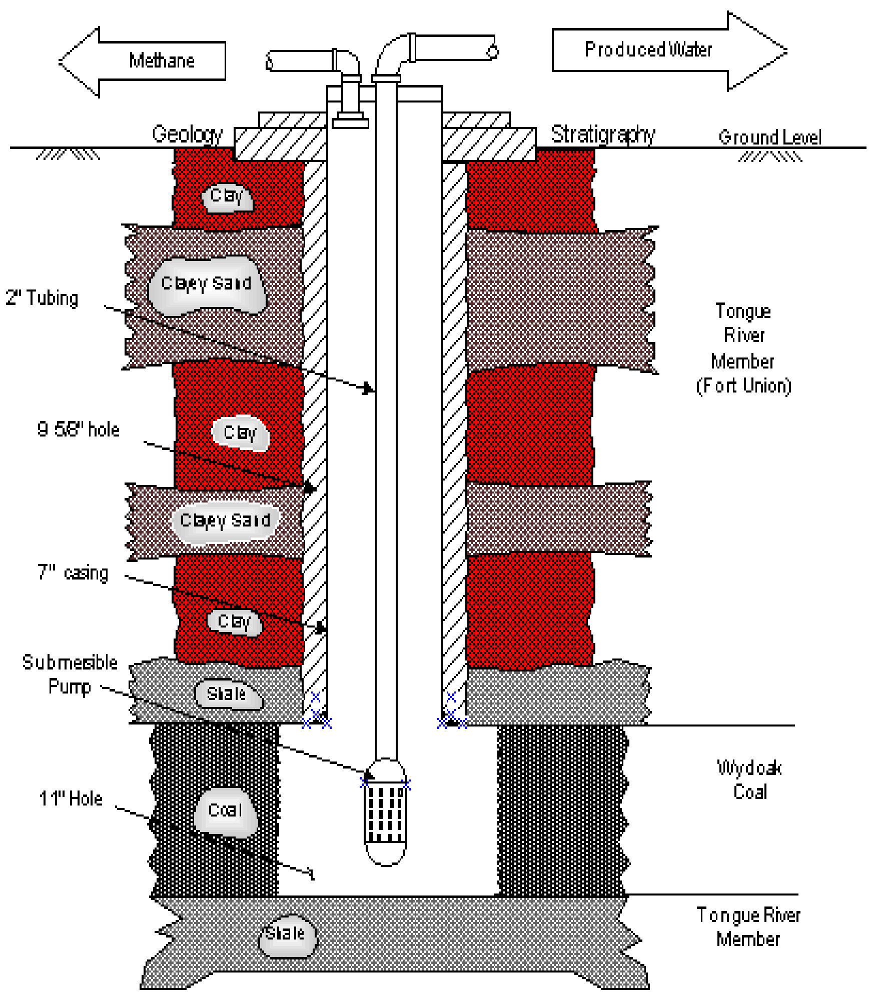


Figure 9
CBM Wellbore Diagram--Open-hole Completion
Example from Powder River Basin

Western Soft Coals

The coals found mostly in the Western U.S. are frequently sub-bituminous in rank and although competent enough to be completed and produced open-hole, they are often too soft to allow the use of horizontal wellbores with any major success to date. Figure 9 provides a typical well completion for CBM production wells in the Western U.S. The well is drilled to the top of the target coal seam and production casing is set and cemented back to surface. The coal seam is then drilled-out and under-reamed to open up more coal face to production. The borehole and coal face are then cleaned with a slug of formation water pumped at a high rate (water-flush). In areas where the cleat or natural fracture system is not fully developed, the coal may be artificially fractured using a low-pressure water fracture treatment.

These shallow wells are typically drilled with a small mobile rig mounted on a truck. For example, most wells in the Powder River basin are drilled in under a week and have a residual foot print of approximately ¼ acre. Spacing between wells is currently 80 acres in the Powder River Basin but can be as much as 320 acres (San Juan Basin) depending on the coal bed characteristics.

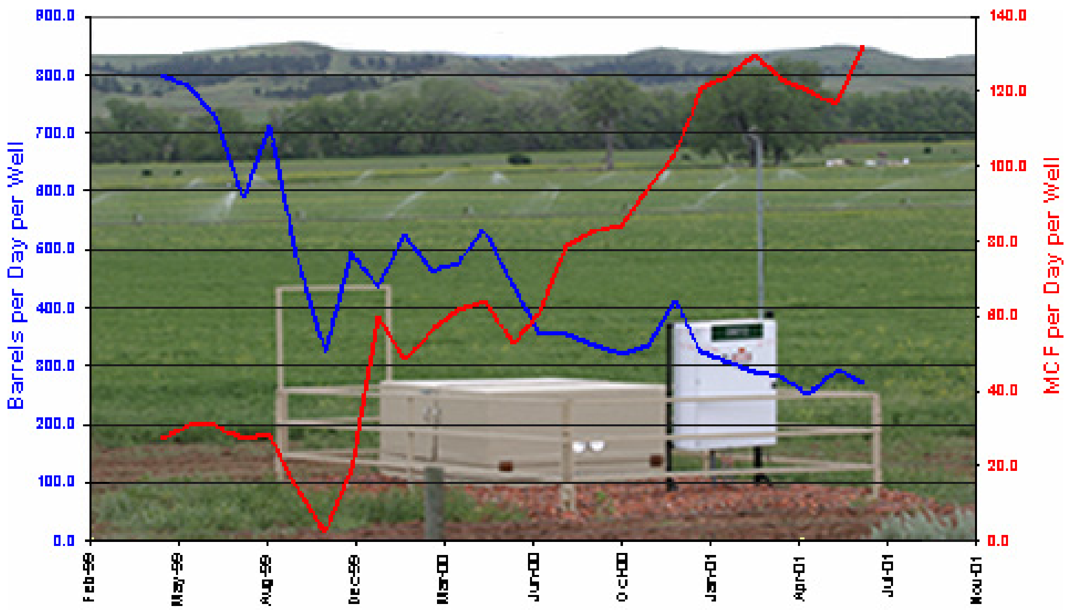


Figure 10
Production Plot, Powder River Basin - Production History

ALL Consulting

Once the well is completed, a submersible pump is run into the well on production tubing to pump the water from the coal seam. By removing the water from the coal seam the formation water pressure is reduced and the methane is desorbed (released) from the coal, thus initiating production. The methane flows up both the casing and tubing of the well and is sent via pipe to a gas/water separator at the compression station. The methane is then compressed for shipment to the sales pipeline. In most western soft coal areas only one coal seam is produced in each well.

Three CBM wells finished with surface enclosures in the Powder River Basin

Attempts at producing more than one coal seam per well have been mostly unsuccessful due to the inherent problem of lowering the water level in each coal seam independent of each other. Size constraints of the production equipment and use of submersible pumps make the use of dual completion complicated and expensive. With CBM production wells typically being so shallow, it is less expensive and less complicated to drill wells into each coal seam independently than to use dual or triple completion well systems.

As water is pumped off the coal aquifer, increasing amounts of methane are produced from the CBM wells. This relationship is shown in the production plot (Figure 10). The plot uses data obtained from the CX ranch in the Montana portion of the Powder River Basin. The plot details the field-wide average water and gas production over time from the date of first production. As can be seen, the water production is very high during the initial stages of production, but declines as more wells are installed and the hydrostatic pressure is lowered in the coal seam. As the hydrostatic pressure is lowered, the gas production increases as new fractures are desorbed and more methane is released.

Eastern Hard Coals

The coals found in the eastern portions of the U.S. are often higher rank medium to low volatile bituminous coals. While these coals are very competent and can be completed open hole, these coals are often drilled and cased to total depth. Wells are then perforated and stimulated to remove damage caused by drilling and to enhance fracturing near the wellbore. However, many of the eastern coals do not have significant water to be removed from the coal to initiate methane production. As such, several coal seams are often perforated in a single bore-hole. Figure 11 provides an example of vertical well bore completed in multiple coal seams.

Eastern hard coals are often exploited by way of horizontal drain-holes from a single bore-hole. Each individual well may have up to 3,500-feet of lateral extent within a single coal seam. Several laterals can be drilled from a single wellbore to exploit several seams or to take advantage of several cleat (fracture) trends. Each leg would not necessarily be horizontal but would closely follow the dip of the individual seam. Many of the coal seams are often less than five-feet thick, requiring the drilling contractor to exercise great care in steering the drill bit. Figure 12 illustrates an example of this method. Operators in Alabama, Arkansas, and Oklahoma have made use of horizontal laterals to enhance CBM production.

The production of CBM from eastern coals is similar to the western coals except for the use of horizontal well bores and the extensive use of fracturing to enhance production. With the coals being of higher rank, the methane content per ton of coal is typically higher, but requires in many areas additional enhancement to the natural fracture content to maximize production. Production rates of CBM depend upon local gas content of the coal, local permeability of the coals, hydrostatic pressure in the coal seam aquifer, completion techniques, and production techniques.

How Does CBM Compare to Conventional Natural Gas?

Methane is the chief component of natural gas, and CBM can be used in very much the same way as conventional gas. Conventional gas is formed in limestone and shale formations; pressure and temperature unite to transform organic matter into hydrocarbons over time, similar to thermogenic production in deeper coals. Natural gas migrates upward until trapped by a geologic barrier or fault and remains in this reservoir until it is discovered and drilled, or released by some natural means. Conventional gas wells are typically 4,000 to 12,000

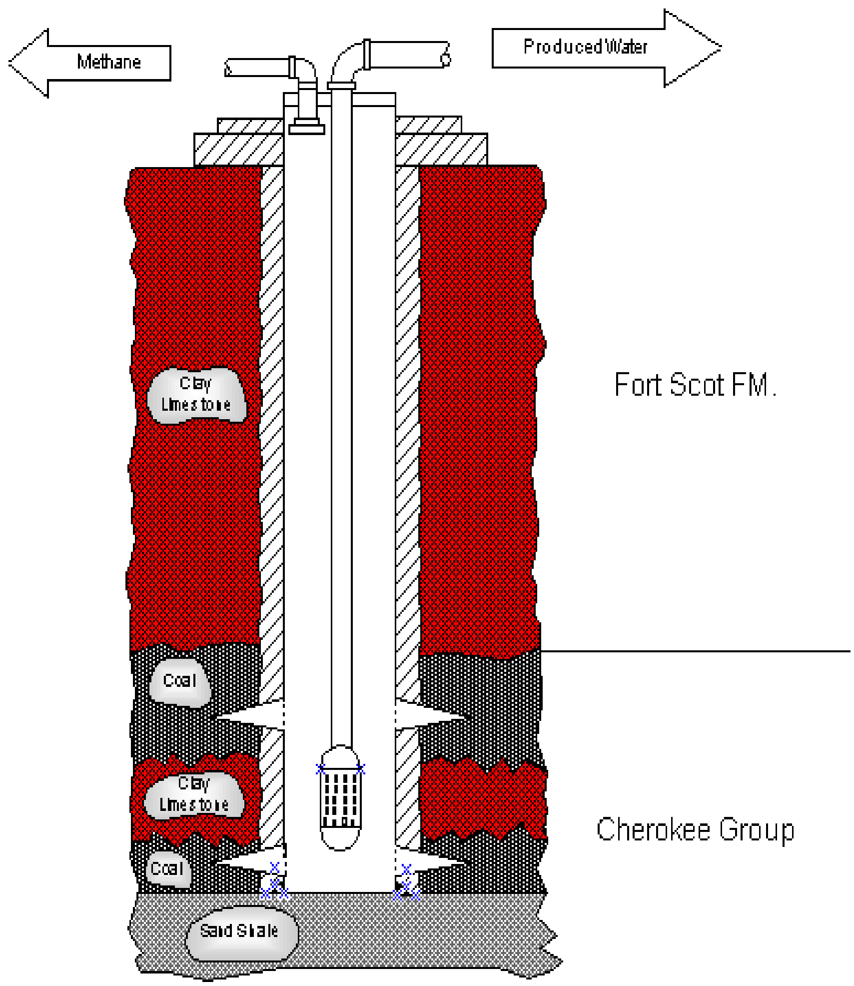


Figure 11
CBM Drilling Example
Vertical Wellbore Example from Cherokee Basin, Kansas

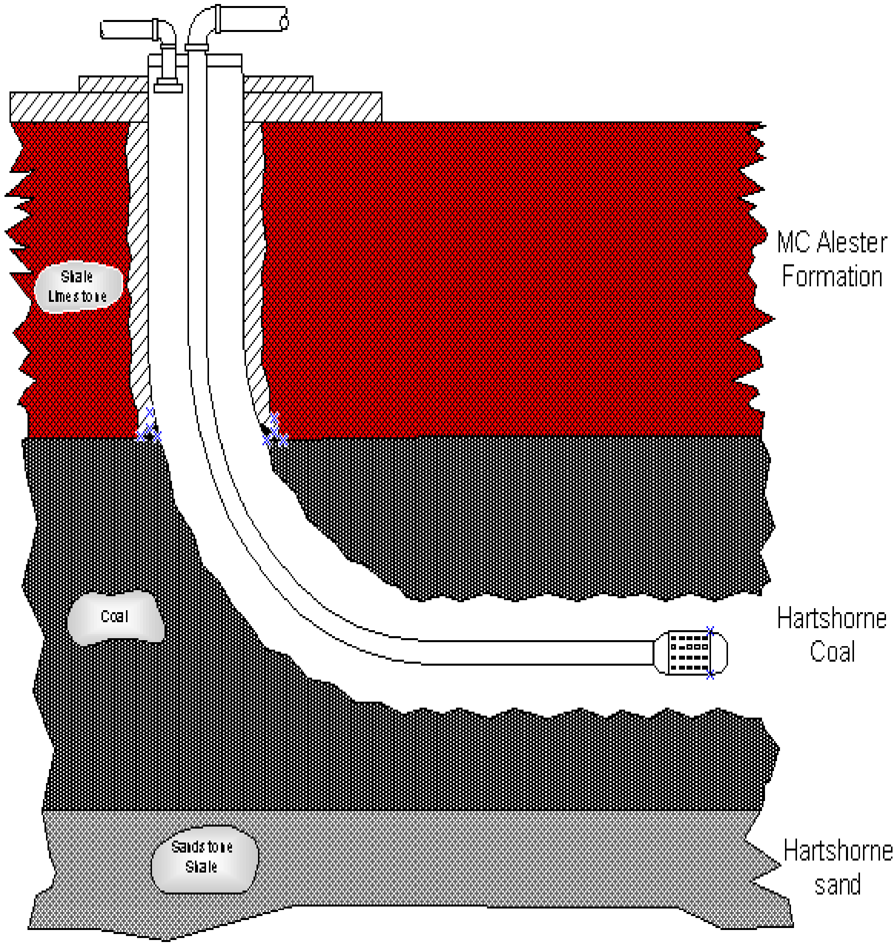


Figure 12
CBM Drilling Example
Horizontal Wellbore Example from Arkoma Basin

feet deep and extract gas from sandstone and shale formations (PRCBMIC, 2002). The location and extent of conventional gas typically requires exploratory drilling since the location of reservoirs is not apparent from the surface (Cullicott et al., 2002). Coal bed wells are generally considered shallow and range from 400 to 1,500 feet in the Powder River basin but can be as deep as 5,000 feet in some basins.

CBM is occasionally compared to another unconventional gas—"tight" gas—which is found at deeper depths and in low permeability sandstones. Companies often use hydraulic fracturing, injecting fluid into the rock formation to cause cracking in anticipation of releasing gas from tight sands (Kelly, 2001). Fracturing is also used in some CBM seams to increase production, as previously explained. CBM differs from conventional natural gas in other important ways. CBM is held in an adsorbed form on the surface of the coal; reservoir pressure must be reduced before CBM can be produced in significant quantities; and water is typically present in the reservoir and is usually co-produced with the CBM (Fidelity, 2002).

The economic feasibility of CBM compared to conventional natural gas is typically affected by four primary variables: the production cost, the rate of gas production, hub price, and economies of scale (Boyer, 1999).

Most CBM wells are shallow (less than 5,000 feet) and can be constructed in a short amount of time resulting in low to moderate well costs in comparison to conventional natural gas.

The volume and rate of gas production from CBM wells may fluctuate significantly unlike conventional gas, which is often more consistent once tapped. Minimum or low gas CBM producers yield about 50 thousand cubic feet (mcf) per day; high yield wells produce as much as 5 MMcf per day (Williams, 2001).

The location of the CBM production field with respect to the regional or interstate transmission pipelines also affects the economics of CBM development. The gas hub price, minus production and transportation costs, equal the wellhead net back price. In some areas, the transportation costs may be as much as the wellhead net back price.

The economy of scale refers to the number of wells or field size that has to be reached in order for the company to make a profit. Costs affecting the economic viability of CBM developments include compression, gas treatment, geologic and engineering services, transmission of gas and field operations. The minimum number of wells or volume of gas produced for a feasible project therefore depends on a diversity of issues.

Conventional natural gas wells produce large volumes of gas initially and then taper off over time as water production steadily increases; the exact opposite is true for CBM production. As previously mentioned CBM wells produce large volumes of water during the initial lowering of the hydrostatic pressure, and as the quantities of produced water decline the gas production increases. This is a result of lowering the hydrostatic pressure of the coal seam and allowing more gas to escape along the fractures and open cleats. Furthermore, conventional gas wells do not need to normally utilize artificial lift until the end of the well life, when pumps are sometimes installed to remove water if a well is incapable of lifting the water to the surface on its own. CBM wells on the other hand have submersible pumps installed initially and remove water for a number of years before peak production is reached, see Figure 13 which depicts a typical Powder River CBM well construction. In most cases towards the end of the CBM life cycle the submersible pumps can be turned off and gas will flow freely from the well even though most of the water remains in the coal seam (PRCBMIC, 2002).

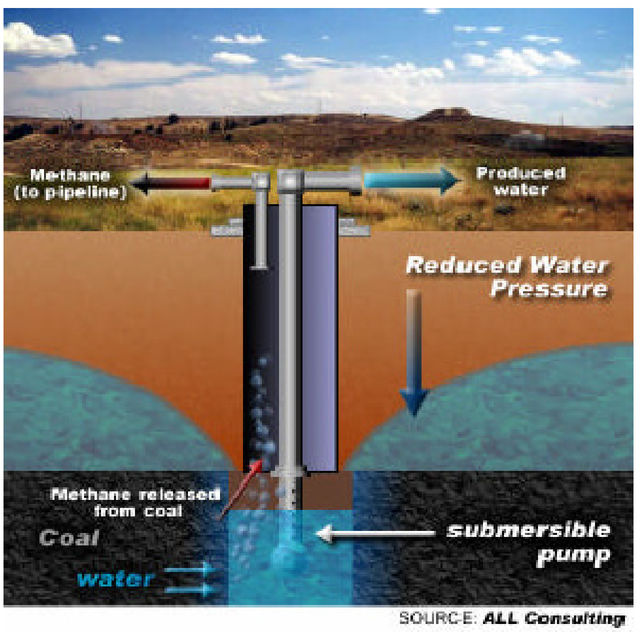


Figure 13
Typical CBM Well Construction Diagram
Powder River Basin, Montana

The production curve will depend on several factors including the field geology, well spacing, permeability of the reservoir, initial reservoir hydrostatic pressure, production techniques, and water saturation. In some basins, such as the San Juan Basin peak gas production can be reached in as little as two or more years (AAPG, BP Seminar, 2001). The relationship between peak gas production and production time is a function of the reservoir's permeability and well density. The lower the reservoir permeability the longer time it takes to reach peak gas production, or the more wells are needed to reach peak production sooner.

Typically, CBM wells produce less gas than conventional wells, therefore the cost to dispose of the production water is a significant expense compared to that of conventional development. Also, unlike conventional gas wells CBM wells are not shut off in reaction to falling gas prices; since the coal seam may refill with water, operators don't alter production rates in response to price fluctuations. Figure 14 compares CBM development to conventional natural gas development with regards to the quantities of water produced over the life of the wells.

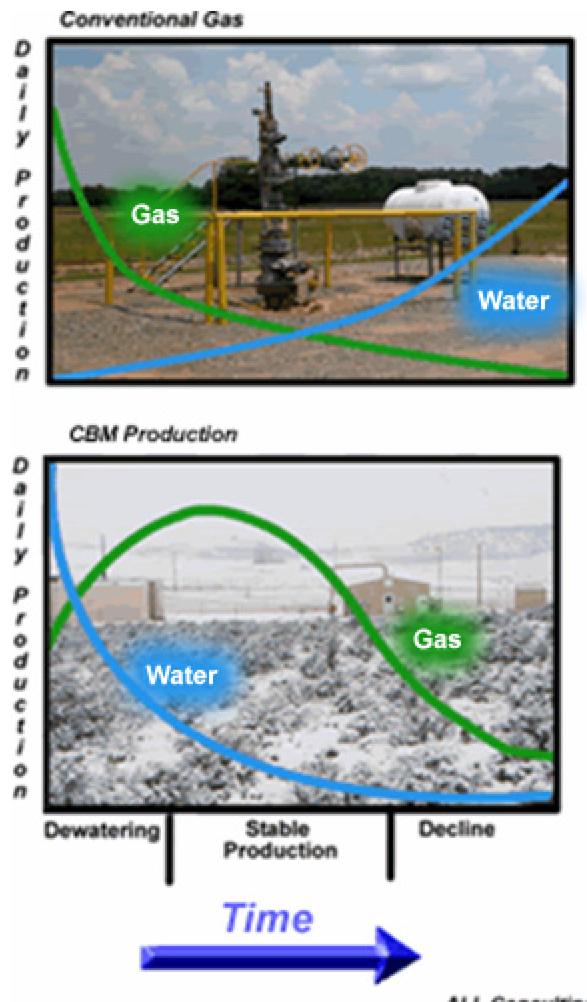


Figure 14
Production of Gas – Coal bed vs Conventional Reservoir

Another important characteristic affecting the economics of CBM development is the comparatively brief production time wells actually produce gas. Wells vary in production duration depending on a variety of factors. Conventional gas wells can produce from a few years to over 50 years. Well duration is affected by technology and as advances are made, reserves are recovered more quickly, which reduces the expected well life. Current estimates for the life of a CBM well vary from 5 to 15 years. CBM wells in the Wyoming portion of the Powder River Basin are estimated at only 7–10 years (BLM, 2003a), while the Montana portion of the same basin was estimated at 10–20 years (BLM, 2003b). Other basins have shown some longer production times, however it is generally feared by the public that basins may be relatively quickly pumped and then abandoned.

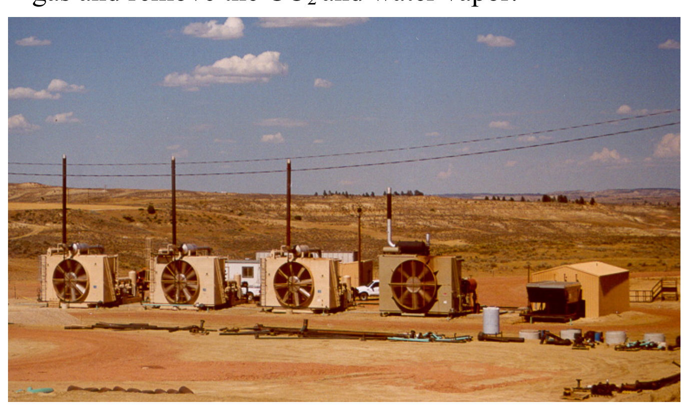
Enhanced Production

The CBM industry is exploring new methods of enhancing gas production from older fields that have produced for more than 10 years. Several companies are experimenting with the injection of nitrogen (N) and carbon dioxide (CO_2) into the coal bed to displace methane along the coal face cleats. Generally, the N and/or CO_2 molecules replace the methane molecules within the cleats at a ratio of approximately 4 to 1 (Schoeling, 2002). This forced gas exchange has resulted in elevated methane production rates as compared to just lowering the hydrostatic pressure. Injection of nitrogen, usually generated by manufactured gas plants, reduces the partial pressure and therefore the concentration of methane in the coals in the fracture system. Even though the partial pressure is reduced, the total pressure is generally constant (depending on whether or not the seams hydrostatic pressure is being lowered) and the fluids maintain head that drives liquids to the production wells. It is theorized that nitrogen injection affects methane production from the coal seam via inert gas stripping and sorption displacement. Coals can replace 25% to 50% of their methane storage capacity with nitrogen.

This enhanced production method has a beneficial side effect—the sequestering of CO_2. Carbon dioxide is a common by-product of many industrial processes and is considered a green house gas. The sequestering of CO_2 lowers the amount available to be exhausted to the atmosphere and helps the United States meet its goal for reduced CO_2 emissions. Laboratory studies indicate that coal adsorbs nearly twice as much volume of CO2 as methane. There are some concerns, however, that injection of CO_2 into mineable coals presents a safety hazard, as the mines are required to have a limit of 3% CO_2 by volume in the mine air. One potential method for reducing CO_2 levels in the mine air is to use a mixture of CO_2 and other gases, such as nitrogen. Studies indicate that for each volume of nitrogen that is injected, two volumes of methane are produced (Schoeling 2002). There is growing interest in mixed nitrogen/CO_2 injection for two reasons: there may be a synergy of production mechanisms, and its use would result in the lowering of CO_2 levels in the mine air (EPA 2002a). More research is needed in this arena, but preliminary results are promising for both CBM production and CO_2 sequestering.

Compression

Gas produced from CBM wells requires dehydration to remove the water vapor in the gas, and is usually compressed 2 to 3 times before it reaches the sales line. CBM leaves the wellhead at relatively low pressures that range from 2 to 5 pounds per square inch/gauge (psig) (Fidelity 2003). The CBM first passes through a field compressor unit, typically a rotary screw compressor that will increase the gas to 70-80 psig. At this pressure the gas flows through a gathering system on its way to the sales compressor. The sales compressor boosts the pressure to approximately 1200 psig. Following this stage the CBM in the sales line is transported locally or regionally to end-user sites, which are metered. It is important to note that as a CBM field matures, the CBM may contain increased levels of CO_2 that needs to be removed prior to being transported to market (Fidelity, 2003). Gas processing plants installed on the pipelines typically in conjunction with sales compressors treat the natural gas and remove the CO_2 and water vapor.



Typical sales compressor facility in the Powder River Basin, Wyoming

WHERE ARE CBM RESOURCES LOCATED?

The majority of CBM development has been conducted in the West, South, and, to a smaller degree, the Midwest. Figure 15 identifies the major CBM basins in the Rocky Mountain region.

To date approximately 56 percent of CBM production in the United States has come from the Rocky Mountain region. The four principal basins responsible for this include the Powder River, Raton, San Juan, and Uinta. Potential development is being considered for the Piceance and Denver basins in Colorado and for the Greater Green River basin in Wyoming. These basins may contain as much as 200 Tcf of recoverable CBM, representing approximately 50 to 80 percent of the estimated recoverable CBM in the United States. In addition to those basins another 1,000 Tcf of methane may also be located in Alaska (Lang 2000). It's important to recognize that estimates differ greatly, based on conflicting hypothesis's and differences between proven reserves and those that are economically or technically recoverable.

HOW DO THE WESTERN CBM BASINS COMPARE?

The major producing CBM basins in the Rocky Mountain region include the San Juan, Raton, Uinta, and the Powder River Basin. Potential or initial development is being considered for the Piceance, Green River, and Denver basins.

Each coal basin is different and poses its own unique set of development criteria and exploration challenges. Due to these differences, developments in various basins cause distinct changes to the surrounding communities and ecosystems. Some basins have been produced for many years and are nearing their peak while others are in the initial stages of development and some have still yet to be considered. Some basins produce good quality water that can be used for a variety of beneficial uses including irrigation, dust control, livestock watering, wetlands construction, wildlife source ponds, and even human consumption (ALL 2003), while other basins have poor quality water that must be managed for proper disposal. The common factor among CBM basins in the Rocky Mountains is that they each have unique characteristics. Operators take a long hard look at the various basins regional geology, coal types and characteristics, existing infrastructure, surrounding ecosystems and production potential before any investments are contemplated. New technologies are being advanced each year, which make some seemingly non-profitable basins more economic as differences are evaluated time and again. Table 2 summarizes the key characteristics of producing CBM basins in the Rocky Mountain Region of the United States.

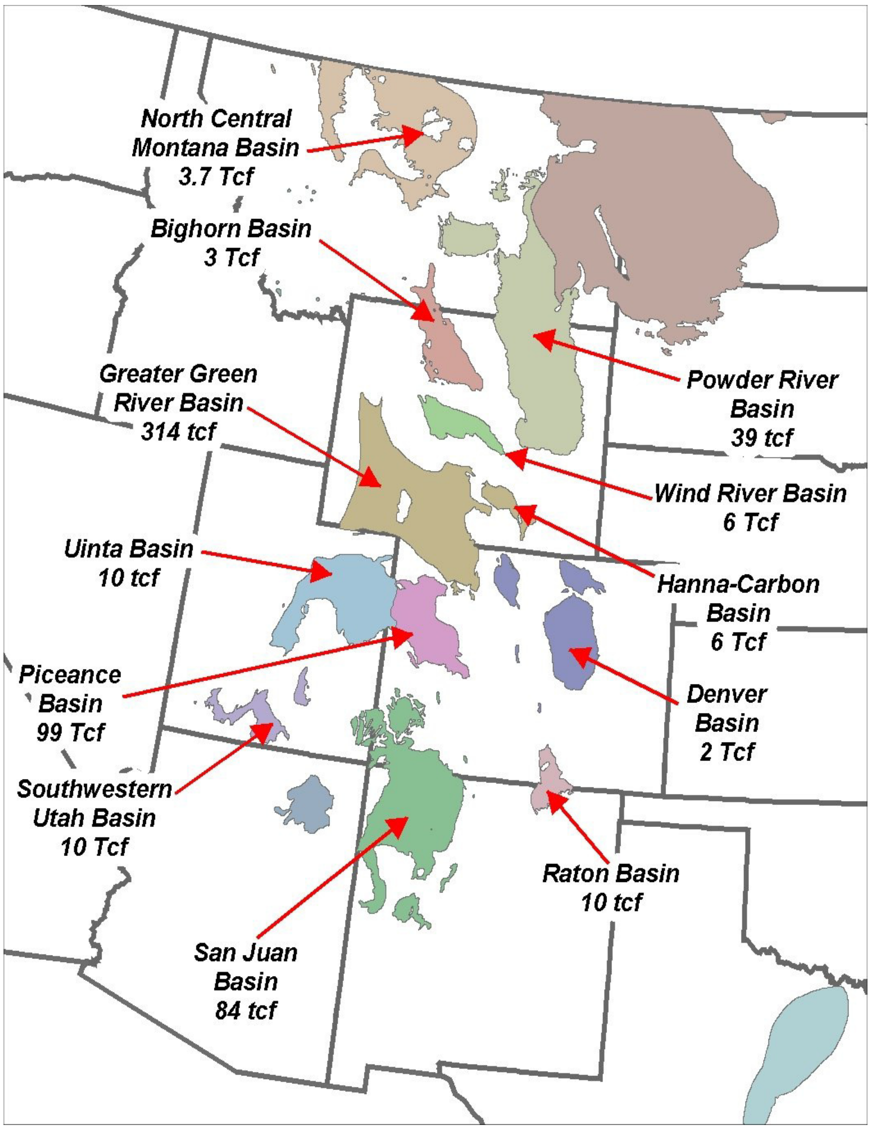


Figure 15
Rocky Mountain Region Coal Basins and Estimated CBM Reserves
Source: Nelson 2000

Table 2

Comparison of Producing CBM Basins in the Rocky Mountain Region

Basin	San Juan	Raton	Uinta	Powder River
State Location	NM, CO	NM, CO	UT	WY, MT
Drilling Method	Air Percussion	Air Percussion	Air Percussion	Air-Water
Completion Methods	Cased Hole Perforate/Multistage	Cased Hole Perforate/Multistage N_2 Foam/Sand	Cased Hole Perforate/Multistage X-Link/Sand	Open-hole Under-ream
Producing Wells	2,550	694	558	10,358
Primary Water Disposal Methods	Injection	Deep Injection	Deep Injection	Surface Discharge, Beneficial Use
Water Lift Method	Rod Pump	Progressive Cavity and Rod Pump	Rod Pump	Electric Pump
Average water Production per well	25 Bbl/day	266 Bbl/day	215 Bbl/Day	400 Bbl/day
Coal Rank	Sub-bituminous	high-volatile bituminous	high-volatile bituminous	Sub-bituminous
Well Depth (feet)	550-4000 bsl	400-4000 bsl	2000-7000 bsl	200-2500 bsl
Net Coal Thickness	20-80 feet	10-40 feet	10-40 feet	75 feet
Gas Content	350-450 scf/ton	50-400 scf/ton	250-400 scf/ton	30 scf/ton
Well Spacing	320-160 acres	160 acres	160 acres	80 acres
Average Well Cost	$275,000	$330,000	$375,000	$75,000
Average Well Reserves	10 Bcf	1.8 Bcf	1.5 Bcf	0.4 Bcf
Average Well Gas Production Rate	800 Mscf/day	300 Mscf/day	625 Mscf/day	180 Mscf/day
Bbl, Barrel (42 gallons), bsl – below surface level				

Sources: PTTC Rockies 2000, GTI 2000, EPA 2002, USGS 2000, CO, NM, WY, MT Oil and Gas Commissions, Williams 2001,

The San Juan Basin

The San Juan Basin covers an area of about 7,500 square miles located near the Four Corners region of Colorado, New Mexico, Arizona and Utah (Figure 16). The basin measures roughly 100 miles in length in the north-south direction and 90 miles in width.

The foremost coal-bearing unit in the basin is known as the Fruitland formation. CBM production occurs predominantly in coals of the Fruitland Formation, however, some CBM is held in the underlying and adjacent Pictured Cliffs sandstone, and numerous wells are completed in both zones. Individual coalbeds of the Fruitland Formation average from 20 to over 40 feet thick. The total net thickness of the coal beds ranges from 20 to over 80 feet across the basin.

The waters in parts of the Fruitland Formation usually contains less than 10,000 mg/L TDS. In the northern half of the formation, most water contains less than 3,000 mg/L, and wells near the outcrop produce water that contains less than 500 mg/L.

Typical CBM wells in the San Juan Basin range from 550 to 4,000 feet in depth, and about 2,550 such wells are currently operating (COGCC and NM OCD, 2001). The San Juan Basin is the most productive CBM basin in North America. CBM production in the basin averages about 800 Mscf per day per well (Stevens et al., 1996).

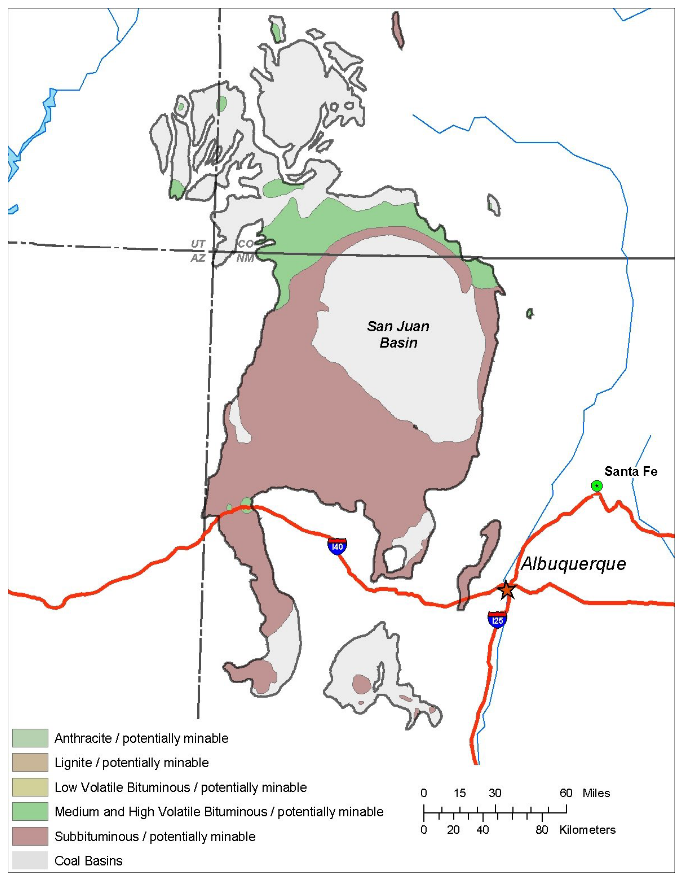


Figure 16
General location map and coal rank map of the San Juan Basin

Production began in the late 1980s and rapidly expanded through the 1990s but is no longer increasing. Companies are attempting to maintain production by focusing on enlarging gathering facilities, upgrading production equipment, installing pumping units and wellhead compression, recavitating producing wells, experimenting with secondary recovery efforts, and downspacing from 320-acre units to 160 acre spacing.

In 2000, the San Juan Basin produced 0.78 Tcf of gas, representing 4% of total U.S. natural gas production and 80% of the nation's CBM production. The BLM's recently completed EIS predicts that 12,500 new oil, gas, and CBM wells will be drilled in the San Juan Basin over the next 20 years. Infill drilling—drilling wells on reduced spacing requirements, at every 160 acres rather than 320 acres—has already begun.

The Powder River Basin

The Powder River Basin is located in northeastern Wyoming and southeastern Montana (Figure 17). The basin covers an area of approximately 25,800 square miles, of which approximately 75% is in Wyoming. Fifty percent of the Powder River basin is believed to have the potential for CBM production.

Coal beds in this region intermingle at varying depths with sandstones and shale. The majority of the productive coal zones range from 150 feet to 1,850 feet below ground (Randall, 1991). The uppermost formation is the Wasatch Formation, extending from land surface to 1,000 feet deep. Most of the coal seams in the Wasatch Formation are continuous, but thin (six feet or less). The Fort Union Formation lies directly below the Wasatch Formation and can be as thick as 3,000 feet. The coal beds in Fort Union formation are usually more plentiful in the upper portion, named the Tongue River member. This member is normally 1,500 to 1,800 feet thick, of which a net total of 350 feet of coal can be found in various seams. The thickest of the individual coal seams is over 150 feet thick. CBM production is primarily from the Fort Union rather than the overlying Wasatch.

The Fort Union Formation supplies municipal water to the city of Gillette, WY and is the same formation that contains the coals that are developed for CBM. The coal beds contain and transmit more water than the sandstones. The sandstones and coal beds are both used for the production of water and the production of CBM. Total Dissolved Solids (TDS) levels in the

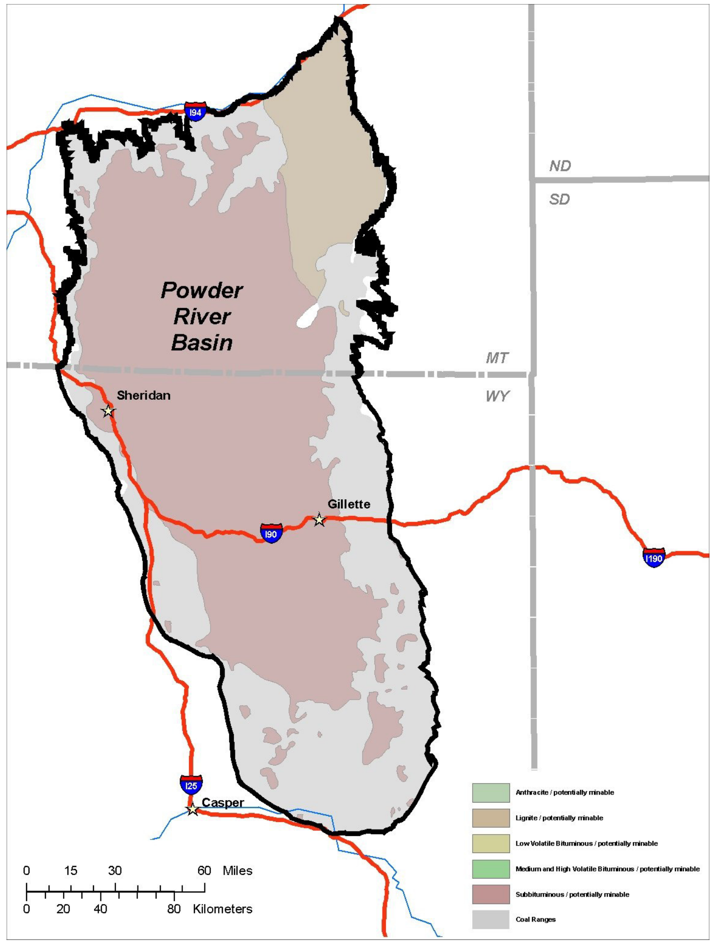


Figure 17
General location map and coal rank map of the Powder River Basin

water produced from these coal beds meet the water quality criteria for drinking water.

The Powder River Basin is the fastest growing CBM area in the United States. The huge coal deposits contain enormous amounts of methane gas due to their unusual thickness as evident in the amount of coal produced from this region. The low gas content per ton and low pressure were initially seen as barriers to development. The first wells drilled and completed produced massive volumes of water but little gas. As companies altered their drilling to more shallow wells, production increased. The low drilling costs, the short completion time and the relatively good quality of water coupled with inexpensive water management i.e. surface discharge encouraged development.

The BLM in Montana and Wyoming issued their Final EISs for the Powder River Basin in January 2003, and they anticipate combined activity of upwards of

60,000 new wells and accompanying roads, pipelines, and electrical utilities, and compressors in the basin. Currently, there are approximately 14,000 producing wells in the Powder River Basin, mainly in the Wyoming portion.

The Raton Basin

The Raton Basin is the southern most Laramide basin in the Rockies and covers about 2,200 square miles along the Colorado-New Mexico border (Figure 18). The basin extends 80 miles north to south and as much as 50 miles east to west (Stevens et al., 1992). It is an elongate asymmetric syncline, 20,000 to 25,000 feet thick in the deepest part.

Coal beds occur in the Upper Cretaceous Vermejo and Paleocene Raton formations at depths from outcrop to more than 4,000 ft. Vermejo coal beds are lenticular and fairly continuous, with net coal thickness of 10 to 40 ft. Raton coals generally are thinner and less continuous. Most of the coal in the basin is high-volatile bituminous in rank. Measured gas contents range from less than 50 scf/ton to more than 400 scf/ton.

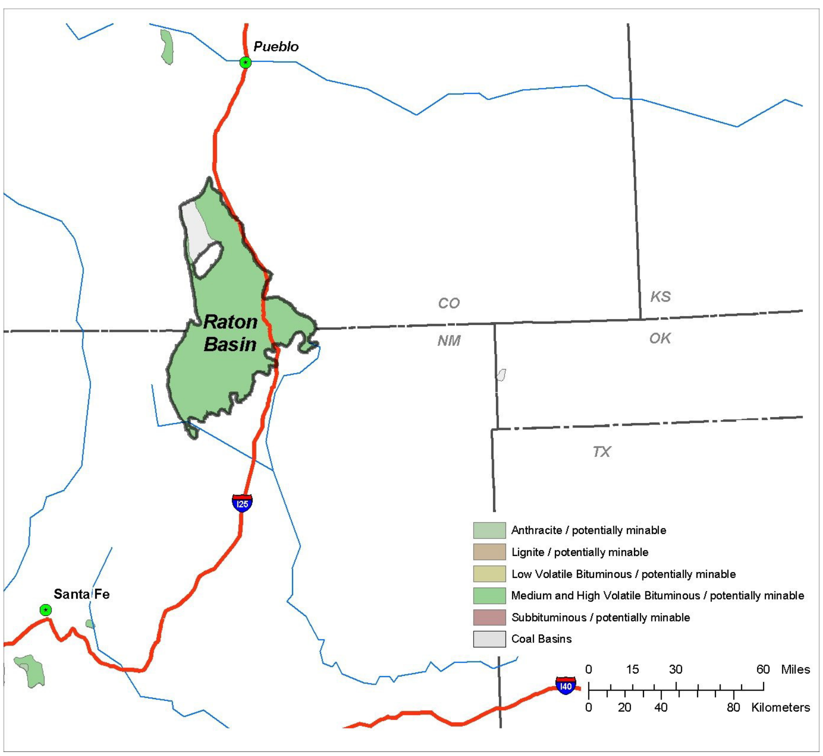


Figure 18
General location map and coal rank map of the Raton Basin

The coal seams of the Vermejo and Raton formations developed for methane production also contain water that meets the federal water quality criteria for drinking water. The underlying Trinidad Sandstone and other sandstone beds within the Vermejo and Raton formations, as well as intrusive dikes and sills, also contain water of sufficient quality to meet the drinking water quality criteria.

