Report for 2003WY10B: Geochemistry of CBM Retention Ponds Across the Powder River Basin, Wyoming

- Conference Proceedings:
    - Jackson, R.E., K.J. Reddy, R.E. Olson, and D.E. Legg. 2004. Geochemistry of coalbed methane disposal ponds across the Powder River Basin, Wyoming. In Proceedings of Society of Range Management 2004 Annual Meetings, Salt Lake City, Utah.

Report Follows

Abstract:

The Wyoming Water Research Program (2002) funded the project geochemistry changes of coalbed methane (CBM) disposal pond waters across the Powder River Basin (PRB) in collaboration with the US Geological Survey and the Wyoming Water Development Commission. Objectives of this research were to monitor the geochemical changes and water quality of CBM disposal ponds in Tongue River Basin (TRB), Powder River Basin (PRB), Little Powder River Basin (LPRB), Belle Fourche River Basin (BFRB), and Cheyenne River Basin (CRB) over a period of 3 years. This report summarizes results from year 1 data collected from March 2003 to February 2004. The CBM product water samples from discharge points and corresponding disposal ponds were collected during the summer months of 2003. Samples were analyzed for pH, dissolved oxygen (DO), electrical conductivity (EC), major cations (e.g., Ca, Mg, Na, and K), major anions (e.g., alkalinity, sulfate, chloride, fluoride, nitrate, and phosphate), and trace elements (e.g., Al, As, Ba, B, Fe, Cd, Cu, Cr, Mn, Mo, Se, Pb, and Zn). Sodium adsorption ratio (SAR) was calculated from the measurements of Ca, Mg, and Na. The results of year 1 data show how quality of CBM discharge and disposal pond waters change, predominantly salt concentration and SAR as a function of watershed physical and chemical characteristics. Letters to local landowners have been drafted and will be sent near future to inform them of CBM water quality on their property. All aquatic macroinvertebrate samples have been prepared to be analyzed. Samples will be sent to a professional consulting company that specializes in aquatic macroinvertebrate identification. CBM pond sediment fractionation analysis is in progress. The proposed research helps water users (landowners, agriculture and livestock producers, and ranchers) and water managers (state, federal, and local agencies) with the planning and management of CBM product water within the Powder River Basin.

Statement of Critical Regional or State Water Problems:

Demand for natural gas (methane) is increasing within the United States because of the energy shortage. Further, methane is a clean form of burning fossil fuel. Several states within the United States (e.g., Wyoming, Colorado, Montana, New Mexico, and Utah) are exploring methane extraction from their coal resources. As an example, in the Powder River Basin (PRB) of Wyoming, it is estimated that there are 31.7 trillion cubic feet of recoverable CBM (coalbed methane). Currently, the CBM development in this basin is occurring at a rapid pace as demand for natural gas has increased in the United States (DeBruin et al., 2000).

Methane is formed deep in confined coalbed aquifers through biogeophysical processes and remains trapped by water pressure. Recovery of the methane is facilitated by pumping water from the aquifer (product water). It is estimated that a single CBM well in the Powder River Basin may produce from 8 to 80 L of product water per minute, but this amount varies with aquifer that is being pumped and the density of the wells. At present, more than 16,000 wells are under production in the PRB and this number is expected to increase to at least 30,000. Based on information provided by the Wyoming Geological Survey, approximately 2 trillion L of product water will eventually be produced from CBM extraction in Wyoming. Commonly 2 to 10 CBM extraction wells are placed together in a manifold system discharging to a single point and releasing into constructed unlined disposal ponds. These disposal ponds are constructed with initial well pumping. The Wyoming DEQ considers this water as surface water of the state with Class 4C designation.

Various metals such as Fe, Ba, As, and Se in the CBM pond waters are expected to go through several geochemical processes including desorption and dissolution, ion complexation (speciation), and adsorption and precipitation. These processes in turn control the quality of product water in disposal ponds as well as the water that is infiltrating into the shallow ground water. Very little information is available on the geochemistry of CBM product water and associated disposal ponds in the Powder River Basin (Rice et al., 1999; McBeth et al., 2003a and b). The studies conducted by Rice et al. (1999) only examined the chemistry of CBM discharge water at wellhead. McBeth et al. (2003a and b) studies examined the chemistry changes of product water both at wellhead and in disposal ponds of the Powder River Basin. However, to our knowledge no studies involved the monitoring of the geochemical processes that product water undergoes in disposal ponds across the Powder River Basin. The CBM product water discharged to the surface is managed and regulated by several state and federal agencies. To effectively manage this water resource there is a need to understand the geochemical changes that occur in CBM disposal ponds over time.

