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Tradable Permits for CBM Produced Water: A Potential Tool for Managing Quantity and Quality Issues in the Powder River Basin

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Abstract: Water is a by-product of coal-bed methane (CBM) production. Much CBM produced water is discharged to drainages, where it alters not only the volume and timing of flow, but land and water quality as well. These effects have resulted in disputes between CBM producers and some downstream agricultural landowners. Management tools that engage all parties in mutual negotiation are therefore needed to resolve conflict over CBM produced water. We explore the potential for tradable water quality/quantity permits to help resolve these conflicts in the Powder River Basin of Wyoming. Tradable permits would provide flexibility in the means by which standards are met, as well as an opportunity for CBM and agricultural producers to express the value or damages associated with produced water. We develop a stylized model of CBM and agricultural producers' economic decisions for a representative Powder River Basin watershed, subject to water quality/quantity standards and the relationship between them. Results reveal the potential for a tradable permits system to reduce the cost of achieving water quality/quantity standards. They also provide a springboard for discussion of the potential for market-based approaches to help resolve issues surrounding CBM produced water.¹

Introduction

Water is a by-product of coal-bed methane (CBM) production. Much CBM produced water is discharged to drainages, where it alters not only the volume and timing of flow, but land and water quality as well. These effects have resulted in disputes between CBM producers and some downstream agricultural landowners. Because CBM generates significant profit for industry and tax revenue for state government, development is likely to continue. Local communities depend, however, on agricultural and environmental sectors for important economic and cultural resources. Management tools that engage all parties in mutual negotiation are therefore needed to resolve conflict over CBM produced water.

Our objective in this study is to explore the potential for tradable water quality/quantity permits to help resolve conflict. The state of Wyoming is currently revising water quality and

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quantity standards for drainages in the Powder River Basin. Once standards are defined, a tradable permits system would enable CBM and agricultural producers to buy and sell from each other the right to discharge water of various quantities and qualities within and across drainages. Tradable permits would provide flexibility in the means by which standards are met, as well as an opportunity for CBM and agricultural producers to express the value or damages associated with produced water.

We develop a stylized model of CBM and agricultural producers' economic decisions for a representative Powder River Basin watershed, subject to water quality/quantity standards and the relationship between them. The model is solved in the presence and absence of a tradable permit system and under alternative property rights assumptions. Results reveal the potential for a tradable permits system to reduce the cost of achieving water quality/quantity standards. They also provide a springboard for discussion of the potential for market-based approaches to help resolve issues surrounding CBM produced water.

Policy Background

While the presence of coal bed methane in coal deposits has been known for quite some time, it is only in the last 25 years that the gas can be extracted economically. Under current technology, water is pumped from gas-bearing coal seams to reduce pressure on the coal seams. After this depressurization, which can last approximately five to ten years, CBM is released from the coal, where it can flow to the well for recovery (Ruckelshaus 2005). Since drilling for CBM began in 1987, nearly 3.7 trillion cubic feet has been produced in the Powder River Basin (WSGS 2010). This quantity of natural gas is sufficient to meet the needs of approximately 4 million homes for 10 years (WSGS 2010). As of 2006, over 1.5 million barrels of water per day were being extracted in total from all active CBM wells in the Powder River Basin. The water is

disposed of through discharge into drainages, stock ponds, evaporation ponds or infiltration ponds. Treatment to remove sodium is another common management strategy. Produced water is also sometimes used in irrigation, when the water is of acceptable quality for agricultural use. Reinjection of produced water into the ground is occasionally employed as well, though this is a less common strategy (USGS 2006). Boysen *et al.* (2002) outlines the costs associated with different management strategies.

CBM produced water must be permitted by the Wyoming State Engineer's Office (SEO). The permit required is called, *Application for Permit to Appropriate Ground Water*. Within the permit, the applicant must clearly describe the uses to which the water will be put to use and indicate the areas and/or points where the use will occur. Generally speaking, energy operators cite water produced in the production of coal bed methane gas as the beneficial use. If the produced water will not be stored, no further permitting is required by the SEO. If it will be stored underground, then further permitting is required from the SEO Ground Water Division and DEQ. If it will be stored off-channel, then the CBM producer must follow the rules of the Oil and Gas Conservation Commission. If it will be stored on-channel or if it will be stored off-channel and there is another use in addition to CBM production, then a reservoir permit for the construction of the impoundment is required from the SEO. (WYSEO 2004). CBM produced water must also be permitted by the Wyoming Department of Environmental Quality (DEQ). (WYDEQ 2004).

