Use of Wetland Plant Species and Communities for Phytoremediation of Coalbed Natural Gas Produced Water and Waters of Quality Similar to that Associated with Coalbed Natural Gas Deposits of the Powder River Basin

DE-FG26-01BC15166

Goal

The project goal is to evaluate coalbed natural gas (CBNG) produced water and determine which plants can best be irrigated with it. The specific focus of the project is to study how produced water with a characteristic saline-sodic fingerprint will interact with soil and water resources in CBNG production areas in the Powder River Basin (PRB) of Montana and Wyoming.

Performers

Department of Land Resources and Environmental Sciences, Montana State University (MSU), Bozeman, MT

Drake Engineering, Helena, MT

Results

In many cases, PRB CBNG produced water can be used to augment drought-limited water supplies and complement limited water resources for irrigation within the PRB. Hay barley, native grass, and selected livestock forage crops irrigated with PRB CBNG produced water deliver yields substantially greater than non-irrigated crops. The most functional species identified included Valier, Haybet, and Haxby varieties of hay barley, Altai Basin rye, tall fescue, and intermediate wheatgrass. Sustainable PRB CBNG produced-water irrigation necessitates a dependable, relatively plentiful supply of water and requires detailed site and crop selection and continuous mitigation of sodium-induced soil dispersion with use of surface-applied amendments. Considerations need to be given to shallow alluvial groundwater changes including, elevated salinity and water table.

Combinations-appropriate management practices, technology-advanced treatment, and bioremediation processes can turn CBNG produced water into a valuable supplement to existing irrigation water supplies. Use of CBNG produced water with low concentrations of total salts resulted in 300-400% higher crop yields over non-irrigated crops. As a tool for water management and use, adaptive wetland halophytes and tolerant glycophytes demonstrated evapotranspiration components equal to or in excess of open pond evaporative losses while producing high-quality livestock forage. Changes in ephemeral channel biomass production and salt-tolerant species composition will likely occur in areas of sustained PRB CBNG produced water discharge. Baltic rush, American bulrush, inland salt grass, alkali grass, and prairie and alkaline cord grasses dominated ephemeral channels where PRB CBNG produced water was discharged for extended periods of time. Significant in-channel plant growth (under limited ephemeral and perennial flow) and accumulations of biomass can play a role (although limited) in carbon sequestration, enhanced wildlife habitat, sediment transport abatement, and extreme flow mitigation.

Parametric and non-parametric, flow-weighted time series analyses of quality of the Little Powder River at Weston, WY, a tributary to the Powder River, revealed no significant differences in salinity, sodium, and constituent concentrations between pre-and post-CBNG development. Although trends of elevated salinity and sodicity were determined for low-flow conditions, variability of the data precluded statistical significance of observed differences. As one component of collaborative endeavors with the private sector, new technologies have been developed, patented, and field-tested for treatment of CBNG product water to reduce sodium and salinity. Beta units are scheduled for deployment in the PRB in 2007. In collaboration with Nance Petroleum, the Bureau of Land Management's (BLM) Miles City, MT, office, the MSU Film and Television-Theatre Arts Department, a 28-minute documentary detailing CBNG development in the PRB was developed and publicly distributed in 2006-2007. The documentary, titled "Pipelines and Prairies," has aired on the PBS network, and more than 120 copies of the video have been distributed. Montana State University Extension Service completed publication of a landowner manual "A guide to changing plant communities," with emphasis on saline and sodic environments. This bulletin,

developed cooperatively with the University of Wyoming and South Dakota State University, provides guidance and assistance to land owners seeking information about suitability of various plant communities for irrigation with CBNG-type product water.

Benefits

The evaluation of PRB CBNG produced water resulted in several significant findings. Several agricultural crops species and wetland species have the capability of beneficially using CBNG produced water as either a sole or blended water source. Additionally, these plant communities offer the opportunity for disposal of CBNG water by means of beneficial use. Native saltbush and maritime barley, both perennial species with good production and forage potential, survived and produced commercially harvestable forage with sustained CBNG water irrigation. Other grass-forage mixes produced well under continuous mitigation of soil dispersion due to sodium. Additional studies (still underway) have assessed the potential utilization of PRB CBNG produced water for shallow alluvial groundwater recharge, low-flow stream augmentation, terrestrial carbon sequestration, biomass production for biofuel synthesis, and low-CO_2-emission biofuels for coblending with higher-CO_2-emission coals. Essentially all qualities of PRB CBNG produced water present opportunities either for enhanced livestock forage production or enhanced wildlife habitat along ephemeral streams and upland locations or for impoundments. The Montana legislature is presently deliberating legislation specific to discharge of untreated CBNG product water directly to ephemeral streams and livestock impoundments for the purpose of livestock watering.