Objectives:

The overall objectives of this research were to:

1. Collect product water samples from discharge points and disposal ponds over a period of three years and analyze for pH, DO, EC, major cations (e.g., Ca, Mg, Na, and K), major anions (e.g., alkalinity, sulfate, chloride, fluoride, nitrate, and phosphate), and trace elements (e.g., Al, As, Ba, B, Fe, Cd, Cu, Cr, Mn, Mo, Se, Pb, and Zn);
2. Monitor the pH, DO, EC, major cations (e.g., Ca, Mg, Na, and K), major anions (e.g., alkalinity, sulfate, chloride, fluoride, nitrate, and phosphate), and trace elements (e.g., Al, As, Ba, B, Fe, Cd, Cu, Cr, Mn, Mo, Se, Pb, and Zn) of product water at discharge points and associated ponds over a period of 3 years;
3. Predict geochemical changes (speciation, adsorption, and precipitation) for critical metals such as Fe, Ba, As, and Se in the disposal pond;
4. Quantify relationships between CBM water quality, aquatic macroinvertebrates and vegetation.
5. Assess the diversity of benthic macroinvertebrates found in disposal ponds; and
6. Transfer research results to user groups through project demonstrations, workshops, and local meetings.

This final report outlines research progress accomplished for year 1 from March 2003 to February 2004. This report consists of objectives, methods and procedures, site selection, sample collection and analysis, results, clientele network, presentations, and student education and training.

Methods and Procedures:

Site Selection

We selected twenty-six sites within five Wyoming watersheds to obtain CBM well and associated pond data. Site selection was coordinated with a network of working partners. These working partners include: Wyoming Department of Environmental Quality (WY-DEQ), Wyoming Water Development Commission (WY-WDC), Coalbed Methane Industry, Wyoming Landowners and Citizens, U.S. Geological Survey (USGS), Wyoming State Geological Survey (WYSGS), U.S. Environmental Protection Agency (USEPA), Colorado, and Montana. We sampled seven sites in each of the Little Powder River and Powder River watersheds. We sampled three sites from Cheyenne River watershed and four sites from Bell Fourche River watershed, and five sites from Tongue River watershed (figure 1).

Sample Collection and Analysis

Before sample collection, a pilot study was conducted to determine sampling location within the CBM pond waters. Chemical, plant, and aquatic macroinvertebrates were also examined to determine the sampling locations to obtain a representative sample. CBM water samples from each well and corresponding ponds were collected during the summer of 2003. Before sample collection, field measurements including pH, conductivity, temperature, ORP, and dissolved oxygen were taken in each well and pond.

These measurements were conducted using Model 1230 Multi-Probe Field Kit. Duplicate water samples of wells and ponds were taken from each site as well as three trip blanks (112 total water samples). These water samples were analyzed for: Ca, Na, Mg, K, Fe, Al, Cr, Mn, Pb, Cu, Zn, As, Se, Mo, Cd, Ba and B by ICP-MS. Sulfate, chloride, fluoride, nitrate, and phosphorus were analyzed on IC. In addition to these analyses, samples were analyzed for dissolved organic carbon due to appearance of organic matter in disposal ponds. Dissolved organic carbon was analyzed using a Tekma-Dohrmann 8000 TOC. The quality control/quality assurances protocols such as duplicate sampling and analysis, trip blanks, and known concentrations of reference standards were included. Laboratory measurements of pH, electrical conductivity, alkalinity and total dissolved solids were accomplished using standard laboratory procedures. Sodium adsorption ratios will be calculated from Ca, Na and Mg concentrations. All analyses were preformed following CFR 40, Part 1, Chapter 36 procedures (Wyoming DEQ, 2001).

Sites used to sample pond sediment were located directly away from discharge and locations were chosen upon pH stabilization at different distances from discharge point. Typically sediment was collected approximately three meters into pond from discharge point. Sediment was taken from every pond and at least two samples from each watershed (10 total samples) will be separated into different mineral fractions and each fraction will be dissolved in an appropriate solution and extracted. Each clear extract will be analyzed for Fe, Ba, As and Se on ICP-MS as described by Tessier et al. (1979). Macroinvertebrates were collected from the water column and sediment from two ponds in each different watershed (20 total samples). Identification to lowest taxonomic level will be conducted using a certified laboratory specializing in analysis of benthic invertebrate communities. Vegetation species list of all vegetation that was present in and around ponds was conducted for every pond. Multiple detailed digital photos were taken at all study sites. Exact locations of sites were conducted using Garmin GPS unit.

