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COALBED-METHANE BASICS:

Powder River Basin, Montana

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INTRODUCTION

Production of coalbed methane (CBM), or coalbed natural gas, is a growing industry in many coal-bearing regions of the United States, but nowhere has growth been as spectacular as in the Powder River Basin of Wyoming. This growth has been prompted by two features: (1) shallow coalbeds that are inexpensive to drill, and (2) good quality water contained in the coals, enabling inexpensive disposal of water by direct release at the surface in the initially developed areas of the basin. Development in Montana has lagged behind that of Wyoming, largely because of concerns about water disposal.

Methane molecules are held in the cleats (small fractures) and micropores of coal (fig. 1a), and retention of methane is enhanced by hydrostatic water pressure in the coalbed. Gas production is accom-

plished by pumping water from the coalbed; this reduces the hydrostatic pressure, allowing the methane to migrate from the coal into the water stream flowing to the well, where it separates from the water (fig. 1b). This is a simple and clean process; however, the extraction and subsequent discharge of large volumes of water from coalbeds have raised significant concerns. Coalbeds are important aquifers for livestock and domestic use in southeastern Montana. Water availability from wells and springs that receive their water from the produced coal seams will be reduced in and adjacent to CBM operations. Produced water is acceptable for domestic and livestock use; however, the high sodium content of produced water in Montana makes it undesirable for application to most soils. Thus the quantity and quality of discharged water are concerns that must be satisfactorily addressed when making decisions that

will lead to a beneficial and sustainable development of the resource.

COALBED-METHANE GENERATION

CBM forms by both biogenic (biologic) and thermogenic processes (heat and pressure resulting from burial; Law and Rice, 1993). Much of the earliest formed methane may have been lost to the atmosphere because overlying sediments are too thin to trap the gas,

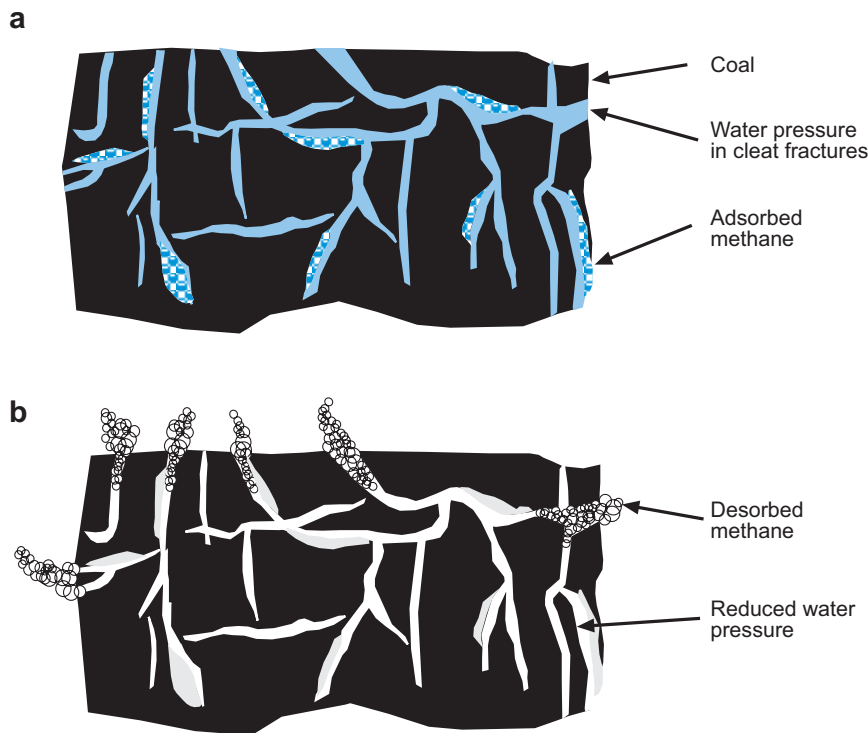
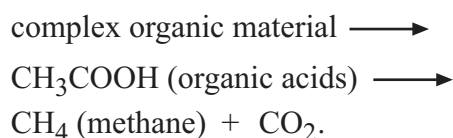


Figure 1. Coalbed methane is adsorbed on coal surfaces along cleat faces and in micropores, and is held by hydrostatic pressures exerted by ground water (a). Pumping water from coal beds reduces hydrostatic pressure and allows the methane to desorb from the coal and migrate to a production well (b).

but in later stages, at greater depths of burial, little methane is lost to the atmosphere.

During deposition and burial of sediments in coal-forming swamps, organic material is decomposed through a series of processes. In the final stages of decomposition, one process is the formation of biogenic methane by methyl fermentation under anaerobic (oxygen-deprived) conditions, simplified in the following reaction (Stumm and Morgan, 1996):



During later stages of burial, if an active ground-water flow system is present, additional biogenic methane may form by CO_2 reduction, as shown in the reaction:



Biogenic methane is formed under anaerobic and sulfate-depleted conditions with a high pH.

At increasing depth, thermogenic methane is generated by the thermal breakdown of coal. The high temperatures and pressures that create thermogenic methane mean that the coal involved will be high-volatile bituminous or higher rank, not the sub-bituminous coal found in the Powder River Basin.

Methane is held on cleat faces and micropore surfaces in coal by a combination of physical sorption and hydrostatic pressure from ground water in the coal (Law and Rice, 1993; Rightmire and others, 1984), and is released when the water pressure is reduced. Water is pumped from wells drilled and completed in coalbeds to

reduce hydrostatic pressure and capture released gas (fig. 2). Greater efficiency in reducing water pressure in the coalbeds is achieved by completing wells in grid patterns called pods, so that pressures are reduced over a larger area of the coalbed (fig. 3). Pods in Montana are expected to cover an area of about 5–15 sections, and typically contain 4 wells per section in each coal seam. In some areas, up to 5 coal seams are targeted, so a separate well may be drilled to each bed using a single well pod. This results in as many as 20 individual wells per section.

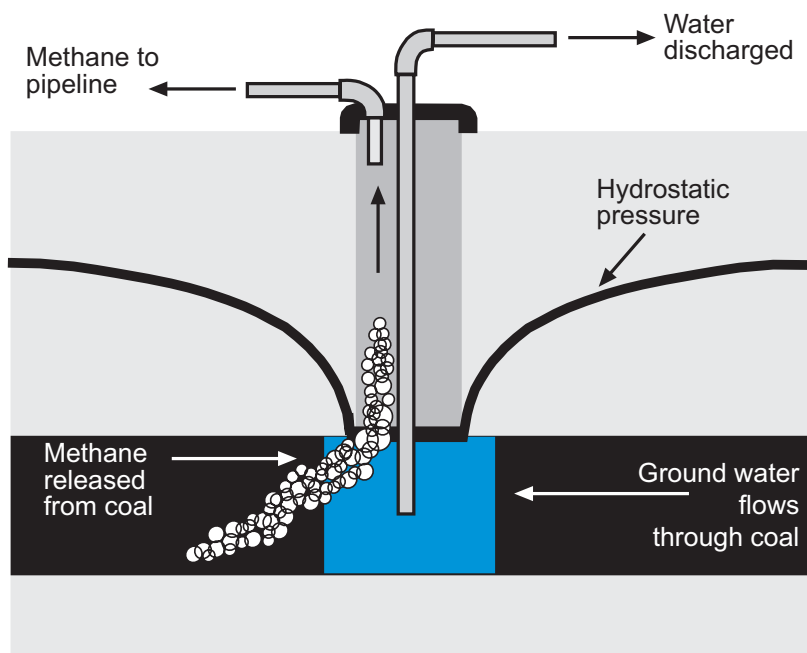


Figure 2. Coalbed methane is produced by completing a well in the target coal seam and pumping water from that coal, thereby reducing the ground-water pressure. In the area of reduced ground-water pressure artesian wells may stop flowing, pumped wells may produce less water, and springs may have reduced flow.