Methane resources for the basin have been estimated at approximately 10.2 Tcf contained in the Vermejo and Raton formations (Stevens et al., 1992). It was reported recently that the average CBM production rate of wells in the Raton Basin was close to 300 Mcf per day, and annual production in 2000 was 30.8 Bcf (GTI, 2002).

The Unita Basin

The majority of the Uinta Basin is contained within Utah, with a small segment of the basin lying in northwestern Colorado (Figure 19). The basin covers approximately 14,450 square miles (Quarterly Review, August 1993). Stratigraphically the Uinta Basin is adjacent to the Piceance Basin of Colorado, but is structurally separated from it by the Douglas Creek Arch, an uplift near the state line. It is bordered on the West by the San Rafael Swell and Uncompahgre Uplift and on the north by the Uinta Mountains.

Significant down-warping of the basin occurred during the Late Createceous and Eocene (Laramide) timeframe. Coal beds in the Uinta Basin occur in the Mesaverde Group, however the majority of development activity targets the high-volatile bituminous coals in the Ferron Sandstone member of the Mancos Shale. A 80-mile-long, 12-mile-wide, "Corridor" paralleling the thickest development (10 to 40 ft) of Ferron coal seams has been identified by the Utah Geological Survey. (UGS 1997)

Sandstone is interbedded with the Ferron coals and forms a segment of clastic sediment 150 to 750 feet thick. The Ferron Sandstone coals range in depth from 1,000 to over 7,000 feet below surface level (Garrison et al., 1997). The Blackhawk Formation comprises coal seams interbedded with sandstone in combination with shale and siltstone. Wells drilled in the Blackhawk

Formation coals are finished at 4,200 to 4,400 feet below the surface (Gloyn and Sommer, 1993).

The Blackhawk Formation and the Ferron coals of the Uinta Basin have water that meets the National Primary Drinking Water (NPDW) criteria. Groundwater from the Blackhawk Formation taken at the Castlegate Field contains a TDS level below the federal drinking water standard of 10,000 mg/L. Castlegate Field coal beds have published TDS levels of 5,000 mg/L in production waters indicating that the methane gas wells in this portion of the basin are located in an aquifer that meets the NPDW standard (EPA 2002b).

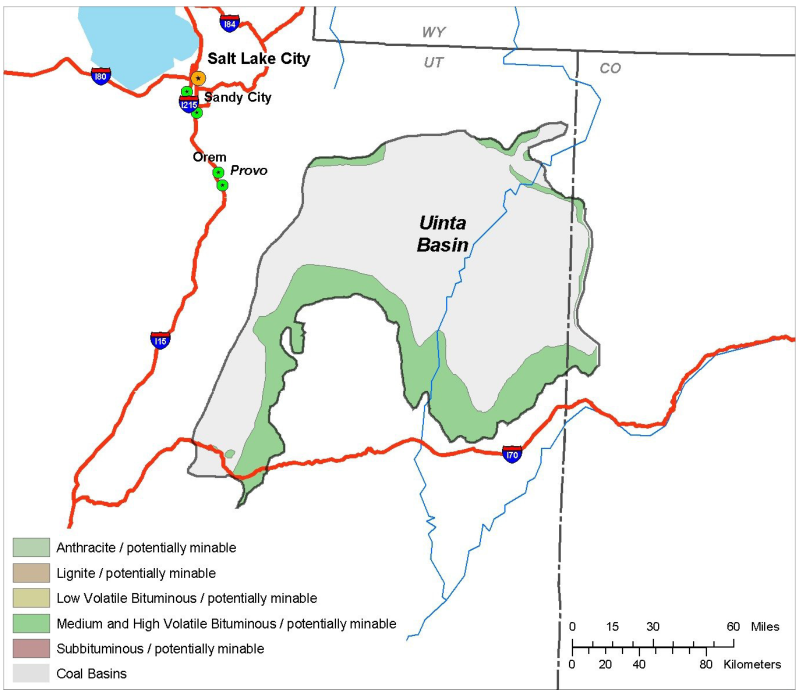


Figure 19
General location map and coal rank map of the Uinta Basin

Full scale exploration within the Uinta Basin began in the 1990s (Quarterly Review, 1993). The CBM potential of the Uinta Basin was estimated by the Utah Geological Survey in the early 1990s to be between 8 Tcf and 10 Tcf (Gloyn and Sommer, 1993). Total production was 75.7 Bcf in 2000 (GTI, 2002). The Ferron coals at the north end of the corridor, primarily in River Gas Utah's Drunkards Wash Unit, have produced more than 200 Bcf of methane with daily production of 260 MMcfd from 470 wells (EPA 2002b).

OTHER BASINS

The other major basins in the Rocky Mountain region which have tremendous potential to produce vast amounts of CBM are the Denver, Greater Green River, and Piceance basins. These basins are currently being investigated by numerous development companies and it is anticipated that several federal EISs will be conducted in the next few years (DOI 2003).

The majority of the Denver Basin lies in the east central region of Colorado and contains an estimated 2 Tcf of CBM (Figure 15). Development has been delayed by a deficiency in the data regarding the extent of the CBM resource and the disposition of the gas reservoirs. The two main coal formations are enclosed by four Denver basin aquifers, presenting concerns about the degree to which the aquifers and coals are linked hydraulically and to what extent CBM development would have on the groundwater resources (Wray & Koening, 2001).

CBM resources in the Greater Green River Basin of Colorado and Wyoming have been estimated at upwards of 314 Tcf (GTI 2001). A sizable portion of CBM resource is located at depths less than 6,000 feet. (Kaiser et al., 1995). Some exploration and limited development of CBM occurred in the late 1980s and early 1990s. Colorado Oil and Gas Commission records indicate that approximately 31 Bcf of CBM was produced in Moffat County during 1995 (COGCC web site, 2001). There appears to be no commercial production at present. Development of CBM in the basin has lagged due to the current limited economic viability. The degree to which the lowering of the hydrostatic pressure is required in most wells has been the chief restraining factor, compounded by the depth of the coal zone and the relatively low CBM recovery potential. Recently, permits for new gas wells have been issued indicating that there may be some continued interest in this area (COGCC, web site 2001).

The Piceance Basin is located within the state of Colorado in the northwest corner of the state (Figure 15). The depth to the CBM bearing coal zone (Cameo-Wheeler-Fairfield) is about 6,000 feet. Two-thirds of the CBM occurs in coals deeper than 5,000 feet making the Piceance Basin one of the deepest CBM areas in the U.S. (Quarterly Review, August 1993). Due to the depth of the coals the permeability is reduced, thereby increasing the difficulty of extraction. This has hindered CBM development in the basin. However, the Cameo-Wheeler-Fairfield coal zone in the basin is estimated to contain between 80 and 136 Tcf of CBM (Tyler et al., 1998). Total CBM production was 1.2 Bcf in 2000 (GTI, 2002).

Basins of interest outside the Rockies (Figure 20) include Black Warrior Basin in Alabama; the Central Appalachian Coal Basin located across parts of Kentucky, Tennessee, Virginia, and West Virginia; the Northern Appalachian Coal Basin in Pennsylvania, West Virginia, Ohio, Kentucky, and Maryland; the Western Interior Coal Region which encompasses the areas of six states Arkansas, Oklahoma, Kansas, Missouri, Nebraska, and Iowa; and coal basins in Alaska.

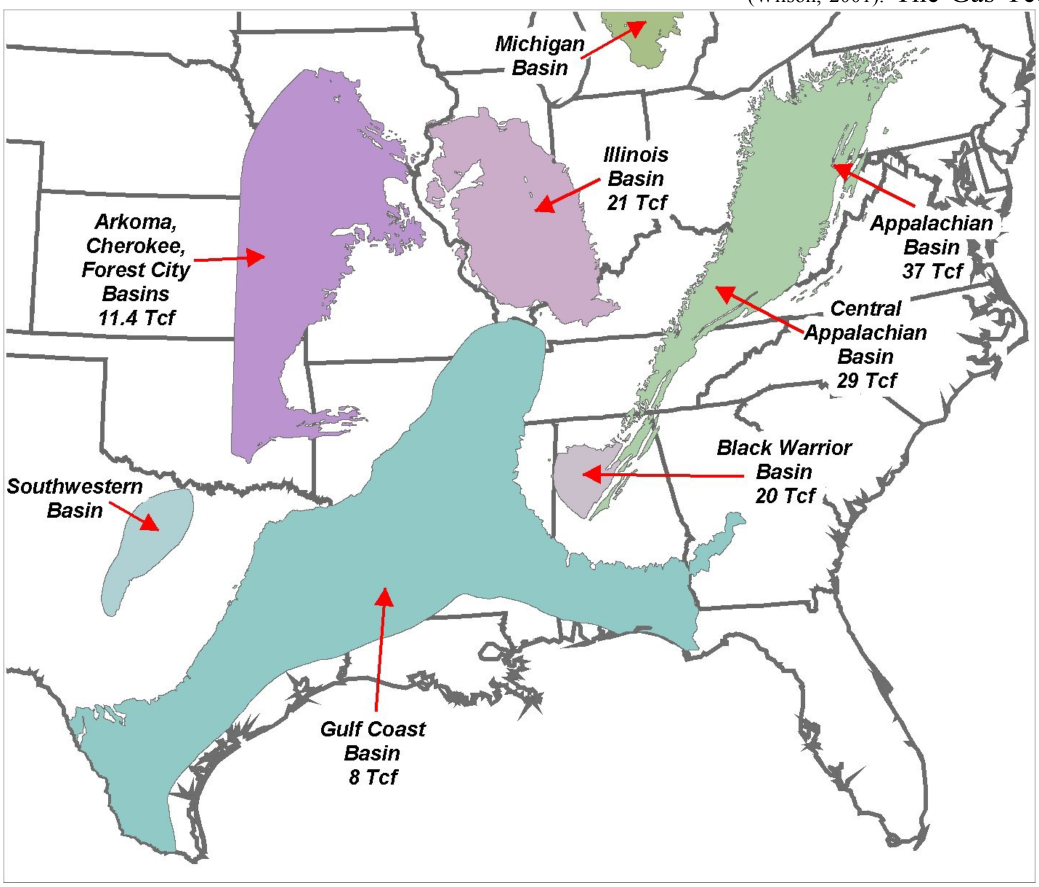


Figure 20
General location map of eastern coal basins
Source: Nelson 2000

Of these the Black Warrior Basin has been the most productive. To date there has been nearly 4,000 wells permitted in Alabama (GTI, 2002). These wells produce an average of about 300 Mcf per day per well (Hewitt, 1984; McFall et al., 1986; Schraufnagel, 1993). It has been estimated that the Black Warrior Basin produces roughly 100 Bcf of gas annually, which is about 20 percent of Alabama's gas production from all methods (Pashin and Hinkle 1997).

The Central Appalachian basin has seen recent development in the Nora Field in southwestern Virginia. The Nora Field had over 250 CBM wells drilled in 2000. Approximately 2,500 new CBM wells were drilled last year within Buchanan County, southwestern Virginia (Wilson, 2001). The State of Virginia reportedly produced 72 Bcf of CBM in 2000 (Wilson, 2001). The Gas Technology Institute reports that basin-wide CBM production stood at 52.9 Bcf in 2000 (GTI, 2002).

CBM has been produced in commercial quantities from the Pittsburgh coal bed of the Northern Appalachian Coal Basin since 1932 (Lyons, 1997). As of 1993 at least 20 wells have been in continuous production in southern Indiana County, Pennsylvania (Quarterly Review, 1993). CBM production development in the Northern Appalachian Basin has lagged, however, due to insufficient reservoir knowledge, inadequate well completion techniques, and CBM ownership issues revolving around whether the gas is owned by the mineral owner or the oil and gas owner (Zebrowitz et al., 1991). This issue is discussed in detail in the Regulatory Framework section. Discharge of produced waters has also proven to be problematic (Lyons, 1997) for current and would-be CBM field operators in the Northern Appalachian Coal Basin. Total CBM production stood at 1.41 Bcf in 2000 (GTI, 2002).

The Western Interior Coal Region comprises three coal basins that include the Arkoma, the Cherokee, and the Forest City basins. As of March 2000, there were 377 CBM wells in the Arkoma Basin of Eastern Oklahoma, ranging in depth from 589 to 3,726 feet (Oklahoma Geological Survey website, 2002). The Arkoma basin contains an estimated 1.58 to 3.55 Tcf of gas reserves contained primarily in the Hartshorne coals (Quarterly Review, 1993). In the Cherokee Basin, unknown amounts of CBM gas have been produced as conventional natural gas for over 50 years (Quarterly Review, 1993). Targeted CBM production increased in the late 1980s, and at least 232 CBM wells had been completed as of January 1993 (Quarterly Review, 1993). The Cherokee Basin contains an estimated 1.38 MMcf of gas per square mile basin-wide (Stoeckinger and Brady, 1989) in the targeted Mulky, Weir-Pittsburg, and Riverton coal seams of the Cherokee Group (Quarterly Review, 1993). Nearly 10 Tcf of gas is located in eastern Kansas alone (PTTC, 1999). The Forest City Basin was relatively unexplored in 1993, with about ten coal bed wells concentrated in Atchison, Jefferson, Miami, Leavenworth, and Franklin Counties, Kansas (Quarterly Review, 1993). The Forest City Basin contains an estimated 1.0 TCF of in-place gas (Nelson, 1999). For the entire region, CBM production was 6.5 Bcf in 2000 (GTI, 2002).

Additionally, Alaska has nearly as much coal as the entire continental U.S. Investigations have indicated that coals in Northern Alaska's Bristol Bay Basin, the Colville Basin, and the Yukon Basin of the Alaskan Peninsula have the highest CBM production potential (PTTC 2000).

The Future Role of CBM in the U.S. Energy Policy

Natural gas currently provides 24 percent of the energy needs of the U.S. and CBM comprises 8 percent of the natural gas domestically extracted (EIA 2001). The United States produces the majority (85%) of the gas it consumes and imports the remainder from Canada. The average U.S. family uses about 45,000 cubic feet of natural gas per year consuming 4.4 Tcf of natural gas to meet the nation's residential needs annually (NEP 2001).

By the year 2020, the Energy Information Administration projects the United States will need nearly 50 percent more natural gas to meet demand. While the resource base that supplies today's natural gas is immense, conventional production in the U.S. is expected to reach a peak in 2015, see Figure 21. The demand for natural gas will almost certainly continue to increase, widening the gap with domestic production. Consequently, the U.S. will progressively rely on imports of natural gas from Canada, and imports of liquified natural gas from producers across the globe (NEP 2001). Additionally, the nation will look for natural gas from unconventional resources, such as CBM.

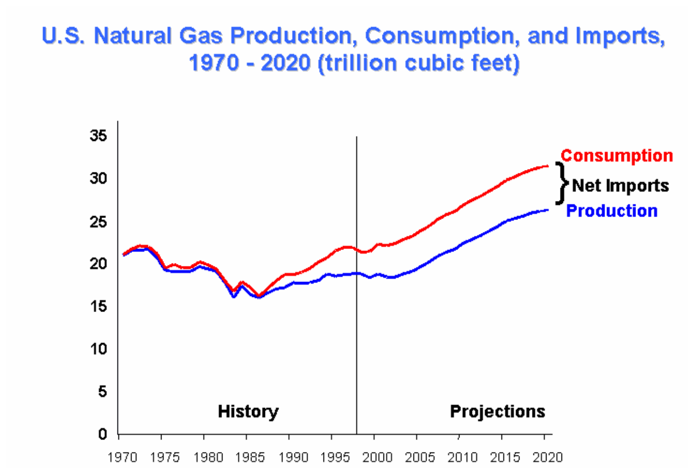


Figure 21
Natural Gas Production, Consumption, and Imports
Source: Mariner-Volpe, 2000

Many CBM basins are found in environmentally sensitive areas that increasingly require the use of less intrusive technologies. New technologies are being engineered to decrease both the environmental effects and the economic costs of CBM exploration and development. These new technologies like horizontal drilling and enhanced recovery through CO_2 or N_2 injection technology permit greater exactness and significantly reduce surface disturbing activities.

Natural gas, including CBM has been assigned a major role in the current administration's energy policy. The Bush administration's National Energy Policy emphasizes escalating domestic sources of fossil fuels, in fact 35 specific recommendations were made that address increasing supplies of fossil fuels. The recommendations include opening new lands or redefining federal lands for increased exploration, streamlining the permitting process, reducing the regulatory burden, and expanding the nation's energy related infrastructure. The energy challenge presented can be summarized as follows: Even if the U.S. can improve energy efficiency there will still be a need for more energy supplies. The future projected shortfall between supply and demand can be made up in only a few ways: improve energy efficiency, import more energy; increase domestic energy supply or utilize a combination of these methods (PTTC 2000).

Economically, the most important long-term challenge relating to natural gas is the ability to maintain the price in the face of ever increasing demand tied to limited supplies (DOE 2002). If supplies cannot be maintained, elevated natural gas prices such as experienced in 2000 could become a common problem. Elevated natural gas prices could have an impact on electricity prices, home heating bills, and the cost of industrial production. To meet this long-term challenge, the U.S. natural gas industry needs to increase production and invest in the natural gas pipeline network and infrastructure (NEP 2001).

It is evident in the National Energy Plan that the Bush administration recognizes that short-term increases in natural gas production will come from non-traditional sources in the Rocky Mountain Region such as CBM. The increased reliance on Rocky Mountain CBM production coupled with the national energy policy recommendations to open more federal land to exploration, expedite permitting and reduce regulatory hurdles can only mean that the Rocky Mountain States will be at the center of the national energy policy debates. These changes and their associated implications could result in energy development clashes with other closely held western values such as, preservation of wild lands, protection of ecoystems and wildlife habitat, recreational and aesthetic interests, and traditional lifestyles. Conflicts will be unavoidable as people across the Rocky Mountains have intensely opposed opinions about what should be done on public lands.

Weathered landscape with exposed Fort Union Formation, Powder River Basin, Montana

Regulatory Framework

Federal, State and Local Regulations Governing CBM Development across the West

Numerous regulations designed to control conventional natural gas development can and do apply to CBM exploration and production. However, due to the differences in produced water volumes and quality, well spacing, and utility infrastructure, specific CBM regulations have been drafted by federal, state and local agencies to meet various concerns. This section provides an overview of the current regulations and discusses some case histories regarding CBM development.

Federal Regulations

CBM ownership has been a point of contention since the early 1900s; questions regarding its status as part of the coal estate or as part of the natural gas resource is still under debate in some Eastern states. However, CBM originating in federally held coal deposits may be explored for and extracted under either a fee or Federal oil and gas lease, depending on the non-coal minerals ownership. This determination was made by the Department of the Interior's (DOI) solicitor, after examining the relevant Federal statutes. The determination states that U.S. reservations of coal do not include the CBM. However, Federal reservations of gas do include the CBM found in coal deposits. The CBM is therefore disposable as a gas under Section 17 of the Mineral Leasing Act (DOI 1981). As a result where the coal and oil and gas are federally owned, Federal oil and gas lease regulations cover the CBM. CBM operations and production under a Federal lease are subject to the regulations governing conventional oil and gas drilling and production operations (Cohen et. al. 1984).

The Mineral Leasing Act (MLA) of 1920 was determined in 1981 by the DOI solicitor to refer only to gas or natural gas, without excluding CBM (DOI 1981). Additionally, the standard Federal oil and gas lease allows the lessee to drill for, extract, and dispose of any oil and gas, except helium. Therefore, since 1981 CBM gas has been developed under the oil and gas leasing provisions of the Mineral Leasing Act.

The DOI Solicitor also concluded that the coal leasing requirements of the MLA do not grant the coal lessee the right to extract minerals associated with coal (Kemp and Peterson 1988). The Solicitor clarified that the requirements do not authorize a coal lessee to extract CBM, other than the venting of gas required to maintain a safe working atmosphere. It was also pointed out in the determination that the oil and gas lease holder does not have the right to extract the CBM utilizing a method that would harm the coal deposit or generate hazardous conditions for later coal mining operations. In conclusion, the Solicitor affirmed that the rights of an oil and gas lessee would be restricted to the rights not previously granted to the coal lessee (Kemp and Peterson 1988).

Since this determination was made the MLA has provided the framework for authorization and management of CBM operations on federal lands. The MLA serves as the umbrella regulation for all Federal agency policies regarding fluid minerals development. BLM and U.S. Forest Service managed lands and other lands owned by the U.S. are available for CBM production under the MLA. BLM manages the majority of the federal mineral estate and is the primary agency responsible for developing and implementing land management plans. BLM's management of federal lands is also governed by the Federal Land Policy and Management Act (FLPMA). The National Environmental Policy Act (NEPA) addresses the procedures required to evaluate impacts on federal lands. Activity in national forests follows the National Forest Management Act (NFMA), which guides development operations. However, before drilling can take place on fee or federal lands numerous documents must be drafted and decisions made, including revisions to land use plans, leasing determinations, Environmental Assessments or Impact Statements, Surface Owner Agreements, Plans of Development (POD), and Applications for Permit to Drill (APD). Several of these steps require public involvement and have provisions for public feedback.

Land Use Plans

The BLM and Forest Service maintain Land Use Management plans for all property under their jurisdiction. These plans known as Resource Management Plans (RMPs) or Land and Resource Management Plans (LRMPs), respectively, are the principal documents used to govern the development of mineral extraction on federal lands including CBM. BLM RMPs are developed following the requirements of section 202 of FLPMA. Forest Service LRMPs are drafted in accordance with NFMA. Land Use Plans typically include discussions of expected land uses, such as livestock grazing, wilderness study areas, and mineral extraction. Opening areas to activities addressed in the plans usually requires conducting an Environmental Assessment (EA) or Environmental Impact Statement (EIS) following the requirements of the National Environmental Policy Act (NEPA). Figure 22 shows the BLM RMP areas for the Rocky Mountain States, each area has a land use plan which addresses the specific development actions within their boundaries. The figure also shows shadows of the coal basins.

In a formal EIS process, the lead agency must state the "reasonably foreseeable development" (RFD) scenario that is anticipated from allowing lands to be developed. The EIS addresses impacts to the land based on the agency's prediction as to where and how development will occur.

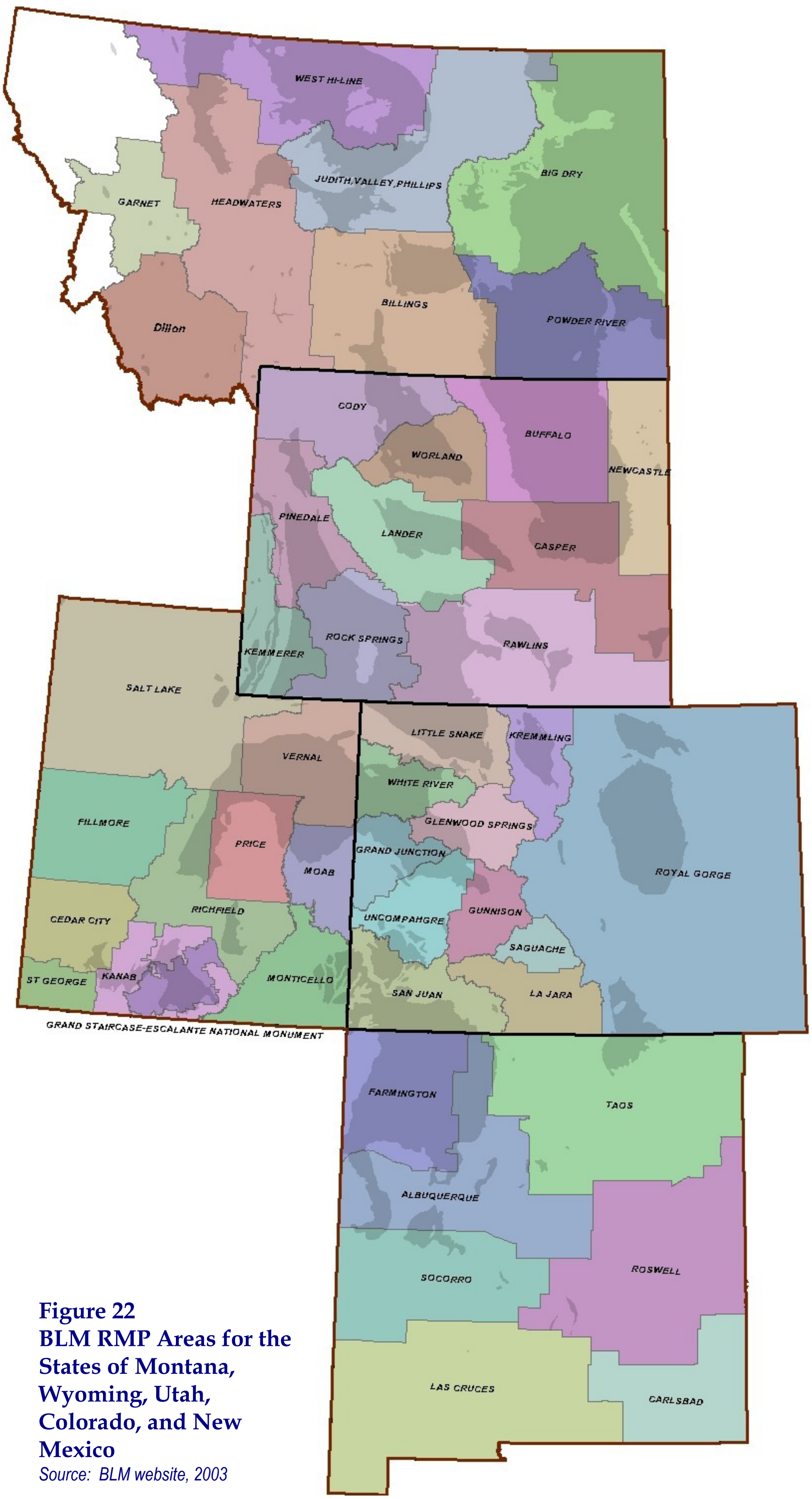


Figure 22
BLM RMP Areas for the States of Montana, Wyoming, Utah, Colorado, and New Mexico
Source: BLM website, 2003

Typically, agencies provide alternatives, which can be compared with one another to assess the impact potential of various approaches. CBM development has been very rapid in the Rocky Mountain region and most existing RMPs/LRMPs did not foresee or address the impacts from this level of CBM development. Recent EISs have been completed for the Southern Ute Tribe in the San Juan Basin and for the States of Montana and Wyoming. Additionally, several CBM related EISs and/or RMP/LRMP updates are planned for USFS and BLM areas throughout the Rockies in the coming year.

NEPA and the EIS Process

The National Environmental Policy Act of 1969 requires all federal agencies to conduct an EA or EIS when proposed actions may have an impact on man's environment. EIS' have recently been conducted for actions such as CBM development throughout a RMP area or when lands are opened to previously unconsidered oil and gas leasing activities. EAs are conducted for new development scenarios proposed within areas covered by an EIS, unless the proposed action was not adequately addressed in the original EIS or land use plan. NEPA affects leasing decisions, although it is often contested whether an EIS or an environmental assessment is appropriate. Federal courts have issued contradictory rulings on the issue.

Photograph of typical CBM well head in Wyoming with pronghorn antilope (*Antilocapra Americana)*

The EIS process considers the proposed action whether it is leasing or development, and attempts to quantify the impacts under various alternatives for several natural resources. A typical EIS may address impacts to the following: air quality, cultural resources, environmental justice issues, geology and minerals, hydrology (surface- and ground-water), Indian Trust assets, lands and realty, livestock grazing, noise, paleontological resources, recreational opportunities, social and economic values, soils, vegetation, visual quality, wilderness study areas, and wildlife. Mitigation is then applied via standard lease stipulations or other measures such as agency guidelines or by imposing new mitigation measures to the alternative approaches. It is important to note that the EIS process is not designed to eliminate all impacts from the proposed action but to quantify the residual impacts so a balanced decision can be made with regards to the proposed action.

Following the impact analysis a comparison of the alternatives is conducted using residual impacts (impacts after mitigation). By comparing residual impacts from various different alternatives, decision makers can assess the various components of each alternative and either choose one or develop a different approach based on portions of the analyzed alternatives. When a decision is made it is drafted in a document referred to as the Record of Decision (ROD), which is used to update the RMP/LRMP with the addressed changes (CEQ 2002).

During the EIS process the public is provided several opportunities to state their concerns and help design the scope of the impact analysis. Usually, the lead federal agency will hold public scoping meetings throughout the area that will be affected by the proposed action. The public scoping meetings are the first opportunity for citizens to express their concerns with the proposed action and to request impact analysis for various resources. This is also the appropriate time for citizens and special interest groups to provide the lead federal agency with data and special reports to be included in the impact analysis. The purpose of these meetings is to gather information regarding issues the public is particularly concerned with, and to exchange information with the public for project clarification. After all the scoping meetings are held the public scoping comments are entered into a database where they can be grouped by topic and analyzed. A scoping report detailing the public concerns is typically issued and the impact analysis is designed to encompass all the applicable concerns.

It is possible for some concerns to be outside the scope of the intended EIS and therefore not considered in the analysis. For example, if the proposed action addresses a resource development scenario i.e. gas, and the public comment requests that a particular area be excluded from leasing, this may not be possible to analyze under the current development EIS. Typically, a leasing EIS is conducted prior to determining which lands will be developed for which resources or multiple resources. If a leasing EIS has been conducted and a particular area was designed for gas development it would not be appropriate to revisit that determination when a gas development action is proposed.

The next opportunity the public has to comment is typically at the Draft EIS stage, unless supporting technical reports have been conducted. Supporting technical reports are issued in draft form and the public is provided an opportunity to review the findings and submit comments. Regarding the Draft EIS, there is a 90-day public review period built in for EIS' which will result in a management plan amendment. Anyone who requests a copy of the Draft EIS is provided one, and has until the deadline to submit comments. These comments are grouped by topic, and similar comments are paraphrased into a public concern statement (PCS). A PCS can cause various actions to be taken, the most common of which is a reanalysis of a portion of the EIS; a clarification added to a specific section; an explanation regarding where information can be found or why the PCS is not relevant to the analysis. In either case, all PCSs are specifically addressed in the Final EIS and all citizens who submitted comments are typically listed.

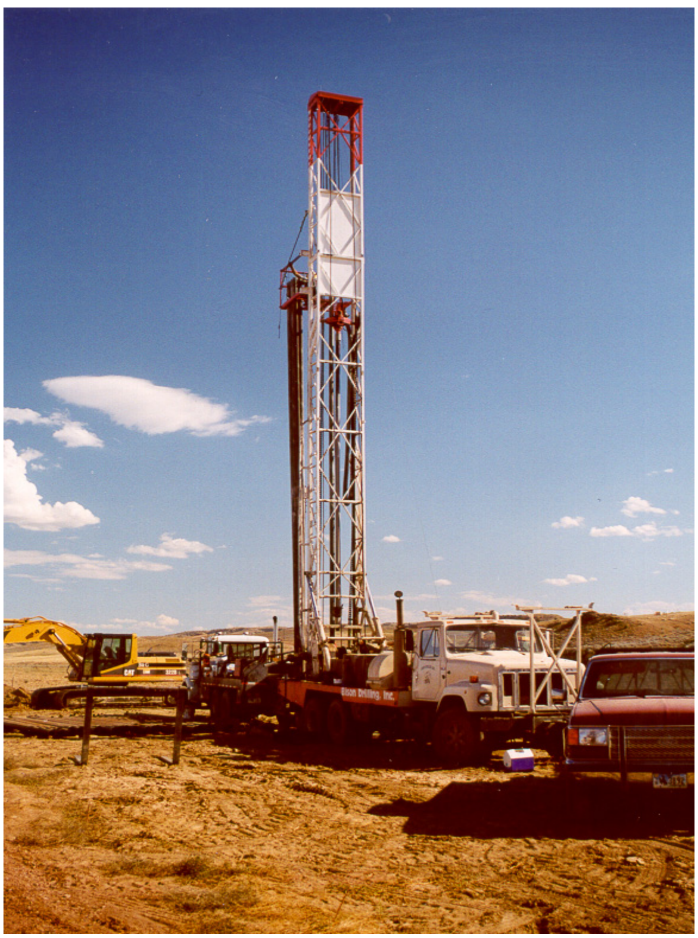
Once the Draft EIS has been modified based on public feedback a Final EIS is issued. A 30-day protest period is generally incorporated into this process to allow the public a final opportunity to express their concerns with the proposed action. Following the protest period a ROD is issued, effectively changing the land use plan and adopting the preferred alternative or a combination of actions derived from the various alternatives.

Photograph of CBM well cluster CX Ranch Montana

Leasing

Leases issued on federal land are competitively bid in accordance with the Federal Onshore Oil and Gas Leasing Reform Act (FOOGLRA) of 1987. Federal environmental laws are generally incorporated into standard lease terms. However, lease terms may be augmented with additional mitigation measures to minimize specific foreseen impacts (FOOGLRA 1987). These added mitigation measures can include special or supplemental stipulations suggested by State or local governments. Standard lease terms provide the lessee the right to access the leased land to explore, drill, and extract oil and gas resources beneath the surface.

Leasing decisions can be disputed in court and are often challenged by special interest groups. If the lead federal agency fails to conduct adequate environmental analysis before issuing leases a court decision could bring a halt to the proposed development. In fact, this very scenario was recently played out in the spring of 2002 in Wyoming. The Wyoming Outdoor and Powder River Basin Resource Councils challenged three BLM issued CBM leases as being based on inadequate environmental data (IBLA 2002). The Interior Board of Land Appeals (IBLA) found that the two BLM reports that the agency based their leasing decisions on were not sufficient to provide the necessary pre-leasing NEPA analysis (IBLA 2002). The decision effectively stopped existing leasing, and questioned whether the analysis process the BLM follows is adequate for the thousands of anticipated new leases. Consequently, the Wyoming BLM could not depend on those documents to fulfill its commitments under NEPA. The Wyoming BLM issued a new CBM Final EIS in February 2003 to clarify the issues.



Typical truck mounted drill rig used for shallow CBM wells

Development

Before a gas developer can drill an exploration well or develop a field an Application for Permit to Drill (APD) must be submitted along with a Plan of Development (POD). Exploration and development of CBM resources on BLM minerals are allowed subject to agency decisions, lease stipulations, permit requirements, and surface owner agreements. In the newly issued Montana and Wyoming RODs operators are required to submit a POD outlining the proposed development of an area (BLM 2003a./b.). PODs are required when the development spacing proposed is tighter than 1 well per 640 acres. The PODs are to be developed in consultation with affected Tribes, affected surface owner(s), and other involved permitting agencies.

A step-by-step guideline for preparation of the POD was recently issued by the Buffalo, WY and Miles City, MT BLM offices, respectively (Breisch 2003). PODs are required to be submitted in draft form so that they can be reviewed and any changes made prior to allowing surface disturbing activities. Key components to a PODs include:

- An APD (form 3160-3) for each federal well in the project area
- An application for permit form for all state and private wells
- A list of all other permitting agencies involved in the project and the point-of-contact for each office
- A list of all existing wells in the project area, including monitoring wells
- Maps showing proposed roads, compressor stations, pipelines, powerlines, CBM well locations, all existing wells, current and proposed monitoring wells, surface ownership, mineral ownership, surface features, and existing structures
- Master drilling and surface use information as required by Onshore Order No. 1 (for BLM lands)

- A Reclamation Plan for surface disturbance
- A wildlife monitoring plan demonstrating how the project will meet the needs of the BLM Wildlife Monitoring and Protection Plan (WMPP) for BLM lands
- A Water Management Plan for the project area
- Surface owner agreements, including water well agreements (or notice that the Surface Owner Damage and Disruption Compensation Act applies and surface owner agreements are pending settlement or court action)
- A list of all potentially affected surface owners within the project area
- A cultural resource plan addressing identification of strategies commensurate with the level of the proposed development
- BLM also requires compliance with Onshore Oil and Gas Order Number 7 (Disposal of produced water)

Draft PODs are used by the lead federal agency to analyze the local cumulative effects of a proposed development project, and to evaluate ways to further reduce these effects such as requiring companies to consider alternative beneficial uses of production water in the case of CBM development (Laakso 2003). A team of interdisciplinary professionals comprised of land planners, environmental scientists, geologists, biologists, archaeologists, hydrologists, wildlife specialists, cultural specialists, engineers and others evaluate the PODs, perform on-site inspections, and conduct field monitoring (Bloom 2003). Onsite inspections conducted by the lead agencies personnel may activate alterations of the APD or conditions of approval. Prior to approving the APD, the lead agency will also verify that the required performance bond is in place.

Laws Governing Water

The Clean Water Act (CWA) of 1987, as amended, establishes objectives to restore and maintain the chemical, physical, and biological integrity of the Nation's Water. In accordance with the CWA, CBM extraction is controlled by water quality standards so that designated uses of water are protected. Standards include both numerical and narrative descriptions. Numerical standards are directed at controlling the daily pollutant discharges from point sources to ensure that total pollution levels are not exceeded. Numerical standards usually take the form of pollution limits or total maximum daily loads (TMDLs). Currently most Rocky Mountain States are still in the process of developing their TMDLs as per EPA Region VIII requirements (EPA 2001). Narrative standards are typically written to prevent the degradation of current water quality and protect established uses of the surface water (MDEQ 2002).

CBM developers must determine what they are going to do with their excess production water and at that point various other water laws apply. For example, if they decide to discharge produced water into the surface waters of the state they will have to obtain a National Pollution Discharge Elimination System (NPDES) permit from EPA. State Water Quality Standards and effluent volume limits will be applied to the NPDES permit, however at present there are no scientifically established effluent standards for CBM discharges. To ensure that State Water Quality Standards are not violated the permits will have effluent limitations attached.

Photograph of typical CBM wells co-located with injection well, Wyoming

In the Powder River Basin the BLM chose to draft two EISs because of the differences between Montana and Wyoming state law and various other reasons (BLM 2003 a./b.). In Wyoming, for example CBM produced water is not regulated by numeric standards, WDEQ simply requires that CBM produced water does not degrade designated uses of surface water. Montana, on the other hand, has numeric standards for some constituents in produced water and therefore Wyoming operators are required to comply with Montana regulations since they are downstream. The two states have negotiated an 18-month interim memorandum of cooperation (expires in early 2004) intended to protect the quality of the downstream watersheds (BLM 2001). Often irrigated agriculture is the most sensitive beneficial use for surface waters and therefore downstream water quality standards are based on vegetation changes.

The Clean Water Act requires applicants to obtain a certification stating that their activities will comply with the Clean Water Act. The certificate is issued from the state where the discharge originates. Requirements initiated by the state become part of the federal permit and are enforced by either the BLM or Forest Service. Additionally, operators must receive a 404 permit the Corps of Engineers anytime they dispose of or deposit fill into the waters of the U.S.

The Federal Water Pollution Control Act requires federal land managers to comply with all Federal, State, and Local requirements, administrative authorities, process, and sanctions regarding the control and abatement of water pollution in the same manner and to the same extent as any nongovernmental entity. The BLM requires all operators to obtain appropriate water handling, discharge and injection permits prior to submitting their Application for Permit to Drill (APD).

The Safe Drinking Water Act (SDWA) is designed to make the nation's waters "drinkable" as well as "swimmable". Amendments in 1996 established a direct connection between safe drinking water and watershed protection and management. The SDWA regulates the re-injection of produced water from CBM production. Underground injection is permitted under various well classes depending on the quality of the injectate and the zone where the fluid is injected: Part C of the SDWA attempts to protect underground sources of drinking water by requiring permits for all underground injection of liquids. There are five classes of injection wells under these regulations, the majority of CBM produced water is injected via Class II wells. Class II wells handle liquids that are produced as a by-product of oil and gas operations or are used in enhanced recovery.

The EPA conducted a study of the environmental risks to underground sources of drinking water (USDWs) when hydraulic fracturing is used to enhance CBM recovery. The study was prompted by complaints that CBM development has altered water quality in some drinking wells. The goal of EPA's nationwide hydraulic fracturing study was to determine if a threat exists to public health, as a result of aquifer contamination from the narrow practice of hydraulic fracturing, as it relates to CBM wells, and if so, is high enough to warrant further study (EPA 2002b). The process of hydraulic fracturing involves forcing fluids under pressure into subsurface cracks utilizing the wellbore tubulars, treated fluids and surface pumps to form pathways for the natural gas and water to reach the well.

EPA's final report published in October 2002 states that they reviewed claimed incidents of drinking water well contamination and found no confirmed cases, despite the thousands of fracturing events that have been conducted on CBM wells during the past decade. EPA also assessed the theoretical potential for hydraulic fracturing to contaminate drinking water wells. Two potential scenarios by which hydraulic fracturing may effect aquifer water quality were evaluated: (1) the injection of fracturing fluids directly into a aquifer, and (2) the creation of a hydraulic communication through a confining layer between the target coal bed formation and adjacent aquifer. EPA's determination is that the threat of contaminating drinking water supplies by CBM hydraulic fracturing activities is low. Studies have found no observed breach of confining layers from hydraulically-created fractures, consistent with theoretical understanding of fracturing behavior (EPA 2002b).

Laws Governing Air

The Clean Air Act (CAA) of 1990, as amended, requires Federal agencies to comply with all Federal, state, and local requirements regarding the control and abatement of air pollution. This includes abiding by requirements of the State Implementation Plans. Potential changes in ambient air quality from CBM activities, such as reduced visibility, air quality emissions, dust emissions, harmful gases, and changes in climate are evaluated in the BLM EISs.

Photograph of typical CBM field compressor station

Air pollution emissions are limited by local, state, tribal and federal air quality regulations, standards, and implementation plans established under the CAA. These rules are administered by the State via Environmental Quality Departments and the EPA. Air quality regulations require certain proposed new, or modified existing, air pollutant emission sources (including CBM compression facilities) to undergo a permitting review before their construction can begin. Therefore, the applicable air quality regulatory agencies have the primary authority and responsibility to review permit applications and to require emission permits, fees and control devices, prior to construction and/or operation.

In addition, the U.S. Congress (through the CAA Section 116) authorizes local, state, and tribal air quality regulatory agencies to establish air pollution control requirements more (but not less) stringent than federal requirements. Site-specific air quality analysis would be performed, and additional emission control measures, including a best available control technology (BACT) analysis and determination, may be required by the applicable air quality regulatory agencies to ensure protection of air quality resources. Also, under the Federal Land Policy and Management Act (FLPMA) and the CAA, BLM cannot authorize any activity that does not conform to all applicable local, state, tribal, and federal air quality laws, regulations, standards, and implementation plans.

The significance criteria for potential air quality changes include local, state, tribal, and federally enforced legal requirements to ensure that air pollutant concentrations remain within specific allowable levels. These requirements include the National and State Ambient Air Quality Standards, which set maximum limits for several air pollutants, and PSD increments, which limit the incremental increase of NO_2, SO_2, and PM_{10} concentrations above legally defined baseline levels. Where legal limits have not been established, the BLM uses the best available scientific information to identify thresholds of significant adverse impacts.

Endangered Species Act

As required by Section 7 of the Endangered Species Act (ESA) of 1973, the BLM and Forest Service must prepare and submit a Biological Assessment to the U.S. Fish and Wildlife Service (FWS). The biological assessment defines the potential impacts to threatened and endangered species as a result of management actions proposed in the RMP/EIS. Perceived impacts to threatened and endangered species are required to be mitigated or management actions altered to reduce impacts.

In addition to complying with the ESA and consulting with the FWS, lead agencies often develop Wildlife Monitoring and Protect Plans (WMPP) which outline the steps they will take to ensure threatened and endangered species as well as candidate species are protected (BLM 2003b). WMPP may also require operators to conduct periodic surveys for various plant and animal species and alter their operations if observations indicate increased impacts (BLM 2003b).

Photograph of endangered Ute ladies-tresses orchid, Spiranthes diluvialis (Photograph provided by BLM)

Antiquities Act

The Antiquities Act of 1906 protects cultural resources on Federal lands and authorizes the President to designate National Monuments on Federal Lands. The BLM EISs completed for CBM development in Montana and Wyoming have requirements for the POD to include provision for a cultural resource plan addressing identification strategies commensurate with the level of the proposed development (for BLM lands) (BLM 2003a./b.). Developers are required to use a qualified archeologist to conduct a study of their proposed CBM field and identify any cultural resources present. The survey finds are incorporated in the APD and reviewed prior to issuing permission to drill. The identification and protection of these important sites meets the requirements of the Antiquities Act.

