FILED

FEB 1 0 2006

Terri A. Lorenzon, Director
Environmental Quality Council

Williams Production RMT Company
300 North Works Avenue
Gillette, WY 82716
307.686.1636
307.686.7574 (fax)

February 9, 2006

Terri A. Lorenzon, Director
Wyoming Environmental Quality Council
122 W. 25th Street
Herschler Building, Room 1714
Cheyenne, Wyoming 82002

Re: Petition to Amend Wyoming Water Quality Rule, Chapter 2, Appendix H

Dear Director Lorenzon:

On December 7, 2005, The Powder River Basin Resource Council et al. ("Petitioners") filed a Petition with the Environmental Quality Council ("EQC") to amend Wyoming Water Quality Rules and Regulations ("WQRR"), Chapter 2, Permit Regulations for Discharges to Wyoming Surface Waters. Williams Production RMT Company ("Williams") believes that the current Water Quality Rules adequately control coalbed methane ("CBM") facility discharges. The proposed amendments would interfere with the current water appropriation, distribution and diversion system in Wyoming, and would expand the current Wyoming Pollutant Discharge Elimination System ("WYPDES") permitting program beyond the limits of its statutory authority.

More importantly, the PRBRC proposal would not meet the purported objective of maximizing the beneficial use of Wyoming water. To the contrary, by forcing re-injection and other alternative disposal methods, it would have the unintended consequence of wasting water and limiting its availability for use by Wyoming farmers, ranchers and others. The Petitioners' purported support of treatment options is only a panacea, since many of the treatments are not technologically proven and each creates its own disposal issues.

No amendment of the WQRR is needed at this time. Williams respectfully requests that the EQC deny the petition to initiate rulemaking.

I. <u>Background</u>

The Wyoming Constitution provides that the Board of Control, which includes the State Engineer and superintendents of water divisions, shall "have the supervision of the waters of the state and of their appropriation, distribution and diversion." Wyo. Const. Art. 8, § 2; Wyo. Stat. Ann. § 97-8-002. The State Engineer's Office has the primary responsibility for the regulation of quantities of water used, discharged and

Attachment 1

distributed throughout Wyoming. It is the State Engineer's job to make sure that State waters are put to beneficial use.

In contrast, the Wyoming Department of Environmental Quality's ("DEQ") authority to regulate water is focused on the quality of State waters and discharges into these waters. DEQ regulates water quality by implementing regulations developed to meet requirements under both the Wyoming Environmental Quality Act and the federal Clean Water Act ("CWA"). Wyo. Stat. Ann. § 35-11-101 et seq.; 33 U.S.C. § 1251 et seq. The broad purpose of the Environmental Quality Act is to protect State air, land and water resources. Wyo. Stat. Ann. § 35-11-102. Similarly, in the area of water quality protection, the CWA prohibits the unauthorized discharge of pollutants into waters of the United States. 33 U.S.C. § 1311. At the time the United States Congress passed the CWA, it wanted to control the amount of various contaminating substances discharged so that water quality could be improved or maintained. The CWA originally focused on the control of the discharge of conventional polluting substances e.g., BOD, TSS and pH, and was amended to include toxic and priority polluting substances. 33 U.S.C. §§ 1314(a)(4), 1317(a)(1).[1]

The WYPDES permit program, Wyoming's version of the CWA's pollutant discharge permit program, establishes limits on the discharge of specific chemical compounds. By controlling the discharge of specific chemical compounds, the WYPDES permit program ensures that water discharges have the <u>potential</u> to meet certain uses, e.g., agricultural or wildlife. The purpose of this program is not to ensure that such discharges are 100% used since the program must operate within existing constraints for the control of water within the State. The CWA expressly states, "[T]he authority of each State to allocate quantities of water within its jurisdiction shall not be superseded, abrogated or otherwise impaired [by the CWA permit program]. 33 U.S.C. § 1251(g); Wyo. Stat. Ann. § 35-1-1104(a).

II. <u>State Engineer Controls Water Quantity and Beneficial Use</u>

The Petitioners request that the EQC change the WYPDES permit program in a fundamental way. The Petitioners want DEQ to police and control the quantities and distribution of waters in the State and want DEQ to ensure that each and every drop of CBM water discharged is used. Such a request is misguided. The amendment the Petitioners request cannot be implemented for practical reasons and should not be considered for constitutional and statutory reasons.

DEQ currently evaluates and regulates CBM facility discharges in a comprehensive, thorough way. DEQ authorizes certain produced water discharges from CBM production facilities, if such discharges meet specified standards. WQRR, Chs. 1, 2. The standards have been methodically and carefully developed. The Appendix

[1] Coal bed methane produced water contains certain conventional pollutant parameters which are regulated.

H(a)(i) standard is one of many limits placed on CBM produced water discharges. Appendix H(a)(i) requires that discharged produced water be suitable for agriculture or wildlife use and be put to such use during periods of discharge. This current standard makes sense.

The Petitioners seek to maximize the beneficial use of produced water discharges by demanding proof of 100% actual use of discharges by livestock, wildlife or agriculture. This is unreasonable and impractical. Wyoming adopted the Appendix H(a)(i) standard because it knew that discharges of produced water from facilities in the arid western United States could be used beneficially. See Exhibit 1 (Petitioners' Exhibit 5). However, in an arid climate, the goal has never been to consume 100% of existing surface water or to dispose of discharged water without any use. Such assumptions remain true of CBM produced water today.

In Wyoming, where surface water has generally been scarce, water use develops from the presence of water. Contrary to Petitioners' assertion, produced water in Wyoming is generally being used. Wildlife, livestock and plants are attracted to and collect where they find water. It is impossible to predict how much water an animal or plant will use from a water source or on what schedule in any given year. Petitioners' proposed amendment to the WQRR would require WYPDES permit applicants to forecast animal and plant consumption patterns which cannot be determined. The proposed amendment would require DEQ to confirm such predictions for a specific drainage and then regulate quantities of produced water discharged under WYPDES permits to ensure that such consumption needs were met. Permittees would be required to adjust the timing and amount of discharges to meet agricultural irrigation schedules and livestock and wildlife drinking schedules. Requiring WYPDES permittees to release water with such precision is impractical.

The Petitioners' proposed amendment also would have an effect beyond how oil and gas operations, whether conventional or CBM, are operated. It would have a direct effect on and interfere with appropriated water rights. Despite the claims of many of the Petitioners, farmers and ranchers in many drainages depend on and frequently use substantial quantities of discharged produced water for agricultural and livestock propagation purposes. Appropriated water rights incorporate certain assumptions about produced water discharge levels and are dependent on the release of such water. The proposed amendment would adversely affect many of these appropriated water rights, again interfering with water quantity allocations established by the State Engineer. If 100% use criteria were required before a permittee could discharge water, the operator could choose to cease producing gas in a certain area or choose to consider options where there is <u>no</u> beneficial use, thus depriving Wyoming farmers and ranchers of a plentiful source of water for their crops and livestock. In many cases, the Petitioners' proposal, if adopted, would harm the very citizens in rural agricultural communities it seeks to protect. The Petitioners' "all or nothing" approach does not meet the water needs of many landowners in arid Wyoming.

On the other hand, assuming a WYPDES permittee could prove 100% use of produced water, the permitee could continue to discharge as much water as it produced, without ever reducing the quantity of water discharged. This would meet Petitioners' 100% use goal but could exacerbate rather than solve flooding or other issues accurately or inaccurately attributed to produced water discharges.

The proposed amendment would distort the purpose of the WYPDES program and would interfere enormously with the distribution of water in the State. The State Engineer, not the DEQ, is the regulatory entity authorized to distribute and divert waters of the State on specific schedules to meet the multiple water resource demands within the State. For that reason, our legislature expressly precluded the DEQ from interfering with the jurisdiction, duties or authority of the State Engineer or the Board of Control. Wyo Stat. Ann. § 35-1-1104(a).

The practical effects of the Petitioners' proposal would be significant. The WYPDES permit program is not a program meant to manipulate the quantity and distribution of water in Wyoming. It is essentially a water quality permit program and should remain one.

III. Appropriate WYPDES Standards Exist

Chapters 1 and 2 of the WQRR currently provide DEQ with appropriate directions and standards to protect Wyoming water quality consistent with the mandates of the Wyoming Environmental Quality Act and the CWA. Wyoming very recently completed its triennial review of Chapter 2 of WQRR. Citizens had numerous opportunities to comment and participate in the amendment of the WQRR, including any revisions to Appendix H. The EQC already considered and rejected proposals strikingly similar to that of the Petitioners during the 2004 deliberations. No revisions to these rules are necessary, particularly to regulate water quantity per se.

The WYPDES permit application is detailed and extensive. See Exhibit 2 (WYPDES Permit Application). DEQ evaluates requests for WPDES discharges on an area-specific basis; DEQ considers the type of facility whose discharges will be authorized and the nature of downstream facilities which require protection. Before granting a WYPDES permit, the permit applicant supplies data and DEQ evaluates whether the proposed representative discharge contains any of 25 chemical parameters, including barium, pH, chlorides and sodium adsorption ratio. Id. at § 14. DEQ also evaluates control measures that the applicant proposes to implement to prevent erosion of the receiving water channel and measures used to meet chemical parameters. Id. at §§ 9, 10. DEQ reviews the applicant's flow volume estimates and considers the nature and quality of the receiving water before issuing a WYPDES permit. Id. at §§ 15, 16; WQRR, Ch. 1.

The Appendix H(a)(i) limit is not the only basis for determining whether a CBM facility can discharge produced water in Wyoming. Appendix H also identifies multiple additional criteria which a permittee must meet in order to discharge CBM produced water. Some of these criteria include numeric limits on certain identified substances e.g., chlorides, sulfates, total dissolved solids, and other criteria describe general principles which must be met e.g., erosion control. Appendix H, b(ii), (iv), (vii).

DEQ has not turned a blind eye to quantity, but rather has incorporated it appropriately into its regulatory control of specific contaminant discharges. The combination of the numeric limits and other general principles makes the Appendix H criteria more stringent than the federal discharge criteria for conventional oil and gas operations. Exhibit 1; 40 C.F.R. § 135.52.

IV. Nexus Required Between Water Quality and Water Quantity

The Petitioners readily admit that DEQ evaluates the interplay of water quantity and water quality in many contexts. Exhibit 3 (Petition to Amend Wyoming Water Quality Rule, Ch. 2 Appendix H, pp. 13-14). However, the CWA and implementing regulations in Wyoming do not and should not require that DEQ establish volume limits per se on produced water discharges in WYPDES permits. The CWA cases the Petitioners cite also do not support such an interpretation of DEQ's WYPDES permitting authority.

The Petitioners cite no 10th Circuit cases which involved requests for NPDES authorization of discharges, much less authorization for discharges of produced water in an arid region.[2] Several of the cases cited involved requests for authorization to discharge dredged and fill materials into waters of the United States in connection with the proposed construction of dams. *PUD No. 1 of Jefferson County v. Washington Dept. of Ecology,* 511 U.S. 700 (1994); *Riverside Irrigation District,* 758 F.2d 508 (10th Cir. 1985); *Alameda Water & Sanitation Dist. v. Reilly,* 930 F. Supp. 486 (D. Colo. 1996). Section 404 of the CWA authorizes the U.S. Army Corps of Engineers ("Corps") to issue permits for the discharge of dredged or fill material into regulated waters. 33 U.S.C. § 1344(a). Before issuing a Section 404 permit, the Corps must evaluate whether a proposed discharge of fill material complies with certain EPA guidelines; the guidelines require the agency to evaluate potential impacts of the discharge to the physical, chemical and biological characteristics of the aquatic ecosystem including current patterns and downstream flows. 40 C.F.R. § 230.11. (Emphasis added).

The CWA discharge authorization requested in the cases cited by the Petitioners is not the same authorization requested under the WYPDES program. By definition, dam construction requires that fill material (dirt, rock, concrete) be placed in an

---

[2] The Petitioners did cite one 9th Circuit case that dealt with CBM produced water. *Northern Plains Resource Council v. Fidelity Exploration and Development Co.*, 325 F.3d 1155 (9th Cir. 2003). However, this case addressed the question of whether the discharge of produced water required an NPDES discharge permit in the first instance, and not whether the quantity of water was appropriately regulated under such a permit.

existing stream or channel which typically transports water. The fill material blocks the regular flow of the water, thus impacting the physical characteristic of the aquatic ecosystem. The courts in each of these cases discussed water quality in connection with water quantity since water quantity (the existing stream flows) would be altered (significantly reduced) if the CWA permits were granted.

The Petitioners have not identified any cases where a state asserted authority to regulate the volume of water discharged directly into a waterway, as opposed to cases where the discharge of fill material was regulated due to potential impacts on stream flow. The Petitioners quote language from *United States v. Earth Sciences*, 599 F.2d 368 (10th Cir. 1979) and *Quivira Mining Co. v. U.S. Envt'l Prot. Agency*, 765 F.2d 126 (10th Cir. 1985) in support of the assertion that the DEQ should regulate water quantity as part of the WYPDES program. The courts in these cases did not evaluate a state's ability to regulate the quantity of water discharged under a program like the WYPDES permit program. The language the Petitioners quoted from these cases merely offers a general paraphrasing of the purposes of the CWA, unsubstantiated by statutory analysis.

V. <u>Request for Petition Denial</u>

DEQ must ensure and regulate the quality of whatever quantities of water a WYPDES permit applicant proposes to discharge into the State's surface waters. DEQ, through the WYPDES permit program, allows certain discharges which the Department determines will not degrade the quality of Wyoming's waters. There is no need to amend Chapter 2, Permit Regulations for Discharges to Wyoming Surface Waters. The Petition should be denied.

Sincerely,

Joe Olson /eau

Joe Olson
Facilities Engineer

Department of Environmental Quality

To protect, conserve and enhance the quality of Wyoming's environment for the benefit of current and future generations.

Dave Freudenthal, Governor

John Corra, Direc

April 25, 2005

FILED

FEB 10 2006

Terri A. Lorenzon, Director
Environmental Quality Council

Mr. Stephen Tuber
Assistant Regional Administrator
Office of Partnerships and Regulatory Assistance
U.S. EPA, Region 8
999 18th Street - Suite 300
Denver, CO 80202-2466

RE: Factors Considered for Developing BPJ Limits for Coal Bed Natural Gas

Dear Mr. Tuber:

This document has been prepared in response to EPA's September 16, 2004 letter to WDEQ in response to the March 5, 2001 *Petition for Corrective Action or Withdrawal of the State of Wyoming's Authority to Administer the Clean Water Act's National Pollutant Discharge Elimination System Program* filed by the Wyoming Outdoor Council and the Powder River Basin Resource Council. More specifically, this document addresses Allegation I.A.2 ***"The WDEQ does not apply the Best Professional Judgment factors, a violation of the CWA"*** and the request by EPA for WDEQ to explain how it considered the factors for developing BPJ limits (40 CFR 125.3), deciding to rely on the oil and gas effluent limitations guideline (40 CFR 435) as guidance for developing BPJ limitations for coal bed methane (CBNG).

Please feel free to contact Todd Parfitt of my staff at 307-777-6709 or tparfi@state.wy.us with any questions regarding this matter.

Sincerely,

John Corra
Director
Department of Environmental Quality

JVC/jd/5-0488
Attachment
cc: John Wagner, WQD Administrator
Todd Parfitt, WYPDES Program Manager
Vicci Colgan, Senior Assistant Attorney General

WILLIAMS
EXHIBIT 1

Wyoming Pollutant Discharge Elimination System (WYPDES) Program
Basis for Technology-Based Effluent Limits
in
Coal Bed Methane (Natural Gas) WYPDES Permits

This document provides the basis for the technology-based effluent limits that have been incorporated into WYPDES permits for the coal bed natural gas (CBNG) industry. These limits are based upon review and consideration of: current knowledge and factual information about CBNG production; the national effluent limitations guidelines (ELGs) for the Coal Mining Point Source Category (40 CFR 434); ELGs for the Oil and Gas Extraction Point Source Category (40 CFR 435); U.S. EPA NPDES Permit Writers' Manual, December 1996; and the 1976 Development Document for the Oil and Gas Extraction Point Source Category.

The Wyoming Department of Environmental Quality (WDEQ), Water Quality Division, Wyoming Pollution Discharge Elimination System (WYPDES) program was granted authority to implement the NPDES program under the Federal Water Pollution Control Act in 1974. The federal Clean Water Act, Wyoming Environmental Quality Act and Wyoming Water Quality Rules and Regulations Chapter 2 require operators who discharge pollutants to a water of the United States, or a surface water of the state under state statute, to obtain a WYPDES permit for the discharge.

The primary industrial activity with surface water discharge in the State of Wyoming is the oil and gas industry. In the early 1970s, conventional oil production was the predominate oil and gas activity within the state. Natural gas development has also been occurring within the state since the 1970's, but in a more limited capacity. CBNG development in Wyoming began in the late 1980's and by the end of 1997, there were 578 active WYPDES permits for oil and natural gas production facilities, 47 of these permits were for CBNG facilities.

During the late 1990s, technological advances provided the oil and gas industry with the ability to extract methane from coal bearing formations in a more economic, efficient and prolific manner. As a result, CBNG development spread rapidly throughout the Greater Powder River Basin. Initial development occurred in the Belle Fourche River Basin and eventually moved into the Cheyenne, Tongue and Powder River Basins. The number of active CBNG permits began to rapidly increase in 1999 and 2000. As of March 3, 2005 there were 1268 active oil and natural gas permits; 823 of these permits were for CBNG facilities.

When establishing effluent limits in WYPDES permits, water quality-based and technology-based effluent limits are always evaluated, taking into consideration all appropriate federal and state regulations. Determination of water quality-based limits is based upon Chapter 1 of the Wyoming Water Quality Rules and Regulations. Technology-based limits can be based upon ELGs or, in the absence of ELGs, best professional judgment (40 CFR 125.3). Technology-based effluent limits for the oil and gas industry in Wyoming are based upon Wyoming Water Quality Rules and Regulations Chapter 2 Appendix H which are consistent with the federal ELGs for the Oil and Gas Extraction Point Source Category (40 CFR Part

435) except that the WDEQ rules provide more stringent controls than the federal rules and the WDEQ rules specifically addresses CBNG produced water.

EPA has taken the position that no ELGs apply to CBNG. However, EPA has recognized that NPDES permit writers can develop BPJ limits by using one of two different methods. A permit writer can either transfer numerical limitations from an existing source such as a similar NPDES permit or an existing ELG, or derive new numerical limitations. WDEQ has used the first method to develop CBNG BPJ limits.

A summary of WDEQ's rationale for developing BPJ limits (40 CFR 125.3) for CBNG relying on the oil and gas effluent limitations guideline (40 CFR 435) as guidance are as follows:

1. Comparison of CBNG Discharges to 40 CFR 434 Coal Mining Point Source Category and 40 CFR 435 Oil and Gas Extraction Point Source Category

A. Comparison of CBNG Discharges to 40 CFR 434

The WYPDES Program evaluated ELGs for the Coal Mining Point Source Category (40 CFR, Part 434). The ELG for the Coal Mining Industry applies to discharges from any coal mine at which the extraction of coal is taking place or is planned to be undertaken and to coal preparation plants and associated areas. The primary Standard Industrial Classification Categories evaluated by the Development Document are:

1111 Anthracite Mining

1112 Anthracite Mining Services

1211 Bituminous Coal and Lignite Mining, and

1213 Bituminous Coal and Lignite Mining Services

The effluent limitations for the coal mining industry include: pH, Total Suspended Solids, Total Iron and Total Manganese. CBNG discharges typically have a pH of 7.5-8.0 standard units; Total Iron is typically a constituent of concern, Total Suspended Solids are typically not a concern and Total Manganese is not a constituent of concern.

The activities conducted by the coal mining industry were compared to those of the CBNG industry. The activities typically conducted by the mining industry were clearly dissimilar. Specifically, the coal mining industry does not rely on drilling activities, commercial extraction of methane gas or the discharge of similar volumes of produced water for their operations.

Based on the review, the WDEQ concluded that there was valuable insight to be gained from evaluating water quality data from coal mine operations, however, because the industrial activities were so dissimilar, using 40 CFR 434 as guidance for developing BPJ limitations for (CBNG) was deemed inappropriate.

B. Comparison of CBNG Discharges to 40 CFR 435

CBNG development is a subset of the oil and gas industry as is conventional oil and conventional natural gas development. CBNG operations are reviewed in the context of oil and gas development as a whole. Comparisons are made to conventional oil and gas technology based on regulations, which have been in place for nearly 30 years.

To determine the appropriateness of relying on 40 CFR 435 as per 40 CFR 125.3, the WYPDES Program conducted an evaluation of 40 CFR 435 and the 1976 Development Document for the Oil and Gas Extraction Point Source Category. According to the development document, the study covered pollutants arising from the production of crude petroleum and natural gas, drilling oil and gas wells, and oil and gas field exploration services. The document makes no explicit exclusion of varying types of oil and gas operations.

CBNG is exceptionally pure compared to conventional natural gas, in that it contains very small proportions of heavier hydrocarbons and other gases. Natural gas is termed "dry" when it is almost pure methane, lacking other commonly associated hydrocarbons, which is the case with CBNG. When other hydrocarbons are present the natural gas is referred to as "wet". The concept of "dry" natural gas is recognized in the 1976 Development Document for the Oil and Gas Extraction Point Source Category, which states "...Gas wells may produce dry gas but usually also produce varying quantities of light hydrocarbon liquids (known as gas liquids or condensate) and salt water."

Segments of the industry covered by the Oil and Gas Extraction Point Source Category are based on the following Standard Industrial Classification (SIC) Codes:

1311 Crude Petroleum and Natural Gas

1381 Drilling Oil and Gas Wells

1382 Oil and Gas Field Exploration Services

1389 Oil and Gas Field Services, not classified elsewhere

These SIC codes were compared to the 1987 Standard Industrial Classification Manual which defines SIC codes for various industrial activities. The Major Group for the Oil and Gas Extraction Category (Major Group 13) includes establishments engaged in:

(1) producing crude petroleum and natural gas;
(2) extracting oil from oil sands and oil shale;
(3) producing natural gasoline and cycle condensate; and
(4) producing gas hydrocarbon liquids from coal at the mine site.

Types of activities included in this major category include exploration, drilling, oil and gas well operation and maintenance, the operation of natural gasoline and cycle plants, and the gasification, liquefaction and pyrolysis of coal at the mine site.

Based on the review of Part 435, the Development Document and the 1987 Standard Industrial Classification Manual, the WDEQ concludes that CBNG activities are similar in nature to those activities outlined in 40 CFR 435. CBNG is clearly within the Major Group 13 and more specifically within the SIC code 1311, which is clearly an industry that was evaluated and included in the Development Document.

EPA established BPT ELGs for the Onshore subcategory (Subpart B) and Agricultural and Wildlife Water Use subcategory (Subpart E) for the Oil and Gas Extraction Point Source Category, on April 13, 1979. EPA imposed a zero discharge requirement for all pollutants in the Onshore subcategory (40 CFR 435.32):

"...there shall be no discharge of wastewater pollutants into navigable waters from any source associated with production, field exploration, drilling, well completion, or well treatment (i.e., produced water, drilling muds, drill cuttings, and produced sand)."

For the Agricultural and Wildlife Water Use subcategory, EPA imposed a zero discharge requirement for all pollutants with the exception of some produced waters (40 CFR 435, Subpart E). To qualify this exemption:

(1) The produced water must be generated from facilities that are engaged in production, drilling, well completion, and well treatment in the oil and gas extraction industry and be located in the continental United States and west of the 98th meridian (40 CFR 435.50).
(2) The produced water must be used in agriculture or wildlife propagation when discharged into navigable waters (40 CFR 435.50).
(3) The produced water discharges must not exceed an oil and grease daily maximum limitation of 35 mg/l (40 CFR 435.52(b)).

EPA defined the term "use in agricultural or wildlife propagation" by stating "the produced water is of good enough quality to be used for wildlife or livestock water or other agricultural uses, and the produced water is actually put to such use during periods of discharge." (40 CFR 435.51(c)). The provisions of 40 CFR 435 make no mention of water quantity necessary to support stock and/or wildlife use.

In 1979, WDEQ promulgated Water Quality Rules and Regulations Chapter 7, "Surface Discharge of Water Associated with the Production of Oil and Gas," which was the WDEQ equivalent to the federal ELG 40 CFR 435 except that the Chapter 7 rules provided more stringent controls than the federal rules. In the early development stages of CBNG the WDEQ applied the requirements of Chapter 7 as the technology based effluent limitations. In November 2004, WDEQ promulgated revised Chapter 2 rules, which incorporated and updated the provisions of Chapter 7 as Appendix H and explicitly identified CBNG as an industrial activity covered under the oil and gas technology based limitations.

For oil and gas discharges, including CBNG, permits issued from 1974 through 2000 by Wyoming, it was assumed that in the arid west region, the produced water would be used for agricultural or wildlife propagation as long as water quality standards and effluent limitations were met. Historically, documentation related to this requirement was not contained or required in the permit applications or permit files for WYPDES permits. It is WDEQ's belief and understanding that federal permits issued on Indian Lands have been processed in a similar manner. However, in 2000, at the request of Region 8 EPA, the WYPDES Program modified the CBNG permit application to require the applicant to provide a demonstration of compliance with Subpart E.

In September 2001, the EPA provided written comments related to several CBNG permits that the WYPDES Program was proposing to issue. The comments primarily focused on the statements of basis (SOBs) for CBNG permits which invoked WWQRR Chapter 7 and 40 CFR 435. The EPA suggested that the SOBs should describe the beneficial use for the discharged water and that the quality support such a use. The nature of EPA's comments clearly suggested to WDEQ that EPA concurred with the approach of relying on the oil and gas effluent limitations guideline (40 CFR 435 and WWQRR Chapter 7) as guidance for developing BPJ limitations for CBNG.

While not initially stated in the SOBs for the proposed permits, the permit files contained application information regarding the identification of the use(s) for the discharged water and the potential water quality of the proposed discharge. In December 2001, the WYPDES Program began including statements in the SOBs of each CBNG permit to specifically address how the produced water would be used.

Although the ELG associated with the Oil and Gas Point Source Category predates the development of CBNG extraction technology, based on the comparison outlined above, it is the professional judgment of WDEQ that discharges related to CBNG facilities are similar enough to other types of natural gas extraction that the technology-based effluent limits contained in WWQRR Chapter 7 (now WWQRR Chapter 2, Appendix H) and 40 CFR 435 are appropriately applied. EPA acknowledged acceptance of Wyoming's reliance on the technical and economic assumptions of the federal effluent guidelines for the oil and gas extraction point source category (40 CFR 435) to establish technology based effluent limitations for CBNG in its February 26, 2003 letter to WDEQ.

2. Comparison of Water Management Options

The oil and gas industry has historically been forced to manage produced water and other production related wastes based on the constraints of water quality based effluent limitations, technology based effluent limitations and other state regulatory requirements, such as compliance with the Colorado River Salinity Control Forum policies. Because of these constraints the oil and gas industry has historically disposed of produced water by injection, disposal pits and ponds, land application, discharge to surface waters of the state that are not waters of the United States, and discharge to surface waters of the state that are waters of the United States.

Injection:

Injection has been used by the oil and gas industry primarily in the Green River and Snake River Drainage Basins due to high total dissolved solids concentrations in the produced water and the Colorado River Salinity Control Forum policies that are enforced through the

WYPDES program under WWQRR Chapter 6. Similarly, injection has been successfully utilized for CBNG produced water disposal, but on a limited scale, largely due to technological constraints.

Disposal Pits and Ponds:

One method of produced water management historically used by the oil and gas industry has been the use of disposal pits and ponds, typically for evaporation and concentration of brine waste. Similarly, CBNG produced water has been disposed of in pits and ponds. However, because the quality of CBNG produced water is of much higher quality (i.e. meets all Class 4 and most Class 3 water quality criteria at the point of discharge), evaporation plays a small role in the actual management of the produced water. The pits and ponds associated with CBNG produced water are categorized as surface waters of the state and are designed to infiltrate into and recharge shallow aquifers versus evaporation ponds, which are constructed with a liner.