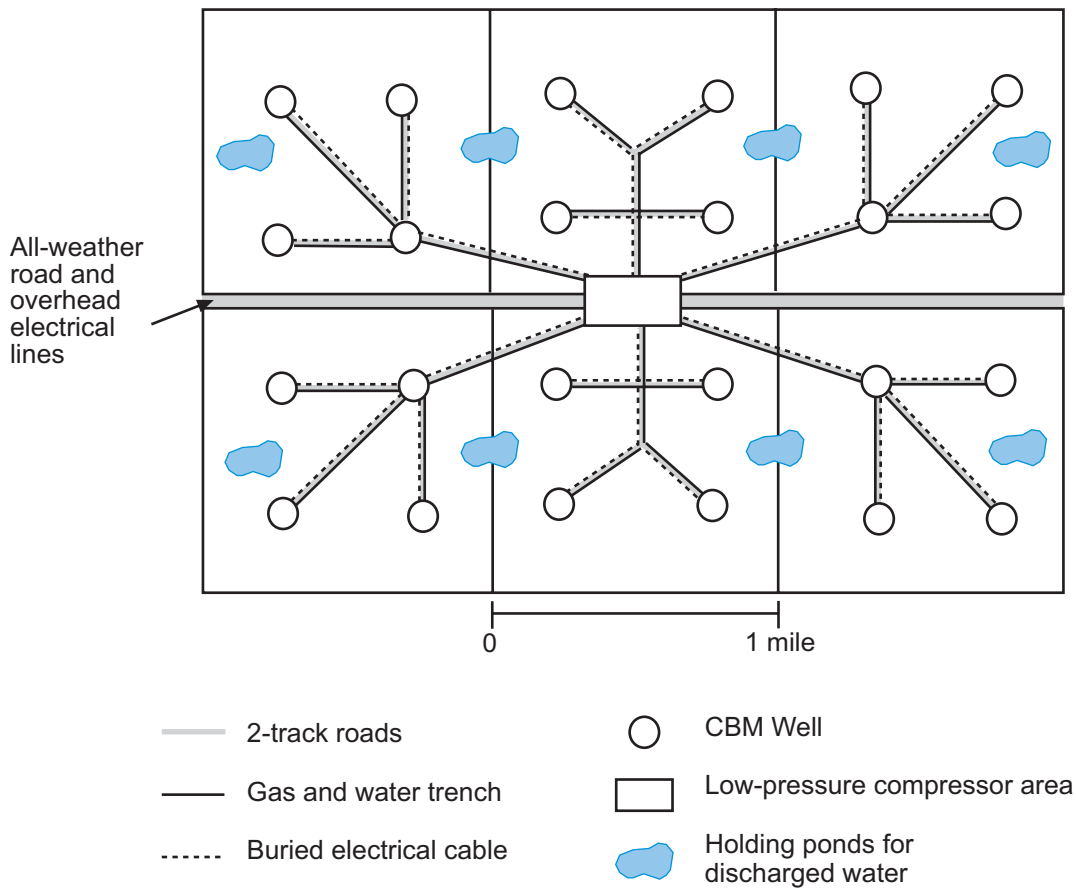


Figure 3. Groups or pods of coalbed-methane wells feeding a central low-pressure compressor make production over large areas practical. In this example, the pod covers an area of 6 sections with well sites spaced approximately 160 acres apart. Spacing may be affected by streams, wildlife habitat, and topography.

The gas from the production wells within a pod is compressed through a local compressor station that typically increases the gas pressure to about 70 to 80 pounds per square inch (psi). The gas from several pods is consolidated through a high-pressure station, which increases the pressure to about 1200 psi. The high-pressure gas is then moved to market through a network of pipelines.

COALBED-METHANE PRODUCTION

Data published by the Potential Gas Committee (Decker, 2001) indicate that coalbed methane has become a major factor in the domestic production of energy

and may represent 10 to 15 percent of total natural gas reserves in the United States. Natural gas meets roughly 25% of the nation's energy needs, and of that, about 90% is produced domestically. For comparison, oil provides about 40% of the energy needs of the United States, with less than one-half of that being produced domestically.

Natural gas is measured and sold in terms of cubic feet. For perspective, the United States used 24 trillion cubic feet (tcf) of natural gas in 2001. The Potential Gas Committee estimated recoverable coalbed-methane resources in the Powder River Basin at 24 tcf (Decker, 2001), whereas the Department of Energy pub-

lished an estimate of 39 tcf (Department of Energy, 2002). The wide range of estimates of recoverable methane in the Powder River Basin reflects the infancy of the industry. The portion of the total recoverable resources that occur in the Montana portion of the Powder River Basin is estimated at 0.86 tcf (Department of Energy, 2002). This relatively small estimate for Montana reflects the less favorable geologic setting.

The first commercial production of CBM in the United States began in the Black Warrior Basin, Alabama, as part of an underground mine-safety program (Pashin and Hinkle, 1997). In the western United States, production of CBM is now well-established in New Mexico, Colo-

rado, Utah, and Wyoming. Currently CBM is being produced over much of the Powder River Basin in Wyoming, but in Montana is limited to areas surrounding the coal mines at Decker.

REGIONAL SETTING FOR THE POWDER RIVER BASIN

Geologic Setting

The Powder River Basin is bounded by the Black Hills to the east, the Big Horn Mountains to the west, and the Miles City Arch to the north. About one-third of the Basin lies in Montana, and two-thirds is in Wyoming (fig. 4). The land surface in the Powder River Basin slopes generally northward toward the Yellowstone River,

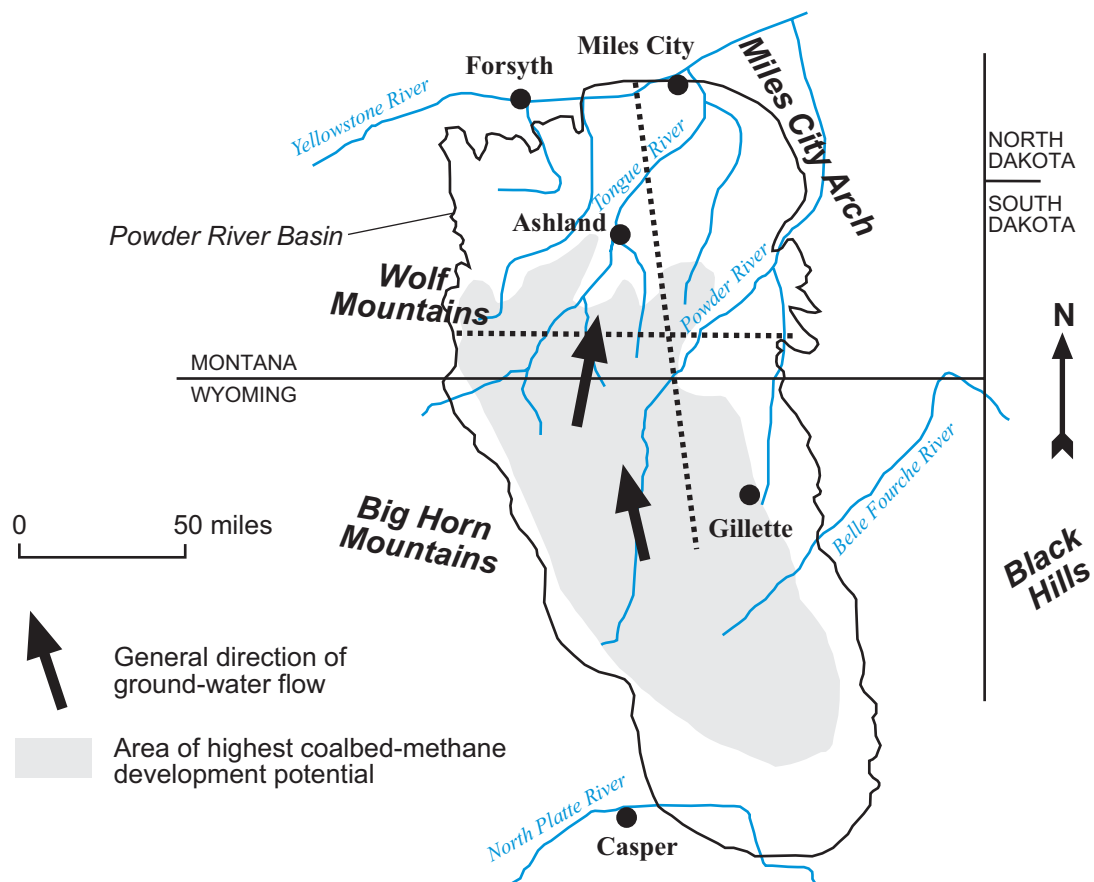


Figure 4. About one-third of the Powder River Basin is in Montana. However, far less than one-third of the area with good coalbed-methane potential is in Montana (Van Voast and Thale, 2001). Dotted lines indicate locations of geologic cross sections (figs. 6, 7).

from higher elevations in Wyoming.

The areas most favorable for coalbed-methane development are where thick seams are present at sufficient depth and distance from outcrops that the methane is still adsorbed on the coal. These conditions are more common in Wyoming than in Montana due to the geologic structure and topographic relief of the basin. Production of CBM is therefore more favorable in Wyoming than in Montana. The highest potential for development in Montana is within about 10 to 12 miles of the southern border, between the Wolf Mountains to the west and the Powder River to the east (fig. 4). Moderate development potential exists as far north as Ashland.

Geologic changes that roughly coincide with the Montana–Wyoming state line also have important implications for how produced water from CBM wells can be handled. Within the Powder River Basin the predominant geologic units exposed at the surface are the Tertiary Fort Union Formation and the overlying Wasatch Formation (fig. 5). In the Wyoming portion of the basin the Wasatch Formation is widely exposed at the surface. The soils that result are sandy, reflecting the nature of that formation. By contrast, in Montana the Wasatch Formation has largely been removed by erosion, and the soils have developed from interbedded claystone and sandstone units in the Tongue River Member of the Fort Union Formation, resulting in a much finer and more clayey soil structure. These clayey soils have a much greater tendency to be affected by CBM-produced water than the sandy soils.

Of the numerous coalbeds in the Powder River Basin, the primary targets for CBM development in Montana are the Anderson, Dietz, Canyon, and Knobloch coalbeds within the Tongue River Member.

Resources may also exist locally in other seams such as the Cook, Wall, Carney, Brewster-Arnold, Sawyer, and Flowers-Goodale (fig. 5).

Hydrogeologic Setting

Ground-water flow in the Powder River Basin is generally from the south to the north. Coal seams are the most continuous water-bearing geologic units and provide an important ground-water resource. Due to the basin's structural and topographic relationships, coal seams in Montana commonly crop out along valley walls and ground-water discharge forms springs (figs. 6, 7). Therefore, coal seams are not only the major target for water wells, but also provide significant amounts of surface water through springs. The latter factor is much less common in Wyoming.

In the Montana portion of the Powder River Basin, 2740 water-supply wells are on record, corresponding to a density of about 1 well for every 2 square miles. In the same area, 1100 springs are on record, for a density of about 1 spring for every 5 square miles. Current inventory work is expected to greatly increase the number of known spring locations, as these resources have not typically been documented in the past.

