Coalbed Natural Gas and Water Management in the Powder River Basin

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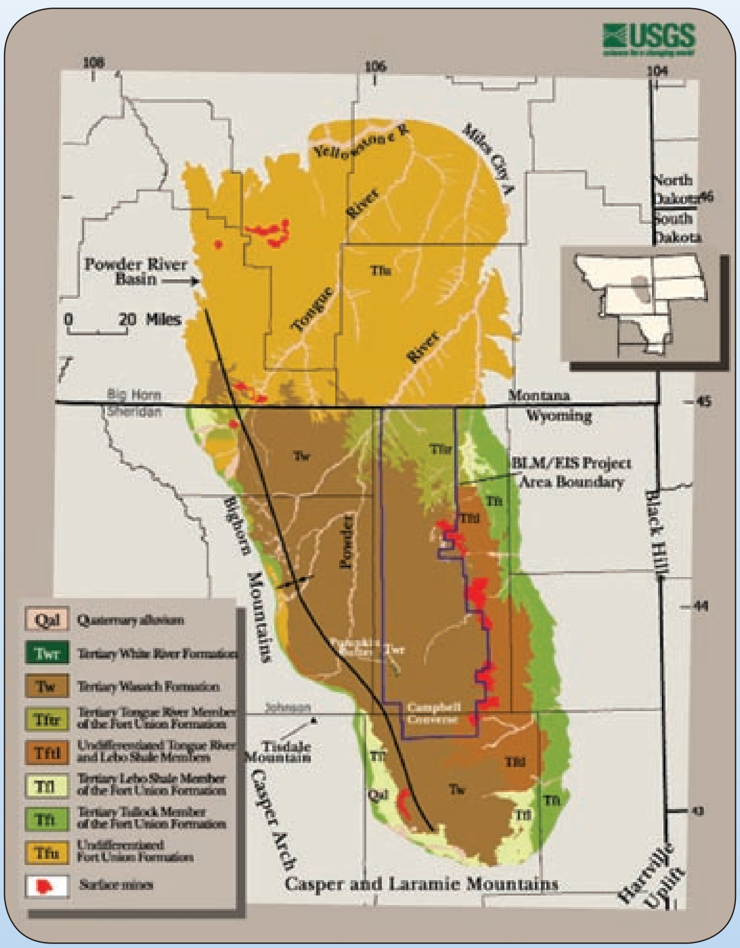
Increased demand for natural gas and commensurate higher prices in North America have boosted the exploration and production of coalbed natural gas (CBNG) resources nationwide. The in-place coalbed methane resources of the United States are estimated to be more than 700 trillion cubic feet (Tcf), of which an estimated 100 Tcf may be economically recoverable, equivalent to a five-year U.S. supply at present consumption rates (Nuccio, 1997). Accompanying the CBNG gas production is over 14 billion barrels (Bbbls) (about 1.8 million acre-feet) per year of produced water, according to a 2002 Argonne National Laboratory study.



Tertiary geologic map of the Powder River Basin. Source: Flores and others, 2001.

The Powder River Basin (PRB) of Wyoming and Montana (see location map) contains an abundance of CBNG due to the thickness and number of coal beds in the Tertiary Fort Union Formation. However, it also results in some of the highest water-to-gas production ratios of any fields currently produced. Cumulative CBNG gas production in Wyoming through June 2005 was 1.685 Tcf with cumulative water production of 3.15 Bbbls (400,000 acre-feet), from a total of over 14,000 wells. Montana's production has been much less, with cumulative CBNG production of about 0.4 Tcf and cumulative water production of 0.102 Bbbls (13,000 acre-feet) from 495 wells through 2004 (MBOGC, 2005; Fidelity, 2005). Over the past 10 years, water production rates in the PRB have averaged 2.2 bbls water per thousand cubic feet (Mcf) of gas, whereas the average in the San Juan Basin of New Mexico and Colorado, one of the richest natural gas reserves in the world, is only about 0.031 bbls water per MCF.

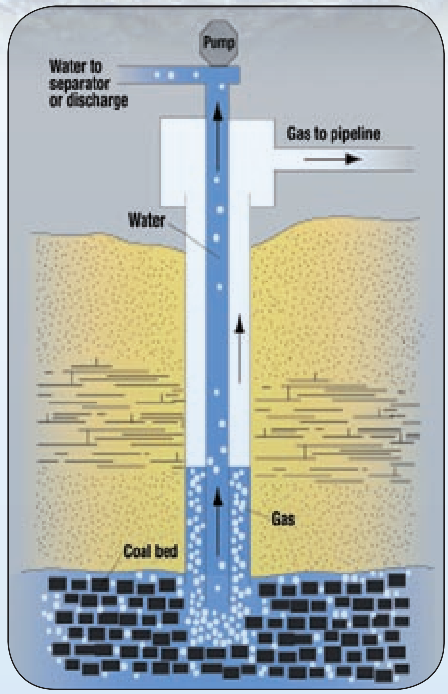


Diagram illustrating the production of water and gas in a typical coal-bed methane well. Source: USGS, 2004.