Discharge to Surface Waters of the State that are Not Waters of the United States

As mentioned earlier, water quality-based and technology-based effluent limits are always evaluated for all oil and gas discharges. Waters of the state that are not waters of the United States, such as off-channel pits and ponds, are not subject to federal oversight or federal rules including BPJ or ELGs. However, because the WDEQ promulgated rules consistent with the federal rules for all surface waters of the state, WWQRR Chapter 2 is applied to these discharges.

Discharge to Surface Waters of the State that are Waters of the United States

Historical oil and gas produced water discharges to surface waters of the state that are waters of the United States have been and continue to be subject to the provisions of WWQRR Chapter 7 (now Chapter 2, Appendix H) and 40 CFR 435, as well as, WWQRR Chapter 1. Similarly, CBNG discharges are subject to the same regulations, including the management of drilling muds and other liquids associated with the drilling of wells. In all cases these drilling muds and other associated liquids are not permitted to be discharged to surface waters of the state.

Land Application

Land application has historically been an option for the oil and gas industry to manage disposal of produced water provided they meet the criteria of WWQRR Chapter 3 and obtain a permit from the WDEQ. Similarly, land application is an option for CBNG produced water and has been utilized by several companies for production of a variety of crops and vegetation.

3. **Comparison of Water Quality Data**

Since the beginning of large scale CBNG development in Wyoming, the DEQ has evaluated the range of possible ground water quality from coal seams based on the following data sources:

A. Land Quality Division records.
B. Water Quality Division records.
C. State Engineers Office records.
D. Oil and Gas Conservation Commission records.
E. USGS records.
F. Wyoming Geological Survey records.
G. Industry records.
H. Other miscellaneous sources.

Based on these reviews the DEQ has identified constituents of concern associated with the groundwater being produced and discharged from CBNG operations across the state. These constituents have been continually monitored. Findings from the evaluation of the data have revealed that iron, SAR and Ec are the primary constituents/parameters of concern. Other parameters such as barium, arsenic and whole effluent toxicity have been identified as concerns in isolated areas.

The 1976 Development Document for the Oil and Gas Extraction Point Source Category identified the significant or potentially significant wastewater constituents as oil and grease, fecal coliform, oxygen demanding parameters, heavy metals, total dissolved solids, and toxic materials. It is the WDEQ's opinion that the fecal coliform and oxygen demanding parameters referenced in the Development Document relate to the off-shore drilling operations where disposal of sewage wastewater would be involved in the process. Because the on-shore category does not include the discharge of sewage wastewater they are excluded from the comparison evaluation. The remaining constituents of concern in the Development Document are the same as the constituents of concern identified for CBNG discharges.

Additionally, the Development Document states that "...the wastes associated with this category result from the discharge of produced water, drilling muds, drill cutting, well treatment and produced sands for all subcategories..." Similar to conventional oil and gas operations, CBNG operations produce drilling muds, drill cuttings and other associated liquids. Appendix H(b)(ix) of Chapter 2 prohibits discharges associated with drilling and well completion (i.e., drilling muds and cuttings) to be discharged to the surface, consistent with 40 CFR 435.

Over the years, the WYPDES Program has collected and reviewed thousands of water quality data from hundreds of facilities. Based upon this data, there have been relatively few instances where additional constituents have required numerical effluent limits to be incorporated into CBNG permits. Concentrations of dissolved iron typically have high concentrations regardless of the location of the discharge point within the Greater Powder River Basin. However, because iron oxidizes rapidly, concentrations are easily and commonly managed through aeration. Metals, such as total barium, total aluminum, total

49senic, dissolved copper, dissolved lead, dissolved zinc and chlorides, on occasion have been identified as having a potential to exceed water quality standards. However, elevated concentrations of these metals are not consistently seen in the produced water.

In certain areas of CBNG development the discharge water has exhibited high sodium adsorption ratio (SAR) values, primarily due to the relative absence of calcium and magnesium. Discharges of CBNG produced water have been managed to ensure protection of Wyoming's narrative standard, Chapter 1, Section 20 "Agricultural Use" and to ensure protection of down stream surface water quality standards of adjacent states (Montana and South Dakota). CBNG surface discharges have been managed primarily through the use of containment ponds in the headwaters. However, other management techniques, such as reverse osmosis and ion exchange, for treatment of the produced water for SAR and specific conductance, are beginning to emerge as potential options on a small scale. As the technology and economics of these alternative management techniques evolve, they will likely become more widely used.

Summary

After consideration of information described above, the WYPDES Program concluded and maintains that it is appropriate to rely on WWQRR Chapter 2 Appendix H (formerly WWQRR Chapter 7) and the ELGs for the Oil and Gas Extraction Point Source Category (40 CFR Part 435) for establishing technology based effluent limits and equally appropriate for developing BPJ limits (40 CFR 125.3) for CBNG.

Finally, the state is aware that EPA is currently developing a guidance document for developing technology-based limits for CBNG operations and an economic analysis of the Powder River Basin. This document is draft and not available for quoting or citing at this time. However, if and when this document is finalized, the WDEQ will review and consider the merits of the guidance document.

If EPA determines that it is necessary to develop a federal ELG for CBNG and proceeds to develop a CBNG ELG the WDEQ would defer to the federal ELG.

TTP/jd/5-0492

FILED

FEB 1 0 2006

Terri A. Lorenzon, Director
Environmental Quality Council

SUBMIT IN TRIPLICATE

Agency Use Only
Application Number
WY00________
Date Received:
________ (mo/day/yr)

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM
APPLICATION FOR PERMIT TO SURFACE DISCHARGE PRODUCED WATER FROM COAL BED METHANE NEW DISCHARGES, RENEWALS, OR MAJOR MODIFICATIONS

Revised 12-19-03

PLEASE PRINT OR TYPE

1. Check the box corresponding to the type of application being applied for

☐ New CBM permit

☐ CBM permit renewal Permit number ________________

☐ CBM permit major modification Permit number ________________

2. Select a permit option

☐ Option 1A - complete containment to an off-channel man made containment unit(s) (class 4C), no discharge allowed to surface waters of the state outside the containment unit.

☐ Option 1B - complete containment to a natural closed basin or playa lake (class 3A), no discharge allowed to surface waters of the state outside the basin or playa.

☐ Option 2 - surface discharge to class 2 or 3 receiving stream of the Belle Fourche River or Cheyenne River drainage (class 2ABWW).

☐ Option 2 - surface discharge to class 2 or 3 receiving stream of the Powder River or Little Powder Rivers (class 2ABWW).

☐ Option 2 – surface discharge to class 2 or 3 receiving streams of the Tongue, Clear Creek, or Crazy Woman Creek (class 2AB)– this option requires the permittee to demonstrate that quality of the effluent at the discharge point is equal to or better than the ambient quality of the perennial class 2 receiving water.

3. Name, mailing address, e-mail address, location and telephone number of the individual or company which owns the facility producing the discharge.

Name: ________________

Street Address: ________________

City, State, and Zip Code: ________________

Telephone Number: ________________

E-Mail Address: ________________

WILLIAMS
EXHIBIT 2

4. Name(s) and mailing address(es) of owner(s) of the surface rights on whose land the discharge occurs (in cases where the land is owned by the state or federal government but surface rights are leased to a private individual, provide lessee's name and address)

Name:

Street Address:

City, State, and Zip Code:

Telephone Number:

5. Name of the facility producing the discharge (this is the facility name that will appear on the NPDES permit. It is not necessary to name every well contributing to this facility's discharge in this section)

6. For Option 1A or 1B permit, attach a water balance that demonstrates, considering total maximum projected discharge inflows, natural precipitation, evaporation and infiltration, that the containment unit will be adequately sized to contain all projected discharge and stormwater runoff from a 100 year, 24 hour storm event. If actual flow rates are available, use the maximum flow rate from all active wells within the previous six months of operation in the water balance.

7. For an Option 2 permit utilizing on-channel reservoirs, attach a water balance and mixing analysis documenting the amount of CBM discharge that, under normal operating conditions, can be contained within the reservoirs, the amount and circumstances under which the reservoirs will discharge, and the expected water quality upon discharge from the reservoirs.

8. Attach a description and a clear, legible, detailed topographic map of the discharging facility. Include the following:
   a. A legend
   b. Well locations
   c. Ponds
   d. Reservoirs
   e. Stock tanks
   f. Discharge points (outfalls)
   g. Immediate receiving streams
   h. Water quality monitoring stations
   i. Irrigation compliance points
   j. Location of nearest downstream irrigator.
   k. Section, Township, and Range information

   If any of the above are not applicable please indicate in the description and include a brief explanation as to why the item is not applicable)

9. Describe the control measures that will be implemented to prevent significant damage to or erosion of the receiving water channel at the point of discharge.

10. Describe the control measures that will be implemented to achieve water quality standards and effluent limits. If proposing to utilize a treatment process, provide a detailed description of the treatment process, including, but not limited to: Water quality analyses demonstrating the effluent quality before and after treatment; waste stream volumes and planned method of disposal; aquatic life toxicity data for any chemicals being used in the treatment process; description of how the chemicals will be handled at the facility and the potential for any impacts to waters of the state in the event of a spill; and diagrams of the facility indicating the water treatment path. Additional sheets and diagrams may be attached.

11. Outfall locations must be established as part of a preliminary field reconnaissance survey using GPS or conventional survey equipment and documented in Table 1. Please document the type of equipment used, the expected accuracy of your measurements, and a brief rationale for locating the outfalls at the requested sites below.

12. Complete the attached **Table 1**. Provide all the information in the table for each proposed discharge point or monitoring point. If proposing changes (a major modification) to an existing facility, **clearly** indicate the desired changes on the table. Additional tables may be attached. Use the format provided.

13. Complete the attached **Table 2**. Provide all the information in the table for each well associated with this proposed discharge authorization. If proposing changes (a major modification) to an existing facility, **clearly** indicate the desired changes on the table. Additional tables may be attached. Use the format provided.

14. Provide the results of water analyses for a sample collected from a location representative of the quality of the water being proposed for discharge for the 25 chemical parameters listed below. The sample must be collected from well(s) or outfall(s) within a twenty mile radius of the proposed facility's location, and from the same coal formation(s) and the same approximate depth(s) as proposed in this application. If filing an application for a permit renewal or modification, the representative sample must be collected from the facility being proposed for renewal or modification. Explain why this sample is representative of the produced water to be discharged.

Samples from co-mingled coal seams are acceptable as long as the sample(s) meet the following criteria:

A. all of the coal seams being proposed for development are represented in the co-mingled sample,

B. the ratio of each coal seam's contribution is approximately the same in the sample and the proposed development,

C. documentation is provided to verify the criteria listed in A. and B.

The analyses must be conducted in accordance with approved EPA test procedures (40 CFR Part 136). Include a signed copy of your lab report that includes the following:

a. detection limits
b. results of each of the 25 chemical parameters at the chemical state given below
c. quarter/quarter, section, township and range of the sample collection location
d. Time and date of sample collection

e. Time and date of analysis for each parameter
f. Analyst's initials for each parameter
g. Detection limit for each parameter as achieved by the laboratory
h. NPDES permit number and outfall number, where the sample was collected.
i. Origin of produced water (coal seam)

If more than one coal seam is being proposed for development, the permittee must submit a lab analysis and complete information characterizing water quality from each coal seam being proposed for development. If the permittee is proposing to include discharges from a coal seam not previously developed at this facility, the permittee must submit a lab analysis and complete information characterizing water quality from the new coal seam being proposed for development. Analyses must be provided in the units listed below.

Parameter* (See notes following the table on chemical states)	Required Detection Limits and Required Units
Alkalinity, Total	1 mg/l as $CaCO_3$
Aluminum, Total Recoverable	50 µg/l
Arsenic, Total	1 µg/l
Barium, Total	100 µg/l
Bicarbonate	10 mg/l
Cadmium, Dissolved	5 µg/l
Calcium, Total	50 µg/l, report as meq/l
Calcium, Total	50 µg/l, report as mg/l
Chlorides	5 mg/l
Chlorides	5 mg/l
Copper, Dissolved	10 µg/l
Dissolved Solids, Total	5 mg/l
Hardness, Total	10 mg/l as $CaCO_3$
Iron, Dissolved	50 µg/l
Lead, Dissolved	2 µg/l
Magnesium, Total	100 µg/l, report as meq/l
Magnesium, Total	100 µg/l, report as mg/l
Manganese, Dissolved	50 µg/l
Mercury, Dissolved	1 µg/l
pH	to 0.1 pH unit
Radium 226, Total	0.2 pCi/l
Selenium, Total Recoverable	5 µg/l
Sodium Adsorption Ratio	Calculated as unadjusted ratio
Sodium, Total	100 µg/l, report as meq/l
Sodium, Total	100 µg/l, report as mg/l
Specific Conductance	5 micromhos/cm
Sulfates	10 mg/l
Zinc, Dissolved	50 µg/l

Discharges into drainages other than the Powder River geologic basin may require analysis of additional parameters, please contact the WDEQ for a separate list.

15. For new facilities, provide the expected (estimated) flow volume from each well in gallons per day, and provide the rationale behind the flow volume estimate. For existing facilities, provide actual flow data from all wells within the last six months.

____

____

16. For applications for new facilities, are any of the required chemical constituents in the laboratory analysis present in concentrations above Wyoming Water Quality Standards?

☐ **YES** ☐ **NO**

If the answer to question # 16 is yes, answer 16.a. – 16.b below. If no, proceed to question 18.

a. Which constituents?

b. Has this constituent been addressed in the response to question 10?

17. For applications for existing facilities, has the facility ever exceeded permit limits or water quality standards?

☐ **YES** ☐ **NO**

If the answer to question 17 is yes, answer 17.a. – 17.b. If no, proceed to question 18.

a. Which constituents?

b. Has the exceedance been addressed?

c. Describe how the exceedance is being addressed.

18. Is there active irrigation, (including but not limited to irrigation of cultivars or flood irrigation) in the drainage of the discharge?

☐ **YES** ☐ **NO**

If the answer to question #18 is yes, then documentation demonstrating one of the following must be provided:

A. Effluent will meet SAR and specific conductance (EC) values that are equal or of better quality to ambient values in the mainstem or highest quality receiving stream; or
B. Demonstrate that a higher level of EC and SAR at the point of irrigation diversion can be tolerated by irrigated soils and crops without a significant reduction in crop yield and soil quality/permeability.

This information should include, but is not limited to the following:

a. Location and description of irrigated crop land between the discharge points and mainstem, including maximum local tolerance thresholds to SAR, EC, and sodium of each crop.
b. Description of irrigation practices including when and how frequent irrigation occurs.
c. Soil characteristics for each area where irrigation occurs which includes:Classification of soils and soil type (i.e. sandy loam, clay, etc.) Composition of soils (% clay, silt, sand), type of soils, texture and permeability
d. Baseline soil parameters in all actively irrigated areas which includes soil SAR, EC, Na, Mg, Ca, permeability, and exchangeable sodium percentage (ESP).
e. Determine the maximum SAR and EC of water that can be applied to the least tolerant and most sensitive identified irrigated soil type and crop, which would not result in a short and/or long-term reduction in soil infiltration/permeability or yield.
f. Provide the location (township, range, section, quarter quarter and lat/long coordinates) of point(s) upstream from the first downstream point of irrigation diversion/use between the outfalls and mainstem and/or provide the location(s) of the irrigation diversion/use that requires the least flow to operate.
g. An evaluation that demonstrates the proposed discharge will be in compliance with Section 20, Chapter 1 of the Wyoming Water Quality Rules and Regulations.
h. If necessary to protect irrigated crops and/or soils, describe changes that must be made in traditional irrigation practices to protect downstream irrigation activities.
i. A monitoring plan, if necessary to gauge changes in water/soil quality and make adjustments before substantial reduction in crop production and soil permeability would occur.
j. Citations of reference for all the above information must be provided.

19. Name(s) and address(es) of all downstream irrigators between the outfalls and the mainstem must be provided.

Name:

____

Street Address:

____

City, State, and Zip Code:

____

Telephone Number:

____

20. Section 40 CFR Part 435 Subpart E requires that the permittee document agricultural and wildlife uses of produced water. Provide documentation that the produced water will be used for agriculture or wildlife during periods of discharge. Agriculture and wildlife use includes irrigation, livestock watering, wildlife watering and other agricultural uses. Agricultural and wildlife use documentation includes (but is not limited to) a certified letter from a landowner(s), a formal written statement from a state, federal or local resource management agency, or a formal written statement with supporting documentation from a natural resources or environmental professional accompanied by the credentials of the natural resources or environmental professional. Agriculture and wildlife use documentation must be provided for each outfall included in the application. Agricultural and wildlife certification must be submitted for each outfall's discharge, and must have original signatures.

I (CEO or other authorized person) certify that I am familiar with the information contained in this application and that to the best of my knowledge and belief, such information is true, complete, and accurate. I am requesting ___________ outfalls in this application.

______________________________ ______________________________

Printed Name of Person signing* Title*

Signature Date

*All permit applications must be signed in accordance with 40 CFR Part 122.22, "for" or "by" signatures are not acceptable.

Section 35-11-901 of Wyoming Statutes provides that:
Any person who knowingly makes any false statement, representation, or certification in any application ... shall upon conviction be fined not more than $10,000 or imprisoned for not more than one year, or both.

Mail this application to:

NPDES Permits Section
Department of Environmental Quality/WQD
122 West 25th Street, Herschler Building, 4W
Cheyenne, WY 82002

Please include unique footer information on each page of this application and on all supporting documentation using the following format:
Company Name: Year/Month/Day/NEW, MOD, RENEWAL/10 Digit HUC Code/Permit # (if a modification or renewal) or Application # (from this particular company) for that particular day

TABLE 1: OUTFALL INFORMATION

Discharge Point # (Outfall)	Immediate Receiving Stream	Mainstem	Distance from outfall to mainstem (stream miles)	Quarter / Quarter	Section	Township	Range	Latitude *(decimal degree format, accuracy to nearest 5 seconds)*	Longitude *(decimal degree format, accuracy to nearest 5 seconds)*	County	Reservoir Permit Application Submitted to SEO?	SEO Reservoir Permit #	Reservoir Name	SEO Reservoir Requirements
001														
002														
003														
004														
005														
006														
007														
008														
009														
010														
ICP1														
ICP2														
TRIB														
WQMS - Up														
WQMS - Down														

ICP - Irrigation Compliance Point, TRIB - Tributary water quality monitoring station, WQMS - Up - upstream mainstem water quality monitoring station, WQMS- Down - downstream mainstem water quality monitoring station

Additional sheets may be attached as necessary. Use the format provided.

TABLE 2 - WELL INFORMATION

Well Name	API Number	Coal Seam	Well Depth	Discharges to Outfall #*

**AWAO - all wells to all outfalls*

Additional sheets may be attached as necessary. Use the format provided.

time. To sustain irrigation, irrigators must add additional water above the needs of the crop to leach excess salt from the root zone.[17]

- Increased flows can raise local ground water tables and slow infiltration that is crucial to leaching salts from soils.
- Timing of flows, regardless of quality, is important for seedling growth and soil leaching.
- Salt loading is the effect of quality times volume. For example, if a billion gallons of water is produced per day, and it contains 2000 ppm salts, then 8,000 tons of salt per day will be generated. The salt will go either into the soil or down the creek, where there will be significant adverse consequences to crops or aquatic habitat.

DEQ recognizes the interplay of water quantity and water quality in many contexts. Consider, for example, the Mixing Zone and Dilution Allowances Implementation Policy, which can only be calculated if one of the factors is the mean daily flow.[18] The majority of WYPDES permit applications in the Powder River Basin

---

fraction are the most important factors affecting the salinity of the soil water. The salinity of the soil water is important, since the salinity of the soil water, rather than the salinity of the irrigation water itself, is the critical factor resulting in any decrease in crop yield. Continued irrigation will result in the salinity of the soil water coming into equilibrium with the salinity of the irrigation water. The actual relationship will be dependent on the average salinity of the irrigation water and the actual leaching fraction.

Horpestad, Abe, *Water Quality Technical Report, Water Quality Impacts from Coal Bed Methane Development in the Powder River Basin, Wyoming and Montana*, Dec. 10, 2001. Exhibit 9.

[17] Munn, Ex. 6.

[18] Wyoming Surface Water Quality Standards, Implementation Policies for Antidegredation Mixing Zones Turbidity and Use Attainability Analysis, p. 16, 3rd draft, November, 2005. http://deq.state.wy.us./wqd/surfacestandards/Triennial/Policies_3rd.pdf

are submitted with mixing calculations and water budgets. This is because they count on natural flows for dilution, and none of those calculations can be made without considering the quantity factor. WYPDES permits do in fact contain a limit to the quantity of water discharged under the permits. This is because the concentration of a particular constituent is only one factor in determination of the total load – quantity is essential to that calculation. DEQ is in the process of implementing a new policy to control total salt load in order to meet limits in flows to Montana. The Powder River Basin sodium management plan allocates total sodium discharges to producers, calculated by TDS (quality) times quantity. Here again, DEQ cannot regulate load without regulating water quantity. Yet DEQ turns a blind eye to quantity in Chapter 2, Appendix H, and in doing so it hamstrings its own ability to effectively regulate CBM water.

EPA has also recognized the various impacts that can result from both quantity and quality of CBM water, and advised DEQ that "large quantities of produced water discharged to small tributaries with erosive soils and geology can have unanticipated adverse impacts on wildlife habitat and/or agriculture."[19] EPA has further explained:

> The many potential environmental impacts from CBM operations are diverse. Possible impacts include: reduced flow or loss of domestic water wells, mortality and reduced growth and vigor of vegetation, erosion, soil compaction, and loss of topsoil. One of the major concerns associated with CBM production in the Powder River Basin is disposal of the produced water. The surface disposal of CBM-produced water may result in erosion or damage to drainages and associated vegetation within the area. Even though CBM discharge is essentially sediment-free, discharge to streams and creeks can increase sediment loading due to increased erosion.[20]

---

[19] 1/5/01 Reed letter to Krafft, Ex. 3.

[20] EPA Guidance for Developing Technology-Based Limits for Coalbed Methane Operations: Economic Analysis of the Powder River Basin, February, 2003. Interagency

RECEIVED
MAY 08 2006
WATER QUALITY DIVISION
WYOMING

May 8, 2006

Mr. Bill DiRienzo
Wyoming Department of Environmental Quality - Water Quality Division
Herschler Building, 4W
122 West 25th Street
Cheyenne, WY 82002

Re: Comments on Proposed Wyoming Department of Environmental Quality Draft Agricultural Use Protection Policy (4th Draft, 2006)

Dear Mr. DiRienzo:

Williams Production RMT Company (Williams) appreciates the opportunity to present comments to the Wyoming Department of Environmental Quality (DEQ), Water Quality Division regarding implementation of Chapter 1, Section 20 of the Water Quality Rules and Regulations (WQRR) through DEQ's proposed Draft Agricultural Use Protection Policy (Draft Policy). Williams is a significant operator in Wyoming and, in particular, in the Powder River Basin (PRB). Williams is concerned about the potential of the Draft Policy to affect adversely its coalbed natural gas (CBNG) operations.

As you know, a collaborative effort was undertaken last summer to define an implementation policy to afford protection under Section 20. Experts were contacted and asked to participate with WDEQ in drafting that policy, and that version of the policy was published in late summer, 2005. At a meeting of the Water and Waste Advisory in September, 2005, the policy was discussed at length, and a decision was made to extend the public comment period into October. In December of 2005, comments were received from two professors from the University of Wyoming concerning this policy. WDEQ then made the decision to significantly alter the policy based on those comments, even though they were received after the comment period had ended. Those comments affected significant changes to the policy.

In its current draft, the draft Agricultural Use Protection Policy has the potential to impose significant costs and technical burdens upon CBNG operators. Yet, there is no evidence that DEQ considered these impacts, nor balanced the burdens imposed against the purported environmental effects sought to be protected. Our legislature expressly imposed such a requirement upon the DEQ with regard to any standards, rules, or regulations proposed by the Water Quality Administrator. Pursuant to W.S. 35-11-302 (a):

> "In recommending any standards, rules, regulations, or permits, the administrator and advisory board shall consider all the facts and circumstances bearing upon the reasonableness of the pollution involved including:
>
> (A) the character and degree of injury to or interference with the health and well being of people, animals, wildlife, aquatic life and plant life affected:
>
> B) The social and economic value of the source of pollution:
>
> (C) The priority of location in the area involved;
>
> (D) The technical practicability and economic reasonableness of reducing or eliminating the source of pollution; and
>
> (E) The effect upon the environment."

In proposing the Agricultural Protection Policy, which implements existing rules, the DEQ is duty-bound to consider these same criteria. Yet, based upon this draft, there is no indication the DEQ gave serious consideration to this legislative mandate. Had it done so, Williams believes the Policy would be significantly different in its requirements and breadth. For example, the DEQ would not be able to justify imposing an SAR cap designed to protect naturally irrigated parcels of no more than 20 acres, where the requirement is overly conservative[1] and may only be able to be met through expensive water treatment methodologies. As the DEQ promulgates its final Policy based upon the comments submitted on behalf of Williams and others, we respectfully ask that DEQ do so in the context of the 6 criteria set forth above. Williams also questions the use of a "Policy" to establish effluent limitations more restrictive than those established through formal rule-making.

Our specific comments regarding the text of the policy follow.

I. <u>Purpose - Chapter 1, Section 20 Should Not be Implemented to Protect Illegal Irrigation.</u>

We agree with DEQ that the purpose of Ch. 1, Section 20 is to protect irrigation that existed prior to an application for a WYPDES discharge permit. As DEQ has noted, the language infers a pre-existing agricultural use prior to an application for a

---

[1] See comments on page 9 infra.

WYPDES permit, which can serve as a baseline from which a decrease in crop or livestock production could be measured. We also agree that, to be afforded the protection of Section 20, a landowner must have an existing irrigation structure or mechanism in place for diverting water. However, in its Draft Policy, DEQ proposes the continuation of its historic practice of protecting illegal diversions, i.e., irrigation which occurs in the absence of a valid existing water right. Williams takes issue with this practice, particularly when DEQ recommends in written guidance that this illegal practice be followed by State personnel when translating the Section 20 narrative goals into appropriate WYPDES permit limits.

If a landowner is irrigating without the benefit of a water right from the office of the State Engineer, then the irrigation is illegal. Since there is no right to the use of the water in the drainage, the irrigation could be ordered to cease and desist at any time. Therefore, there is really nothing for the DEQ to protect. Moreover, the DEQ's current practice of protecting illegal irrigation is in direct conflict with the Wyoming law regulating the use of water:

> Water being always the property of the state, rights to its use shall attach to the land for irrigation, or to such other purposes or object for which acquired in accordance with the beneficial use made for which the right receives public recognition, under the law and the administration provided thereby. W.S. § 41-3-101.

By allowing unauthorized structures to trigger application of the standard, the DEQ protects unlawful irrigation use, sanctions the unlawful conduct, and rewards the offender for its offense. In effect, the Department is aiding and abetting the offending behavior in direct conflict with the requirements set out above. We submit that this practice constitutes egregiously bad public policy and produces an absurd result in violation of the canons of statutory and regulatory interpretation declared by the Wyoming Supreme Court. See *In re KP v. State*, 102 P.3d 217 (Wyo. 2004), 2004 Wyo. LEXIS 213, *23 ("[T]his Court will not interpret a statute in a manner producing absurd results"); *Corkill v. Knowles*, 955 P.2d 438, 444 (Wyo. 1998).

Lastly, the Environmental Quality Act (EQA) expressly states that the actions of the DEQ shall not limit or interfere with the jurisdiction, duties or authority of the State Engineer in administering water rights. W.S. §35-11-1104.a.(iii). Protection of illegal diversions could certainly be construed as interfering with these jurisdictional constraints, as it aids conduct directly contrary to the requirements for use of water set out above.[2] CBNG dischargers should not be required to protect such illegal practices. We therefore request the DEQ amend its Draft Policy to expressly state that in the future unauthorized irrigation use will not be protected and that existing diversion structures not covered by an existing water right will not trigger application of the agricultural standard.