The quality of ground water in the Montana portion of the Powder River Basin reflects chemical and biological reactions that occur along flow paths. Near recharge areas, dissolved constituents consist of low concentrations of calcium, magnesium, and bicarbonate ions. Sulfate and sodium concentrations increase as waters move further through the aquifers. However, in deep coalbeds, such as those that contain coalbed methane, chemical reactions have greatly reduced the amounts of sulfate, calcium, and magnesium, so that

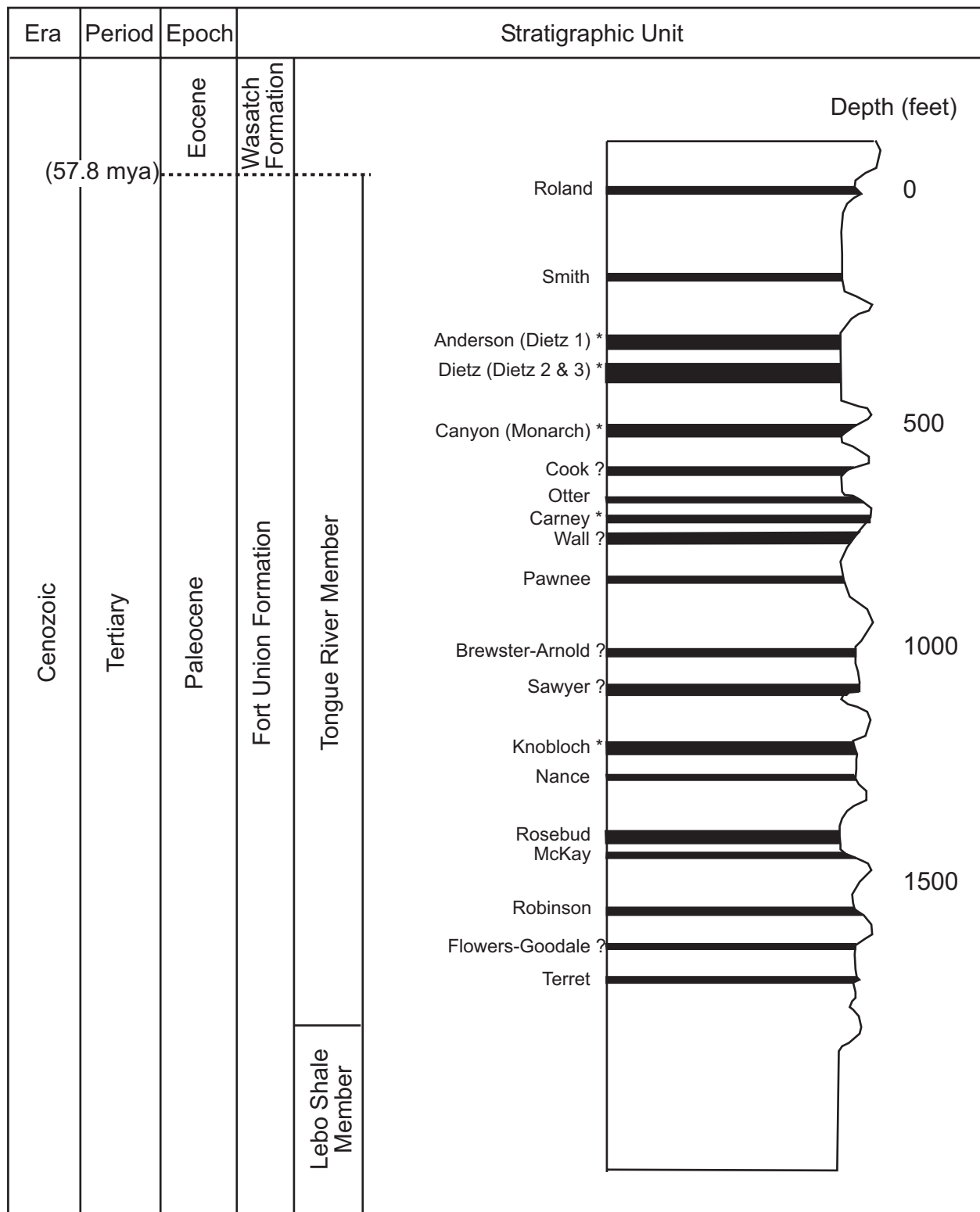


Figure 5. Several coalbeds within the Tongue River Member of the Fort Union Formation are prospective for CBM production. Position, depth, and thickness are only approximate. Sources: Matson and Blumer, 1973; McLellan and others, 1990; Law and others, 1979; Fort Union Coal Assessment Team, 1999. The base of the Fort Union Formation (not shown) is the contact with the underlying Cretaceous rocks, about 66.4 million years ago (mya). The Fort Union/Wasatch boundary occurred about 57.8 mya. Alternative coalbed names are shown in parentheses. *Coalbeds considered to have high CBM potential; ? marks coalbeds with moderate potential.

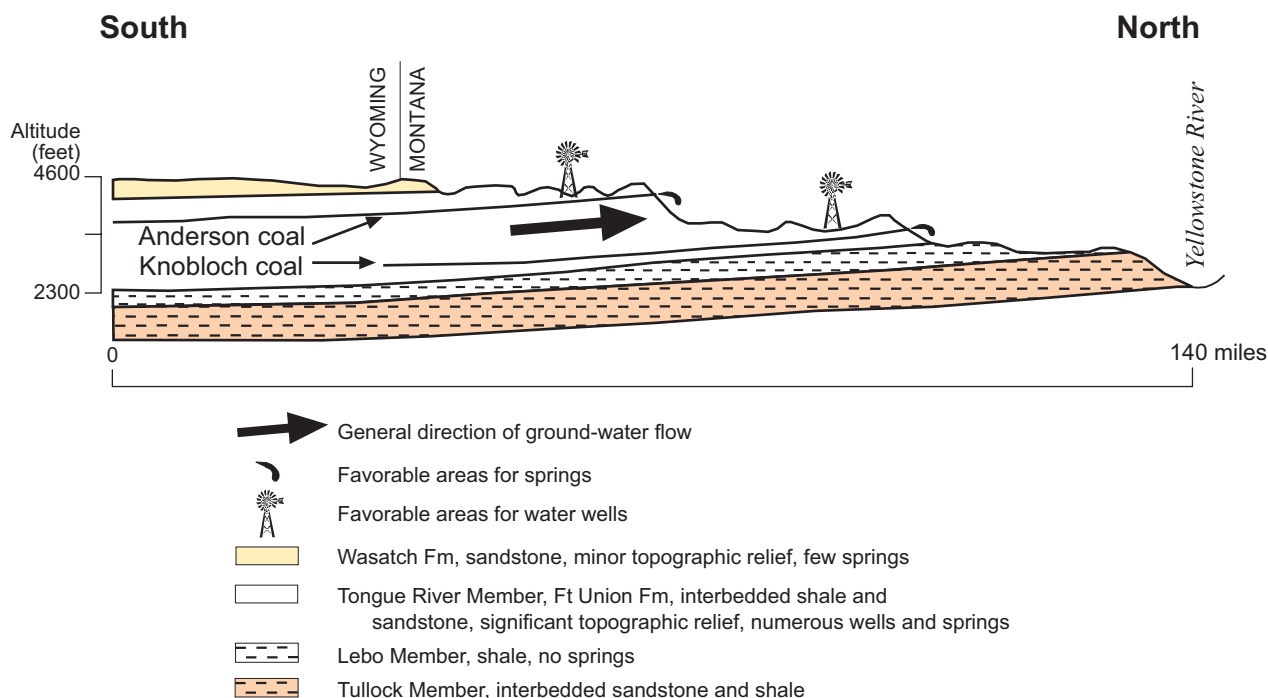


Figure 6. Both ground water and surface water in the Powder River Basin flow generally from south to north, toward the Yellowstone River in Montana. Coalbeds such as the Anderson are deeply buried in the Powder River Basin in Wyoming, but crop out in Montana. Farther north, stratigraphically deeper beds are exposed at land surface. Areas where aquifers are shallow are favorable for water-well drilling. Springs occur in outcrop areas along hillsides. Location of cross section is shown in fig. 4.

