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COAL BED METHANE PRODUCED WATER REINJECTION

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I. Overview of Coal Bed Methane Impacts and Issues – CBM Produced Water

The magnitude of the projected Coal Bed Methane development in Montana and Wyoming is staggering. Recently, the BLM issued a "Reasonably Forseeable Development Scenario for Oil & Gas Development" (RFD) to cover the 5 areas of the CBM EIS in Montana. BLM provides a forecast range of 14,019 (low) to 39,520 (high) wells—or an average of 26,770 wells--will be drilled during the next ten years. Exhibit 1 is a tabulation of the BLM RFD by county, tribal, and BLM RMP areas. This unprecedented level of drilling and producing activity poses unprecedented environmental risks and impacts over a vast geographic area in SE/SC Montana. The cumulative environmental and socio-economic impacts for roads, drilling sites, treatment facilities, compression, pipelines and gathering lines, electric transmission/distribution lines and facilities, etc. are extraordinary and would radically change the nature of SE/SC Montana. (These infrastructure-related surface impacts are beyond the scope of this "CBM produced water reinjection" paper.)

Importantly, the CBM gas development involves joint production of substantial quantities of saline produced water, which present extreme and intractable environmental threats. The Coal Bed Methane Coordination Group's (10/2000) "typical well" production forecast (decline curve) indicates total (cumulative) gas production of 300,000 MMCF and about 250,000 barrels of saline water (BW) per well during its economic life**. Based on BLM's RFD mid-range estimate of 26,770 drilled wells (24,093 producing wells), the cumulative produced water forecast would be nearly 6.0 billion oilfield barrels (42 gallons per barrel) of water in Montana—which would cover 1,213 sections of land 1 foot deep (or 135 Townships 3 inches deep) with saline produced water.**

The magnitude of the CBM produced water disposal issues and impacts is mind-boggling. Furthermore, the runaway CBM development in upstream Wyoming -- where CBM estimates approach *50,000-70,000 producing wells* -- dwarfs the Montana activity and magnifies the cumulative impacts on Montana. *The cumulative CBM produced water impacts and issues must be resolved now! This paper concludes that unless CBM produced water is reinjected into the same coal zones, the resulting impacts upon both the surface ecosystem and coal bed aquifer depletion would be extreme and unacceptable. Comprehensive EIS conditions must also established that requires "best practices" be developed and implemented to ensure against contamination and "communication" outside the coal zone (to other formations and/or surface.)*

II. CBM Impacts and Risks Demand Comprehensive Action by Federal & State Agencies in EIS

The vast geographic scope and magnitude of the cumulative CBM impacts demand unprecedented actions by state and federal agencies to ensure that SE/SC Montana is not sacrificed to CBM development. It is essential that the EIS rigorously identify the cumulative impacts and require that comprehensive mitigation conditions be applied to all CBM activities throughout Montana. The State of Montana and federal agencies have a once in a lifetime opportunity and responsibility to establish prudent rules of the game **before** significant CBM exploration and development commence in Montana. The MDEQ / MBOGC / DNRC / BLM / EPA / USGS / Others have an extraordinary responsibility to assure that CBM development meets Montana's Constitutional right to a "clean and healthful environment". The outcome of the EIS process must require that any CBM development that is allowed must be conducted in the "Right Way from the Get Go". *CBM development must cover its full societal costs. Anything less must be judged uneconomic, unjustified, unacceptable and unlawful.*

Furthermore, because the impacts of CBM development reach across state lines, it is essential that the federal and state agencies establish the most responsible and prudent practices as "model standards" for the region. Montana is directly and adversely impacted by the lack of comprehensive environmental standards for CBM development in "upstream" Wyoming. Therefore, it is essential that the federal agencies use the Montana EIS on CBM as a "model process and framework" for prudent CBM development and apply equivalent standards on federal lands in Wyoming and the region. Furthermore, the State of Montana and the federal agencies must act aggressively to assure that the Wyoming approach to CBM development on private and state lands does not damage Montana and US lands. Responsible standards for CBM development must not be driven by the lowest common denominator!