II. Presumption of Naturally Irrigated Lands is Overly Broad

The Draft Policy implies there is a pre-existing agricultural use of a stream or drainage when "a substantial acreage of naturally sub-irrigated pasture within a stream floodplain" exists. The Draft Policy states that infra-red photography, surficial geologic maps, wetland mapping, landowner testimony or any combination of these sources may be used to establish that lands are naturally irrigated. Each of these information sources presents a snapshot of conditions at a specific time, and conditions may have changed e.g., wetlands mapping.[3] In addition, a permit applicant has no method by which it could disprove the presumption of sub-irrigation presented in the Draft Policy. The application of EC and SAR effluent limits should not be applied unless there is some presence and evidence of the ability to irrigate with a surficial flow ---period.

The EC and SAR effluent limits will be applied where the naturally irrigated land reaches a threshold deemed "agriculturally significant." This threshold is triggered when a stream segment contains "single parcels of naturally irrigated land greater than 20 acres or multiple parcels in near proximity that total more than 20 acres." Given the size of parcels in Wyoming, the definition of agricultural significance could be easily met through single parcels or the sum of smaller parcels. The practical effect of this definition combined with an easily triggered (unrefutable) definition of sub-irrigated land is that the Draft Policy's irrigation effluent limits would be applied to discharges into virtually any and every drainage in the State. The Draft Policy, if implemented, would result in a gross over-extension of the prior agricultural use presumption, would be overly protective of established agricultural uses which may

---

[2] The lack of a water right is often an indication that the drainage did not maintain adequate flows or water quality to facilitate irrigation or that the soils or other conditions were simply not supportive of irrigation adequate to allow the landowner to prove up its beneficial use of water and thus obtain a valid water right. And, in the absence of a valid existing water right, applicants for a discharge permit have no notice of irrigation use by such downstream landowners and no way to account for them in their WYPDES permit applications.

[3] The DEQ should not be able to rely solely upon landowner testimony which is inherently biased to establish the existence of naturally irrigated lands.

no longer exist and would significantly restrict CBNG operators' ability to discharge into State waters without expensive treatment of discharges to protect nominally useful parcels of land.

III. Irrigation Data and Information

The Draft Policy indicates that "...the goal is to ensure that preexisting irrigated crop production will not be diminished as a result of the lowering of water quality." The difficulty, of course, is in assessing the preexisting or baseline crop production that existed prior to any proposed discharge. Often there are no records of crop yield, stream flows, historic water quality, etc., making it very difficult for all parties to apply the "no measurable decrease" standard. This has caused DEQ to historically take an overly conservative approach in developing numeric permit effluent limitations to assure no measurable decrease in crop production. For that reason, we recommend that the following be added to the data and information required under Section III. B:

- Extent of irrigation permitted by office of the State Engineer under a valid and existing Wyoming water right.

- Rate of flow required to activate irrigation under the system in place.

- As to the season of use, DEQ should further refine its definition of "irrigation season." The EC and SAR limits will apply during those periods when crop growth is occurring and then only when irrigable flows exist. Irrigable flows are those in which adequate water exists to activate a spreader dike system for artificially irrigated lands or to cause natural flooding or sub-irrigation on naturally irrigated lands. It is not reasonable to assume that the irrigation season is generally considered year-round in Wyoming for passively irrigated lands, given the variation and intensity of storm events supplying water to ephemeral or intermittent drainages used for irrigation purposes. In the absence of such events, the naturally-occurring salinity in these drainages limits their utility for irrigation. When irrigation cannot occur, the water quality standards protective of irrigation should not be applied. Operators should not be required to make the water quality in the stream system better year round than mother nature provided.

- Most importantly, in place of using published tolerance values for the most sensitive crops grown, we suggest use of the Hanson Diagram to manage the SAR limit for two reasons. First, the published tolerance values for most crops generally assume conditions exist for attaining a 100% crop yield. Our experience throughout the PRB is that, given the growing conditions, e.g., a lack of precipitation, poor alkaline and saline soils, and intermittent flows, etc., irrigators in the PRB achieve a crop yield well below the 100% value. Second, as DEQ has noted, the significant irrigation-related effluent limits in the PRB are EC and SAR. DEQ is aware that, within certain broad limits, it is the ratio of EC and SAR that determine the suitability of water quality for irrigation purposes for any given crop. We therefore suggest that DEQ apply the Hanson Diagram in establishing SAR limits. As stated above, these limits should be applied only when adequate water is available to create an irrigable flow. At all other times, to apply effluent limitations which are adequate to irrigate the most sensitive crop would require the dischargers to make the water in the stream better than mother nature provides. That is an undue burden, with no environmental benefit, which will not in any meaningful way enhance the crop production. It will only impose unnecessary additional expense and effort on dischargers of water from CBNG operations.

IV. Tiered Approach Should Protect Measurable Decrease in Crop Production.

The Draft Policy establishes a tiered approach which is designed to establish appropriate effluent limits to ensure there is no measurable decrease in crop production. Williams agrees that a tiered approach is absolutely necessary to address the variety of background conditions and quality of discharges in different drainages within the PRB. Williams believes that default EC and SAR limits in Tier 1 require revision. As discussed above, Williams does not believe that the use of default EC limits should be based on tolerance values for the most sensitive crop or upon 100% yield threshold values. To the extent DEQ decides to use such criteria, calculated values should be based on data which more accurately reflects soil chemistry and crop production in the PRB and Wyoming, not California. The Tier 1 approach is overly conservative and protects against any decrease in crop production, not merely a measurable decrease in such production. The Draft Policy proposes the application of effluent limits to achieve an end beyond that described in the narrative goals stated in Chapter 1, Section 20 and does so without sufficient supporting credible evidence. This point is well made and fully documented in letters dated May 5, 2006 submitted by Kevin C. Harvey on behalf of several CBM operators including Williams, and we urge the DEQ to carefully and fully consider Mr. Harvey's comments and conclusions and modify its draft proposal accordingly.

Tier 2 offers Williams and other dischargers a viable permitting option in instances in which background water quality is worse than its CBNG effluent quality. In such circumstances, Tier 1 default limits should be inapplicable. Williams requests that DEQ amend the Draft Policy to state that if such circumstances exist, EC and SAR effluent limits must be based upon those background conditions rather than tolerance values for the most sensitive crop.

V. <u>The EQA Does Not Give DEQ Authority to Regulate Water Quantity Per Se</u>

While DEQ has deleted the previous Section IV, "Bottomland Forage" from the Draft Policy, it cites in support of this deletion the Environmental Quality Council's (EQC) February 16, 2006 decision to initiate rulemaking concerning the regulation of the volume of water which could be discharged into naturally low flow stream channels. In his February 3, 2006 letter, to the EQC, John Wagner, Administrator, Water Quality Control Division, expressly stated that the DEQ did not have the authority to regulate effluent quantity as proposed in the petition to the EQC. Attachment 1. In his April 12, 2006 opinion relating to the EQC's decision to initiate rulemaking, Wyoming Attorney General, Patrick Crank, confirmed Mr. Wagner's interpretation of DEQ's limited authority to regulate volumes of water discharged under the WYPDES permit program. Attachment 2.

Williams agrees that the EQA does not grant the EQC the authority to amend the WQRR to regulate water quantity per se, any more than the EQA granted the DEQ the ability to regulate flows without regard to water quality to protect bottomland grazing in ephemeral drainages in previous iterations of the Draft Policy. Moreover, Williams takes the position that there is a flowage easement which attaches to all natural water courses within the State of Wyoming, and there is no basis for eliminating or minimizing the use of the natural stream channel where produced water flows do not exceed the beds and banks of the stream channel.

Williams appreciates the opportunity to comment on the Draft Policy and appreciates your consideration of our comments. We would be pleased to discuss our comments further with you and respond to any questions you may have.

Sincerely,

Joe Olson
Facilities Engineer

KC HARVEY, LLC
SOIL AND WATER RESOURCE CONSULTANTS

May 4, 2006

Mr. Bill DiRienzo
Wyoming Department of Environmental Quality
Water Quality Division
Herschler Building, 4th Floor West
122 West 25th Street
Cheyenne, Wyoming 82002

Subject: Comments pertaining to the derivation of default effluent limits for EC in the Draft Section 20 Agricultural Use Protection Policy.

Dear Mr. DiRienzo:

I respectfully submit for your consideration the following comments regarding the fourth draft of the Section 20 Agricultural Use Protection Policy as it pertains to the derivation of default effluent limits for EC. These comments are being submitted on behalf of Yates Petroleum Company, Williams Production RMT Company, Petro-Canada Resources (USA) Inc., Marathon Oil Company, Lance Oil & Gas Company, Inc., Fidelity Exploration & Production Company, Devon Energy Production Company L.P., Bill Barrett Corporation, and Anadarko Petroleum Corporation. I have submitted additional comments regarding the derivation of SAR limits and the proposed SAR cap to you in a separate letter.

By way of introduction, I am a board-certified professional soil scientist having practiced as an environmental consultant in Montana and Wyoming, and throughout the world, for nearly 25 years. For the past seven years, my practice has focused on water management and soil and water salinity/sodicity issues associated with oil and gas development. I am credited as the first to research, develop, and apply managed irrigation techniques for the beneficial use of coalbed natural gas produced water. I have directed or participated in over 75 separate projects related to produced water management, WPDES permitting, soil and water chemistry investigations, and reclamation for coalbed and conventional natural gas projects in Wyoming, Colorado, and Montana. I have a M.S. degree in land rehabilitation (soil science emphasis) from Montana State University, and a B.S. in Resource Conservation (soil science emphasis) from the University of Montana.

I would like to comment on the proposed changes made to the Agricultural Use Protection Policy by the WDEQ subsequent to the January 26, 2006 meeting of the Water and Waste Advisory Board. My comments will focus on the comments provided by Dr. Larry Munn in his letter to the DEQ dated December 5, 2005. It is my understanding that Dr. Munn's comments resulted in the changes made to the proposed Policy. Specifically, I comment on Dr. Munn's request that the California-based soil salinity tolerance thresholds be used to establish default effluent limits for electrical conductivity (EC) under the Tier 1 process.

233 EDELWEISS DRIVE, UNIT 11, BOZEMAN, MONTANA 59718
VOICE: 406/585-7402, FAX: 406/585-7428, EMAIL: INFO@KCHARVEY.COM

Summary of Findings

The fourth draft of the Agricultural Use Protection Policy describes a 3-tiered decision making process for deriving appropriate effluent limits for EC and SAR whenever a proposed discharge may reach irrigated lands. The Tier 1 process would be followed for deriving "default" limits, and as such, this procedure would require a minimum of background information from the applicant. Specifically, the default EC limits would be based on the species-specific 100 percent yield potential values for soil EC reported by the USDA Agricultural Research Service (ARS) Salt Tolerance Database (USDA ARS, 2006).

Alfalfa is considered to be the most salt sensitive plant irrigated in northeastern Wyoming. Given this, my comments focus on the relevant information regarding alfalfa salinity tolerance. The ramifications of the concepts and data discussed herein for alfalfa can be applied to the more tolerant irrigated forage species commonly found in northeastern Wyoming, for example, western wheatgrass and smooth brome.

A considerable amount of research went into preparing these comments, including three months searching and reviewing the relevant scientific literature, and compiling and analyzing available and relevant soil, plant, and water data. The key conclusions of the literature review and data analysis are presented below and will be substantiated by the discussion that follows.

California Based Salinity Thresholds

- The ARS Salt tolerance database relies on California based salinity thresholds developed to approximate the specific plant, soil and environmental variables associated with that region.
- Regional differences in soil chemistry, climate and agricultural practices are likely to have a profound effect on the applicability of California based salinity threshold data to alfalfa growing in Wyoming.

Chloridic Versus Sulfatic Soils

- The natural soil salinity in the Powder River Basin is dominated by the sulfate ion; California soils are dominated by chloride. This conclusion is supported herein by the literature and by an evaluation of actual soil chemistry data provided by the USDA National Soil Survey Center.
- The term "gypsiferous" refers to sulfatic soils and is applicable to the Powder River Basin of Wyoming. Numerous documents, including the ARS Salt Tolerance Database, indicate that in sulfatic (or "gypsiferous") soils, plants will tolerate about 2 dS/m higher salinity than indicated.

The Influence of Soil Salinity on Alfalfa Yield

- Alfalfa is considered the most salt sensitive plant irrigated in northeastern Wyoming. Conditions required for the growth of alfalfa at 100 percent of its physiological yield potential probably do not exist anywhere in northeastern Wyoming and place doubt on the application of this benchmark value there.

- Sources of research and field guidance outside of California suggest alfalfa has a higher relative 100 percent yield soil EC tolerance than 2 dS/m, perhaps as high as 4 to 8 dS/m.

- Alfalfa yield comparisons between California and Wyoming show actual harvest values independent of soil salinity. Identical yields were reported in Wyoming for soil EC values ranging from 1.8 dS/m to 6.5 dS/m.

Based on the review summarized herein, we respectfully suggest that the WDEQ consider adopting an acceptable average root zone EC threshold of 4 dS/m for protection of alfalfa. This would equate to a default (Tier 1) effluent limit of 2.7 dS/m based on the 1.5 concentration factor cited by the draft Agricultural Use Protection Policy. The EC limits for protecting other species of concern in the Powder River Basin, e.g., western wheatgrass, should also be adjusted accordingly, based on the inherent differences in soil chemistry and climate between the northern Great Plains and the California agricultural areas. These conclusions and recommendations are substantiated by the discussion below.

California-based Salinity Thresholds

The majority of salinity tolerance data generated in the United States have been a product of field and laboratory trials conducted by the U.S. Salinity Laboratory (USSL) in Riverside, California. The salinity tolerance data generated by the USSL were prompted in response to agricultural production in the areas of the San Joaquin and Imperial Valleys of California. In 1977, Maas and Hoffman compiled the California research in a seminal article titled "Crop Salt Tolerance -- Current Assessment," listing salt tolerance levels for various crops. The subsequent year, Francois and Maas (1978) published an indexed bibliography of plant responses to salinity from 1900 to 1977 with 2,357 references to about 1,400 species. These articles serve as the primary references regarding crop tolerance and yield potential of selected crops as influenced by irrigation water (EC_w) or the average root zone soil salinity level (EC_e). This information was updated by Mass (1990). The ARS Salt Tolerance Database relies entirely on the Mass (1990) summary as the primary source of relative salt tolerance levels among crops. With respect to alfalfa, the original salt tolerance listings remain unchanged from the original Mass and Hoffman (1977) article.

The Mass and Hoffman (1977) and Mass (1990) listings of salt tolerance levels include the establishment of the 100 percent yield threshold for soil salinity. This value refers to the maximum allowable average root zone salinity level (EC_e) that results in no yield reduction for crops grown in chloritic soils. The term chloritic soil refers to the dominant salt type found in California soils (see below). For alfalfa, Mass and Hoffman (1977) and Mass (1990) list the 100 percent yield potential for alfalfa grown in chloritic soils as 2.0 dS/m (EC_e). The Mass and

Hoffman (1977) and Mass (1990) assessments also contain a disclaimer that the yield potentials listed should only serve as a guide to relative tolerances among crops, and that the absolute salt tolerance of crops is not simply a function of soil EC but is dependent on "many plant, soil, water, and environmental variables."

Six studies conducted at the US Salinity Laboratory in Riverside, California, served as the foundation for the determination of Maas and Hoffman's 2.0 dS/m threshold value (Gauch and Magistad, 1943; Brown and Hayward, 1956; Bernstein and Ogata, 1966; Bower et al., 1969; Bernstein and Francois, 1973; Hoffman et al., 1975). These studies vary in their methodology, including greenhouse and field experiments, different growth mediums (sand, gravel and soil), various watering regimes (automatic watering, tension-based watering), and multiple sources of chloritic salinity (NaCl, $CaCl_2$, and $MgCl_2$). These studies were designed to assess relative yield values, irrigation leaching fractions, root zone salt profiles, or salinity-ozone interactions. They were not specifically designed to determine a threshold salinity value for alfalfa. Usually, only four salinity levels were tested, with data used to produce a crop yield reduction line.

Furthermore, the source of salinity in the six studies was consistently chloride dominated, with either NaCl or a blend of NaCl, $CaCl_2$, and $MgCl_2$ added to the irrigation water. In Southern California, where these studies occurred, salts found in the soils are largely chloride-dominated. None of these studies were conducted using sulfate-dominated salts, such as are found in Wyoming soils (see below). Such regional differences in soil salinity are likely to have a profound effect on the application of existing salinity threshold data to alfalfa growing in the Northern Great Plains. Recognizing this, Mass (1990), Ayers and Westcot (1985), Hanson et al. (1999), as well as the ARS Salt Tolerance Database, all indicate that plants grown in sulfatic soils will tolerate average root zone EC_e values about 2 dS/m higher than indicated by each of these references. For alfalfa, this would equate to a 100 percent yield threshold of approximately 4 dS/m. This fact is discussed in detail below.

Chloridic Versus Sulfatic Soils

Research efforts of the USSL in California identified adjustments in effective plant salinity tolerance expressed or repressed in the field by physiological responses to climate, cultural practices, soil fertility, irrigation methods, physical condition of the soils and the distribution and speciation of salts within soil profiles. A critical difference between the environmental conditions in California and the northern Great Plains (including northeastern Wyoming) is soil chemistry and the primary salt constituents found in these soils. It is widely accepted that the soils of the agricultural areas of California are dominated by salts where chloride is the dominant anion, and that the soils of the northern Great Plains are dominated by salts where sulfate is the dominant anion. In earlier publications, sulfatic soils are sometimes termed "gypsiferous," referring to the most common sulfate salt found in semi-arid soils -- gypsum (calcium sulfate dehydrate). The correct term used today is sulfatic soils.

To incorporate the variation of salinity tolerance exhibited by plant response to different salt distributions and dominant salt species, the authors of salt tolerance research included a provision for sulfatic soils. Soils may contain amounts of sparingly soluble salts, such as gypsum and other sulfate salts, many times greater than can be held in solution in the field water-

content range. Sulfatic soils may appear to be saline when exhaustively extracted in the lab (i.e., saturated paste extract), but the in-situ soil solution may be nonsaline because of the limited solubility of gypsum and other sulfate salts (Bernstein, 1975). Thus, the EC measured in a saturated paste extract is higher than the actual concentration of salts seen by plants in sulfatic soils. It was suggested originally by Bernstein (1962) that plants will tolerate about 2 dS/m higher soil salinity (EC_e) than indicated in sulfatic soils due to this solubility effect. Since calcium sulfate is disproportionately dissolved in preparing saturated-soil extracts, the EC_e of sulfatic soils will range an average of 2 dS/m higher than that of chloritic soils with the same water conductivity at field capacity (Bernstein 1962). Therefore, plants grown in sulfatic soils will tolerate an EC_e of approximately 2 dS/m higher than those grown where chloride is the predominant ion (Maas, 1990). This narrative provision for sulfatic soils is included in the ARS Salt Tolerance Database, and the classic irrigation guidelines presented in Ayers and Wescot (1985).

Sulfatic soils are the rule not the exception in Wyoming and the northern Great Plains. Sulfatic soils identified by salinity tolerance references are characterized by the presence and influence of gypsum, or calcium sulfate dihydrate ($CaSO_4 \cdot 2H_20$), within the soil profile, as well as the geological and climactic prerequisites for sulfatic soil conditions. Soil gypsum may stem from one of several sources. Soils formed from geologic material containing anhydrite or gypsum often contains gypsum. The amount of rainfall and the topographic setting will strongly influence the amount and location of gypsum in the soil (Dixon and Weed, 1989). Accumulations of soluble salts, including sulfates in the surface layers, are characteristic of saline soils of arid and semiarid regions (Brady, 1974), including Wyoming. Research conducted by the U.S. Geological Survey confirms the presence of gypsiferous parent materials in the Powder River Basin (Johnson, 1993). At this point, it is important to differentiate between the soil taxonomic terms "gypsic" or "petrogypsic," which are used to describe significant gypsum accumulation within soil horizons, from the terms "gypsiferous" or "sulfatic" soils which refer to the dominate salt type in soils of Wyoming and the northern Great Plains.

Published research has addressed the issue of prevailing salt distribution and climate influenced salt dominance. In Springer et al. (1999), Curtin et al. (1993) and Trooien (2001), northern Great Plains prairie soil chemistry is comparatively summarized and/or contrasted to soils of California. Research suggests that recommendations developed for the western United States, where chloride is the major anion in soil and water chemistry, may not be appropriate for sulfatic soils (Springer et al., 1999). Trooien (2001) notes that most plant salinity tolerance information is developed in California and that the chemistry of salinity is different in the northern Great Plains (i.e., sulfate dominated salinity). Therefore, Trooien (2001) indicates that salinity thresholds are greater and yield losses are somewhat smaller in the Northern Great Plains compared to those of California (i.e., chloride dominated salinity). Research in Canadian prairie soils by Curtin et al. (1993) and Wentz (2001) suggest that salt tolerance testing at the Swift Current, Saskatchewan, salinity laboratory (and also at the US Salinity Laboratory) has mostly involved the determination of crop responses to chloride salinity. However, there is reason to suspect that responses to sulfate salinity, which is the predominant form of salinity in prairie soils, may differ from those observed in chloride salt systems. Wentz (2001) summarizes that crop tolerances developed for chloride dominated soils, such as those in California, may not be applicable to crops grown on the sulfate dominated soils typically found in western Canada.

Comparison of actual soil analytical data from the NSSC Soil Survey Laboratory, Lincoln, Nebraska, supports the chloride and sulfate salt dominance designations suggested by Springer et al. (1999), Curtin et al. (1993), Trooien (2001), and Wentz (2001). Analyses from the U.S. Soil Survey Laboratory are available online at http://ssldata.nrcs.usda.gov/ and organized by soil pedon. Data from selected counties in Wyoming and California were obtained from the NSSC Soil Survey Laboratory Research Database in order to determine the dominance of chloride or sulfate soil chemistry in the respective regions. Soil chemistry data were downloaded for use in this study for counties of the Powder River Basin in Wyoming (Sheridan, Campbell and Johnson Counties). Soil chemistry data were also downloaded for counties in California where intensive agricultural production takes place (Imperial, Fresno, Kern, Kings and Tulare).

Data pertaining to soil chloride and sulfate in the saturated paste extract are arranged and averaged by county and state in Table 1 below. These values are based on all of the available data provided by the U.S. Soil Survey Laboratory.

Table 1
A Comparison of Average Soil Saturated Paste Extract Sulfate and Chloride Levels from Counties in Wyoming and California.

County	Average Soil Sulfate Level (meq/L)	Average Soil Chloride Level (meq/L)
Sheridan, WY	14.9	4.1
Campbell, WY	130.4	3.0
Johnson, WY	30.9	1.8
Wyoming Average	**58.7**	**2.9**
Imperial, CA	48.4	295.7
Fresno, CA	98.6	26.3
Kern, CA	44.3	73.0
Kings, CA	110.7	23.9
Tulare, CA	9.3	21.6
California Average	**62.3**	**88.1**

The summary data suggest that the relative proportion of chloride salts in the selected California counties outweigh the proportion of sulfate salts and verify the chloride dominance suggested by the literature summarized above. In northeastern Wyoming, the relative proportion of sulfate salts in selected counties outweigh the proportion of chloride by an order of magnitude and verify the sulfate dominance and sulfatic conditions implied by the literature. Therefore, the recommendation by the ARS Salt Tolerance Database signifying that plants grown in sulfatic soils will tolerate average root zone EC_e values about 2 dS/m higher than indicated, is valid for the Powder River Basin, and probably all of Wyoming. For alfalfa, this would equate to a 100 percent yield threshold of 4 dS/m.

The Influence of Soil Salinity on Alfalfa Yield

As indicated above, the *relative* 100 percent yield potential reported for alfalfa in the ARS Salt Tolerance Database is 2 dS/m (EC_e). As such, alfalfa is regarded in the California-based literature as "moderately sensitive" to salinity. An *absolute* salinity tolerance would reflect predictable inherent physiological responses by plants, but cannot be determined because interactions among plant, salt, water and environmental factors influence the plant's ability to tolerate salt. *Relative* salt tolerance is a value based on the climatic and cultural conditions under which a crop is grown (Maas and Hoffman, 1977). Research generated outside the U.S. Salinity Laboratory in the U.S. and Canada has introduced alternative salinity tolerance values for alfalfa influenced by these climatic and cultural conditions.

In a study based on field trials in western Canada, McKenzie (1988) reported the "relative maximum salinity crops will tolerate when combined with intermittent moisture stress throughout the growing season." McKenzie (1988) places alfalfa within a moderate tolerance category, as opposed to moderate sensitivity, and extends alfalfa's 100 percent yield tolerance to an EC range of 4-8 dS/m, as opposed to 2 dS/m. Similar tolerance descriptors and EC values for alfalfa can be found associated with Britton et al. (1977), who supports moderate salt tolerance and an EC range of 5-10 dS/m for alfalfa. Likewise, Milne and Rapp (1968) present alfalfa with a moderate tolerance and an EC range of 4-8 dS/m. Cavers (2002); Wentz (2001); Schafer (1983); Holzworth and Wiesner (1990) and Dodds and Vasey (1985) also contribute to a departure from the established Maas classification of alfalfa salinity tolerance and threshold values. Bower et al., suggests an alfalfa tolerance somewhat between the previous authors and Maas (1990), suggesting maximum alfalfa yield is obtained when the average EC_e value for the root zone is 3 dS/m. Using salinized field plots in southern Saskatchewan, Holm (1983) reported a small, 0.037 ton/acre, reduction in alfalfa yields resulting from an increase in the surface EC_e (0 to 15 cm sample) from a 0 to 4 dS/m range to a 4 to 8 dS/m range. Holm presented these scales as representative of low and medium EC levels.

Relative salinity tolerances reported outside of peer reviewed literature stem from professional observations and judgments, roundtable discussions, experience in the field, and experience with the region, culture and climate; not from experimental data. Incorporation of field experience, observation, and limited data into supporting documents of the Salt Tolerance Database is acknowledged in Ayers and Wescot (1985). Alternative sources listed herein do not always report EC values in terms of 100 percent yield thresholds for alfalfa, but should not be discounted, as they pertain to what is realistic in the field. As an example, the Montana Salinity Control Association reports forage salt tolerances in terms of marginal establishment levels, not 100 percent yield potentials. Conditions allowing alfalfa to produce at 100 percent of its physiochemical yield potential probably do not exist anywhere within the northern Great Plains.

A suggested field-yield value corresponding to the 100 percent yield of alfalfa has never been reported by authors of salinity literature. Specifically, what yield of alfalfa, in tons per acre, could one expect if it was grown under conditions supporting 100 percent yield? Conditions supporting 100 percent alfalfa yields recommended by the ARS Salt Tolerance Database and its supporting documents would be: a soil EC_e of 2 dS/m or less, an irrigation water EC_w less than or equal to 1.3 dS/m, water contents maintained at field capacity, available N, P and K nutrient

levels maximized for alfalfa growth, a sufficiently long growing season, no associated phytotoxicity or pest issues, etc. This data limitation precludes the direct comparison of alfalfa yields generated in an agricultural area to the potential yields theoretically available under optimized conditions. The only available analysis is to compare an alfalfa yield to the average yield generated in its area, or generated between areas.

Using data available from the National Agricultural Statistics Service, selected county agricultural commissioner's data, and the U.S. Census of Agriculture (2002, 1997), irrigated alfalfa yield data were obtained for periods of interest. Alfalfa yield data for Wyoming counties are available from 1959 through 2005, but were averaged from 1970-2005 to reflect the integration of new irrigation technologies. Alfalfa yield data were summarized for the area encompassing the Powder River Basin: Sheridan, Johnson and Campbell counties. Alfalfa yield data for California counties are available from 1980-2004 so the entire dataset was averaged. Alfalfa data were summarized for counties in California related to intensive agriculture: Imperial, Fresno, Kern, Kings and Tulare counties.

Soil salinity data (as measured by EC) collected by the USDA National Soil Survey and analyzed by the National Soil Survey Center (NSSC) Soil Survey Laboratory were also obtained and summarized for the aforementioned counties. Average root zone EC values were calculated to a maximum depth of five feet. The county alfalfa yield and average root zone EC summaries are presented in Table 2 below.