CBNG and Groundwater

Most gas in coal is stored on the internal surfaces of organic matter. Gas content generally increases with coal rank, depth of burial of the coal bed, and reservoir pressure. Fractures that permeate coal beds are usually filled with water; the deeper the coal bed, the less water is present, but the more saline it generally becomes. For gas to be released from the coal, its partial pressure must be reduced. This is accomplished by pumping water from the coal beds through a well field. Unlike conventional oil and gas operations, which typically produce more water as the field ages, peak water rates from CBNG production occur at the outset (see curves below).

Water production falls markedly over time as the wells create overlapping cones of depression in the producing area. CBNG production depressurizes, but does not dewater the coal bed aquifers, since some hydrostatic pressure is desirable to maintain formation permeability. Once the fluid pressure is lowered in the coal seam, the methane is released and becomes available for production through the same wells (see well schematic, left).

Staying on top of produced water management requires keeping one foot firmly rooted in good earth science and the other skating at high speed through an array of technical, financial feasibility, regulatory, legal, and political traffic cones.

Produced-Water Issues in the PRB

Currently, the hydrologic issues receiving the most attention in the PRB are:

- aquifer drawdown and concern for potential effects to springs, wells, and long-term groundwater availability;
- potential effects of direct or indirect discharge of CBNG-produced waters on the quality of irrigation water available from the Tongue and Powder rivers;
- potential groundwater quality effects of seepage from unlined produced-water impoundments;
- interstate and tribal-state water quality regulations and allocation of assimilative capacity relative to salinity and sodium adsorption ratio (SAR).

Water Quantity Issues

CBNG in the PRB is considered a "shallow" gas play, with production occurring from as many as 20 coal seams at depths of 250 to 2,500 feet. Ranchers and landowners rely on alluvial groundwater and the uppermost coal and sandstone aquifers and are concerned with effects of drawdown and aquifer depletion. However, economic supplies of CBNG are not likely to exist in the shallow groundwater system since the pressures required to confine the gas over a geologic time frame do not exist.

Aquitards of claystone or siltstone usually overlie and separate the coalbed aquifers. Observations of paired monitoring wells along with modeling studies have shown CBNG-induced drawdown of overlying aquifers to range from 1 to 6 percent of that in the produced coal beds. Evaluation of well depths in Montana's CBNG play indicates that 90 percent of private wells are less than 300 feet deep, while the same percentage of CBNG wells are deeper than 300 feet. In some areas, faults that offset the coal beds against other strata occur with regularity, limiting the zone of influence from CBNG drawdown.

In Montana, CBNG producers are required to prevent and mitigate potential adverse effects to private groundwater users by offering mitigation agreements to landowners within one mile of their operations and provide alternative water supplies if wells or springs are affected. If an effect is observed, mitigation agreements must be offered that extend an additional mile from the affected source. In Wyoming it is common practice for producers and landowners to include provisions for groundwater protection through private surface use agreements.

Water Quality Issues

Unlike the more saline produced water in the San Juan Basin, CBNG water in the PRB is acceptable for livestock and some domestic uses. Many landowners have welcomed the opportunity to put CBNG water to beneficial uses. However, downstream irrigators in Montana have viewed any potential increase in salinity or SAR as a potential threat. These constituents are usually higher in CBNG water than in the Tongue and Powder rivers.

Thus an interesting dichotomy has developed concerning CBNG-produced water in the PRB. In the ground, the water is regulated and regarded as an essential resource for livestock and domestic use. But when co-produced to the surface with CBNG, the water becomes a contaminant under the Clean Water Act, requiring a permit for any discharge to waters of the states. Further complicating water management issues, the Tongue and Powder rivers flow from Wyoming, with one set of regulations, into Montana, with a different set.