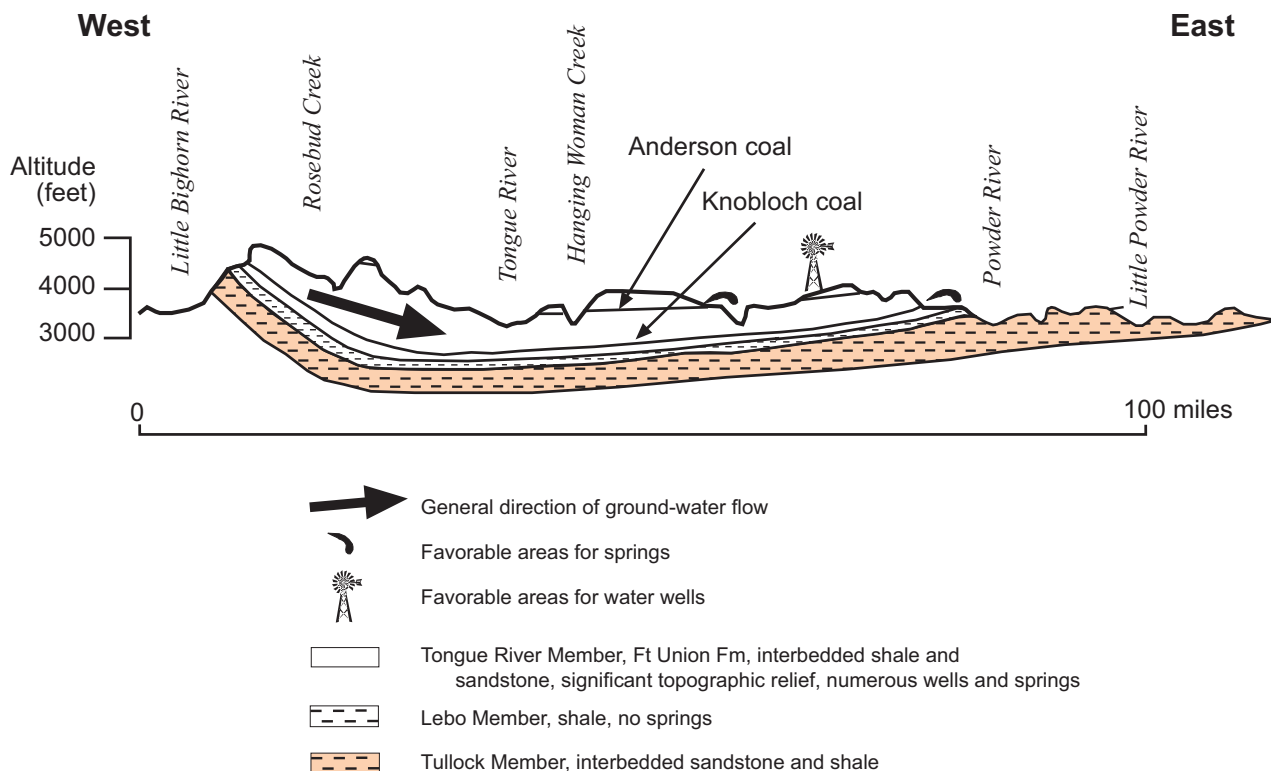


Figure 7. The formation of valleys has removed portions of some coalbeds. Hydrostatic pressure is naturally low adjacent to areas of outcrop, allowing methane to desorb from the coal and vent to the atmosphere. Location of cross section is shown in fig. 4.

the water quality is dominated by moderate concentrations of sodium and bicarbonate. The increased sodium concentration and decreased calcium and magnesium increases the sodium adsorption ratio (SAR), which is a relationship between the sodium concentration and the calcium plus magnesium concentrations, as expressed in miliequivalents per liter. The ratio is defined by the following equation, which demonstrates that as either sodium concentration increases or calcium or magnesium concentrations decrease, the SAR increases.

$$SAR = \frac{(Na)}{\sqrt{[(Ca + Mg)/2]}}$$

Coalbed methane can only exist in the sulfate-depleted, anaerobic conditions which occur in deeper coals (Van Voast, 2003). Therefore, all CBM production water is rich in sodium and much of it has a high SAR value. Those high SAR values are critical as an indicator of how water may interact with clays in soils: a high SAR may cause clay-rich soils to be less permeable, thereby greatly reducing the productivity of the soil (Hanson and others, 1999).

GROUND-WATER ISSUES RELATED TO CBM DEVELOPMENT

Production of water with coalbed methane reduces both the volume and hydrostatic pressure of water in the coalbeds. This results in lower water levels in wells and also reduces flow through the aquifer, which may reduce discharge at springs. In these cases, water resources will be reduced for the duration of CBM production plus a recovery time that may be years or decades long (Wheaton and

Metesh, 2002).

In the Powder River Basin, water in the coalbeds is generally suitable for drinking and livestock useage. However, with CBM production, discharge of this water might cause soil erosion downstream from the discharge point, and the chemical reactions discussed above could cause changes in soil structure and alter the quality of receiving surface and ground water.

On the other hand, some shallow aquifers could be beneficially recharged by infiltration from coalbed-methane discharge holding ponds, and if the water quality is suitable, farmers and ranchers in some areas may benefit by being able to greatly expand irrigation acreage. These factors are significant to the shallow water that supports the agricultural community in southeastern Montana; understanding the potential impacts so that adequate mitigation plans can be prepared is not straightforward, particularly considering that impacts will not be uniform across the basin.

In traditional oil and gas activities, the interaction with shallow aquifers is not an issue in properly designed and maintained wells. Production is from much deeper reservoirs, and the quality of co-produced waters is typically so poor that surface disposal is not an option (fig. 8).

Ground-Water Levels

Thirty years of coal hydrogeology study by the Montana Bureau of Mines and Geology has produced a significant amount of monitoring data and a good understanding of the ground water in southeastern Montana coalbeds. Figure 9 illustrates differences in aquifer drawdown caused by coal mining and current coalbed-methane development at one monitor well. Coalbed-methane wells are much

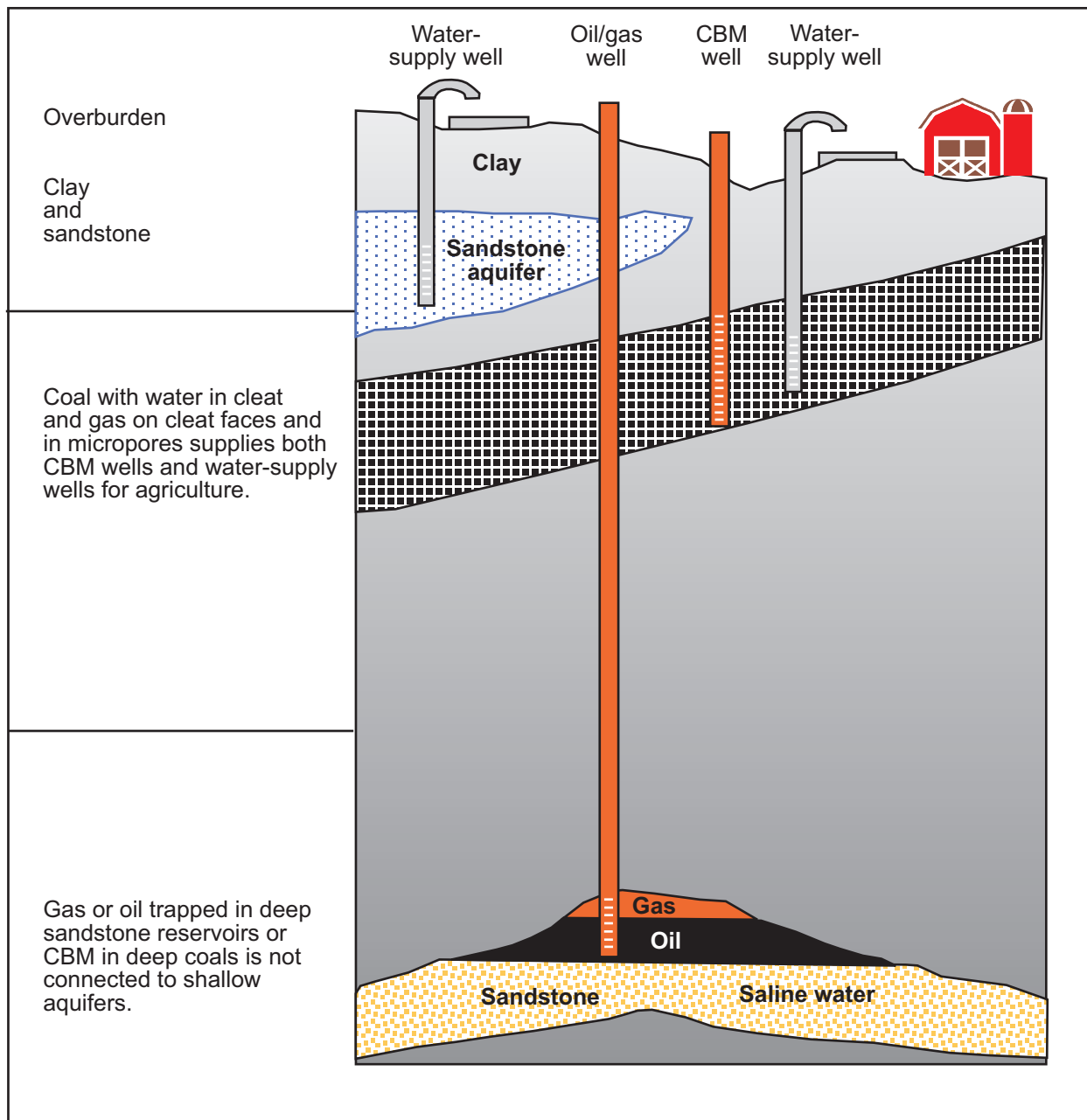


Figure 8. The interaction between energy extraction and local water resources is very different for coalbed methane than for traditional natural gas.