Table 2
Comparison of Average Root Zone Soil Salinity (EC) Values with Historical Alfalfa Yields for Selected Counties in Wyoming and California.

County	Average Root Zone Soil Salinity (EC as dS/m)	Historical Average Alfalfa Yield (tons/acre)
Sheridan, WY	1.5	2.7
Johnson, WY	1.9	2.4
Campbell, WY	2.0	2.4
Wyoming Average	**1.8**	**2.5**
Tulare, CA	2.8	8.4
Kings, CA	6.9	6.9
Kern, CA	4.6	8.0
Fresno, CA	6.7	7.9
Imperial, CA	6.7	7.8
California Average	**5.5**	**8.0**

Values expressed in Table 2 show substantially higher average root zone salinities in California than in Wyoming. Alfalfa yields reported in California are three times greater than those in Wyoming, even though, on average, the soil salinity values are nearly three times higher than those reported for the Wyoming counties. The values generated in this exercise suggest that environmental factors other than salinity, e.g., climate, may be dictating the obtainable degree of alfalfa yield produced. However, the data also suggest that the California-based 100 percent yield threshold of 2 dS/m may not be appropriate for even the chloritic soils of California. For

example, the historical average yield of alfalfa in Tulare County is 8.4 tons per acre with a corresponding average root zone EC of 2.8 dS/m. The yield from Tulare County is actually slightly greater than the yields from Fresno and Imperial Counties where the corresponding average root zone EC values are substantially higher at 6.7 and 6.7 dS/m, respectively. Regardless, there does not appear to be a substantial difference in yields reported by the California counties with soil EC values ranging from 2.8 to 6.7 dS/m.

Other field data from Wyoming have been reviewed that also suggest an alternative to the California-based salinity tolerance values. The Use Attainability Analysis (UAA) report for Cottonwood Creek (SWWRC et al., 2002) was downloaded from the Wyoming Department of Quality, Water Quality Division webpage. Cottonwood Creek is located in Hot Springs County within the Bighorn Basin of Wyoming. This is an area of extensive conventional oil and gas production. According to the UAA report, discharge of produced water from the Hamilton Dome oil field to Cottonwood Creek constitutes the majority of flow to the ephemeral stream and constitutes the only irrigation water source for approximately 35 ranching operations. The waters of Cottonwood Creek exhibit an EC_w between 4.1 and 4.5 dS/m. At an average EC_w of 4.3 dS/m, an average root zone soil EC_e value can be calculated using the widely accepted relationship: $EC_e = 1.5\ EC_w$ (Ayers and Wescot, 1985). This relationship is expressed in the draft Section 20 Agricultural Use Protection Policy. From this relationship, an average root zone soil EC value of 6.5 is estimated for the fields irrigated long-term with water from Cottonwood Creek. Average alfalfa hay yields reported in the UAA amount to 2.5 tons per acre. This yield is identical to the average of the three Wyoming counties reported in Table 2 above. This is compelling given that the average soil EC value for the three other Wyoming counties is 1.8 dS/m, while the estimated soil EC for the fields irrigated with water from Cottonwood Creek is 6.5.

Closing Statement

Based on the review summarized herein, we respectfully suggest that the WDEQ consider adopting an acceptable average root zone EC threshold of 4 dS/m for protection of alfalfa. This would equate to a default (Tier 1) effluent limit of 2.7 dS/m based on the 1.5 concentration factor cited by the draft Agricultural Use Protection Policy. Other species of concern, including western wheatgrass, should be given equal consideration due to the inherent differences in soil chemistry between the northern Great Plains and the California agricultural areas for which the ARS Salt Tolerance Database is based. Factors such as extreme climate, periodic drought, soil moisture regime, duration of growing season, soil depth, and fertility limitations can collectively exert an overriding regional influence on the yield potential of forage crops. Based on this, we ask that the WDEQ exercise caution interpreting the applicability of specific salinity tolerances outlined by the ARS Salt Tolerance Database and thoughtfully consider the difficulty in detecting a "measurable" change in plant production due to soil salinity alone.

References Cited

Ayers, R.S. and Wescot, D.W. 1985. Water quality for agriculture. FAO Irrigation and Drainage Paper, 29 (rev. 1).

Bernstein, L. 1975. Effects of salinity and sodicity on plant growth. p. 295-312. In: Baker, K.F., Zentmyer, G.A. and Cowling, E.B. (ed.) Annual Review of Phytopathology. Vol. 13. Palo Alto, California.

Bernstein, L. 1962. Salt affected soils and plants. Problems of the Arid Zones. Proc. UNESCO Symp. 18: 139-174. Paris, France.

Bernstein, L. and Francios, L.E. 1973. Leaching requirement studies: Sensitivity of alfalfa to salinity of irrigation and drainage waters. Proceedings, Soil Science Society of America. 37:931-943.

Bernstein, L. and Ogata, G. 1966. Effects of salinity on nodulation, nitrogen fixation, and growth of soybeans and alfalfa. Agronomy Journal. 58:201-203.

Bower, C.A., Ogata, G., and Tucker, G.M. 1969. Rootzone salt profiles and alfalfa growth as influenced by irrigation water salinity and leaching fraction. Agronomy Journal. 61:783-785.

Brady, N.C. 1974. The nature and properties of soils 8th ed. Macmillan Publishing Company, Incorporated, New York, NY.

Brown, J.W. and Hayward, H.E.. 1956. Salt tolerance of alfalfa varieties. Agronomy Journal. 48:18-20.

Britton, M.G., Buchannan, L.C. and Muir, W.E. 1977. Principles and practices of commercial farming (5th edition). Faculty of Agriculture, University of Manitoba. Winnipeg, Manitoba.

Cavers, C. 2002. Please don't pass the salt – Preventing and Managing Soil Salinity. Manitoba Agriculture & Food; Soils and Crops Branch. Accessed from the internet, 3/20/06 from; http://www.umanitoba.ca/afs/ agronomists_conf/2002/pdf/cavers.pdf.

Curtin, D., Steppuhn, H. and Selles, F. 1993. Plant responses to sulfate and chloride salinity: Growth and Ionic Relations. Soil Science Soc. Am. J. 57:1304-1310.

Dixon, J.B. and Weed, S.B., eds. 1989. Minerals in soil environment 2nd ed. SSSA book series no. 1.

Dodds, D.L. and Vasey, E. 1989. Forages for salt-affected soils. Bulletin R-584 Rev. Cooperative Extension Service, North Dakota State University; Fargo, North Dakota.

Francois, L.E. and Maas, E.V. (ed.). 1978. Plant responses to salinity: An indexed bibliography. USDA-SEA (Science and Education Admin.) Agric. Reviews and manuals, ARM-W-6. U.S. Gov. Print. Office, Washington, DC.

Gauch, H.C. and Magistad, O.C. 1943. Growth of strawberry clover varieties and of alfalfa and Ladino clover as affected by salt. Journal of American Society of Agronomy. 35:871-880.

Hanson, B., Grattan, S.R. and Fulton, A.F. 1999. Agricultural salinity and drainage. Division of Agriculture and Natural Resources Publication 3375. University of California Irrigation Program. University of California, Davis, California.

Hoffman, G.J., Maas, E.V. and Rawlins, S.L. 1975. Salinity-ozone interactive effects on alfalfa yield and water relations. Journal of Environmental Quality. 4:326-331.

Holm, H.M. 1983. Soil salinity, a study in crop tolerances and cropping practices. Sask. Agriculture, Plant Industries Branch, Publ. 25M/3/83.

Holzworth, L.K. and Wiesner, L.E. 1990. Principles of establishment and seedling year management. p. 170-228. In: Baldridge, D.E. and Lohmiller, R.G. (ed.) Montana Interagency Plant Materials Handbook for Forage Production, Conservation, Reclamation and Wildlife. Montana State University, Bozeman, Montana.

Johnson, E.A. 1993. Depositional history of triassic rocks in the area of the powder river basin, northeastern Wyoming and southeastern Montana. U.S. Geological Survey Bulletin 1917 Chapter P.

Maas, E.V. 1990. Crop salt tolerance. p. 262-304. In: K.K. Tanji (ed.) Agricultural salinity assessment and management. ASCE Manuals Rep. Eng. Practive no.71. Am. Soc. Civ. Eng., New York, NY.

Maas, E.V. and Hoffman, G.H. 1977. Crop salt tolerance – current assessment. J. Irrigation and Drainage Div., Am. Soc. Civil Eng. 103(IR2):115-134.

McKenzie, R.C. 1988. Tolerance of plants to soil salinity. Soil and water program, 1987. Alberta Special Crops and Horticultural Research Centre Pamphlet 88-10. Brooks, AB.

Milne, R.A. and Rapp, E. 1968. Soil salinity and drainage problems; causes, effects, management. Publication 1314; Canadian Department of Agriculture.

Schafer, W.D. 1983. Salinity control under irrigation. Montguide Document MT 8382. Cooperative Extension Service, Montana State University; Bozeman, Montana.

Soil Survey Staff. 2006. National Soil Survey Characterization Data; Soil Survey Laboratory, National Soil Survey Center USDA-NRCS - Lincoln, NE. Saturday, March 11, 2006.

Springer, G., Wienhold, B.J., Richardson, J.L. and Disrud, L.A. 1999. Salinity and sodicity changes in dispersive clay and saturated hydraulic conductivity in sulfatic soils. Communications in soil science and plant analysis. 30(15&16), 2211-2220.

States West Water Resources Corporation, Western EcoSystems Technology, Inc., Blankenship Consulting LLC. 2002. Merit Energy Company Use Attainability Analysis to Accompany Petition to Change Use Criteria on Cottonwood Creek Near Hamilton Dome, Hot Springs County, Wyoming as Provided Under Wyoming Surface Water Standards, Chapter 1.

Trooien, T.P. 2001. Salinity down under. In: Proceedings of the South Dakota No-Till Association Meeting. pp. 35-38.

U.S. Census of Agriculture. 1997. Accessed from the U.S. Census Bureau website: http://www.census.gov/prod/www/abs/agric.html

U.S. Census of Agriculture. 2002. Accessed from the USDA National Agricultural Statistics Service website: http://www.nass.usda.gov/Census_of_Agriculture/index.asp.

U.S.D.A. Agricultural Research Service. 2006. Salt Tolerance Database. Relative Salt Tolerance of Herbaceous Crops. George E. Brown, Jr. Salinity Laboratory. Riverside, California.

U.S. Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA Agric. Handbook no. 60, Washington, D.C.

Wentz, D. 2001. Salt tolerance of plants. Alberta Agriculture, Food and Rural Development. Accessed from the internet, 3/25/06 from; http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex3303

* * * * *

Thank you very much for your time and consideration of this review and the recommendations stemming from it. If you, your WDEQ colleagues, or the members of the Water and Waste Advisory Board have any questions or comments regarding our findings, please contact me.

Sincerely,

Kevin C. Harvey, M.Sc., CPSSc.
Principal Soil Scientist

KC HARVEY, LLC
SOIL AND WATER RESOURCE CONSULTANTS

May 4, 2006

Mr. Bill DiRienzo
Wyoming Department of Environmental Quality
Water Quality Division
Herschler Building, 4th Floor West
122 West 25th Street
Cheyenne, Wyoming 82002

Subject: Comments pertaining to the proposed default SAR effluent limit cap of 10 in the Draft Section 20 Agricultural Use Protection Policy.

Dear Mr. DiRienzo:

I respectfully submit for your consideration the following comments regarding the fourth draft of the Section 20 Agricultural Use Protection Policy as it pertains to the derivation of effluent limits for SAR, particularly the proposed SAR cap of 10. These comments are being submitted on behalf of Yates Petroleum Company, Williams Production RMT Company, Petro-Canada Resources (USA) Inc., Marathon Oil Company, Lance Oil & Gas Company, Inc., Fidelity Exploration & Production Company, Devon Energy Production Company L.P., Bill Barrett Corporation, and Anadarko Petroleum Corporation. I have submitted additional comments regarding the derivation of EC limits in a separate letter.

By way of introduction, I am a board-certified professional soil scientist having practiced as an environmental consultant in Montana and Wyoming, and throughout the world, for nearly 25 years. For the past seven years, my practice has focused on water management and soil and water salinity/sodicity issues associated with oil and gas development. I am credited as the first to research, develop, and apply managed irrigation techniques for the beneficial use of coalbed natural gas produced water. I have directed or participated in over 75 separate projects related to produced water management, WPDES permitting, soil and water chemistry investigations, and reclamation for coalbed and conventional natural gas projects in Wyoming, Colorado, and Montana. I have a M.S. degree in land rehabilitation (soil science emphasis) from Montana State University and a B.S. in Resource Conservation (soil science emphasis) from the University of Montana.

I would like to comment on the proposed changes made to the Agricultural Use Protection Policy by the WDEQ subsequent to the January 26, 2006 meeting of the Water and Waste Advisory Board. My comments will focus on the comments provided by Dr. Larry Munn in his letter to the DEQ dated December 5, 2005. It is my understanding that Dr. Munn's comments resulted in the changes made to the proposed Policy. Specifically, I comment on Dr. Munn's proposal that all WPDES default effluent limits for SAR be capped at 10 under the Tier 1 process.

233 EDELWEISS DRIVE, UNIT 11, BOZEMAN, MONTANA 59718
VOICE: 406/585-7402, FAX: 406/585-7428, EMAIL: INFO@KCHARVEY.COM

Summary of Findings

The fourth draft of the Agricultural Use Protection Policy describes a 3-tiered decision making process for deriving appropriate effluent limits for EC and SAR whenever a proposed discharge may reach irrigated lands. The Tier 1 process would be followed for deriving "default" limits, and as such, this procedure would require a minimum of background information from the applicant. The default SAR limits would be extrapolated from the Hanson et al. (1999) chart relating the established EC effluent limit to SAR, up to a maximum default value of 10. The effluent limit for SAR will be determined in conjunction with EC so that the relationship of SAR to EC remains within the "no reduction in rate of infiltration" zone of the Hanson et al. (1999) diagram.

Two key concerns arise from Dr. Munn's letter regarding sodicity and the discharge of CBNG produced water in the Powder River Basin: (1) the potential impacts on the hydraulic function of irrigated soils during produced water discharge; and (2) the potential impacts of residual adsorbed sodium on the hydraulic function of irrigated fields after produced water discharge has ceased and rainfall/snowmelt leaches salts from the upper root zone. It is assumed that these concerns led Dr. Munn and the WDEQ to propose the SAR effluent limit cap of 10 under the Tier 1 process.

In addressing these concerns, I performed a considerable amount of research, including three months searching and reviewing the relevant scientific literature, and compiling and analyzing available and relevant soil, plant, and water data. The key conclusions of the literature review and data analysis are presented below and will be substantiated by the discussion that follows.

Review of Soil Sodicity

- Plant growth problems associated with excess sodium adsorption are in response to negative changes in soil structure resulting in reduced air exchange, water infiltration and hydraulic conductivity.

- The universally applied sodic soil threshold is an exchangeable sodium percentage (ESP) greater than 15.

- SAR is a measure of the sodicity risk in irrigation water. The higher the salinity of irrigation water, the higher the SAR can be without impacting soil structure and impairing soil infiltration and permeability.

The ESP-SAR Relationship for Soils in Northeastern Wyoming

- Using regression analysis, the relationship between ESP and soil SAR was determined for the Powder River Basin (n=382, R^2=.74).

- A 1:1 relationship of soil SAR to water SAR exists for soils in equilibrium with irrigation water. This relationship is widely accepted and confirmed by recent research led by Dr.

James Bauder at Montana State University. The relationship of ESP to soil SAR is therefore equivalent to the relationship of ESP to water SAR.

- Based on the regional specific relationship of ESP and SAR, an effluent limit of SAR = 16 corresponds to an ESP of 10, and provides a 33% margin of safety against the formation of sodic conditions (i.e., exceeding an ESP of 15). The proposed default SAR cap of 10 is, therefore, unnecessarily conservative.

The Effect of Rainwater Leaching on Soils Irrigated with Produced Water

- Concern has been raised that subsequent rainfall/snowmelt leaching of residual soil salinity may lower the electrolyte concentration and naturally raise the ESP past the dispersive sodic soil threshold.

- Research demonstrates that arid land soils can release 0.3 to 0.5 dS/m of Ca and Mg to solution as a result of the dissolution of primary minerals and the inherent calcium carbonate content of surface soils. Shainberg et al. (1981) indicates that these concentrations are sufficient to counter the deleterious effects of exchangeable sodium, even when the soil is leached with rainwater.

A Review of Soil Sodicity

The physical and chemical phenomena associated with soil sodicity are complex. Therefore, a brief summary is provided regarding the soil and water chemistry associated with the physical affects of soil sodicity.

A large body of research concerning sodic, or "black alkali" soils has been generated in response to the negative effects of high sodium concentrations on soils. Toxicity effects of sodium are rarely expressed in forage and grass crops, but do cause injury to selected woody plants (Lilleand et al., 1945; Ayers et al., 1951; Brown et al., 1953). Plant growth problems associated with high concentrations of sodium are generally a response to negative changes in soil structure. Sodic soils are "nonsaline soils containing sufficient exchangeable sodium to adversely affect crop production and soil structure (Soil Science Society of America, 2001)." High levels of adsorbed sodium tend to disperse soil particles thereby sealing the soil. The result can produce clogged soil pores, hard surface crusts, reduced infiltration, reduced permeability, and reduced oxygen diffusion rates, all of which interfere with or prevent plant growth. By definition, sodic soils are those that have an exchangeable sodium percentage (ESP) greater than 15. The universally applied ESP threshold of 15 percent is acknowledged in numerous publications, including Levy et al. (1998), Abrol et al., (1988), Evangelou (1998), McNeal and Coleman (1966), Sparks (1995), Sumner et al. (1998), Shainberg et al. (1971), the Soil Improvement Committee (2002), university extension publications, etc.

Clay minerals are the most physically and chemically reactive components of the sand, silt, and clay matrix in soil. The structural arrangement of clay minerals in soil is akin to a deck of cards; the clay mineral itself can be thought of as the deck, and the cards as individual layers. The

properties of the deck depend upon the arrangement of the cards and the electrochemical interlayer forces holding the cards together.

Clay minerals in soils are negatively charged and consequently attract ions with a positive charge such as calcium, magnesium, potassium, and sodium. Positively charged ions are called cations. Each cation competes with others in the soil solution for access to the bonding sites based on its valence and hydrated size. Every soil has a definite capacity to adsorb the positively charged cations. This is termed the cation exchange capacity (CEC). The various adsorbed cations (such as calcium and sodium) can be exchanged one for another and the extent of exchange depends upon their relative concentrations in the soil solution (dissolved), the ionic charge (valence), the nature and amount of other cations, etc. ESP is, accordingly, the amount of adsorbed sodium on the soil exchange complex expressed in percent of the cation exchange capacity in milliequivalents per 100 grams of soil (meq/100 g). Thus,

$$\text{ESP} = (\text{exchangeable sodium} / \text{cation exchange capacity}) \times 100.$$

Sodic soil conditions arise when greater than 15 percent of the ions bonded to the deck are sodium, which has a +1 valence and a large hydrated radius. When the ESP exceeds 15, the large hydrated sodium ions can wedge in-between the individual cards and cause "swelling" of the deck (Levy et al., 1998). This causes negative effects on the physical structure of the soil. Upon re-wetting, the individual decks may disperse and settle into soil pores, effectively clogging them and reducing the efficiency of air exchange, water infiltration, and permeability (i.e., hydraulic conductivity). In general, soils with moderately high, to high, clay contents are at higher risk.

Excessive adsorbed or exchangeable sodium can result from sustained use of irrigation water that is high in sodium and low in calcium and magnesium. Consequently, the ratio of sodium to calcium and magnesium ions in water is an important property affecting the infiltration and permeability hazard. The water quality index used to measure the hazard related to sodium abundance or sodicity in irrigation water is the sodium adsorption ratio or SAR.

The SAR is the ratio of the dissolved sodium concentration in water divided by the square root of the average calcium plus magnesium concentration. The SAR can be calculated from the sodium, calcium and magnesium concentrations via the formula:

$$\text{SAR} = [\text{sodium}] / (([\text{calcium}] + [\text{magnesium}])/2)^{1/2}$$

where the concentrations are in milliequivalents per liter (meq/L).

What is not apparent from the SAR formula is the fact that the higher the salinity of the water, the higher the SAR can be without impacting soil structure and impairing soil infiltration and permeability. Put another way, for a given SAR, infiltration rates generally increase as salinity (measured by the EC) increases. The changes in soil infiltration and permeability occur at varying SAR levels, higher if the salinity is high, and lower if the salinity is low. Therefore, in order to evaluate the sodicity risk of irrigation water, the EC must be considered. To this end,

the SAR-EC guidelines presented in Ayers and Westcot (1985) and Hanson et al. (1999) are used to assess the potential sodicity risk of irrigation water.

The ESP-SAR Relationship for Soils in Northeastern Wyoming

In addition to measuring the SAR of irrigation water, one can also measure the SAR of the soil solution via a saturated paste extract (i.e., the dissolved concentrations of sodium, calcium, and magnesium are measured in a saturated paste extract and applied via the SAR formula presented above). The soil SAR was developed to serve as a rapid and relatively inexpensive index of ESP. It is widely accepted that the SAR of the soil in equilibrium with the SAR of the irrigation water is equal to the long-term average SAR of the irrigation water.

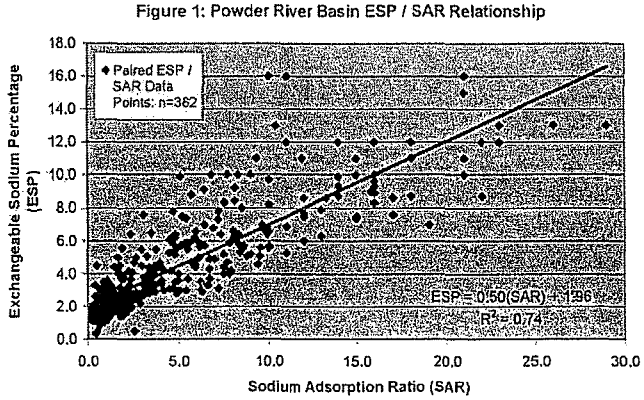
The fourth draft of the Agricultural Use Protection Policy includes a proposed SAR cap of 10 for Tier 1 default effluent limits. To evaluate the appropriateness of the proposed cap, an analysis was performed using 382 ESP-SAR data pairs generated from ongoing soils assessment work in the Powder River Basin of Wyoming (KC Harvey LLC, 2006). This database represents flood plain soils associated with tributaries to the Powder River and the Tongue River, including spreader dike irrigated fields. This database represents baseline soil chemical conditions. In no case were any of these soils irrigated with or influenced by coalbed natural gas produced water. The soil samples from which the analyses were made were collected during soil profile descriptions to five feet, and with a Giddings hydraulic probe up to eight feet in depth. The numerous soil investigations involved were required for various coalbed natural gas water management planning, permitting, and design purposes.

The ESP-SAR data pairs were graphed in Microsoft Excel using simple scatter-plot and trend line analysis. The best fit line resulted in a linear regression which yielded the equation:

$$ESP = 0.5(SAR) + 1.96, \text{ with an } R^2 \text{ value of } 0.74.$$

The regional-specific "Powder River Basin" relationship, based on 382 soil samples, is shown on Figure 1. According to the Powder River Basin equation, a soil SAR of 26 corresponds to the critical ESP threshold of 15 percent.

Figure 1: Powder River Basin ESP / SAR Relationship



It is widely accepted that the SAR of soil in equilibrium with irrigation water equals the long-term average SAR of irrigation water. Recent Department of Energy funded research directed by Dr. James Bauder at Montana State University (Robinson and Bauder, 2003) confirms this relationship. Their research, which is related to the potential effects of coalbed natural gas produced water on soils, reports that in general, soil solution SAR

represents the SAR of the applied water. The 1:1 soil SAR to water SAR relationship allows one to relate the SAR of discharge water to the SAR of the soil in the Powder River Basin ESP-SAR graph and equation described above. For example, after long-term irrigation with water exhibiting an SAR of 15, the equilibrated ESP of the irrigated soil would be approximately 9.5 percent. The proposed SAR cap of 10 would equate to a corresponding ESP of 7. An ESP cap of 7 appears to be unnecessarily conservative given the regional specific relationship of ESP and SAR. While an ESP threshold of 15 is widely accepted to be the point at which clay swelling and dispersion occurs, we respectfully suggest that the WDEQ consider establishing a Tier 1 default SAR effluent limit cap of 16, which corresponds to an ESP of 10. An ESP value of 10 provides a 33 percent margin of safety.

The Effect of Rainwater Leaching on Soils Irrigated with Produced Water

In his December 5, 2005 letter, Dr. Munn indicates his concern about the potential effects of rainwater leaching of fields that had received produced water due to upstream permitted discharges. In particular, what is the effect of leaching on the sodicity status and hydraulic function of soils after discharge and irrigation with produced water ceases? Fortunately, the considerable research on this subject has been well documented in the scientific literature.

Discontinuation of produced water discharge in the Powder River Basin will effectively reduce the EC and SAR of irrigation waters from tributaries and mainstems so long as the surface water is of higher quality than the produced water. In the case of fields that are irrigated opportunistically (e.g., in response to runoff events that are captured behind spreader dike systems), there can be three sources of water supplying soil moisture: (1) meteoric water (rain and snowmelt); (2) natural runoff water; and (3) subirrigation from a shallow aquifer. In the case of rainfall and snowmelt, the EC of these waters will be similar to that of distilled water, i.e., they will exhibit very low dissolved solids. Owing to the dissolution of soluble constituents within the watershed, natural runoff EC values can range up to 5 dS/m or higher. Regarding subirrigation, shallow aquifers can be relatively saline due to the entrainment of dissolved minerals along the groundwater flowpath.

The concern arises from leaching of residual surface soil salinity with rainfall and snowmelt. Intermittent rainfall and snowmelt may lower the electrolyte concentration (i.e., EC) sufficiently to promote clay dispersion, depending on soil properties (Levy et al., 1998). Conversely, when the electrolyte concentration in the soil solution reaches a moderate level (1-2 dS/m), high sodicity levels (ESP between 10 and 30) cause only small to moderate changes in the physical and hydraulic properties of the soils, which are mostly reversible (Levy et al., 1998). Shainberg et al. (1981) showed that a major factor causing differences among various sodic soils in their susceptibility to hydraulic failure when leached with low electrolyte concentrations (i.e., a low EC) was their rate of salt release from mineral dissolution.

Arid land soils can release 0.3 to 0.5 dS/m of calcium and magnesium to solution as a result of the dissolution of plagioclase, feldspars, hornblends and other sparingly soluble minerals within the soil matrix (Rhoades et al. 1968). The solution composition of a calcareous soil at a given ESP in contact with distilled water (i.e., rainwater or snowmelt) can be calculated (Shainberg et al., 1981). As calcium carbonate ($CaCO_3$) dissolves, the EC of the soil solution increases and

calcium replaces sodium on exchange sites until the solution is in equilibrium with the cation exchange system and the $CaCO_3$ solid phase. Shainberg et al. (1981) calculated that the EC values of solutions in equilibrium with soils having ESP values of 5, 10, and 20 are 0.4, 0.6, and 1.2 dS/m, respectively. Shainberg et al. (1981) indicates that these concentrations are sufficient to counter the deleterious effects of exchangeable sodium, even when the soil is leached with rainwater.

It is evident that water equilibrated with a calcareous soil can never be a very low salinity (Shainberg et al., 1981). Using the same database discussed above for evaluation of the ESP-SAR relationship in 382 soil samples from the Powder River Basin, we can compute an average percent lime ($CaCO_3$) content in surface soil samples (n=81), which is 5.1 percent. This represents a considerable reserve of calcium. Other sources of calcium include residual gypsum ($CaSO_4$) which we know to be prevalent in Wyoming soils.