III. CBM Produced Water Quality Is Marginal / Poor

CBM produced water quality is marginal to poor for most uses and is not acceptable for irrigation. There are now extensive water quality samples of the CBM produced water from the CX Field in Montana. Redstone Gas Partners (now Fidelity Exploration and Production) submitted a Report to the Montana Board of Oil and Gas Conservation in Docket 155-2000, December 14, 2000 for permanent spacing in CX Field. The Report provides useful public information relative to the Land, Geology, Hydrology, Production, Engineering and Water Quality Data and Monitoring. Redstone's Exhibit H-3a, Docket 155-2000, is a copy of summary water quality data from each of the three primary coal zones produced at CX Field. Provided below are three key elements:

Coal Zone	**Tot. Dissolved Solids (TDS)** *Mean mg/l*	**Sodium** *Mean mg/l*	**SAR** *Mean*
Dietz 1,2,3	1308	529	42.2
Monarch	1333	541	50.6
Carney	1473	572	29.7

Given the extraordinary volumes (i.e., 6.0 Billion barrels) of poor quality CBM produced water forecasted in Montana, *it is essential that the produced water disposal issue be resolved in the EIS* ***prior to CBM development***.

IV. Reinjection / Recycling of CBM Produced Water into Coal Zones

CBM saline produced water discharges constitute extreme risks and impacts to the entire ecosystem in the CBM EIS region as outlined above. Surface discharge / disposal of CBM produced water, which is currently being allowed in both Montana and Wyoming, poses significant threats and irreversible impacts to the environment. Obviously, surface "discharge / disposal / dumping" is the "cheapest and easiest" method for CBM producers, but such surface discharges certainly do not satisfy prudent or reasonable standards of operation in meeting statutory requirements and Montana's constitutional standard. Untreated surface water discharge of CBM produced water cannot be deemed acceptable, prudent or lawful given the significant environmental risks, uncertainties and impacts upon the ecosystem. Prudent and responsible actions must assure that the overall natural systems balance is substantially preserved (i.e., maintain the status quo) for both the surface waters and subsurface aquifers. Surely, in this new millennium it is unconscionable to allow major resource development with unprecedented environmental risks before adopting comprehensive conditions and protections.

The most direct and prudent approach to dealing with and mitigating both surface and subsurface risks and impacts is to require reinjection of the unaltered produced water into the coal seams / producing zones of origin. Reinjection is and has been a recognized and responsible method for produced water disposal (and pressure maintenance) in the petroleum industry for decades. For example, BP (formerly Pan American Petroleum Corp. and Amoco) commenced treating and reinjecting oil field produced water in giant Salt Creek Field in the early 1970's—shortly after the Clean Water Act—as both produced water disposal and water flood pressure maintenance methods.

As stated in BLM's Onshore Oil and Gas Order No. 7; Disposal of Produced Water, the preferred produced water disposal method is injection:

> *"All produced water from Federal/Indian leases must be disposed of by (1) injection into the subsurface; (2) into pits; or (3) other acceptable methods approved by the authorized officer, including surface discharge under NPDES permit.* ***Injection is generally the preferred method****." (Italics and Bold added)*

Reinjection into the same coal zones eliminates/mitigates the full range of adverse *surface water impacts*, including damage to aquatic and wildlife ecosystem, threatened and endangered species, natural surface irrigation water / reservoirs (e.g., Tongue), soil contamination, crops and recreation values of the rivers and streams.

Reinjection (recycling) of CBM produced water into the coal seams also mitigates the risk and impacts to the existing coal bed aquifers. Reinjection (recycling) of unaltered CBM produced water (back) into the CBM producing zones is the only responsible method to substantially preserve and restore the hydrostatic balance in the coal bed aquifers. Potential formation "damage or contamination" is minimized by

reinjecting the unaltered CBM produced water in a closed loop system into the same coal zones. The pros and cons of reinjection are separately outlined in Section V.