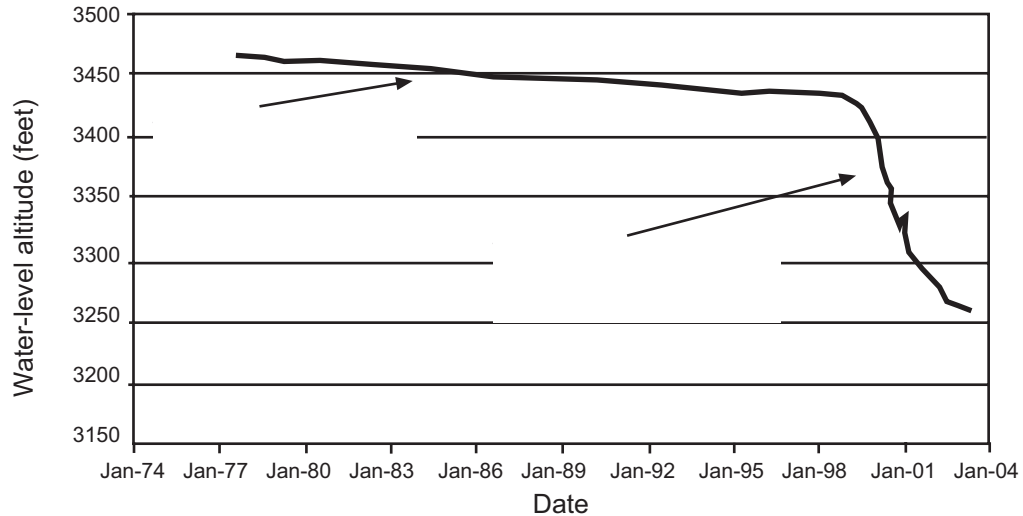


Figure 9. Water levels in the Anderson-Dietz coalbed have decreased over about 25 years in response to the West Decker Coal Mine. CBM production, which began in 1999, has caused a much faster and larger decline in water levels at this site.

closer to this monitoring well than is the nearest coal mine. These data are being used to project future drawdown and recovery. Shallow ground-water recharge from leakage below coalbed-methane holding ponds has also been documented (fig. 10). Drawdown and recovery of ground-water levels near Decker, Montana due to coal-strip mining at a small mine and CBM production are illustrated in fig. 11.

Figure 12 shows the comparative effects of water-level drawdown from coal mining and CBM production adjacent to the Decker coal mines. Monitoring data show that over 25 years of coal mining produced water-level drawdowns of 10 feet at a distance of about 5 miles from the mines. CBM production began in the same area in October 1999, and within 4 years had resulted in an additional 5 feet of drawdown at a distance of only 1–2 miles from

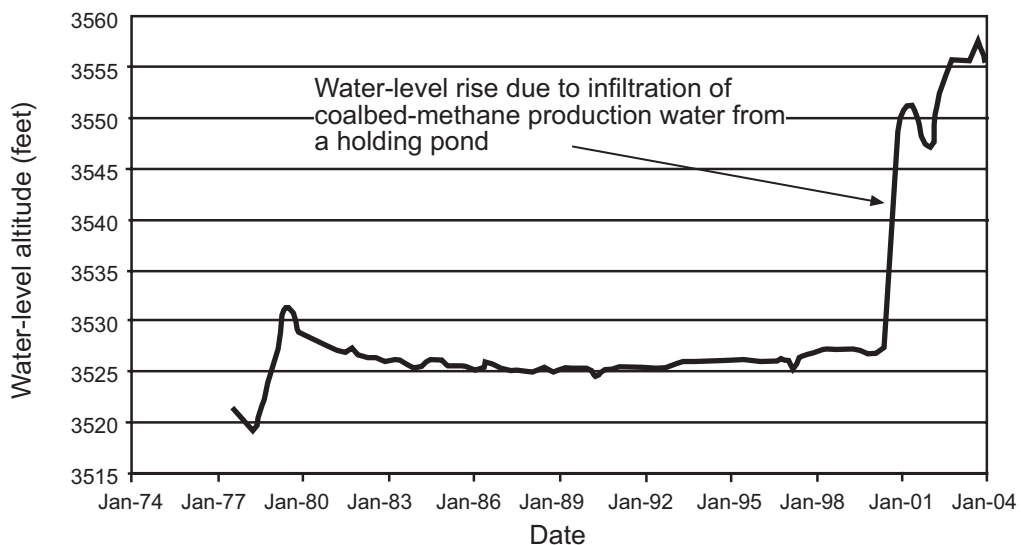


Figure 10. In certain instances, water levels rise in response to infiltration from holding ponds. In this example, a shallow and unconfined overburden sandstone aquifer is receiving recharge from CBM discharge water.

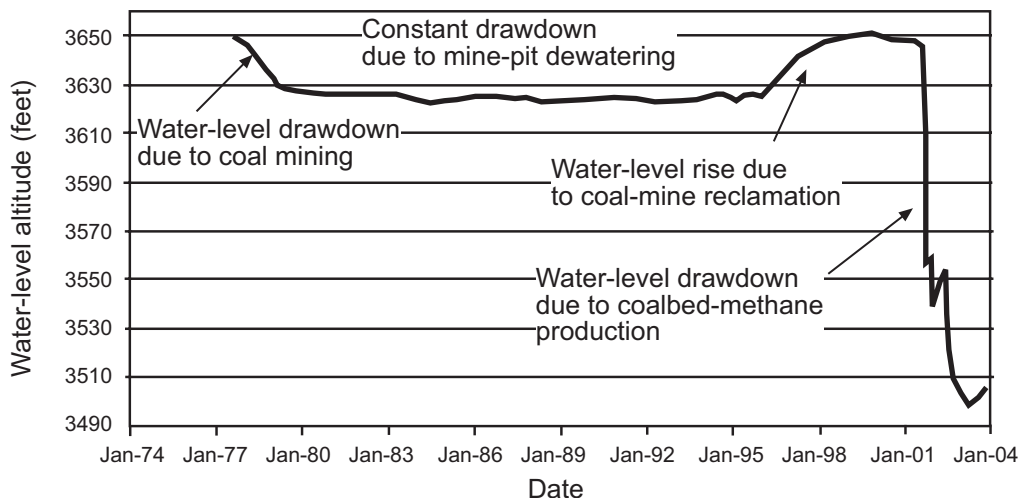


Figure 11. In the Anderson-Dietz coalbed near Decker, Montana, water levels were lowered by dewatering at a coal mine pit, but recovered to approximately original levels after mine reclamation. CBM impacts are expected to occur over a greater area than those from mining and the recovery is anticipated to be similar, but to require more time.

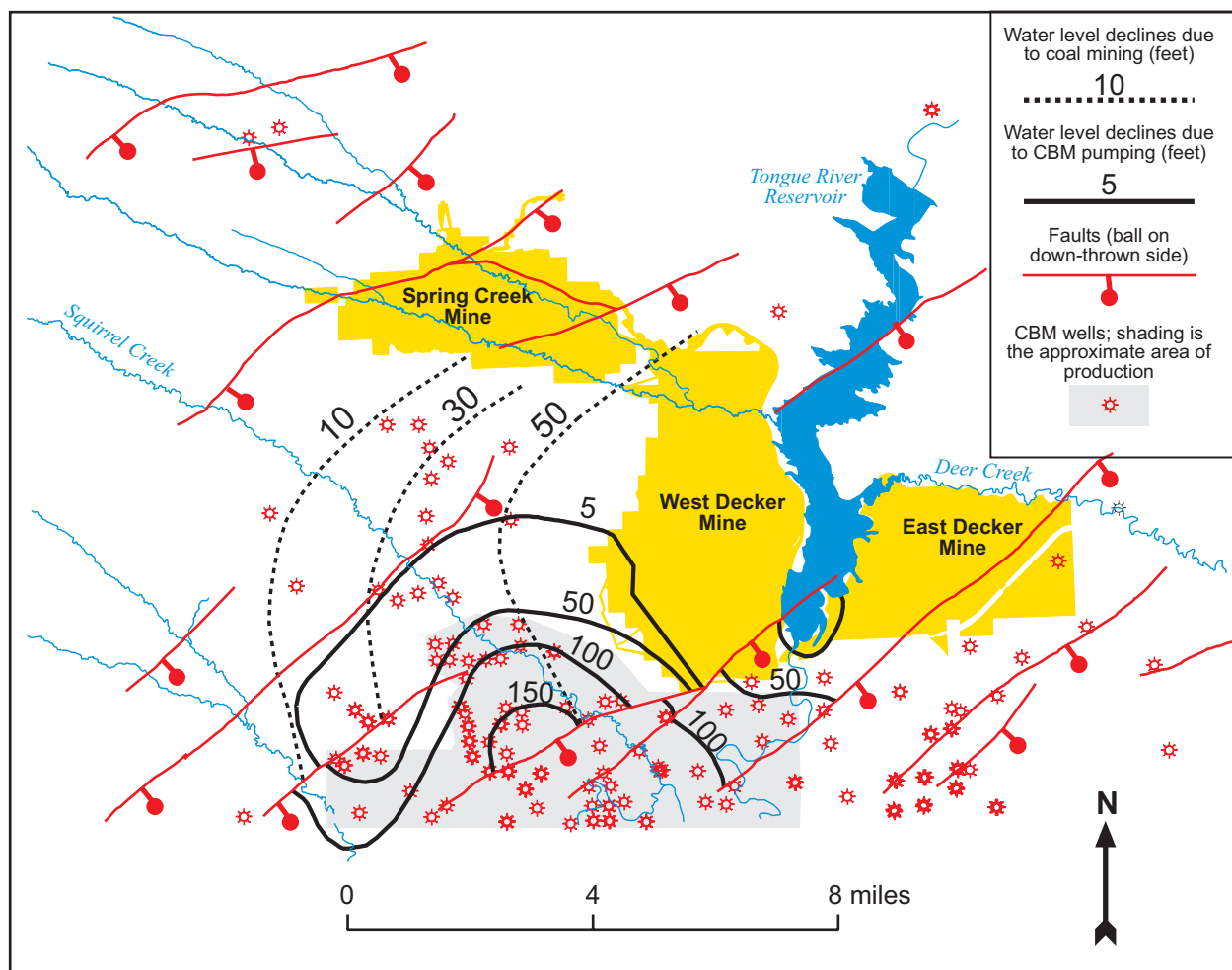


Figure 12. Water-level declines of 10 feet in sites farther than 5 miles from the West Decker coal mine after 25 years of mining. Aquifer drawdown exceeds 5 feet at distances of about 1 to 2 miles beyond the active CBM development area after 4 years of production.