Various soil SAR-EC relationships (not to be confused with irrigation water SAR-EC relationships) have been reported in the literature by introducing low electrolyte concentration waters to sodic soils. Felhendler et al. (1974) measured the hydraulic conductivity of two montmorillonitic soils as a function of the SAR and found that both were only slightly affected by the SAR of the percolating solution up to a SAR of 20 as long as the concentration of the percolating solution exceeded 1 dS/m. Shainberg et al. (1981) studied the effects of leaching a 1:1 sand-soil column with distilled water and increasing concentrations of a weak electrolyte solution. His findings concluded that an electrolyte concentration of 0.3 dS/m in the percolating solution was adequate to prevent the adverse effects of a SAR of 15 on the hydraulic conductivity of the soil-sand mixture. These findings are very similar to the conclusions of the U.S. Salinity Laboratory Staff (1954) who used electrolyte concentrations equal to or greater than 0.3 dS/m in their regression analysis to determine the sodic soils threshold of ESP = 15.

As a review, an electrolyte concentration of 0.3 dS/m is the minimum value of calcium and magnesium contributions to soil solution associated solely to arid soil weathering. This suggests that an arid Powder River Basin soil with a SAR of 16 (ESP = 10), will have no sodicity related impacts to the hydraulic conductivity, even when the salt concentration of the irrigation or rainwater is equal to that of distilled water.

Of course, irrigation water in the Powder River Basin has an intrinsic electrical conductivity greater than that of distilled water. Use of surface water for irrigation will actually supplement the inputs of calcium and magnesium from weathering and carbonate dissolution alone.

Using the aforementioned Powder River Basin soils assessment database (KC Harvey LLC, 2006), an average surface soil ECe of 1.64 dS/m was calculated from 81 individual surface soil samples. This value suggests that electrolyte concentrations in surface soils of the Powder River Basin, in equilibrium with mineral dissolution, the salinity of runoff irrigation water, and rainwater/snowmelt, is about 1.6 dS/m, or five times (1.6 dS/m divided by 0.3 dS/m) the concentration required to maintain the hydraulic conductivity of a soil at an ESP of 16.

Closing Statement

Results of the Powder River Basin regression analysis indicates that a relationship between ESP and soil/water SAR exists, which allows the calculation of one parameter from the other. Using the proposed, default ESP cap of 10 percent, the scientific literature indicates that water with a SAR of 16 can be effectively used for irrigation without adverse effects on the physical structure or hydraulic conductivity of Powder River Basin soils during irrigation. Furthermore, it has been shown that inputs of Ca and Mg from the natural dissolution of plagioclase, feldspars, hornblends and other sparingly soluble minerals, especially calcium carbonate and gypsum, will provide an effective buffer to residual soil sodicity after the discontinuation of produced water discharge and the transition back to native irrigation, precipitation, and runoff regimes.

References Cited

Abrol, I.P., Yadav, J.S.P. and Massoud, F.I. 1988. Salt-affected soils and their management. FAO Land and Water Management Division, Soils Bulletin 39.

Ayers, A.D., Aldrich, D.G. and Coony, J.J. 1951. Sodium chloride and injury of Fuerte avocado leafs. California Avocado Soc. Yearbook: 1951 174-178 illus.

Ayers, R.S. and Wescot, D.W. 1985. Water quality for agriculture. FAO Irrigation and Drainage Paper, 29 (rev. 1).

Brown, J.W., Wadleigh, C.H. and Hayward, H.E. 1953. Foliar analysis of stone fruit and almond trees on saline substrates. Amer. Soc. Hort. Proc. 61: 49-55.

Evangelou, V.P. 1998. Environmental soil and water chemistry principles and applications. John Wiley and Sons (Pub), New York, NY.

Felhendler, R.I., Shainberg, I. and Frenkel, H. 1974. Dispersion and hydraulic conductivity of soils in mixed solutions. Int. Congr. Soil Sci., Trans. 10th (Moscow) 1:103-112.

Hanson, B., Grattan, S.R. and Fulton, A.F. 1999. Agricultural salinity and drainage. Division of Agriculture and Natural Resources Publication 3375. University of California Irrigation Program. University of California, Davis, CA.

KC Harvey, LLC. 2006. Unpublished data. Compilation of various soil investigation sampling and analysis data from Sheridan, Johnson and Campbell Counties, Wyoming. Bozeman, MT.

Levy, G.J., Shainberg, I. and Miller, W.P. 1998. Physical Properties of Sodic Soils. In: Sumner, M.E. and Naidu, R. 1998. Sodic soils: Distribution, properties, management and environmental consequences. Oxford University Press, Inc. New York, NY.

Lilleand, O., Brown, J.G. and Swanson, C. 1945. Research shows sodium may cause leaf tip burn. Almond Facts 9 (2): 1, 5, illus.

McNeal, B.L and Coleman, N.T. 1966. Effect of solution composition on hydraulic conductivity. Soil Sci. Soc. Am. Proc., 30, 308-312.

Rhoades, L.D. 1968. Mineral weathering correction for estimating the sodium hazard of irrigation waters. Soil Sci. Soc. Am. Proc. 32:648-652.

Robinson, K.M. and Bauder, J.W. 2003. Soil behavior upon wetting with saline sodic water part 2: Soil chemical responses. Adapted from Robinson, K.M. 2003. Effects of saline-sodic water on EC, SAR, and water retention.

Shainberg, I., Bresler, E., and Klausner, Y. 1971. Studies on Na/Ca montmorillonite systems, I: The swelling pressure. Soil Sci. 111:214-219.

Shainberg, I., Rhoades, J.D., Suarez, D.L. and Prather, R.J. 1981. Effect of mineral weathering on clay dispersion and hydraulic conductivity of sodic soils. Soil Sci. Soc. Am. J. 45:287-291.

Soil Improvement Committee, California Plant Health Association. 2002. Western Fertilizer Handbook, ninth edition. Interstate Publishers, Inc. Danville, Illinois.

Soil Science Society of America. 2001. Glossary of Soil Science Terms. Madison, WI.

Sparks, D.L. 1995. Environmental Soil Chemistry. Academic Press, San Diego, Ca.

Sumner, M.E., Rengasamy, P. and Naiud, R. 1998. Sodic soils: A reappraisal. In: Sumner, M.E and Naidu, R. 1998. Sodic soils: Distribution, properties, management and environmental consequences. Oxford University Press, Inc. New York, NY.

U.S. Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA Agric. Handbook no. 60, Washington, D.C.

* * * * *

Thank you very much for your time and consideration of this review and the recommendations stemming from it. If you, your WDEQ colleagues, or the members of the Water and Waste Advisory Board have any questions or comments regarding our findings, please contact me.

Sincerely,

Kevin C. Harvey, M.Sc., CPSSc.
Principal Soil Scientist

Williams Production RMT Company
300 North Works Avenue
Gillette, WY 82716
307.686.1636
307.686.7574 (fax)

February 14, 2007

Wyoming Department of Environmental Quality
Water Quality Division
Herschler Building – 4W
122 West 25th Street
Cheyenne, WY 82002
Attn: Bill DiRienzo

Re: Comments on Proposed Revisions to Chapter 1 of the Wyoming Water Quality Rules and Regulations, Appendix H, Agricultural Use Protection

Dear Mr. DiRienzo:

Williams Production RMT Company (Williams) appreciates the opportunity to submit comments to the Environmental Quality Council (EQC) regarding the adoption of Appendix H, Agricultural Use Protection standards, as part of the revisions to Chapter 1 of the Wyoming Water Quality Rules and Regulations. Williams is a significant operator in Wyoming and, in particular, in the Powder River Basin (PRB). Williams is concerned about Appendix H's potential to affect its coalbed natural gas (CBNG) operations adversely.

Appendix H has undergone significant changes over two years and four public comment periods. Throughout that time, the agricultural use protection standards in Appendix H were proposed as a Wyoming Department of Environmental Quality (DEQ) implementing policy. It was only in the last several months that DEQ decided to submit the Agricultural Use Protection Policy to the EQC as a rule rather than a policy. DEQ has failed to consider the mandatory factors specified in the Environmental Quality Act (EQA) for proposing Appendix H as a rule to the EQC. W.S. § 35-11-302 (a)(vi).

The Agricultural Use Protection standards in Appendix H have the potential to impose significant costs and technical burdens upon CBNG operators. Yet, DEQ failed to consider these impacts, and failed to balance the burdens imposed against the purported environmental effects sought to be protected, prior to recommending the adoption of Appendix H as a rule. Williams believes Appendix H would be significantly different in its requirements and breadth if the DEQ had thoroughly considered the factors set forth in W.S. § 35-11-302(a)(vi).

Williams' specific comments regarding the text of the proposed Appendix H follow. In addition, Williams encourages the EQC to consider seriously the development of a risk-based approach to implementation of the agricultural protection narrative standard, as opposed to the one-size-fits-all approach of the currently proposed Appendix H.

I. Purpose - Chapter 1, Section 20 Should Not be Implemented to Protect Illegal Irrigation.

We agree with DEQ that the purpose of Ch. 1, Section 20 is to protect irrigation that existed prior to an application for a WYPDES discharge permit. As the DEQ has noted, the language infers a pre-existing agricultural use prior to an application for a WYPDES permit, which can serve as a baseline from which a decrease in crop or livestock production could be measured. We also agree that, to be afforded the protection of Section 20, a landowner must have an existing irrigation structure or mechanism in place for diverting water. However, in Appendix H, the DEQ proposes the continuation of its historic practice of protecting illegal diversions, i.e., irrigation which occurs in the absence of a valid existing water right. Williams takes issue with this practice, particularly when the DEQ endorses in a rule this illegal practice be followed by State personnel when translating the Section 20 narrative goals into appropriate WYPDES permit limits.

If a landowner is irrigating without the benefit of a water right from the office of the State Engineer, then the irrigation is illegal. Since there is no right to the use of the water in the drainage, the irrigation could be ordered to cease and desist at any time. Therefore, there is really nothing for the DEQ to protect. Moreover, the DEQ's current practice of protecting illegal irrigation is in direct conflict with the Wyoming law regulating the use of water:

> Water being always the property of the state, rights to its use shall attach to the land for irrigation, or to such other purposes or object for which acquired in accordance with the beneficial use made for which the right receives public recognition, under the law and the administration provided thereby. W.S. § 41-3-101.

By allowing unauthorized structures to trigger application of the standard, Appendix H protects unlawful irrigation use, sanctions the unlawful conduct, and rewards the offender for its offense. We submit that this practice constitutes egregiously bad public policy and produces an absurd result in violation of the canons of statutory and regulatory interpretation declared by the Wyoming Supreme Court. See *In re KP v. State,* 102 P.3d 217, 224 (Wyo. 2004) ("[T]his Court will not interpret a statute in a manner producing absurd results"); *Corkill v. Knowles,* 955 P.2d 438, 444 (Wyo. 1998).

Lastly, the EQA expressly states that the actions of the DEQ shall not limit or interfere with the jurisdiction, duties or authority of the State Engineer in administering water rights. W.S. §35-11-1104(a)(iii). Protection of illegal diversions could certainly be construed as interfering with these jurisdictional constraints, as it aids conduct directly contrary to the requirements for use of water set out above.[1] CBNG dischargers should not be required to protect such illegal practices. Appendix H should expressly state that in the future unauthorized irrigation use will not be protected and that existing diversion structures not covered by an existing water right will not trigger application of the agricultural standard.

II. Presumption of Naturally Irrigated Lands is Overly Broad

Appendix H implies there is a pre-existing agricultural use of a stream or drainage when "a substantial acreage of naturally sub-irrigated pasture within a stream floodplain" exists. Appendix H states that infra-red photography, surficial geologic maps, wetland mapping, landowner testimony or any combination of these sources may be used to establish that lands are naturally irrigated. Each of these information sources presents a snapshot of conditions at a specific time, and conditions may have changed e.g., wetlands mapping.[2] In addition, a permit applicant has no method by which it could disprove the presumption of sub-irrigation presented in Appendix H. The application of EC and SAR effluent limits should not be applied unless there is some presence and evidence of the ability to irrigate with a surficial flow.

The EC and SAR effluent limits will be applied where the naturally irrigated land reaches a threshold deemed "agriculturally significant." This threshold is triggered when a stream segment contains "single parcels of naturally irrigated land

---

[1] The lack of a water right is often an indication that the drainage did not maintain adequate flows or water quality to facilitate irrigation or that the soils or other conditions were simply not supportive of irrigation adequate to allow the landowner to prove up its beneficial use of water and thus obtain a valid water right. And, in the absence of a valid existing water right, applicants for a discharge permit have no notice of irrigation use by such downstream landowners and no way to account for them in their WYPDES permit applications.

[2] The DEQ should not be able to rely solely upon landowner testimony which is inherently biased to establish the existence of naturally irrigated lands.

greater than 20 acres or multiple parcels in near proximity that total more than 20 acres." Given the size of parcels in Wyoming, the definition of agricultural significance could be easily met through single parcels or the sum of smaller parcels. The practical effect of this definition combined with an easily triggered (unrefutable) definition of sub-irrigated land is that Appendix H's irrigation effluent limits would be applied to discharges into virtually any and every drainage in the State. The agricultural protection standards in Appendix H, if implemented, would result in a gross over-extension of the prior agricultural use presumption, would be overly protective of established agricultural uses which may no longer exist and would significantly restrict CBNG operators' ability to discharge into State waters without expensive treatment of discharges to protect nominally useful parcels of land.

III. Irrigation Data and Information

Appendix H indicates that "the goal is to ensure that preexisting irrigated crop production will not be diminished as a result of the lowering of water quality." The difficulty, of course, is in assessing the preexisting or baseline crop production that existed prior to any proposed discharge. Often there are no records of crop yield, stream flows, historic water quality, etc., making it very difficult for all parties to apply the "no measurable decrease" standard. This has caused DEQ to historically take an overly conservative approach in developing numeric permit effluent limitations to assure no measurable decrease in crop production. For that reason, we recommend that the following be added to the data and information required under Section d:

- Extent of irrigation permitted by Office of the State Engineer under a valid and existing Wyoming water right.

- Rate of flow required to activate irrigation under the system in place.

- As to the season of use, the EQC should further refine the definition of "irrigation season." The EC and SAR limits will apply during those periods when crop growth is occurring and then only when irrigable flows exist. Irrigable flows are those in which adequate water exists to activate a spreader dike system for artificially irrigated lands or to cause natural flooding or sub-irrigation on naturally irrigated lands. It is not reasonable to assume that the irrigation season is generally considered year-round in Wyoming for passively irrigated lands, given the variation and intensity of storm events supplying water to ephemeral or intermittent drainages used for irrigation purposes. In the absence of such events, the naturally-occurring salinity in these drainages limits their utility for irrigation. When irrigation cannot occur, the water quality standards protective of irrigation should not be applied. Operators should not be required to make the water quality in the stream system better year round than mother nature provided.

- Most importantly, in place of using published tolerance values for the most sensitive crops grown, we suggest use of the Hanson Diagram to manage the SAR limit for two reasons. First, the published tolerance values for most crops generally assume conditions exist for attaining a 100% crop yield. Our experience throughout the PRB is that, given the growing conditions, e.g., a lack of precipitation, poor alkaline and saline soils, and intermittent flows, etc., irrigators in the PRB achieve a crop yield well below the 100% value. Second, as Appendix H acknowledges, the significant irrigation-related effluent limits in the PRB are EC and SAR. The EQC is aware that, within certain broad limits, it is the ratio of EC and SAR that determine the suitability of water quality for irrigation purposes for any given crop. We therefore suggest that the EQC apply the Hanson Diagram in establishing SAR limits. As stated above, these limits should be applied only when adequate water is available to create an irrigable flow. At all other times, to apply effluent limitations which are adequate to irrigate the most sensitive crop would require the dischargers to make the water in the stream better than mother nature provides. That is an undue burden, with no environmental benefit, which will not in any meaningful way enhance the crop production. It will only impose unnecessary additional expense and effort on dischargers of water from CBNG operations.

IV. <u>Tiered Approach Should Protect Measurable Decrease in Crop Production.</u>

The agricultural protection standards in Appendix H establish a tiered approach which is designed to establish appropriate effluent limits to ensure there is no measurable decrease in crop production. While a tiered approach is absolutely necessary to address the variety of background conditions and quality of discharges in different drainages within the PRB, the default EC and SAR limits in Tier 1 require revision. As discussed above, Williams does not believe that the use of default EC limits should be based on tolerance values for the most sensitive crop or upon 100% yield threshold values. To the extent the EQC decides to use such criteria, calculated values should be based on data which more accurately reflects soil chemistry and crop production in the PRB and Wyoming, not California. The Tier 1 approach is overly conservative and protects against <u>any</u> decrease in crop production, not merely a <u>measurable</u> decrease in such production. Appendix H proposes the application of effluent limits to achieve an end beyond that described in the narrative goals stated in Chapter 1, Section 20 and does so without sufficient supporting credible evidence. This point is well made and fully documented in letters dated May 5, 2006 submitted to the Water and Waste Advisory Board by Kevin C. Harvey on behalf of several CBMG operators including Williams, and we urge the EQC to carefully and fully consider Mr. Harvey's comments and conclusions and modify Appendix H accordingly. See attached letters.

Tier 2 offers dischargers a viable permitting option in instances in which background water quality is worse than its CBNG effluent quality. In such circumstances, Tier 1 default limits should be inapplicable. Williams requests that the EQC amend Appendix H to state that if such circumstances exist, EC and SAR effluent limits must be based upon those background conditions rather than tolerance values for the most sensitive crop.

V. A New Approach

The agricultural protection standards in Appendix H have undergone a number of changes over the past two years as DEQ and the Water and Waste Advisory Board have struggled with how best to implement Chapter 1, Section 20's prohibition against measurable decrease in crop or livestock production. The agricultural use protection standards were originally contemplated as internal policy guidance, giving DEQ sufficient flexibility to change the standards as needed. Given the renewed consideration of the standard as a rule rather than a policy, Williams believes it is time for the EQC and DEQ to step back and consider whether Appendix H truly addresses its originally intended purpose—to provide a practical, workable, and predictable solution for applying the narrative measurable decrease standard in Chapter 1, Section 20. The last two years of consideration by the Water and Waste Advisory Board, DEQ, and the public has culminated in proposed rule that Williams believes fails to achieve that purpose. Appendix H does not in any practical or realistic way define what is a "measurable decrease" and what is the best way to avoid it.

Williams suggests that the EQC and DEQ take a fresh look at the no measurable decrease standard and work with all stakeholders to develop a new rule that reflects the realities of agricultural production in an arid environment. Measurable decrease must be considered in the context of the background conditions. Not all waters of the State have the same quality and not all agricultural use has the same value. For example, where water quality is poor and agricultural use is limited to low-yield production from naturally irrigated native plants, less protection may be necessary than in situations where the background water quality is high and artificial irrigation supports high-yield commercial crops. Any new rule should take into account site-specific conditions and uses of water in each drainage, rather than applying blanket standards which are derived from data generated in California.

Williams recommends that the newly drafted rule take a risk-based approach to measurable decrease. Effluent limits should reflect that agricultural production in most areas of Wyoming is not at 100% yield under natural conditions due to lack of precipitation, poor alkaline and saline soils, and intermittent flows. EC and SAR standards should not be set to protect 100% yield, but should reflect the actual yield where produced water may actually be applied. Further, in many cases, stream conditions are such that there is little risk that produced water will reach irrigated acres unless mixed with substantial quantities of natural flows. Any rule should require consideration of whether the water being discharged will be applied to irrigated acreage, the impact of irrigation practices (the amount of water necessary to activate artificial and natural irrigation systems), and the condition of the soil being irrigated. Though Appendix H as currently drafted attempts to address these issues, it does so in an inflexible manner that does not acknowledge varied applications in the field.

Williams appreciates the opportunity to comment on the agricultural use protection standards in Appendix H and appreciates your consideration of our comments. We would be pleased to discuss our comments further with you and respond to any questions you may have.

Sincerely,

/s/

Joe Olson
Facilities Engineer

Attachments

3668614_1.DOC

KC HARVEY, LLC
SOIL AND WATER RESOURCE CONSULTANTS

May 4, 2006

Mr. Bill DiRienzo
Wyoming Department of Environmental Quality
Water Quality Division
Herschler Building, 4th Floor West
122 West 25th Street
Cheyenne, Wyoming 82002

Subject: Comments pertaining to the derivation of default effluent limits for EC in the Draft Section 20 Agricultural Use Protection Policy.

Dear Mr. DiRienzo:

I respectfully submit for your consideration the following comments regarding the fourth draft of the Section 20 Agricultural Use Protection Policy as it pertains to the derivation of default effluent limits for EC. These comments are being submitted on behalf of Yates Petroleum Company, Williams Production RMT Company, Petro-Canada Resources (USA) Inc., Marathon Oil Company, Lance Oil & Gas Company, Inc., Fidelity Exploration & Production Company, Devon Energy Production Company L.P., Bill Barrett Corporation, and Anadarko Petroleum Corporation. I have submitted additional comments regarding the derivation of SAR limits and the proposed SAR cap to you in a separate letter.

By way of introduction, I am a board-certified professional soil scientist having practiced as an environmental consultant in Montana and Wyoming, and throughout the world, for nearly 25 years. For the past seven years, my practice has focused on water management and soil and water salinity/sodicity issues associated with oil and gas development. I am credited as the first to research, develop, and apply managed irrigation techniques for the beneficial use of coalbed natural gas produced water. I have directed or participated in over 75 separate projects related to produced water management, WPDES permitting, soil and water chemistry investigations, and reclamation for coalbed and conventional natural gas projects in Wyoming, Colorado, and Montana. I have a M.S. degree in land rehabilitation (soil science emphasis) from Montana State University, and a B.S. in Resource Conservation (soil science emphasis) from the University of Montana.

I would like to comment on the proposed changes made to the Agricultural Use Protection Policy by the WDEQ subsequent to the January 26, 2006 meeting of the Water and Waste Advisory Board. My comments will focus on the comments provided by Dr. Larry Munn in his letter to the DEQ dated December 5, 2005. It is my understanding that Dr. Munn's comments resulted in the changes made to the proposed Policy. Specifically, I comment on Dr. Munn's request that the California-based soil salinity tolerance thresholds be used to establish default effluent limits for electrical conductivity (EC) under the Tier 1 process.

233 EDELWEISS DRIVE, UNIT 11, BOZEMAN, MONTANA 59718
VOICE: 406/585-7402, FAX: 406/585-7428, EMAIL: INFO@KCHARVEY.COM

Summary of Findings

The fourth draft of the Agricultural Use Protection Policy describes a 3-tiered decision making process for deriving appropriate effluent limits for EC and SAR whenever a proposed discharge may reach irrigated lands. The Tier 1 process would be followed for deriving "default" limits, and as such, this procedure would require a minimum of background information from the applicant. Specifically, the default EC limits would be based on the species-specific 100 percent yield potential values for soil EC reported by the USDA Agricultural Research Service (ARS) Salt Tolerance Database (USDA ARS, 2006).

Alfalfa is considered to be the most salt sensitive plant irrigated in northeastern Wyoming. Given this, my comments focus on the relevant information regarding alfalfa salinity tolerance. The ramifications of the concepts and data discussed herein for alfalfa can be applied to the more tolerant irrigated forage species commonly found in northeastern Wyoming, for example, western wheatgrass and smooth brome.

A considerable amount of research went into preparing these comments, including three months searching and reviewing the relevant scientific literature, and compiling and analyzing available and relevant soil, plant, and water data. The key conclusions of the literature review and data analysis are presented below and will be substantiated by the discussion that follows.

California Based Salinity Thresholds

- The ARS Salt tolerance database relies on California based salinity thresholds developed to approximate the specific plant, soil and environmental variables associated with that region.
- Regional differences in soil chemistry, climate and agricultural practices are likely to have a profound effect on the applicability of California based salinity threshold data to alfalfa growing in Wyoming.

Chloridic Versus Sulfatic Soils

- The natural soil salinity in the Powder River Basin is dominated by the sulfate ion; California soils are dominated by chloride. This conclusion is supported herein by the literature and by an evaluation of actual soil chemistry data provided by the USDA National Soil Survey Center.
- The term "gypsiferous" refers to sulfatic soils and is applicable to the Powder River Basin of Wyoming. Numerous documents, including the ARS Salt Tolerance Database, indicate that in sulfatic (or "gypsiferous") soils, plants will tolerate about 2 dS/m higher salinity than indicated.

The Influence of Soil Salinity on Alfalfa Yield

- Alfalfa is considered the most salt sensitive plant irrigated in northeastern Wyoming. Conditions required for the growth of alfalfa at 100 percent of its physiological yield potential probably do not exist anywhere in northeastern Wyoming and place doubt on the application of this benchmark value there.

- Sources of research and field guidance outside of California suggest alfalfa has a higher relative 100 percent yield soil EC tolerance than 2 dS/m, perhaps as high as 4 to 8 dS/m.

- Alfalfa yield comparisons between California and Wyoming show actual harvest values independent of soil salinity. Identical yields were reported in Wyoming for soil EC values ranging from 1.8 dS/m to 6.5 dS/m.

Based on the review summarized herein, we respectfully suggest that the WDEQ consider adopting an acceptable average root zone EC threshold of 4 dS/m for protection of alfalfa. This would equate to a default (Tier 1) effluent limit of 2.7 dS/m based on the 1.5 concentration factor cited by the draft Agricultural Use Protection Policy. The EC limits for protecting other species of concern in the Powder River Basin, e.g., western wheatgrass, should also be adjusted accordingly, based on the inherent differences in soil chemistry and climate between the northern Great Plains and the California agricultural areas. These conclusions and recommendations are substantiated by the discussion below.

California-based Salinity Thresholds

The majority of salinity tolerance data generated in the United States have been a product of field and laboratory trials conducted by the U.S. Salinity Laboratory (USSL) in Riverside, California. The salinity tolerance data generated by the USSL were prompted in response to agricultural production in the areas of the San Joaquin and Imperial Valleys of California. In 1977, Maas and Hoffman compiled the California research in a seminal article titled "Crop Salt Tolerance -- Current Assessment," listing salt tolerance levels for various crops. The subsequent year, Francois and Maas (1978) published an indexed bibliography of plant responses to salinity from 1900 to 1977 with 2,357 references to about 1,400 species. These articles serve as the primary references regarding crop tolerance and yield potential of selected crops as influenced by irrigation water (EC_w) or the average root zone soil salinity level (EC_e). This information was updated by Mass (1990). The ARS Salt Tolerance Database relies entirely on the Mass (1990) summary as the primary source of relative salt tolerance levels among crops. With respect to alfalfa, the original salt tolerance listings remain unchanged from the original Mass and Hoffman (1977) article.

The Mass and Hoffman (1977) and Mass (1990) listings of salt tolerance levels include the establishment of the 100 percent yield threshold for soil salinity. This value refers to the maximum allowable average root zone salinity level (EC_e) that results in no yield reduction for crops grown in chloritic soils. The term chloritic soil refers to the dominant salt type found in California soils (see below). For alfalfa, Mass and Hoffman (1977) and Mass (1990) list the 100 percent yield potential for alfalfa grown in chloritic soils as 2.0 dS/m (EC_e). The Mass and

Hoffman (1977) and Mass (1990) assessments also contain a disclaimer that the yield potentials listed should only serve as a guide to relative tolerances among crops, and that the absolute salt tolerance of crops is not simply a function of soil EC but is dependent on "many plant, soil, water, and environmental variables."

Six studies conducted at the US Salinity Laboratory in Riverside, California, served as the foundation for the determination of Maas and Hoffman's 2.0 dS/m threshold value (Gauch and Magistad, 1943; Brown and Hayward, 1956; Bernstein and Ogata, 1966; Bower et al., 1969; Bernstein and Francois, 1973; Hoffman et al., 1975). These studies vary in their methodology, including greenhouse and field experiments, different growth mediums (sand, gravel and soil), various watering regimes (automatic watering, tension-based watering), and multiple sources of chloritic salinity (NaCl, $CaCl_2$, and $MgCl_2$). These studies were designed to assess relative yield values, irrigation leaching fractions, root zone salt profiles, or salinity-ozone interactions. They were not specifically designed to determine a threshold salinity value for alfalfa. Usually, only four salinity levels were tested, with data used to produce a crop yield reduction line.

