# GROUND WATER AND COALBED METHANE INFILTRATION PONDS IN THE POWDER RIVER BASIN[1]

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**Extended Abstract.** Large volumes of water are produced in association with coalbed-methane (CBM) production. This water must be disposed of economically to enhance gas development activities, yet in a manner that is sensitive to the semi-arid, agricultural area of southeastern Montana and northeastern Wyoming. Several methods of water management, such as infiltration, evaporation, irrigation, and treatment require the use of impoundments. These impoundments may be either lined or unlined and constructed on-channel or off-channel, depending on the design purpose and site-specific conditions.

Ground water produced with CBM is high in bicarbonate, is low or devoid of sulfate, has low concentrations of calcium and magnesium, and has relatively high sodium concentrations (high sodium adsorption ratios). The concentrations of total dissolved solids (TDS) and the sodium adsorption ratios (SAR) in ground water generally increase from south to north in the Powder River Basin. In southeastern Montana TDS concentrations are expected to be between 900 and 1,400 mg/L with values of SAR between 35 and 55.

Unlined "infiltration basins" have been in use in Wyoming and Montana for several years. These basins are designed and sited to infiltrate water into the sub-surface and recharge underlying aquifers. These ponds have several advantages in that they require a low initial investment and can help recharge the shallow ground-water system which then conserves the produced water making it available for future uses.

There are also several potential disadvantages to unlined ponds. The infiltrated water tends to stay fairly shallow and moves laterally as well as vertically. Due to this shallow flow, the water does not recharge the deeper aquifers from which it was produced, but rather, adds water to the shallow system. Depending on the site-specific hydrogeologic setting, infiltrated water could percolate downward to recharge existing aquifers or may intersect an aquitard. If an aquitard is encountered the water may saturate previously unsaturated zones, or may flow horizontally to the outcrop and form seeps along hillsides. This increased flow into aquifers or from seeps may augment stream flows, and potentially alter surface-water quality, but at the research sites of this study, no changes in the surface-water flow or quality have been observed.

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Our study has shown, however, that the rate of infiltration from ponds decreases with time. Clays in the material in the bottoms of the ponds disperses, blocking flow paths, due to the sodium concentration in the CBM-produced water. The effective life of infiltration ponds is site specific and depends upon the type and abundance of clay.

As the infiltrated water moves through the shallow weathered bedrock, a known series of chemical reactions take place (primarily dissolution and oxidation) which increase the TDS, the concentrations of all cations, and the concentration of $SO_4$.

Preliminary interpretations of data from three sites suggest that the changes in water quality that will occur as CBM-production water infiltrates into the shallow aquifers can be predicted based on saturated paste extracts (SPE) analyses and lithologic investigations. In off-channel sites, significant increases in TDS, Mg and $SO_4$ will occur. At one site the increase in TDS has exceeded about 8 times the baseline concentrations; increases at other sites are less dramatic. More recent samples indicate that decreases in TDS concentrations are occurring. The decrease probably occurs due to flushing of the available salts from the flow paths and due to the decrease in flow as the rate of infiltration decreases.

In on-channel sites, a mix of increases and decreases in TDS were measured. Increases of $SO_4$ and TDS are nearly double the baseline concentrations. Where decreasing concentrations occurred, concentrations of $SO_4$ and TDS have dropped by as much as 75% and 67%, respectively, in response to relatively lower TDS CBM-production water.

The depths and areas where changes occur in ground-water quality are limited. At one site, changes were measured directly beneath the pond at depths of 6 feet and 23 feet, but the water quality in the aquifer 35 feet beneath the pond did not respond. At this same site, changes in water quality have been limited to an area within about 200 feet of the pond.

The changes in water quality are controlled by available soluble minerals in the shallow soil and bedrock profile. Calcite, dolomite, and gypsum are common minerals in the Powder River Basin. Dissolution of these minerals increases Ca, Mg, and $SO_4$ concentrations. Pyrite ($FeS_2$) may be involved in the reactions in some settings, further increasing $SO_4$ and Fe concentrations. Increases in Fe are rare in the data collected during this study and suggest that pyrite may not be a significant source of $SO_4$. In on-channel sites where natural ground-water recharge and flow have flushed the salts from the alluvial aquifer, water quality may be diluted by CBM-production discharge.

At off-channel ponds, the quality of the infiltrating water has shown little effect on the ultimate water quality within the time frame of the current study. Mineralogy and available salts control the reactions and final concentrations, which so far exceed any CBM-production water ionic concentrations. For this reason, the Na concentration in the CBM-production water is less of a concern than is the increase in total salt load.

The duration of water-quality impacts is not yet known. Based on research in coal mine spoils aquifers, at least one pore volume of water must move along the flow path to flush the immediately available salts prior to any decrease in TDS. In some cases, more than one pore volume will be necessary before improvement is seen.

The results of decades of mine spoils research provides appropriate methods for assessing CBM infiltration ponds. The mineralogy and reactions are very similar and the SPE data can be used to successfully predict water-quality trends. Both sites and specific depths with generally high levels of available salts can be identified and avoided during the pond-design phase. Relative concentrations of cations are particularly appropriate for SPE assessment, giving reliable estimates of SAR values.

Proper management of CBM infiltration ponds requires proper sitting, monitoring, and adaptive management. The proper sitting and monitoring of ponds must be based on site-specific conditions such as soils, stratigraphy, ground-water and surface-water. Adaptive management should follow from monitoring information.

The study sites chosen for this research have been well established with monitoring wells and stream gauging stations. Coal mine spoils studies have shown the value of long-term studies and similar continued research is vital to successfully evaluating CBM ponds. The research now underway at these sites should be maintained until recovery of water quality in underlying aquifers is documented.