Results:

The results from year 1 studies are presented in figures 2 and 3. These results suggest that moving from south towards northwest of the Powder River Basin increases the pH of CBM discharge water in disposal ponds. Electrical conductivity (dissolved salt concentration) also increases moving from south towards northwest of the Powder River Basin. However, salt concentration of CBM discharge water decreased in Tongue River basin when compared with Powder River basin. Dissolved sodium was major cation in both CBM discharge well and disposal pond water with minor concentrations of calcium and magnesium. The sodium adsorption ratio (SAR) increased in both discharge wells and disposal ponds from Cheyenne River Watershed to Tongue River Watershed with an observed SAR approaching 35 in Tongue River Watershed. Data analysis and interpretation of dissolved organic carbon and sediment trace elements is in progress.

Clientele Network:

Several contacts were made with different clientele groups to obtain access to the sampling sites and permission to collect samples. These contacts or clientele included WY-DEQ, WY-WDC, CBM Industry, WY Landowners and Citizens, NRCS personnel, Conservation Districts personnel, WY Cooperative Extension Agency, USGS, EPA, Colorado, Montana.

Graduate Student Support:

Rich Jackson, Ph.D. student, majoring in Rangeland Ecology and Watershed Management with Water Resources Option

Part-time Student Support:

Michelle Patterson, graduate student in Rangeland Ecology and Watershed Management with Water Resources Option
Jonathon Anderson, graduate student in Soil Science
Keri Bousman, undergraduate student in Rangeland Ecology and Watershed Management

Presentations:

1. University of Wyoming 2003 Graduate Student Symposium March 2nd, 2004, Laramie, Wyoming. This presentation won Best Project Presentation Award.
2. USDA-CSREES National Water Quality Conference: Integrating Research, Extension and Education scheduled January 11-14, 2004 in Clearwater, Florida.
3. Wyoming Water Development Commission Annual Meetings, December 4th, 2003, Cheyenne, Wyoming.
4. Rangeland National Annual Meetings, Water Quality Division, scheduled January 24-30, 2004 in Salt Lake City, Utah.
5. American Society of Agronomy (Soil and Water Ecology Section) Meetings, Denver, Colorado. November 5, 2003
6. Wyoming Department of Environmental Quality Meeting, Cheyenne, Wyoming. August 21, 2003.
7. EPA-USGS Meeting for Tongue River and Powder River Long-term Monitoring Network. Sheridan, Wyoming. June 5, 2003

8. Missouri River Basin Natural Resources Meeting, Benedictine, Kansas. June 2-4, 2003 (invited).
9. American Society of Surface Mining and Reclamation Symposium, Billings, Montana. June 5-6, 2003.
10. Wyoming Water Development Commission, River Basin Meeting, Kaycee, Wyoming. June 16, 2003.
11. Wyoming Department of Environmental Quality (Water Quality Division) Meeting, Cheyenne, Wyoming. May 10, 2003. This meeting included represents from U.S. EPA Region VIII, BLM, CBM Industry, Colorado State University.

References:

DeBruin, R.H., R.M. Lyman, R.W. Jones, and L.W. Cook. 2000. Coalbed methane development in Wyoming. Information Pamphlet number 7. Wyoming State Geological Survey, Laramie, WY.

McBeth, I.H., K.J. Reddy, and Q.D. Skinner. 2003a. Chemistry of coalbed methane product water in three Wyoming watersheds. Journal of American Water Resources Association. 39:575-585 .

McBeth, I.H., K.J. Reddy, and Q.D. Skinner. 2003b. Chemistry of trace elements in coalbed methane product water. Journal of Water Research. 37:884-890 .

Rice, C.A., Ellis, M.S, and Bullock, J.H., Jr. 1999. Water co-produced with coalbed methane in the Powder River Basin, Wyoming: Preliminary compositional data. Open-File Report 00-372. U.S. Geological Survey, Denver, CO.

Tressier, A., Campbell, P.G.C, and Bisson, M. 1979. Sequential extraction procedure for the separation of particulate trace elements. Analytical Chemistry. 51:844-850.