1. Reinjection Plan

Because CBM water production rates are at *maximum levels* at the outset of production, it is essential that a program / plan for reinjection and/or injection into acceptable subsurface formation(s) be established prior to production operations. A rational strategy and pattern of reinjection wells must be proposed and built into the exploration and development program by CBM developers. Geologic and hydrologic studies and exploration drilling / testing results should provide guidance concerning the outer limits of gas production. Given the level of CBM E&D drilling that has already occurred in Wyoming and Montana, there should be a substantial base of shut-in and high water/gas ratio wells that could be used for reinjection.

Since CBM producing wells are connected to batteries, PODS or produced water outflow /discharge points by gathering lines, it should be relatively inexpensive to convert "marginal" gas wells to reinjection wells. *Again, it is essential that the requirement to reinject CBM produced water be built in to the entire exploration and development plan to minimize both the cost and impacts associated with "redoing" field designs*. Likely and desirable reinjection well candidates would:

(a) produce (or have produced) at significant water rates (i.e., high permeability to water and corresponding high water injection rates) and low gas rates;
(b) be located structurally lower, on the flanks of reservoir(s) or other portions of the fields that are marginal; and otherwise depleted areas

Obviously, fault blocks and other trapping mechanisms may influence the producing characteristics and location of reinjection wells. Other reinjection patterns could also be tested. Injection manifolds and pumps would be located at existing batteries or outflow/discharge points as necessary to establish reinjection -- in lieu of surface discharge and dumping. Design and operation of reinjection systems should be required in all exploration and development leasing, drilling and development plans. It is essential that state and federal agencies require "best practices" be established for reinjection, reporting, onsite monitoring and inspection of reinjection programs. Early unitization of CBM fields should be encouraged to assure that: correlative rights are protected, gas and water production operations are conducted and water reinjection is optimized.

2. Water & Gas Production Characteristics – CX Field, MT

The CBM well production histories for gas and water at CX Field (MT portion), operated by Fidelity, suggest that the relative quality of the CBM "gas" wells can be determined within the first several months. Many "poor / marginal" gas wells produce significant quantities of water. Shutting-in and converting such wells to reinjection would minimize the environmental impacts of the water discharges with very little impact on gas production. As long as these marginal wells are allowed to "discharge / dump" to the surface and do not face the real social and environmental cost of acceptable disposal, those environmental costs are shifted to the public and surface owners.

[Reinjection and or shutting-in high water wells may also enhance producing rates and ultimate gas recovery at better quality wells through a pressure maintenance effect.]

Exhibit 2, pages 1-3, is a summary tabulation of the monthly CBM gas and water production for "marginal" wells for the three CBM coal formations/zones which are productive in CX Field—Dietz 1,2,3; Monarch; and Carney through December 2000. There are 40 wells that are excellent candidates to be shut-in and converted to reinjection wells. Individual well monthly production histories were "aggregated" to develop the coal "zone totals" for marginal wells. Provided below is a December 2000 production summary, which illustrates the urgency and relative value of early action to require re-injection at CX Field:

Formation	No. Wells	Mo.Gas MCF	Water BW	BW/MCF
Dietz 1,2,3	7	4,294	222,668	51.9
Monarch	15	4,079	184,175	45.2
Carney	18	3,528	163,680	46.4
Total	**40**	**11,901**	**570,523**	**47.9**

It is obvious that simply shutting-in 40 "marginal wells" (producing less than about 10 MCFD per well) would reduce CX Field gas production by only 384 MCFD (11,901 MCF / 31 days), *while reducing saline water production and discharge by 18,400 BWPD (570,523 BW / 31 days) or 536 gallons per minute (gpm).* As illustrated on Exhibit 3 the December 2000 production for these marginal wells represent only 2.2% (11,901 MCF/ 549,456 MCF) of the gas production but 38.6 % (570,523 BW / 1,477,872 BW) of the water production. Montana agencies (DEQ & BOGC) must act immediately to require shut-in to eliminate further water discharges from these wells**.**

Exhibit 2, pages 1-3, also illustrates the importance of early identification of marginal wells to be shut-in and converted to reinjection. Cumulative results (through 12/2001) from the seven marginal Dietz wells indicate that they have produced only **1.9% of the gas but 33% of the cbm water for the Dietz 1,2,3**. The 15 marginal Monarch wells have produced only **4.4 % of the gas but 51.1% of Monarch water**. The 18 marginal Carney wells have produced **5.3% of the gas production but 41.5% of the Carney water production**.