Furthermore, the source of salinity in the six studies was consistently chloride dominated, with either NaCl or a blend of NaCl, $CaCl_2$, and $MgCl_2$ added to the irrigation water. In Southern California, where these studies occurred, salts found in the soils are largely chloride-dominated. None of these studies were conducted using sulfate-dominated salts, such as are found in Wyoming soils (see below). Such regional differences in soil salinity are likely to have a profound effect on the application of existing salinity threshold data to alfalfa growing in the Northern Great Plains. Recognizing this, Mass (1990), Ayers and Westcot (1985), Hanson et al. (1999), as well as the ARS Salt Tolerance Database, all indicate that plants grown in sulfatic soils will tolerate average root zone EC_e values about 2 dS/m higher than indicated by each of these references. For alfalfa, this would equate to a 100 percent yield threshold of approximately 4 dS/m. This fact is discussed in detail below.

Chloridic Versus Sulfatic Soils

Research efforts of the USSL in California identified adjustments in effective plant salinity tolerance expressed or repressed in the field by physiological responses to climate, cultural practices, soil fertility, irrigation methods, physical condition of the soils and the distribution and speciation of salts within soil profiles. A critical difference between the environmental conditions in California and the northern Great Plains (including northeastern Wyoming) is soil chemistry and the primary salt constituents found in these soils. It is widely accepted that the soils of the agricultural areas of California are dominated by salts where chloride is the dominant anion, and that the soils of the northern Great Plains are dominated by salts where sulfate is the dominant anion. In earlier publications, sulfatic soils are sometimes termed "gypsiferous," referring to the most common sulfate salt found in semi-arid soils -- gypsum (calcium sulfate dehydrate). The correct term used today is sulfatic soils.

To incorporate the variation of salinity tolerance exhibited by plant response to different salt distributions and dominant salt species, the authors of salt tolerance research included a provision for sulfatic soils. Soils may contain amounts of sparingly soluble salts, such as gypsum and other sulfate salts, many times greater than can be held in solution in the field water-

content range. Sulfatic soils may appear to be saline when exhaustively extracted in the lab (i.e., saturated paste extract), but the in-situ soil solution may be nonsaline because of the limited solubility of gypsum and other sulfate salts (Bernstein, 1975). Thus, the EC measured in a saturated paste extract is higher than the actual concentration of salts seen by plants in sulfatic soils. It was suggested originally by Bernstein (1962) that plants will tolerate about 2 dS/m higher soil salinity (EC_e) than indicated in sulfatic soils due to this solubility effect. Since calcium sulfate is disproportionately dissolved in preparing saturated-soil extracts, the EC_e of sulfatic soils will range an average of 2 dS/m higher than that of chloritic soils with the same water conductivity at field capacity (Bernstein 1962). Therefore, plants grown in sulfatic soils will tolerate an EC_e of approximately 2 dS/m higher than those grown where chloride is the predominant ion (Maas, 1990). This narrative provision for sulfatic soils is included in the ARS Salt Tolerance Database, and the classic irrigation guidelines presented in Ayers and Wescot (1985).

Sulfatic soils are the rule not the exception in Wyoming and the northern Great Plains. Sulfatic soils identified by salinity tolerance references are characterized by the presence and influence of gypsum, or calcium sulfate dihydrate ($CaSO_4 \cdot 2H_20$), within the soil profile, as well as the geological and climactic prerequisites for sulfatic soil conditions. Soil gypsum may stem from one of several sources. Soils formed from geologic material containing anhydrite or gypsum often contains gypsum. The amount of rainfall and the topographic setting will strongly influence the amount and location of gypsum in the soil (Dixon and Weed, 1989). Accumulations of soluble salts, including sulfates in the surface layers, are characteristic of saline soils of arid and semiarid regions (Brady, 1974), including Wyoming. Research conducted by the U.S. Geological Survey confirms the presence of gypsiferous parent materials in the Powder River Basin (Johnson, 1993). At this point, it is important to differentiate between the soil taxonomic terms "gypsic" or "petrogypsic," which are used to describe significant gypsum accumulation within soil horizons, from the terms "gypsiferous" or "sulfatic" soils which refer to the dominate salt type in soils of Wyoming and the northern Great Plains.

Published research has addressed the issue of prevailing salt distribution and climate influenced salt dominance. In Springer et al. (1999), Curtin et al. (1993) and Trooien (2001), northern Great Plains prairie soil chemistry is comparatively summarized and/or contrasted to soils of California. Research suggests that recommendations developed for the western United States, where chloride is the major anion in soil and water chemistry, may not be appropriate for sulfatic soils (Springer et al., 1999). Trooien (2001) notes that most plant salinity tolerance information is developed in California and that the chemistry of salinity is different in the northern Great Plains (i.e., sulfate dominated salinity). Therefore, Trooien (2001) indicates that salinity thresholds are greater and yield losses are somewhat smaller in the Northern Great Plains compared to those of California (i.e., chloride dominated salinity). Research in Canadian prairie soils by Curtin et al. (1993) and Wentz (2001) suggest that salt tolerance testing at the Swift Current, Saskatchewan, salinity laboratory (and also at the US Salinity Laboratory) has mostly involved the determination of crop responses to chloride salinity. However, there is reason to suspect that responses to sulfate salinity, which is the predominant form of salinity in prairie soils, may differ from those observed in chloride salt systems. Wentz (2001) summarizes that crop tolerances developed for chloride dominated soils, such as those in California, may not be applicable to crops grown on the sulfate dominated soils typically found in western Canada.

Comparison of actual soil analytical data from the NSSC Soil Survey Laboratory, Lincoln, Nebraska, supports the chloride and sulfate salt dominance designations suggested by Springer et al. (1999), Curtin et al. (1993), Trooien (2001), and Wentz (2001). Analyses from the U.S. Soil Survey Laboratory are available online at http://ssldata.nrcs.usda.gov/ and organized by soil pedon. Data from selected counties in Wyoming and California were obtained from the NSSC Soil Survey Laboratory Research Database in order to determine the dominance of chloride or sulfate soil chemistry in the respective regions. Soil chemistry data were downloaded for use in this study for counties of the Powder River Basin in Wyoming (Sheridan, Campbell and Johnson Counties). Soil chemistry data were also downloaded for counties in California where intensive agricultural production takes place (Imperial, Fresno, Kern, Kings and Tulare).

Data pertaining to soil chloride and sulfate in the saturated paste extract are arranged and averaged by county and state in Table 1 below. These values are based on all of the available data provided by the U.S. Soil Survey Laboratory.

Table 1
A Comparison of Average Soil Saturated Paste Extract Sulfate and Chloride Levels from Counties in Wyoming and California.

County	Average Soil Sulfate Level (meq/L)	Average Soil Chloride Level (meq/L)
Sheridan, WY	14.9	4.1
Campbell, WY	130.4	3.0
Johnson, WY	30.9	1.8
Wyoming Average	**58.7**	**2.9**
Imperial, CA	48.4	295.7
Fresno, CA	98.6	26.3
Kern, CA	44.3	73.0
Kings, CA	110.7	23.9
Tulare, CA	9.3	21.6
California Average	**62.3**	**88.1**

The summary data suggest that the relative proportion of chloride salts in the selected California counties outweigh the proportion of sulfate salts and verify the chloride dominance suggested by the literature summarized above. In northeastern Wyoming, the relative proportion of sulfate salts in selected counties outweigh the proportion of chloride by an order of magnitude and verify the sulfate dominance and sulfatic conditions implied by the literature. Therefore, the recommendation by the ARS Salt Tolerance Database signifying that plants grown in sulfatic soils will tolerate average root zone EC_e values about 2 dS/m higher than indicated, is valid for the Powder River Basin, and probably all of Wyoming. For alfalfa, this would equate to a 100 percent yield threshold of 4 dS/m.

The Influence of Soil Salinity on Alfalfa Yield

As indicated above, the *relative* 100 percent yield potential reported for alfalfa in the ARS Salt Tolerance Database is 2 dS/m (EC_e). As such, alfalfa is regarded in the California-based literature as "moderately sensitive" to salinity. An *absolute* salinity tolerance would reflect predictable inherent physiological responses by plants, but cannot be determined because interactions among plant, salt, water and environmental factors influence the plant's ability to tolerate salt. *Relative* salt tolerance is a value based on the climatic and cultural conditions under which a crop is grown (Maas and Hoffman, 1977). Research generated outside the U.S. Salinity Laboratory in the U.S. and Canada has introduced alternative salinity tolerance values for alfalfa influenced by these climatic and cultural conditions.

In a study based on field trials in western Canada, McKenzie (1988) reported the "relative maximum salinity crops will tolerate when combined with intermittent moisture stress throughout the growing season." McKenzie (1988) places alfalfa within a moderate tolerance category, as opposed to moderate sensitivity, and extends alfalfa's 100 percent yield tolerance to an EC range of 4-8 dS/m, as opposed to 2 dS/m. Similar tolerance descriptors and EC values for alfalfa can be found associated with Britton et al. (1977), who supports moderate salt tolerance and an EC range of 5-10 dS/m for alfalfa. Likewise, Milne and Rapp (1968) present alfalfa with a moderate tolerance and an EC range of 4-8 dS/m. Cavers (2002); Wentz (2001); Schafer (1983); Holzworth and Wiesner (1990) and Dodds and Vasey (1985) also contribute to a departure from the established Maas classification of alfalfa salinity tolerance and threshold values. Bower et al., suggests an alfalfa tolerance somewhat between the previous authors and Maas (1990), suggesting maximum alfalfa yield is obtained when the average EC_e value for the root zone is 3 dS/m. Using salinized field plots in southern Saskatchewan, Holm (1983) reported a small, 0.037 ton/acre, reduction in alfalfa yields resulting from an increase in the surface EC_e (0 to 15 cm sample) from a 0 to 4 dS/m range to a 4 to 8 dS/m range. Holm presented these scales as representative of low and medium EC levels.

Relative salinity tolerances reported outside of peer reviewed literature stem from professional observations and judgments, roundtable discussions, experience in the field, and experience with the region, culture and climate; not from experimental data. Incorporation of field experience, observation, and limited data into supporting documents of the Salt Tolerance Database is acknowledged in Ayers and Wescot (1985). Alternative sources listed herein do not always report EC values in terms of 100 percent yield thresholds for alfalfa, but should not be discounted, as they pertain to what is realistic in the field. As an example, the Montana Salinity Control Association reports forage salt tolerances in terms of marginal establishment levels, not 100 percent yield potentials. Conditions allowing alfalfa to produce at 100 percent of its physiochemical yield potential probably do not exist anywhere within the northern Great Plains.

A suggested field-yield value corresponding to the 100 percent yield of alfalfa has never been reported by authors of salinity literature. Specifically, what yield of alfalfa, in tons per acre, could one expect if it was grown under conditions supporting 100 percent yield? Conditions supporting 100 percent alfalfa yields recommended by the ARS Salt Tolerance Database and its supporting documents would be: a soil EC_e of 2 dS/m or less, an irrigation water EC_w less than or equal to 1.3 dS/m, water contents maintained at field capacity, available N, P and K nutrient

levels maximized for alfalfa growth, a sufficiently long growing season, no associated phytotoxicity or pest issues, etc. This data limitation precludes the direct comparison of alfalfa yields generated in an agricultural area to the potential yields theoretically available under optimized conditions. The only available analysis is to compare an alfalfa yield to the average yield generated in its area, or generated between areas.

Using data available from the National Agricultural Statistics Service, selected county agricultural commissioner's data, and the U.S. Census of Agriculture (2002, 1997), irrigated alfalfa yield data were obtained for periods of interest. Alfalfa yield data for Wyoming counties are available from 1959 through 2005, but were averaged from 1970-2005 to reflect the integration of new irrigation technologies. Alfalfa yield data were summarized for the area encompassing the Powder River Basin: Sheridan, Johnson and Campbell counties. Alfalfa yield data for California counties are available from 1980-2004 so the entire dataset was averaged. Alfalfa data were summarized for counties in California related to intensive agriculture: Imperial, Fresno, Kern, Kings and Tulare counties.

Soil salinity data (as measured by EC) collected by the USDA National Soil Survey and analyzed by the National Soil Survey Center (NSSC) Soil Survey Laboratory were also obtained and summarized for the aforementioned counties. Average root zone EC values were calculated to a maximum depth of five feet. The county alfalfa yield and average root zone EC summaries are presented in Table 2 below.

Table 2
Comparison of Average Root Zone Soil Salinity (EC) Values with Historical Alfalfa Yields for Selected Counties in Wyoming and California.

County	Average Root Zone Soil Salinity (EC as dS/m)	Historical Average Alfalfa Yield (tons/acre)
Sheridan, WY	1.5	2.7
Johnson, WY	1.9	2.4
Campbell, WY	2.0	2.4
Wyoming Average	**1.8**	**2.5**
Tulare, CA	2.8	8.4
Kings, CA	6.9	6.9
Kern, CA	4.6	8.0
Fresno, CA	6.7	7.9
Imperial, CA	6.7	7.8
California Average	**5.5**	**8.0**

Values expressed in Table 2 show substantially higher average root zone salinities in California than in Wyoming. Alfalfa yields reported in California are three times greater than those in Wyoming, even though, on average, the soil salinity values are nearly three times higher than those reported for the Wyoming counties. The values generated in this exercise suggest that environmental factors other than salinity, e.g., climate, may be dictating the obtainable degree of alfalfa yield produced. However, the data also suggest that the California-based 100 percent yield threshold of 2 dS/m may not be appropriate for even the chloritic soils of California. For

example, the historical average yield of alfalfa in Tulare County is 8.4 tons per acre with a corresponding average root zone EC of 2.8 dS/m. The yield from Tulare County is actually slightly greater than the yields from Fresno and Imperial Counties where the corresponding average root zone EC values are substantially higher at 6.7 and 6.7 dS/m, respectively. Regardless, there does not appear to be a substantial difference in yields reported by the California counties with soil EC values ranging from 2.8 to 6.7 dS/m.

Other field data from Wyoming have been reviewed that also suggest an alternative to the California-based salinity tolerance values. The Use Attainability Analysis (UAA) report for Cottonwood Creek (SWWRC et al., 2002) was downloaded from the Wyoming Department of Quality, Water Quality Division webpage. Cottonwood Creek is located in Hot Springs County within the Bighorn Basin of Wyoming. This is an area of extensive conventional oil and gas production. According to the UAA report, discharge of produced water from the Hamilton Dome oil field to Cottonwood Creek constitutes the majority of flow to the ephemeral stream and constitutes the only irrigation water source for approximately 35 ranching operations. The waters of Cottonwood Creek exhibit an EC_w between 4.1 and 4.5 dS/m. At an average EC_w of 4.3 dS/m, an average root zone soil EC_e value can be calculated using the widely accepted relationship: $EC_e = 1.5\ EC_w$ (Ayers and Wescot, 1985). This relationship is expressed in the draft Section 20 Agricultural Use Protection Policy. From this relationship, an average root zone soil EC value of 6.5 is estimated for the fields irrigated long-term with water from Cottonwood Creek. Average alfalfa hay yields reported in the UAA amount to 2.5 tons per acre. This yield is identical to the average of the three Wyoming counties reported in Table 2 above. This is compelling given that the average soil EC value for the three other Wyoming counties is 1.8 dS/m, while the estimated soil EC for the fields irrigated with water from Cottonwood Creek is 6.5.

Closing Statement

Based on the review summarized herein, we respectfully suggest that the WDEQ consider adopting an acceptable average root zone EC threshold of 4 dS/m for protection of alfalfa. This would equate to a default (Tier 1) effluent limit of 2.7 dS/m based on the 1.5 concentration factor cited by the draft Agricultural Use Protection Policy. Other species of concern, including western wheatgrass, should be given equal consideration due to the inherent differences in soil chemistry between the northern Great Plains and the California agricultural areas for which the ARS Salt Tolerance Database is based. Factors such as extreme climate, periodic drought, soil moisture regime, duration of growing season, soil depth, and fertility limitations can collectively exert an overriding regional influence on the yield potential of forage crops. Based on this, we ask that the WDEQ exercise caution interpreting the applicability of specific salinity tolerances outlined by the ARS Salt Tolerance Database and thoughtfully consider the difficulty in detecting a "measurable" change in plant production due to soil salinity alone.

References Cited

Ayers, R.S. and Wescot, D.W. 1985. Water quality for agriculture. FAO Irrigation and Drainage Paper, 29 (rev. 1).

Bernstein, L. 1975. Effects of salinity and sodicity on plant growth. p. 295-312. In: Baker, K.F., Zentmyer, G.A. and Cowling, E.B. (ed.) Annual Review of Phytopathology. Vol. 13. Palo Alto, California.

Bernstein, L. 1962. Salt affected soils and plants. Problems of the Arid Zones. Proc. UNESCO Symp. 18: 139-174. Paris, France.

Bernstein, L. and Francios, L.E. 1973. Leaching requirement studies: Sensitivity of alfalfa to salinity of irrigation and drainage waters. Proceedings, Soil Science Society of America. 37:931-943.

Bernstein, L. and Ogata, G. 1966. Effects of salinity on nodulation, nitrogen fixation, and growth of soybeans and alfalfa. Agronomy Journal. 58:201-203.

Bower, C.A., Ogata, G., and Tucker, G.M. 1969. Rootzone salt profiles and alfalfa growth as influenced by irrigation water salinity and leaching fraction. Agronomy Journal. 61:783-785.

Brady, N.C. 1974. The nature and properties of soils 8th ed. Macmillan Publishing Company, Incorporated, New York, NY.

Brown, J.W. and Hayward, H.E.. 1956. Salt tolerance of alfalfa varieties. Agronomy Journal. 48:18-20.

Britton, M.G., Buchannan, L.C. and Muir, W.E. 1977. Principles and practices of commercial farming (5th edition). Faculty of Agriculture, University of Manitoba. Winnipeg, Manitoba.

Cavers, C. 2002. Please don't pass the salt – Preventing and Managing Soil Salinity. Manitoba Agriculture & Food; Soils and Crops Branch. Accessed from the internet, 3/20/06 from; http://www.umanitoba.ca/afs/ agronomists_conf/2002/pdf/cavers.pdf.

Curtin, D., Steppuhn, H. and Selles, F. 1993. Plant responses to sulfate and chloride salinity: Growth and Ionic Relations. Soil Science Soc. Am. J. 57:1304-1310.

Dixon, J.B. and Weed, S.B., eds. 1989. Minerals in soil environment 2nd ed. SSSA book series no. 1.

Dodds, D.L. and Vasey, E. 1989. Forages for salt-affected soils. Bulletin R-584 Rev. Cooperative Extension Service, North Dakota State University; Fargo, North Dakota.

Francois, L.E. and Maas, E.V. (ed.). 1978. Plant responses to salinity: An indexed bibliography. USDA-SEA (Science and Education Admin.) Agric. Reviews and manuals, ARM-W-6. U.S. Gov. Print. Office, Washington, DC.

Gauch, H.C. and Magistad, O.C. 1943. Growth of strawberry clover varieties and of alfalfa and Ladino clover as affected by salt. Journal of American Society of Agronomy. 35:871-880.

Hanson, B., Grattan, S.R. and Fulton, A.F. 1999. Agricultural salinity and drainage. Division of Agriculture and Natural Resources Publication 3375. University of California Irrigation Program. University of California, Davis, California.

Hoffman, G.J., Maas, E.V. and Rawlins, S.L. 1975. Salinity-ozone interactive effects on alfalfa yield and water relations. Journal of Environmental Quality. 4:326-331.

Holm, H.M. 1983. Soil salinity, a study in crop tolerances and cropping practices. Sask. Agriculture, Plant Industries Branch, Publ. 25M/3/83.

Holzworth, L.K. and Wiesner, L.E. 1990. Principles of establishment and seedling year management. p. 170-228. In: Baldridge, D.E. and Lohmiller, R.G. (ed.) Montana Interagency Plant Materials Handbook for Forage Production, Conservation, Reclamation and Wildlife. Montana State University, Bozeman, Montana.

Johnson, E.A. 1993. Depositional history of triassic rocks in the area of the powder river basin, northeastern Wyoming and southeastern Montana. U.S. Geological Survey Bulletin 1917 Chapter P.

Maas, E.V. 1990. Crop salt tolerance. p. 262-304. In: K.K. Tanji (ed.) Agricultural salinity assessment and management. ASCE Manuals Rep. Eng. Practive no.71. Am. Soc. Civ. Eng., New York, NY.

Maas, E.V. and Hoffman, G.H. 1977. Crop salt tolerance – current assessment. J. Irrigation and Drainage Div., Am. Soc. Civil Eng. 103(IR2):115-134.

McKenzie, R.C. 1988. Tolerance of plants to soil salinity. Soil and water program, 1987. Alberta Special Crops and Horticultural Research Centre Pamphlet 88-10. Brooks, AB.

Milne, R.A. and Rapp, E. 1968. Soil salinity and drainage problems; causes, effects, management. Publication 1314; Canadian Department of Agriculture.

Schafer, W.D. 1983. Salinity control under irrigation. Montguide Document MT 8382. Cooperative Extension Service, Montana State University; Bozeman, Montana.

Soil Survey Staff. 2006. National Soil Survey Characterization Data; Soil Survey Laboratory, National Soil Survey Center USDA-NRCS - Lincoln, NE. Saturday, March 11, 2006.

Springer, G., Wienhold, B.J., Richardson, J.L. and Disrud, L.A. 1999. Salinity and sodicity changes in dispersive clay and saturated hydraulic conductivity in sulfatic soils. Communications in soil science and plant analysis. 30(15&16), 2211-2220.

States West Water Resources Corporation, Western EcoSystems Technology, Inc., Blankenship Consulting LLC. 2002. Merit Energy Company Use Attainability Analysis to Accompany Petition to Change Use Criteria on Cottonwood Creek Near Hamilton Dome, Hot Springs County, Wyoming as Provided Under Wyoming Surface Water Standards, Chapter 1.

Trooien, T.P. 2001. Salinity down under. In: Proceedings of the South Dakota No-Till Association Meeting. pp. 35-38.

U.S. Census of Agriculture. 1997. Accessed from the U.S. Census Bureau website: http://www.census.gov/prod/www/abs/agric.html

U.S. Census of Agriculture. 2002. Accessed from the USDA National Agricultural Statistics Service website: http://www.nass.usda.gov/Census_of_Agriculture/index.asp.

U.S.D.A. Agricultural Research Service. 2006. Salt Tolerance Database. Relative Salt Tolerance of Herbaceous Crops. George E. Brown, Jr. Salinity Laboratory. Riverside, California.

U.S. Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA Agric. Handbook no. 60, Washington, D.C.

Wentz, D. 2001. Salt tolerance of plants. Alberta Agriculture, Food and Rural Development. Accessed from the internet, 3/25/06 from; http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex3303

* * * * *

Thank you very much for your time and consideration of this review and the recommendations stemming from it. If you, your WDEQ colleagues, or the members of the Water and Waste Advisory Board have any questions or comments regarding our findings, please contact me.

Sincerely,

Kevin C. Harvey, M.Sc., CPSSc.
Principal Soil Scientist

KC HARVEY, LLC
SOIL AND WATER RESOURCE CONSULTANTS

May 4, 2006

Mr. Bill DiRienzo
Wyoming Department of Environmental Quality
Water Quality Division
Herschler Building, 4th Floor West
122 West 25th Street
Cheyenne, Wyoming 82002

Subject: Comments pertaining to the proposed default SAR effluent limit cap of 10 in the Draft Section 20 Agricultural Use Protection Policy.

Dear Mr. DiRienzo:

I respectfully submit for your consideration the following comments regarding the fourth draft of the Section 20 Agricultural Use Protection Policy as it pertains to the derivation of effluent limits for SAR, particularly the proposed SAR cap of 10. These comments are being submitted on behalf of Yates Petroleum Company, Williams Production RMT Company, Petro-Canada Resources (USA) Inc., Marathon Oil Company, Lance Oil & Gas Company, Inc., Fidelity Exploration & Production Company, Devon Energy Production Company L.P., Bill Barrett Corporation, and Anadarko Petroleum Corporation. I have submitted additional comments regarding the derivation of EC limits in a separate letter.

By way of introduction, I am a board-certified professional soil scientist having practiced as an environmental consultant in Montana and Wyoming, and throughout the world, for nearly 25 years. For the past seven years, my practice has focused on water management and soil and water salinity/sodicity issues associated with oil and gas development. I am credited as the first to research, develop, and apply managed irrigation techniques for the beneficial use of coalbed natural gas produced water. I have directed or participated in over 75 separate projects related to produced water management, WPDES permitting, soil and water chemistry investigations, and reclamation for coalbed and conventional natural gas projects in Wyoming, Colorado, and Montana. I have a M.S. degree in land rehabilitation (soil science emphasis) from Montana State University and a B.S. in Resource Conservation (soil science emphasis) from the University of Montana.

I would like to comment on the proposed changes made to the Agricultural Use Protection Policy by the WDEQ subsequent to the January 26, 2006 meeting of the Water and Waste Advisory Board. My comments will focus on the comments provided by Dr. Larry Munn in his letter to the DEQ dated December 5, 2005. It is my understanding that Dr. Munn's comments resulted in the changes made to the proposed Policy. Specifically, I comment on Dr. Munn's proposal that all WPDES default effluent limits for SAR be capped at 10 under the Tier 1 process.

233 EDELWEISS DRIVE, UNIT 11, BOZEMAN, MONTANA 59718
VOICE: 406/585-7402, FAX: 406/585-7428, EMAIL: INFO@KCHARVEY.COM

Summary of Findings

The fourth draft of the Agricultural Use Protection Policy describes a 3-tiered decision making process for deriving appropriate effluent limits for EC and SAR whenever a proposed discharge may reach irrigated lands. The Tier 1 process would be followed for deriving "default" limits, and as such, this procedure would require a minimum of background information from the applicant. The default SAR limits would be extrapolated from the Hanson et al. (1999) chart relating the established EC effluent limit to SAR, up to a maximum default value of 10. The effluent limit for SAR will be determined in conjunction with EC so that the relationship of SAR to EC remains within the "no reduction in rate of infiltration" zone of the Hanson et al. (1999) diagram.

Two key concerns arise from Dr. Munn's letter regarding sodicity and the discharge of CBNG produced water in the Powder River Basin: (1) the potential impacts on the hydraulic function of irrigated soils during produced water discharge; and (2) the potential impacts of residual adsorbed sodium on the hydraulic function of irrigated fields after produced water discharge has ceased and rainfall/snowmelt leaches salts from the upper root zone. It is assumed that these concerns led Dr. Munn and the WDEQ to propose the SAR effluent limit cap of 10 under the Tier 1 process.

In addressing these concerns, I performed a considerable amount of research, including three months searching and reviewing the relevant scientific literature, and compiling and analyzing available and relevant soil, plant, and water data. The key conclusions of the literature review and data analysis are presented below and will be substantiated by the discussion that follows.

Review of Soil Sodicity

- Plant growth problems associated with excess sodium adsorption are in response to negative changes in soil structure resulting in reduced air exchange, water infiltration and hydraulic conductivity.
- The universally applied sodic soil threshold is an exchangeable sodium percentage (ESP) greater than 15.
- SAR is a measure of the sodicity risk in irrigation water. The higher the salinity of irrigation water, the higher the SAR can be without impacting soil structure and impairing soil infiltration and permeability.

The ESP-SAR Relationship for Soils in Northeastern Wyoming

- Using regression analysis, the relationship between ESP and soil SAR was determined for the Powder River Basin (n=382, R^2=.74).
- A 1:1 relationship of soil SAR to water SAR exists for soils in equilibrium with irrigation water. This relationship is widely accepted and confirmed by recent research led by Dr.

James Bauder at Montana State University. The relationship of ESP to soil SAR is therefore equivalent to the relationship of ESP to water SAR.

- Based on the regional specific relationship of ESP and SAR, an effluent limit of SAR = 16 corresponds to an ESP of 10, and provides a 33% margin of safety against the formation of sodic conditions (i.e., exceeding an ESP of 15). The proposed default SAR cap of 10 is, therefore, unnecessarily conservative.

The Effect of Rainwater Leaching on Soils Irrigated with Produced Water

- Concern has been raised that subsequent rainfall/snowmelt leaching of residual soil salinity may lower the electrolyte concentration and naturally raise the ESP past the dispersive sodic soil threshold.