CBM produced water is contentious. Energy operators are permitted by SEO to release water into on-channel waterways. However, downstream ranchers have a right to clean water for agricultural purposes under Chapter 1 Section 20 of the Wyoming Water Quality Rules and

Regulations (WYDEQ 2006; WYDEQ 2007)². There are also disagreements within the ranching community regarding the benefit and harm from CBM produced water. Generally speaking, upstream ranchers who are able to manage the extra water to their benefit are not motivated to change the current situation. Downstream ranchers who are unable to manage the extra water are harmed. Operators are currently required to pay damages, but it seems that they do not always do so. There are also sometimes side payments between operators and downstream livestock producers in which operators pay producers damages. However, there still seems to be unresolved issues and contention. The Wyoming Environmental Quality Council (EQC) ruled in March 2010 in a lawsuit brought forward by Powder River Basin ranchers that a particular permit to discharge CBM produced water be revoked because the regulations under which it had been issued, Tier 2, were not scientifically valid (WY EQC 2010). The EQC made a similar ruling for a different permit several months later (Gruver 2010).

Several attempts have been made during the last decade to better define the property rights associated with disposal of CBM produced water. For example, in the 2009 session of the Wyoming Legislature, DEQ sponsored HB0014 to regulate the discharge of CBM water. However, the bill died in committee and was not passed. The most recent effort to develop a consensus among stakeholders for regulating CBM produced water has just concluded. A group of Powder River Basin stakeholders met repeatedly over the course of 2010 in meetings moderated by the University of Wyoming Ruckelshaus Institute of Environment and Natural Resources. Their goal was to make recommendations to DEQ on rules and regulations governing a resolution to the conflicts between energy operators, livestock producers, and environmental

² The Wyoming DEQ finalized its agricultural use policy in August 2006. At that time, a modified version of the policy was under review at the Wyoming Environmental Quality Council, for adoption as an appendix to Chapter 1 of DEQ's Wyoming Water Quality Rules and Regulations (WYDEQ 2006)..

groups on the discharge of CBM produced water. DEQ has subsequently incorporated those recommendations into a draft permitting requirements proposal that will likely result in a rulemaking process. Most notably, the draft permitting requirements indicate that a watershed group consisting of stakeholders within the relevant irrigation drainage area will be formed before new or renewed CBM discharge permits are issued. They also contain requirements for monitoring of water quality downstream from the point of discharge as well as permissible threshold levels for sodium and salts (WYDEQ 2010).

Technical Background

We briefly describe here the technical and physical details of CBM production that are important to a model of CBM produced water.

Water-to-Gas Ratio. When a well is drilled for CBM, water is pumped to release the hydrostatic pressure in the coal seam. After five to seven years, the coal seam is sufficiently depressurized that natural gas can be extracted. Powder River Basin coal beds produced 558 billion cubic feet of coal bed natural gas in 2009. Although this was the most CBM produced in any year since production began in 1987, the number of producing wells actually decreased in 2009 by 20% from the 2008 level. The water-to-gas ratio also decreased in 2009 to its lowest levels since drilling began, and this decrease is expected to continue. (WSGS 2010).³ This trend indicates a maturing of the industry, in that existing wells are beginning to pump natural gas rather than water. Further, the wells that are being taken out of production are probably producing water, not natural gas, and new wells are not being drilled due to low natural gas prices (Bleizeffer, 2010).

³ More facts from the WSGS press release: There were 17,000 producing wells at the start of the year. By the end of the year, there were only 3500. Water production decreased by 17 percent in 2009, from 681 million barrels in 2008 to 566 million barrels in 2009. Approximately 1.02 barrels of water were produced in 2009 for every 1,000 cubic feet of gas (these are 42-gallon barrels). This is definitely part of a trend. In 2000, the water-to-gas ratio was approximately 2.5 barrels per 1,000 cubic feet of gas. In 2005: 1.7. Next year, it may be below 1.0.