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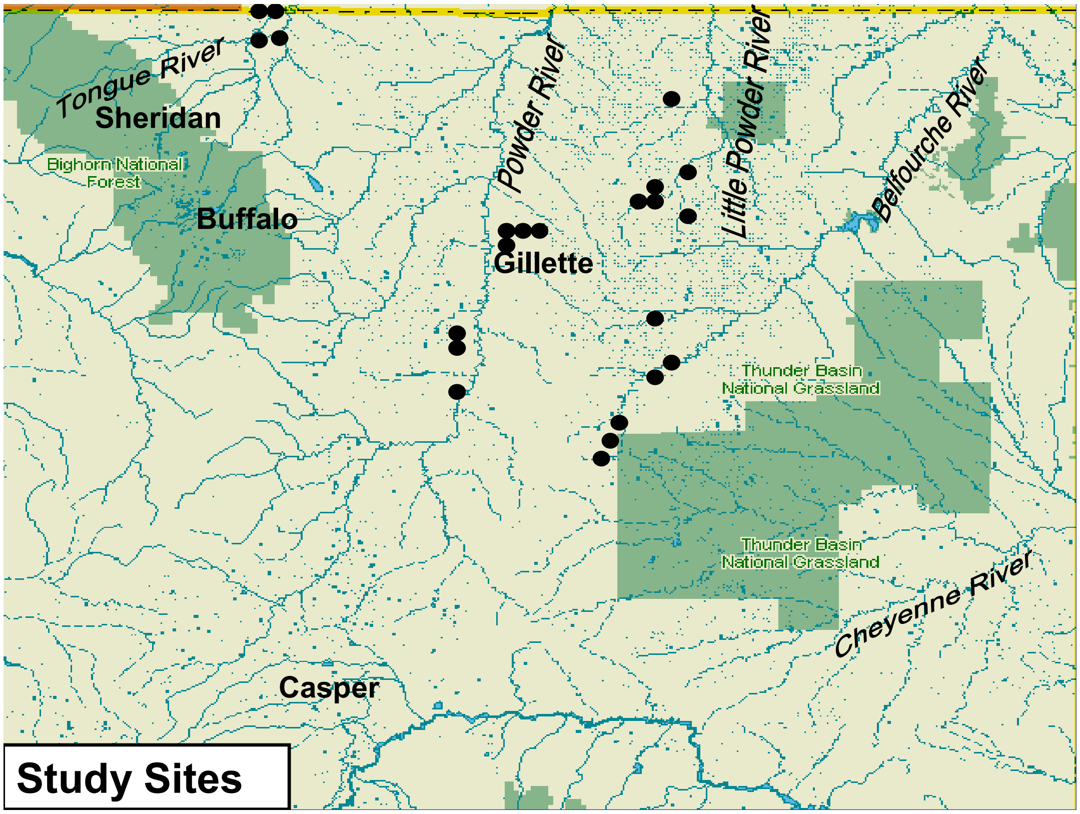

Figure 1. Map of study sites in the Powder River Basin, Wyoming (not to scale).