- Research demonstrates that arid land soils can release 0.3 to 0.5 dS/m of Ca and Mg to solution as a result of the dissolution of primary minerals and the inherent calcium carbonate content of surface soils. Shainberg et al. (1981) indicates that these concentrations are sufficient to counter the deleterious effects of exchangeable sodium, even when the soil is leached with rainwater.

A Review of Soil Sodicity

The physical and chemical phenomena associated with soil sodicity are complex. Therefore, a brief summary is provided regarding the soil and water chemistry associated with the physical affects of soil sodicity.

A large body of research concerning sodic, or "black alkali" soils has been generated in response to the negative effects of high sodium concentrations on soils. Toxicity effects of sodium are rarely expressed in forage and grass crops, but do cause injury to selected woody plants (Lilleand et al., 1945; Ayers et al., 1951; Brown et al., 1953). Plant growth problems associated with high concentrations of sodium are generally a response to negative changes in soil structure. Sodic soils are "nonsaline soils containing sufficient exchangeable sodium to adversely affect crop production and soil structure (Soil Science Society of America, 2001)." High levels of adsorbed sodium tend to disperse soil particles thereby sealing the soil. The result can produce clogged soil pores, hard surface crusts, reduced infiltration, reduced permeability, and reduced oxygen diffusion rates, all of which interfere with or prevent plant growth. By definition, sodic soils are those that have an exchangeable sodium percentage (ESP) greater than 15. The universally applied ESP threshold of 15 percent is acknowledged in numerous publications, including Levy et al. (1998), Abrol et al., (1988), Evangelou (1998), McNeal and Coleman (1966), Sparks (1995), Sumner et al. (1998), Shainberg et al. (1971), the Soil Improvement Committee (2002), university extension publications, etc.

Clay minerals are the most physically and chemically reactive components of the sand, silt, and clay matrix in soil. The structural arrangement of clay minerals in soil is akin to a deck of cards; the clay mineral itself can be thought of as the deck, and the cards as individual layers. The

properties of the deck depend upon the arrangement of the cards and the electrochemical interlayer forces holding the cards together.

Clay minerals in soils are negatively charged and consequently attract ions with a positive charge such as calcium, magnesium, potassium, and sodium. Positively charged ions are called cations. Each cation competes with others in the soil solution for access to the bonding sites based on its valence and hydrated size. Every soil has a definite capacity to adsorb the positively charged cations. This is termed the cation exchange capacity (CEC). The various adsorbed cations (such as calcium and sodium) can be exchanged one for another and the extent of exchange depends upon their relative concentrations in the soil solution (dissolved), the ionic charge (valence), the nature and amount of other cations, etc. ESP is, accordingly, the amount of adsorbed sodium on the soil exchange complex expressed in percent of the cation exchange capacity in milliequivalents per 100 grams of soil (meq/100 g). Thus,

ESP = (exchangeable sodium / cation exchange capacity) x 100.

Sodic soil conditions arise when greater than 15 percent of the ions bonded to the deck are sodium, which has a +1 valence and a large hydrated radius. When the ESP exceeds 15, the large hydrated sodium ions can wedge in-between the individual cards and cause "swelling" of the deck (Levy et al., 1998). This causes negative effects on the physical structure of the soil. Upon re-wetting, the individual decks may disperse and settle into soil pores, effectively clogging them and reducing the efficiency of air exchange, water infiltration, and permeability (i.e., hydraulic conductivity). In general, soils with moderately high, to high, clay contents are at higher risk.

Excessive adsorbed or exchangeable sodium can result from sustained use of irrigation water that is high in sodium and low in calcium and magnesium. Consequently, the ratio of sodium to calcium and magnesium ions in water is an important property affecting the infiltration and permeability hazard. The water quality index used to measure the hazard related to sodium abundance or sodicity in irrigation water is the sodium adsorption ratio or SAR.

The SAR is the ratio of the dissolved sodium concentration in water divided by the square root of the average calcium plus magnesium concentration. The SAR can be calculated from the sodium, calcium and magnesium concentrations via the formula:

$$SAR = [sodium] / (([calcium] + [magnesium])/2)^{1/2}$$

where the concentrations are in milliequivalents per liter (meq/L).

What is not apparent from the SAR formula is the fact that the higher the salinity of the water, the higher the SAR can be without impacting soil structure and impairing soil infiltration and permeability. Put another way, for a given SAR, infiltration rates generally increase as salinity (measured by the EC) increases. The changes in soil infiltration and permeability occur at varying SAR levels, higher if the salinity is high, and lower if the salinity is low. Therefore, in order to evaluate the sodicity risk of irrigation water, the EC must be considered. To this end,

the SAR-EC guidelines presented in Ayers and Westcot (1985) and Hanson et al. (1999) are used to assess the potential sodicity risk of irrigation water.

The ESP-SAR Relationship for Soils in Northeastern Wyoming

In addition to measuring the SAR of irrigation water, one can also measure the SAR of the soil solution via a saturated paste extract (i.e., the dissolved concentrations of sodium, calcium, and magnesium are measured in a saturated paste extract and applied via the SAR formula presented above). The soil SAR was developed to serve as a rapid and relatively inexpensive index of ESP. It is widely accepted that the SAR of the soil in equilibrium with the SAR of the irrigation water is equal to the long-term average SAR of the irrigation water.

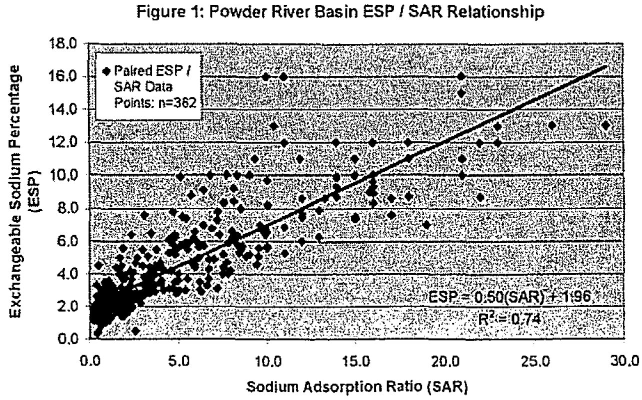
The fourth draft of the Agricultural Use Protection Policy includes a proposed SAR cap of 10 for Tier 1 default effluent limits. To evaluate the appropriateness of the proposed cap, an analysis was performed using 382 ESP-SAR data pairs generated from ongoing soils assessment work in the Powder River Basin of Wyoming (KC Harvey LLC, 2006). This database represents flood plain soils associated with tributaries to the Powder River and the Tongue River, including spreader dike irrigated fields. This database represents baseline soil chemical conditions. In no case were any of these soils irrigated with or influenced by coalbed natural gas produced water. The soil samples from which the analyses were made were collected during soil profile descriptions to five feet, and with a Giddings hydraulic probe up to eight feet in depth. The numerous soil investigations involved were required for various coalbed natural gas water management planning, permitting, and design purposes.

The ESP-SAR data pairs were graphed in Microsoft Excel using simple scatter-plot and trend line analysis. The best fit line resulted in a linear regression which yielded the equation:

$$ESP = 0.5(SAR) + 1.96, \text{ with an } R^2 \text{ value of } 0.74.$$

The regional-specific "Powder River Basin" relationship, based on 382 soil samples, is shown on Figure 1. According to the Powder River Basin equation, a soil SAR of 26 corresponds to the critical ESP threshold of 15 percent.

Figure 1: Powder River Basin ESP / SAR Relationship



It is widely accepted that the SAR of soil in equilibrium with irrigation water equals the long-term average SAR of irrigation water. Recent Department of Energy funded research directed by Dr. James Bauder at Montana State University (Robinson and Bauder, 2003) confirms this relationship. Their research, which is related to the potential effects of coalbed natural gas produced water on soils, reports that in general, soil solution SAR

represents the SAR of the applied water. The 1:1 soil SAR to water SAR relationship allows one to relate the SAR of discharge water to the SAR of the soil in the Powder River Basin ESP-SAR graph and equation described above. For example, after long-term irrigation with water exhibiting an SAR of 15, the equilibrated ESP of the irrigated soil would be approximately 9.5 percent. The proposed SAR cap of 10 would equate to a corresponding ESP of 7. An ESP cap of 7 appears to be unnecessarily conservative given the regional specific relationship of ESP and SAR. While an ESP threshold of 15 is widely accepted to be the point at which clay swelling and dispersion occurs, we respectfully suggest that the WDEQ consider establishing a Tier 1 default SAR effluent limit cap of 16, which corresponds to an ESP of 10. An ESP value of 10 provides a 33 percent margin of safety.

The Effect of Rainwater Leaching on Soils Irrigated with Produced Water

In his December 5, 2005 letter, Dr. Munn indicates his concern about the potential effects of rainwater leaching of fields that had received produced water due to upstream permitted discharges. In particular, what is the effect of leaching on the sodicity status and hydraulic function of soils after discharge and irrigation with produced water ceases? Fortunately, the considerable research on this subject has been well documented in the scientific literature.

Discontinuation of produced water discharge in the Powder River Basin will effectively reduce the EC and SAR of irrigation waters from tributaries and mainstems so long as the surface water is of higher quality than the produced water. In the case of fields that are irrigated opportunistically (e.g., in response to runoff events that are captured behind spreader dike systems), there can be three sources of water supplying soil moisture: (1) meteoric water (rain and snowmelt); (2) natural runoff water; and (3) subirrigation from a shallow aquifer. In the case of rainfall and snowmelt, the EC of these waters will be similar to that of distilled water, i.e., they will exhibit very low dissolved solids. Owing to the dissolution of soluble constituents within the watershed, natural runoff EC values can range up to 5 dS/m or higher. Regarding subirrigation, shallow aquifers can be relatively saline due to the entrainment of dissolved minerals along the groundwater flowpath.

The concern arises from leaching of residual surface soil salinity with rainfall and snowmelt. Intermittent rainfall and snowmelt may lower the electrolyte concentration (i.e., EC) sufficiently to promote clay dispersion, depending on soil properties (Levy et al., 1998). Conversely, when the electrolyte concentration in the soil solution reaches a moderate level (1-2 dS/m), high sodicity levels (ESP between 10 and 30) cause only small to moderate changes in the physical and hydraulic properties of the soils, which are mostly reversible (Levy et al., 1998). Shainberg et al. (1981) showed that a major factor causing differences among various sodic soils in their susceptibility to hydraulic failure when leached with low electrolyte concentrations (i.e., a low EC) was their rate of salt release from mineral dissolution.

Arid land soils can release 0.3 to 0.5 dS/m of calcium and magnesium to solution as a result of the dissolution of plagioclase, feldspars, hornblends and other sparingly soluble minerals within the soil matrix (Rhoades et al. 1968). The solution composition of a calcareous soil at a given ESP in contact with distilled water (i.e., rainwater or snowmelt) can be calculated (Shainberg et al., 1981). As calcium carbonate ($CaCO_3$) dissolves, the EC of the soil solution increases and

calcium replaces sodium on exchange sites until the solution is in equilibrium with the cation exchange system and the $CaCO_3$ solid phase. Shainberg et al. (1981) calculated that the EC values of solutions in equilibrium with soils having ESP values of 5, 10, and 20 are 0.4, 0.6, and 1.2 dS/m, respectively. Shainberg et al. (1981) indicates that these concentrations are sufficient to counter the deleterious effects of exchangeable sodium, even when the soil is leached with rainwater.

It is evident that water equilibrated with a calcareous soil can never be a very low salinity (Shainberg et al., 1981). Using the same database discussed above for evaluation of the ESP-SAR relationship in 382 soil samples from the Powder River Basin, we can compute an average percent lime ($CaCO_3$) content in surface soil samples (n=81), which is 5.1 percent. This represents a considerable reserve of calcium. Other sources of calcium include residual gypsum ($CaSO_4$) which we know to be prevalent in Wyoming soils.

Various soil SAR-EC relationships (not to be confused with irrigation water SAR-EC relationships) have been reported in the literature by introducing low electrolyte concentration waters to sodic soils. Felhendler et al. (1974) measured the hydraulic conductivity of two montmorillonitic soils as a function of the SAR and found that both were only slightly affected by the SAR of the percolating solution up to a SAR of 20 as long as the concentration of the percolating solution exceeded 1 dS/m. Shainberg et al. (1981) studied the effects of leaching a 1:1 sand-soil column with distilled water and increasing concentrations of a weak electrolyte solution. His findings concluded that an electrolyte concentration of 0.3 dS/m in the percolating solution was adequate to prevent the adverse effects of a SAR of 15 on the hydraulic conductivity of the soil-sand mixture. These findings are very similar to the conclusions of the U.S. Salinity Laboratory Staff (1954) who used electrolyte concentrations equal to or greater than 0.3 dS/m in their regression analysis to determine the sodic soils threshold of ESP = 15.

As a review, an electrolyte concentration of 0.3 dS/m is the minimum value of calcium and magnesium contributions to soil solution associated solely to arid soil weathering. This suggests that an arid Powder River Basin soil with a SAR of 16 (ESP = 10), will have no sodicity related impacts to the hydraulic conductivity, even when the salt concentration of the irrigation or rainwater is equal to that of distilled water.

Of course, irrigation water in the Powder River Basin has an intrinsic electrical conductivity greater than that of distilled water. Use of surface water for irrigation will actually supplement the inputs of calcium and magnesium from weathering and carbonate dissolution alone.

Using the aforementioned Powder River Basin soils assessment database (KC Harvey LLC, 2006), an average surface soil ECe of 1.64 dS/m was calculated from 81 individual surface soil samples. This value suggests that electrolyte concentrations in surface soils of the Powder River Basin, in equilibrium with mineral dissolution, the salinity of runoff irrigation water, and rainwater/snowmelt, is about 1.6 dS/m, or five times (1.6 dS/m divided by 0.3 dS/m) the concentration required to maintain the hydraulic conductivity of a soil at an ESP of 16.

Closing Statement

Results of the Powder River Basin regression analysis indicates that a relationship between ESP and soil/water SAR exists, which allows the calculation of one parameter from the other. Using the proposed, default ESP cap of 10 percent, the scientific literature indicates that water with a SAR of 16 can be effectively used for irrigation without adverse effects on the physical structure or hydraulic conductivity of Powder River Basin soils during irrigation. Furthermore, it has been shown that inputs of Ca and Mg from the natural dissolution of plagioclase, feldspars, hornblends and other sparingly soluble minerals, especially calcium carbonate and gypsum, will provide an effective buffer to residual soil sodicity after the discontinuation of produced water discharge and the transition back to native irrigation, precipitation, and runoff regimes.

References Cited

Abrol, I.P., Yadav, J.S.P. and Massoud, F.I. 1988. Salt-affected soils and their management. FAO Land and Water Management Division, Soils Bulletin 39.

Ayers, A.D., Aldrich, D.G. and Coony, J.J. 1951. Sodium chloride and injury of Fuerte avocado leafs. California Avocado Soc. Yearbook: 1951 174-178 illus.

Ayers, R.S. and Wescot, D.W. 1985. Water quality for agriculture. FAO Irrigation and Drainage Paper, 29 (rev. 1).

Brown, J.W., Wadleigh, C.H. and Hayward, H.E. 1953. Foliar analysis of stone fruit and almond trees on saline substrates. Amer. Soc. Hort. Proc. 61: 49-55.

Evangelou, V.P. 1998. Environmental soil and water chemistry principles and applications. John Wiley and Sons (Pub), New York, NY.

Felhendler, R.I., Shainberg, I. and Frenkel, H. 1974. Dispersion and hydraulic conductivity of soils in mixed solutions. Int. Congr. Soil Sci., Trans. 10th (Moscow) 1:103-112.

Hanson, B., Grattan, S.R. and Fulton, A.F. 1999. Agricultural salinity and drainage. Division of Agriculture and Natural Resources Publication 3375. University of California Irrigation Program. University of California, Davis, CA.

KC Harvey, LLC. 2006. Unpublished data. Compilation of various soil investigation sampling and analysis data from Sheridan, Johnson and Campbell Counties, Wyoming. Bozeman, MT.

Levy, G.J., Shainberg, I. and Miller, W.P. 1998. Physical Properties of Sodic Soils. In: Sumner, M.E. and Naidu, R. 1998. Sodic soils: Distribution, properties, management and environmental consequences. Oxford University Press, Inc. New York, NY.

Lilleand, O., Brown, J.G. and Swanson, C. 1945. Research shows sodium may cause leaf tip burn. Almond Facts 9 (2): 1, 5, illus.

McNeal, B.L and Coleman, N.T. 1966. Effect of solution composition on hydraulic conductivity. Soil Sci. Soc. Am. Proc., 30, 308-312.

Rhoades, L.D. 1968. Mineral weathering correction for estimating the sodium hazard of irrigation waters. Soil Sci. Soc. Am. Proc. 32:648-652.

Robinson, K.M. and Bauder, J.W. 2003. Soil behavior upon wetting with saline sodic water part 2: Soil chemical responses. Adapted from Robinson, K.M. 2003. Effects of saline-sodic water on EC, SAR, and water retention.

Shainberg, I., Bresler, E., and Klausner, Y. 1971. Studies on Na/Ca montmorillonite systems, I: The swelling pressure. Soil Sci. 111:214-219.

Shainberg, I., Rhoades, J.D., Suarez, D.L. and Prather, R.J. 1981. Effect of mineral weathering on clay dispersion and hydraulic conductivity of sodic soils. Soil Sci. Soc. Am. J. 45:287-291.

Soil Improvement Committee, California Plant Health Association. 2002. Western Fertilizer Handbook, ninth edition. Interstate Publishers, Inc. Danville, Illinois.

Soil Science Society of America. 2001. Glossary of Soil Science Terms. Madison, WI.

Sparks, D.L. 1995. Environmental Soil Chemistry. Academic Press, San Diego, Ca.

Sumner, M.E., Rengasamy, P. and Naiud, R. 1998. Sodic soils: A reappraisal. In: Sumner, M.E and Naidu, R. 1998. Sodic soils: Distribution, properties, management and environmental consequences. Oxford University Press, Inc. New York, NY.

U.S. Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA Agric. Handbook no. 60, Washington, D.C.

* * * * *

Thank you very much for your time and consideration of this review and the recommendations stemming from it. If you, your WDEQ colleagues, or the members of the Water and Waste Advisory Board have any questions or comments regarding our findings, please contact me.

Sincerely,

Kevin C. Harvey, M.Sc., CPSSc.
Principal Soil Scientist

Williams Production RMT Company
300 North Works Avenue
Gillette, WY 82716
307.686.1636
307.686.7574 (fax)

June 12, 2007

David Waterstreet
Herschler Building – 4W
122 West 25th Street
Cheyenne, WY 82002

Re: Comments on Revisions to Appendix H, Agricultural Use Protection and Associated Language in Section 20 of Chapter 1

Dear Mr. Waterstreet:

Williams Production RMT Company ("Williams") appreciates the opportunity to submit comments to the Wyoming Water and Waste Advisory Board ("WWAB") regarding revisions to Appendix H, Agricultural Use Protection and associated language in Section 20 of Chapter 1 of the Wyoming Water Quality Rules and Regulations. Williams is a significant operator in Wyoming and, in particular, in the Power River Basin. Williams is concerned about Appendix H's potential to affect its coalbed natural gas operations adversely.

Appendix H has undergone significant changes over the past two and a half years and multiple public comment periods. Williams continues to have concerns about multiple provisions of Appendix H which is currently under consideration by the WWAB. Williams incorporates by reference its most recent comments on February 14, 2007 to the Wyoming Environmental Quality Council. See Attachment 1. However, at this time, Williams wishes to focus its comments on 1) the definition of historical discharges which would not be subject to Appendix H; and 2) clarification of the effect of a landowner's denial of access on an applicant's data collection and application obligations.

The revised Appendix H establishes a bright line of applicability. The Wyoming Department of Environmental Quality ("DEQ") will not use Appendix H to establish new effluent limits on discharges of produced water that began prior to January 1, 1997. DEQ has issued permits with effluent limits on discharges of produced water both prior to and since January 1, 1997. To date, discharges of produced water pursuant to valid, existing permits have protected agricultural uses, having met the narrative standard of Section 20 i.e., no measurable decrease in existing livestock or crop production. As currently drafted, Appendix H arbitrarily protects certain historical conventional oil and gas discharges while expressly targeting coalbed natural gas operations for application of the new, more stringent standards. DEQ does not present any rationale for the selection of the January 1, 1997 cutoff date or for the selective application of the new, more stringent standards to coalbed natural gas operations – nor could it. The historical discharges of record are the best empirical evidence that no measurable decrease to existing livestock and crop production has occurred. Therefore, Appendix H should not apply to establish effluent limits on discharges which have been occurring pursuant to a valid and existing permit as of the date of the adoption of Appendix H. See Attachment 2.

Appendix H includes a section entitled "Reasonable Access Requirement." To the extent the applicant for a discharge permit seeks effluent limits other than the Tier 1 default limits, the applicant has the burden of proof to provide data supporting the use of Tiers 2 and 3 of Appendix H. Appendix H should acknowledge that the applicant can develop only so much data for a Section 20 analysis without landowner cooperation on access issues. In order to prove that no measurable decrease in agricultural production will occur, the applicant must have access to collect data to meet that burden. Williams believes that Reasonable Access Requirement section requires some minimal but important revisions to ensure that the applicant will be able to obtain a permit based upon the best information that can reasonably be obtained by the applicant. Similarly, the identification of naturally irrigated lands should not be made solely on the basis of landowner testimony in the absence of granting an applicant reasonable access to determine the extent of the claimed naturally irrigated lands. See Attachment 2.

Williams appreciates the opportunity to comment on the Agricultural Use Protection Standards in Appendix H, and appreciates your consideration of our comments. We would be pleased to discuss our comments further with you and respond to any questions you may have.

Sincerely,

Joe Olson by [signature]

Joe Olson
Facilities Engineer

Attachments

3720383_1.DOC

ATTACHMENT 1

Williams Production RMT Company
300 North Works Avenue
Gillette, WY 82716
307.686.1636
307.686.7574 (fax)

February 14, 2007

Wyoming Department of Environmental Quality
Water Quality Division
Herschler Building – 4W
122 West 25th Street
Cheyenne, WY 82002
Attn: Bill DiRienzo

Re: Comments on Proposed Revisions to Chapter 1 of the Wyoming Water Quality Rules and Regulations, Appendix H, Agricultural Use Protection

Dear Mr. DiRienzo:

Williams Production RMT Company (Williams) appreciates the opportunity to submit comments to the Environmental Quality Council (EQC) regarding the adoption of Appendix H, Agricultural Use Protection standards, as part of the revisions to Chapter 1 of the Wyoming Water Quality Rules and Regulations. Williams is a significant operator in Wyoming and, in particular, in the Powder River Basin (PRB). Williams is concerned about Appendix H's potential to affect its coalbed natural gas (CBNG) operations adversely.

Appendix H has undergone significant changes over two years and four public comment periods. Throughout that time, the agricultural use protection standards in Appendix H were proposed as a Wyoming Department of Environmental Quality (DEQ) implementing policy. It was only in the last several months that DEQ decided to submit the Agricultural Use Protection Policy to the EQC as a rule rather than a policy. DEQ has failed to consider the mandatory factors specified in the Environmental Quality Act (EQA) for proposing Appendix H as a rule to the EQC. W.S. § 35-11-302 (a)(vi).

The Agricultural Use Protection standards in Appendix H have the potential to impose significant costs and technical burdens upon CBNG operators. Yet, DEQ failed to consider these impacts, and failed to balance the burdens imposed against the purported environmental effects sought to be protected, prior to recommending the adoption of Appendix H as a rule. Williams believes Appendix H would be significantly different in its requirements and breadth if the DEQ had thoroughly considered the factors set forth in W.S. § 35-11-302(a)(vi).

Williams' specific comments regarding the text of the proposed Appendix H follow. In addition, Williams encourages the EQC to consider seriously the development of a risk-based approach to implementation of the agricultural protection narrative standard, as opposed to the one-size-fits-all approach of the currently proposed Appendix H.

I. Purpose - Chapter 1, Section 20 Should Not be Implemented to Protect Illegal Irrigation.

We agree with DEQ that the purpose of Ch. 1, Section 20 is to protect irrigation that existed prior to an application for a WYPDES discharge permit. As the DEQ has noted, the language infers a pre-existing agricultural use prior to an application for a WYPDES permit, which can serve as a baseline from which a decrease in crop or livestock production could be measured. We also agree that, to be afforded the protection of Section 20, a landowner must have an existing irrigation structure or mechanism in place for diverting water. However, in Appendix H, the DEQ proposes the continuation of its historic practice of protecting illegal diversions, i.e., irrigation which occurs in the absence of a valid existing water right. Williams takes issue with this practice, particularly when the DEQ endorses in a rule this illegal practice be followed by State personnel when translating the Section 20 narrative goals into appropriate WYPDES permit limits.

If a landowner is irrigating without the benefit of a water right from the office of the State Engineer, then the irrigation is illegal. Since there is no right to the use of the water in the drainage, the irrigation could be ordered to cease and desist at any time. Therefore, there is really nothing for the DEQ to protect. Moreover, the DEQ's current practice of protecting illegal irrigation is in direct conflict with the Wyoming law regulating the use of water:

> Water being always the property of the state, rights to its use shall attach to the land for irrigation, or to such other purposes or object for which acquired in accordance with the beneficial use made for which the right receives public recognition, under the law and the administration provided thereby. W.S. § 41-3-101.

By allowing unauthorized structures to trigger application of the standard, Appendix H protects unlawful irrigation use, sanctions the unlawful conduct, and rewards the offender for its offense. We submit that this practice constitutes egregiously bad public policy and produces an absurd result in violation of the canons of statutory and regulatory interpretation declared by the Wyoming Supreme Court. See *In re KP v. State,* 102 P.3d 217, 224 (Wyo. 2004) ("[T]his Court will not interpret a statute in a manner producing absurd results"); *Corkill v. Knowles,* 955 P.2d 438, 444 (Wyo. 1998).

Lastly, the EQA expressly states that the actions of the DEQ shall not limit or interfere with the jurisdiction, duties or authority of the State Engineer in administering water rights. W.S. §35-11-1104(a)(iii). Protection of illegal diversions could certainly be construed as interfering with these jurisdictional constraints, as it aids conduct directly contrary to the requirements for use of water set out above.[1] CBNG dischargers should not be required to protect such illegal practices. Appendix H should expressly state that in the future unauthorized irrigation use will not be protected and that existing diversion structures not covered by an existing water right will not trigger application of the agricultural standard.

II. Presumption of Naturally Irrigated Lands is Overly Broad

Appendix H implies there is a pre-existing agricultural use of a stream or drainage when "a substantial acreage of naturally sub-irrigated pasture within a stream floodplain" exists. Appendix H states that infra-red photography, surficial geologic maps, wetland mapping, landowner testimony or any combination of these sources may be used to establish that lands are naturally irrigated. Each of these information sources presents a snapshot of conditions at a specific time, and conditions may have changed c.g., wetlands mapping.[2] In addition, a permit applicant has no method by which it could disprove the presumption of sub-irrigation presented in Appendix H. The application of EC and SAR effluent limits should not be applied unless there is some presence and evidence of the ability to irrigate with a surficial flow.

The EC and SAR effluent limits will be applied where the naturally irrigated land reaches a threshold deemed "agriculturally significant." This threshold is triggered when a stream segment contains "single parcels of naturally irrigated land

[1] The lack of a water right is often an indication that the drainage did not maintain adequate flows or water quality to facilitate irrigation or that the soils or other conditions were simply not supportive of irrigation adequate to allow the landowner to prove up its beneficial use of water and thus obtain a valid water right. And, in the absence of a valid existing water right, applicants for a discharge permit have no notice of irrigation use by such downstream landowners and no way to account for them in their WYPDES permit applications.

[2] The DEQ should not be able to rely solely upon landowner testimony which is inherently biased to establish the existence of naturally irrigated lands.

greater than 20 acres or multiple parcels in near proximity that total more than 20 acres." Given the size of parcels in Wyoming, the definition of agricultural significance could be easily met through single parcels or the sum of smaller parcels. The practical effect of this definition combined with an easily triggered (unrefutable) definition of sub-irrigated land is that Appendix H's irrigation effluent limits would be applied to discharges into virtually any and every drainage in the State. The agricultural protection standards in Appendix H, if implemented, would result in a gross over-extension of the prior agricultural use presumption, would be overly protective of established agricultural uses which may no longer exist and would significantly restrict CBNG operators' ability to discharge into State waters without expensive treatment of discharges to protect nominally useful parcels of land.