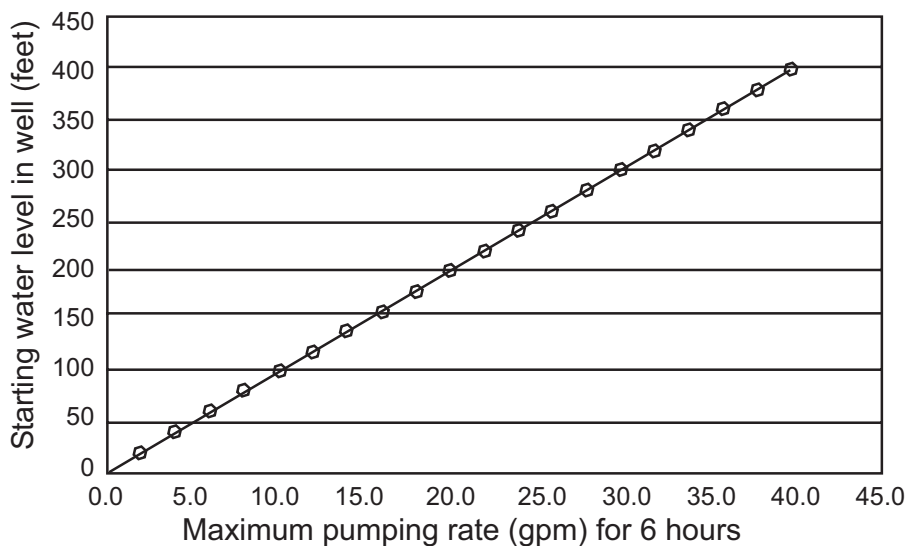
the producing wells. Water-level draw-down is the critical parameter for determining potential reduction in available water yield at wells and springs. For example, reduced pressure in the aquifer is proportional to lower yields at wells (fig. 13).

Production-Water Management

Near Gillette, Wyoming, where production of CBM initially commenced in the Powder River Basin, concentrations of dissolved chemicals in CBM waters are very low; regional data show that concentrations increase from the Gillette area to the north and west, with the highest concentrations being in Montana (fig. 14). In CBM waters, these dissolved constituents are predominantly sodium and bicarbonate ions (Van Voast, 2003). The discharge water in Montana will typically have an SAR greater than 30. Total dissolved solids in Montana may range from 1500 to more than 2000 mg/L. This water is usable for

stock and domestic supplies but cannot be used for irrigation without intensive management.

Water disposal is of primary importance during the early life of coalbed-methane wells, when production rates are greatest (fig. 15). Discharge rates vary with field size and start-up time, but are expected to be around 10–20 gallons per minute (gpm) at start-up, decreasing to about 3–20 gpm after several years (Wheaton and Metesh, 2002). Calculations from available data indicate that 1000 CBM wells would be expected to have cumulative discharge rates between 15,000 and 25,000 acre-feet per year. A limited amount of the produced water can be put to beneficial uses such as dust suppression around operations, livestock watering, or irrigation if SAR values are not prohibitive. The remaining produced water may be managed by discharging to streams and rivers, injecting to other aquifers, placing



Based on Theis Equation $\frac{Q}{W(u)} = \frac{4 \pi s K b}{W(u)}$ with $W(u)$ as well function from Fetter, 1980; s as starting water level; K as 1 foot/day; b as 25 feet. For supporting equations, S is 4×10^{-5} and t is 6 hours.

Figure 13. The quantity of water that can be pumped from a stock well is dependent in part upon the water level in the aquifer.

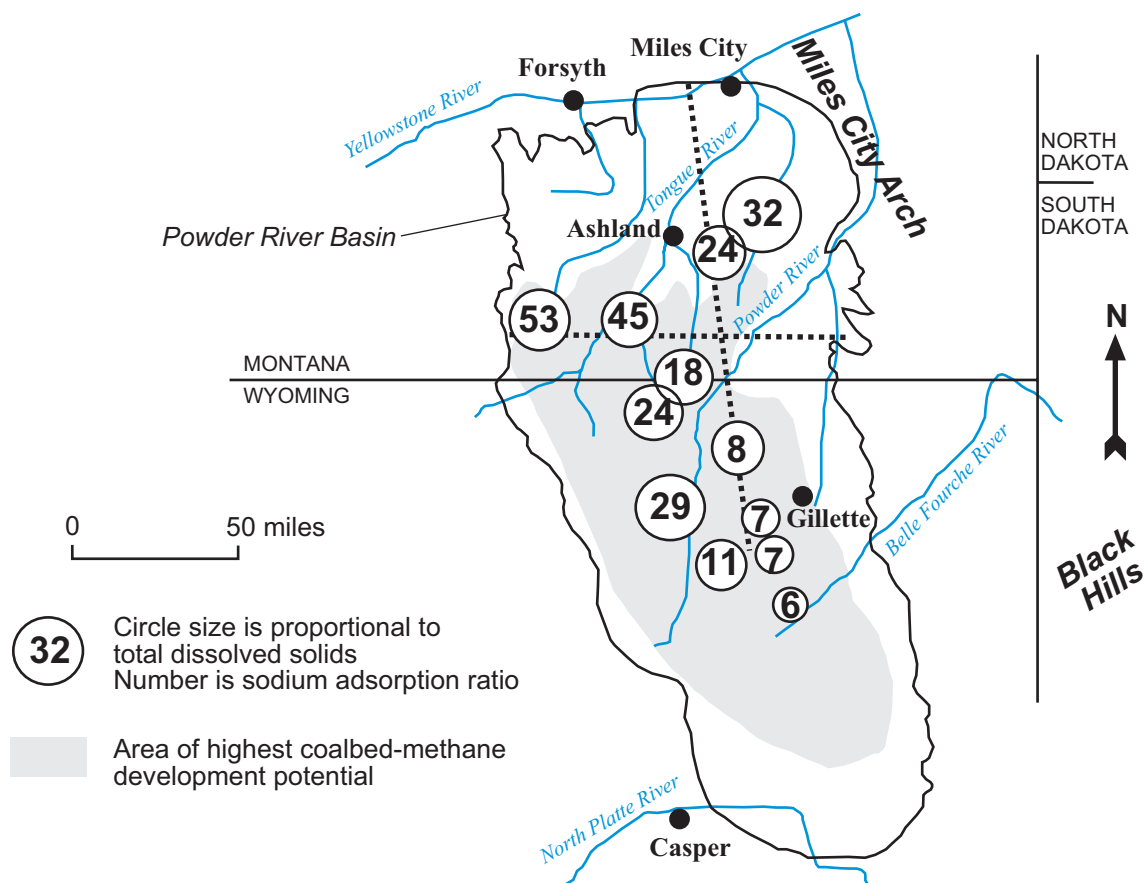


Figure 14. All CBM-produced water in the Powder River Basin is dominated by sodium and bicarbonate ions (Rice and others, 2000; MBMG file data). However, the total dissolved solids and the relative concentration of sodium (as represented by the sodium adsorption ratio) increase along the flow path toward the north.

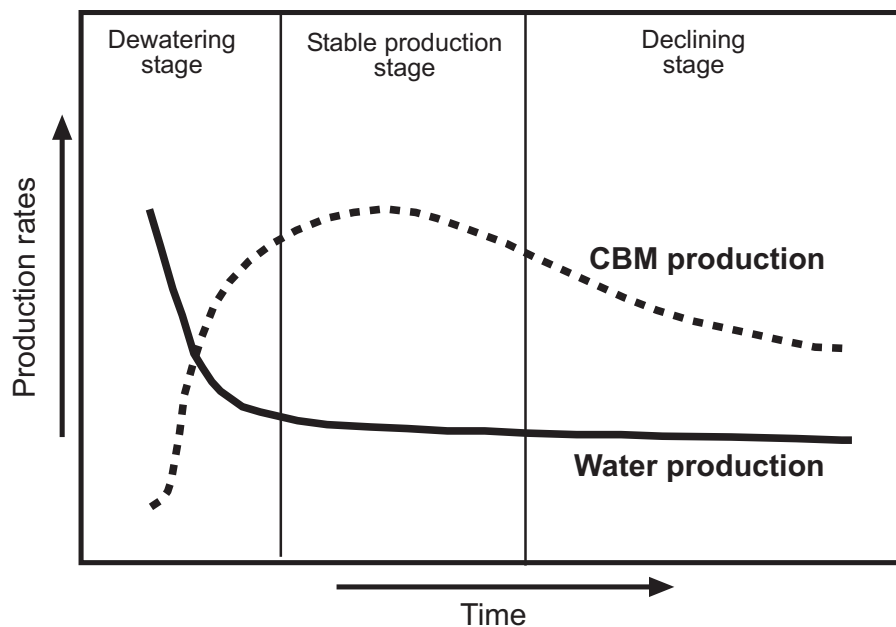


Figure 15. Water production from a coalbed-methane well is greatest during the early stages of production and after a sharp decline approaches a constant rate. Gas production is initially low, increases sharply as hydrostatic pressure drops, and then gradually declines through the well's life.

in holding ponds where it will recharge shallow aquifers or evaporate, or treating the water to increase its potential for beneficial uses. Each of these management options has both benefits and disadvantages. Understanding the potential benefits and disadvantages is vital to developing appropriate water-management strategies.