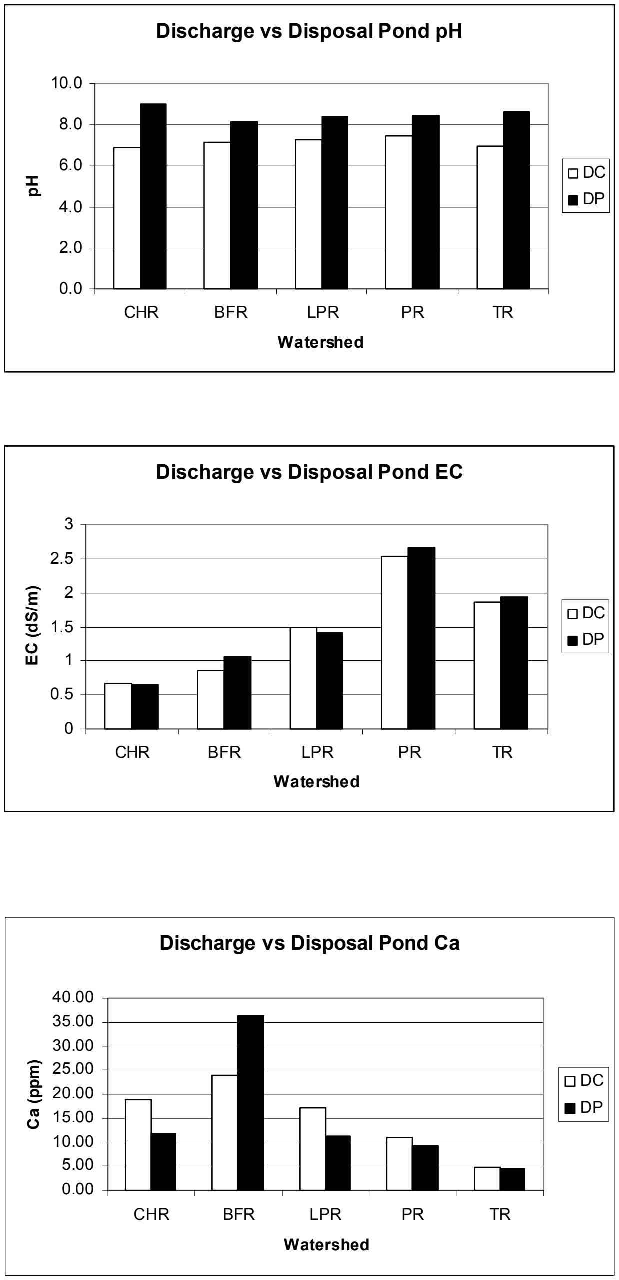

Figure 2. CBM discharge and disposal pond water pH (top), EC (middle), and Ca (bottom) as a function watershed.

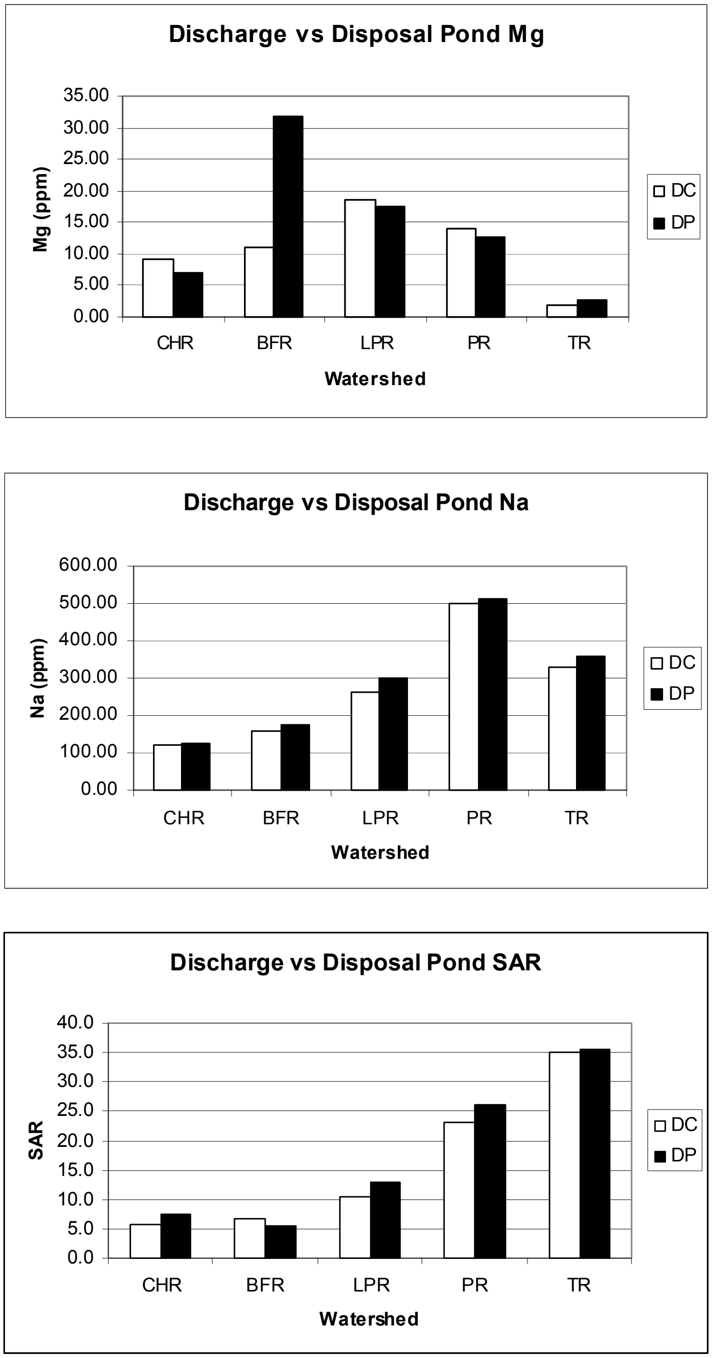

Figure 3. CBM discharge and disposal pond water Mg (top), Na (middle), and SAR (bottom) as a function watershed.