National Historic Preservation Act

Lead federal agencies must complete the process for considering the effects of the development action on historic properties as required by Section 106 of the National Historic Preservation Act (NHPA). The area of potential effect has to be reviewed and all existing inventory data scrutinized, historic properties identified also need to be reviewed, and interested parties consulted. Consultation under Section 106 of the NHPA for CBM development is usually required with the State Historic Preservation Office (SHPO), the Advisory Council on Historic Preservation (ACHP), affected Tribes and other interested parties (Federal Register, 1983).

BLM has a National Programmatic Agreement in place with most Western state SHPOs and the ACHP. The agreement states that there would be no new disturbance of historic properties not previously considered, and outlines survey procedures to be followed for all new oil and gas developments.

Tribal Resources

The Indian Mineral Leasing Act of 1938 and the Indian Mineral Development Act of 1982 govern the development of CBM on tribal lands. A dual legal system of federal and tribal laws control energy development on tribal lands. The Bureau of Indian Affairs (BIA) is required under these acts to authorize energy leases. NEPA regulations also apply to any energy development decisions made for Tribe lands. Under certain federal laws such as the CWA and CAA, qualifying tribes can obtain states status and draft more stringent environmental laws. The Tribes are also responsible for enforcement and may regulate their lands in areas not covered by federal laws or programs (BOR 1994).

Rock art near Blackleaf Canyon, Montana

Indian lands can also be owned by individual Indians pursuant to Federal statute or treaty providing for the distribution of tribal property in severalty or pursuant to the General Allotment Act of 1887. An allotted parcel of land may be owned by the United States in trust for an individual Indian (trust allotment) or owned by the individual subject to certain restrictions. Allotted Indian lands may be leased for the development of oil and gas (25 CFR 214.2 – 212.6) and other minerals pursuant to the Indian Leasing Act of 1909 or the Indian Mineral Development Act of 1982.

American Indian Religious Freedom Act

The American Indian Religious Freedom Act (AIRFA) was passed as a joint resolution of Congress. The resolution states that it shall be the policy of the United States to protect and preserve for the American Indian the inherent right of freedom to believe, express and exercise their traditional religions, to use sacred objects and to worship through ceremonies and ritual. Federal agencies comply with this Act by consulting with and considering the views of American Indians when proposed land uses might conflict with traditional American Indian religious beliefs or practices. The Act does not require that land uses be denied, if it conflicts with such religious beliefs or practices.

Split Estates

Many federally administered minerals, including oil and gas rights, underlie privately owned surface. In addition, in many Western states, federally administered surface lands greatly exceed private and state lands. Furthermore, Western states, recognize separate ownership of surface and subsurface (or mineral) estates and the unique private property rights connected with each. Often, different parties own the surface and the subsurface. This is commonly referred to as “split estate” or "severed minerals". The ownership differences are commonly the result of the U.S. government reserving minerals when the lands were originally patented, or may be the outcome of a decision by a previous landowner to separately sell or lease the subsurface mineral interest. In the area of emphasis in the Western U.S., the federal government frequently withheld mineral interests on homestead land, which resulted in large areas of CBM plays in split estate.

A mineral estate provides property rights to selected natural resources lying on or below the earth's surface. A transfer of the mineral estate may be accomplished without transfer of the surface estate. For example, a landowner may sell or lease the rights to natural gas or oil found under the surface to an oil company. Later, the same landowner can sell the surface to a purchaser and reserve the rights to all coal that may be found under the land. After these transactions, three parties have ownership interests in this piece of real estate: (1) the oil company owns the oil and gas; (2) the seller owns the coal; and (3) the purchaser owns the surface.

An easement is a property interest that one party has in land owned by another, entitling the holder of the easement to use the other's land. Easements are typically in writing, usually in the form of a separate document or by a reservation in a deed. Thus, an easement is an interest in land rather than a mere contractual agreement. When easements are properly created and recorded they are transferred with a land sale and remain in effect.

A right-of-way is a type of easement conveying the right or privilege, acquired through accepted usage or by contract, to pass over, through or under a designated portion of the property of another. A right-of-way may be either private, as in an access easement given a neighbor, or public, as in the right of the public to use the highways. For example, a gas company might send its agents to meet with landowners and negotiate the purchase of rights-of-ways or easements for a pipeline. Under Federal law, the mineral estate is dominant (Straube and Holland, 2003), therefore surface owners cannot deny access to developers, but may demand compensation for that access. In many states the oil and gas or CBM operator is required to obtain a Surface Use and Damage Agreement with the land owner or owners. Due to the senior estate, the holder of CBM interests can obtain access to the property by way of court action if the CBM operator has shown good faith in attempting to make an agreement with the land owner and been denied. Surface access may include drilling site, pits, roads, and pipelines.

Split ownership is a common phenomenon. Fifty-eight million acres of privately owned property are split estates where the federal government owns some or all of the mineral estate. That is 6 million more acres than are contained in the State of Kansas and represents 1/8 of all privately owned land in the U.S. The federal government owns mineral rights to 744 million acres, equivalent to 29 percent of all the land of the U.S. Most of the split estates are located in the Western U.S. and many overlap prime CBM locations, see table 3.

Tables 3

SPLIT ESTATES -The BLM manages (controls) subsurface acreage of privately owned land as follows:

State	Acreage
Arkansas	1 in 9 acres
California	1 in 19 acres
Colorado	1 in 6 acres
Idaho	1 in 4 acres
Montana	1 in 5 acres
New Mexico	1 in 4 acres
North Dakota	1 in 8 acres
Oregon	1 in 14 acres
South Dakota	1 in 24 acres
Utah	1 in 11 acres
Wyoming	1 in 2 ¼ acres

AK, NE, NV, OK, WA and Eastern states AL, FL, IL, IN, IO, KS, LA, MI, MN, MS, MO, OH, WI. Split estates total 920,000 acres, representing small to very small fractions of privately owned land.

Source: http://www.blm.gov/natacq/pls02/pls1-3_02.pdf

State Regulations

State oil and gas commissions and boards were created out of conservation statutes and were intended to oversee oil and gas operations by establishing drilling units and providing well permit regulations. Oil and Gas commissions/boards were commonly established to maintain a level playing field for all owners to pursue oil and gas production, to prevent the waste of oil and gas resources, and to prevent the drilling of unnecessary wells. The responsibilities of the boards have changed as production has matured to include the regulation of drilling, casing, plugging and abandonment of wells and in some States the administration of the Underground Injection Control Program. Additionally, some boards may be tasked with protecting the rights of surface owners. The different Rocky Mountain state boards involved in overseeing CBM development are charged with varying statutory provisions:

Colorado: the role of the Colorado Oil and Gas Conservation Commission (COGCC) is to promote production and prevent and/or encourage the mitigation of adverse environmental impacts. The COGCC was originally created to foster, encourage, and promote the development, production, and utilization of oil and gas, however, in 1994 its mandate was expanded to include the prevention and mitigation of significant adverse environmental impacts on any air, water, soil, or biological resource resulting from oil and gas operations. The 1994 mandate also called for the COGCC to investigate, prevent, monitor, or mitigate conditions that threaten to cause, or that actually cause, a significant adverse environmental impact (Colo. Rev. Stat.)

Montana: Montana passed the Montana Oil and Gas Conservation Act in 1953 establishing the Board of Oil and Gas Conservation (MBOGC). The act authorizes the MBOGC to require a drilling permit before any oil or gas exploration, development, production, or disposal well may be drilled. MBOGC's mandate includes the prevention of oil and gas resource waste, encouragement of the efficient recovery of oil and gas, and the protection of owner's rights to recover their share of the resource. The MBOGC oversees the Underground Injection Control Class II program for oil and gas production water. The MBOGC also issues field rules and guidelines to prevent contamination of or damage to the environment caused by drilling operations. The State of Montana also has a State environmental policy act similar to NEPA which requires its state agencies to complete environmental analyses prior to approving management actions (Mt. Admin. Code Annotated).

New Mexico: The Energy, Minerals and Natural Resources Department of New Mexico contains the Oil Conservation Division and the Oil Conservation Commission. The Commission and Division regulate the conservation of oil and gas and handling and disposal of wastes generated by oil and gas operations. They also establish guidelines and field rules for the protection of public health and the environment (N.M. Stat. Ann.).

Utah: There are two agencies in Utah which govern the testing, spacing, drilling, completing, locating, operating, producing, and plugging of wells as well as the disposal of salt water and field wastes. These agencies are the Board of Oil, Gas and Mining and the Division of Oil, Gas and Mining. The Board has set rules requiring operators to "take all reasonable precautions to avoid polluting lands, streams, reservoirs, natural drainage ways, and underground water". The Board also attempts to encourage the development of surface use agreements with landowners but has not adopted statewide standards for reclamation (Utah Admin Code). The division serves in a technical and administrative capacity with regards to well development.

Wyoming: The Wyoming Oil and Gas Conservation Commission (WOGCC) regulates the drilling, casing, spacing and plugging of wells, it also requires operators to furnish a reasonable bond for plugging each dry or abandoned well. The WOGCC also monitors well performance throughout the state and regulates the production, as well as the perforating and chemical treatment of wells, disposal of production water and drilling fluids, and the protection and conservation of underground water. The WOGCC has a responsibility to encourage the development of natural gas and to prevent the waste of this resource. According to WOGCC rules the operator cannot pollute streams, ground-water, or unreasonably damage or occupy the surface. The WOGCC is also tasked with keeping natural gas from polluting or damaging crops, vegetation, livestock, or wildlife. (WOGCC Rules)

CBM Well produced water discharge point, Powder River Basin, Wyoming

State Water Laws

Of particular concern regarding CBM produced water is its affects on water rights. Water rights are governed under the prior appropriation approach to water law in all the Rocky Mountain States. The prior appropriation approach refers to the creation of water rights by usage or diversion, for a beneficial purpose, thus, ownership of land does not guarantee ownership of water. Prior appropriation primarily refers to surface waters; groundwater that is produced generally is not subject to appropriation, but belongs to those who produce it, unless otherwise specified. The key stipulations of prior appropriation fall under the general categories as follows:

- Purpose
- Date
- Quantity
- Beneficial Use
- Acquisition
- Transfer

Purpose – The purpose for appropriating waters does not need to be for riparian lands; waters may be diverted to any location and do not need to be used in the watershed from which they are drawn. A practical means of diverting the water which is both direct and efficient is generally required.

CBM produced water being aerated in the Powder River Basin, Wyoming

Date - The water right priority date is established based on the date of the original appropriation. Right-holders are either senior or junior to other right holders depending on the date of their appropriation. The oldest or senior water right is guaranteed conveyance of the full right; junior right-holders are permitted to obtain water from the remaining available source only after senior rights-holders have withdrawn their water. Upstream junior right-holders are required to allow adequate amounts of water to flow past their capture points to meet downstream senior rights.

Seniors are not permitted to reduce the volume of water available for juniors. This may restrict the senior's ability to transfer their rights, change diversion, purpose, or place of use. A large portion of water in the west is diverted for agriculture and typically about half is returned to the hydrologic cycle. The return flow may have been "called" by other right-holders, and therefore senior right-holders are not permitted to adversely affect the return flow; junior right-holders should receive their full appropriation based on the stream conditions that existed when they established their right.

Quantity - A water right is the volume put to a recognized beneficial use; there are no restrictions to the quantity of water used as long as it is reasonable for the intended use. Most state statutes, however, stipulate that right-holders must show via records that the water appropriated is put to a beneficial use and not misspent.

Use/Non-use - Beneficial use is generally defined as agricultural, irrigation, commercial, domestic, industrial, municipal, mining, hydropower production, recreation, stockwatering and fisheries, wildlife and wetlands maintenance. Conservation of environmental and visual resources have also recently been included as beneficial use. Beneficial uses are not ranked and one does not outweigh another, therefore, junior claims can not displace a senior right by stating their use is more beneficial. However, right-holders can lose their appropriation if their diversion method or purpose is determined wasteful. Restrictions are also placed on the use of water for environmental protection and recreational uses by the public trust doctrine.

Acquisition – Recognition of a water right is generally accepted when an appropriator obtains a permit or ruling from the appropriate state engineering office or is acknowledged by a court that the water is being used for a beneficial purpose. The majority of Western states require rights-holders to apply for a permit.

Generally the appropriator must notify all affected parties, construct a diversion facility within a specified time period, and put the water to beneficial use. If these requirements are met a hearing is held to review the criteria and establish the right.

Colorado uses a water court system to decide rights, instead of issuing permits. Seniority is recognized when the appropriator puts the water to beneficial use, and makes a physical demonstration of the intent to divert the water.

Colorado also allows water to be reserved for future use under a "conditional decree". The right is established on the date of the decree, however, appropriators need to prove that there is a significant likelihood that the project will be finished within a evenhanded timeframe. The court must also, decide if there is enough water available for the proposed diversion.

Water rights obtained through use, may be forfeited by non-use. Forfeiture can occur when there is non-use for a specific time-period or if the diversion is not constructed in time, but in either case does not require the appropriator to intentionally abandon the water right. Abandonment, on the other hand, can be initiated by the right-holder if they intend to surrender the water right.

Transfer - Water rights can be transferred to new land owners when land is sold, but does not have to be if the right-holder specifically reserves those rights. Furthermore, water rights may be transferred separately from the land if allowed by state law.

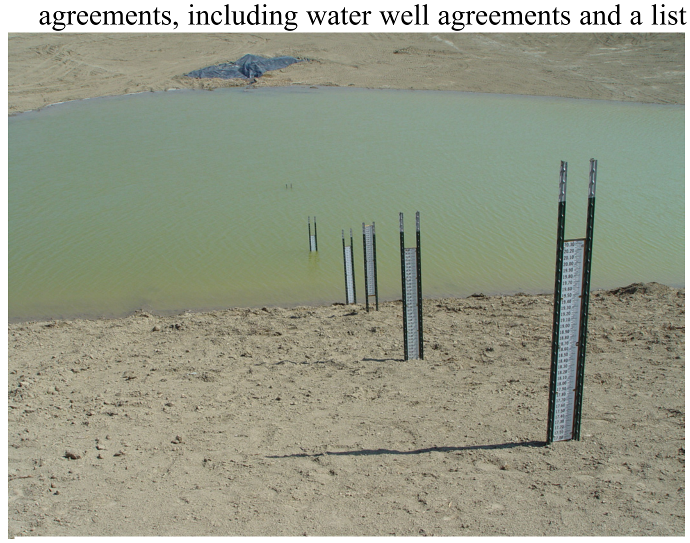
COLORADO WATER LAW

Colorado water law does not require operators to obtain a permit from the state engineer's office when producing or withdrawing non-tributary water except when that water is intended for beneficial use. If produced water is going to be used for a beneficial purpose, the state engineer needs to ascertain whether the use will cause a "material injury to the vested water rights of others" (Co. Rev. Stat.). If material injury is anticipated, the permit needs to include mitigation measures to protect the other right holders. It is important to note that a lowering of the hydrostatic pressure in an aquifer or reduction in groundwater level is not deemed a material injury. (Colo. Rev. Stat.)

Produced water falls under the Colorado Oil and Gas Conservation Commission's (COGCC) definition of "exploration and production waste." The COGCC jurisdiction over produced water is covered in Rule 907 which addresses the management and disposal of "E&P" waste. The rule includes various disposal options such as evaporation, infiltration, reinjection, commercial disposal, reuse and discharge into state waters. Evaporation and infiltration must take place in a permitted pit either lined or unlined and the produced water needs to be treated prior to reaching the pit to eliminate crude oil and condensate. Reinjection needs to be accomplished via a permitted Class II well. Commercial disposal may include dust control through road-spreading. Reuse generally refers to enhanced recovery or drilling but in both cases it must meet the water quality standards. Permits are required for all of these options. Additionally, the rule includes a provision which allows the surface owner to use the water as an alternative domestic water supply that cannot be traded or sold.

MONTANA WATER LAW

The Montana statutes directly address CBM wells and specifically protects groundwater from being wasted. However, under certain scenarios, including management, discharge, or reinjection of CBM water, the production and use of groundwater is not considered a waste. Currently CBM operators are given three choices for produced water management; (1) beneficial use, such as irrigation, stock water, dust control, wetlands protection, etc., (2) reinject via a permitted Class II injection well, or (3) discharge into surface waters of the state provided a NPDES permit is obtained. CBM operators are required to have a Water Management Plan for their project area, surface owner agreements, including water well agreements and a list



Unlined water retention/infiltration pond being filled, Powder River Basin, Wyoming of all potentially affected surface owners within the project area. Under the water well agreements the operators must replace any affected wells or offer other mitigation measures to avoid impacts to existing groundwater users (Mt. Admin. Code Annotated).

Montana law also recognizes the designation of controlled groundwater areas; areas where groundwater withdrawals exceed or are likely to exceed the recharge rate of the aquifers. Operators in these areas must obtain a permit in order to withdraw and appropriate water. The permit application needs to demonstrate that the water withdrawn is available, that existing uses will not be impacted, and that all produced water will be beneficially used.

New Mexico Water Law

Waters used for drilling, mining, or prospecting operations intended to discover or develop natural resources in the state are classified as beneficial. Under certain circumstances mine operators need to obtain permits to withdraw these waters. Aquifers at 2,500 feet below ground surface that contain non-potable water are outside the jurisdiction of the state engineer and do not require a permit to be produced. Most CBM wells in New Mexico are completed below 2,500 feet in non-potable aquifers, and therefore are not required to be permitted by the state engineer. Water produced or used in connection with drilling for or production of oil and gas falls under the authority of the Oil Conservation Division of the Energy, Minerals and Natural Resources Department. The division regulates the subsurface and surface discharge of producted water with the intention of protecting fresh water sources. All groundwater with a background concentration of 10,000 mg/l or less of Total Dissolved Solids (TDS) is protected and reserved for beneficial use. The injection of produced water into subsurface reservoirs is also regulated by the Division.

New Mexico law also has requirements fashioned to safeguard existing water rights during mineral development throughout the state. Under New Mexico's Mine Dewatering Act, any operator who desires to acquire water for a beneficial use or to dewater a mine has the opportunity to replace the waters of existing users which may be impacted (N.M. ST. ANN a. The cost to restore the water is solely the operators' liability, who must submit an application with the state engineer to replace water. Although, an operator may make an appropriation of water under this act, merely dewatering a mine does not create water rights for the applicant. The state engineer may only approve an application under this statute if he is satisfied that the water restoration plan will provide sufficient waters to the affected parties. Before the water restoration plan is approved the state engineer considers the following issues; characteristics of the aquifer, present withdrawals on the aquifer and their collective effects on water levels and water quality, the impact of the mine dewatering on the aquifer, and the present and future withdrawal from, recharge to and storage of water in the aquifer (N.M. ST. ANN b).

Utah Water Law

The Utah Board and Division of Oil, Gas and Mining has jurisdiction over byproduct water even though there is a groundwater appropriations system in place the state. The state engineer may under certain circumstances issue a temporary water right to put byproduct water resulting from mining development to a beneficial use. However, this can only happen after the water has been diverted from its original underground source. An assortment of rules has been developed by the Division to control the disposal of "salt water and oil field wastes," (Utah Admin. Code a) this includes CBM water. Produced water can be placed in lined pits, or unlined pits provided it does not

CBM well head equipped with radio monitoring system and field irrigation in background, Wyoming have a TDS content higher than the groundwater, that could be affected or contain other unacceptable components such as oil, grease, heavy metals, chlorides, sulfates, aromatic hydrocarbons or pH outside of an acceptable range (Utah Admin. Code b). If all, or a considerable part of the produced water is being used for beneficial purposes unlined pits may be used provided an analysis of the water has been preformed and indicates that it can be used for those purposes. Finally, unlined pits may also be used when the quantity of produced water is less than five barrels per day. Operators may also choose to inject the produced water into Class II injection wells under the state UIC program (Utah Admin. Code c).

WYOMING WATER LAW

Wyoming water regulations address byproduct water appropriations; however they do not apply to CBM produced water. The state engineer has jurisdiction over CBM produced water, and operators therefore are required to obtain a permit for groundwater appropriation. The Wyoming water law states that applications to acquire groundwater "shall be granted as a matter of purpose, if the proposed use is beneficial and, if the state engineer finds that the proposed means of diversion and construction are adequate" (WY. Stat. a). If the state engineer finds that the application would not be in the public's best water interest he may deny it (WY. Stat. b). Wyoming water law outlines beneficial uses by preference.

The importance assigned to putting appropriated groundwater to a beneficial use and preventing waste created problems for the initial CBM applicants. On the early versions of "Application for Permit to Appropriate Ground Water" (WY. Stat. c) forms, applicants were required to identify which beneficial use would be used. CBM operators routinely checked the "miscellaneous" box and explained that the water was used to produce CBM. Revised forms now have a box for CBM produced water. The Wyoming State Engineer has determined that a beneficial use is the production of water in conjunction with the production of the CBM.

LOCAL REGULATIONS

CBM development has been subject to county regulation in some areas while it has been contested in others. Some counties have placed regulations on operations which require special use, building, and road permits; establish visual requirements and address noxious weeds. La Plata and Las Animas Counties in Colorado have ratified regulations that restrict noise levels, establish air and water quality standards, address vibration and odor levels, institute access requirements, define visual impacts, require fire protection, and attempt to mitigate impacts to wildlife and public safety. Disagreements have transpired between the county and state officials and between the county and developers.

La Plata County was the first to adopt regulations regarding CBM development in 1991. These regulations were contested by several gas companies claiming that they were superceded by state and/or federal laws. The county was sued by the industry and the court upheld the county's authority. The county then issued new regulations in 1995, stating that surface owners must be given an opportunity to determine the specific sites where drilling and road construction could take place. The county was again sued, and this time the court found in favor of industry and struck down the regulations (Bryner, 2002). County officials explained that their objective is to tackle the impacts of CBM development on local communities and not to inhibit production.

Counties in other states may have broad regulations that effect CBM development, but have not developed specific regulations for CBM development. In Montana, local regulations are permitted if they guarantee actual use of resources. In New Mexico, counties can adopt regulations provided they address traditional issues currently within the jurisdiction of county government. In Utah, counties are prohibited from drafting regulations relating to state law, especially where the oil and gas board has exclusive authority. However it is foreseeable that Utah counties can regulate noise, appearance, traffic, and compatibility with surrounding activity.

In Wyoming, counties can not prevent the use of land for the extraction or production of mineral resources. Five Wyoming counties along with the State and two conservation districts have signed a Memorandum of Understanding (MOU) designed to coordinate the flow of information and provide consistency between agencies. These counties have hired a CBM coordinator to help resolve any problems. The coordinator has attempted to maintain regulatory consistency across the Powder River Basin.

BEST MANAGEMENT PRACTICES/MITIGATION

Typical Environmental Impacts vs Mitigation Measures

This section addresses the typical environmental effects associated with CBM development in the west and the mitigation measures employed to address these effects. Focus is on the influences from production and distribution affecting natural resources and local populations and the tension between opposing land uses and users. Vital to this discussion are the potential affects of CBM extraction on water quality and quantity, and the numerous mitigation measures employed to control and eliminate these concerns.

INTRODUCTION

Environmental resources altered from present-day conditions by CBM production practices have caused concern for federal, state, and local regulatory agencies; land and resource managers; industry; landowners; and the general public. Along with rising public awareness and more stringent regulations, increased pressure has been placed on those involved in the CBM industry to develop methodologies to accurately define specific areas of environmental risk as well as develop Best Management Practices (BMPs) and mitigation strategies to aid in minimizing and alleviating these risks. As a result, development of fundamentally sound BMP's and mitigation strategies that facilitate resource development in an effective, timely, and environmentally sensitive manner, have become increasingly important.

BMPs are defined as techniques, procedures, and sustainable strategic plans which are generally site specific, economically feasible, and are used to guide, or may be applied to, management actions to aid in achieving desired outcomes. Implementation of BMPs can be used to reduce adverse environmental effects or enhance beneficial effects resulting from CBM operations. Typically, available management options for BMPs are dictated by site-specific characteristics such as, land and mineral ownership, geologic and hydrologic conditions (including depth of coal seams), soil types, local and regional wildlife issues, etc., and project objectives and applicable regulations. In any case, effective use of BMPs can assure at a minimum, a basic level of maintainable environmental protection in a cost efficient manner. Although BMPs are often derived from Federal, State, or local standards, BMPs by definition do not constitute regulations and therefore, should only be considered as a guidance tool for protecting foreseeable affects to resources.

Mitigation measures are closely associated with BMPs and are best described as techniques, procedures, and sustainable strategic *practices* which are implemented upon formulation of environmentally sound BMPs. Mitigation measures, in all cases, are site specific and will vary depending on the type of disturbance, the degree of the disturbance, and the requirements of landowners or other involved parties. These practices are often implemented in phases or in a practical chronological order to ensure that the disturbances of a specific phase of a project is linked with the appropriate measures so as to maximize the efficiency and effectiveness of the mitigation (EPA, 2002c). As with BMPs, the objective(s) of mitigation measures are to aid or alleviate the consequence to various resources resulting from CBM project operations.

Effective use of BMPs necessitates careful planning and coordination with federal and state agencies, as well as between operators and landowners. From a functional perspective, successful mitigation are development of preventative or beneficial plans, that when implemented, maximize the number and magnitude of protected resources. As an example, immediately reseeding bare soils during construction activities or after a project's completion can help minimize erosion events that may occur during seasonal flooding. This practice can also aid in the reclamation of native vegetation, help prevent infestation of noxious weeds, reduce dust control issues, provide additional lands for livestock grazing, provide suitable habitat and food resources for certain wildlife species, and control sediment run-off to nearby water systems. With this cost effective and flexible approach, the quantity and quality of protected resources can be enhanced to meet or exceed expectations of affected landowners, resource managers, or public agencies.

To further augment the effectiveness of BMPs, many employers are now providing mitigation specific training to employees. The training opportunities assure that employees are proficient in contemporary, as well as traditional techniques, which include; dust and noise control, hazardous waste reduction, seeding, and construction "footprint" minimization. With this approach and minimal investment employers can help protect vulnerable resources while at the same time, maintain a high level of project efficiency.

There are many aspects of CBM exploration and development that present unique challenges to resource managers, landowners, and State and Federal agencies. BMPs and mitigation measures specific to the CBM industry have been developed, as an example, by the Bureau of Land Management (BLM), the Montana Board of Oil & Gas Conservation (MBOGC), and others to identify resource issues, provide guidance for potential mitigation strategies, and to further enhance related beneficial uses. Within these documents implementations of measures to mitigate effects are generally presented as a procedure that is based on industry or activity related issues specific to the CBM industry that may negatively affect or potentially enhance individual resources.

The discussion below redirects this approach by focusing on resource specific issues, as well as resource-specific mitigation strategies that can or are required to be implemented to minimize disturbances to these resources. It is hoped this approach will help better define and clarify CBM related resource issues in a manner that will benefit landowners, operators, and federal or state agencies. This concise discussion should not be considered exhaustive since additional measures may also be identified during CBM development or in the NEPA process.

Beneficial Use

During the production of CBM, groundwater is extracted from coal seam aquifers to facilitate the release of methane gas trapped under hydrostatic pressure. Development of new CBM fields typically generate large volumes of water that may represent an opportunity for operators to provide themselves, the landowner, and nearby industry with water that does not result in the waste of this resource. The ability of a CBM operator to provide CBM produced water for uses by industry, landowners, or other parties, can provide unique and substantial benefits.

The water produced from CBM wells varies from very high quality (meeting state and federal drinking water standards) to low quality, essentially unusable (with Total Dissolved Solids [TDS] concentration up to 180,000 parts per million). Currently, the management of CBM produced water is conducted using various water management practices depending on the quality of the produced water. In areas where the produced water is relatively fresh, the produced water is handled by a wide range of activities including direct discharge, storage in impoundments, livestock watering, irrigation, and dust control. In areas where the water quality is not suitable for direct use, operators use various treatments prior to discharge, and/or injection wells to dispose of the fluids.

The use of CBM produced water for beneficial use represents a flexible and valuable approach to utilizing an important resource by providing benefits to operators, land owners, and in some cases the general public. The quality of the produced water, the surrounding environmental setting, operator and landowner needs, and pertinent regulations, will often dictate the water's designated use. In most cases certain aspects of development can benefit either by practical resolution or by satisfying public requests or needs. Beneficial uses for CBM produced water have been integrated into the resource discussion, when applicable, to provide the reader with a practical understanding of this mitigation approach. For more information on beneficial uses for CBM produced water refer to: CBM Produced Water: Management and Beneficial Use Alternatives, GWPRF, 2003, in cooperation with BLM and the Department of Energy (http://www.all-llc.com/CBM/BU/index.htm).

Resources of Concern

Air Quality

The 1990 Clean Air Act is a federal law that establishes nationwide limits on how much of a pollutant can be in the air. This ensures that all Americans have the same basic health and environmental protection with respect to the air they breathe. Under this Act, states are responsible for implementing the law; since pollution control problems often require special understanding of local industries, geography, housing patterns, etc. The law allows individual states to require more stringent pollution controls, but does not allow for weaker pollution regulations. Figure 23 shows the Class I areas in the Rocky Mountain region as designated by the Clean Air Act. Class I areas are generally major parks and wilderness areas over 6,000 acres, where pristine air quality and scenic vistas are integral features.

Excessive air emissions resulting from CBM development will vary for any region since pollutant transport is affected by the magnitude and distribution of pollutant emissions, as well as local topography and meteorology. Although air quality changes from the CBM industry can be localized and short-term in duration, appropriate mitigation could eliminate potential long-term air quality affects and conciliate concerns raised by involved parties. Fugitive dust and exhaust from construction activities, along with air pollutants emitted during operation, (compression) may be expected to cause some air quality changes.

Dust from construction activities and standard travel of personnel and equipment over unpaved roads has the potential to alter air quality and create a nuisance to those traveling or living in these areas. The use of high quality CBM produced water (low SAR) for dust control offers multiple benefits from an environmental viewpoint, including the prevention of air quality concerns and the loss of surface soils. Possible applications of produced water for dust control include use on lease roads, other unpaved roads in the development area, and various construction sites where surface disturbances due to CBM development exist.

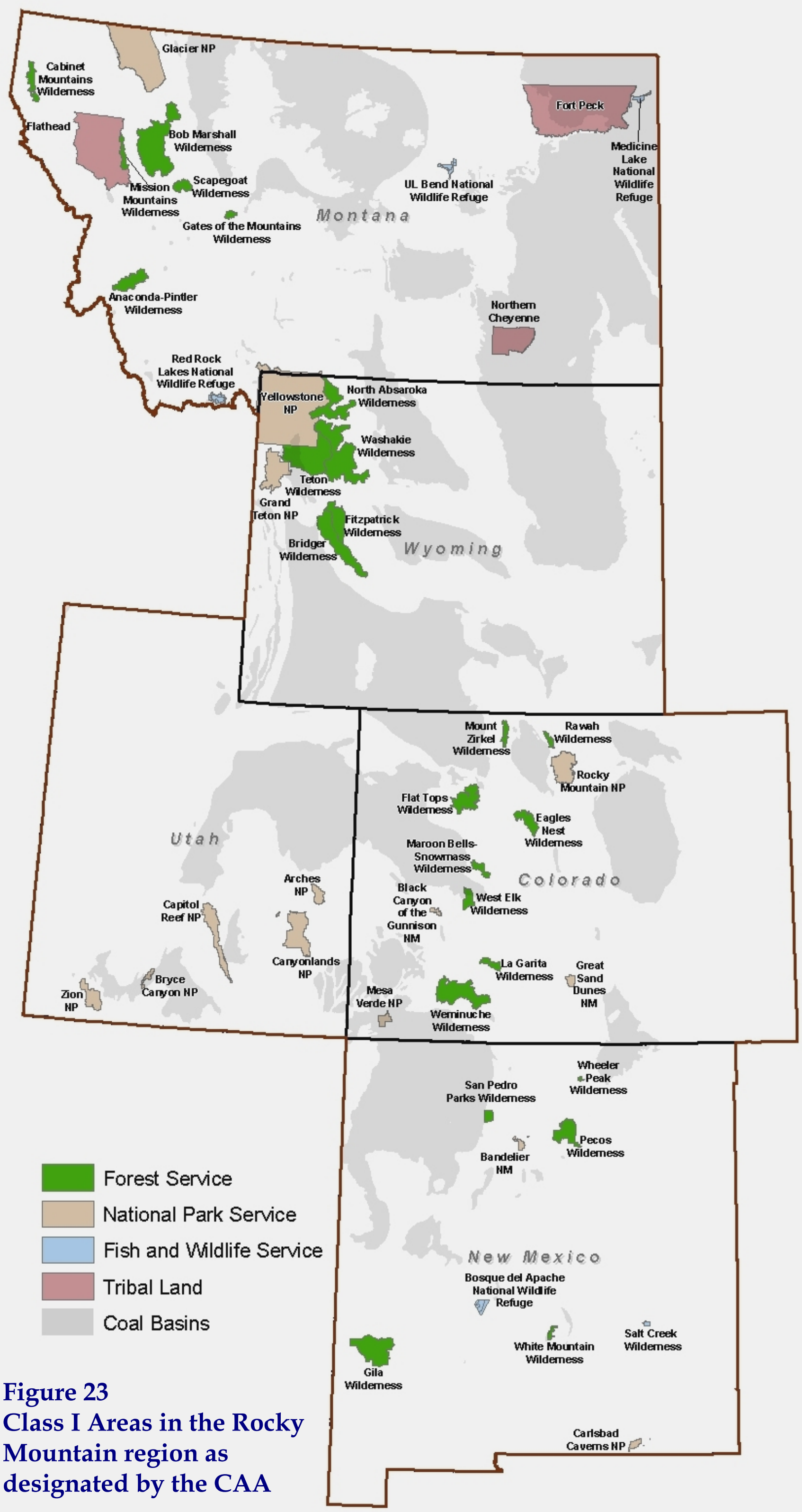


Figure 23
Class I Areas in the Rocky Mountain region as designated by the CAA

Applying seed or re-vegetating bare soil areas is another successful measure that is used to minimize dust emissions, as well as to protect soils, and reduce erosion. The benefit of re-seeding bare areas far out ways management and monitoring costs and should be looked on as a necessity, rather than an option. This measure not only aids in the reduction of fugitive dust emissions, but facilitates the health and abundance of native vegetation, helps prevent the infestation of noxious weeds, may provide additional lands for livestock grazing and wildlife habitat and, can control sediment run-off to nearby water systems resulting from erosion.

Compressor engine emissions are another source of air pollution commonly associate with CBM development. Emissions from compressor engines would have an appropriate level of control determined by the applicable air quality regulatory agencies during a mandatory preconstruction permit process. Some of the measure employed to control emissions may include, limiting the number of field compressors, requiring the use of electric-powered compressors or the use of Best Available Control Technology to reduce the NO_x emission rate.

As with any BMP, site specific conditions will dictate which BMP strategy is best suited to address and mitigate potential air quality changes. Common practices that could be applied to a BMP program to control air quality issues are listed below.

- Avoidance of surface construction on soils susceptible to wind erosion
- Use of dust inhibitors as necessary on unpaved collector, local, and resource roads to minimize fugitive dust emissions
- Install pollution control equipment on field and sales compressors
- Install catalytic converters on heavy machinery to minimize air pollutants
- Avoid specific geographic locations susceptible to excessive winds
- Use soil erosion control techniques when bare ground is temporarily or permanently exposed
- Enclose painting operations, consistent with local air quality operations
- Properly store materials that are normally used in repair such as paints and solvents.

Cultural Resources and Paleontological Resources

Cultural resources are best described as material remains of, or the locations of past human activities, including sites of traditional cultural importance to both past and contemporary Native American communities. The existence of cultural resources within a specific location is determined through examination of existing records, field surveys, and subsurface testing of areas that are proposed for disturbance on federal and state lands. Section 106 of the National Historic Preservation Act (NHPA) requires an inventory of cultural resources if federal involvement is present either in terms of surface or mineral estate, federal funds, federal grant, or federal license. The BLM has also identified survey standards that must include approved plans for avoidance when resources are discovered. In addition, State Historical Preservation Offices (SHPO) maintain a register of all identified sites, as well as all sites that are listed or eligible for listing on the National Register of Historic Places (NRHP).

Native American Petroglyphs, Utah

Unidentified cultural resources could potentially be affected by surface and subsurface activities that involve the use of heavy equipment (road construction, well drilling, pad construction, pipeline and utility placement, etc.) that ultimately change the natural landscape of an area. As such, the most sensible and preventative measure to protect this resource is to properly identify historic or pre-historic locations and more importantly, to avoid or relocate project facilities in these areas when feasible a point which is enforced by Federal mandate. Federal and state laws require the performance of surveys prior to the commencement of construction or other surface disturbing activities as well as prohibit land usage when an area is designated for conservation use, public use, or sociocultural use.

In the rare event when exploratory or development procedures unearth previously undiscovered resources, enforceable mitigation would require that work be stopped in the area of discovery until an evaluation can be preformed. If appropriate, consultations would be conducted with the SHPO, tribal historic preservation officer and/or Advisory Council on Historic Preservation. Appropriate and responsible action would be determined by these agencies and coordinated with operators and/or landowners.

In most cases, instruction on procedures to follow in case previously unknown archeological resources are uncovered during construction would constitute an important element of the BMP. This may include; informing operators of the penalties for illegally collecting artifacts or intentionally damaging archeological sites or historic properties, instruction on rehabilitation of buildings or structures, minimizing equipment traffic, and restricting placement of equipment and material staging areas near known archeological resources (National Park Service, 2002).

Paleontologic resources consist of fossil-bearing rock formations containing information that can be interpreted to provide a further understanding about any given location's past.

Aquatic fossils
Photograph provided by The Fossil Conservancy

Surface occupancy is prohibited within paleontological sites on BLM project lands unless it can be demonstrated that the paleontological resource values can be protected, or undesirable disturbances can be mitigated. BLM provides guidelines for notifying and mitigating damage to paleontological resources discovered during oil and gas construction activities. Limitations include restricted use of explosives for geophysical exploration, monitoring requirements, and work stoppages for discovered damaged resources. As with Cultural Resources, investigative surveys to identify this resources and/or avoidance are typically considered the most effective mitigation to prevent damage.

Geology and Minerals

As stated earlier in this document, it is important to recognize that geology and mineral resources are directly associated with coal deposits. CBM gas is generated within the coal deposits under both thermogenic (heat-driven) and biogenic (microbe-driven) conditions. The magnitude of the CBM resource is determined by coal type and volume; and the location of coal seams, which coincide with the location of CBM resources. Existing BLM regulations allow for the production of CBM, but dictate that development be conducted in a manner that conserves these other resources present so they are not wasted.

The selection of an appropriate BMP to minimize alterations to these resources will depend greatly on local site conditions, but will usually consist of a collection of practices. Well spacing and field rules are established to maintain the integrity of surface formations while at the same time aiding in the efficient production of hydrocarbons. Drilling and completion practices, such as steel casing and cementing, stabilize the well bore dramatically and reduce the opportunity for hydrocarbon migration. In addition, certain operator practices can reduce surface disturbances as well. Sharing access roads, flowline routes, and utility line routes minimize surface disturbances and in certain circumstances, constructing multiple well pads and production facilities on the same pad can be implemented to consolidate work disturbing operations.

BMPs with a hydrologic component (e.g., storage ponds or impoundments) can directly affect geologic resources and require planning. When designed properly, however, they can be utilized to help control soil erosion and sedimentation ocurring from rainfall events, as well as provide benificial use. State engineering offices or related agencies often provide specific construction guidelines for impoundments. These guidelines can dictate preventative elements in their design that may include topographic restrictions (slope), water rights permitting requirements, and specific benificial use limitations. As an example of benefical use, the Montana Department of Environmental Quality considers CBM produced water to be unaltered State water and therefore; does not require permitting if the water meets certain water quality standards. Under a current proposal, this high quality water could be used specifically for livestock or wildlife watering and would have minimum impact to geological or mineral resources.

Reclamation practices to re-establish local landscapes are considered an integral (and BLM required) BMP component during the production and abandonment phases of CBM development. In most cases operators, along with landowners should discuss development and reclamation plans to reach a common agreement. This process ensures that acceptable guidelines and objectives are met to satisfy regulatory stipulations, as well as provide suitable guarantees for the landowner. From a functional and aesthetic perspective, re-seeding disturbed areas, such as well pad locations or road systems, restores the visual appearance of any disturbed location, and resolves or prevents local erosion and climatic, i.e., dust control issues. "No Surface Occupancy" stipulations could also be utilized on new oil and gas leases, which are issued for lands that have existing coal leases to prevent additional disturbance.

Hydrological Resources

CBM production can produce large volumes of water that can affect both ground and surface water when the quality of the water is low. Generally, water quality in a certain watershed will vary, but in many cases is dependent on the volume and season. During times of high flow, streams receive large volumes of runoff water; while during times of base-flow, streams receive little runoff and are supplied primarily by groundwater. High-flow periods correspond to the seasonal influx of relatively high-quality, low-Sodium Absorption Ratio (SAR) surface water typically associated with spring snow-melt and early summer rains. Base-flow periods correspond to periods of scarce surface water during the winter when streams are fed only by the influx of lower quality, high-SAR groundwater from shallow aquifers.

When groundcover is broken it exposes soil to wind and water erosion, leading to suspended sediment being deposited in bodies of surface water. Artificial impoundments can cause water infiltration into the soil and migration into surface water, and accidental releases of wastes can migrate into water bodies. These issues are of particular importance to residents. As a result, implementation of water management alternatives is in the forefront of CBM development.

CBM Supplied Impoundment, Powder River Basin, Montana

Current protection of hydrological resources primarily focus on maintaining beneficial uses for the produced water; although water well, and spring mitigation agreements are often used to facilitate the replacement of groundwater lost to drawdown.

New technologies or strategies for CBM produced water are continually being developed and are responsible for reshaping the way landowners and operators think about beneficial use and resource protection. Current water management strategies include using the water for certain job specific needs, such as dust control, or to supplement other water related activities, including irrigation, impoundments, livestock watering, industrial use, and in some cases, potable water use.

In areas where there are distinct wet and dry seasons, during the wet seasons water is abundant in both surface streams and groundwater supplies. However, water supplies are often depleted during the dry season leaving a demand upon water supplies at this time. In these areas, water is captured from surface streams and other sources, then stored in permeable aquifers for use during the dry season to ensure that this resource is not wasted. The storage of produced water for future use could be accomplished through the use of a proven technology, Aquifer Storage and Recovery (ASR). In the case of CBM, large quantities of produced water could be stored in depleted aquifers or coal seams where gas has been depleted. ASR provides water storage at lower cost than traditional surface storage methods while functioning in a manner similar to a traditional surface reservoir.

Another management option for produced water is impoundment use. The impoundment of CBM water is the placement of water produced during operations at the surface in a pit or pond. There are a variety of ways in which operators can impound produced water at the surface. Impoundments can be constructed on or off channel, and the regulatory authority in some states varies based on whether the impoundments are off or on channel. See Figure 24 for a schematic diagram of an off-channel impoundment. The impoundment of

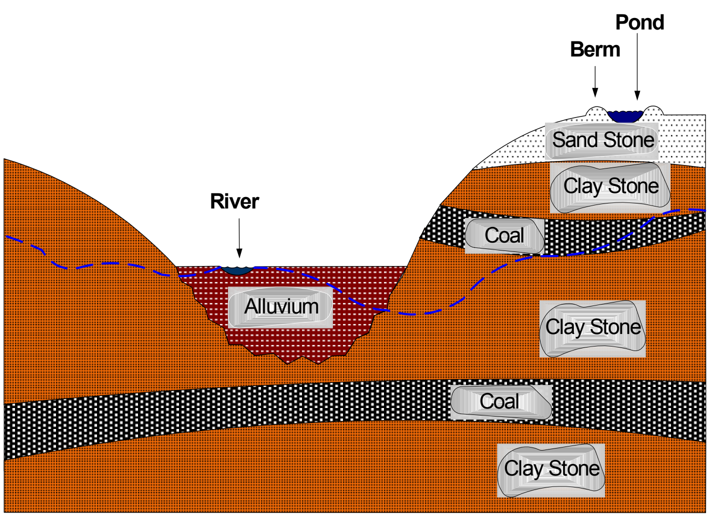


Figure 24
Off-Channel Impoundment
Schematic Diagram of Off-Channel Pond

produced water can be used as part of a water management plan to provide a variety of disposal options and benefits to both the lease operator and landowners. The options depend on site-specific conditions such as, the quality of produced water, soil type, current and future land use, and certain terrain factors. Under the right set of regulatory conditions, including water right and NPDES requirements, CBM supplied water could be used to sustain fish ponds, wildlife watering facilities, small recreational ponds, and utilized in retention ponds to restore depleted aquifers.