Thus although CBM water is definitely problematic for downstream users now, the problem in aggregate is becoming less severe. This fact is the motivation for the “do-nothing” scenario that we model below.

Current Methods for Cleaning CBM Produced Water The two most common methods for managing CBM water are direct discharge to a surface drainage or to on- or off-channel ponds for evaporation and/or infiltration (Ruckelshaus 2005).

Water Quality/Quantity Issues. There are three types of damage that can result downstream from CBM produced water. First, in locations where the produced water is particularly sodic and/or saline, treatment is required before the water can be used for agricultural use. Second, the produced water may flood meadows that have historically been used for producing hay and/or grazing. When the produced water quality is poor, the meadows may no longer be suitable for the historical use, even after the waters have receded. Third, agricultural producers in some parts of the Powder River Basin are concerned that water extraction is drawing down the groundwater aquifer on which they rely for their operations.

Stylized Watershed Model

We model a simplified watershed to capture the essence of the conflict between operators and producers. The simplified watershed contains a single waterway, three agents, and two methods of mitigating the effects of CBM water. This is a one-year model that contains 12 seasons within the year. Figure 1 illustrates the arrangement of the model agents on the waterway.

Agents. The first agent in the model is the upstream energy operator who generates CBM produced water as a byproduct of CBM extraction. We assume for the moment that this operator produces a fixed amount of CBM water. This quantity of CBM water is assumed to be associated

with the profit-maximizing quantity of CBM. This profit-maximizing quantity of CBM is assumed to be exogenous to our model, since his decision of how much CBM to produce is assumed to be a function of current and forecasted natural gas prices rather than anything that is happening within the watershed model. The energy operator's objective is to minimize the cost of whatever treatment and permitting constraints he is required to do under each policy scenario we model.

The second agent is an upstream livestock producer who maximizes his profits by managing his land and water for optimal livestock production.⁴ This producer uses a portion of his land and water resources to graze cattle and a portion to grow alfalfa hay and native grasses. He is not harmed by the increase in water flows resulting from upstream CBM water production for two reasons. First, the CBM produced water he receives is of sufficiently good quality that he can incorporate it into his existing water supplies with no harm. Second, he has a storage pond in which he can store the extra flows and subsequently release them to his land when needed.

The third agent is a downstream livestock producer who also maximizes profits by managing land and water for optimal livestock production. He also grazes cattle and grows alfalfa hay and native grasses for optimal livestock production. However, this producer does not have a storage pond that prevents his land from being flooded when the CBM produced water augments flows in the river. Further, the CBM produced water has become more saline and more sodic as it travels downstream. Even if he were able to manage the water with a storage pond, the water would still be of such poor quality that using it would cause permanent damage to his land.

⁴ Some agricultural producers own the mineral rights underlying their land; others do not. Those who do own mineral rights benefit monetarily from the presence of drilling, as energy operators must pay the landowners for the right to drill in such cases. The presence or absence of such side payments are not incorporated into the present analysis.

Thus this downstream livestock producer is harmed by CBM produced water in two ways. First, his hay meadows are flooded, decreasing the amount of alfalfa hay and native grasses available to him for livestock production. Second, the CBM produced water decreases water quality to the point that there are permanent negative effects on his land's productivity for hay production in future periods.

Scenarios. We use our stylized watershed model to analyze four scenarios (Table 1). Scenario 1 represents the status quo. Under this arrangement, there is little to no regulation of produced water that harms downstream agricultural producers. The energy operator generates the quantity of CBM produced water that maximizes his profits, without regard to downstream effects. This is a benchmark scenario that provides maximum benefit to the energy operator. It is important to note that in a number of cases within the Powder River Basin, energy operators and agricultural producers have already worked together to develop a management strategy that mitigates the harm to the agricultural producer resulting from produced water. In some cases, such arrangements result in improved water supply for the agricultural producer. Scenario 1 is extreme in that it does not incorporate such negotiated outcomes.

Scenario 2 is a fully constrained model, in which the energy operator is required to treat or store all produced water so that no downstream livestock producer is harmed by the flows. This is a benchmark scenario that results in maximum benefit to the livestock producers.