Disposal of produced water is an issue in all coalbed-methane fields, and site-specific methods of disposal are based on water quality, water use, soils, and related issues (table 1). In most coalbed-methane fields, the produced water is highly saline, so it is not considered a resource and production is not in competition with existing water users. Only in the Powder River Basin is the issue of the water as a resource a major problem. Options being considered in the Powder River Basin include treatment of production water prior to discharge, to decrease sodium concentrations and increase the discharge options. Several techniques, including reverse osmosis and reverse ion exchange, are currently being evaluated for costs and efficiency.

Discharge to Irrigated Fields

Direct application of high-SAR CBM water to clay-rich soils reduces the ability of water to move through them (figs. 16, 17). Use of coalbed-methane production water for irrigation will require intensive soils management for the duration of production plus some duration of recovery. Management concerns include the quantity and timing of water applications, the use of soil amendments such as acid, sulfur, and gypsum, and the choice of crops being grown.

Discharge to Streams and Rivers

Produced water, mixed with river water in low enough concentrations, may have very little negative effect on soils. However, the appropriate ratios are site- and soil-specific (fig. 18). More high-SAR water would be produced from CBM wells than could reasonably be mixed with the Tongue River, which would carry the potential CBM-water discharge from most of the Powder River Basin in Montana. For a watershed-based

Table 1. Coalbed-methane production water summary for various fields

Basin	No. of Wells	Average Water Production per Well (gpm)	Typical Total Dissolved Solids (mg/L)	Primary Disposal Method
Powder River Basin				
WY	7628	5.3	600 to 3100	Surface
MT	231	8.6	2600	Surface
San Juan Basin				
CO, NM	3089	0.7	19,000	Injection
Black Warrior				
AL	2917	1.7	2500	Injection
Raton				
CO	459	7.8	2200	Injection
Uinta				
UT	393	6.3	20,000	Injection

Note. Data sources: USGS FS-156-00; U.S. Bureau of Land Management 2003a and 2003b, Nov, 2000; WY BOG Home Page (<http://wogcc.state.wy.us/>), Jan 2002; MT BOGC Home Page (<http://www.bogc.dnrc.state.mt.us/>), Jan 2002.

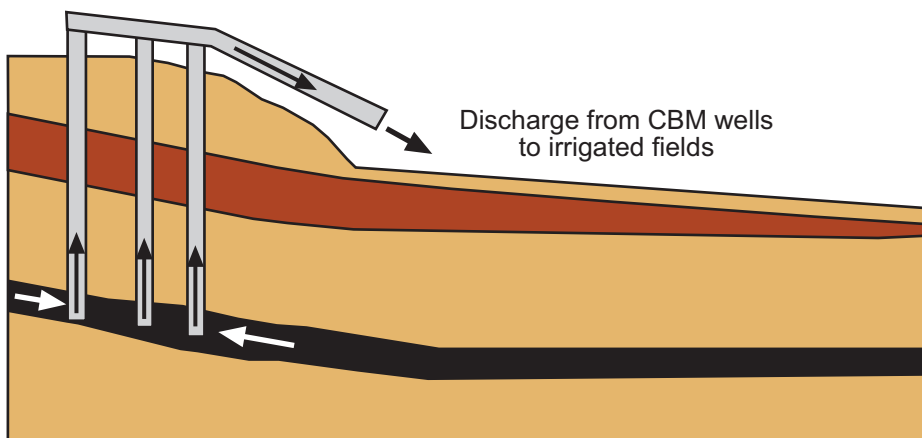


Figure 16. Coalbed-methane-produced water may be put to beneficial use for irrigation in certain situations. However, reactions between the water and soils raise serious concerns that require careful management.

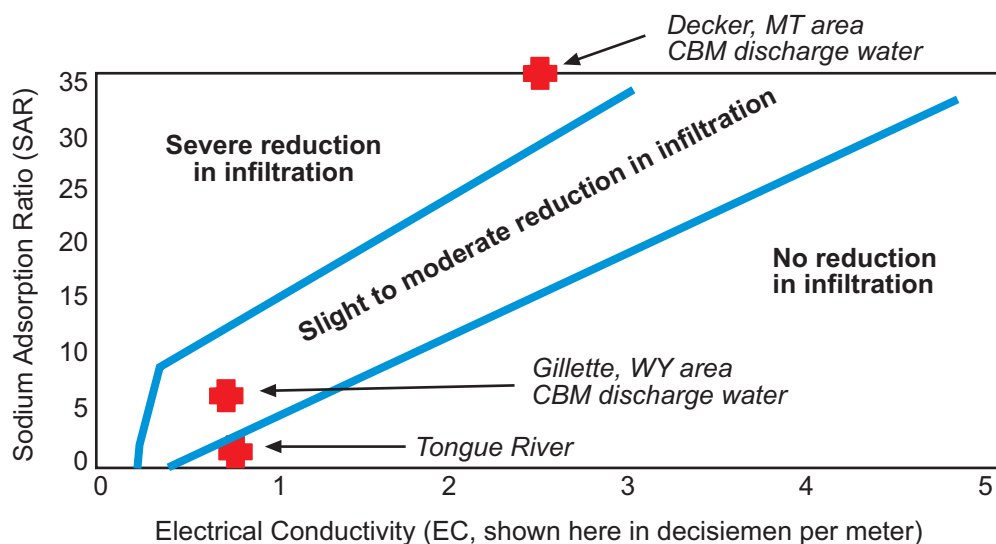


Figure 17. The effect of water on soil structure is based in part on both the EC and the SAR of the water, as well as the type of soil (based on Hanson and others, 1999).

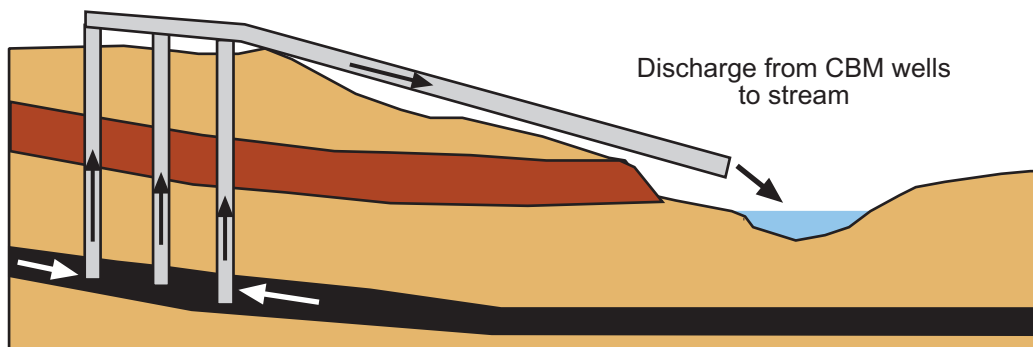


Figure 18. Discharge of coalbed-methane production water to streams and rivers will increase surface-water flow, but may decrease water quality due to sodium concentrations and possible chemical reactions.

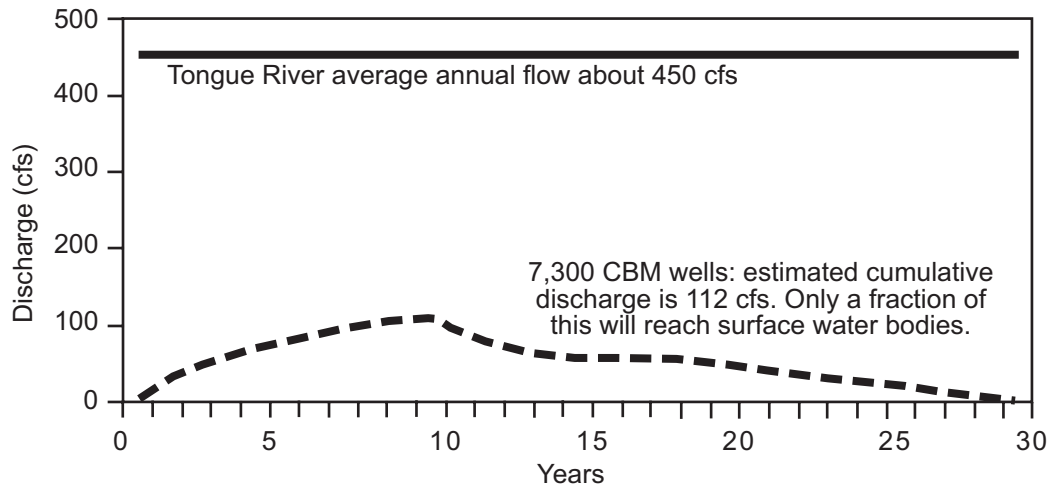


Figure 19. Estimated maximum cumulative discharge from coalbed-methane wells is based on a total of 7,300 wells constructed over a period of 10 years, with discharge rates starting at 20 gpm, decreasing to 6 gpm over a period of 20 years.

hydrologic-budget perspective, fig. 19 shows the annual average flow for the Tongue River compared to estimated, cumulative CBM water production rates for that watershed. Direct discharge to surface-water bodies is controlled by State rules under the Clean Water Act, and the quantity of CBM-production water shown in the figure is not expected to be released directly to surface-water bodies. For the Tongue River the Montana Board of Environmental Review has set a maximum allowable monthly average SAR value of 3 during the irrigation season (March through October) and 5

for the remainder of the year. Normal SAR values for the river vary with flow and time of year. Table 2 presents baseline SAR values for the low flows (7Q10), lowest monthly average flow (December), and highest monthly average flow (June) for the Brandenburg Bridge gaging station (Greystone Environmental Consultants, Inc. and ALL Consulting, 2003). The maximum amount of CBM-discharge water (assuming an SAR value of 30) that could be directly discharged to the Tongue River without violating the State SAR standard varies between approximately 4130 and

Table 2. Calculated SAR values for the Tongue River at Brandenburg Bridge gaging station reflect time of year, flow rates, background SAR, and the quantity of CBM-produced water discharged to the river

	Background Stream		CBM Discharge Water		Calculated Stream Values	
	SAR	Flow (cfs)	SAR	Flow (cfs)	Flow (gpm)	SAR
7Q10	1.8	30	30	9	4130	3.0
Min Month (Dec)	1.4	207	30	63	28,140	3.0
Max Month (June)	0.7	1633	30	485	217,670	3.0

217,670 gpm (9 and 485 cfs) depending on time of year and river flow.