The impoundment of water can be performed in any area where there is sufficient construction space. In areas with limited rainfall or drought conditions, impoundments could be used to recharge groundwater in shallow alluvial and coal seam aquifers to provide livestock and wildlife water or for the storage of water prior to irrigation. Impoundments can be constructed to provide a single management option or a combination of management options including: livestock and wildlife watering from wetlands, fisheries and recreational ponds, recharge and evaporation ponds or other combinations.

Lands and Realty

Potential land use issues resulting from CBM development primarily consist of conflicts between conventional oil and gas activities and other uses of property, such as agriculture, residences, State lands, and coal mines. New realty authorizations for major gathering lines, major transportation lines, and power lines, for example, affect rights-of-way (ROWs) and land segmenting. The development of oil and gas resources affects agricultural production by taking land out of production, and by potential soil contamination from drilling and production. Soil contamination could result in loss of vegetation, reduced crop yields, or reduced acreage available for livestock grazing.

Proper surface selection and facility arrangement minimizes and mitigates surface conflicts and avoids unnecessary surface uses that would require additional reclamation, special operating procedures, or other restrictions that could be avoided. Geo-referenced spatial data depicting proposed facility locations, well locations, roads, pipelines, power lines, impoundments etc., is currently being utilized to mitigate potential surface conflicts. Locations in areas with a potential for high surface run-off, with increased erosion potential or in the flood plain of surface drainages could dramatically alter lands and thus, mitigation efforts. Avoidance of steep slopes, unstable soils, and locations that block or restrict natural drainages are successful tactics being implemented by operators to reduce surface alterations.

Another surface related issue involves removal of native vegetation, particularly in those areas where vegetation will be difficult to re-establish. Bare soils are susceptible to erosion and as a consequence, can lead to sediment build-up in local water systems, or result in negative alteration to the pre-existing topography. In situations where vegetative removal is necessary, reseeding should be performed immediately after development or when possible, during operations, to aid in the reclamation process and halt future surface disturbances. BLM provides seeding guidance when disturbances of this nature occur on federal lands (see Wildlife and Vegetation).

Livestock Grazing

CBM development only requires a small area for equipment, i.e., well pads and compressor stations, and therefore is relatively compatible with the foraging characteristics of livestock. Some changes to rangeland are expected however, and can be compensated for by appropriate mitigation. Loss of vegetation for livestock grazing, the disruption to livestock management practices, and loss of grazing capacity from construction of well pads and roads are some of the expected disruptions. Mitigation strategies that affect livestock grazing are often the result of coordination between the landowner and operator and serve to provide basic, sustainable practices which can help protect cattle, sheep, horses, and associated structures, such as watering ponds or fences.

Recycled Tire Stock Tank, Designed for Livestock Use

The availability of produced water from CBM activities would allow for, especially in arid regions, additional lands that could be utilized for grazing. There are estimates that, on average, cattle consume 11.5 gallons of water per day. Governmental standards for livestock water are less restrictive than potable water and would allow for the use of lesser quality CBM water for this purpose. Early coordination and cooperation between area CBM operators, landowners, and local ranchers on the potential uses of produced water could prove beneficial for involved parties. This practice is currently being implemented in portions of Montana through the use of stock tanks made from old heavy equipment tires such as the one depicted in the photo here. In some cases, ranchers would be responsible for obtaining water rights for such use of produced water.

The following list provides additional BMPs that can help protect livestock and their rangeland:

- Repair or replace damaged or displaced facilities such as fences or gates according to landowner requirements.
- Minimize project-related construction equipment and vehicle movement except on specific access roads to avoid disturbance of grazing land.
- Clearly define stipulations and responsibility for fence, gate, and cattle guard maintenance and for noxious weed control and incorporate into the planning process.
- Develop a reclamation plan for all areas that have been disturbed during production, and specify techniques for reclamation of well pads, pipeline rights-of-way, and roads.
- Locate facilities to avoid or minimize changes to livestock waters.

Recreation

Recreational areas are a vital component for communities nationwide and require close management to assure their protection. CBM related surface disturbances involving the use of heavy equipment for road construction or well drilling constitute a potential risk to this resource by changing the natural landscape. These types of construction activities could affect hiking, fishing, hunting, etc, as well as infringe on the solitude and rural characteristics of the area. Other activities such as increased travel, and vandalism resulting from access improvements, wildlife displacement, and increased erosion could also potentially affect recreational areas.

To prevent these potential disturbances to the extent possible, BLM has established stipulations that protect recreation areas. Specifically BLM has established such stipulations in areas receiving concentrated public use and in areas with reservoirs containing fish. Many states have also established stipulations for protection of recreation areas including prohibiting activity near streams, ponds, lakes, or other water facilities. Other possible mitigation strategies include coordinating the timing of exploration activities to minimize conflicts during peak periods of use.

The availability and volume of CBM produced water could be managed in a way to supplement, or in arid regions, create recreational opportunities for nearby communities. According to the second national water assessment by the U.S. Water Research Council, less than one-fourth of the surface waters in the Continental U.S. are accessible and useable for recreation because of pollution or other restrictions (Harney, undated). The construction of artificial lakes supplied by produced water could potentially have widespread use depending primarily on available lands, water volume and quality. Many areas of the country are overwhelmed with overcrowded or limited recreational facilities as a result of overpopulation and urban encroachment. The development of artificial lakes could provide additional recreational opportunities within these areas, while at the same time promoting community involvement and habitat improvement. In colder climates artificial lakes could also provide ice fishing or ice skating opportunities.

The addition of a large water body to an ecological community could provide additional habitat for resident and migratory birds, including waterfowl, and possibly provide resting and nesting sites for raptors (Bryan et al, 1996). An increase of waterfowl populations in the area could help support the local hunting community and potentially deter illegal hunting due to limited population sizes. The lake would effectively function as a watering pond or wetland system, potentially increasing wildlife ranges and populations resulting in an increase to the overall dynamics of the local ecosystem.

Social and Economic Values

The effects of CBM development on the socio-economics of any community is a dynamic issue which will differ at the community and individual level. Influences to social conditions would include changes in employment and population, changes in the services provided by governments, the effects of drilling and related activities on rural lifestyles in the project area, changes in levels of traffic, noise, visual resource alterations, and psychological stress levels; and the effects of population change on local housing, schools, and services.

Options to mitigate economic concerns will typically be performed as a case-by-case procedure, since varying aspects of this resource are often difficult to predict or are intrinsically linked with other resources or primary community industry(s). The most pragmatic solution would be to resolve issues by evoking public participation to determine appropriate minimization strategies or more importantly, approaches to maximize community benefits. Meetings to instruct and inform the public of proposed actions are one way to accomplish this task.

Soils

Changes to soils and the ensuing consequences have been well documented with regards to the oil and gas industry and as a result, many preventative and economically feasible measures have been developed to deal with these chnages. Changes to soils from CBM activities could occur from various facets of exploration, construction, operation, and abandonment processes. These changes include soil compaction under disturbed areas, such as well sites and lease access roads, soil erosion in disturbed areas, and chemical influences from spills of liquids. Some changes are unavoidable, such as those resulting from the construction of well sites. Short-term disturbances occur typically during construction phases, including

Revegetation of brine site using salt resistant prairie grasses reclamation of construction sites.

A healthy soil can absorb storm water, filter sediment, and reduce irrigation and fertilizer needs (Field and Engel, 2003). Changes to soils resulting from CBM related practices can affect multiple resources and as such, justifies serious consideration when devising appropriate management practices. In general, soil erosion is a gradual process that occurs when the actions of water, wind, and other factors deteriorate the land into an unproductive and in some cases, hazardous state. Application of BMPs to control such problems is dependent on proper evaluation and planning, and may include considerations such as, organic matter content and nutrient levels, mulching, topography, soil testing, and native plantings.

An example of an effective BMP to control erosion is to keep water from accumulating on road surfaces. Fast-moving water can easily erode soil from road surfaces and ditches, but can be controlled by dispersing runoff into vegetation and ground litter (Iowa Department of Natural Resources, undated). Roads can be designed to keep the surface dry, while at the same time maintaining a certain level of structural integrity. In-sloped roads should contain adequate drainage, whereas out-sloped roads, which are less expensive to construct and maintain, should be designed for moderate gradients and stable soils (Iowa Department of Natural Resources, undated).

Soil changes have been well documented allowing for development of many preventative measures. The list below provides some of these measures.

- Vegetation will be removed only when necessary
- Drill seeds into the ground
- Reduce timber cutting
- Control increases in turbidity and suspended sediments to the maximum extent practical by using berms, dykes or impoundments
- Areas with steep topography will be developed in accordance with the BLM Gold Book (USDI and USDA 1989) requirements
- Federal leases with slopes in excess of 30 percent will be required to obtain approval for occupancy from the BLM based on mitigation of erosion, surface productivity after remediation, and mitigation to surface water quality
- Riparian zones will be protected by federal lease stipulations and permit mitigation measures
- In areas of construction, topsoil will be stockpiled separately from other material, and be reused in reclamation of the disturbed areas
- Surface owners or surface lessee will be consulted regarding the location of new roads and facilities related to oil and gas lease operations
- Unused portions of the drill location will have topsoil spread over it and reseeded
- Construction activities will be restricted during wet or muddy conditions
- If groundwater is encountered in shallow or near shallow surface materials during drilling, all onsite fluid pits will be lined
- During road and utility construction, surface soils will be stockpiled adjacent to the sides of the cuts and fills
- Stream crossings will be designed to minimize soil disturbances and impede stream flow
- Erosion control measures will be maintained and continued until adequate vegetation cover is re-established.

A road decommissioned by ripping, mulching, and seeding. Mulching as Best Management Practice to reduce soil erosion and control the infestation of noxious weeds. Photograph provided by BLM, Coos Bay District

Solid and Hazardous Wastes

In general, hazardous waste is a material or combination of hazardous materials that are no longer useable and are regulated by the Resource Conservation and Recovery Act of 1976 (RCRA). RCRA hazardous materials programs are designed to protect public health and environmental resources from improper disposal or releases of regulated materials. These programs assure future hazardous substance risks, costs, and liabilities on public lands are minimized. On Federal lands BLM is responsible for all releases of hazardous materials and requires notification of all hazardous materials to be used or transported on public land. Typical solid waste generated by drilling related procedures are considered RCRA-exempt waste and can be disposed of in local landfills. The largest volume of exempt waste generated from drilling activities are drilling mud and cuttings. Classified RCRA waste, such as paints would be disposed of in accordance with applicable regulations.

Waste minimization on CBM development sites is limited because waste volumes are primarily a function of activity, age, and state of depletion of a producing site (American Petroleum Industry, 1989). Nevertheless, mitigation planning will include proven practices to reduce waste to the extent practical. The mitigation of solid and hazardous waste consists primarily of disposing of all wastes according to federal and state regulations. Other mitigation activities include leak detection or monitoring system for hydraulic and lubricating systems, construction of secondary containments, and drilling mud retention ponds. The mitigation of accidental spills and releases involves the clean up and reporting of all spills in accordance with an approved Spill Prevention Control and Countermeasures Plan and any applicable state regulations. In addition site clearance surveys should be conducted prior to surface disturbance commencement.

Visual Resource Management

Visual resources are visual features that include landform, water, vegetation, color, adjacent scenery, uniqueness or rarity, structures, and other man-made features. Alterations resulting from oil and gas exploration and production activities occur locally on a case-by-case basis as native vegetation is disturbed and small structures are erected. Exploration may involve minor visual changes from clearing operations for access to exploratory sites. The majority of these changes result from access road construction, site construction, drill rig operations, and on-site generator use. Short-term visual changes occur where construction and drilling equipment are visually evident to observers. Long-term alterations may occur from construction of roads and pads, installation of facilities and equipment, vegetation removal, and change in vegetation communities. These could produce changes in landscape line, form, color, and texture.

Visual Resource Management Class I Area near Bozeman, Montana

The USDA Forest Service recognizes special management zones surrounding riparian resources. For example, the Superior National Forest in Minnesota designates a 200- to 300-foot forest buffer, which is managed to optimize riparian resource values (Jaakko Pöyry Consulting, Inc., 1993). This management option can easily be applied to visual resources and in specific situations, coupled together with riparian or recreational resources to consolidate management efforts. Retaining a visual timber buffer could help isolate CBM-specific visual impairments such as, compressor stations or well pads, from local communities, highway travelers, and nearby recreational areas. Proper identification of timberlands play an important role in implementing this strategy. Due to the associated low costs and the flexibility of this strategy, successful implementation is often feasible.

Federally authorized projects undergo a visual assessment to comply with aesthetic requirements. Typically, sensitive areas include residential areas, recreation sites, historical sites, significant landmarks or topographic features, or any areas where existing visual quality is valued. Measures to minimize disturbance include designing compressor stations to blend into the background, landscaping options, and painting to camouflage the above ground equipment. Power lines and pipelines can be placed underground and wellheads camouflaged with landscaping or vegetation. Facilities on BLM lands require ample screening from highways or camouflage to retain basic elements of form, line, color and texture of the landscape.

Wilderness Study Areas

To the extent practical, BLM leasing restrictions are designed to protect Wilderness Study Areas (WSA). As such, the most reasonable practices to minimize disturbance is avoidance. BLM has implemented this type of strategy by identifying WSA policies that prohibit leasing of these lands for resource extraction. Such policies can be supplemented by collaborative partnerships among federal and state government agencies, local governments, business communities, volunteers, user groups, educational institutions, and individuals in the private sector to achieve management objectives and implement these guidelines (BLM, 2000).

Wildlife and Vegetation

Stipulations to perform wildlife surveys to assure responsible actions are taken to protect listed species associated with lands owned by the federal government and/or with projects which involve federal participation is an important element of any wildlife BMP. These stipulations are mandatory for federally owned (split-estates) or federally funded projects. (It should be noted that management practices, as well as identification of stipulations, for split-estates are the responsibility of the BLM.) If development practices occur on private lands, landowners, along with operators, are not bound by these same stipulations from a legal perspective even though they are still considered accountable for actions affecting state or federally listed species. Wildlife regulations are complex and will vary depending on geographic location, state and federal involvement, land-usage, and species distribution. In any case, wildlife surveys are a critical component of any mitigation strategy as they help identify listed species and alert operators and landowners of areas or habitats which should be avoided.

Black-footed Ferret
Mustela nigripes (Photograph provided by BLM)

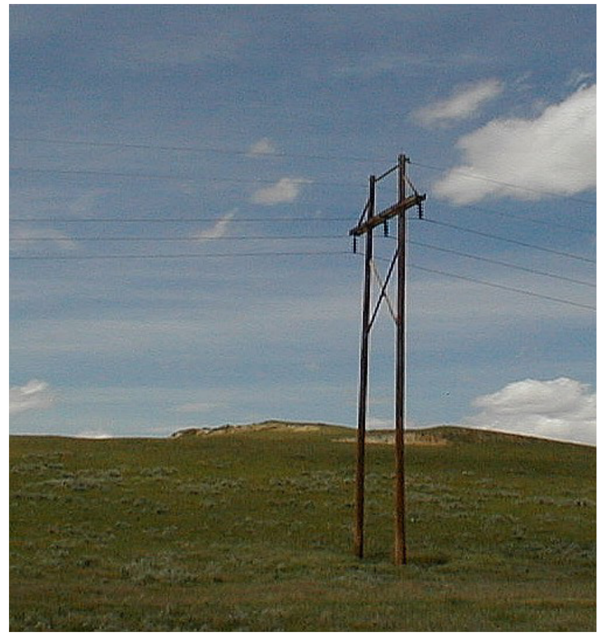
Wildlife surveys and inventories are used to identify fish and/or wildlife populations, their habitats, and other associated parameters such as home ranges, biodiversity values, and habitat usage. The inventory and monitoring of the abundance and distribution of wildlife species are essential in addressing development disturbances that pose threats to the effective and sustained management for protected, as well as common species. Monitoring programs provide the basis for formulation of adaptive wildlife management plans that document mitigation objectives and outline how each is to be implemented. Management issues relating to degree of human disturbance, conservation, management constraints, local communities' interests, and development are influenced by the resource availability and abundance over time.

A comprehensive biota database ensures that the full ranges of species utilizing the project area are identified as well as the time of year in which they are most likely present. This information can then be extrapolated and used as a strategy tool by wildlife biologists or resource managers to predict the degree of change(s) for specific species. With this inventory strategy, proper identification of fish, wildlife, and botanical species in the area will help those involved identity species-specific critical resources and plan for appropriate mitigation.

CBM development triggers Section 7 and/or Section 9 of the Endangered Species Act if environmental alterations are planned and if those alterations will pose as a potential threat to endangered species and their habitat. Section 7 of the Act directs federal agencies to mange projects in a manner that will not jeopardize the continued existence of listed species or modify their critical habitat during any federally authorized project. Section 9 identifies prohibited actions and outlines litigation authority for the FWS. Prohibited actions defined in this Section are extensive and require review to insure planning strategies are consistent with the law. In addition, identified sensitive species on federal lands are protected under the BLM Sensitive Species Policy (BLM Manual 6849).

Section 7 of the Endangered Species Act is not applicable to project related actions taking place solely on private lands. However, under Section 9 of the Act, operators or land owners still need to assure prohibited violations defined in this section are avoided, that is, in general, negative or deleterious disturbances to listed species. From a regulatory perspective, actions on private lands do not require performance of wildlife inventories, but as stated above, disturbances to threatened or endangered species could trigger Section 9 of the act, and subsequent law enforcement penalties from the FWS. To avoid such situations, the FWS service recommends incorporating wildlife inventory requirements into mitigations plans or at a minimum, assuming listed species inhabit the area.

In some cases, exemptions to Section 7 of the Endangered Species Act may apply if the FWS establishes "reasonable mitigation and enhancement measures, including, but not limited to, live propagation, transplantation, and habitat acquisition and improvement, as are necessary and appropriate to minimize the adverse effects of the agency action upon the endangered species, threatened species, or critical habitat concerned." This point alone establishes the importance of developing efficient and sustainable BMPs.



Raptor Safe Utility Pole
Photograph provided by the Wyoming Game and Fish Department

Practices to minimize alterations to habitat or natural activities can be very challenging and in some cases overwhelming, since the dynamics of any environment will vary from region to region, and as is often the case, will change over time. In any case however, wildlife management options are directly related to project-specific procedures and the findings of wildlife surveys. It is therefore, the responsibility of operators (and landowners) to submit work plans prior to the initiation of project activities to assure proper planning and if applicable, subsequent mitigation. Provided below is a listing of potential mitigation measures that could be used in a project plan to minimize disturbances to wildlife and their habitats. This list should not be considered all inclusive as wildlife mitigation measures are generally species specific and are continually being revised as more information is collected.

- No surface occupancy or use within 0.5 miles of known nests or riparian nesting habitat to minimize disturbances to nesting bald eagles.
- Surveys should be made for all prairie dog towns within the roadway corridor and pad sites. If prairie dog colonies or several of the other indicators are found, FWS survey protocol for mountain plover should be followed. Construction activities should be avoided during

breeding periods to allow nesting mountain plovers to establish territories.

- Surface occupancy and use is prohibited within 1/4 mile of wetlands used by nesting interior least tern during exploration. This stipulation would minimize disturbances to interior least tern.
- Construction of facilities or roadways that will disturb migration routes of terrestrial wildlife species should be avoided, unless construction activities can be scheduled in a manner to minimize disturbance.
- Overhead electric lines can threaten birds such as raptors or waterfowl and may impair visual resources. Buried electric lines can prevent such incidents and be as cost effective as pole-mounted lines when utility corridors are utilized. In situations where pole-mounted lines are the only feasible or best option, the use of raptor safe poles should be incorporated into the mitigation strategy.
- Remote monitoring of field data can help reduce traffic volume and the possibility of wildlife collisions. This type of monitoring will also decrease habitat defragmentation and sediment load to nearby water systems resulting from erosion.
- Use existing water structures including, reservoirs, impoundments, or stock ponds to dispose of water. This action will help avoid unnecessary disturbances to other areas, while possibly benefiting landowners or wildlife. Impoundments could be used as wildlife watering ponds or used for recreational or fish ponds by the local landowner.
- Construction of roadways in natural settings can affect multiple resources including wildlife. Reclamation of roads to pre-existing conditions upon completion of the project should be clearly defined within the project plan.

As a beneficial use, non-treated CBM produced water is currently being used to sustain privately owned fishponds in some states, including Wyoming. Water quality levels have been sufficient to support healthy populations of rainbow trout, blue gill, small-mouth bass, etc. The State of Wyoming discontinued fish stocking programs in certain ponds due to a general lack of available water needed to sustain the system. CBM produced waters are now being beneficially used to supplement these ponds, allowing for continuation of the State's stocking program.

Wetland system initial planting, June 2000, Marathon Oil Company, Powder River Basin, Wyoming

Same planting area as above, August 2001, Marathon Oil Company, Powder River Basin, Wyoming

Disturbances to native vegetation resulting from CBM activities will require a case by case evaluation to determine strategies to minimize the effected area. In general, pockets of vegetation will be lost to roads and drill sites, as well as other construction related procedures. Proper mitigation strategies will be based on area vegetative inventories to determine the presence of threatened, endangered, and regional sensitive species.

As directed by BLM or survey findings, operator plans should be adjusted as appropriate to avoid disturbances to federally listed species or state species of concern.

Sensitive habitats including wetlands and some riparian areas are also protected from direct disturbance under current stipulations on BLM land that restrict surface occupancy. In such cases riparian vegetation or other sensitive habitats should be avoided. When drilling sites are located in or at the head of drainages, drill sites and access roads may add sediment to streams and wetlands. Channel degradation may also occur. Heavy sediment loads or severe degradation would affect riparian vegetation. Roads and facilities are supposed to avoid sensitive areas "to the extent practicable."

When CBM development and operation practices result in the disturbance of existing non-protected vegetation and plant communities the potential exists for the loss of overall grazing/wildlife forage productivity, erosion, and introduction of noxious weeds. To help minimize disturbances to native vegetation operators are required to reduce the size of the drilling pads and to immediately restore the area once operations are complete or out-of-use. In situations that include unavoidable disturbances to common vegetation, proper mitigation can be applied to identify and re-introduce native species where necessary, to re-establish a local distribution, and to plant selected species that are determined to be valuable and successful in the area being restored. Other measures identified by BLM for specific protection of vegetation include:

- Where riparian areas and special habitat types have the potential to be inundated with water on a continuous basis. Measures will be taken to prevent continual inundation.
- Where water crossings cannot be avoided, crossings will be constructed perpendicular to wetland/riparian areas, where practical.For power lines, the minimum number of poles necessary to cross the area will be used.
- Wetland areas will be disturbed only during dry conditions or when the ground is frozen during the winter.
- No waste material will be deposited below high water lines in riparian areas, flood plains, or in natural drainage ways.
- Drilling mud pits will be located outside of riparian areas, wetlands, and floodplains, where practical.
- Reclamation of disturbed wetland/riparian areas will begin immediately after project activities are complete.

Noxious Weeds

Infestations of noxious weeds can occur in CBM development areas and require careful consideration on a site by site basis. Weeds can be transported and spread from vehicles, persons, and by other construction and reclamation materials. In some case native vegetation is unable to compete with exotic species and could lead to their elimination in a given local area. Mitigation, when properly applied, can help eliminate this problem, as well as sustain healthy native populations. To help assure the success of mitigation to control noxious weeds, BLM has identified certain protocols and practices that are required on federally involved projects in their Integrated Pest Management Plan (IPMP). Identified measures include: Prompt reseeding, cleaning of equipment prior to on-site delivery, minimization of soil disturbances, use of weed free mulch and hay, use of livestock to control outbreaks of certain weeds, use of BLM approved herbicides, and weed control instruction.

Dalmatian Toadflax (*Linaria genistifolia ssp. dalmatica*)is scattered throughout northern and western U.S. *Photograph provide by Rich Hansen, USDA-APHIS-PPQ. Above: Sweet Grass Co., MT.*

In general, the success of a mitigation or BMP vegetation program will be measured by how closely the revitalized area resembles, in both appearance and functionality, its original state. As directed by BLM, re-establishment of vegetation is considered complete when the disturbed area is stabilized, soil erosion is controlled, and at least 60 percent of the disturbed surface is covered with the prescribed vegetation. On private lands, restoration efforts will be directed by landowner stipulations resulting from operator and landowner coordination.

Aquatic Resources

CBM exploration, production, and abandonment activities could disturb aquatic resources in a number of ways. The likelihood of these disturbances occurring depends on the exact nature, location, and timing of CBM activities; the proximity of CBM activities to water bodies and the presence of sensitive species and/or sensitive life stages in these water bodies; and the nature of stipulations and mitigation measures that should be implemented to minimize, avoid, or mitigate the potential disturbances. These include direct removal of habitat, habitat degradation from sedimentation, altered spawning and seasonal migration because of stream obstructions, direct loss of fish from accidental spills or pipeline ruptures releasing toxic substances, increased legal harvests of fish because of increased human access, and reduced stream flow because of removing water for drilling activities.

Tongue River, *Powder River Basin, Montana*

BLM has stipulations for federally involved projects that avoid or minimize disturbances to biological resources and hydrological features resulting from CBM exploration, production, and abandonment activities (BLM, 1992). Stipulations related to aquatic resources include a prohibition on the surface occupancy or use of water bodies and streams, within the 100-year floodplains for major rivers, and riparian areas. In addition, surface occupancy and use is prohibited within 1/4 mile of designated reservoirs with fisheries to protect the fisheries and recreational values of reservoirs. Surface occupancy is also prohibited on slopes exceeding 30 degrees to prevent excessive soil erosion, slope failure, and mass wasting, all of which would contribute increased sediment to drainages that may affect aquatic resources (BLM, 1992).

Stream channel monitoring for erosion, degradation, and riparian health is required by BLM on an annual basis, which includes surveying stream reach's above all CBM discharges and several stream reaches below CBM discharges. When avoidance of stream channel alteration is not feasible, BLM also requires re-contouring and stabilization of the channels.

Additional mitigation measures associated with aquatic resources, some of which are directed at special status species, include considerations of the location and timing of stream crossings as they relate to spawning periods and habitat, minimization or avoidance of in-channel activities to reduce the potential for habitat loss, the development of Spill Prevention Control and Countermeasures Plans to deal with accidental spills, control of storm water pollutant run-off, and various measures to prevent eroded materials from entering drainages.

PROJECT PLANNING

As stated above, there are many aspects of the CBM industry that are unique and different from the conventional oil and gas industry. Also, given the fact that each project will present distinctive circumstances and challenges for resource managers or operators, it becomes imperative to systematically evaluate the situation prior to proposing or implementing BMPs in a project plan. A successful project plan will include BMPs and mitigation strategies aimed at minimizing environmental disturbances, while at the same time maintaining overall site productivity. Achieving effective use of BMPs requires consideration of lease stipulations, pre-planning, NEPA requirements, identification of permitting issues, monitoring, and implementation.

Lease stipulations consist of specific measures that are incorporated into a mineral lease and are intended to avoid potential effects on resources and land uses from oil and gas operations, including CBM. Lease stipulations can include provisions for, and constraints on, such things as site clearances, occupancy, and timing restrictions. Lease stipulations should be identified and agreed upon at the time of the lease signing before conducting exploration, production, and abandonment activities.

Depending on the situation, pre-planning for BMPs may occur before, during, or after CBM exploration activities. The success (or lack there of) of exploratory "findings" in many cases would contribute to the scheduling or initiation of a pre-planning program. In either case however, good planning is the best tool for effective implementation of BMPs. The pre-planning process should consider BMPs or mitigation strategies that are flexible, enforceable, have a preventative ability, and as stated earlier, can be implemented in phases.

Phase implementation for a particular aspect of the project should assure specific operations are paired up with the appropriate mitigation measures so as to maximize the effectiveness of any specific mitigation (EPA, 2002). This type of planning strategy should also ensure smooth implementation of the subsequent phases of work. Considering that the primary purpose of a BMP or mitigation measure is not only to resolve problems which may arise upon project initiation, but to prevent environmental problems before they occur, successful BMPs should be readily adapted to changes resulting from unforeseeable changes to a particular project (EPA, 2002). A flexible strategy can also prevent unnecessary delay due to further changes in the work environment. Lastly, a successful BMP should be easily enforceable. Operators should ask such questions as; What type of measure will be used? Where will the measure be implemented? and Why is the measure necessary? Sound and practical answers to these questions will aid operators in reducing concerns from the regulatory community, landowners, and citizens groups.

Planning efforts should begin with a thorough evaluation of the surface proposed for CBM development. Selection of the proper surface may help minimize and mitigate surface conflicts and avoid unnecessary surface uses that could require additional reclamation, special operating procedures, or other restrictions that could be avoided. At this time consideration also needs to be given to the proximity to schools, residences and other public areas, visual alterations, erosion potential, wildlife habit, and the improvements and structures of the landowner/surface lessee.

In addition operators should consider avoiding surfaces with steep slopes, unstable soils, and locations that block or restrict natural drainages during the pre-planning phase. Care should also be taken to disturb the minimum amount of native vegetation as possible, particularly in those areas where vegetation will be difficult to re-establish. Locations in areas with a potential for high surface run-off, with increased erosion potential or in the flood plain of surface drainages could dramatically increase maintenance costs and mitigation efforts, as well as create additional safety concerns. An exploration site that has a low slope, soils with low erosion potential, and a site that can be readily re-vegetated benefits the operator by reducing the costs of compliance with storm water discharge permits and associated well and road site remediation.

Section 102 of the National Environmental Policy Act requires Federal agencies to incorporate environmental considerations in their planning and decision-making process through a systematic interdisciplinary approach. Specifically, Federal agencies are to assess the environmental effects of, and alternatives to major federal actions significantly affecting the environment. Actions are classified into one of three categories and include: Categorically Excluded, Finding of No Significant Impact (as identified by an Environmental Assessment), and Finding of Significant Impact (as identified in an Environmental Impact Statement and Record of Decision).

Under this Act, Environmental Impact Statements (EIS) are developed to identify and evaluate the severity of project specific environmental disturbances that may result from CBM development practices. Identification of existing environmental conditions and potential disturbances will help those involved identify appropriate mitigation for site-specific impacts. Typically, resources evaluated in the EIS include:

- Environmental quality, including air, water, soils
- Social and socioeconomic conditions
- Natural resources, including fish, wildlife, and plants
- Endangered and threatened species

- Historical and cultural resources, including archeological materials
- Initial assessment for any hazardous, toxic, or radiological wastes

The number and complexity of applicable permit requirements and water right issues that can apply to CBM operations can be overwhelming, but are critical to the successful implementation of BMPs and mitigation strategies. Permit requirements can and will vary for any given state or region. Coupled with the discretionary practices agencies can exercise when applying their programs, it becomes essential for operators and landowners to have a thorough understanding of these requirements to allow for informed decisions as they relate to identifying and implementing site specific BMPs. Operators, landowners, or other entities involved in the CBM industry should contact their appropriate state authority for additional information. It should also be noted that permitting requirements within the CBM industry are continually being modified or new requirements are being drafted.

Conclusion

Not all BMPs or mitigation measures will be appropriate for any given resource and proper implementation will vary by the region, topography, climate, reclamation objectives, landowner stipulations, applicable regulations, and development characteristics. Established mitigation plans will require amendment when there are significant changes in design, construction, and operation or maintenance practices. Since operational and development conditions will likely change over time, developing monitoring plans for these changes will help faciltitae necessary adjustments to BMP programs.

The focus of many monitoring plans is to conduct an overall evaluation of the potential effects of CBM development and to track the changes that occur as CBM fields mature, and gas production declines and eventually ends. The end result of monitoring will allow those involved to determine if measures are achieving their intended environmental objectives, as well as to identify any further disturbances caused by the mitigation measures themselves (EPA, 2002). Effective monitoring can also provide a means for developing improved analytical procedures for future analysis and improving mitigation measures. Standards for monitoring resources such as air quality, water, wildlife, and surface disturbances historically have been well documented, and serve as a baseline for monitoring.

BMPs should not be thought of as a rigid set of guidelines that are mandatory for reduction of disturbances, but as an adaptive and concise management tool which can facilitate enhancement, as well as protection, for multiple resource use. Unfortunately, there is no one measure with a “fix all” quality. Rather, BMPs represent an intricate web of methodologies and practices resulting from careful planning and coordination that are used to accomplish pre-determined objectives. BMPs must be incorporated into the final design plan for any CBM construction project to help assure the success of the project, as well as the protection of the environment.

DEFINITIONS

AIR QUALITY. Air quality is based on the amount of pollutants emitted into the atmosphere and the dispersion potential of an area to dilute those pollutants.

ALKALINITY. The quantity and kinds of compounds present in water that collectively shift the pH to the alkaline side of neutrality. See **salinity**.

ALLUVIUM. General term for debris deposited by streams on river beds, floodplains, and alluvial fans, especially deposits brought down during a flood. Applies to stream deposits of recent time. Does not include below water sediments of seas and lakes.

ANNULUS OR ANNULAR SPACE. The space around a pipe in a wellbore, the outer wall of which may be the wall of either the borehole or the casing.

AQUIFER. A body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs.

APPLICATION FOR PERMIT TO DRILL, DEEPEN OR PLUG BACK (APD). The Department of Interior application permit form to authorize oil and gas drilling activities on federal land or the state application form for similar purposes.

AREA OF CRITICAL ENVIRONMENTAL CONCERN. An area that needs special management attention to preserve historic, cultural, or scenic values; to protect fish and wildlife resources or other natural systems or processes; or to protect life and provide safety from natural hazards.

ARTESIAN. Groundwater with sufficient pressure to flow without pumping.

BASIN. A closed geologic structure in which the beds dip toward the center; the youngest rocks are at the center of a basin and are partly or completely ringed by progressively older rocks.

BEDROCK. The solid, unweathered rock underlying soils.

BEST AVAILABLE CONTROL TECHNOLOGY (BACT). The best available air pollution control technology for a given emission source, considering environmental benefits, economic and energy costs, as defined by the applicable air quality regulatory authority.

BIOGENIC. Produced by living organisms or biological processes.

BITUMINOUS. The most abundant rank of coal (synonymous with soft coal). It is dark brown to black and burns with a smoky flame.

BRACKISH WATER. Water that contains relatively moderate concentrations of any soluble salts. Brackish water is saltier than fresh water but not as salty as salt water or brine water.

BRINE. Water containing relatively large concentrations of dissolved salts, particularly sodium chloride. Brine has higher salt concentrations than ordinary ocean water.

BUFFER ZONE.

1. An area between two different land uses that is intended to resist, absorb or otherwise preclude developments or intrusions between the two use areas.

2. A strip of undisturbed vegetation that retards the flow of runoff water, causing deposition of transported sediment and reducing sedimentation in the receiving stream.

CASING. Steel pipe placed in a well and cemented in place to prevent the earth from collapsing and to isolate water, gas and oil from the original formations.

CAVITATION. The formation of an undercut in a mineral formation by means of mechanical forces, such as those resulting from rotation of a special drill bit at the base of a well.

CHANNEL INTEGRITY (STABILITY). A relative term describing erosion or movement of the channel walls or bottom because of water flow.

CLAYEY. A soil containing more than 35 percent clay. The textural classes are sandy clay, silty clay, clay, clay loam, and silty clay loam.

CLEAN AIR ACT. Public Law 84-159, established July 14, 1955, and amended numerous times since. The Clean Air Act: establishes federal standards for air pollutants emitted from stationary and mobile sources; authorizes states, tribes and local agencies to regulate polluting emissions; requires those agencies to improve air quality in areas of the country which do not meet federal standards; and to prevent significant deterioration in areas where air quality is cleaner than those standards. The Act also requires that all federal activities (either direct or authorized) comply with applicable local, state, tribal and federal air quality laws, statutes, regulations, standards and implementation plans. In addition, before these activities can take place in non-attainment or maintenance areas, the federal agencies must conduct a Conformity Analysis (and possible Determination) demonstrating the proposed activity will comply with all applicable air quality requirements.

CLOSED MUD SYSTEM. A drill mud system that reuses or reclaims all the drilling fluid used. Oil-based mud systems are often closed mud systems.

COAL BED METHANE. A clean-burning natural gas found deep inside and around coal seams. The gas has an affinity to coal and is held in place by pressure from groundwater. Coalbed methane is produced by drilling a wellbore into the coal seam(s), pumping out large volumes of groundwater to reduce the hydrostatic pressure and allow the gas to flow.

COALIFICATION. Compression and hardening over long periods of time, the processes by which coal is formed from plant materials.

COLLUVIAL. Loose, incoherent geological deposits at the bottom of a slope or cliff, having fallen from above.

COMMUNITIZATION. The pooling of mineral acreages based on the spacing for a well or wells set by the state or BLM.

COMPACTION. The process of packing firmly and closely together; the state of being so packed; for example, mechanical compaction of soil by livestock or vehicular activity. Soil compaction results from particles being pressed together so that the volume of the soil is reduced. It is influenced by the physical properties of the soil, moisture content, and the type and amount of compactive effort.

COMPLETION. The activities and methods to prepare a well for production. Includes installation of equipment for production from a gas well.

CONDITION OF APPROVAL (COA). Conditions or provisions (requirements) under which an Application for a Permit to Drill or a Sundry Notice is approved.

CONTROLLED SURFACE USE (CSU). Use or occupancy is allowed (unless restricted by another stipulation), but identified resource values require special operational constraints that may modify the lease rights. CSU is used for operating guidance, not as a substitute for the NSO or Timing stipulations.

CONVEYANCE LOSS. The percentage reduction in water volume between the time it is discharged to the surface and the time it reaches a perennial stream. This reduction in volume is due to the processes of infiltration and evaporation.

CORRIDOR. A strip of land through which one or more existing or potential facilities may be located.

CRUCIAL WINTER RANGE. That portion of the winter range on which a wildlife species is dependent for survival during periods of heaviest snow cover.

CULTURAL RESOURCE. A term that includes items of historical, archaeological, or architectural items; a remnant of human activity.

CUMULATIVE IMPACT. The impact on the environment that results from the positive or negative impacts of an action when added to other past, present, and reasonable foreseeable future actions, regardless of what agency or person performed such action(s).

DEEPER COAL SEAM. Designates a coal seam that is deep enough that it can be drilled to at a directional angle from a well pad in one spacing unit to another spacing unit. This avoids the need for constructing additional roads and well pads. The exact depth that the term "deeper" applies to is relative and will vary according to field spacing requirements and local geology.

DEVELOPMENT WELL. A well drilled in proven territory (usually within 1 mile of an existing production well).

DESORBED. To remove (an absorbed or adsorbed substance) from.

DISPOSAL WELL. A well into which produced water from other wells is injected into an underground formation for disposal.

DRAINAGE (GEOMORPHIC). A collective term for all the water bodies by which a region is drained; or, all the water features shown on a map.

DRAINAGE (OIL AND GAS). The uncompensated loss of hydrocarbons from Federal, Indian tribal or Indian-allotted mineral lands from wells on adjacent non-jurisdictional lands or jurisdictional lands with lower participation, allocation, royalty rate, or distribution of funds, resulting in revenue losses to the Federal or Indian lessors.

DRILL DIRECTIONALLY. The technique of drilling at an angle from a location at the surface to a different subsurface location at a specific target depth.

DRILL RIG. The mast, drawworks, and attendant surface equipment of a drilling or workover unit.

DRY HOLE. Any well incapable of producing oil or gas in commercial quantities. A dry hole may produce water, gas or even oil, but not enough to justify production.

ECOSYSTEM. A biological community, together with its nonliving environment, forming an interacting system inhabiting an identifiable space.

ELECTRICAL CONDUCTIVITY. A measure of the ability of a formation and the fluids present in it to conduct an electrical current. For shallow formations and coals, the conductivity is generally related to the soluble salts present in the formation fluid.

EMISSION. Air pollution discharge into the atmosphere, usually specified by mass per unit time.

ENDANGERED SPECIES. Those species of plants or animals classified by the Secretary of the Interior or the Secretary of Commerce as endangered pursuant to Section 4 of the Endangered Species Act of 1973, as amended. See also Threatened and Endangered Species.

ENHANCED RECOVERY. The use of artificial means to increase the amount of hydrocarbons that can be recovered from a reservoir. A reservoir depleted by normal extraction practices usually can be restored to production by secondary or tertiary methods of enhanced recovery.

EXPLORATION. The process of identifying a potential subsurface geologic target and the active drilling of a borehole designed to assess the coalbed methane potential. See also **development**.

EXPLORATION WELL. A well drilled in an area where there is no oil or gas production. Same as a “wildcat” well.

FAULT. A fracture surface in rocks along which movement of rock on one side has occurred relative to rock on the other side.

FLOODPLAIN. The relatively flat area or lowlands adjoining a body of standing or flowing water that has been or might be covered by floodwater.

FLOW LINE. A small diameter pipeline that generally connects a well to the initial processing facility.

FORMATION (GEOLOGIC). A rock body distinguishable from other rock bodies and useful for mapping or description. Formations may be combined into groups or subdivided into members.

FUGITIVE DUST. Airborne particles emitted from any source other than through a controllable stack or vent.

GEOMORPHIC. Pertaining to the form of the earth or its surface features.

GROUND COVER. Vegetation, mulch, litter, or rocks.

GROUNDWATER. Subsurface water that is in the zone of saturation. The top surface of the groundwater is the “water table.” Source of water for wells, seepage, and springs.

HABITAT. In wildlife management, the major elements of habitat are considered to be food, water, cover, and living space.

HAZARDOUS WASTE. (A) Any substance designated pursuant to section 311(b)(2)(A) of the Federal Water Pollution Control Act. (B) Any element, compound, mixture, solution, or substance designated pursuant to section 102 of this Act. (C) Any hazardous waste having the characteristics identified under or listed pursuant to section 3001 of the Solid Waste Disposal Act (but not including any waste the regulation of which under the Solid Waste Disposal Act has been suspended by Act of Congress.) (D) Any toxic pollutant listed under section 307(a) of the Federal Water Pollution Control Act. (E) Any hazardous air pollutant listed under section 112 of the Clean Air Act. (F) Any imminently hazardous chemical substance or mixture with respect to which the Administrator has taken action pursuant to section 7 of the Toxic Substances Control Act. The term does not include petroleum, including crude oil or any fraction thereof which is not otherwise specifically listed or designated as a hazardous substance under subparagraphs (A) through (F) of this paragraph, and the term does not include natural gas, natural gas liquids, liquefied natural gas, or synthetic gas usable for fuel (or mixtures of natural gas and such synthetic gas).

HYDROSTATIC PRESSURE. relating to fluids at rest or to the pressures they exert or transmit; "hydrostatic pressure"

INFILTRATION. The flow of a fluid into a solid substance through pores or small openings; specifically, the movement of water into soil or porous rock.

INJECTION WELL. A well used to inject fluids into an underground formation either for enhanced recovery or disposal.

INTERMITTENT STREAM. A stream that flows most of the time but occasionally is dry or reduced to pool stage when losses from evaporation or seepage exceed the available streamflow.

LAND AND WATER CONSERVATION FUNDS. Federal revenues generated by a tax on federal off-shore oil and gas development through the Land and Water Conservation Fund Act; used to acquire highly desirable lands for the United States by the various governmental agencies.

LEASABLE MINERALS. Federal minerals subject to lease under the Mineral Leasing Act of 1920, as amended, and supplemented. Includes minerals, such as oil, gas, coal, geothermal, tar sands, oil shale, potassium, phosphate, sodium, asphaltic materials.

LEASE.