Converting these wells to reinjection would reduce saline produced water impacts on both the surface and aquifer depletion. It can be reasonably assumed that water "reinjection rates" into these wells would approximate the water "production rates", especially given that the maximum water production rates to date for these wells have been higher. Under this assumption the net effect of establishing reinjection at these wells would be to reduce cbm discharges by 36,800 BWPD (or 1,072 gpm). It is, therefore, reasonable that surface discharges at CX Field could be eliminated entirely. (Redstone's Vice President, Mr. Caskey, testified before Montana's U.S. Senators Burns & Baucus in Billings that their January and February discharges were less than 1,000 gpm.) Individual well analysis (kw, zone thickness, etc.), re-injection patterns, structural position and other factors may also be considered.

*The fundamental point remains—**immediate reinjection** of CX Field produced water is feasible and desirable.* Eleven water discharge permits by the MT DEQ under the moratorium in the CX Field settlement were issued for CX Field during the moratorium period. Rapid elimination of these early discharges through an immediate

reinjection requirement for CX Ranch is necessary to prevent continued damage to the ecosystem and to assure a level playing field for all producers after the CBM EIS is issued and conditions for responsible exploration and development are established. Since CX Field (Montana portion) has produced for about 17 months, there is significant "reservoir or aquifer space" available for reinjection to commence immediately. Cumulative CX Field (MT) production through December 2000 approximates 3.67 million MCF of gas and **21.3 million barrels of water.** The goal is to require (1) reduction / minimization of cbm water production by shutting-in high W/G ratio wells and (2) reinjection of CBM produced water.

V. Conclusion

Federal and state agencies must adopt produced water reinjection and disposal requirements in the EIS decision and implementation. The federal and state agencies must also place the burden squarely on producers to propose and establish a comprehensive plan of CBM exploration and development that satisfies the "core" EIS requirement reinjection (recycling) of CBM produced water into the producing coal formations prior to leasing, exploration and development. Federal and state agencies must evaluate specific plans prior to approval of leasing, exploration and development. Furthermore, federal and state agencies must monitor and enforce compliance with of approved produced water reinjection programs.

VI. Outline of Pros and Cons of Re-injection and / or Subsurface Disposal of CBM Produced Water

Pros

- Reinjection (recycling) of unaltered CBM produced water back into the coal seam(s) from which it was produced eliminates the full range of surface water discharge/disposal issues

    - Damage to ecosystem in drainage short and long term: fish, aquatic life, threatened and endangered species, wildlife, migratory patterns, saline damage to streambed, infiltration and evaporation effects on alluvium and surface waters, introduction of exotic species of plants and animals, post production effects (when CBM water ceases), irreversible impacts and reclamation risks
    - Degradation of irrigation and reservoir water quality with resulting contamination and damage to quality of irrigation water, resulting in soil contamination and reduced crop yields from high sodium content (approx. 550 mg/l) and sodium adsorption ratio (SAR) of about 30-50.
    - Threatens water compacts and irrigation water rights of private and tribal interests

- Reinjection also preserves coal bed aquifer pressure by recycling and recharging rather than depleting water and pressure from coal bed aquifers from which springs and water wells for stock and some human consumption are fed. Tends to maintain natural balance.