Scenarios 3 and 4 incorporate tradable permits. Within these scenarios, our optimization model determines the socially optimal level of discharge by balancing energy operator disposal costs and livestock producer profitability. Agents' costs are subsequently determined for each scenario, depending on whether the permits are initially allocated to energy operators (Scenario 3) or the agricultural producers (Scenario 4). Each permit is worth one acre-foot. Thus in

Scenario 3, the energy operator may choose to retain his permits, which allow him to discharge one acre-foot of water per permit into the drainage. Alternatively, the energy operator may choose to sell some or all of his permits to agricultural producers downstream. In Scenario 4, in which permits are allocated to the agricultural producers, the agricultural producers can retain their permits, which essentially give them the right to clean water. Alternatively, they may choose to sell some or all of their permits to the energy operator. In this circumstance, the produced water harms their agricultural production. However, as the permit trade was voluntary, the price they have received for the permit is presumably sufficient to compensate them for the resulting harm.

Model Results

Table 2 presents model results.⁵ In Scenario 1 (minimum regulation), the energy operator discharges the maximum possible quantity of water (1200 acre-feet) into the drainage. Livestock producer A is not negatively affected by this maximum discharge, but all 635 acres of livestock producer B's fields are flooded. The energy operator's costs of disposal are zero, livestock producer A generates maximum possible profits of \$162,000, and livestock producer B yields no profits. Overall profits for the drainage are consequently \$162,000.

In Scenario 2 (maximum regulation), the energy operator is required to implement a management strategy that prevents produced water from entering the drainage. We assume that the cost of implementing such a management strategy is \$80/acre-foot. Given this cost of disposal, the energy operator chooses to discharge no water into the drainage. The energy operator's disposal costs are \$92,000, and each livestock producer makes net profits of \$162,000. Overall profits for the drainage are consequently \$227,000.

⁵ The model is programmed in the General Algebraic Modeling System (GAMS) using the CONOPT solver.

In Scenario 3 (tradable permits allocated to the energy operator), the socially optimal level of discharge into the drainage is determined to be 307 acre-feet. Thus, the energy operator is allocated 307 permits. The energy operator chooses to use the permits to discharge 307 acre-feet into the drainage. We assume that the energy operator still chooses to produce 1200 acre-feet of water; the residual 896 acre-feet are managed by the energy operator at the disposal cost of \$80/acre-feet. 259 acres of livestock producer B's fields are flooded, yielding him profits of \$147,000. Livestock producer A once again makes \$162,000. Thus, overall profits for the drainage are \$237,000. Scenario 3a in Table 2 indicates the allocation of profits within the drainage.

In Scenario 4 (tradable permits allocated to livestock producer B), livestock producer B is allocated the 307 permits available in the drainage. He can hold onto the permits, thereby ensuring that the 307 acre-feet of produced water will not enter the drainage, or he can sell the 307 permits to the energy operator. Given the parameters in our model, livestock producer B decides to sell the permits to the energy operator at a price of \$76/permit. The energy operator makes a side payment of \$20,000 to livestock producer B in exchange for the permits. Scenario 4a in Table 2 indicates the allocation of profits within the drainage before the side payment is made. Scenario 4b indicates profits after incorporation of the side payment.

The agents in the drainage are collectively better off under the tradable permits scenario than they are under the minimum or maximum regulation scenarios. The relative well-being of agents under the tradable permits scenario is a function of how the permits are initially allocated. Note that there is an implicit tradeoff in the model between treatment costs and permit value. When livestock producers own the permits and can sell them to the energy operator, the price of a permit will be capped by the cost of treating CBM water. There is also an implicit tradeoff in

the model between the market price of hay and permit value. When energy operators own the permits and can sell them to the livestock producers, the price of a permit will be capped by the cost of purchasing alfalfa hay.

Discussion and Conclusion

This drainage-level tradable permits model is conceptual. Its purpose is to introduce the concept of tradable permits and to demonstrate that such a model could help stakeholders and policymakers organize their thoughts on how best to resolve conflicts regarding the disposition of CBM produced water. We observe that a property rights regime which assigns the right to discharge CBM produced water into a drainage and subsequently allows trading increases efficiency over the other scenarios modeled.