1. A legal document that conveys to an operator the right to drill for oil and gas.

2. The tract of land, on which a lease has been obtained, where producing wells and production equipment are located.

LEASE NOTICE. Provides more detailed information concerning limitations that already exist in law, lease terms, regulations, or operational orders. A lease notice also addresses special items the lessee should consider when planning operations, but does not impose new or additional restrictions. Lease notices attached to leases should not be confused with NTLs (Notices to Lessees).

LEK. A traditional breeding area for grouse species where territorial males display and establish dominance.

LIGNITE. A brownish-black coal that is intermediate between peat and subbituminous coal.

LOAMY. Soil that is intermediate in texture and properties between sandy and clayey soils. Textural classes are sandy loam, fine sandy loam, very fine sandy loam, loam, silt loam, sandy clay loam, and clay loam with clay content between 18 and 35 percent.

LOCALITY. The area where paleontologic material is discovered.

LOCATABLE MINERALS. Minerals or materials subject to disposal and development through the Mining Law of 1872 (as amended). Generally includes metallic minerals such as gold and silver and other materials not subject to lease or sale.

MACERALS. the small fragments formed in peat and coal, and can be identified microscopically as coming from plant products.

MINERAL MATERIALS. Widespread deposits of common clay, sand, gravel, or stone that are not subject to disposal under the 1872 Mining Law, as amended.

MITIGATION MEASURES. Methods or procedures developed for the purpose of reducing or lessening the impacts of an action.

MONITORING. Specific studies that evaluate the effectiveness of actions taken toward achieving management objectives.

NATIONAL AMBIENT AIR QUALITY STANDARDS OR NAAQS. The allowable concentrations of air pollutants in the air specified by the federal government. The air quality standards are divided into primary standards (based on air quality criteria and allowing an adequate margin of safety requisite to protect the public health) and secondary standards (based on air quality criteria and allowing an adequate margin of safety to protect the public welfare from any unknown or expected adverse effects of air pollutants).

NO SURFACE OCCUPANCY. Use or occupancy of the land surface for fluid mineral exploration or development is prohibited to protect identified resource values.

NOTICE TO LESSEES (NTL). The NTL is a written notice issued by the Authorized Officer. NTLs implement regulations and operating orders, and serve as instructions on specific item(s) of importance within a State, District, or Area.

PARTICULATE MATTER. A particle of soil or liquid matter (e.g., soot, dust, aerosols, fumes and mist).

PERENNIAL STREAM. A permanent stream that flows 9 months or more out of the year.

PERMEABILITY. The ease with which gases, liquids or plant roots pass through a layer of soil. Accepted as a measure of this property is the rate at which soil transmits water while saturated, and may imply how well water passes through the least permeable soil layer.

PERFORATING. Penetrating the well casing to open the reservoir to the surface.

pH. A measure of acidity or alkalinity. A solution with a pH of 7 is neutral, pH greater than 7 (to 14) is alkaline, and a pH less than 7 (to 0) is acidic.

PARTS PER MILLION (PPM). A measurement to identify the amount of particulates in air or water.

POD. Describes the general location of a series of wells that tap individual coal seams within a single spacing unit. For example, within the Powder River Basin, three coal seams are layered beneath the surface. On the surface, an operator may drill three separate wells to different depths to tap these individual seams. The wells may be located within 20 feet of each other, representing a pod of wells.

POROSITY. The ratio of the volume of all the pores in a material to the volume of the whole.

PREVENTION OF SIGNIFICANT DETERIORATION OR PSD. A regulatory program under the Clean Air Act (Public Law 84-159, as amended) to limit air quality degradation in areas currently achieving the National Ambient Air Quality Standards. The PSD program established air quality classes in which differing amounts of additional air pollution is allowed above a legally defined baseline level. Almost any additional air pollution would be considered significant in PSD Class I areas (certain large national parks and wilderness areas in existence on August 7, 1977, and specific Tribal lands redesignated since then). PSD Class II areas allow that deterioration associated with moderate, well-controlled growth (most of the country).

Class I. An area that allows only minimal degradation above "baseline." The Clean Air Act designated existing national parks over 6,000 acres and national wilderness areas over 5,000 acres in existence on August 7, 1977, as mandatory Federal Class I Areas. These areas also have special visibility protection. In addition, four tribal governments have redesignated their lands as Class I Areas.

Class II. An area that allows moderate degradation above "baseline." Most of the United States (outside nonattainment areas) is Class II.

Class III. Any area that allows the maximum amount of degradation above "baseline." Although the U.S. Congress allows air quality regulatory agencies to redesignate Class II lands to Class III, none have been designated.

PRODUCED WATER. Water produced from oil and gas wells.

RAPTOR. Bird of prey with sharp talons and strongly curved beaks (hawks, falcons, owls, and eagles).

RECLAMATION. Rehabilitation of a disturbed area to make it acceptable for designated uses. This normally involves regrading, replacement of topsoil, revegetation, and other work necessary to restore it for use.

RESERVE PIT.

1. Usually an excavated pit that may be lined with plastic, that holds drill cuttings and waste mud.

2. Term for the pit that holds the drilling mud.

RIGHT-OF-WAY GRANT. A document authorizing a nonpossessory, nonexclusive right to use federal lands for the limited purpose of construction, operation, maintenance, and termination of a pipeline, road, or powerline.

RILL. Small, conspicuous water channel or rivulet that concentrates runoff; usually less than 6 inches deep.

RIPARIAN/WETLAND AREA. An area of land directly influenced by permanent water. It has visible vegetation or physical characteristics reflective of permanent water influence. Lakeshores, streams and permanent springs are typical riparian areas. Excluded are such sites as ephemeral streams or washes that do not exhibit the presence of vegetation dependent upon free water in the soil.

ROAD. A vehicle route that has either been improved and maintained by mechanical means to ensure relatively regular and continuous use, or been established where vehicle travel has created two parallel tracks lacking vegetation.

SALINITY. A measure of the salts dissolved in water. See **alkalinity**.

SEDIMENT. Soil, rock particles and organic or other debris carried from one place to another by wind, water, gravity, ice, or other geologic agent.

SEDIMENTARY ROCK. A layered rock resulting from the consolidation of sediment, such as shale, sandstone, and limestone.

SEISMIC OPERATIONS. Use of explosive or mechanical thumpers to generate shock waves that can be read by special equipment to give clues to subsurface conditions.

SHALLOW COAL SEAM. Those coal seams that are too shallow to drill to directionally given the area geology and spacing limitations.

SHUT IN. To close the valves on a well so it ceases production.

SODIUM ABSORPTION RATIO. An expression of relative activity of sodium ions in exchange reactions with soil, indicating the sodium or alkali hazard to soil. It is a particularly important measure in waters used for irrigation purposes.

SODIUM-AFFECTED SOIL. A nontechnical term for sodic soil (also called alkali soil) that contains sufficient sodium to interfere with the growth of most crop plants and in which the exchangeable sodium percentage is 15 or higher. It is also a generic way of describing nonsaline-alkali soil or saline-alkali soil.

SOLID WASTE. Any solid, semi-solid, liquid, or contained gaseous material that is intended for disposal.

SPACING UNIT. The number of acres that one oil or gas well will efficiently drain. The state oil and gas commissions typically establish the size of spacing units for each oil and gas field.

SPECIES OF SPECIAL INTEREST OR CONCERN. Animals not yet listed as endangered or threatened but that are undergoing status review by a federal or state agency. This may include animals whose populations could become extinct by any major habitat change. A species that is particularly sensitive to some external disturbance factors.

SPLIT ESTATE. Surface and minerals of a given area in different ownerships. Frequently, the surface is privately-owned while the minerals are federally or state-owned.

STIPULATION. A condition or requirement attached to a lease or contract, usually dealing with protection of the environment, or recovery of a mineral.

SUBBITUMINOUS. A black coal, intermediate in rank between lignite and bituminous coal. Distinguished from lignite by higher carbon and lower moisture content.

SULFUR DIOXIDE OR SO_2. A colorless gas formed when sulfur oxidizes, often as a result of burning trace amounts of sulfur in fossil fuels.

THERMOGENIC. Generation or production of heat, especially by physiological processes.

TOTAL DISSOLVED SOLIDS (TDS). The dry weight of dissolved material, organic and inorganic, contained in water and usually expressed as parts per million (ppm).

TRANSMISSION LINE. A large diameter pipeline through which oil or gas moves off lease after being sold.

TURBIDITY. An interference to the passage of light through water due to insoluble particles of soil, organic material, micro-organisms, and other materials.

UNDERGROUND INJECTION CONTROL PROGRAM. A program administered by the Environmental Protection Agency, primacy State, or Indian Tribe under the Safe Drinking Act to ensure that subsurface emplacement of fluids does not endanger underground sources of drinking water.

UNITIZATION. Pooling of mineral acreages proposed by a company to facilitate the efficient development of a reservoir based on geology and reservoir characteristics of a producing formation or formations.

VIEWSHED. Landscape that can be directly seen under favorable atmospheric conditions, from a viewpoint or along a transportation corridor.

VITRINITE. A kind of naturally occurring glass which is very hard.

WATER QUALITY. The chemical, physical, and biological characteristics of water with respect to its suitability for a particular use.

WATERSHED. All lands which are enclosed by a continuous hydrologic drainage divide and lie upslope from a specified point on a stream.

WELL COMPLETION. See **completion**.

WELL LIFE. For the purposes of this plan the well life is defined as from the time the well is drilled until the final abandonment of the well is approved.

WETLANDS. Permanently wet or intermittently flooded areas where the water table (fresh, saline, or brackish) is at, near, or above the soil surface for extended intervals; where hydric wet soil conditions are normally exhibited, and where water depths generally do not exceed two meters.

WILDERNESS STUDY AREA (WSA). An area determined to have wilderness characteristics. WSAs are submitted to the President and Congress for wilderness designation. These areas are an interim designation, valid until either designated as wilderness or released to multiple-use management.

WORKOVER. To perform one or more remedial operations on a producing or injection well to increase production. Deepening, plugging back, pulling, and resetting the liner are examples of workover operations.

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COALBED METHANE DEVELOPMENT IN THE INTERMOUNTAIN WEST: PRIMER

Coalbed methane is one of the most important and valuable natural resources in the Western United States. The natural gas that results from CBM development is the cleanest burning fossil fuel, and the extensive domestic supply makes it a central element of the national goal of a secure supply of energy. Demand for natural gas will continue to grow and CBM will play an increasingly larger role in meeting that demand. CBM production has expanded tremendously over the past decade, and the rapidity with which development has expanded has resulted in stresses and tension in affected communities. Development of this important energy resource must be balanced with a number of other important goals of protecting water, land, and other resources in the West. The primary purposes of the report are to: provide an overview of where CBM resources are located and how they are extracted, provide some background for understanding the issues surrounding CBM development and the role that it plays in the nation's energy policy, review the public policies affecting the production of CBM, assess the major issues that have arisen in the West concerning CBM development and its impact on local communities and other natural resources, examine lessons that might be learned from different basins and that might be applied elsewhere, and suggest some basic principles and practical steps that might serve to address some of the conflicts that have arisen in CBM basins and that might be applied to shape future development in other basins.

GARY BRYNER, *Natural Resources Law Center, University of Colorado School of Law*

Overview

Coalbed methane (CBM) is a form of natural gas that is trapped within coal seams and held in place by hydraulic pressure. The gas is adsorbed to the internal surfaces of the coal; when wells are drilled that extract the water holding the gas in place, the methane eventually flows through fractures to the well and is captured for use. Coalbed methane extraction began as an effort to reduce the threat of methane explosions in coal mines, and has been produced in commercial quantities since 1981. CBM development in the United States has grown rapidly from a few dozen wells in the 1980s to some 14,000 wells in 2000. In 1989, the United States produced 91 billion cubic feet of coalbed methane; ten years later, the total produced had grown to nearly 1.3 trillion cubic feet, representing seven percent of the total natural gas production in the United States.[1]

Some 56 percent of the total CBM production in the United States has come from the Rocky Mountains. The San Juan basin in Southern Colorado/Northern New Mexico has been the major source of CBM. Development began in 1988 and rapidly expanded by the end of the 1990s. Production has now begun to decline and companies are trying to maintain output by more intensive development. The Powder River Basin in Northeast Wyoming is the fastest growing CBM play. In 1997, the basin produced 54 million cubic feet of gas/day from 360 wells. Four years later, 5,854 wells were producing 656 million cubic feet/day. CBM resources are also being developed in the Uinta Basin in Eastern Utah, the Raton Basin in south-central Colorado, and the Piceance Basin in northwest Colorado, and major expansions of coalbed development are expected in Montana, the Green River basin in Wyoming, and perhaps other areas in the West. Colorado, New Mexico, Utah, and Wyoming may contain as much as 47 trillion cubic feet of coalbed methane, one third of the total estimated recoverable amount in the United States. According to the US Geological Survey, the United States may contain more than 700 trillion cubic feet (Tcf) of coalbed methane in place, with more than 100 Tcf economically recoverable with existing technology.[2]

The tremendous and rapid growth in coalbed methane development has posed daunting challenges for the communities in which it has occurred. The construction of new roads, pipelines, compressors, and other facilities have transformed landscapes. Air and noise pollution have become sources of conflict. Some land owners possess only surface rights; government agencies have leased the subsurface mineral rights to companies, and those rights clash with the interests of some ranchers, farmers, homeowners, and others who seek different kinds of land uses. Just as difficult as land use issues have been conflicts over the water produced from CBM development. CBM development may affect underground water quantity and contaminate aquifers, underground water supply may be diminished as dewatering occurs, groundwater may be contaminated by mineral-laden discharged water, and local ecosystems may be adversely affected by the surface release of large quantities of water. Produced water may also be a valuable source of fresh water in arid regions.

CBM development is a major issue facing federal land agencies, state governments, county commissions, energy companies, and citizens throughout the Intermountain West. Another major challenge is that of governance—how to coordinate the efforts of federal, tribal, state, and local governments that have varying interests and responsibilities for regulating CBM production.

This primer seeks to contribute to public discussion and policy making for CBM development by providing a non-technical, accessible, reference tool that explains what CBM is, examines and compares the experience of CBM development throughout the mountain West, explores options for resolving conflicts and improving policies that govern CBM development, and identifies lessons that can be learned from different areas that might help other regions better deal with the challenges posed by development. The sections of the primer focus on four major questions.

First, what is CBM, where is it located, and how is it developed? This section provides background and context for framing the issues surrounding CBM development, including the nature of CBM, its role in meeting national energy needs; the location of major CBM resources in the Interior West, including the relationship of reserves to private and public lands, including split estates and sensitive public lands, such as wilderness study areas, National Forest roadless areas, and national monuments; and the role of CBM in national energy policy.

Second, what are the problems, conflicts, and challenges associated with CBM development? Section two examines the environmental and other impacts associated with CBM development, particularly the impacts of production and distribution of CBM on local landscapes and residents and the conflicts between competing land uses and users, and the impact of CBM extraction on water quality and quantity.

Third, how is CBM development regulated? This section examines current public policies governing CBM development, including Federal clean water, natural gas, and other laws and regulations; Federal tax incentives and its implications for CBM development; state regulatory programs; and local land use, zoning, and other regulatory programs in the Intermountain states where CBM development is occurring.

Fourth, how can conflicts surrounding CBM development be reduced? This section focuses on suggestions that have been made to minimize the environmental and other impacts of CBM extraction and actions that communities, governments, and companies might take to reduce conflicts over land use and water impacts from development.

I. What is CBM, where is it located, and how is it developed?

What is coalbed methane?

Coalbed methane is a form of natural gas that is trapped within coal seams. Coalbed gas is primarily made up of methane (typically 95 percent), with varying amounts of heavier fractions and, in some cases, traces of carbon dioxide. Coals have a tremendous amount of surface area and can hold massive quantities of methane. Since coalbeds have large internal surfaces, they can store six to seven times more gas than the equivalent volume of rock in a conventional gas reservoir. [3] Coal varies considerably in terms of its chemical composition, its permeability, and other characteristics. Some kinds of organic matter are more suited to produce CBM than are others. Permeability is a key characteristic, since the coalbed must allow the gas to move once the water pressure is reduced. The gas in higher rank coals is produced as heat and pressure transform organic material in the coal; gas in low rank coals results from the decomposition of organic matter by bacteria. Figure 1 provides a simplified view of how CBM is formed.

Coalbeds are both the source of the gas that is generated and the storage reservoir once it is produced.[4] Gas

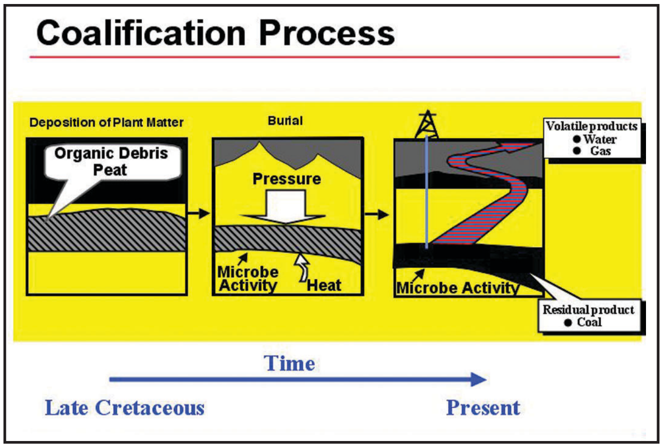

FIGURE 1 *Source: William T. Brown, NRLC coalbed methane conference, April 4–5, 2002.*

molecules adhere to the surface of the coal. Most of the coalbed methane is stored within the molecular structure of the coal; some is stored in the fractures or cleats of the coal or dissolved in the water trapped in the fractures. Coals can generally generate more gas than they can absorb and store. Basins that contain 500–600 standard cubic feet (SCF) of methane per ton are considered to be "very favorable for commercial coalbed gas production," as long as there is sufficient reservoir permeability and rate of desorption. Some coals have generated more than 8,000 SCF of methane per ton of coal. [5] The most productive coalbeds are highly permeable, saturated with gas, and fractured.[6]

Coalbed methane is produced either through chemical reactions or bacterial action. Chemical action occurs over time as heat and pressure are applied to coal in a sedimentary basin. Bacteria that obtain nutrition from coal produce methane as a by-product.[7] Methane attaches to the surface areas of coal and throughout fractures, and is held in place by water pressure. When the water is released, the gas flows through the fractures into a well bore or migrates to the surface. Figure 2 illustrates the different kinds of coal, the production of coalbed methane, and the kinds of coal found in the major CBM basins in the West.

Most coals contain methane, but it cannot be economically extracted unless there are open fractures that provide the pathway for the desorbed gas to flow to the well. Methane remains in a coalbed as long as the water table is higher than the coal.[8] These cleats and fractures are typically saturated with water, and the coal must be dewatered (usually pumped out) before the gas will flow.[9] Some coals never produce methane if they cannot be dewatered economically. Some coal beds may produce gas but be too deep to feasibility drill to release the gas. CBM wells are typically no more than 5000' in depth, although some deeper wells have been drilled to extract the gas. The deeper the coalbed, the less the volume of water in the fractures, but the more saline it becomes. The volume of gas typically increases with coal rank, how far underground the coalbed is located, and the reservoir pressure.[10]

As the fracture system produces water, the adsorptive capacity of the coals is exceeded, pressure falls, and the gas trapped in the coal matrix begins to desorb and move to the empty spaces in the fracture system. The gas remains stored in nearby non-coal reservoirs until it is extracted.[11] Drilling dewaters the coal and accelerates the desorption process. Drilling initially produces water primarily; gas production eventually increases and water

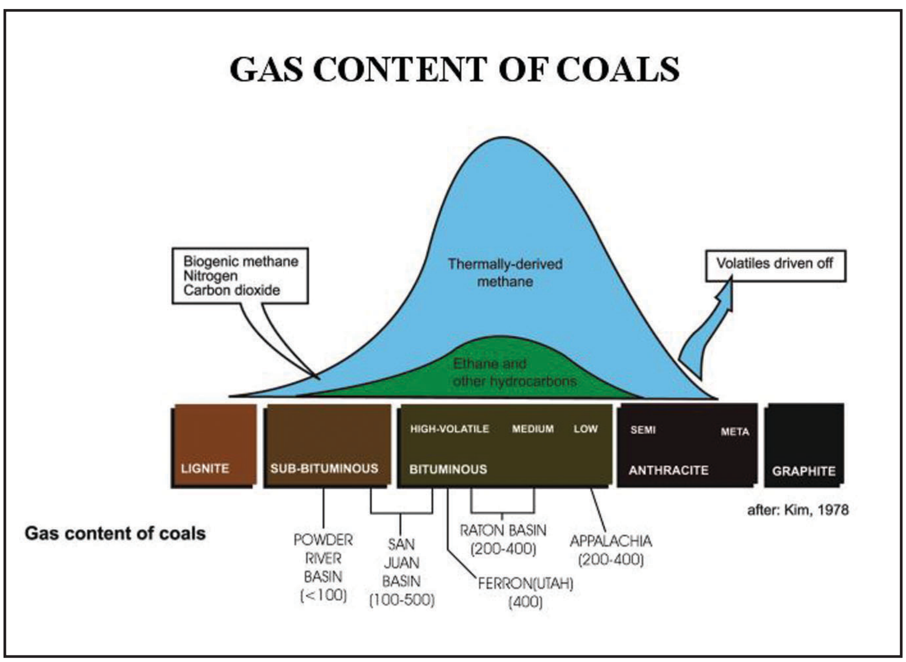

FIGURE 2 *Source: William T. Brown, NRLC coalbed methane conference, April 4–5, 2002.*

production declines. Some wells do not produce any water and begin producing gas immediately, depending on the nature of the fracture system. Once the gas is released, it is free of sulfur and usually of sufficient quality to be directly pumped into pipelines.[12]

What role does CBM play in U.S. Energy Policy?

Oil and natural gas are the dominant fuels in the U.S. energy supply, providing 62 percent of the total energy supply.[13] Natural gas provides 24 percent of the energy used in the United States and 27 percent of total domestic production.[14] The United States produces 85% of the gas it uses and imports the rest from Canada. Natural gas is used to produce 16 percent of the electricity generated in the United States, and the fastest growing use of natural gas is to produce electricity.[15] It is also used for space and water heating, cooking, fueling industrial processes, vehicle fuel, and other purposes. Natural gas prices have fluctuated considerably in recent years, affecting incentives to explore for new reserves. Prices were stable throughout the late 1980s and 1990s, and low prices in 1998 and 1999 resulted in cutbacks in exploration. In 2000, prices quadrupled, reaching an all-time high of $9.98 per million Btus in December 2000, and exploratory activity expanded accordingly.[16] Figure 3 charts the growth in natural gas and other fuels in the United States.

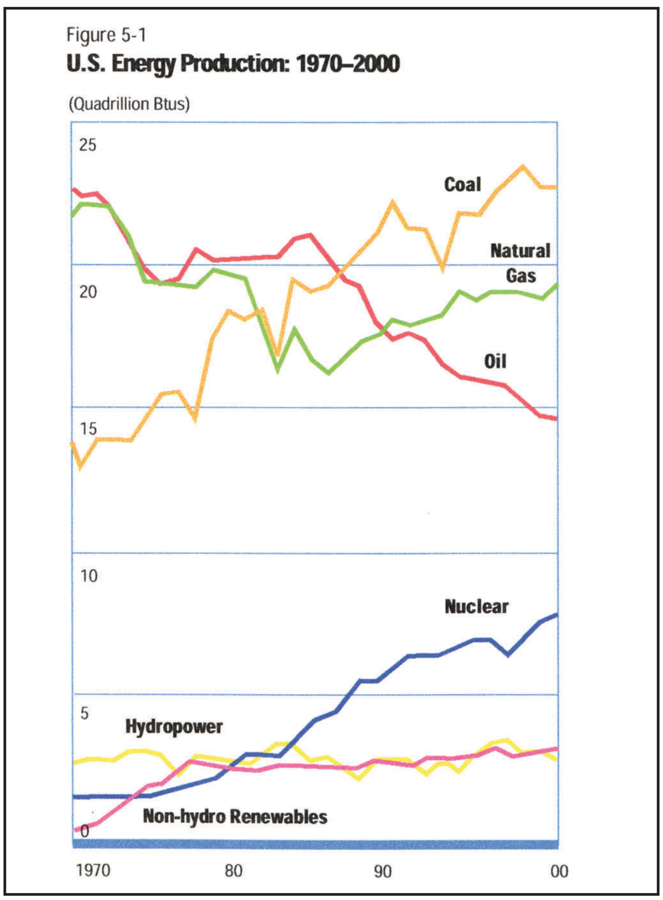

FIGURE 3 *Source: National Energy Policy Development Group, National Energy Policy, 5-1.*

The average household uses about 50,000 cubic feet of natural gas each year. One trillion (1,000,000,000,000) cubic feet of natural gas is enough to meet residential needs for about 75 days. The balance of the natural gas used each year fuels electricity production and industrial and commercial operations. Demand for natural gas is currently growing at about 1 Tcf per year.[17] The Bush administration's national energy policy projects that the United States will need about 50 percent more natural gas to meet demand in 2020 and that demand will eventually outstrip domestic supply, requiring increased imports of natural gas from Canada and elsewhere.[18] The U.S. Department of Energy (DOE) on which the national energy policy projections is based suggests that natural gas use will increase between 2000 and 2020 from 22.8 to 34.7 Trillion cubic feet (Tcf); another estimate suggested consumption will climb to 31 Tcf by 2015.[19] Others project an even more rapid increase in consumption. Many executives of natural gas companies believe that by 2007 the market for gas will reach 30 Tcf.[20]

Domestic production of natural gas is expected to increase from 19.3 Tcf in 2000 to 29.0 Tcf in 2020, resulting in increased natural gas imports. According to a DOE report,

> *the most significant long-term challenge relating to natural gas is whether adequate supplies can be provided to meet sharply increased projected demand at reasonable prices. If supplies are not adequate, the high natural gas prices experienced over the past year could become a continuing problem, with consequent impacts on electricity prices, home heating bills, and the cost of industrial production. . . . To meet this long-term challenge, the United States not only needs to boost production, but also must ensure that the natural gas pipeline network is expanded to the extent necessary.*[21]

Natural gas, including coalbed methane, and other domestically-produced energy sources play a major role in the Bush administration's energy policy. The administration's National Energy Policy and other policy statements all emphasize expanding U.S. sources of fossil fuels. The report includes 105 specific recommendations, including forty-two suggestions for policies to promote conservation, efficiency, and renewable energy sources and thirty-five that deal with expanding supplies of fossil fuels. The report, however, clearly emphasizes and gives priority to expanding the supply of traditional energy sources by opening new lands for exploration, streamlining the permitting process, easing regulatory requirements, and enlarging the nation's energy infrastructure. It summarizes the energy challenge this way:

Even with improved efficiency, the United States will need more energy supply. . . .The shortfall between projected energy supply and demand in 2020 is nearly 50 percent. That shortfall can be made up in only three ways: import more energy; improve energy efficiency even more than expected; and increase domestic energy supply.[22]

The Bush national energy plan argues that in the near term, increase in natural gas production will come from "unconventional sources" in the Rocky Mountain and other regions, and includes a number of recommendations that affect natural gas and CBM development. The plan:[23]

- Calls on federal agencies to promote enhanced recovery of oil and gas from existing wells, encourage oil and gas technology through public-private partnerships, reduce impediments to federal oil and gas leases, and reduce royalties and create other financial incentives to encourage environmentally sound offshore oil and gas development.
- Recommends additional oil and gas development in the National Petroleum Reserve in Alaska and the opening of an area (called section 1002) in the Arctic National Wildlife Refuge for exploration.
- Calls for streamlining the regulatory process, providing "greater regulatory certainty" for power plant operators, and reducing the time and cost involved in licensing hydroelectric power plants.
- Urges continued development of clean coal technology through a permanent extension of the research and development tax credit and investing $2 billion in research and development over ten years.
- Suggests the President issue an executive order to "rationalize permitting for energy production in an environmentally sound manner" and federal agencies "expedite permits and other federal actions necessary for energy-related project approvals."24
- Suggests the Interior Department reassess decisions it has made to withdraw certain lands from energy exploration and development, and to simplify its leasing policy so that more oil and natural gas are produced, including in the Outer Continental Shelf.
- Urges Congress to resolve the legal status of eleven million acres of BLM lands and 1.8 million acres managed by the Fish and Wildlife Service that have been designated by the agencies as wilderness study areas, and to determine which lands could be opened up to energy development.

The Bush administration's national energy policy, the energy legislation currently before Congress (passed by the House in 2001 and and Senate in the spring of 2002), and the importance of energy in the American economy and the foreign policy consequences of our reliance on imported oil all raise important and difficult policy questions that have profound implications for the American West. Energy development clashes with other values of preservation of wild lands, protection of ecoystems and wildlife habitat, and recreational and aesthetic interests, and conflicts are inevitable as people throughout the West have greatly differing views about what should happen on public and private lands. Coalbed methane is no different from that of other natural resources, in that respect, but the rapid pace of development in areas has compressed and magnified these conflicts.

How is CBM produced?

CBM was first noticed as a problem in coal mining, when fires or explosions of methane gas threatened miners. To reduce the risk of explosions, coalmine methane has been vented during mining operations. Some companies began capturing coalbed methane as a valuable resource and later, as attention came to be focused on methane as a potent greenhouse gas, coalmine methane production has been pursued as a way to help reduce the threat of climate change.

There have been some legal disputes over ownership of coalmine and coalbed methane. In *Amoco Production Company v Southern Ute Indian Tribe*, 526 U.S. 865 (1999), the Supreme Court ruled that CBM is not included in the meaning of coal; CBM is part of the gas estate not the coal estate. The Court indicated that coal companies can vent the gas while mining, but that the right to vent the gas does not imply ownership of it. The ruling is not binding on state law and private contracts. Oil and gas rights, including coalbed methane rights, are generally more senior than coal mining rights, and CBM companies may seek injunctions to ensure mining operations do not adversely affect methane extraction. In some cases, coal companies have bought out CBM leases so mining can continue unobstructed. In other cases, they complain that their operations are being held up unfairly by CBM owners who buy up gas rights and then sell them at above market prices.[25]

In 1980, Congress enacted a tax credit to encourage domestic production from unconventional sources, including CBM. Referred to as the Section 29 tax credit (section 29 of the 1980 Crude Oil Windfall Profit Tax Act), the provision has two limits: the gas must be sold to an unrelated party, and the credit only applies to wells placed in service before Dec 31, 1992. The tax credit, worth $3 barrel of oil or Btu equivalent, expired on December 31, 2000 and the tax credit is modified and extended in both the House and Senate energy bills that the two chambers passed in 2001 and 2002, respectively, and are the subject of a conference committee convened in May 2002.

CBM has been produced in commercial quantities since 1981.[26] CBM development in the United States grew rapidly from a few dozen wells in the 1980s to nearly 6,000 wells producing 1.5 Bcf by 1992. Despite the tax credit no longer being available for new wells after that time, production skyrocketed; the Gas Research Technology Institute reported in 2000 that 14,000 wells produced 1.5 Tcf of gas, representing seven percent of the total gas production in the United States.[27] In 1989, the United States produced 91 Bcf of coalbed methane. Ten years later, the total produced had grown to nearly 1.3 Tcf.[28] Figures for CBM production in the state of Colorado illustrate the rapid growth of development in the state. In 1990, CBM wells in the state produced 27 Bcf of methane; by 1995, they produced 240 Bcf; and their output steadily increased throughout the rest of the decade, reaching 417 Bcf in 2000.[29]

How does CBM compare with other forms of natural gas?

Methane is a major component of natural gas, and coalbed methane can be used in the same way as conventional gas. Conventional gas is formed in shale and limestone formations; pressure and temperature combine to transform organic matter into hydrocarbons. The gas migrates upward until trapped by a geologic fault or fold and rests in this reservoir rock until it is discovered, drilled, and extracted. The location and extent of conventional gas typically requires exploratory drilling since the location of reservoirs is not apparent from the surface.[30]

Coalbed methane is sometimes compared with another unconventional gas—“tight” gas—that is found at much deeper depths and in low permeability sandstone. Companies must use hydraulic fracturing, where they inject a fluid into a rock formation that causes cracking, in order to release gas from tight Cretaceous sands.[31] Fracturing is also used in some CBM plays to increase production, as explained below.

Coalbed methane differs from other gas reservoirs in several ways:[32]

- CBM is stored in an adsorbed state on the surface of the coal;
- Before CBM can be produced in significant quantities, the average reservoir pressure must be reduced; and
- Water is usually present in the reservoir and is normally co-produced with the CBM.[33]

The competitiveness of coalbed methane with conventional natural gas is a function of four primary variables: the rates of gas production, the production costs, markets, and economies of scale.[34]

- The rate and volume of gas production from CBM wells vary considerably. Low gas producers yield about 50 thousand cubic feet per day; high yield wells—“sweet spots” in basins produce 5 million cubic feet/day.
- Since coalbed methane wells are typically shallow (less than 4,000 feet) and on land, well costs are low to moderate in comparison with conventional natural gas.

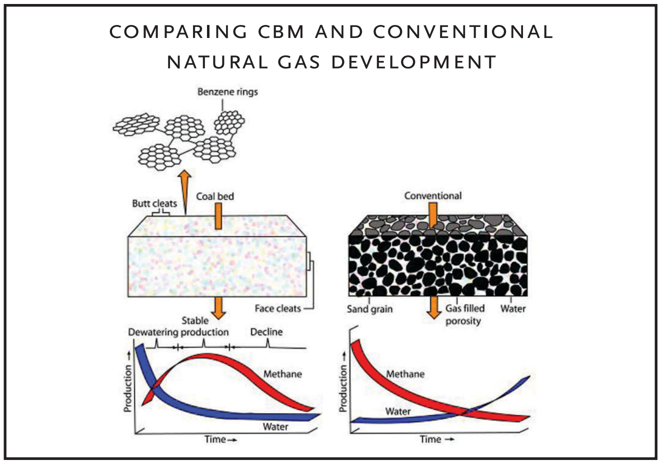

FIGURE 4 *Source: William T. Brown, NRLC coalbed methane conference, April 4–5, 2002*

- The distance between the producing wells and consumers also shapes the economics of CBM development. The market price, minus transportation and compression costs, equal the wellhead net back price. In some areas, the transportation costs may be as great as the wellhead net back price.
- CBM development needs to reach a critical volume of production in order to be economically viable. Costs include gas treatment, compression, transportation, geologic and engineering services, and field operations. The minimum threshold for a viable project varies depends on a variety of factors, but one estimate is that a new, remote basin requires at least 400 wells or 200 billion cubic feet of production to be viable.

In conventional wells, gas production peaks early and then declines over time, and water production eventually increases, the opposite of CBM extraction. The figure below depicts the stages in production of both kinds of wells. For CBM wells, large quantities of water are produced during the initial phase, then water volume declines as the pressure of the reservoir falls. The actual shape of the production curve is a function of production techniques (well spacing, reservoir permeability, reservoir pressure, and water saturation), and varies considerably by reservoir. In some basins, peak gas production occurs in three or more years. The length of time required to produce peak gas production increases in low permeability reservoirs and increased well density.[35] Since CBM wells generally produce gas at lower rates than conventional gas wells, the cost of water disposal in CBM development is significant relative to that of conventional development. Further, CBM development cannot simply be shut off when prices fall, since the coal may refill with water: "you don't start and stop wells in response to short-term price swings."[36] Figure 4 compares CBM and conventional natural gas development and the differences in the volumes of water produced over time. One of the most important characteristics of CBM development is the relatively short span of time wells produce gas. Wells typically produce gas for 7–10 years, and basins may be relatively quickly pumped and then abandoned.

Where are CBM resources located?

Development of CBM resources has been concentrated in the West, South, and, to a lesser extent, the Midwest. Figure 5 is a map that identifies the major CBM plays in the United States.

Some 56 percent of the total CBM production in the United States has come from the Rocky Mountains. Colorado, New Mexico, Utah, and Wyoming may contain as much as 47 trillion cubic feet of coalbed methane, one third to one-half of the total estimated recoverable reserves in the United States. The San Juan basin in southern Colorado/northern New Mexico has been the major source of CBM. Development began in 1988 and rapidly expanded by the end of the 1990s. Production has now leveled off and companies are trying to maintain

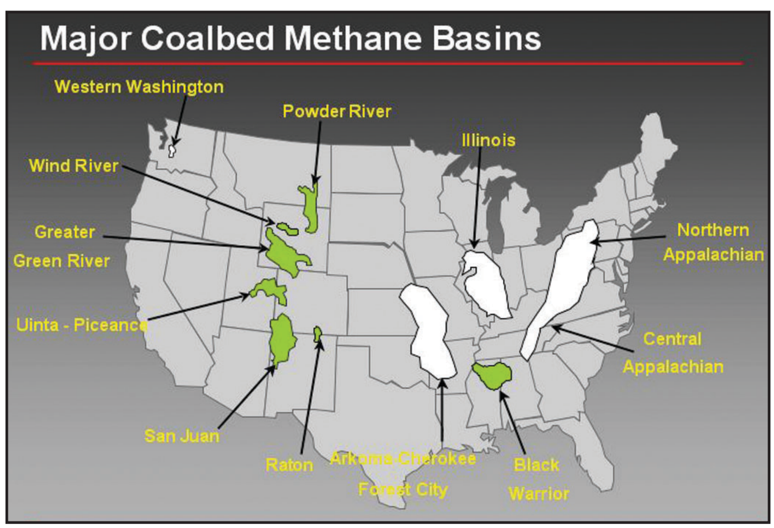

FIGURE 5 *Source: Steve de Albuquerque, NRLC coalbed methane conference, April 4–5, 2002*

output by more intensive development. The Powder River Basin in northwest Wyoming is the area of CBM production that is growing the most rapidly. In 1997, the basin produced 54 million cubic feet of gas/day from 360 wells. Four years later, 5,854 wells were producing 656 million cubic feet/day. CBM resources are also being developed in the Uinta Basin in eastern Utah, the Raton Basin in south-central Colorado, and the Piceance Basin in northwest Colorado, and major expansions of coalbed development are expected in Montana, the Green River basin in Wyoming, and perhaps other areas in the West.

The Potential Gas Committee estimated in 1991 that the four states contained a "most likely recoverable resource" ("probable, possible, and speculative") of coalbed methane of 47.2 Tcf. That amount represents about one-third of the estimated 145 Tcf in the United States.[37] In addition to those reserves, the Gas Research Institute estimates that between 87 and 110 Tcf may exist but is yet undiscovered. Another 1,000 Tcf of methane may also be located in Alaska.[38]

A more recent estimate looked at national reserves. The National Petroleum Council reported in 1999 that the United States' "natural resource base" in the lower 48 states was 1,466 trillion cubic feet; an additional 25 Tcf may be located in the Prudhoe Bay area in Alaska. According to Matt Silverman, CBM resources in the Rocky Mountain states are as follows: About 7 Tcf of CBM has been produced; 11 Tcf are the proved reserves that remain, and another 42 Tcf are economically recoverable reserves. Finally, the total resource base may be some 536 Tcf.[39] Estimates vary considerably, based on differing assumptions and differences between discovered resources and those that are economically or technically extractable.

Figure 6 is a map of the major coal-bearing regions of the Rocky Mountain states; figures for the estimated coalbed gas-in-place, in Tcf, are indicated in parentheses.

How do CBM basins compare?

The major CBM basins in the West include the following:

- Colorado/New Mexico:
  - —San Juan Basin (most mature basin 80% of U.S. production)
  - —Raton Basin (production for several years)
  - —Piceance Basin (potential development)
- Colorado/Utah
  - —Piceance (emerging area of development)
  - —Uinta Basin (production for several years)
- Wyoming/Montana
  - —Powder River Basin (fastest growing area)
- Colorado/Wyoming
  - —Green River Basin (potential development)
- There is also potential CBM development in the Denver Basin, Colorado, and in Alaska.

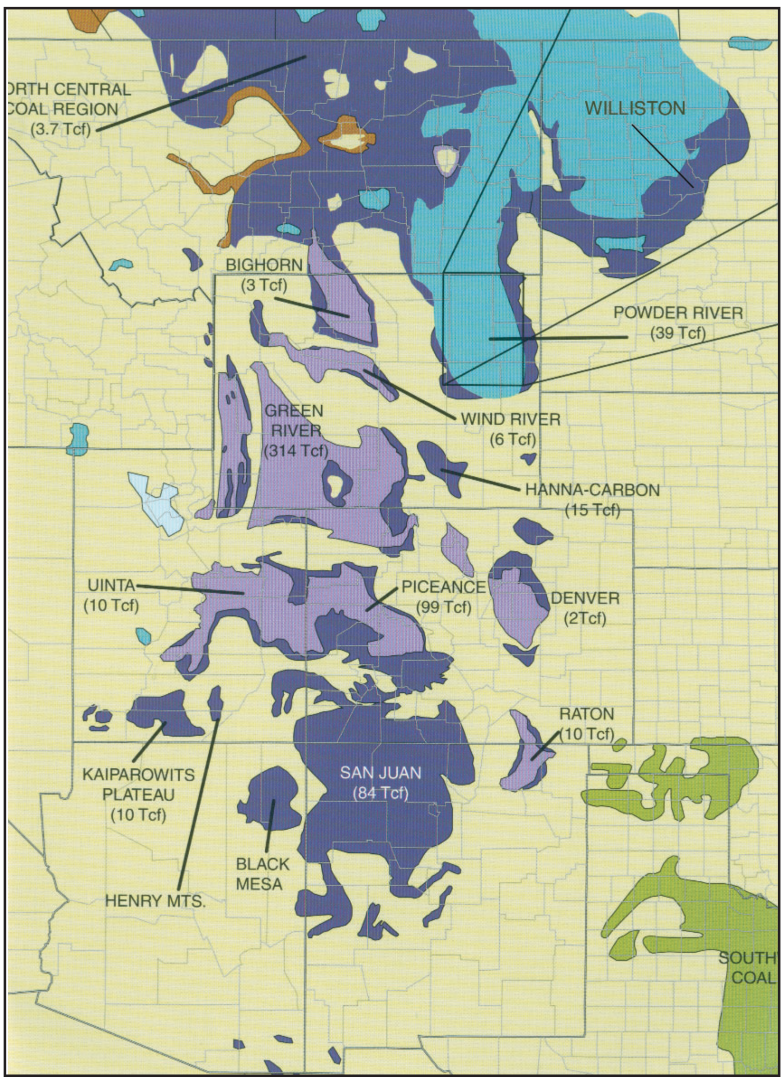

FIGURE 6 *Coalbed methane basisns of the Rocky Mountains*
Source: Matthew R. Silverman, NRLC conference, April 4–5, 2002

Each coalbed methane basin is unique. Each poses a different set of exploration and development challenges and produces a distinctive set of impacts on surrounding communities and ecosystems. Some basins have reached their peak in production while others are in the early stages of development. In some areas, the water that is produced is of high quality and ready to be used for a variety of human, agricultural, ranching, and other purposes; in other areas, water quality is poor and must be treated or re-injected. According to an engineer with Schlumberger-Holditch Reservoir Technologies, "The one thing coalbed methane plays in the U.S. have in common is that they are all different. You have to consider the complete package of coal characteristics, regional geology, and infrastructure . . . you can't get locked into one mindset."[40] The economics of each basin also varies: some basins may not look profitable at first, but innovative technologies are developed that make development feasible. The Powder River Basin, for example, was originally believed to be unsuited for CBM development, but companies experimented with various production and extraction techniques until development became feasible. Table 1 summarizes the main characteristics of CBM basins in the United States.