Background

Within the past decade America's resources for natural gas production have dwindled, and exploration and development of new, unconventional reservoirs such as CBNG has increased. One of the fastest-growing new supplies of unconventional natural gas is the CBNG being produced in the Powder and Tongue River basins of Wyoming and Montana.

One of the significant environmental production concerns is the amount of water and its mineral constituents associated with CBNG production. It has generated a great deal of interest from the regulatory community, environmental groups, and agricultural community, as well as a tremendous effort by the gas production companies to properly handle the water and to demonstrate beneficial uses for the produced water. The water associated with much of the basin has the potential to be utilized in irrigation, stock watering, and wildlife enhancement efforts. What to do with the water is an immensely complex problem.

A January 2003 Environmental Impact Statement for CBNG development in Montana's PRB, prepared by the Bureau of Land Management and Montana's Department of Environmental Quality (DEQ) and Board of Oil and Gas Conservation, estimated 2.5 trillion cubic feet of recoverable gas within the basin. Estimates from State and Federal agencies and industry are that 15,000-70,000 CBNG wells will be developed in the basin in the next 15-20 years. CBNG extraction requires significant volumes of water to be pumped from the coal seams to release water pressure that traps the gas within the coals. The quantity, quality, and dispersal of this water needed to be evaluated.

Summary

Baseline U.S. Geological Survey, DEQ, and local watershed database surveys and a literature search of PRB CBNG produced water found that it is characterized as generally non-saline and ranges from slightly to excessively sodic. Data from the Montana Bureau of Mines and Geology and the Montana and Wyoming boards of oil and gas conservation substantiate these findings. Total dissolved solids concentration ranges from 270 mg per liter to 2,300 mg per liter, with an average of 850 mg per liter. Sodicity ranges from 5 to over 50, with an average sodium adsorption rate (SAR) of 12 throughout the PRB. Generally, salinity and sodicity are lower in the southeastern portion of the basin. The maximum salinity is found just north of the Montana-Wyoming border, and the highest sodicity levels are in the extreme northwestern part of the basin near the Montana-Wyoming border. CBNG produced water undergoes rapid chemical changes once it is exposed to the atmosphere. The water has a rapid increase in sodicity or SAR levels and an increase in alkalinity (pH level).

Phytoremediation for removal of salts and sodic concentrations from the CBNG produced water was determined not to be feasible as a management practice for large volumes of produced water. Salt-tolerant wetland plant species survived and increased significantly in biomass production; in some instances, high evaporation caused the soils to increase in salinity and sodicity over time. Under circumstances where amendments (gypsum and sulfur) were surface-applied to mitigate sodium-induced dispersion, salinity and sodicity of shallow alluvial groundwater increased subsequent to irrigation and abandoned irrigation sites became both sodic and saline over time.

Use of CBNG irrigation for native grasses resulted in uptake of salts, and when harvested or grazed, the excess salts were removed from the system. The amount of salt uptake and removal was determined to be a function of both species selectivity and amount of biomass produced. Salt uptake and removal was disproportionately small relative to the amount of salt sourced in PRB CBNG produced water used for irrigation. The agricultural crop and wetland species most capable of beneficial use of CBNG produced water were maize, hay, forage barley, Altai Basin rye, tall fescue, intermediate wheatgrass, *Atriplex* species, Baltic rush and American bulrush, inland salt grass, and prairie and alkali cord grasses. Irrigation with CBNG water with low total salt yielded crops 300-400% higher in biomass, digestible fiber, and total digestible nutrients than the same crops grown under non-irrigated conditions. In all circumstances where PRB CBNG produced water was used for irrigation of historically non-irrigated alluvial channel soils, surface soil salinity increased. In some instances, subsurface salinity decreased due to leaching of geologic accumulations below the root zone.

Overall, the project found that when used in combination with existing water resources and/or on selected compatible soils, proper irrigation management with CBNG produced water can be effectively used for irrigation of forage for agricultural use and wildlife enhancement. Sustainability of such irrigation practices mandates considerations of routine surface soil management (amendments), long-term availability of PRB CBNG produced water, alterations to shallow alluvial groundwater and contributory sources to receiving streams, and water conveyance habitat changes.

A significant outcome of a subcontracted research component of this project has been the design, development, testing, and patenting of an onsite, mobile water treatment plant specific to the signature of PRB CBNG produced water (details are available at http://waterquality.montana.edu/docs/methane/cbm-wts.shtml). Drake Engineering's water-treatment process is an outgrowth of the MSU project evaluating phytoremediation of CBNG produced water. Through a project subcontract, Drake Engineering designed and developed a prototype of a lab-tested fluid-bed resin exchange treatment system for removing sodium from CBNG produced water. The technology has since been patented, and efforts are underway to begin commercializing the process by field-testing it in PRB CBNG operations. Equipment leasing contracts already are being issued.