A few caveats are in order. First, we can model the willingness to pay of energy operators for the right to discharge CBM produced water as well as the willingness on the part of livestock producers to accept payment in exchange for damages. However, this type of optimization model cannot capture the bargaining power of the different stakeholders. As such, the model only provides a benchmark of what outcomes could be possible under different policy scenarios. Second, the result that assigning tradable permits increases efficiency over the other scenarios modeled is to some extent an artifact of the fact that the model currently consists of a single drainage. An expanded model allowing agents to transport water (and trade permits) between drainages would likely demonstrate even greater efficiencies over the minimum and maximum regulation cases. (Figure 2 illustrates an expanded, two-drainage model.) The extent to which efficiencies would be observed in the expanded model would be a function of the degree of heterogeneity between the two drainages.

Our tradable permits could be meaningfully expanded in several ways. First, CBM produced water within the current model only harms Livestock Producer B. We model the negative effects of the CBM water by directly reducing the amount of acres of land available for grazing or growing hay and grasses in proportion to the amount of CBM water that Livestock Producer B receives. A more sophisticated damage function could yield interesting results. Second, this version of the model is for a single year in which CBM water flows are fixed. CBM produced water flows could be determined endogenously, through some ecological function that sets social marginal cost and social marginal benefit equal to each other in each period. This ecological function would be set based on the socially optimal amount of water to have in the river each month.

Finally, our model uses cost, damage, and water flow parameters not associated with any particular drainage in the Powder River Basin. The use of parameters from a particular drainage would allow us to assess the relative gains in efficiency that would result from adopting tradable permits for a specific empirical setting.

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Figure 1. Stylized CBM Watershed Model