Coalbed methane play characteristics
Table 1 comparison of coalbed methane plays

Basin	States	Producing Wells (1996)	Cummulative CBM Prod. in mmcf (1981–1996)	typical Net Coal Thickness (ft)	Typical Gas Content (scf/ton)	Typical Well Spacing (acres)	Avg. Prod. (mcfd/well)	Est. Finding Cost ($/mcf)
San Juan	CO, NM	3,036	3,857	70	430	320	2,000	0.11
Black Warrior	AL, MS	2,739	728	25	350	80	100	.25
Central Appalachian	WV, VA, KY, TN	814	121	16	na	80	120	na
Piceance	CO	123	36	80	768	40	140	1.23
Powder River	WY, MT	193	17	75	30	80	250	0.25
Uinta	UT	72	14	24	400	160	690	0.25
Raton	CO, NM	59	8	35	300	160	300	0.18

Source: Karl Hart, "Coalbed Methane Trends," Hart Energy Publications, *PTTC Network News, 2nd quarter, 2000.*

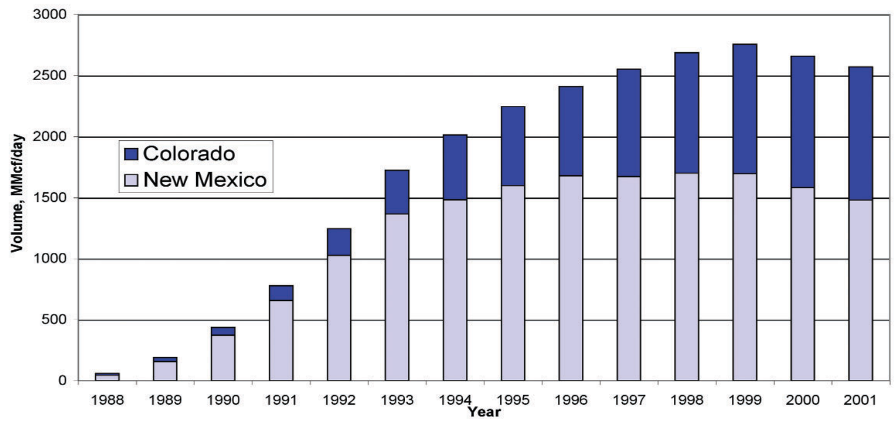

FIGURE 7, *CBM production from the San Juan Basin*
Source: Catherine Cullicott, Carolyn Dunmire, Jerry Brown, Chris Calwell, Ecos Consulting, Coalbed Methane in the San Juan Basin of Colorado and New Mexico.

THE SAN JUAN BASIN—COLORADO/NEW MEXICO

The San Juan basin has been the major source of CBM in the United States. The first recorded CBM well was drilled in 1951, but the first coalbed methane discovery well was drilled in 1976. Development began in 1988 and rapidly expanded to 2.7 Bcf/day by 1999. By 2002, there were some 4,50 active CBM wells in the basin. Production is no longer increasing and companies are trying to maintain output by focusing on enlarging gathering facilities, upgrading production equipment, installing pumping units and wellhead compression, recavitating producing wells, experimenting with secondary recovery efforts, and downspacing from 320-acre units. Typical wells in the San Juan Basin produce a total of from 7–12 Bcf, and many produce several million cubic feet each day. [41] In 2000, the San Juan Basin produced 0.78 Tcf of gas, 4% of total U.S. natural gas production and 80% of its CBM production, valued at $2.5 billion.[42] The BLM projects that 12,500 new oil, gas, and CBM wells will be drilled in the San Juan Basin over the next 20 years. Infill drilling—drilling wells more densely, at every 160 acres rather than 320 acres—has already begun. Figure 7 depicts the evolution of CBM production in the San Juan Basin in Colorado and New Mexico.

Estimates of the total CBM resource available in the San Juan vary greatly. The US Geological Survey's 1995 estimate suggested some 7.53 Tcf while others project 50 Tcf and higher. [43] According to Matt Silverman, there are 84 Tcf of CBM gas in place in the San Juan Basin and 8.5 Tcf of the 12 Tcf recoverable gas has already been extracted. [44]

The BLM and USFS are preparing an EIS in response to industry proposals to open new areas to drilling, and the draft EIS is expected to be released in the summer of 2002. The agencies are considering five options for expanded drilling: all five proposals call for increasing the density of drilling to one well per 160 acres, and all but one call for expanding drilling into the HD Mountains, a Forest Service roadless area.[45]

Coalbed methane development on the Southern Ute Indian Reservation has taken place for more than a decade and generated significant resources for the tribe. CBM development began in the early 1990s. In 1989, the Tribe's net worth was $39,000,000; by 2002, it had grown to $1,200,000,000.[46]

THE POWDER RIVER BASIN—WYOMING

The Powder River Basin is the fastest growing CBM play in the United States. The vast coal deposits of Wyoming contain massive quantities of methane gas and the Powder River Basin is one of the thickest accumulations of coal in the world.[47] In Wyoming, the first CBM wells were drilled in 1986. Companies drilled 10–55 wells/year through 1995, then 253 in 1996 to 4,502 in 2000 and 4,232 in 2001; 13,700 wells had been drilled by 2001. Production has climbed from about 1 Bcf in 1993 to 9 Bcf in 1996 to 251 Bcf in 2001.[48] In 1997, the basin produced 54 million cubic feet of gas/day from 360 wells. By 2001, 5,854 wells were producing 656 million cubic feet/day. Some 400 Bcf had been recovered since drilling began and the Wyoming Geological Survey estimates total recoverable resources at 25.1 Tcf (about the total U.S. demand for natural gas for one year) and a production level by 2010 of 3 Bcf/day.[49] Other estimates range from less than 10 to more than 20 Tcf.[50] Matt Silverman suggests that the total CBM resource in place in the basin is 40 Tcf, with at least 10 Tcf and likely more that is recoverable.[51] Industry representatives estimate that the eight million acre basin will eventually have 50,000–100,000 producing wells.[52]

Coals in the Powder River Basin are very permeable, shallow, and thick, and the low gas content and low pressure were initially seen as barriers to development. The initial wells drilled and completed produced large quantities of water but little gas. As companies shifted to drilling more shallow wells, production increased significantly. The low drilling costs (as low as $35,000 per well, and taking two to three days to drill and complete) and high water quality that allowed it to be discharged on the surface encouraged development. The Powder River basin has become so promising that it has attracted dozens and dozens of operators, both large and small. One industry official explained the popularity as a result of the certainty about development: "It's a fantastic play, and the technical risk is very low. We know the resource is there, we know what the capital costs are going to be."[53] The play is attractive to independent companies since "it has very low geologic risk, and the financial engineering opportunities that are created by that risk profile are not found anywhere else in the natural gas business." [54]

Development costs are described as low: finding costs are in the range of 30 to 40 cents per thousand cubic feet, and the play is profitable even at prices of $2/mcf.

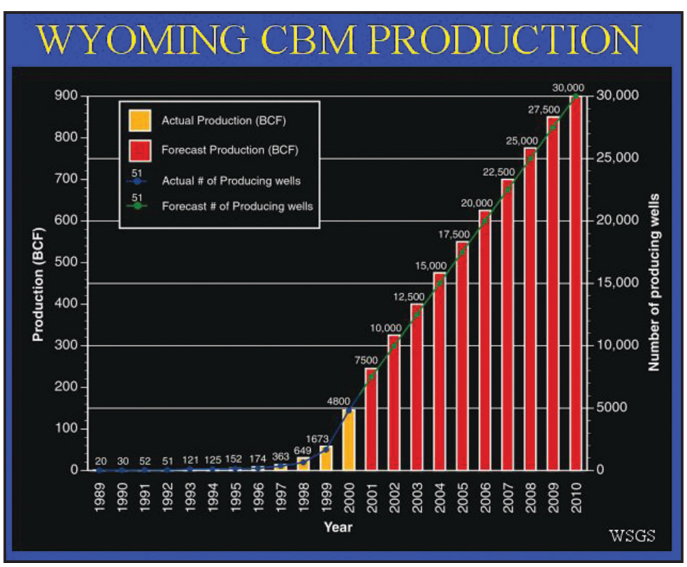

FIGURE 8, *CBM production in Wyoming*
Source: Matthew Silverman, NRLC CBM conference April 4–5, 2002.

But the wells are not huge money-makers: "the per-well recoveries are fairly low {and} high operating costs, mainly from pumping the well and managing the water once it reaches the surface, are ongoing challenges."[55]

By 2000, some 40 companies were working in the area, including Pennaco Energy and Lance Oil and Gas, two of the largest producers of CBM in the basin. A group of oil and gas companies have proposed drilling some 39,400 new wells and accompanying roads, pipelines, and electrical utilities, and compressors in an 8,000,000 acre parcel of private and federal lands. As the CBM play moves west, more and more of the gas lies under lands owned by the Federal government.[56] Before new drilling can take place on these lands, the BLM must complete an environmental impact statement. The draft EIS was released in January 2002.[57] The Powder River EIS assesses the proposal to develop 51,444 new CBM and 3,200 conventional oil and gas wells in a 12,500 square mile area.

Powder River Basin coal ranges from 200 to 2,500 feet below the surface, and most CBM drilling is at the 200–1,200 foot range. Wells typically take from three to six days to complete. Wyoming law provides for 40-acre spacing, but rules issued in March 2001 for units in the northeast and southwest part of the Powder River Basin specified 80-acre units. The CBM wells are projected to produce 3.6 Bcf at maximum production.[58] Wyoming also includes the following other CBM basins: [59]

Washakie Basin: Coal is 5–20 feet thick, at 300–3,000 feet of depth, wells take 5–15 days to complete, hydraulic fracturing may be required, spacing is at 40–80 acres.
Hanna Basin: Coal is 20–50 feet thick, at 3,400–4,500 feet depth, wells take 15 days to complete.
Green River Basin: Wells are 2,500–3,000 feet deep, 80-acre spacing; water is reinjected at 6,700 feet.
Wind River: The basin's CBM resources were estimated in 1995 to be 0.43 Tcf.

Figure 8 charts the dramatic increase in Wyoming CBM production:

POWDER RIVER BASIN—MONTANA

Montana has placed a moratorium on new drilling in its portion of the Powder River basin, and the BLM is preparing an environmental review of the area.[60] Industry officials are optimistic about development in Montana: "In a year's time, after the EIS is complete, CBM could be quicker and easier in Montana than in Wyoming." The proposal being examined in the EIS calls for 20,000 wells, producing 1.5 Tcf per year.[61] One estimate suggests the Montana region of the PRB contains 4.5 Tcf of coalbed methane.[62] Another estimate suggests a total resource in place of 10 Tcf, with half of that recoverable. [63]

THE RATON BASIN—COLORADO/NEW MEXICO

The Raton basin straddles the Colorado-New Mexico border. The Gas Research Institute estimated its recoverable CBM resources at 3.7 Tcf. Others suggest the basin may contain 10 Tcf of resource and 3.5–4.0 Tcf of recoverable CBM.[64] By the end of 2000, some 100 Bcf had been produced. The basin's coal, in comparison with the Powder River Basin, is thin, relatively deep, not particularly permeable, and distributed throughout a wide sedimentary section.[65] Evergreen Resources, Inc., has been the leader in developing the play. By 2001 it had some 675 wells on 200,000 acres that produced about 120 Mcf/day, and planned to drill during that year another 1,000 wells. One third of the wells are expected to be increased density wells (adding a fifth well in a section); one third will be shallower wells; and one-third will extend the field. The average recoverable reserves of these three wells ranges from 1 to 1.6 Bcf per well. The average well costs $400,000; 60 percent of that goes to drilling, completing, and equipping; gathering, gas collection, and compression make up the remaining 40 percent.[66]

The Raton contains two coal bearing formations: Evergreen Company's production has largely been from the Vermejo formation coals (between 450 and 3,500 feet), but it believes that the shallower Raton formation coal seams are also promising. Evergreen is a vertically integrated company. It has compressor stations, owns its own water trucks, has its own pipeline and hydraulic fracturing crews, and operates a low-pressure gathering system that extends for several hundred miles.[67] About half the water it produces goes into surface impoundments and percolates into the ground; 40 percent is discharged onto the surface or is given to local ranchers; and 10 percent is reinjected into formations 2,000 to 3,000 feet below the coals. [68] Devon Energy and El Paso Energy Corp. acquired PennzEnergy and Sonat Exploration and may jointly develop CBM reserves in the Vermejo Ranch property in New Mexico.[69]

THE UINTA BASIN—UTAH/COLORADO

The Uinta Basin CBM play is located on the west side of the San Rafael Swell, at the Southwest edge of the Uinta basin. By the end of 2000, a total of 190 Bcf of gas had been produced and gas was flowing in 2001 at about 250 Mcf/day. Total recoverable reserves in the Ferron are more than 2 Tcf. The largest producing area is Drunkards Wash, where Phillips Petroleum has 350 wells spread over 170,000 acres that produce 210 Mcf/day. The company planned to drill 85 new wells in 2001 and 110 in 2002. Typical wells are drilled at a 160 acre spacing, 1,100 to 4,000 feet deep, and fracturing is used to free up the gas. The average well cost is $330,000. Water is not potable, and some 65,000 barrels per day is reinjected into the Navajo sandstone. River Gas Corporation has some 200 producing wells and plans to develop 400 more. River Gas' operations are in a remote plateau. To save costs, the company installed an automated system that only requires a minimal staff in a remote station. The system includes a "radio system for communicating well data and remote control commands, electronic gas measurement to eliminate chart recorders, and a supervisory control and data acquisition (SCADA) system to manage the operation."[70] Texaco and Anadarko are also operating in the basin.[71]

DENVER BASIN

The Denver Basin in Eastern Colorado contains an estimated 2 Tcf of CBM. Development has been hindered by a lack of data on the extent of the resource and the nature of the gas reservoirs. The two major coal bearing formations are also surrounded by four Denver basin aquifers, raising questions about the extent to which the aquifers and coals are connected hydraulically and what the impacts of CBM development would be on the water.[72]

OTHER BASINS

The Black Warrior Basin, in Alabama, has been the most productive CBM basin outside the Rockies. According to one summary, "relatively limited commercial exploitation of CBM has taken place in other basins, but that is changing." Some production has occurred in the Appalachian basin in Pennsylvania (30 wells in 2000), West Virginia (36 wells), and southwestern Virginia

(1321 wells). Alaska contains nearly half of the total U.S. coal reserves, and studies have found that coals in Northern Alaska's Colville Basin, the Yukon Basin and the Chignik Basin of the Alaskan Peninsula have the highest CBM production potential. Some have suggested that CBM produced in Alaska will likely only be for used for local consumption, while others believe that a gas pipeline may be built from the Prudhoe Basin to the lower 48 states.[73]

II. What are the conflicts, problems, and challenges associated with CBM development?

There are three consequences of CBM development that are responsible for most of the conflicts: the large quantities of water produced during extraction, split estates and the impact of extraction on the owners of surface lands, and development of CBM resources on public lands that might also be reserved for other purposes. These three topics are discussed in detail below. Since methane is a greenhouse gas, CBM development also relates to the threat of climate change and that issue is briefly addressed at the end of this section.

CBM development and water

The amount of water produced during the CBM production process is staggering and represents a major challenge. In the Colorado portion of the San Juan Basin, approximately 1,200 wells have produced nearly 36 billion gallons of water to date.[74] In the Wyoming portion of the Powder River Basin, it is estimated that in the next 15 years, approximately 51,000 wells will have produced over 1.4 trillion gallons of water.[75]

The cleats and fractures in coal are typically saturated with water, and the coal must be dewatered (usually pumped out) before the gas will flow.[76] Some coals never produce methane if they cannot be dewatered economically. As the fracture system produces water, the adsorptive capacity of the coals is exceeded, pressure falls, and the gas trapped in the coal matrix begins to desorb and move to the empty spaces in the fracture system. The gas remains stored in nearby non-coal reservoirs until it is extracted.[77] Drilling dewaters the coal and accelerates the desorption process. The deeper the coalbed, the less the volume of water in the fractures, but the more saline it becomes.[78] The volume of gas typically increases with coal rank, how far underground the coalbed is located, and the reservoir pressure.[79] Initially, drilling primarily produces water; gas production eventually increases and water production declines. Occasionally, wells do not produce any water and begin producing gas immediately, depending on the nature of the fracture system.[80]

When the CBM is extracted, the water must be separated, the gas is sent to pipes, and the water is dumped into ponds or injected back into the ground. In order to develop the resource, companies must first pump large quantities of water from the ground, about 12,000 gallons a day on average for each well, to release the methane. Discharged water that is of high quality, as is the case in many areas in the Powder River Basin, may be used by ranchers to water stock or to irrigate crops. Water that is not useable for irrigation or watering stock may be reinjected into underground regions.[81] Given the scarcity of water in the West, virtually any production of water that is not put to beneficial use or that might affect water quality or water supply and rights is controversial. The development of CBM sometime pits energy developers against ranchers and other water users. CBM development raises several issues surrounding its impacts on:

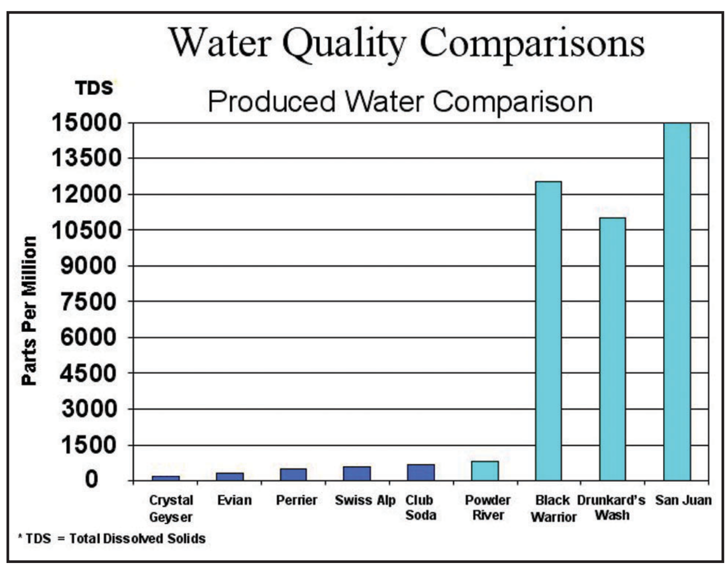

FIGURE 9 *Source: Lance Cook, "Geology of CBM in Wyoming," NRLC CBM conference April 4–5, 2002.*

- underground water quantity and the possibility that drilling or fracturing fluids contaminate aquifers with water of lower quality;
- water rights and underground water supplies that may be diminished as dewatering occurs;
- groundwater that may be contaminated by discharged water that is polluted; and
- aquatic areas, stream beds, and local ecosystems that are unaccustomed to receiving such large volumes of water.

Water quality indicators vary across and even within basins, depending on the depth of the methane, geology, and environment of the deposition. The major elements of CBM water quality include:

- total dissolved solids (salts)
- pH and temperature
- major cations (positively charged ions)—sodium, potassium, magnesium, calcium
- major anions (negatively charged ions)—chlorine, sulfate, hydrogen carbonate
- trace elements—iron, manganese, barium, chromium, arsenic, selenium, and mercury
- organics—hydrocarbons, additives.[82]

Water quality varies tremendously across basins, as figure 9 illustrates (note that the figure also compares CBM produced water with different brands of bottled water):

Because of differences in water quality, CBM-produced water is dealt with differently across the major basins:[83]

San Juan:	99.9% of produced water is injected
Uinta:	97% injected, 3% evaporation
Powder River:	99.9% surface discharge
Black Warrior:	100% surface discharge
Raton Basin:	
Colorado:	70% surface, 28% injected
New Mexico:	100% injected

Even if water quality is high, salts may concentrate during evaporation or may overwhelm the semi-arid environment, inundating vegetation and causing erosion.

The options for dealing with the large quantities of water released include the following (costs generally increase as one moves down the list):[84]

- Traditional surface discharge: water is allowed to travel downstream and be absorbed or evaporate as it moves;
- Irrigation: water released to agricultural areas;
- Treatment: water is treated to improve quality;
- Containment with reservoirs: water is piped to a surface impoundment where it is absorbed or evaporates, or may be used to water cattle;
- Atomization: water evaporates more quickly than normal through the use of misters placed in surface impoundments.
- Shallow injection or aquifer recharge: water is pumped into freshwater aquifers;
- Deep injection: salty water is typically reinjected deep into the ground.[85]

The volume of produced water in the major basins also varies considerably, as Table 2 illustrates:

TABLE 2. AVERAGE WATER PRODUCTION WATER/GAS

BASIN	STATE	No. of WELLS	BBL/DAY/WELL	BBL/MCF
Black Warrior	Alabama	2,917	58	0.55
Powder River	Wyoming	4,454	275	2.17
Raton	Colorado	459	266	1.34
San Juan	CO/NM	3,089	25	0.031
Unita	Utah	393	215	0.42

SOURCE: *C.A. Rice and T.T. Bartos, "Nature and Characteristics of Water Co-Produced with Coalbed Methane with Emphasis on the Powder River Basin" USGS CD.*

SAN JUAN BASIN

The average CBM well in the San Juan basin produces 25 barrels or 1,050 gallons of water a day, a ratio of 0.031 gallons of water/thousand cubic feet of gas. The 4,208 CBM wells produce on average 4.42 million gallons of water a day or 13.6 acre feet.[86] Because of poor quality, virtually all produced water in the San Juan is reinjected. The threat of water contamination is one of the major complaints of local residents surrounding CBM development:

Some residents report that in some areas, their drinking water has been contaminated by methane or by hydraulic fracturing;[87] BP Amoco purchased four homes and leveled them as part of the settlement of a lawsuit after owners charged the company with responsibility for methane in their basements and water wells.[88]

Residents have complained that drilling reduces the water levels of residents' and ranchers' wells as aquifer rock is fractured and water escapes.[89]

Some residents emphasize that while drilling is not directly responsible for the natural seepage of hydrogen sulfide into rivers, it may amplify the natural seepage, and point to signs along the Animas River, a popular kayaking and river running area, that warn of harmful levels of hydrogen sulfide seeping from the ground into the water.[90]

Water storage pits are another source of contention. Dehydrator/separator pits are required to be lined. Residents have complained that companies do not always comply with these requirements.[91]

Industry representatives disagree that CBM development significantly impacts water quality and quantity, although they acknowledge there have been occasional problems. According to one BP official, "different companies have different standards," but there has been improvement over the years in the impacts on water quality.[92] According to a BP official, CBM wells are 2–3,000 feet deep, while drinking water wells are only 200–400 feet deep. CBM well bores are encased in steel and cement 50 feet below the lowest water table to ensure no contamination of aquifers occurs. When BP began drilling at one well in each 160 acre plot, company officials tested water quality near the new wells before and after drilling commenced. Since biogenic-produced methane is found at shallower depths and thermogenic gas at deeper levels, companies can conduct isotopic analyses that fingerprints the gas and allows analysts to trace its origins and learn whether the methane is a result of natural migration or a result of drilling. The Colorado Oil and Gas Commission requires additional testing if methane is found in domestic drinking water wells, and methane has been found in 12 percent of those wells. [93]

The impact of CBM drilling on local water supplies has been very contentious in other areas such as the Raton Basin. Residents of Cokedale, in Las Animas County, protested coalbed methane drilling of one hundred wells that produce twenty-four million gallons of waste water a month, because they feared the water will contaminate the shallow wells that residents depend on, and the dispute resulted in lawsuits and countersuits.[94] The issue of water contamination is critical. The EPA is expected to release a report in the summer of 2002 on CBM contamination of water. If the report concludes that contamination has occurred, it will be difficult for development to continue until more detailed studies are completed.[95]

POWDER RIVER BASIN

The average flow of water from a CBM well in Wyoming is 12–15 gallons/minute.[96] In contrast to the San Juan basin, much of the produced water in Wyoming may be useable for a variety of purposes. A major challenge has been managing in a semiarid landscape the tremendous amount of produced water. CBM wells in Wyoming produce on average 150 barrels of water a day over a 7? year life-time.[97] The rate of water production during initial stages of development range from 400–800 barrels/day to 1,000–1,500 barrels/day in deeper wells.[98] More than 1.28 million barrels of water were produced each day from CBM extraction in 2000.[99] The average production rate of oil per well, after dewatering, is a much smaller amount than in the San Juan.[100]

Critics of CBM development argue that the amount of water withdrawn from CBM production will greatly lower the aquifer levels in Wyoming. They warn that by 2010, surface discharge of produced water will reach 1 billion gallons a day. Data from coal mine permits and plans suggest that it will take 800–1,500 years following reclamation to recharge the coal aquifer and argue that, despite the differences between coal mining and CBM extraction, CBM development poses the same kind of threat to the region's long-term water supply.[101]

The draft environmental impact statement (DEIS) for the next round of development in the Powder River Basin suggests that the drawdown of the Fort Union Coal Aquifer under all alternatives will be from 300–1,200 feet and 10–250 feet for the Deep Wasatch Sands. For the Shallow Wasatch Sands, drawdown projections range from 1–50 feet in areas of thin cover and –1 to –50 feet in areas of impoundments and creeks receiving produced water. Peak drawdown will likely occur between 2006 and 2009, and the aquifers will, according to the DEIS, recover to within 95 percent "over the next hundred years or so."[102]

Just as controversial as impacts on the region's aquifers have been the consequences of the produced water from CBM extraction. The quality of produced water varies across the Powder River Basin. In general, water quality is highest in the southeast, and diminishes to the West and North, where total dissolved solids increase.[103] A USGS study concluded that total dissolved solids (TDS) range from 370 to 1940 mg/L, with a mean of 840 mg/L; the national drinking water standard for potable water is 500 mg/L. TDS levels increase as sampling wells moved North and West.[104]

Discharges into the Tongue and Powder Rivers have been particularly contentious. The water there is generally of sufficiently high quality for drinking water and watering stock, but the produced water is not as good as in the Tongue River, so no discharge permits can be issued.[105] In other areas, the water can be discharged into the Belle Fouche and Cheyenne Rivers and Caballo Creek.[106] While the water is suitable for cattle, there are insufficient cattle to use the produced water. Surface disposal is a challenge as it may result in erosion when discharged into drainages or inundate vegetation. Even though water quality is good, salts may concentrate during evaporation and harm soils.[107]

Some local residents believe domestic and stock water wells are drying up or becoming contaminated, and that discharge of water is causing erosion and soil damage.[108] Others have reported that domestic well lids have been blown off by gas pressure, methane has been found in their water wells, and they have seen companies continue to discharge water after they have received notices of violations.[109] Stock reservoirs have been created, and while some ranchers have wanted the water source, others do not since that takes land out of production.[110] Ranchers are faced with soils damaged by the salts and metals remaining after evaporation, less grass is available for cattle, clay soils become hard pan, and dead cottonwood trees, dead grass, and weeds result from the discharge of produced water that destroys native vegetation.[111]

Given the aridity of the West, the region's water is at least as valuable as its natural gas. One of the most important challenges surrounding CBM development is finding beneficial uses for the produced water. One industry consulting hydrologist emphasized many beneficial uses for produced water—livestock, dust control, industrial, fish and wildlife, recreation, irrigation, and aquifer recharge. He summarized water management options in the Powder River in these terms:[112]

- Discharge to surface streams—acceptable on the Eastern part of the basin; erosion controls are needed but treatment is not; shallow groundwater recharge occurs, and there may be downstream impacts; iron and manganese may need to be removed;
- Impoundment—problems of limited locations, need for erosion controls; few isolated instances of this, the volume is often too low to cause problems;
- Injection—not economic or practical; no evidence of contamination of drinking water, it is often better quality; no toxins; it would reduce water quality of the Tongue River but not others.

CBM development and conflicts with other land uses

Just as contentious as water has been conflicts between local residents and energy companies over land use. CBM development impacts rural lands in several ways. The construction of roads, drill pads, water disposal sites and related facilities and the operation of these facilities may conflict with livestock operations and farming. Noise from pumps, compressors, and traffic may disturb residents and wildlife. Air pollution problems include health effects of fine particles and reduced visibility. CBM development has disrupted areas that were previously isolated from development or valued for undisturbed vistas and solitude. In contrast, in other communities where conventional gas development or coal mining has already occurred, new CBM projects often produce relatively little incremental impact.

Many of the conflicts are rooted in laws that were enacted to promote the development of the West by opening lands to settlers but reserving mineral rights to the Federal government. Most of the land disposition statutes enacted by Congress in the late 19th and early 20th centuries reserved the mineral estate to the United States. The Stockraising Homestead Act of 1916, for example, reserved to the United States "all the coal and other minerals" under the federal lands sold to settlers.[113] The Taylor Grazing Act of 1934 similarly reserved "all minerals to the United States" for federal lands that were exchanged for private lands in order to consolidate BLM grazing districts.[114]

Much CBM development is occurring on split estates—areas where those who own the surface rights of land are not the same as those who own the subsurface mineral rights. Some surface owners have been able to negotiate with energy companies payments for damage to their lands or even a share of the proceeds from development. But conflicts have occurred when residents have purchased surface rights to settle in quiet, undeveloped rural settings or in residential areas, and not realized that those who own the subsurface rights must be given access to the land to develop those rights. Landowners have been forced to allow drilling on lands they assume would be used for grazing or hunting. This is not a problem unique to CBM, but the rapid pace and magnitude of development appears to have intensified conflicts.

The socio-economic impacts of coalbed methane development are similar to those resulting from development of conventional gas. Development produces new jobs, new income, and new revenues for governments from taxes and royalties. It also increases demand for new public services and housing and increases traffic, air pollution (from construction as well as traffic and other sources once construction is completed), noise, and congestion. One difference between CBM and conventional gas that has exacerbated tension is that drilling and construction typically proceeds much more quickly for CBM than for conventional gas. CBM wells may only take a few days to drill and a few more to complete, whereas conventional wells may take 45–60 days to drill and complete. CBM development may rapidly transform a rural community into an energy production area with pipelines, compressors, and other facilities, while the transformation resulting from conventional gas development will likely proceed more slowly. As a result, CBM projects may place more strain on communities than conventional projects because of the speed of development.[115]

THE SAN JUAN BASIN

While most of the San Juan basin is located in New Mexico, conflicts seem to be more pronounced in Colorado. Tax policy differences between the two states are one factor. In New Mexico, oil and gas taxes directly fund educational programs, and that connection helps strengthen support for drilling. In Colorado, oil and gas revenues are not so closely identified with funding for such programs. [116] Perhaps even more important are differences in land use between the San Juan basin in Southern Colorado and Northern New Mexico. The Durango area has become a recreational, residential, retirement community, in contrast with New Mexico, which is still largely an energy production region. Expansion of CBM development in La Plata County clashes with strongly held expectations for protection of roadless areas, vistas, and residential areas.[117] Many people moved into the area because of the solitude, quiet, vistas, and rural landscape, and believe CBM development threatens those characteristics of the land and diminishes their property values. Proposals to intensify drilling density have generated particular opposition in the affected communities.[118]

Other land use conflicts pit preservationists against developers. Some roads are closed for the winter to protect wildlife habitat, but if CBM development occurs in the area, companies get can get a waiver to use the road to get to their sites. [119] There are some roadless areas that include old growth Ponderosa pines that companies would like to open for drilling but are treasured areas for preservationists.[120] Ranches, retirement homes, and roadless areas do not easily coexist with extensive energy development infrastructure. Some residents feel that the long-term goals of sustainability and community are threatened by short-term energy development. The anger and frustration felt by some local residents is palpable, as they accuse companies of failing to comply with the law and arrogantly dismissing residents' complaints and lament the discounting by governments and by energy companies of the personal, anecdotal problems that local landowners report because they are not part of formal scientific studies.[121]

Jim Baca, former director of the BLM and former mayor of Albuquerque, said in a tour of western states sponsored by The Wilderness Society that CBM development in the San Juan Basin "has absolutely destroyed whole landscapes there and quality of life for people." Baca warned that the BLM lacks the resources or staff to deal with the greatly expanded workload due to CBM development, and that as a result, the agency is not inspecting wells in the San Juan area and water is not being properly contained and wells aren't properly maintained. He suggested the agency will need a massive infusion of funds in order to adequately manage CBM development.[122]

THE POWDER RIVER BASIN

As is true of other basins, CBM development brings many benefits to the Powder River Basin. It is less invasive than other forms of non-renewable energy development like coal mining, and it has brought tax revenues, business, employment, and other important economic benefits. Deputy Secretary of the Interior Steve Griles said in a March 2002 speech that energy development in Wyoming is a blueprint for the rest of the nation: "It is restoring the environment and it is allowing us to have both healthy, sound environment and the recovery of energy that fuels this great country and the economy we have." He rejected criticism of coal and CBM development in particular as damaging to the environment: "It's just not a fair representation . . . I looked at coalbed methane development here in and around Gillette. When it is done correct and right, the impact on the environment can be positive." [123]

Local residents, however, have complained about noise, particulate emissions from vehicles and traffic, wind-generated dust, emissions from compressors, reduced visibility, fragmentation of habitat by roads, noxious weeds, increased human damage to fragile ecosystems, loss of privacy, and diminished quality of life. Visibility on Native American reservations and protected federal is threatened, and CBM development appears to have contributed to the problem. Fine particles affect visibility and also pose the greatest threat to human health. Fine particles have increased by 50 percent and average concentrations in the area average 12 micrograms/cubic meter.[124] Larger particles, measured as PM10, are less deadly, but still a health threat for those with asthma and other respiratory diseases. Noise levels provoked one resident to fire 17 shots at a compressor. Others complained of companies leaving garbage and the loss of scenery, solitude, and wildlife.[125]

Landowners argue that CBM development challenges their ability to manage their land in a sustainable fashion. They report that they were not given the option to not sign development agreements, not notified when subsurface minerals were leased, that surface use agreements were not required, that eminent domain was used to install pipelines, and that communications towers have been installed without their permission, that there is a lack of planning for infrastructure needs, a failure to deal with threatened and endangered species, no planning to protect air quality, that little information on development is given to land owners, and bonding is inadequate and some orphan wells have resulted. For these residents, such insults do not just represent damage to their lands and the wasting of scarce and precious water, but are rooted in a sense of powerlessness and a violation of property rights. They view some CBM companies as irresponsible, and complain of signed agreements that are not honored, such as violating royalty agreements by companies that subtract expenses before calculating payments. They feel powerless to protect their lands and ensure their sustainability.[126]

Issues in reducing surface impacts

While split estates have been a major issue in the San Juan and Powder River basins, future CBM development may face a different set of challenges. Issues of overlapping governance will always be a concern as federal, state, and local government boundary conflicts permeate the West. The Bureau of Land Management will play a major role in determining the scope, speed, and impacts of CBM development on public lands and the process of updating resource management plans and preparing environmental impact statements for large scale leasing will be a major task of the agency. CBM development will bump up against other public values, such as protecting habitat and migration routes for wildlife and preserving biodiversity, and insulating recreational lands from the impacts of resource extraction. BLM's resource management plans are largely out of date and some 160 plans will need to be revised during the next ten years.[127]

As discussed below, the failure to have up to date and comprehensive management plans and environmental assessments may block CBM development affecting public lands and federal mineral resources.

For the existing CBM basins, the conflicts between surface and mineral owners are often intense. The BLM requires, under Secretarial Order No. 1, that mineral leaseholders provide evidence that they have entered into good faith negotiations with surface owners before they can receive an approval for a permit to develop.[128] Ranchers, farmers, and others complain that some gas companies fail to consult with them and explore ways to minimize surface impacts. BP officials have argued that reducing visual and noise impacts of drilling and recovery has not been a priority for companies, since their operations are typically not located in inhabited areas. They have begun to develop equipment and practices that reduce impacts. One option is to use a pneumatic pump that pumps without an engine, produces no noise, and is only about 10–15 feet tall (conventional pumps may be 30–40 feet tall). But pneumatic pumps may not work well when large volumes of water are extracted in the process; an alternative is the progressive cavity pump, smaller than traditional pumps (only about 7 feet tall) but requires an engine. Engines can be equipped with a muffler much as in a motor vehicle. Well pads are typically one acre in size, and must be sufficiently large to accommodate drilling equipment, but that size may be reduced as technology improves.[129]

Another option is to place sound barriers, formed with sound insulation, above and on the sides of engines. Noise, traffic, and dust from operators driving to monitor production can be reduced through automated monitoring systems. These systems can be solar powered. J.M. Huber officials have camouflaged wells from nearby residents by building a ridge of dirt and planting trees on the ridge. Companies have also replaced controllers on wells in order to reduce leaking methane and thereby reducing greenhouse gas emissions.[130] At least one company is developing a diagnostic device for assessing the concentration of CBM in a coal seam that uses a slender tube with sensors that produce immediate data on coal conditions. If reservoir assessments can be improved, that will decrease the likelihood that a company will pump out a large volume of groundwater and then discover that there is insufficient recoverable methane to make the process worthwhile.[131]

The Northern Plains Resource Council was organized in 1971 by ranchers to fight coal strip-mining and the group played a key role in getting mining reclamation legislation enacted in Montana in 1973 that served as a model for the 1977 federal strip-mining law. It negotiated in 2000 a "good neighbor agreement" with the Stillwater Mining Company that included more strict water protection standards than provided by law and included other safeguards. In 2001, it published a booklet giving recommendations for how CBM development should take place in the state.[132] And it has launched lawsuits. One suit against the state board of oil and gas conservation board was settled when the agency agreed to conduct an environmental impact assessment of CBM before issuing permits. Another suit against the BLM is pending.[133] The council's call for responsible CBM development includes six provisions: [134]

- Effective monitoring of coalbed methane development and active enforcement of existing laws to protect private property rights, Montana citizens, and Montana's natural resources,
- Surface owner consent, surface use agreements, and reimbursement of attorney fees to help landowners better protect their property rights,
- Use of aquifer recharge, clustered development, mufflers for compressor stations, and other low-impact, best-available technologies to minimize impacts on underground water reserves, rivers and streams, and surface resources,
- Collection of thorough fish, wildlife, and plant inventories before development proceeds to protect habitat, followed by phased-in development to diffuse impacts over time,
- Meaningful public involvement in the decision-making process,
- Complete reclamation of all disturbed areas and bonding that protects Montana taxpayers from all cleanup liability costs.

These and other ideas for reducing conflicts surrounding CBM development are discussed in Section IV, below.

CBM development and public lands

While the development of CBM on private lands has been very contentious in many areas, conflict surrounding CBM development on public lands has also been controversial. As indicated earlier, a major thrust of the Bush administration's national energy plan is to expand development of energy resources on public lands. Congressional Republicans have also vowed to open public lands to energy development. Developing resources on public lands is a major theme of the House energy bill passed in 2001. House Resources Committee chair Jim Hansen (R-UT) said in introducing a March 2001 hearing, "[i]t's time for a course correction in the management of our public lands. It's ironic that we are faced with an energy crisis while we have abundant reserves of oil, coal, natural gas and hydro-electricity locked up in our public lands and waters."[135]

The Senate energy bill proceeded much more slowly, and much of the debate focused on energy development in the Arctic National Wildlife Refuge.[136] In April, 2002, the Senate defeated an amendment to the energy bill to open ANWR to drilling.[137] The House passed a similar provision and the House-Senate energy conference committee was slated to begin negotiating a compromise bill in June. The House bill favors incentives for expanding fossil fuel and nuclear power production, while the Senate version emphasizes conservation and alternative energy sources.[138]

While the national energy policy debate continues, the Bush administration is accelerating plans to develop oil and gas resources on federal lands in the West. Deputy Secretary of the Interior Steve Griles said in a March 2002 speech that energy development in Wyoming is serving as a blueprint for the rest of the country and that the objective of the president's plan is to "have a steady increase in the use of fossil fuel, and at the same time ratcheting down any type of environmental impact."[139] The BLM is reducing the time it takes companies to apply for drilling permits by one-third in order to increase development.[140] In March 2002, Peter Culp, BLM's assistant director for minerals and resource protection said that oil and gas companies can expect speedier drilling approvals, easier access to petroleum deposits, reduced royalty payments, and fewer environmental restrictions as part of the Bush administration's national energy plan. He indicated that the BLM would also expedite reviews of oil and gas resources in the Powder River and San Juan basins.[141] The BLM is also conducting a new study of how much oil and gas might be available in BLM lands in the lower 48 states, expected to be completed in 2002; the study will be used by the BLM to find ways to expedite exploration and "evaluate potentially overly restrictive impediments to determine if alternative methods are available."[142]

State officials have been just as adamant in arguing for the development of energy on public lands. Montana Governor Judy Martz has complained that the Clinton administration had tried to "lock up the West" and prohibit the development of the region's resources, claiming that "we have seen our ability to responsibly develop those resources grind to a halt. . . ."[143] Wyoming Governor Jim Geringer claims that "Wyoming's energy potential could completely replace the entire OPEC production for the next forty-one years."[144]

Controversy swirls around a number of issues, including the methods used to assess resources. Environmental resource economists like Pete Morton have suggested only reserves that are economically viable be counted.[145] Wyoming Congresswoman Barbara Cubin counters that the economic viability test discourages exploratory development that might discover resources, such as the state's Jonah Gas field.[146]

There is little agreement concerning the role public lands have played in energy development. Representative Hansen, for example, argues that domestic natural gas production has steadily declined since 1973.[147] But natural gas production on public lands has increased, while production on private lands has fallen. A Natural Resources Defense Council report found that energy production on public lands steadily increased between 1988 and 1998. During those years, oil production on public lands grew by 39 percent, natural gas by 26 percent, and coal by more than 20 percent. [148] The Department of the Interior reported in January 2001 on the production of oil, gas, and coal from offshore and onshore Federal and Indian lands: the contribution of oil and gas production on federal lands grew from thirteen percent of total domestic production in 1992 to twenty-five percent in 1999.[149] Some industry officials, such as Ed Porter of the American Petroleum Institute, have acknowledged that natural gas production had increased, but argue for expanded drilling on public lands to capture the remaining resources.[150]

Two key issues at the heart of these disagreements over energy development and public lands are the volume of natural gas resources available and their location. As indicated above, the National Petroleum Council reported in 1999 that the United States' "natural resource base" of natural gas (not just CBM) in the lower 48 states was 1,466 trillion cubic feet. While current consumption is about 22 Tcf/year, that is projected to increase to 31 Tcf by 2015.[151] The Council also concluded that some 105 Tcf of this resource base was off limits to development: 29 Tcf in the Rocky Mountain states and 76 Tcf because of restrictions on off-shore development. A representative of The Wilderness Society, in a hearing before the House Resources Committee, suggested that in addition to the 105 Tcf, an additional nine Tcf of gas would not be available as a result of the Forest Service's roadless protection initiative, making 115 Tcf unavailable. If that figure is subtracted from the resource base of 1,466 Tcf, the amount of resource available is 1,351 Tcf. At the projected consumption rate of 31 Tcf per year several years from now, the resource would last 40 years, assuming consumption did not grow. As a result, he argued, we need not feel pressure to move into these environmentally sensitive areas in order to expand natural gas production.[152]

The National Petroleum Council also estimated that some 108 Tcf of natural gas resource in the Rocky Mountain region are available with restrictions. Although these areas can be leased, these restrictions are aimed at protecting sensitive wildlife and habitat areas. The BLM imposes three different kinds of stipulations that affect CBM and other natural gas development:

Standard stipulations that place limits on operations, such as prohibiting development within 500 feet of surface water or riparian areas and are typically applied to all oil and gas leases;

Seasonal or other special stipulations that prohibit activities during specified time periods when suggested by the Fish and Wildlife Service or others to protect nesting, calving, and other seasonal habitat use;

No surface occupancy stipulations that prohibit operations directly over a leased area and require directional drilling to protect underground mining operations, archaeological sites, caves, steep slopes, campsites, or wildlife habitat. [153]

A Wilderness Society analysis of CBM and public land, using USGS data, concludes that there is between 500–943 Bcf of coalbed methane in the roadless areas of the Rocky Mountain States. If these Forest Service lands were opened for drilling, and the economically recoverable CBM were made available, that would increase America's natural gas reserves by only one-tenth of one percent. It cited a USGS report that concluded there is no economically recoverable CBM within any national monument. The analysis emphasized the importance of focusing on economically extractable reserves, rather than technically recoverable resources. If technically recoverable resources are used, this overestimates the value of resources that may be inaccessible due to public land protection policies and may contribute to pressure to open those lands to development when the economically recoverable resources are quite modest.[154]

There are numerous examples of conflicts between developing energy resources and preserving protected public lands that illustrate the challenges confronting CBM and other energy development in the West and will require careful planning, environmental assessments, and other analyses. A draft report from the Interior Department circulated in April 2001 recommended that millions of acres of lands that had been managed by the Clinton administration as protected areas be opened for energy development. The report urged Congress to decide which of the 17 million acres in 11 western states that have been protected as wilderness study areas (WSA) should be designated as wilderness and which should be opened to development. It also recommends that the Forest Service modify forest plans to allow for more energy development.[155] In 1997, in order to protect its jagged peaks and diverse wildlife, the Clinton administration Forest Service banned oil and gas drilling for ten to fifteen years in that portion of the Lewis and Clark National Forest that is part of the Overthrust Belt, a resource-rich mineral formation that primarily traverses Montana, Idaho, and Wyoming.[156] Interior Secretary Gale Norton said in early 2001 that the Overthrust Belt was one of the areas "that would be studied as part of an across-the-board look at energy resources."[157]

In Wyoming, 94 percent of the state's eighteen million acres of public lands are open to development.