The "water as a resource" versus "water as a pollutant" dichotomy has spawned considerable acrimony, lawsuits, and environmental rule-making. Most of the water quality issues have revolved around total dissolved solids (TDS; measured as electrical conductivity, EC) and SAR. The TDS of groundwater in PRB coal seams typically ranges from 1,000 to

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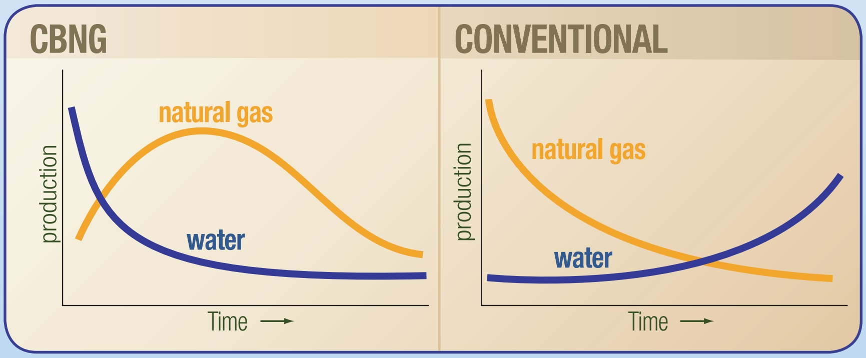

In coalbed natural gas production (left), water production is greatest at the beginning of operations. In contrast, water production increases with time in conventional oil and gas production (right).

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3,000 milligrams per liter (mg/l), but is generally lower than surface waters in the upgradient (southern and eastern) portions of the PRB and higher than the Tongue and Powder rivers in the downgradient (northern and western) portions. SAR ranges from 6 along the eastern edge of the basin to over 50 in the northern portion.

The variation in water quality creates a challenge among the interested parties in these two regions to quantify and apportion the available assimilative capacity for salinity and SAR. In both watersheds and in both states, direct and indirect discharge of CBNG water to these streams is limited by the EC and SAR standards set by Montana to protect downstream irrigators. A further complication is that seven-day, 10-year low flows of the Powder River in late summer are at or near zero, providing no assimilative capacity.

Treating produced water is not always a panacea. When the Wyoming Department of Environmental Quality recently planned to issue a discharge permit for 100 cubic feet per second (cfs) from a series of proposed ion-exchange treatment systems, the state's Game and Fish Department objected that too much clean water could adversely affect the unique aquatic ecology of the sediment-rich Powder River. As a result, the permit was scaled back to 20 cfs.

Although CBNG water is often of better quality than that of the shallow groundwater system, soils and surface sediments of the semi-arid PRB often contain abundant soluble salts that can drive TDS of infiltrating produced water to high levels. Groundwater monitoring beneath one CBNG reservoir revealed TDS levels in excess of 70,000 mg/l (Healy et al., 2004). Seepage quality beneath some sites can meet existing groundwater standards if site lithology and salt content are favorable. Wyoming's Groundwater Pollution Control Division has taken a regulatory approach similar to that used at underground storage tank sites, requiring baseline characterization of shallow aquifers and groundwater quality, generally three monitoring wells around impoundments, a defined monitoring and reporting schedule, and a compliance plan if adverse impacts are observed.

Management Options

Staying on top of produced water management requires keeping one foot firmly rooted in good earth science and the other skating at high speed through an array of technical, financial feasibility, regulatory, legal, and political traffic cones. Environmental and agricultural advocacy groups and CBNG companies have gone to state legislatures, regulatory bodies, and the courts with petitions, studies, and lawsuits over produced water issues, resulting in some major shifts in produced water management. Water management options that result in direct or indirect discharge of untreated CBNG-produced water to the surface have become more difficult or impossible to permit. Increasingly popular options include treatment and discharge, on-channel storage with controlled releases, injection wells, managed irrigation, and water marketing or other off-site use. A trend is evolving to fewer but larger water management facilities, which require greater capital investment but which producers hope will provide more technical and regulatory certainty.

Existing and alternative technologies are also being evaluated. Watershed modeling studies help predict water quality after mixing treated and untreated CBNG water with runoff or streamflow under various statistical scenarios. Pre-construction hydrogeologic studies evaluate impoundment sites for baseline groundwater conditions, seepage migration pathways, and the potential need for engineered pond liners. The geology and hydrology of the upper several hundred feet of the earth's surface, once thought irrelevant for production, is now examined for suitability for CBNG-water injection and impoundments. Industry and agencies are adapting information technology and geographic information systems to utilize results of groundwater and surface water monitoring programs and improve the science and understanding of the hydrogeologic systems of the PRB.

Perspective

In the early years of the play, management of CBNG-produced water in the PRB was driven by traditional economics and practices. More recently, challenging basin-wide water quality issues, environmental regulations that transcend state borders, and an array of complex sociopolitical forces have squeezed out some practices and stimulated innovations. The outlook for sustained higher gas prices is driving development of new but costlier methods of water management, such as treatment, managed irrigation, deep injection and water re-use/marketing. The intensity surrounding regulation and management of CBNG-produced water is likely to affect many aspects of water resource management throughout the West.

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