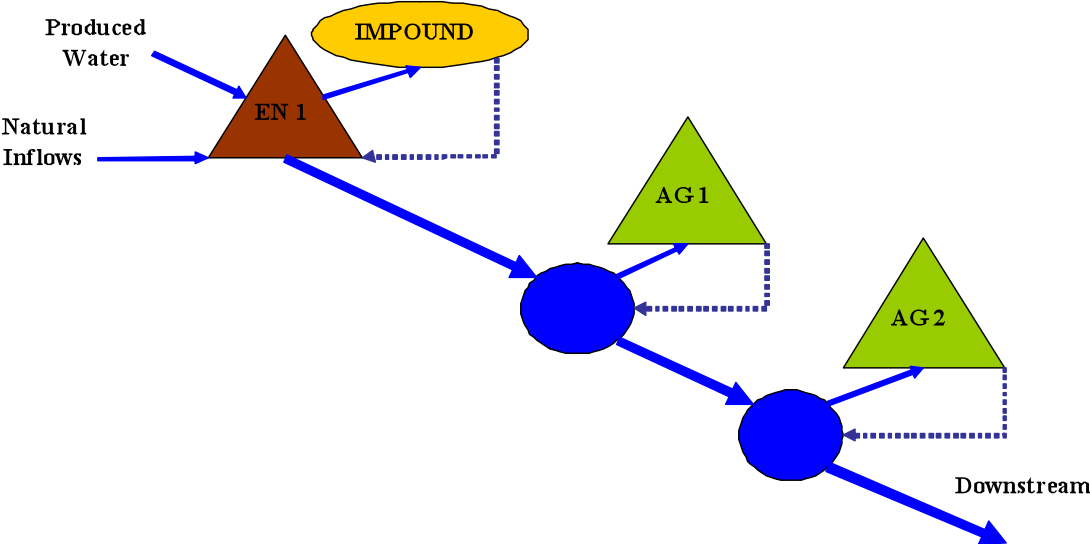


Figure 2. Expanded CBM Watershed Model

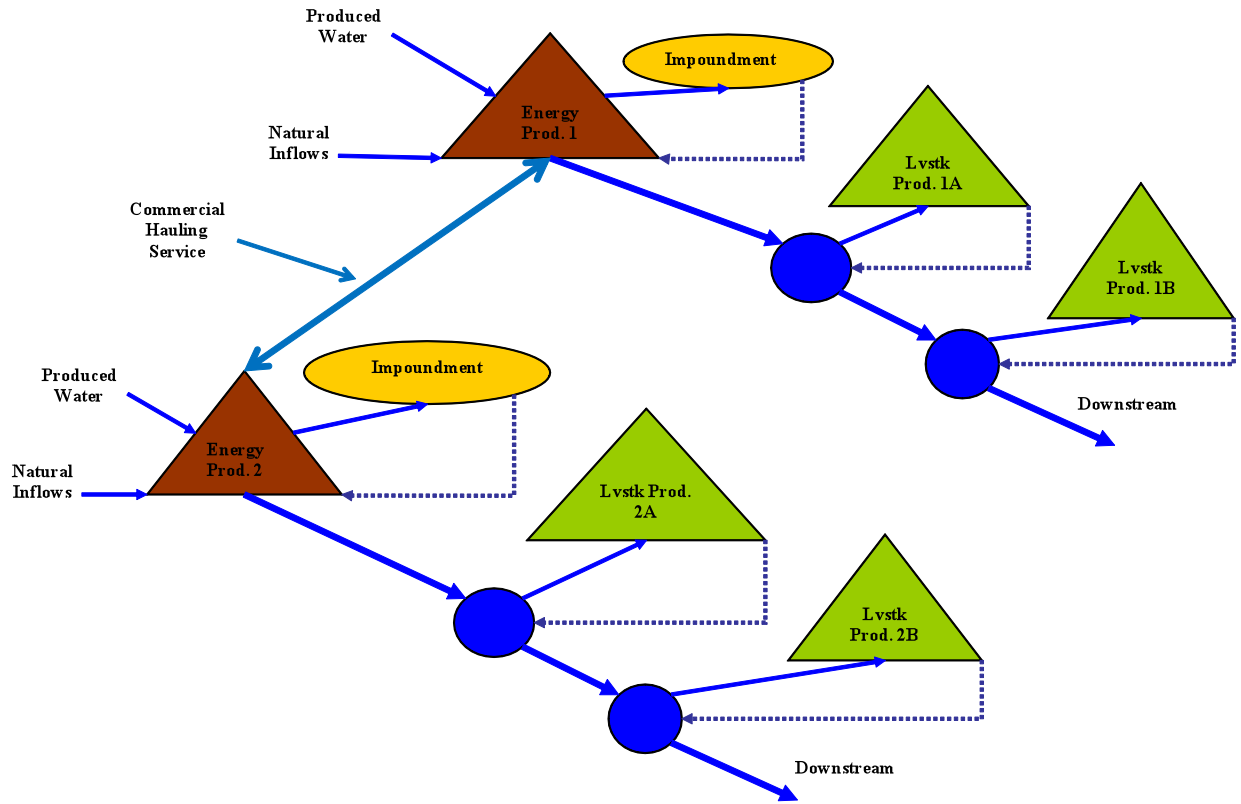


Table 1. Model Scenarios

#	Scenario	Features
1	Minimum Regulation	No quantity cap on discharge
2	Maximum Regulation	No discharge allowed
3	Permit Trading: rights assigned to energy operators	No quantity cap on discharge; the model determines optimal discharge levels, taking into account the well-being of all stakeholders
4	Permit Trading: rights assigned to agricultural producers	

Table 2. Profits to Model Agents Under Different Scenarios

#	Scenario	Discharge (acre- feet)	Flooded Fields (acres)	Energy Op. Costs (\$1000s)	Livestock A Profits (\$1000s)	Livestock B Profits (\$1000s)	All Profits (Energy Op. + A + B) (\$1000s)
		(1)	(2)	(3)	(4)	(5)	(6)
1	Minimum Regulation	1200	635	0	162	0	162
2	Maximum Regulation	0	0	-96	162	162	227
3a	Tradable permits assigned to energy operator	307	259	-71	162	147	237
3b	Tradable permits assigned to energy operator with side payments	307	259	-71	162	147	237
4a	Tradable permits assigned to Livestock Producer B	307	259	-71	162	147	237
4b	Tradable permits assigned to Livestock Producer B with side payments	307	259	-91	162	166	237