Within the 6 percent of protected area is the 600,000-acre Jack Morrow Hills that is part of the Red Desert. Former Interior Secretary Babbitt toured the area in the late 1990s and would have suggested it for designation as a national monument, but the Wyoming congressional delegation in 1950 had pressed Congress to pass an amendment to the Antiquities Act prohibiting presidents from declaring national monuments in the state without congressional approval.[158] The BLM developed a plan to reopen some lands to oil and gas development, but in December 2000, Secretary Babbitt ordered the agency to come up with a new plan that gave top priority to conservation.[159] Similar disputes have arisen elsewhere in the state, such as in the Bridger-Teton National Forest in northwest Wyoming. In a December 2000 draft environmental impact statement, the forest supervisor announced that oil and gas drilling would not be allowed on some 370,000 acres near the Gros Ventre Wilderness Area southwest of Jackson Hole.[160]

Industry groups first proposed drilling in 1996, and the forest plan provided for drilling in the area. More than seven thousand people submitted comments on the proposal; 85 percent of the respondents opposed development, according to preservationists.[161] Environmentalists have successfully blocked development to protect wetlands and forage for elk, bear, coyotes, wolves, and other wildlife, several blue ribbon trout streams, and four rivers eligible for National Wild and Scenic River designation. In addition, migratory patterns of wildlife from Yellowstone National Park would be threatened by the development.[162] The EPA's position is that the area "is an important buffer between wilderness areas and developed private lands," and represents essential protection for endangered species habitat. Development groups charge the Forest Service with trying to create a de facto wilderness area.[163]

CBM and other energy development on public lands in the West pose daunting dilemmas for policy makers and for affected communities and companies. Some argue that the analysis, though difficult, involves an assessment of costs and benefits, while others reject any effort to quantify variables like solitude, open vistas, and habitat protection. In Wyoming, the BLM had argued that it was possible to balance oil and gas development with preservation of the desert elk herd in the area, and other proponents of drilling argued that the benefits of energy development far outweighed the environmental costs. Energy company executives argued that "we respect the issue of preserving the value of place, but oil and gas drilling will have no impact whatsoever on that value . . . ."[164]

Others argue that energy development on public lands often requires choices between preservation or extraction. The editors of the Great Falls, Montana, Tribune wrote, in response to the debate over energy development in ANWR, the Rocky Mountain Front, and the Missouri Breaks Monument; "We've long opposed drilling in those places, saying the benefits of doing so are far outweighed by the environmental and recreational benefits of not doing so."[165] Conservationists argue that 90 percent of BLM lands are available for energy and other resource development, and the last ten percent, much of which has been proposed for wilderness designation, should be protected. "We don't need to drill the last ten percent," said former BLM director Jim Baca.[166]

Others agree that in some landscapes, the issue is a choice between one or the other, rather than a balancing of both: "It gets down to, do you want cheap oil and gas, or do you want Yellowstone?"[167] An official of Questar, a natural gas company operating in the area, focused the debate by saying " [y]ou can't have Wyoming be a pristine, untouched area and still be a major natural gas producer."[168] Richard Fineberg, an environmental consultant, argues that the concept of wilderness "is immutable. It is like perfection—there are no degrees to it. [Energy] development in a wilderness, no matter how sensitive, changes the very nature of it. It means it's no longer wilderness."[169] Said another, "It's almost like the original temptation. We have this incredibly beautiful place that we can either leave alone or go in and grab the apple."[170]

Public lands play a critical role supplying energy and other natural resources, but also in providing recreation, habitat, and ecosystem services such as improving air and water quality. As CBM development moves into new areas, the BLM faces the challenge of protecting habitat, migration routes for big game, and a host of other environmental goals that are part of the purposes of public lands. The Bush administration has emphasized the importance of increasing domestic production of energy sources, and much of that development will take place on public lands.[171] But principles of compromise, collaboration, communication, balance, and stewardship suggest that development needs to be carefully structured in order to ensure that environmental protection and energy production goals are pursued together.

Environmental impact statements are a key vehicle for assessing the interaction of preservation and development goals. Controversy swirled around the BLM's draft EIS for the Powder River Basin in Montana and Wyoming that was released in February 2002 when EPA officials in Region 8 indicated they would give the study the lowest possible ranking it gives. EPA's concerns were primarily about water quality issues and the impacts of discharged water on the environment and irrigation.[172] The agency faulted the BLM for not examining options for preventing harm from the water, for differences between the Montana and Wyoming studies' analyses of the same water issues, for failing to resolve issues dividing the two states as well as the Northern Cheyenne and Crow tribes, and for inadequate assessment of the effect of development on air quality.[173]

The EPA also found the Montana EIS "environmentally objectionable due to the lack of specifically identified, economically and technically feasible water-management practices that are adequate to assure attainment of water quality standards under the Clean Water Act," and was even more critical of the Wyoming EIS, suggesting that while the Montana document could be remedied, the Wyoming study may need to be scrapped.[174] EPA and BLM officials began meeting to try to resolve the differences, and EPA's views might be altered as they are reviewed at agency headquarters. Interior Department Deputy Secretary J. Steven Griles protested to EPA Deputy Administrator Linda Fisher that the criticisms were misdirected, but then distanced himself from the issue because of his past involvement in the Powder River Basin representing gas companies.[175] In May, 2002, the EPA's Denver office released its assessment of the environmental impact statements, giving the lowest possible rating as had been proposed in the draft letter, and focusing particularly on the water quality issues in the Tongue and Belle Fourche Rivers, but also arguing that environmental safeguards could be devised so that the BLM could approve new development by the fall of 2002.[176]

CBM and the threat of climate change

The development of CBM may contribute to reducing the threat of global climate change. Methane is one of the most important greenhouse gases, more than 20 times as potent as the equivalent volume of carbon dioxide in trapping radiated energy and contributing to the threat of disruptive climate change. One-third of the methane released into the atmosphere is related to energy production and transportation. Fugitive methane emissions occur during the production of natural gas and emissions are expected to increase as natural gas production expands, even though the average rate of emissions per unit of production is declining. Coal-related methane emissions are expected to decline as technologies for the recovery of vented methane improve. Expanded CBM development could actually result in decreased methane releases if methane that would be otherwise vented through coal mining is captured through coalmine methane recovery, carefully transported to ensure minimal loss, and then used to produce energy.[177]

CBM production could also reduce greenhouse gas concentrations in the atmosphere by serving as a sink for carbon dioxide. The adsorption of carbon dioxide molecules by coal stimulates the desorption of methane and thus enhances its production. Carbon dioxide injected into coal seams for secondary recovery of methane drawn from power plant waste streams, for example, is as a consequence not released into the atmosphere where it otherwise would act as a greenhouse gas.[178]

While the United States has not ratified an international agreement that mandates reductions in greenhouse gases, some local governments and businesses have committed to reduce their greenhouse gas emissions. Part of the strategy developed by these companies is to achieve emission reduction goals through emissions trading programs. Divisions generate emission credits through instituting changes in materials or process, and by efficiency improvements that reduce emissions. The companies then allow the divisions to meet their goals by buying and selling these emission credits, and by purchasing carbon credits from agricultural sequestration, tree planting, and other activities. The revenue from marketing these credits might create additional incentives for injecting carbon dioxide into CBM formations.[179] The role that CO_2 injection might play in enhancing CBM production is not well documented and its promise is unclear but likely modes. Natural gas use produces CO2 and contributes to the threat of climate change. But some companies are collecting data from pilot projects on the role of CO_2 in enhancing CBM production.[180]

III. How is CBM development regulated? [181]

Federal regulation

The Mineral Leasing Act of 1920 (MLA) provides the current framework for approval and management of CBM activity on federal lands. Federal agencies' policies regarding fluid minerals are adopted pursuant to MLA. Lands managed by the BLM, U.S. Forest Service and other lands owned by the United States are open to CBM production under MLA. BLM is the principal agency responsible for managing the mineral estate on all federal lands. The Federal Land Policy and Management Act (FLPMA) also governs BLM management of federal lands. The National Forest Management Act (NFMA) governs development in national forests. Multiple layers of decisions precede drilling on public lands, including land use plans, leasing decisions, and the Plan of Development (POD)/Application for Permit to Drill (APD).

Land use plans

CBM and other development on federal lands must conform with BLM Resource Management Plans and Forest Service Land and Resource Management Plans. BLM Land Use Plans or Resource Management Plans (RMPs) are developed in accordance with section 202 of FLPMA. Forest Service Land and Resource Management Plans (LRMPs) are issued pursuant to NFMA. Land Use Plans should include a discussion of anticipated land uses, including mineral extraction. Implementation of plans trigger the requirements provided in the National Environmental Policy Act (NEPA) and the agencies must conduct an environmental assessment that may require a formal environmental impact statement (EIS). In the EIS, the agency must predict "reasonably foreseeable" development that will result from opening lands to mineral development. Further, the land use plan should reflect the agency's determination as to where and how development will occur. Because CBM development has been so rapid and recent, most plans did not anticipate or discuss the impacts of this level of CBM development, if CBM development was discussed at all.

Leasing

The Federal Onshore Oil and Gas Leasing Reform Act (FOOGLRA) of 1987 requires competitive bids for leases on federal lands. Standard lease terms include application of federal environmental laws and additional measures to minimize adverse impacts, and can include special or supplemental stipulations. The National Environmental Policy Act (NEPA) applies to leasing decision, although there is some debate whether environmental assessments or full environmental impact statements are required and federal courts have issued inconsistent opinions on the issue. BLM may provide NEPA analysis for leasing decisions in RMPs, but most RMPs did not anticipate the levels of CBM development. The Forest Service engages in a two tier leasing analysis under FOOGLRA: analysis of all lands under its jurisdiction available for leasing, and leasing decision for specified lands. Standard Lease Terms (SLTs) give the lessee the right to use the leased land to explore, drill, extract, remove and dispose of oil and gas deposits under the land. Additional measures may be added to mitigate adverse impacts to the surface.[182]

Leasing disputes may play a major role in the Powder River Basin and perhaps other areas as well. In April 2002, the Interior Board of Land Appeals ruled, in response to a challenge by the Wyoming Outdoor and Powder River Basin Resource Councils of three CBM leases in the Powder River Basin issued by the BLM, that the agency had failed to perform adequate environmental reviews before issuing the leases.[183] The board found that two BLM studies on which the agency relied in making leasing decisions, a 1985 BLM resource management plan that did not consider CBM development impacts, and a draft environmental impact statement on CBM development, as "insufficient to provide the requisite pres-leasing NEPA analysis for the sale parcels in question." While the decisions only applied to three leases, they appear to be similar to many more and the decision could bring to a halt thousands of CBM leases until the BLM can revise its environmental assessments. In addition to stopping existing leases, the decision puts into question whether the analysis the BLM is doing in anticipation of approving thousands of new leases would meet the board's criteria. The IBLA opinion concluded that *not only does the record amply demonstrate that the magnitude of water production from CBM extraction in the Powder River Basin creates unique problems and the CBM development and transportation present critical air quality issues not adequately addressed in the RMP/EIS, but BLM has also acknowledged the inadequacy of the RMP/EIS as far as the analysis of CBM issues is concerned.* [184]

As a result, the BLM could not rely on that document to satisfy its obligations under NEPA. The decision may have major impacts on CBM development, depending on whether the councils appeal more decisions, the Secretary of the Interior reverses the Board's finding, gas companies sue the board in federal court, or the BLM decides to place a moratorium on leases until environmental assessments can be completed.[185]

Plan of development/application for permit to drill

The application for permit to drill (APD) includes a plan of operations that outlines the nature of surface impacts. The Forest Service emphasizes protection of resources and general reclamation principles. Onsite inspections may trigger revision of APD or conditions of approval. APDs are submitted directly to BLM, which then distributes the APD to any affected surface management agency. Under revised BLM and Forest Service regulations, both a "drilling plan" and a "surface use plan of operations" must be developed. Neither BLM nor FS rules contain specific terms and conditions governing surface reclamation, although FS does set out some general principles. Prior to approving the APD, the BLM must verify that the required performance bond is in place. In some cases, the APD review is preceded by an application for a plan of development (POD). PODs are required when a field of oil or gas is to be developed rather than one well. PODs give the BLM the opportunity to assess the cumulative impacts of development and to consider ways to reduce impacts such as requiring companies to consolidate their infrastructure.

BLM's surface use planning addresses an extensive set of issues, including existing roads, proposed roads, location of existing and proposed wells and facilities, location and type of water supply, construction materials to be used, methods for handling waste disposal, ancillary facilities, wellsite layout, plans for surface reclamation, type of water discharge, discharge points, reservoirs/containment pits, road crossings, culverts, erosion control measures, discharge rate, downstream concerns, water management plans, and water quality maintenance and monitoring. An interdisciplinary team of geologists, engineers, biologists, archaeologists, hydrologists, and others review the plans, conduct on-site investigations, and conduct post-inspection monitoring.[186]

Clean water laws

Under the Federal Clean Water Act, as administered by states, CBM development is governed by water quality standards to protect designated uses of water. Standards include pollution limits, anti-degradation requirements beyond water quality standards, and total maximum daily loads—maximum daily pollutant discharges that are assigned to point and non point sources to ensure total pollution levels are not exceeded. Developers must receive a National Pollution Discharge Elimination System (NPDES) permit if they are discharging produced water into surface waters of the state. State Water Quality Standards and Effluent Limitations also apply to CBM, but there currently are no technology-based effluent standards for CBM discharges. Permits must still impose effluent limitations that will ensure that State Water Quality Standards are not violated. There is little agreement on what they should be. In Wyoming, for example, there are no numeric standards for sodium absorption ratio (SAR); state officials require that CBM-produced water does not degrade designated uses of surface water. Montana has numeric standards for some waters downstream, so Wyoming sources are required to comply, and the two states have negotiated an agreement.

Under Section 401 of the Clean Water Act, applicants must receive certification from the State where the discharge originates stating that their activities will comply with the Clean Water Act; state requirements become part of the federal permit and are enforceable by either BLM or Forest Service. Under Section 404, parties must get 404 permits for any activities that may result in the placement of fill into the waters of the United States

The Federal Safe Drinking Water Act (SDWA) governs re-injection of water produced from CBM extraction. No underground injection is allowed without a permit.

Part C of the SDWA is designed to protect underground resources of drinking water by issuing permits for any underground injections of fluids. There are five classes of injection wells under these regulations, which are classified by the type of fluid injected and the area where the fluid is injected. With CBM, most re-injection is done into Class II wells. Class II wells cover fluids that are either brought to the surface in connection with oil and gas development or are used to enhance the recovery of oil and gas. The EPA is studying the environmental risks associated with hydraulic fracturing used to facilitate methane recovery for underground sources of drinking water in response to complaints that CBM development has compromised water quality in some drinking wells.

Hydraulic fracturing or fracing has been the subject of significant litigation. In *Legal Environmental Assistance Foundation (LEAF) v. EPA*[187], plaintiffs claimed that the nearby use of hydraulic fracturing to extract CBM polluted their well waters and should have been regulated under the SDWA. The court held that fracing fluids fell within the SDWA's definition of "underground injection," stating that "the process of hydraulic fracturing obviously falls within this definition, as it involves subsurface emplacement of fluids by forcing them into cracks in the ground through a well."[188] Accordingly, the court granted the petition for review and remanded the matter to EPA. In July of 2000, EPA published a notice in the *Federal Register* indicating that it is undertaking a nationwide study to the evaluate the environmental risks of fracing to underground sources of drinking water.[189] A final report has not been completed. The LEAF decision may pose significant implications for CBM development in western states as well. For example, although the Wyoming Department of Environmental Quality (WDEQ) has an approved UIC program, WDEQ does not regulate the underground injection of hydraulic fracing fluids.

Other federal laws

CBM development on tribal lands is governed by the Omnibus Indian Mineral Leasing Act of 1938[190] and the Indian Mineral Development Act of 1982.[191] Energy development on tribal lands is subject to a dual legal system of federal and tribal law. These acts require the Bureau of Indian Affairs to authorize energy leases. NEPA review applies to these decisions. Under other laws, qualifying tribes can act as states in enforcing environmental laws, and tribes may regulate their lands more stringently than federal minimum standards and may regulate in areas not covered by federal laws or programs.

Other Federal laws are applicable to CBM development. The Endangered Species Act requires all federal agencies to Ainsure that any action authorized, funded or carried out by such agency . . . is not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of habitat of such species@[192] Agencies must consult with either the United States Fish and Wildlife Service (USFWS) or the National Marine Fisheries Service (NMFS) when any activity they authorize, fund, or carry out could affect listed species.[193] The Surface Mining Control and Reclamation Act includes provisions to water from coal mining operations that might serve as a model for CBM regulation. Underground coal mining permits must include actions to "minimize the disturbances of the prevailing hydrologic balance at the minesite and in associated offsite areas and to the quantity of water in surface ground water systems." Using the "best technology current available," companies are required to "minimize disturbances and adverse impacts of the operation on fish, wildlife, and related environmental values, and achieve enhancement of such resources where practicable."[194] Federal officials are to monitor operations to ensure compliance and to require monitoring of aquifers.[195]

State regulation

State "conservation statutes" created oil and gas commissions and boards. They were originally authorized to establish drilling units and provide for the location of permitted wells. These laws were typically enacted for three purposes: (1) To protect the opportunity of all owners to share in oil and gas production, (2) To prevent waste of the resource, and (3) To avoid drilling unnecessary wells. Their responsibilities have expanded to include the regulating of drilling, casing, plugging and the abandonment of wells. In some states, the commissions or boards may be authorized to protect the rights of surface owners. Specific state statutory provisions differ in terms of the charge they give to oil and gas commissions:[196]

- Colorado: the Oil and Gas Conservation Commission is to encourage production and prevent and mitigate adverse environmental impacts. Its original function was Ato foster, encourage, and promote the development, production and utilization@ of oil and gas. COGCC focused on increasing production by preventing waste;[197] in 1994, its mandate was expanded to Aprevent and mitigate significant adverse environmental impacts on any air, water, soil, or biological resource resulting from oil and gas operations@[198] and to Ainvestigate, prevent, monitor, or mitigate conditions that threaten to cause, or that actually cause, a significant adverse environmental impact.@[199]

- Montana: the Board of Oil and Gas Conservation (MBOGC) was established in 1953 with the passage of the Montana Oil and Gas Conservation Act. No oil or gas exploration, development, production, or disposal well may be drilled until MBOGC issues a drilling permit. MBOGC's mandate is (1) to prevent waste of oil and gas resources; (2) to encourage maximum efficient recovery of the resource; and (3) to protect the right of each owner to recover its fair share of the oil and gas underlying its lands.[200] MBOGC can also take measures to prevent contamination of or damage to surrounding land caused by drilling operations, such as regulating the disposal of produced salt water and the disposal of oil field wastes.[201] Montana also has a state environmental policy act requiring its state agencies to complete environmental analyses similar to those required under NEPA.[202]
- New Mexico: The Oil Conservation Commission and the Oil Conservation Division of the Energy, Minerals and Natural Resources Department regulate the conservation of oil and gas and the disposition of wastes resulting from oil and gas operations, including the protection of public health and the environment.[203]
- Utah: The Board of Oil, Gas and Mining[204] and its related technical and administrative agency, the Division of Oil, Gas and Mining[205] regulate drilling, testing, equipping, completing, operating, producing, and plugging wells; spacing and location of wells; and disposal of salt water and field wastes.[206] Board rules require operators to "take all reasonable precautions to avoid polluting lands, streams, reservoirs, natural drainage ways, and underground water.@ [207] Board rules encourage the development of Asurface use agreements@ with landowners but do not adopt statewide standards of reclamation.[208]
- Wyoming: The Oil and Gas Commission (WOGCC) has the authority to require drilling, casing, and plugging of wells in order to prevent escape of oil or gas, the furnishing of a reasonable bond limited to plugging each dry or abandoned well, and monitoring of well performance.[209] It can also regulate, for conservation purposes, the drilling, producing and plugging of wells, the shooting and chemical treatment of wells, well spacing, disposal of salt water and drilling fluids "uniquely associated" with gas exploration and development, and the contamination or waste of underground water.[210] The Commission has a duty to prevent the waste of natural gas and to keep it from polluting or damaging crops, vegetation, livestock, and wildlife.[211] WOGCC rules provide that, "[t]he owner or operator shall not pollute streams, underground water, or unreasonably damage or occupy the surface of the leased premises or other lands."[212]

Local regulation

County regulation of CBM development has been accepted in some areas and been contentious in others. County regulations may place limits on operations; require special use, building, and road permits; and require companies to paint production tanks and keep sites weed-free. Colorado's La Plata and Las Animas Counties have enacted regulations that require consideration of noise levels, impacts on air and water quality, vibration and odor levels, fire protection, access requirements, visual impacts, impacts to wildlife and public safety. Conflicts have occurred between the county and developers and between the county and state officials.

La Plata County was the first to regulate CBM development and its regulations were challenged by gas companies as pre-empted by state or federal laws. The county first adopted regulations affecting CBM development in 1991. Industry challenged the regulations in court and the county's authority was upheld. It issued new regulations in 1995 providing that surface owners be able to determine, within a window specified by the OGCC, the specific areas on their land where drilling could take place. It was again sued, and this time the court struck down the regulations. County officials have emphasized that their goal is to address the impacts of development on communities and not to block CBM production.[213]

Of particular importance to county officials is the objective of equating the surface and mineral estates so landowners can help shape the location and nature of extractive activities that affect their lands, and these officials have proposed that companies be required to negotiate surface use agreements before drilling begins. Industry representatives argue that they already provide those agreements before drilling, while others claim that such requirements are too onerous and will drive industry out of the state.[214] The county challenged an Oil and Gas Conservation Commission rule that strengthened the Commission's power over county regulation of oil and gas development.[215]

In February 2002, J.M. Huber filed a lawsuit against La Plata County Commissioners, charging they had exceeded their jurisdiction and abused their discretion when they denied Huber's request for a reconsideration of a drilling permit condition. The company also asked for and was granted a hearing before the Colorado Oil and Gas Conservation Commission. The condition required the company to install a low-profile or alternative pump and use an electric motor at its Bellflower gas well east of Durango. The company argued the decision was outside the jurisdiction of the county and was within the purview of the state OGCC, and that complying with the county's directive "will cause waste as prohibited (by state regulations) since it will significantly inhibit or limit production from the well." County officials, local residents, and Huber representatives had met during the summer of 2001 to negotiate noise and visual mitigation steps the company would take in operating the well, but were unable to come to agreement.[216]

La Plata County regulations issued in 1998 require permits for drilling to be processed within seven days. The process typically begins with the company identifying a new site, visiting the site to discuss the proposal, and formulating an agreement with the land owner. If an agreement is reached, the company then submits an application for a drilling permit to the county and to the COGCC. The county and commission may attach conditions to the permit, and that process can take up to a month. Once the permit is approved, a pre-construction notice is sent to the surface owner from 1–14 days before construction begins. A permit is good for up to one year; if not used by the end of that period, a new permit is required. As much as two month's time may pass between the time the surface agreement is negotiated and the construction and drilling are completed.[217]

On July 11, 2000, the COGCC approved infill well applications that provided for one well every 160 acres instead of the standard 320 acre spacing. It also issued an order imposing new requirements on companies drilling for CBM in La Plata County, in response to residents' concerns with noise, gas seepage, and impacts on the local landscape. By August 27th, BP had filed 10 applications to drill with the county and five had been approved. County planning officials reported that "for the most part, we're on the same page" with the state commission. [218] The state's general conditions require companies to take the following actions: [219]

- Request a COGCC hearing to apply for new drilling sites located within 1/2 mile of the Fruitland Outcrop,[220]
- Identify all plugged and abandoned wells near each new well site,
- Submit drilling plans to the COGCC.

Surface mitigation requirements include the following:

- Curtail drilling during wildlife "seasonal" times,
- Install electric motors "where practicable" to reduce noise levels,
- Water roads to control dust,
- Use plugged or abandoned well sites when possible to reduce new wells.

Companies are also required to ensure they don't contaminate drinking water by:

- taking periodic sampling of water from wells located within 1/2 mile of each new well, and
- testing the water wells before drilling occurs, one year after drilling is completed, and twice more within the next six years.[221]

If a proposed CBM well site is near a subdivision:

- the COGCC director or staff member must make an on-site inspection,
- an on-site inspection is required if an agreement with the surface owner is not reached.

An attorney for the San Juan Citizen's Alliance asserted that the state's requirements failed to address noise, visual impact, and other serious issues, and the COGCC director observed that the regulations do not address other issues such as noise, decline in property values, compensation to land owners, and problems with private agreements between land owners and gas companies. [222]

Surface land owners have argued that their rights were not protected by the regulations. In July 2000, landowners in La Plata County filed a class action suit against 13 companies, claiming they were not minimizing surface impacts. If the plaintiffs prevail, companies will be required to use smaller well pads and pumping units whenever possible. [223] The litigation was based on a 1997 Colorado Supreme Court ruling that gas companies must minimize adverse, unnecessary impacts on surface lands.[224] That same year, J.M. Huber applied for a drilling permit in a housing development with lots of ten acres or less. After numerous hearings with county officials and 12 public meetings at the well site with residents, the company and county agreed on 13 conditions for drilling, including an electric pump rather than a more noisy gas-powered pump to run the pump jack within six months of when the well starting producing, burying power lines, and using a smaller pump jack. The company subsequently concluded that those conditions would cost tens or perhaps hundreds of thousands of dollars, and decided not to install the electric pump. The company concluded that the permit conditions made the company operate less efficiently and profitably, and asked the county to reconsider whether it had the authority to impose such conditions. The company's attorney suggested that the county was "regulating down-hole production and sound," contrary to court rulings that the state oil and gas conservation commission alone had that authority. Local residents countered with demands that the county hold the company to conditions it had agreed to.[225] In February, 2002, the company sued the county commissioners and petitioned the COGCC, charging that the county had "exceeded its jurisdiction and abused its discretion" when it denied the company's request in January 2002 to reconsider the drilling permit conditions.[226]

The Colorado Supreme Court's *Gerrity Oil & Gas Corp. v. Magness*[227] opinion has been widely discussed in the context of CBM development, and warrants a brief note here. The issues before the court dealt with a claim of trespass in a split estate. The court explained that,

Severed mineral rights lack value unless they can be developed. For this reason, the owner of a severed mineral estate or lessee is privileged to access the surface and "use that portion of the surface estate that is reasonably necessary to develop the severed mineral interest." The right to use the surface as is reasonably necessary, known as the rule of reasonable surface use, does not include the right to destroy, interfere with or damage the surface owner's correlative rights to the surface.

In this sense, the right of access to the mineral estate is in the nature of an implied easement, since it entitles the holder to a limited right to use the land in order to reach and extract the minerals. As the owner of property subject to the easement, the surface owner " 'continues to enjoy all the rights and benefits of proprietorship consistent with the burden of the easement.' " The surface owner thus continues to enjoy the right to use the entire surface of the land as long as such use does not preclude exercise of the lessee's privilege. [citations omitted]

Although we have referred to the mineral estate as the dominant estate and the surface estate as the servient estate, our cases have consistently emphasized that both estates must exercise their rights in a manner consistent with the other. Hence, in a practical sense, both estates are mutually dominant and mutually servient because each is burdened with the rights of the other. [citations omitted]

The fact that neither the surface owner nor the severed mineral rights holder has any absolute right to exclude the other from the surface may create tension between competing surface uses. "The broad principle by which these tensions are to be resolved is that each owner must have due regard for the rights of the other in making use of the estate in question." This "due regard" concept requires mineral rights holders to accommodate surface owners to the fullest extent possible consistent with their right to develop the mineral estate. How much accommodation is necessary will, of course, vary depending on surface uses and on the alternatives available to the mineral rights holder for exploitation of the underlying mineral estate. However, when the operations of a lessee or other holder of mineral rights would preclude or impair uses by the surface owner, and when reasonable alternatives are available to the lessee, the doctrine of reasonable surface use requires the lessee to adopt an alternative means. [citations omitted].

Communities in other states may have general regulations that impact CBM development, but have not yet enacted regulations that directly address CBM. In Montana, local regulation is allowed if it ensures effective utilization of resources. In New Mexico, it is likely to be upheld if it only deals with issues traditionally within the jurisdiction of county government. In Utah, counties are precluded from regulating in areas of state law, where the oil and gas board is given exclusive authority, but it is likely to be permissible for counties to regulate traffic, noise, and compatibility with surrounding activity.

In Wyoming, counties can regulate land use but can't prevent use necessary to the extraction or production of mineral resources. Wyoming counties have hired a coalbed methane coordinator to help resolve problems. A memorandum of understanding between the state, five county commissions, and two conservation districts is in place to help coordinate the efforts of the various agencies and to facilitate the flow of information. The coordinator has emphasized the need for consistency in regulation across the basin, the importance of impact funding early in development before tax revenues are received, mitigation funds contributed by all companies, more research and data on development and its impacts, and more amenities for communities affected by development.[228]

State water law

Most of the discussion of CBM and water focuses on water quality, but there are many questions about how CBM development affects water rights. The Rocky Mountain states have all adopted the prior appropriation approach to water law. Under prior appropriation, ownership of land does not result in ownership of water, but water rights are created when water is diverted and used or appropriated for a beneficial purpose. The main provisions of prior appropriation include the following.[229]

First, appropriated waters need not be used on riparian lands; they may be used any place and need not remain in the originating watershed. The water right is the amount of water put to a beneficial use; there are no limits to the quantity used such as reasonable use, but state statutes typically require right-holders to show that all the water will be beneficially used and not wasted;

- Appropriators are typically required to use a reasonably efficient means of diversion,
- Seniors may not transfer their rights to another or change diversion, purpose of use, or place of use if that harms the rights of juniors,
  - —Since about half of the water diverted for agriculture typically returns to the hydrologic cycle, the return flow may be used by other right-holders, and senior right-holders may not adversely affect the return flow; junior right-holders are entitled to the stream conditions that existed at the time they received their appropriation.

Second, the date of the original appropriation established the water right priority date; the holder of the oldest or most senior priority right is entitled to delivery of the full right; junior right-holders are entitled to whatever water is available after senior rights-holders have withdrawn their water;

- All right-holders are ranked according to the dates of their appropriation and each is either junior or senior to all other right-holders,
- If downstream senior right-holders "call" their water, upstream juniors must allow sufficient water to flow past their diversion to meet the rights of seniors.

Third, rights are acquired by use and may be lost by non-use;

- Abandonment occurs when the right-holder intends to relinquish the water right,
  - —the burden of proof lies with those who seek to demonstrate that the right holder has abandoned the water right,
  - —a period of non-use creates a rebuttable presumption that the right has been abandoned, and the right-holder may then provide evidence of the intent to retain the right.
- Forfeiture does not require the intent to abandon, but may occur when there is non-use for the specified period of time or the diversion construction does not occur.

Fourth, water rights are "perfected" when an applicant receives a certificate or decree from the state water engineer or court recognizing that the water is being put to beneficial use and belongs to the applicant;

- Most states require rights-holders to apply for a permit,
  - —All affected parties must be given notice and a hearing must be held to determine whether the criteria for establishing a right have been met,

—The construction of the diversion facilities must occur within a specified time period, and
—The water must be put to a beneficial use.

- Colorado does not issue permits, but, instead, uses a water court system to adjudicate rights; priority is established when the applicant
  —Decides to put the water to beneficial use, and
  —Makes an "open, overt physical demonstration of the intent" that gives notice to third parties.
- Colorado also allows for "conditional decrees" that reserve water for future use; the priority of the right is that of the date of the decree;
  —Applicants must demonstrate that there is a "substantial probability" that the water project "can and will" be completed within a reasonable time,
  —A court must determine whether there is sufficient water available for the proposed diversion.

Fifth, beneficial use generally includes domestic, municipal, industrial, commercial, agricultural, hydropower production, stockwatering, and mining; recreation, fish and wildlife maintenance, and preservation of environmental and aesthetic values have also been defined as beneficial use;

- If water use is deemed beneficial, it cannot be defeated by a more junior claim that water will be put to a more beneficial use,
- However, a right-holder may lose that right if the means of diversion or the use is found to be wasteful,
- The public trust doctrine also places some limits on uses of water to protect environment and recreational interests of the public.

Sixth, water rights are passed to new land owners when land is conveyed unless the grantor expressly reserves those rights, and water rights may be transferred separately from the land if allowed by state law;

Finally, the prior appropriation doctrine is primarily applicable to surface waters. Water that occurs as a result of human labor, such as transbasin diversions, is not subject to appropriation but belongs to those responsible for producing it.

In Colorado, Utah, New Mexico and Montana, water produced from coalbed methane operations is generally defined as byproduct water. Although Wyoming also exempts byproduct water from oil and gas operation from its groundwater permitting system, coalbed methane water does not fall into the exemption, and operators must obtain a groundwater permit from the state engineer and put the byproduct water to a beneficial use.[230]

Colorado water law

Under Colorado law, operators are not required to apply for a permit from the state engineer when withdrawing non-tributary water unless that water will be put to a beneficial use.[231] If the produced water is put to a beneficial use, the state engineer must ensure that it will not cause "material injury to the vested water rights of others."[232] If injury will result, the permit must contain mitigation measure to avoid injury. In Colorado, a reduction of hydrostatic pressure level or water level is not considered a material injury.[233]

The Colorado Oil and Gas Conservation Commission (COGCC) has jurisdiction over produced water, which appears to fall under its definition of "exploration and production waste."[234] COGCC Rule 907 covers the management of "E&P" waste, and it dictates how produced water shall be managed and disposed. Under the rule, if produced water is placed in a pit, it must first be treated to prevent crude oil and condensate from polluting the pit.[235] The rule also contains a number of disposal options including reinjection into a Class II well, evaporation or percolation in a permitted lined or unlined pit, disposal at commercial facilities or through road-spreading, or discharge into the waters of the state.[236] All of these provisions require the operator to receive the proper permits before undertaking any of these activities. The produced water may also be reused to aid in enhanced recovery, drilling or other uses as long as the use follows established water quality standards and water rights.[237] Finally, the rule allows for the water to be used by the surface owner as an alternative domestic water supply that cannot be traded or sold.[238] When water is used in such a manner, it is not considered an implicit admission by the operator that his or her activities are impacting existing water wells.

New mexico water law

New Mexico law classifies water used in the "prospecting, mining . . . or drilling operations designed to discover or develop the natural resources of the state" as a beneficial use, and in certain instances, mine operators must obtain permits to withdraw water.[239] However the state engineer does not have authority over aquifers found at 2500 feet or further below the ground surface that contain nonpotable water.[240] In most instances, coalbed methane wells operating in New Mexico fall under this provision, and thus are not permitted by the state engineer. The Oil Conservation Division of the Energy, Minerals and Natural Resources Department has jurisdiction over "water produced or used in connection with the drilling for or production of oil and gas."[241] The division may regulate surface and subsurface disposal of the water in such a manner as to protect fresh water sources.[242] Particular methods include the use of lined pits and below grade tanks to store produced water,[243] and requirements calling for the prevention and abatement of water pollution so that "all ground water . . . which has a background concentration of 10,000mg/L or less of TDS" is either remediated or protected for beneficial uses.[244] The division also regulates the subsurface injection of produced water into reservoirs.[245]

New Mexico law also contains provisions crafted to protect existing water rights while at the same time promoting mineral development in the state.[246] Under the Mine Dewatering Act, any operator who wishes to appropriate water for a beneficial use or to dewater a mine is given the right to replace the appropriations of existing water rights which may be impacted.[247] The cost to replace the water is solely the responsibility of the operator, who must make an application with the state engineer to replace water.[248] Although an appropriation of water may be made under this act, simply dewatering a mine does not establish water rights for the applicant.[249] The state engineer may only approve an application under this statute if he is satisfied that the plan of replacement will prevent the impairment of affected waters.[250] In approving a plan of replacement, the state engineer must consider the characteristics of the aquifer, present withdrawals on the aquifer and their effects on water levels and water quality, the impact of the mine dewatering on the aquifer, and the "present and future discharge from, recharge to and storage of water in the aquifer."[251]

Utah water law

While Utah also has a groundwater appropriations system,[252] jurisdiction over byproduct water rests with the Utah Board and Division of Oil, Gas and Mining.[253] However, in certain circumstances, the state engineer may issue a temporary water right to put byproduct water resulting from mining development to a beneficial use, but only occurs once the water has been diverted from its underground source.[254] The Division has developed various rules that pertain to the disposal of "salt water and oil field wastes," which include coalbed methane water.[255] Operators may use lined pits,[256] or unlined pits if the disposed water does not have a TDS content higher than ground water that could be affected or other objectionable constituents such as chlorides, sulfates, pH, oil, grease, heavy metals or aromatic hydrocarbons.[257] Unlined pits may also be used when "all, or a substantial part of the produced water is being used for beneficial purposes such as irrigation, and livestock or wildlife watering" and an analysis of the water shows that it can be used for those purposes.[258] Finally, unlined pits may also be used when the amount of disposed water does not exceed five barrels per day.[259] Operators may also opt for subsurface disposal into Class II injection wells under the state UIC program.[260]

Montana water law

Montana is the only Western state that addresses coalbed methane wells directly in its statutes. Under Montana law, groundwater may not be wasted, although in certain situations, including the management, discharge, or reinjection of coalbed methane water, the withdrawal and use of groundwater will not be considered waste.[261] Coalbed methane operators have three management options for the groundwater that is produced from their wells. They may (1) use the water for irrigation, stock water or other beneficial uses, (2) reinject the water into an "acceptable subsurface strata or aquifer" according to the applicable laws, or (3) discharge the water to surface waters or the surface upon obtaining an NPDES permit.[262] While Montana law mandates that no groundwater shall be wasted, the methods of disposal available for coalbed methane produced water are not considered "wasteful" under the law. However, even though the quality of coalbed methane water in Montana is quite good, the sodium absorption ratio (SAR) of the water still may be too high to allow the water to be used for irrigation. Likewise, allowing the byproduct water to be lost down stream or possibly reinjected into aquifers containing a lower quality of water may result in the byproduct water being wasted in fact. Coalbed methane operators are required to notify any other appropriators whose rights may be harmed by the withdrawal of water from aquifers due to coalbed methane development.[263] Furthermore, the operators must offer mitigation agreements to those appropriators whose wells are within one mile of a coalbed methane well or within one half of a mile of any well adversely affected by a coalbed methane well.[264]

Montana law also allows for the designation of controlled groundwater areas. These are areas where groundwater withdrawals exceed the recharge rate of the aquifers within the designated area or are likely to exceed the recharge rate in the future.[265] In order to withdraw and appropriate water from designated groundwater areas, one must obtain a permit showing that the withdrawal will take water that is available, that existing uses will be protected, and that the water will be put to a beneficial use.[266] The Powder River Basin was designated a controlled groundwater area in 1999, meaning that coalbed methane operators are required to obtain permits to withdraw water from the basin. It is questionable whether operators can meet the permit requirements of controlled groundwater areas when the amount of water taken from coalbed methane operations is, to some extent, uncontrolled in an area where the amount of appropriations is already taxing the available resources.

Wyoming water law

Although Wyoming water law contains provisions that deal with byproduct water appropriations, they do not apply to coalbed methane produced water.[267] Instead, the state engineer retains jurisdiction over produced water from coalbed methane wells, and as such, operators are required to obtain groundwater appropriation permits.[268] According to Wyoming water law, applications to appropriate groundwater "shall be granted as a matter of purpose, if the proposed use is beneficial and, if the state engineer finds that the proposed means of diversion and construction are adequate."[269] However, the state engineer may also deny the application if he finds that it would not be in the public's water interest.[270] Beneficial uses of water are outlined in Wyoming water law, and are ranked according to preferences.[271]

The emphasis placed on putting appropriated groundwater to a beneficial use and preventing waste presented problems for initial coalbed methane applicants. On original "Application for Permit to Appropriate Ground Water" forms, appropriators were required to specify the use to which the water would be put. Operators often checked the "miscellaneous" box and stated that the water was used to produce coalbed methane. Present forms now have an individual box for coalbed methane operators to check.[272] Apparently, the state engineer now considers the production of water in connection to coalbed methane development alone a beneficial use of ground water.

While coalbed methane produced water varies in quality across the region, it does not generally approach the poor quality of conventional oil and gas byproduct water, which can reach TDS levels five to ten times that of the worst coalbed methane water, and in some cases is of relatively high quality. Regulating coalbed methane-produced water under the traditional oil and gas regulations runs the risk of wasting a potentially important source of water. Given the value of the water which many believe is at least as valuable as the gas, if not more so, state legislatures may decide to fashion provisions expressly aimed at defining who owns CBM produced water and what should happen to it.

A variety of theories have been suggested for governing the withdrawal and use of groundwater in CBM development. (1) States could declare the owner of surface lands the owner of all the water under it as part of the soil; most states have rejected this approach since it provides no recourse when land owners deplete or contaminate groundwater. (2) States may allow landowners to withdraw reasonable amounts of water as long as that use is connected to the beneficial enjoyment of the land. (3) California provides for withdrawals from a common aquifer equal to the proportion of ownership of the land above the aquifer, in recognition that withdrawals by one land owner affect the water available to other land owners. (4) States may employ tort law to hold liable those whose withdrawal of water harms neighboring land owners, is beyond a reasonable share of water use, or affects surface water in ways adverse to right-holders of that water. (5) States may apply prior appropriations principles, but since senior right-holders might drain an aquifer, states may limit the protection provided for seniors through principles such as "unreasonable interference," where the "lowering of the water table is not per se an unreasonable impairment of senior rights." [273]

States may require permits for water withdrawal to protect water rights and water quality. Permits may specify that withdrawals do not exceed recharge rates or adversely affect groundwater rights. Permits may regulate withdrawals of groundwater in areas where surface and groundwater are interconnected in order to protect the senior water rights from junior well owners whose pumping may diminish surface water. In Colorado, juniors may pump underground sources if they augment surface right-holders with supplemental water to offset any loss in surface water from groundwater removal. To protect water quality, states may require that wells do not draw contaminants into an aquifer. If such contamination occurs, landowners may pursue tort claims against those who have contaminated their groundwater. If they have no water appropriation rights, landowners may still pursue nuisance claims if contamination unreasonably interferes with their use and enjoyment of the land above the aquifer.[274]

CBM development and pending national legislation in 2002

Both Houses of Congress have passed major energy bills and concerns about energy prices, energy imports and national security, and other energy issues are likely to lead to legislation in 2002.[275] While the national debate has focused on other issues, such as opening the Arctic National Wildlife Refuge and increasing fuel efficiency requirements, some proposals address coalbed methane development, and the future of these CBM-related provisions are linked to the prospects for passage of the broader bills. The following proposals for legislation affecting CBM development are currently before Congress:[276]

Conflicts between coal and CBM development: In response to conflicts between coal and coalbed methane companies, members of Congress introduced H.R. 2952/ S. 675, the Powder River Basin Resource Development Act, which sets up a process to resolve conflicts between coal and CBM development; coal companies are complaining that coal development is a more valuable lease and they are being held up by CBM development, in response to the *Amoco v. Southern Ute* ruling. The proposal would establish a dispute resolution process; if negotiations fail, the parties file a petition in court and the court will decide which resource is of the greater value and give development rights to it. The less valuable lease will be suspended, typically the CBM lease, and damages awarded to the CBM company. The coal company will get a royalty credit to reimburse them for the payment they make to the CBM company, and as a result the federal government would lose royalty payments and will also reimburse the state for any loss of its CBM royalties.

Environmental impacts of CBM development: Section 607 of the Senate's energy bill, S 617, orders a National Academy of Sciences study of the effects of CBM development on surface and water resources (in the May 2002 Senate energy bill). The NAS would have 18 months to study issues such as water disposal, impacts on groundwater supplies, surface impacts, and possible mitigation associated with CBM production. The Secretary of Interior would then be required to respond to the study and make recommendations for legal or policy changes she feels are required as a result of the study.

Tax credits: Both the House and Senate energy bills would extends and modify the section 29 tax credit for nonconventional fuels. The current tax credit ends January 1, 2003; the House bill would extent it through January 1, 2007; the Senate version would only extend it for three years. The bills also authorize increased spending for permitting processing and inspections and enforcement.