Current Status (February 2007)

Research continues on defining the appropriate limits for SAR concentrations and management practices for beneficial use of CBNG produced water. The fourth year of a native forage biomass and phytoremediation study continues at MSU. A continuation greenhouse study is underway to evaluate the terrestrial carbon sequestration potential of American bulrush grown under continuous irrigation with PRB CBNG produced water. The final year of a study to evaluate the hydraulic characteristics of lined and unlined PRB CBNG produced water impoundments is underway. Studies initiated within the PRB to evaluate hydraulic properties of impoundment site locations and remediation of soil sites altered by long-term discharges of PRB CBNG will continue through 2007 and be concluded in fall 2007. Additionally, at the request of landowner groups in the Hanging Woman Drainage, a tributary to the Tongue River, MSU researchers have collaborated in the development of a detailed CBNG produced water management plan, complementary to a plan of development to be submitted for large-scale development of CBNG recovery in Hanging Woman Drainage, MT, in June 2007. A collaborative project has been initiated with MSU's Department of Microbiology, wherein CBNG product water samples will be collected from diverse PRB sites in March 2007 and subsequently filtered and subjected to DNA analyses to identify uniqueness of methanogenic bacteria contained with CBNG source water. Subsequently, a laboratory study will be initiated to assess the potential of enhancing CBNG generation in coal seams from which CBNG has been depleted due to commercial extraction.

Funding
The project was funded through congressional interest in research to investigate PRB CBNG produced water.

Publications
Bauder, J. W., Kimberly R. Hershberger, and Linzy S. Browning, "Soil solution and exchange complex response to repeated wetting-drying with modestly saline-sodic water," Journal of Irrigation Science (submitted January 12, 2007).

Kirkpatrick, A., H. Sessoms, J. Bauder, and Q. Skinner, 2006, "A guide to changing plant communities, with emphasis on salinizing sites in the arid and semi-arid Northern Plains and Mountains Region," Montana State University Extension Bulletin EB 169, Montana State University-Bozeman, MT, 64 pp.

Browning, L. S., J. W. Bauder, and S. D Phelps, 2006, "Effect of irrigation water salinity and sodicity and water table position on water table chemistry beneath *Atriplex lentiformis* and *Hordeum marinum,*" Arid Land Research and Management, 20:101-115.

Keith, K., H. Sessoms, M. Neibauer, Q. Skinner, J. Bauder, R. Waskom, and N. Mesner. 2005. Land and water inventory guide for landowners in areas of coal bed methane development. 1st Edition. Montana State University Extension Service, EB166. 77 pp.

Kirkpatrick, A., 2005, "Assessing constructed wetlands as a management option for beneficial use of saline-sodic product water," M.S. thesis, Land Resources and Environmental Sciences, Montana State University, Bozeman, MT, 116 pp.

Sessoms, Holly., 2004, "Water use potential and salt tolerance of riparian species in saline-sodic environments," M.S. thesis, Land Resources and Environmental Sciences, Montana State University., Bozeman, MT, 73 pp.

Garver, Keri M., 2004, "Assessment of effect of coalbed methane product water intervention on water quality parameters in the Little Powder River at Weston, Wyoming," M.S. thesis, Land Resources and Environmental Sciences, Montana State University, Bozeman, MT, 144 pp.

Robinson (Hershberger), K., 2003, "Effects of Saline-Sodic Water on EC, SAR, and Water Retention." M.S. thesis, Land Resources and Environmental Sciences, Montana State University, Bozeman, MT, 172 pp.

Phelps, Shannon D., 2003, "Effect of Irrigation Water Quality and Water Table Position on Plant Biomass Production, Crude Protein, and Base Cation Removal," M.S. thesis, Land Resources and Environmental Sciences, Montana State University, Bozeman, MT, 188 pp.

"Pipelines and Prairies: Issues in coalbed methane development," documentary video, Montana State University Extension Publication DVD001, Montana State University, Bozeman, MT, (28:30 minutes).

Project Start: September 1, 2001
Project End: September 30, 2007

Anticipated DOE Contribution: $1,649,000
Performer Contribution: $432,500 (20 percent of total)

Other Government Agencies Involved: Bureau of Land Management

Contact Information
NETL – John Ford (john.ford@netl.doe.gov or 918-699-2061)
MSU – James Bauder (jbauder@montna.edu or 406-994-5685)

Wetland site created by surface discharge of CBNG product water.

Plant community transition along an ephemeral stream caused by an increased volume of water and/or water with chemistry different from normal moving into the stream.

Lysimeters (closed-system wetland cells), each containing one of three wetland communities.

Additional images available at http://waterquality.montana.edu/docs/photo/research.shtml