Discharge to Injection Wells

Injection of produced water to other aquifers can be accomplished where highly permeable aquifers can be tapped and water quality is compatible (fig. 20). In some geologic settings, recharge to aquifers that are shallower or slightly deeper than the producing coal seams will increase local water resources and might aid the recovery of water levels in coal-seam aquifers. The injected water cannot, however, be placed in a situation where it returns to the production area of the CBM field, as this would counter the efforts to lower hydrostatic pressure. Injection to deep geologic strata will generally result in a loss of water resources, as the deep flow systems that would likely be chosen have poor water quality and are too deep to be utilized for stock or domestic supplies. To design an injection system, the hydrogeologic properties of the receiving units and the combined water quality would need to be carefully considered on a site-specific basis.

Discharge to Holding Ponds

Holding ponds provide some control of the timing of release of produced water (fig. 21). Water seeping from the holding ponds recharges shallow aquifers, and in some settings may result in increased availability of acceptable water. In other settings leakage from holding ponds may cause deterioration of shallow water quality due to chemical reactions between the produced water and geologic materials beneath the pond. Water-quality changes at one shallow sandstone monitoring well, in response to infiltration from a holding pond, indicate an improvement in SAR (from 42 to 17). However, total dissolved solids concentrations increased from 2570 to 3550 mg/L (fig. 22). If an impermeable layer, such as shale, is present the water may be diverted horizontally to form unwanted seeps. Surface evaporation loss from ponds is expected to be about 3–4 feet per year. Successful holding ponds will require site-specific planning to evaluate potential effects on surface waters, aquifers, and water quality.

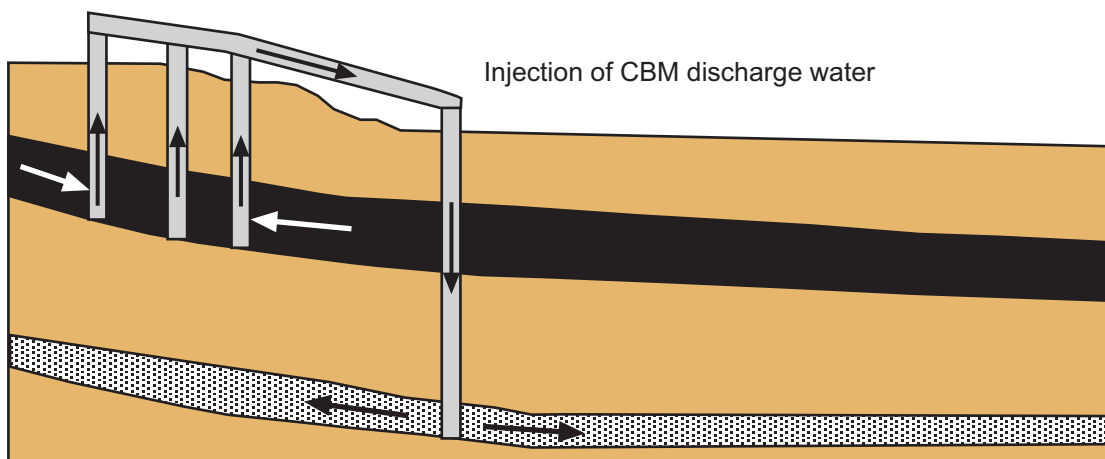


Figure 20. Produced water may be injected to other aquifers if favorable conditions exist. The receiving aquifer must have sufficient permeability to allow water to be pumped into it. Also, the water quality must be compatible between the receiving aquifer and the produced water; otherwise the products of chemical reactions may clog the water flow paths.

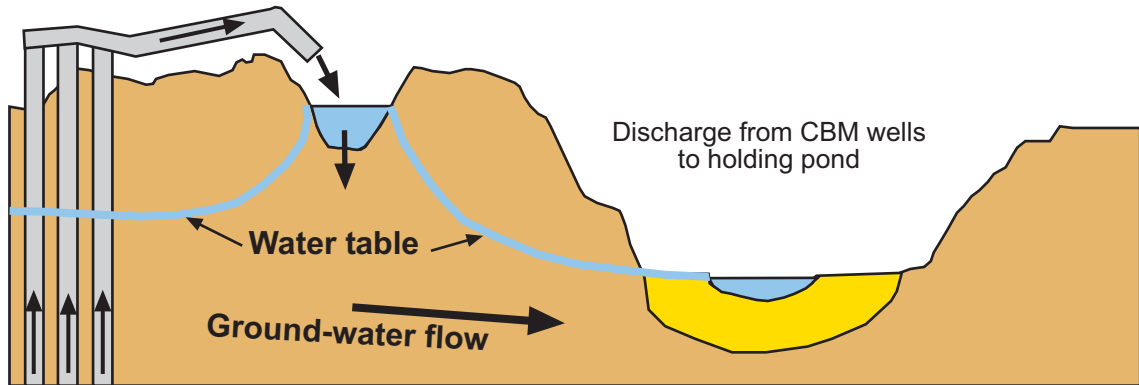


Figure 21. Water infiltrating beneath a coalbed-methane holding pond may recharge the local water-table aquifer. The water may be available for future use or eventually provide baseflow to a stream. However, in some settings detrimental changes in water quality that will impact receiving aquifers may occur. Also, improper siting may result in the formation of saline seeps on nearby hillsides.

SUMMARY

Coalbed-methane resources in Montana are considerably less than those in our neighboring state of Wyoming, where production began in 1987 and has rapidly grown since 1999. Production of CBM in Montana has not seen proportionate growth largely because of a less favorable geologic setting, and concerns over the

potential loss of ground water and impacts from disposal of that water. Coal seams are vital aquifers for the agricultural community in southeastern Montana, and a reduction in available ground-water resources is one part of coalbed-methane production. Ground-water monitoring begun by the Montana Bureau of Mines and Geology in the 1970s enables prediction and modeling of many of the changes that will happen in

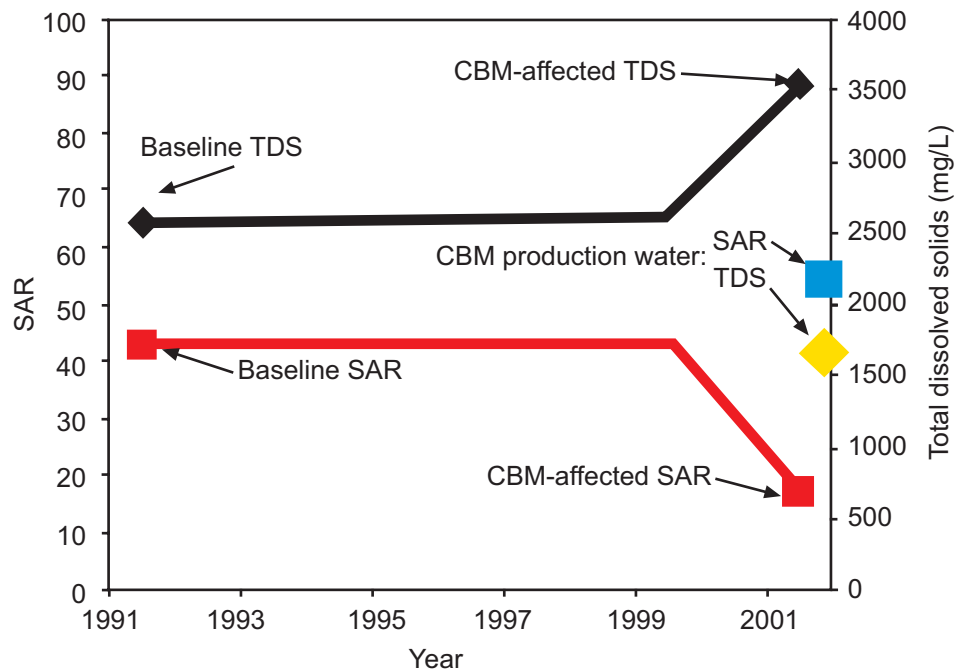


Figure 22. Coalbed-methane production water infiltrating from a holding pond appears to react with geologic material and increase the salt load (TDS) in the water-table aquifer and decrease the sodium adsorption ratio (SAR).

the aquifers. Potential effects associated with water chemistry, water disposal, and other factors are being evaluated by the Bureau and numerous other governmental, academic, and industry groups. Advance planning accompanied by continual monitoring during and after CBM production are critical. Site-specific methods of water handling based on water quantity and quality, water use, soils, local aquifers, and surface-water characteristics will be necessary to reach a solution agreeable to most parties involved.

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