Hydraulic fracturing: As indicated above, the EPA is expected to release sometime in 2002 a draft report on the impacts of hydraulic fracturing during CBM production on underground drinking water sources. If the EPA reports little or no harm the study will end; if harm is shown, there will be multiyear field studies. A provision in the Senate energy bill requires the EPA to complete a study on fracturing within 24 months of enactment, and the National Academy of Science to review the study within nine months

While there has been some discussion of legislation to address surface use agreements, no bills are currently being considered. The oil and gas industry is strongly opposed to the requirement, and ranchers and other land owners are adamantly in favor of legislation, and members of Congress have been unable to broker an agreement so far. There may be some possibility for administrative changes, such as BLM encouragement of more surface agreements, and possible incentives for companies and surface owners to negotiate agreements.

IV. How can conflicts surrounding CBM development be reduced?

Findings and conclusions

From the perspective of many landowners, government officials, and energy companies, coalbed methane development is a great success. It is a source of jobs, income, corporate profits, tax revenues, royalty payments, and other benefits. Many companies are trying to work with local residents to minimize impacts and reduce conflicts. Some company officials argued that there are no real problems with CBM development, and it may be that the majority of companies and community members are satisfied with the way development has unfolded and the public policies that are in place. The strong statements of concern offered at the NRLC conference in April, as well as those that have regularly appeared in other meetings and in media stories, are, however, compelling evidence that some problems have occurred.

Given the great number of companies developing CBM resources, it is likely that some companies are better than others in working out problems and conflicts. It is not surprising that the rapidity of CBM development has resulted in unwanted impacts on and polarization and division across communities and local residents. Nor is it surprising that land owners, ranchers, and recreationists clash with energy companies who all envision very different uses of the same land or that conservationists and developers do not see eye-to-eye over whether roadless areas and wild lands should remain untouched by roads, pumps, pipelines, and power lines. Nevertheless, a review of the issues discussed in this report suggests the following conclusions about CBM development and associated problems.

1. Coalbed methane is an important and valuable resource in meeting the nation's energy demand. CBM is a growing component of the natural gas that is produced in the United States each year, and demand for natural gas to generate electricity is expanding rapidly because it is a secure, domestic source of energy and is the cleanest burning fossil fuel. CBM is a particularly valuable resource in the Western United States and is an important source of income and jobs to westerners and revenue to local, state, and national governments.
2. A unique challenge posed by CBM development is the speed in which change is occurring. Parties are forced to deal with issues of produced water, conflicts between landowners and those who lease mineral rights, impacts of development on communities, demands for governmental and regulatory services, and other issues in a very compact time frame.
3. As is true with other forms of energy production, there have been numerous conflicts between local land owners and energy companies over the impacts of development on other uses of land, noise, and property values. These are a result of split estates and division of ownership of the land and underlying resources; the lack in some cases of the formulation, implementation, and enforcement of adequate surface use agreements; impacts from development on lands owned by one landowner that spill over to adjacent landowners that are not addressed by agreements; disputes over the calculation of royalties; and other differences. Some companies have developed better relations with surface land owners than others.
4. Like other forms of economic activity, CBM development poses challenges for local communities that must absorb increased traffic, noise, air pollution, demands on housing and public services, and other consequences of growth. Impact fees, property taxes, royalties, and other financial resources can help communities cope with growth, but the consequences of growth may come much faster than the eventual flow of funds. Local governments bear the brunt of dealing with the consequences of growth but may lack the resources and authority to address them effectively. Depending on state law, local governments may or may not benefit directly from royalties or severance taxes derived from development.
5. Governance in the United States is fragmented, overlapping, and complex. Natural resources, watersheds, and ecosystems implicated in energy development ignore state and other governmental boundaries.

Governance is particularly complicated in the West by large parcels of public lands and reservations that add additional layers of sovereignty and governmental authority. Federal, state, and local governments all have some regulatory authority over CBM development and a major challenge for energy companies, landowners, and other concerned citizens is negotiating this complex structure of jurisdictions whose policy making efforts are often uncoordinated and inconsistent. Most agencies lack the finances and staff to meet all the demands on them for expeditious processing of applications, timely and comprehensive assessment of environmental impacts, monitoring and enforcement of agreements, and long-term planning.

6. Given the aridity of the West, dealing with the impact of CBM development on water is a tremendous challenge. While there is considerable uncertainty concerning the impact of CBM development on water quality, some residents are convinced that development at least exacerbates the natural seepage of methane into drinking water sources if not directly contaminating aquifers. Produced water can inundate desert ecosystems and damage fragile soils, cause erosion, and pollute cleaner bodies of water. Perhaps most importantly, water is so valuable and scarce that any activity that seems to waste it is problematic.
7. Despite some progress in bringing energy companies and land owners together to resolve differences, considerable efforts at public education and communication, and experience all parties are gaining in understanding and addressing the impacts of CBM development, conflicts and pressures will likely continue as the density of development increases and new lands are opened to development. In some areas, parties may be able to strike a balance between energy extraction and grazing, between economic incentives for development and impact fees and taxes, between government regulation and market forces, and between water used for energy production and for other purposes. In other areas, such as wilderness study and roadless areas, development may be precluded by commitments to preservationist values. Major challenges include identifying lands that should not be leased or developed, examining how we can promote domestic energy and provide for other land uses, and devising analytic tools and frameworks for helping decision makers to clarify and make appropriate choices.
8. As of the writing of this report, in May 2002, the future of CBM development is uncertain. Because of its plentiful supply and clean-burning characteristics, demand for natural gas will continue to grow. But legal challenges may slow development. As explained above, the Department of Interior's Board of Land Appeals decision in April 2002 that the BLM did not perform adequate environmental reviews before issuing three leases in Wyoming may be reversed by the Secretary of the Interior, expanded to vacate thousands of leases in the basin, and/or be challenged through lengthy litigation. Current production in some areas may be halted until the BLM prepares additional environmental analyses and new resource management plans. Disputes over the BLM's environmental impact statements for CBM in Montana and Wyoming may delay the completion of the analyses that are required before a new round of leases can be approved and CBM development expands.

Principles for assessing options for CBM development

As is true for other natural resource issues in the West, there is no consensus over the problems surrounding coal-bed methane development. Ranchers, farmers, wilderness advocates, county commissioners, company executives, air and water quality regulators, oil and gas commissioners, governors, federal agency officials, and others differ in their diagnoses of the causes of the controversies that have swirled around CBM development and possible remedies. There is, however, strong support throughout the West for bringing together parties to increase communication, generate innovative alternatives for solving problems, and build support for implementing solutions. A variety of rationales, assumptions, and ideas have contributed to these efforts to find new ways to resolve natural resource conflicts, and include the following underlying principles:

SUSTAINABILITY. The idea of sustainability provides a useful lens for assessing the rapidity of CBM development and for examining possible responses. Sustainability emphasizes the interaction of ecological, economic, social, cultural, and other values, so that no one set of values, such as environmental or economic factors, can alone determine policy. The methodology of sustainability builds on the idea of ecosystem services, but goes beyond to include several other additional criteria for assessing policy choices, including pollution prevention rather than treating emissions, sustainable yield of renewable resources, the precautionary principle and preservation of ecological values in the face of uncertainty, true-cost pricing that internalizes environmental costs in market exchanges, the development of economic indicators and measures that reflect depletion of natural resources, considerations of equity and distribution, and preservation of ecological conditions and options for future generations. Sustainability focuses on comprehensive solutions that reflect the interconnections of ecology. It respects the maxim, "everything is connected to everything else," that is at the heart of ecology.

An important feature of sustainability is its integration of ecological protection and economic activity with social equity and political empowerment. Political participation is a key ingredient in ensuring that decisions affecting economic and environmental conditions be made more inclusive. Sustainability is not an ecological concept alone, but also one of social justice, inclusion, fairness, community well being, and political engagement. These social and political values are important and valued in their own right as well as because they contribute to ecological protection. It requires fairness in the distribution of benefits and burdens, a perpetual resource base and ecological services, and a social system that secures the interests of all persons. Sustainability is bound up with notions of strong democracy, participation, community, and those social characteristics are fostered through a scale of personal interaction. So too is a commitment to a land ethic. As Aldo Leopold defined the land ethic, sounding much like a proponent of sustainable communities, "An ethic, ecologically, is a limitation on freedom of action in the struggle for existence. . . . All ethics so far evolved rest upon a single premise: that the individual is a member of a community of interdependent parts. . . . The land ethic simply enlarges the boundaries of the community to include soils, water, plants, and animals, or collectively: the land."[277]

There is ongoing debate over how to define and implement the goal of sustainability and apply it in contexts such as developing fossil fuels and other nonrenewable resources. For some, sustainability means that development and growth continue with some balancing of economic and environmental values, while others give primacy to ecological health and place severe constraints on economic activity.[278] Despite global agreements that appeal to sustainability, the concept is inextricably intertwined with the idea of community, and the most thriving examples of sustainability seem to be in that context. Dale Jamieson, for example, argues that, at the local level, sustainable works in the negative: we can agree when local land practices are not sustainable:

> *In many specific contexts the language of sustainability can be made more useful by focusing on what is unsustainable rather than on a positive definition of sustainability. Often people who would initially disagree about what sustainability is can agree about when something is unsustainable. Ranchers and environmentalists (for example) may agree that eroded, denuded land is unsustainable, even if they disagree about what it would be like for the land to be sustainable.*[279]

The idea of sustainability suggests a number of principles that might illuminate the choices surrounding CBM and other forms of energy development:

- Ensure sustainable yield of resources
- Integrate ecological, economic, and community values
- Secure inter- and intra-generational equity and fairness
- Prevent problems rather than treat their impacts
- Conserve ecosystem services in the face of uncertainty
- Promote community, local empowerment/responsibility
- Develop true-cost prices that internalize all costs

COLLABORATIVE DECISION MAKING. The idea of sustainability is intertwined with community-based, collaborative decision making as a process for making sustainable policies. Collaboration seeks to avoid the conflict, litigation, and other problems that have plagued other planning processes, and provide a forum for government officials from different levels of government and overlapping jurisdictions to work together. Various forms of collaborative processes are likely to be used by communities as they develop plans and policies for making CBM development more sustainable. Proponents argue that successful collaborative processes involve the interests or stakeholders who are most affected by decisions, empower local environmental protection groups to advocate for broad environmental values in local decisions, ensure that all interests have adequate resources to represent their views and participate effectively, allow agencies to facilitate participation among stakeholders and develop plans responsive to their concerns, within the constraints of national laws and policies, reduce conflict among stakeholders, generate opportunities to find innovative, and low cost solutions, and promote partnerships between agencies and stakeholders that promote implementation and foster problem solving and learning by experience.[280]

One critical issue here is determining the goal of collaboration: is it to produce actual decisions and plans that governmental authorities simply adopt, or to assist decision makers in discharging their responsibilities? The more collaborative groups are seen as advisory, the less of a concern there is about displacing agency authority. But the more decision-making power collaborative groups have, the more opportunities there are to capture the advantages of collaboration. Collaborative groups have arisen in response to the inadequacies of traditional, agency-based decision making, so there are strong incentives to find new processes and structures.[281]

There are significant challenges involved in devising effective collaborative efforts. The processes may exclude national stakeholders' views and weaken national environmental commitments. They fragment decision making and reduce the power of national planning efforts. Critics warn they inevitably benefit industry interests that are typically better funded than conservation groups and they fail to encourage agencies to make the often difficult decisions mandated by environmental laws. Collaborative efforts must respond to the concern that the efforts de-legitimize the conflict that is sometimes required to move away from unsustainable use of resources and toward their preservation and co-opt the strength of environmentalism as a force rooted in broad public support. Such efforts may increase the costs and time required to make decisions, and win-win solutions will not always be possible as natural resources become increasingly scarce and preservation values fundamentally collide with commodity interests.[282] Part of the evolution of natural resource policy making will be the development of new ways of bringing members of a community together to devise plans that will meet sustainability goals and will generate strong commitments to comply with the difficult choices to be made. While each landscape is different, lessons from one area can be shared with others. Open and inclusive processes that encourage broad participation, initiatives that capitalize on a sense of place and landscape, and agreements that clearly meet or exceed the protections required in natural resource laws are some of the keys to constructive collaboration.[283]

CBM development in the West will inevitably expand as demand for natural gas continues to grow. Companies will continue to operate in areas where resources are already being developed and conflicts may diminish in some areas as combatants become weary or irresponsible companies go out of business. Future CBM plays may pose new conflicts over protecting sensitive lands. The challenge is to manage development in ways that promote ecological, economic, and community sustainability. The interest expressed by many companies in building community and protecting local environments can combine with everyone's interest in reducing conflict. CBM development can be the basis of collaborative efforts that reduce conflicts, resolve problems, and ensure that energy production continues in a more sustainable fashion. Consensus-based decision making suggests the following general principles that can guide CBM decisions:

- Recognize the importance of place-based decision making and a land ethic
- Ensure the participation of all affected interests
- Integrate overlapping government jurisdictions
- Develop partnerships for designing and implementing solutions
- Learn from experience and engage in intelligent trial-and-error
- Employ adaptive management techniques and approaches.

Sustainability and collaboration are reinforced by the Western Governors Association and others who have embraced principles of balance and stewardship in environmental policy making that is reflected in a concept labeled "enlibra." Enlibra, a hybrid term from Latin words, is a set of principles aimed at promoting solutions to natural resource conflicts that avoid litigation, torn communities, and natural resource wars.[284] The governors endorsed the idea as governing principles in 1997 and have held two summits in the West in order to encourage use of enlibra in addressing problems of population growth, developing natural resources, providing for economic growth in new service industries, adjusting to the globalization of markets and competitiveness, controlling more diverse and diffused sources of pollution, changing land use patterns, and new technologies.[285] Enlibra builds on collaborative efforts the governors developed in the 1990s that are reflected in the Park City Principles for Water Management, the High Plains Partnership, the Grand Canyon Visibility Transport Commission, the Oregon Plan for Salmon and Watersheds, the Texas Regional Water Supply Planning Process, Trails and Recreational Access for Alaska, and the Wyoming Open Lands Initiative. These efforts reflect "strong commitment from state and local government, vested local support, and federal collaboration."[286] Enlibra embraces the following eight principles:

- National standards, neighborhood solutions—assign responsibilities at the right level, give flexibility to non-federal governments, and provide accountability
- Collaboration, not polarization—use collaborative processes to break down barriers and find solutions
- Reward results, not programs—move to a performance-based system that encourages problem solving, not just compliance with programs
- Science for facts, process for priorities—separate subjective choices from objective data gathering and seek agreement on facts and uncertainties before framing choices
- Markets before mandates—pursue market-based approaches and economic incentives whenever appropriate
- Change a heart, change a nation—support environmental understanding and education about stewardship
- Recognition of benefits and costs—make sure all decisions affecting infrastructure, development, and environment are fully informed by life-cycle costs and economic externalities
- Solutions transcend political boundaries—use appropriate geographic boundaries to identify the full range of affected interests and facilitate solutions to environmental problems.[287]

The Bush administration has embraced the principles of enlibra. The White House Council on Environmental Quality co-hosted the Western Governors' Association's enlibra summit, and EPA administrator Christie Whitman and Interior Secretary Gale Norton both endorsed its principles in speeches given at the meeting. Administrator Whitman's National Environmental Performance Partnership System emphasizes collaboration between federal and state governments in setting priorities and defining roles. Secretary Norton's "4 Cs" —"communication, cooperation, and consultation in the service of conservation"—is another reflection of these principles.[288] They are rooted in a decades-long effort to redefine federalism and refine the relationship between federal, state, and local governments in natural resources and other policy making arenas that have been given labels like cooperative federalism, new federalism, and policy devolution.[289]

Proponents of these principles of collaboration and conservation will need to be responsive to the fears of environmentalists that devolution to state and local policy making will weaken compliance with national environmental standards and require battles for conservation that were won at the national level be re-fought in each state. An important strength of the environmental movement lies in its ability to tap into broad public interest in protecting the environment and in the aggressive use of the courts to ensure national laws are implemented faithfully, and that they are disadvantaged in other forums. The participation of environmentalists in policy making efforts sponsored by the administration, western governors, and others will likely require a strong commitment to the principles of balance and fairness.

Recommendations for the governance of CBM development

While there are some differences between these prescriptions for policy making, they share a common core of ideas:

- solutions to problems need to engage a wide range of affected interests in their design and implementation,
- national environmental standards need to be pursued in light of local conditions,
- fragmented governmental jurisdictions need to coordinate their efforts,
- policy makers need to balance competing interests and values such as preservation and resource extraction, and

- the interests of future generations need to be reflected in decision making.

The widespread commitment to these principles for managing the West's natural resources and preserving its unique environment is, of course, not a reflection of a consensus over how to deal with CBM development and a host of other issues. Not everyone embraces the principles and some are quite skeptical of their utility in bringing Westerners together in ways that adequately protect national values and environmental quality. If one begins, for example, with the view that the most pressing public purpose is extracting energy resources as quickly as possible to help reduce vulnerability to imported sources of energy, these principles will likely be viewed as a diversion. But they reflect the common view, at least at the level of basic commitments, of a wide range of interests. Applying them to the problems and challenges surrounding CBM may help illuminate possible solutions as well as some of the strengths and weaknesses of these principles of sustainability, collaboration, enlibra, and cooperation in guiding energy policy in the West.

Workshops in existing CBM basins

The active support of and participation in problem solving forums requires sacrifices of time and resources on the part of all parties. Environmental and community group volunteers will need to find time to participate in proceedings, as will industry executives and government officials. While those investments may be costly in the short-run, they may prevent and reduce conflict in the long-run. Environmental groups do not give up their ability to seek remedies in court, but may defer such efforts until more collaborative forums are supported first. Energy companies will be required to take more time initially to meet with land owners and others and lay the foundation for obtaining drilling and water discharge permits, but that investment can result in fewer conflicts, problems, and delays in the future.

Since the problems and conflicts surrounding CBM development differ considerably by basin, it makes sense that people in each basin work together to design and implement solutions. A series of workshops could provide a forum for those interested in CBM development in each basin to produce recommendations and guidelines to governments, companies, and residents concerning many of the most contentious issues surrounding CBM development. Such collaborative efforts seem to be most promising when they are characterized by clear and discrete tasks to be accomplished within a limited time frame, strong leadership and commitment by affected interests, and adequate resources to support the analyses required and ensure the participation of all interests. These workshops could draw upon the expansive materials already available, including environmental impact statements, reports, and studies as well as commission additional research that may be needed. Participants might include representatives from the BLM and other federal agencies, state oil and gas commissions and boards, state air and water quality agencies, county commissions and planning boards, other governmental bodies, as well as citizen and industry representatives.

The first forum could be convened as a pilot project to work out the details of who would participate, how commissioned research would be funded, what kinds of recommendations and guidelines might be produced, and how the forum would be structured. The agenda for these workshops could include the following questions set out below. A separate workshop could be convened for each issue, or a workshop could take on two or three issues.

1. How can the rights and interests of surface and mineral owners be balanced?

Stewardship, sustainability, and collaboration all require that those who own and live on the land play a major role in determining how development occurs. If landowners cannot help shape the surface impacts of CBM development then they will simply not be viable partners in ensuring the sustainability of the western landscape. Their participation in determining the location of pumps, compressors, pipelines, and roads need not be a threat to the ability of companies to extract the gas profitably, and there needs to be a balance between the needs of companies and land owners. Established mineral law generally emphasizes the rights of those who hold leases to extract minerals, and companies could stand firm on this superiority issue. But harmonizing surface and mineral owner rights is an essential element of reducing the conflict surrounding CBM development and balancing resource extraction with other uses of the land. The Supreme Court of Colorado ruled in 1997 that the rights of mineral and surface owners must be exercised in a manner consistent with each other: "Both estates are mutually dominant and mutually servient because each is burdened with the rights of the other."[290] Other states could choose to embrace a similar view. Some suggestions for ways of improving cooperation and reducing conflict between surface owners and companies that could be discussed in CBM workshops include:

- Require consultation and encourage surface owner agreements on split estate lands before issuing drilling permits and effectively enforce this requirement and monitor compliance
  —Some companies report that they already require such agreements before drilling begins;
  —Companies can give land owners options for different ways to locate development and allow them to choose the option that minimizes conflict with other uses of their land;
- Provide an ombudsperson or expedited dispute resolution process to address problems with surface owner agreements;
- Create incentives for companies to work closely with landowners through royalty credits, awards and recognition, and other efforts;
- Assess the need for legislative changes in oil and gas laws to better reflect the balance between land owner and mineral development rights.

2. How can the true costs of resource development be provided for?

The costs of leases, royalty or severance taxes, exploration, extraction, and transportation are reflected in the price at which gas is sold. But other costs of development, including the surface land owner's financial, opportunity, aesthetic, and other costs of the development of CBM resources are often not represented in those prices. Competitive pressures between CBM and other sources of natural gas plays, and between natural gas and other energy sources, create powerful incentives to externalize costs, and the commitments of companies to ensure that prices include more of the real cost of production is essential. CBM workshops might explore several options for better internalizing the costs and benefits of CBM development, including the following:

- Compensate split estate landowners for surface access, mitigation of impacts, damages, and loss of property values resulting from gas development with mineral lease revenues and royalties;
- Require adequate reclamation bonding or create an escrow fund from lease and royalty revenues to ensure the implementation of reclamation agreements.

3. How can the process of issuing permits and enforcing permits and other legal requirements be improved?

Enforcement of permit stipulations, relevant laws, and other legal requirements is important in recognizing the efforts of responsible companies and in creating clear incentives for compliance. Both industry and community representatives emphasize the need for effective enforcement. Effective enforcement helps ensure that all companies are required to incorporate the costs of balanced and environmentally sensitive development in the prices they charge and some firms are not able to undercut their competition by reducing environmental protections. Effective enforcement is a regular refrain of community groups who want to ensure that standards are applied consistently and fairly. Ideas for improving permitting and enforcement efforts of federal and state agencies include the following:

- Secure additional funding for processing, issuing, and enforcing permits, through permit fees on applications as occurs in other environmental permitting (Clean Air Act operating permits, for example), royalty payments, and other sources;
- Ensure companies that are not acting responsibly are identified and sanctioned for noncompliance with relevant laws and regulations;
- Create incentives for companies to comply with permit requirements through self-audits and other innovations that allow conscientious companies to demonstrate compliance and government agencies to focus enforcement resources on problem companies.

4. How can the interests of counties to regulate the impacts of CBM development be better integrated with state and federal agency regulation of CBM development?

Counties are at the front lines of efforts to deal with the impacts of CBM development and they need the legal and financial resources to address those impacts and to be able to coordinate energy and other forms of economic development with zoning and other land use planning efforts. State laws give responsibility to oil and gas commissions to regulate resource extraction and typically emphasize efficient production of resources and minimization of waste, and may not provide much guidance for how the impacts of extractive activities should be addressed. In some areas, county and state official appear to be working together with minimal problems, while in a few areas, conflicts between state and county officials are a major issue. State agencies should work with counties to develop clear statements of authority concerning the governance of CBM. Workshops could seek to devise guidelines for coordinating the efforts of county, state, and federal agencies that could address the following questions:

- How can state oil and gas commissions and environmental quality agencies and counties harmonize their regulatory concerns and cooperate in regulatory activities?
- How can companies work with counties in coordinating the development of CBM infrastructure among themselves to reduce the number and extent of facilities? Contractual obligations, technological differences, and other factors place limits on sharing infrastructure, but some reduction in impacts is likely.
- What state-county relationships have worked in particular areas and how can successful models be adapted elsewhere?

5. How can ecosystem- or watershed-level planning and coordination for CBM development take place?

Each CBM basin poses a unique set of challenges in governing development, but one commonality is the complex, overlapping, and fragmented framework of governance. Specific regulatory authority is given to a variety of government agencies and those jurisdictions do not reflect the landscape, watersheds, and other factors shaped by development. A workshop involving all relevant agencies and citizen and industry representatives could bring participants together to produce guidelines to:

- Create ecosystem or watershed planning efforts and regional air quality planning processes to ensure that CBM-related decisions are integrated with other land use and development decisions;
- Create forums to coordinate CBM permitting and other regulatory decisions to streamline the time required to make decisions, facilitate public participation in regulatory decisions, and increase communication among decision makers.

6. How can water quality and supply be best protected?

There is clear consensus that water quality must be protected during CBM development, and no consensus over how serious a problem this is. As indicated above, governments can assuage concerns by more effective enforcement of permitting requirements for drilling and for disposal of water. A workshop could bring parties together to:

- Formulate plans to produce accurate baselines for water quality and quantity;
- Review compliance with testing and monitoring requirements and regularly assess those requirements to see if they should be strengthened.

7. How can beneficial use of produced water be fostered?

Water is such a valuable commodity that all parties involved in CBM development should renew their efforts to find ways to ensure that produced water is used beneficially. Suggestions for workshops include the following:

- Clarify legal ownership of produced water
- Develop guidelines and processes to ensure that surface owners are involved in decisions concerning the discharge of water onto their lands;

- Develop a research program to carefully trace what happens to produced water and what its impacts are on surface ecosystems and groundwater.

8. How can effective reclamation be secured in permitting and bonding?

Reclamation is not currently the most pressing CBM development-related issue, but the fear of inadequate future reclamation is undoubtedly a concern of those who seek to slow down CBM development. Given the relatively short life-span of CBM wells, the adequacy of reclamation policies will soon be tested as fields mature. Some of the recommendations discussed above address reclamation, but because of the importance of ensuring that reclamation contributes to the sustainability and stewardship of lands in the West, a workshop could develop specific recommendations on how to:

- Ensure surface owners are involved in reclamation planning through surface use agreements;
- Ensure adequate reclamation requirements are included in permits and adequate reclamation bonds are posted as part of the permitting process.

9. Where should CBM development be prohibited?

In most areas, CBM development and other land uses can be balanced. In a few areas, the choice is either to protect them as undeveloped or to allow some development. The vast majority of public lands are available for resource extraction, and lands where no development has yet occurred contain only a small fraction of total CBM reserves. Wilderness study areas, roadless areas, and other protected lands may contain valid leases and the rights and interests of leaseholders need to be preserved. One of the most difficult challenges for a CBM workshop would be to develop recommendations for placing limits on development, compensating leaseholders fairly if they are not able to exercise their leases, and minimizing impacts of development affecting protected areas. A workshop could address the following questions:

- In what places where there are CBM reserves, such as a roadless areas, wilderness study areas, and national monuments and wildlife reserves, should development not take place? How should such decisions be made?
- How can CBM development take place with a minimum of environmental impact in or near these ecologically sensitive areas?
- How can lease holder rights be protected in areas where it is determined that development should not occur?
- How can the broad commitment to collaboration, communication, and conservation ensure that development of new CBM resources is more carefully and systematic planned and adverse impacts minimized?
- How can the BLM apply principles of adaptive management to planning and leasing actions affecting CBM so that development is balanced with protection of habitat, wildlife corridors, and other environmental values?

10. How can we promote conservation and efficient use of natural gas?

Demand for natural gas is increasing and will continue to do so. Satisfying that demand exclusively through increased production will make it very difficult to balance extraction with other values affected by development. The more efficient the use of natural gas and more effective efforts to conserve its use are, the less pressure there will be on increasing well density and developing new areas. In addition to conservation and efficiency in the use of natural gas, collecting methane that would otherwise escape in the process of mining prevents the waste of an important resource and reduces emissions of a very potent greenhouse gas. While conservation and efficiency efforts are not directly part of CBM development, and may not be in the short-term interest of gas companies, all parties should be interested in the sustainability of natural gas as a transition fuel until even cleaner, renewable energy sources are more widely developed. A workshop might address the following questions:

- How can the amount of methane vented in coal mining and conventional gas operations be reduced?
- How can methane extraction be balanced with conservation and efficiency efforts and the promotion of renewable resources in order to reduce pressures for development on sensitive lands, ranching and agriculture, and other values?

Lessons for emerging basins

The Powder River Basin in Montana, the Green River Basin in Wyoming, and other areas are poised to begin major development of CBM resources. Federal, state, and local government officials, energy companies, and local residents could join in a CBM summit before development occurs to examine the lessons learned in areas where CBM development has already occurred. The results of the workshops suggested above could also be valuable not only to the basins with large-scale existing development, but also to these potential sites. These lessons, indicated by the NRLC April CBM conference, suggest the following agenda for such summits:

- A comprehensive inventory of the location of likely CBM wells and base line data on underground and surface water quality, wildlife and soils, and other important resources likely to be affected;
- A framework of governance to clarify governing authority and ensure the permitting and other regulatory decisions are coordinated;
- A set of guidelines for best operating and management practices for companies from cradle-to-grave CBM operations, landowner/gas company relations, and other issues;
- A plan to ensure adequate funding of the impacts of development on communities, funding of the issuance and monitoring of permits, funding of reclamation, and other costs of development;
- A plan to ensure protection of water quality and beneficial use of produced water.

Notes

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22. *Id.,* 1–4.

23. The provisions that follow are listed in National Energy Policy Development Group, Appendix One, Summary of Recommendations, Chapter Five, Energy for a New Century: Increasing Domestic Energy Supplies, unless otherwise noted.

24. National Energy Policy Development Group, Chapter Three, Protecting America's Environment: Sustaining the Nation's Health and Environment, *supra* note 13.

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26. Richard A. Schraufnagel, "Coalbed Methane Production" AAPG, *supra* note 3, at 341.

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	CBM	Natural Gas
Carbon dioxide	1.1%	1.8%
Nitrogen	0.1	2.1
Ethane	0.1	12.4
Methane	98.6	73.9

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155. The report is discussed in Tom Kenworthy, *Open Land to Drilling, Report Urges*, *USA Today*, Apr. 5, 2001, at 1A.

156. Michelle Nijhuis, *Energy plan eyes the Rockies*, *High Country News* (Paonia, Colo.), June 4, 2001, at 3.

157. John Heilprin, *Norton Interested in Oil, Gas in Rockies*, *Great Falls Tribune* (Great Falls, Mont.), Feb. 13, 2001, *available at* http://www.greatfallstribune.com/news/stories/20010213/localnews/272739.html.

158. Mac Blewer, Energy Policy Should Avoid Endangered Wildlands, Wyoming Outdoor Council, *at* http://www.wyomingoutdoorcouncil.org/news/wotr033001. html (Mar. 2001).

159. Douglas Jehl, "Gas-Rich Desert Will Test Bush Resolve," *New York Times,* Feb. 4, 2001, at A1.

160. The Wilderness Society, *Wild Alert*, Feb. 9, 2001, (email from action@tws.org).

161. Dustin Bleizeffer, Plumbing the Greater Yellowstone Ecosystem, Casper Star-Tribune (Casper, Wyo), July 17, 2001, *at* http://www.wyonow.com/NEWS/WYONEWS/16DrillingGYE.htm.

162. *Id.*

163. Todd Wilkinson, Drilling in Rockies Sharpens Split Over Wilderness vs. Oil, *Christian Science Monitor*, Apr. 13, 2001, at 2.

164. *Id.*

165. Editorial, "Senators should reject drilling ANWR and Front" *The Great Falls Tribune* (April 18, 2002) www.greatfallstribune.com/news/stories/20020418/opinion/16055.html

166. Theo Stein, *supra* note 141.

167. Meredith Taylor, Wyoming Outdoor Council, *quoted in* Kim Murphy, *Gas Bounty Amid Natural Treasures: A Volatile Mix*, *Los Angeles Times*, Apr. 30, 2001, at A1, *available at* 2001 WL 2483021.

168. Quoted in Kim Murphy, *Gas Bounty Amid Natural Treasures: A Volatile Mix*, *Los Angeles Times*, Apr. 30, 2001, at A1, *available at* 2001 WL 2483021.

169. Quoted in Thomas Friedman, *Drilling in the Cathedral*, *New York Times*, Mar. 2, 2001, at A23.

170. Harvey Locke, quoted in *id.*

171. Mike Soraghan, "Norton touts 'new environmentalism,'" *Denver Post* (February 11,2002) http://www.denverpost.com/cda/article/detail/0,1040,53%7E415548%7E36%7E%7,00.htl...2/25/02; Weston Kosova, "What's Gale Norton Trying to Hide?" *Outside* (June 2002): 98–104.

172. Clair Johnson, "EPA reaction to methane studied" *Billings Gazette* (May 5, 2002) http://www.billingsgazette.com/Index.php?display=rednews/2002/05/02/build/local/B2-methane.inc.

173. Dustin Bleizeffer, "Agencies split on methane study," *Billings Gazette* (May 1, 2002) http://www.billingsgazette.com/Index.php?id=1&display=rednews/2002/05/01/build/wyoming/me....5/1/2002.

174. Scott McMillion, "EIS on coalbed methane drilling blasted," *Bozeman Chronicle* (May 2, 2002), http://newspapers.mywebpal.com/partners/311/public/newss295454.html

175. Ellen Nakashima and Dan Morgan, "Interior Official Challenges EPA Report on Energy Site," *The Washington Post* (April 25, 2002): A27; Dustin Bleizeffer, "Griles to back off from CBM rift," *Star Tribune* (May 10, 2002) http://www.wyonom.com/NEWS/WYONEWS/Griles9.html.

176. Ellen Nakashima, "Wyo. Drilling Project Gets Failing Grade from EPA," *Washington Post* (May 17, 2002). http://www.washington-post.com/ac2/wp-dyn/A30380-2002May16?language=printer.

177. U.S. Department of Energy, Energy Information Agency, *Annual Energy Outlook* 2001 (December 2000): 98.

178. Lang, *supra* note 4.

179. *Id.*

180. Burlington Resources has been injecting CO_2 into a coal seam in the Northern San Juan Basin since 1996, but its impacts are uncertain. A Canadian company has studied the feasibility of injecting CO_2 emissions from a nearby power plant exhaust: a 100 well, 320 acre-spacing five-spot coalbed methane project that injected a 95% CO_2 stream would, according to the model, yield a recovery of 72% of the gas-in-place, in comparison with a recovery of about 44% without the injection. The company has estimated that it could earn a 12% rate of return with a CO_2 credit of $15/ton at a $2/Mscf gas price and a $30/ton credit at $1/Mscf. The cost of the CO_2 is a key factor. Some processes such as gas processing plants that vent relatively pure CO_2 would be good sources, but the real interest is in tapping the combustion flue gas from power plants. However, the CO_2 concentration in flue gas for a coal-fired plant is only about 13 percent, and it is costly to separate out the CO_2. See Lang, *id.*

181. This section is based on Kate Zimmerman, NRLC CBM conference, April 4–5, 2002.

182. For more on FOOGLRA, see Kate Zimmerman, NRLC conference, April 4–5, 2002.

183. Wyoming Outdoor Council, 156 IBLA 347 (April 26, 2002).

184. The opinion is available at http://plnfpr.com/landnews.htm; the quotes in this paragraph are from p. 9 of the file.

185. According to one report, reversal by the secretary is unlikely. See Ellen Nakashima, "Ruling Could Delay Wyo. Gas Exploration," *The Washington Post* (May 1, 2002): A23.

186. Walt Brown, NRLC CBM conference, April 4–5, 2002.

187. F.3d 1467.

188. *Id*. at 1474–75.

189. *Fed. Reg*. 45774-75 (July 25, 2000).

190. U.S.C. '' 396a-396g.

191. *Id*. '' 2101-2108.

192. U.S.C. ' 1536(a)(2).

193. *Id.*

194. U.S.C. ' 1266(b)(9) and (11).

195. *Id.*, ' 267(b)(2).

196. For more on state regulation, see Kate Zimmerman, NRLC CBM conference, April 4–5, 2002, from which the following paragraphs on state commissions and boards is extracted.

197. Colo. Sess. Laws 250.

198. COLO. REV. STAT. ' 34-60-106(2)(d).

199. COLO. REV. STAT. ' 34-60-124(4).

200. MONT. CODE ANN. ' 82-11-101.

201. MBOGC regulations are located in Title 36, Chapter 22 of the Administrative Rules of Montana.

202. MONT. CODE ANN. ' 75-1-201.

203. N. M. STAT. ANN. '' 70-2-1 through 70-2-38, 19 N.M. ADMIN. CODE tit. 19, ' 15.1.12.

204. UTAH. CODE ANN. ' 40-6-4..

205. *Id.* ' 40-6-15.

206. *Id.* ' 40-6-5(3).

207. UTAH ADMIN. CODE R649-3-15:

208. UTAH ADMIN. CODE R649-3-34.

209. WYO. STAT. ' 30-5-103(a), 30-5-104(d)(i). Bonding requirements cover only plugging. They do not address reclamation.

210. *Id*. ' 30-5-104(d)(ii).

211. *Id*. ' 30-5-121.

212. WOGCC Rules ch. 4, ' 1(ff).

213. Josh Joswick, La Plata County commissioner, NRLC CBM conference, April 4–5, 2002.

214. *Id.* Josh Joswick, La Plata County commissioner, presentation, Oil and Gas Accountability Project, Energy Summit (Denver, April 6, 2002).

215. Counties issue permits for each well that specifies what mitigation activities are required. If there is a conflict between county per-

mits and Commission standards, the Commission standards are to be binding, but the new regulation makes that provision more explicit and more definitive than counties believe is legal under state law. Interview, Adam Keller, Planning Office, La Plata County, February 28, 2002.

216. Bob Schober, "Producer alleges commissioners 'exceeded jurisdiction,' *The Durango Herald* (February 28, 2002): 1A.

217. Shirena Trujillo, "New rules for wells aimed to address landowners' concerns," *The Durango Herald* (August 27, 2000): http://199.45.202.146/OILGAS/1news2988.htm.

218. Adam Keller, La Plata County planner, quoted in *id.* .

219. *Id.*

220. The Fruitland Outcrop is where the Fruitland coal formation reaches the surface; it runs from northeast of Bayfield down to the Southeast, eventually crossing the state line almost due South of Pagosa Springs.

221. Before these regulations were issued, testing of nearby water wells was voluntary.

222. Travis Stills, San Juan Citizens Alliance, and Rich Griebling, GOCGG director, cited in Shirena Trujillo, *supra* note 191.

223. *Id.*

224. Electa Draper, "Gas drilling company says La Plata's rules too tough," *Denver Post* (January 23, 2002): www.denverpost.com/Stories/0,1002,53%7E352494,00.html.

225. *Id.*

226. Bob Schober, "Producer alleges commissioners 'exceeded jurisdiction.' *The Durango Herald* (February 28, 2002):1A.

227. P.2d 913 (Colo. 1997).

228. Mickey Steward, NRLC CBM conference, April 4–5, 2002.

229. The following bulleted points are taken from the discussion of water law in Jan G. Laitos, *Natural Resources Law* (St. Paul, MN: West Group, 2002): 384–99,

230. This discussion of water law is based on a memo written by Jennifer Kemp, Natural Resource Law Center, June 2002..

231. Colo. Rev. Stat. § 37-90-137(7)(a).

232. Colo. Rev. Stat. § 37-90-137(7)(b).

233. *Id.*

234. Colo. Rev. Stat. § 34-60-103(4.5): "'Exploration and Production Waste' means those wastes that are generated during the drilling of and production from oil and gas wells or during primary field operations and that are exempt from regulation as hazardous wastes under" RCRA.

235. COGCC Rules, Exploration and Waste Management, § 907(c)(1).

236. COGCC Rules, Exploration and Waste Management, § 907(c)(2).

237. COGCC Rules, Exploration and Waste Management, § 907(c)(3)

238. COGCC Rules, Exploration and Waste Management, S 907(c)(4).

239. N.M Stat. Ann. § 72-12-1.

240. N.M. Stat. Ann. § 72-12-25.

241. N.M. Stat. Ann § 70-2-12.

242. *Id.*; *See also* N.M. Reg. § 19.15.1.13.

243. N.M. Reg. § 19.15.1.18.

244. N.M. Reg. § 19.15.1.19.

245. N.M. Reg. § 19.15.9.701.

246. N.M. Stat. Ann. §72-12A-2.

247. N.M. Stat Ann. §72-12A-4.

248. *Id.*

249. N.M. Stat. Ann. §72-12A-5A.

250. N.M. Stat. Ann. § 72-12A-7C.

251. N.M. Stat. Ann. § 72-12A-8.

252. *See* Utah Code Ann. § 73-3-1 et seq.

253. Utah Code Ann. § 40-6-5(3)(d).

254. Utah Code Ann. § 73-3-8(2).

255. Utah Admin. Code R649-9-1.1.

256. Utah Admin. Code R649-9-3.1 to 3.2.

257. Utah Admin. Code R649-9-4.2.

258. Utah Admin. Code R649-9-4.3.

259. Utah Admin. Code R649-9-4.4.

260. Utah Admin. Code R649-5-2.

261. Mont. Code Ann. § 85-2-505(e).

262. Mont. Code Ann. § 85-2-521.

263. *Id.* at § 85-2-521(e).

264. *Id.*

265. Mont. Code Ann. § 85-2-506.

266. Mont. Code Ann. § 85-2-508

267. Wyo. Stat. §§ 41-3-903, 41-3-904.

268. Wyo. Stat. § 41-3-905.

269. Wyo. Stat. § 41-3-931.

270. *Id.*

271. Wyo. Stat. § 41-3-102(b), by application of Wyo. Stat. 41-3-906. The statute itself states:

(b) Preferred water uses shall have preference rights in the following order:

(i) Water for drinking purposes for both man and beast;

(ii) Water for municipal purposes;

(iii) Water for the use of steam engines and for general railway use, water for culinary, laundry, bathing, refrigerating, . . . for steam and hot water heating plants, and steam power plants; and

(iv) Industrial purposes.

272. Wyoming State Engineer's Office, Form U.W. 5 (revised as of March 1995).

273. Laitos, *supra* note 229, at 407–09.

274. *Id., at* 410–11.

275. H.R. 4 was passed on August 20, 2001; S 517 (H.R. 4, amended) on April 25, 2002; members of the conference committee were named on April 25, 2002. See Rebecca Adams, "Daschle Must Make Fast Shuffle To Get ANWR Opponents on Panel, *CQ Weekly* (May 4, 2002): 1133.

276. This section is based on John Watts, NRLC CBM conference, April 4–5, 2002.

277. Aldo Leopold, *A Sand County Almanac* (New York: Ballantyne Books, 1966): 238–39.

278. For a thoughtful critique and defense of sustainability, see Thomas Prough, Robert Costanza, and Herman Daly, *The Local Politics of Global Sustainability* (Washington, DC: Island Press, 2000).

279. Dale Jamieson, "Sustainability and Beyond," NRLC Public Land Policy Discussion Paper Series (PL02) (Boulder CO: Natural Resources Law Center, 1996): 12.

280. For a helpful overview and assessment of the functioning of consensus-based groups, see Douglas S. Kenney, "Arguing About Consensus: Examining the Case Against Western Watershed Initiatives and Other Collaborative Groups Active in Natural Resource Management" (Boulder CO: Natural Resources Law Center, University of Colorado School of Law, 2000).

281. *Id.*

282. For a discussion of the challenges facing collaborative efforts and how they might be addressed, see Julia M. Wondolleck and Steven L. Yaffee, *Making Collaboration Work: Lessons from Innovation in Natural Resource Management* (Washington, DC: Island Press, 2000).

283. Barb Cestero, *Beyond the Hundredth Meeting: A Field Guide to Collaboratvie Conservation on the West's Public Lands* (Tucson, AZ: Sonoran Institute, 1999).

284. Richard Halvey and Karen Deike, "Unleashing Enlibra," *Environmental Forum* (September-October 2002): 21–31.

285. Western Governors' Association and the White House Council on Environmental Quality, "Environmental Summit on the West II" Salt Lake City, April 24–26, 2002. www.westgov.org/wga.

286. Western Governors' Association, "Enlibra," www.westgov.org/wga/initiatives/enlibra/default.htm

287. Western Governors' Association, Policy Resolution 99-013, "Principles for Environmental Management in the West" (June 15, 1999) www.westgov.org/wga/policy/99/990113.htm.

288. Western Governors' Association, *supra* note 259; see also Rebecca Watson, NRLC CBM conference April 4–5, 2002.

289. See Denise Scheberle, *Federalism and Environmental Policy: Trust and the Politics of Implementation* (Washington, DC: Georgetown University Press, 1997).

290. Gerrity Oil and Gas Corp. v. Magness, 946 P.2d 913 (Colorado 1997).