    - Avoids/mitigates methane seeps and gassing / foaming action from nearby local wells
    - Mitigates risk of surface and subsurface coal bed fires
    - Substantially maintains or reestablishes coal bed aquifer pressure, reducing aquifer water depletion and "subsidence" concerns for shallow coals

Cons and Problems

- Problematic at outset of production, since methane production typically requires a pressure drop via water production to release or increase gas rate
- Industry opponents contend / argue that reinjecting (recycling) produced water back into same formation defeats the purpose and necessity of drawing down the pressure to release the CBM gas that is adsorbed to coal surface and held by water pressure—need to produce even very high water/gas ratio wells as a "system" to deplete reservoir pressure and maximize gas
- Industry is concerned about increased operating cost associated with reinjection (or other subsurface injection requirement or "treating") – obviously "discharging / dumping" to surface drainages is the "lowest cost"
- Landowners who rely on the coal bed aquifer(s) are concerned that re-injection into coal aquifer will "contaminate or otherwise damage" the aquifer—it is, therefore, important to recycle unaltered CBM water in a closed loop system from production to battery to re-injection wells

B. Injection into Other (Non-CBM) Subsurface Formations

For purposes of this paper, there is a distinction between (1) "reinjection" into CBM coal seams from which the water is produced and (2) "injection/disposal" into other "acceptable" subsurface formations. While subsurface injection of produced CBM water avoids surface discharge impacts in the same manner as CBM reinjection, *it does not avoid the coal bed aquifer depletion and related benefits of recycling back into CBM formations described above.* Once the CBM produced water is either discharged to surface or injected into other deeper horizons, it is "lost" to the coal bed aquifer.

Reinjection into the coal aquifer may problematic during the very early exploration and development period in virgin areas. Injection into a different, deeper formation(s) may be necessary and could be drilled at the outset to allow an initial / threshold pressure draw down of the CBM coal formation to establish CBM gas production--after which full reinjection would commence. It incumbent on CBM developers and the federal/state agencies to evaluate alternative subsurface injection / disposal options Because of the initial pressure draw down requirements for CBM gas production in virgin areas, it may be necessary to initially use a combination of deeper injection into other subsurface formation(s) until CBM wells are produced and evaluated for several months and a threshold level of pressure draw down in CBM reservoir occurs. At that point full CBM "reinjection" into the CBM zones of origin must commence.

Problems with Injection / Disposal

- Because water chemistry of alternative subsurface formations may differ from that of CBM produced water there is a possibility of reactions, plugging or other formation damage to receiving formation
- Injection into other formations should not degrade receiving formation water quality i.e., CBM produced water should not be injected into better quality water formations
- Determining which "deeper" formations are acceptable for CBM produced water disposal will require drilling and testing to establish injection rates
- Pennaco operates three CBM fields near Gillette, Wyoming, where they inject CBM produced water (500-700 mg/l TDS) into deeper formations [Fort Union members: Lower Tongue, Lebo, Tallock], which are of higher saline content (800-900 mg/l) but are public water supply zones
- Injection into other zones does not address the issues outlined above related to coal bed aquifer depletion, gassing, fires, etc. It would represent a "disposal" method rather than a recycling approach

About the Author

Thomas J Schneider holds a B.S. in Petroleum Engineering with honors from Montana Tech, June 1970. He received the Gold Medal Award from the Montana Society of Engineers as the Outstanding Graduate of 1970 at Montana Tech. He was employed in progressively responsible petroleum engineering positions 1970-76 throughout the Rocky Mountain region with Amoco Production (Casper; Denver), Philips Petroleum (Cut Bank), Bison Operating Company (Billings) and as an individual consultant.

Schneider served two terms as a publicly-elected Commissioner (1977-84) and Chairman (1983-84) of the Montana Public Service Commission. He testified on behalf of the Montana PSC before FERC, Canadian NEB, BPA, Montana legislature and Congressional subcommittees. As a Commissioner he testified before the Montana Board of Oil & Gas Conservation in the early 1980's regarding "tight sands" 107(c) 5 issues.

Schneider established a national consulting practice in 1985. He has provided professional services on electricity, natural gas, telecommunications, anti-trust, royalty issues and other public policy matters. He has testified as an expert witness before regulatory commissions in nine (9) states, a federal District Court in Pennsylvania and state District Court in Montana. He provided consulting services on behalf of Plaintiffs in the "Wyoming Tight Sands" anti-trust case 1986-89. He performed consulting services on behalf of royalty owners in a lawsuit involving CO2 production in Colorado and New Mexico 1996-97 for use in tertiary oil recovery in Texas. A complete resume will be provided upon request of the agencies.