III. <u>Irrigation Data and Information</u>

Appendix H indicates that "the goal is to ensure that preexisting irrigated crop production will not be diminished as a result of the lowering of water quality." The difficulty, of course, is in assessing the preexisting or baseline crop production that existed prior to any proposed discharge. Often there are no records of crop yield, stream flows, historic water quality, etc., making it very difficult for all parties to apply the "no measurable decrease" standard. This has caused DEQ to historically take an overly conservative approach in developing numeric permit effluent limitations to assure no measurable decrease in crop production. For that reason, we recommend that the following be added to the data and information required under Section d:

- Extent of irrigation permitted by Office of the State Engineer under a valid and existing Wyoming water right.

- Rate of flow required to activate irrigation under the system in place.

- As to the season of use, the EQC should further refine the definition of "irrigation season." The EC and SAR limits will apply during those periods when crop growth is occurring and then only when irrigable flows exist. Irrigable flows are those in which adequate water exists to activate a spreader dike system for artificially irrigated lands or to cause natural flooding or sub-irrigation on naturally irrigated lands. It is not reasonable to assume that the irrigation season is generally considered year-round in Wyoming for passively irrigated lands, given the variation and intensity of storm events supplying water to ephemeral or intermittent drainages used for irrigation purposes. In the absence of such events, the naturally-occurring salinity in these drainages limits their utility for irrigation. When irrigation cannot occur, the water quality standards protective of irrigation should not be applied. Operators should not be required to make the water quality in the stream system better year round than mother nature provided.

- Most importantly, in place of using published tolerance values for the most sensitive crops grown, we suggest use of the Hanson Diagram to manage the SAR limit for two reasons. First, the published tolerance values for most crops generally assume conditions exist for attaining a 100% crop yield. Our experience throughout the PRB is that, given the growing conditions, e.g., a lack of precipitation, poor alkaline and saline soils, and intermittent flows, etc., irrigators in the PRB achieve a crop yield well below the 100% value. Second, as Appendix H acknowledges, the significant irrigation-related effluent limits in the PRB are EC and SAR. The EQC is aware that, within certain broad limits, it is the ratio of EC and SAR that determine the suitability of water quality for irrigation purposes for any given crop. We therefore suggest that the EQC apply the Hanson Diagram in establishing SAR limits. As stated above, these limits should be applied only when adequate water is available to create an irrigable flow. At all other times, to apply effluent limitations which are adequate to irrigate the most sensitive crop would require the dischargers to make the water in the stream better than mother nature provides. That is an undue burden, with no environmental benefit, which will not in any meaningful way enhance the crop production. It will only impose unnecessary additional expense and effort on dischargers of water from CBNG operations.

IV. Tiered Approach Should Protect Measurable Decrease in Crop Production.

The agricultural protection standards in Appendix H establish a tiered approach which is designed to establish appropriate effluent limits to ensure there is no measurable decrease in crop production. While a tiered approach is absolutely necessary to address the variety of background conditions and quality of discharges in different drainages within the PRB, the default EC and SAR limits in Tier 1 require revision. As discussed above, Williams does not believe that the use of default EC limits should be based on tolerance values for the most sensitive crop or upon 100% yield threshold values. To the extent the EQC decides to use such criteria, calculated values should be based on data which more accurately reflects soil chemistry and crop production in the PRB and Wyoming, not California. The Tier 1 approach is overly conservative and protects against any decrease in crop production, not merely a measurable decrease in such production. Appendix H proposes the application of effluent limits to achieve an end beyond that described in the narrative goals stated in Chapter 1, Section 20 and does so without sufficient supporting credible evidence. This point is well made and fully documented in letters dated May 5, 2006 submitted to the Water and Waste Advisory Board by Kevin C. Harvey on behalf of several CBMG operators including Williams, and we urge the EQC to carefully and fully consider Mr. Harvey's comments and conclusions and modify Appendix H accordingly. See attached letters.

Tier 2 offers dischargers a viable permitting option in instances in which background water quality is worse than its CBNG effluent quality. In such circumstances, Tier 1 default limits should be inapplicable. Williams requests that the EQC amend Appendix H to state that if such circumstances exist, EC and SAR effluent limits must be based upon those background conditions rather than tolerance values for the most sensitive crop.

V. A New Approach

The agricultural protection standards in Appendix H have undergone a number of changes over the past two years as DEQ and the Water and Waste Advisory Board have struggled with how best to implement Chapter 1, Section 20's prohibition against measurable decrease in crop or livestock production. The agricultural use protection standards were originally contemplated as internal policy guidance, giving DEQ sufficient flexibility to change the standards as needed. Given the renewed consideration of the standard as a rule rather than a policy, Williams believes it is time for the EQC and DEQ to step back and consider whether Appendix H truly addresses its originally intended purpose—to provide a practical, workable, and predictable solution for applying the narrative measurable decrease standard in Chapter 1, Section 20. The last two years of consideration by the Water and Waste Advisory Board, DEQ, and the public has culminated in proposed rule that Williams believes fails to achieve that purpose. Appendix H does not in any practical or realistic way define what is a "measurable decrease" and what is the best way to avoid it.

Williams suggests that the EQC and DEQ take a fresh look at the no measurable decrease standard and work with all stakeholders to develop a new rule that reflects the realities of agricultural production in an arid environment. Measurable decrease must be considered in the context of the background conditions. Not all waters of the State have the same quality and not all agricultural use has the same value. For example, where water quality is poor and agricultural use is limited to low-yield production from naturally irrigated native plants, less protection may be necessary than in situations where the background water quality is high and artificial irrigation supports high-yield commercial crops. Any new rule should take into account site-specific conditions and uses of water in each drainage, rather than applying blanket standards which are derived from data generated in California.

Williams recommends that the newly drafted rule take a risk-based approach to measurable decrease. Effluent limits should reflect that agricultural production in most areas of Wyoming is not at 100% yield under natural conditions due to lack of precipitation, poor alkaline and saline soils, and intermittent flows. EC and SAR standards should not be set to protect 100% yield, but should reflect the actual yield where produced water may actually be applied. Further, in many cases, stream conditions are such that there is little risk that produced water will reach irrigated acres unless mixed with substantial quantities of natural flows. Any rule should require consideration of whether the water being discharged will be applied to irrigated acreage, the impact of irrigation practices (the amount of water necessary to activate artificial and natural irrigation systems), and the condition of the soil being irrigated. Though Appendix H as currently drafted attempts to address these issues, it does so in an inflexible manner that does not acknowledge varied applications in the field.

Williams appreciates the opportunity to comment on the agricultural use protection standards in Appendix H and appreciates your consideration of our comments. We would be pleased to discuss our comments further with you and respond to any questions you may have.

Sincerely,

/s/

Joe Olson
Facilities Engineer

Attachments

3668614_1.DOC

KC HARVEY, LLC
SOIL AND WATER RESOURCE CONSULTANTS

May 4, 2006

Mr. Bill DiRienzo
Wyoming Department of Environmental Quality
Water Quality Division
Herschler Building, 4th Floor West
122 West 25th Street
Cheyenne, Wyoming 82002

Subject: Comments pertaining to the derivation of default effluent limits for EC in the Draft Section 20 Agricultural Use Protection Policy.

Dear Mr. DiRienzo:

I respectfully submit for your consideration the following comments regarding the fourth draft of the Section 20 Agricultural Use Protection Policy as it pertains to the derivation of default effluent limits for EC. These comments are being submitted on behalf of Yates Petroleum Company, Williams Production RMT Company, Petro-Canada Resources (USA) Inc., Marathon Oil Company, Lance Oil & Gas Company, Inc., Fidelity Exploration & Production Company, Devon Energy Production Company L.P., Bill Barrett Corporation, and Anadarko Petroleum Corporation. I have submitted additional comments regarding the derivation of SAR limits and the proposed SAR cap to you in a separate letter.

By way of introduction, I am a board-certified professional soil scientist having practiced as an environmental consultant in Montana and Wyoming, and throughout the world, for nearly 25 years. For the past seven years, my practice has focused on water management and soil and water salinity/sodicity issues associated with oil and gas development. I am credited as the first to research, develop, and apply managed irrigation techniques for the beneficial use of coalbed natural gas produced water. I have directed or participated in over 75 separate projects related to produced water management, WPDES permitting, soil and water chemistry investigations, and reclamation for coalbed and conventional natural gas projects in Wyoming, Colorado, and Montana. I have a M.S. degree in land rehabilitation (soil science emphasis) from Montana State University, and a B.S. in Resource Conservation (soil science emphasis) from the University of Montana.

I would like to comment on the proposed changes made to the Agricultural Use Protection Policy by the WDEQ subsequent to the January 26, 2006 meeting of the Water and Waste Advisory Board. My comments will focus on the comments provided by Dr. Larry Munn in his letter to the DEQ dated December 5, 2005. It is my understanding that Dr. Munn's comments resulted in the changes made to the proposed Policy. Specifically, I comment on Dr. Munn's request that the California-based soil salinity tolerance thresholds be used to establish default effluent limits for electrical conductivity (EC) under the Tier 1 process.

233 EDELWEISS DRIVE, UNIT 11, BOZEMAN, MONTANA 59718
VOICE: 406/585-7402, FAX: 406/585-7428, EMAIL: INFO@KCHARVEY.COM

Summary of Findings

The fourth draft of the Agricultural Use Protection Policy describes a 3-tiered decision making process for deriving appropriate effluent limits for EC and SAR whenever a proposed discharge may reach irrigated lands. The Tier 1 process would be followed for deriving "default" limits, and as such, this procedure would require a minimum of background information from the applicant. Specifically, the default EC limits would be based on the species-specific 100 percent yield potential values for soil EC reported by the USDA Agricultural Research Service (ARS) Salt Tolerance Database (USDA ARS, 2006).

Alfalfa is considered to be the most salt sensitive plant irrigated in northeastern Wyoming. Given this, my comments focus on the relevant information regarding alfalfa salinity tolerance. The ramifications of the concepts and data discussed herein for alfalfa can be applied to the more tolerant irrigated forage species commonly found in northeastern Wyoming, for example, western wheatgrass and smooth brome.

A considerable amount of research went into preparing these comments, including three months searching and reviewing the relevant scientific literature, and compiling and analyzing available and relevant soil, plant, and water data. The key conclusions of the literature review and data analysis are presented below and will be substantiated by the discussion that follows.

California Based Salinity Thresholds

- The ARS Salt tolerance database relies on California based salinity thresholds developed to approximate the specific plant, soil and environmental variables associated with that region.
- Regional differences in soil chemistry, climate and agricultural practices are likely to have a profound effect on the applicability of California based salinity threshold data to alfalfa growing in Wyoming.

Chloridic Versus Sulfatic Soils

- The natural soil salinity in the Powder River Basin is dominated by the sulfate ion; California soils are dominated by chloride. This conclusion is supported herein by the literature and by an evaluation of actual soil chemistry data provided by the USDA National Soil Survey Center.
- The term "gypsiferous" refers to sulfatic soils and is applicable to the Powder River Basin of Wyoming. Numerous documents, including the ARS Salt Tolerance Database, indicate that in sulfatic (or "gypsiferous") soils, plants will tolerate about 2 dS/m higher salinity than indicated.

<u>The Influence of Soil Salinity on Alfalfa Yield</u>

- Alfalfa is considered the most salt sensitive plant irrigated in northeastern Wyoming. Conditions required for the growth of alfalfa at 100 percent of its physiological yield potential probably do not exist anywhere in northeastern Wyoming and place doubt on the application of this benchmark value there.

- Sources of research and field guidance outside of California suggest alfalfa has a higher relative 100 percent yield soil EC tolerance than 2 dS/m, perhaps as high as 4 to 8 dS/m.

- Alfalfa yield comparisons between California and Wyoming show actual harvest values independent of soil salinity. Identical yields were reported in Wyoming for soil EC values ranging from 1.8 dS/m to 6.5 dS/m.

Based on the review summarized herein, we respectfully suggest that the WDEQ consider adopting an acceptable average root zone EC threshold of 4 dS/m for protection of alfalfa. This would equate to a default (Tier 1) effluent limit of 2.7 dS/m based on the 1.5 concentration factor cited by the draft Agricultural Use Protection Policy. The EC limits for protecting other species of concern in the Powder River Basin, e.g., western wheatgrass, should also be adjusted accordingly, based on the inherent differences in soil chemistry and climate between the northern Great Plains and the California agricultural areas. These conclusions and recommendations are substantiated by the discussion below.

California-based Salinity Thresholds

The majority of salinity tolerance data generated in the United States have been a product of field and laboratory trials conducted by the U.S. Salinity Laboratory (USSL) in Riverside, California. The salinity tolerance data generated by the USSL were prompted in response to agricultural production in the areas of the San Joaquin and Imperial Valleys of California. In 1977, Maas and Hoffman compiled the California research in a seminal article titled "Crop Salt Tolerance -- Current Assessment," listing salt tolerance levels for various crops. The subsequent year, Francois and Maas (1978) published an indexed bibliography of plant responses to salinity from 1900 to 1977 with 2,357 references to about 1,400 species. These articles serve as the primary references regarding crop tolerance and yield potential of selected crops as influenced by irrigation water (EC_w) or the average root zone soil salinity level (EC_e). This information was updated by Mass (1990). The ARS Salt Tolerance Database relies entirely on the Mass (1990) summary as the primary source of relative salt tolerance levels among crops. With respect to alfalfa, the original salt tolerance listings remain unchanged from the original Mass and Hoffman (1977) article.

The Mass and Hoffman (1977) and Mass (1990) listings of salt tolerance levels include the establishment of the 100 percent yield threshold for soil salinity. This value refers to the maximum allowable average root zone salinity level (EC_e) that results in no yield reduction for crops grown in chloritic soils. The term chloritic soil refers to the dominant salt type found in California soils (see below). For alfalfa, Mass and Hoffman (1977) and Mass (1990) list the 100 percent yield potential for alfalfa grown in chloritic soils as 2.0 dS/m (EC_e). The Mass and

Hoffman (1977) and Mass (1990) assessments also contain a disclaimer that the yield potentials listed should only serve as a guide to relative tolerances among crops, and that the absolute salt tolerance of crops is not simply a function of soil EC but is dependent on "many plant, soil, water, and environmental variables."

Six studies conducted at the US Salinity Laboratory in Riverside, California, served as the foundation for the determination of Maas and Hoffman's 2.0 dS/m threshold value (Gauch and Magistad, 1943; Brown and Hayward, 1956; Bernstein and Ogata, 1966; Bower et al., 1969; Bernstein and Francois, 1973; Hoffman et al., 1975). These studies vary in their methodology, including greenhouse and field experiments, different growth mediums (sand, gravel and soil), various watering regimes (automatic watering, tension-based watering), and multiple sources of chloritic salinity (NaCl, $CaCl_2$, and $MgCl_2$). These studies were designed to assess relative yield values, irrigation leaching fractions, root zone salt profiles, or salinity-ozone interactions. They were not specifically designed to determine a threshold salinity value for alfalfa. Usually, only four salinity levels were tested, with data used to produce a crop yield reduction line.

Furthermore, the source of salinity in the six studies was consistently chloride dominated, with either NaCl or a blend of NaCl, $CaCl_2$, and $MgCl_2$ added to the irrigation water. In Southern California, where these studies occurred, salts found in the soils are largely chloride-dominated. None of these studies were conducted using sulfate-dominated salts, such as are found in Wyoming soils (see below). Such regional differences in soil salinity are likely to have a profound effect on the application of existing salinity threshold data to alfalfa growing in the Northern Great Plains. Recognizing this, Mass (1990), Ayers and Westcot (1985), Hanson et al. (1999), as well as the ARS Salt Tolerance Database, all indicate that plants grown in sulfatic soils will tolerate average root zone EC_e values about 2 dS/m higher than indicated by each of these references. For alfalfa, this would equate to a 100 percent yield threshold of approximately 4 dS/m. This fact is discussed in detail below.

Chloridic Versus Sulfatic Soils

Research efforts of the USSL in California identified adjustments in effective plant salinity tolerance expressed or repressed in the field by physiological responses to climate, cultural practices, soil fertility, irrigation methods, physical condition of the soils and the distribution and speciation of salts within soil profiles. A critical difference between the environmental conditions in California and the northern Great Plains (including northeastern Wyoming) is soil chemistry and the primary salt constituents found in these soils. It is widely accepted that the soils of the agricultural areas of California are dominated by salts where chloride is the dominant anion, and that the soils of the northern Great Plains are dominated by salts where sulfate is the dominant anion. In earlier publications, sulfatic soils are sometimes termed "gypsiferous," referring to the most common sulfate salt found in semi-arid soils -- gypsum (calcium sulfate dehydrate). The correct term used today is sulfatic soils.

To incorporate the variation of salinity tolerance exhibited by plant response to different salt distributions and dominant salt species, the authors of salt tolerance research included a provision for sulfatic soils. Soils may contain amounts of sparingly soluble salts, such as gypsum and other sulfate salts, many times greater than can be held in solution in the field water-

content range. Sulfatic soils may appear to be saline when exhaustively extracted in the lab (i.e., saturated paste extract), but the in-situ soil solution may be nonsaline because of the limited solubility of gypsum and other sulfate salts (Bernstein, 1975). Thus, the EC measured in a saturated paste extract is higher than the actual concentration of salts seen by plants in sulfatic soils. It was suggested originally by Bernstein (1962) that plants will tolerate about 2 dS/m higher soil salinity (EC_e) than indicated in sulfatic soils due to this solubility effect. Since calcium sulfate is disproportionately dissolved in preparing saturated-soil extracts, the EC_e of sulfatic soils will range an average of 2 dS/m higher than that of chloritic soils with the same water conductivity at field capacity (Bernstein 1962). Therefore, plants grown in sulfatic soils will tolerate an EC_e of approximately 2 dS/m higher than those grown where chloride is the predominant ion (Maas, 1990). This narrative provision for sulfatic soils is included in the ARS Salt Tolerance Database, and the classic irrigation guidelines presented in Ayers and Wescot (1985).

Sulfatic soils are the rule not the exception in Wyoming and the northern Great Plains. Sulfatic soils identified by salinity tolerance references are characterized by the presence and influence of gypsum, or calcium sulfate dihydrate ($CaSO_4{\cdot}2H_20$), within the soil profile, as well as the geological and climactic prerequisites for sulfatic soil conditions. Soil gypsum may stem from one of several sources. Soils formed from geologic material containing anhydrite or gypsum often contains gypsum. The amount of rainfall and the topographic setting will strongly influence the amount and location of gypsum in the soil (Dixon and Weed, 1989). Accumulations of soluble salts, including sulfates in the surface layers, are characteristic of saline soils of arid and semiarid regions (Brady, 1974), including Wyoming. Research conducted by the U.S. Geological Survey confirms the presence of gypsiferous parent materials in the Powder River Basin (Johnson, 1993). At this point, it is important to differentiate between the soil taxonomic terms "gypsic" or "petrogypsic," which are used to describe significant gypsum accumulation within soil horizons, from the terms "gypsiferous" or "sulfatic" soils which refer to the dominate salt type in soils of Wyoming and the northern Great Plains.

Published research has addressed the issue of prevailing salt distribution and climate influenced salt dominance. In Springer et al. (1999), Curtin et al. (1993) and Trooien (2001), northern Great Plains prairie soil chemistry is comparatively summarized and/or contrasted to soils of California. Research suggests that recommendations developed for the western United States, where chloride is the major anion in soil and water chemistry, may not be appropriate for sulfatic soils (Springer et al., 1999). Trooien (2001) notes that most plant salinity tolerance information is developed in California and that the chemistry of salinity is different in the northern Great Plains (i.e., sulfate dominated salinity). Therefore, Trooien (2001) indicates that salinity thresholds are greater and yield losses are somewhat smaller in the Northern Great Plains compared to those of California (i.e., chloride dominated salinity). Research in Canadian prairie soils by Curtin et al. (1993) and Wentz (2001) suggest that salt tolerance testing at the Swift Current, Saskatchewan, salinity laboratory (and also at the US Salinity Laboratory) has mostly involved the determination of crop responses to chloride salinity. However, there is reason to suspect that responses to sulfate salinity, which is the predominant form of salinity in prairie soils, may differ from those observed in chloride salt systems. Wentz (2001) summarizes that crop tolerances developed for chloride dominated soils, such as those in California, may not be applicable to crops grown on the sulfate dominated soils typically found in western Canada.

Comparison of actual soil analytical data from the NSSC Soil Survey Laboratory, Lincoln, Nebraska, supports the chloride and sulfate salt dominance designations suggested by Springer et al. (1999), Curtin et al. (1993), Trooien (2001), and Wentz (2001). Analyses from the U.S. Soil Survey Laboratory are available online at http://ssldata.nrcs.usda.gov/ and organized by soil pedon. Data from selected counties in Wyoming and California were obtained from the NSSC Soil Survey Laboratory Research Database in order to determine the dominance of chloride or sulfate soil chemistry in the respective regions. Soil chemistry data were downloaded for use in this study for counties of the Powder River Basin in Wyoming (Sheridan, Campbell and Johnson Counties). Soil chemistry data were also downloaded for counties in California where intensive agricultural production takes place (Imperial, Fresno, Kern, Kings and Tulare).

Data pertaining to soil chloride and sulfate in the saturated paste extract are arranged and averaged by county and state in Table 1 below. These values are based on all of the available data provided by the U.S. Soil Survey Laboratory.

Table 1
A Comparison of Average Soil Saturated Paste Extract Sulfate and Chloride Levels from Counties in Wyoming and California.

County	Average Soil Sulfate Level (meq/L)	Average Soil Chloride Level (meq/L)
Sheridan, WY	14.9	4.1
Campbell, WY	130.4	3.0
Johnson, WY	30.9	1.8
Wyoming Average	**58.7**	**2.9**
Imperial, CA	48.4	295.7
Fresno, CA	98.6	26.3
Kern, CA	44.3	73.0
Kings, CA	110.7	23.9
Tulare, CA	9.3	21.6
California Average	**62.3**	**88.1**

The summary data suggest that the relative proportion of chloride salts in the selected California counties outweigh the proportion of sulfate salts and verify the chloride dominance suggested by the literature summarized above. In northeastern Wyoming, the relative proportion of sulfate salts in selected counties outweigh the proportion of chloride by an order of magnitude and verify the sulfate dominance and sulfatic conditions implied by the literature. Therefore, the recommendation by the ARS Salt Tolerance Database signifying that plants grown in sulfatic soils will tolerate average root zone EC_e values about 2 dS/m higher than indicated, is valid for the Powder River Basin, and probably all of Wyoming. For alfalfa, this would equate to a 100 percent yield threshold of 4 dS/m.

The Influence of Soil Salinity on Alfalfa Yield

As indicated above, the *relative* 100 percent yield potential reported for alfalfa in the ARS Salt Tolerance Database is 2 dS/m (EC_e). As such, alfalfa is regarded in the California-based literature as "moderately sensitive" to salinity. An *absolute* salinity tolerance would reflect predictable inherent physiological responses by plants, but cannot be determined because interactions among plant, salt, water and environmental factors influence the plant's ability to tolerate salt. *Relative* salt tolerance is a value based on the climatic and cultural conditions under which a crop is grown (Maas and Hoffman, 1977). Research generated outside the U.S. Salinity Laboratory in the U.S. and Canada has introduced alternative salinity tolerance values for alfalfa influenced by these climatic and cultural conditions.

In a study based on field trials in western Canada, McKenzie (1988) reported the "relative maximum salinity crops will tolerate when combined with intermittent moisture stress throughout the growing season." McKenzie (1988) places alfalfa within a moderate tolerance category, as opposed to moderate sensitivity, and extends alfalfa's 100 percent yield tolerance to an EC range of 4-8 dS/m, as opposed to 2 dS/m. Similar tolerance descriptors and EC values for alfalfa can be found associated with Britton et al. (1977), who supports moderate salt tolerance and an EC range of 5-10 dS/m for alfalfa. Likewise, Milne and Rapp (1968) present alfalfa with a moderate tolerance and an EC range of 4-8 dS/m. Cavers (2002); Wentz (2001); Schafer (1983); Holzworth and Wiesner (1990) and Dodds and Vasey (1985) also contribute to a departure from the established Maas classification of alfalfa salinity tolerance and threshold values. Bower et al., suggests an alfalfa tolerance somewhat between the previous authors and Maas (1990), suggesting maximum alfalfa yield is obtained when the average EC_e value for the root zone is 3 dS/m. Using salinized field plots in southern Saskatchewan, Holm (1983) reported a small, 0.037 ton/acre, reduction in alfalfa yields resulting from an increase in the surface EC_e (0 to 15 cm sample) from a 0 to 4 dS/m range to a 4 to 8 dS/m range. Holm presented these scales as representative of low and medium EC levels.

Relative salinity tolerances reported outside of peer reviewed literature stem from professional observations and judgments, roundtable discussions, experience in the field, and experience with the region, culture and climate; not from experimental data. Incorporation of field experience, observation, and limited data into supporting documents of the Salt Tolerance Database is acknowledged in Ayers and Wescot (1985). Alternative sources listed herein do not always report EC values in terms of 100 percent yield thresholds for alfalfa, but should not be discounted, as they pertain to what is realistic in the field. As an example, the Montana Salinity Control Association reports forage salt tolerances in terms of marginal establishment levels, not 100 percent yield potentials. Conditions allowing alfalfa to produce at 100 percent of its physiochemical yield potential probably do not exist anywhere within the northern Great Plains.

A suggested field-yield value corresponding to the 100 percent yield of alfalfa has never been reported by authors of salinity literature. Specifically, what yield of alfalfa, in tons per acre, could one expect if it was grown under conditions supporting 100 percent yield? Conditions supporting 100 percent alfalfa yields recommended by the ARS Salt Tolerance Database and its supporting documents would be: a soil EC_e of 2 dS/m or less, an irrigation water EC_w less than or equal to 1.3 dS/m, water contents maintained at field capacity, available N, P and K nutrient

levels maximized for alfalfa growth, a sufficiently long growing season, no associated phytotoxicity or pest issues, etc. This data limitation precludes the direct comparison of alfalfa yields generated in an agricultural area to the potential yields theoretically available under optimized conditions. The only available analysis is to compare an alfalfa yield to the average yield generated in its area, or generated between areas.

Using data available from the National Agricultural Statistics Service, selected county agricultural commissioner's data, and the U.S. Census of Agriculture (2002, 1997), irrigated alfalfa yield data were obtained for periods of interest. Alfalfa yield data for Wyoming counties are available from 1959 through 2005, but were averaged from 1970-2005 to reflect the integration of new irrigation technologies. Alfalfa yield data were summarized for the area encompassing the Powder River Basin: Sheridan, Johnson and Campbell counties. Alfalfa yield data for California counties are available from 1980-2004 so the entire dataset was averaged. Alfalfa data were summarized for counties in California related to intensive agriculture: Imperial, Fresno, Kern, Kings and Tulare counties.

Soil salinity data (as measured by EC) collected by the USDA National Soil Survey and analyzed by the National Soil Survey Center (NSSC) Soil Survey Laboratory were also obtained and summarized for the aforementioned counties. Average root zone EC values were calculated to a maximum depth of five feet. The county alfalfa yield and average root zone EC summaries are presented in Table 2 below.

Table 2
Comparison of Average Root Zone Soil Salinity (EC) Values with Historical Alfalfa Yields for Selected Counties in Wyoming and California.

County	Average Root Zone Soil Salinity (EC as dS/m)	Historical Average Alfalfa Yield (tons/acre)
Sheridan, WY	1.5	2.7
Johnson, WY	1.9	2.4
Campbell, WY	2.0	2.4
Wyoming Average	**1.8**	**2.5**
Tulare, CA	2.8	8.4
Kings, CA	6.9	6.9
Kern, CA	4.6	8.0
Fresno, CA	6.7	7.9
Imperial, CA	6.7	7.8
California Average	**5.5**	**8.0**

Values expressed in Table 2 show substantially higher average root zone salinities in California than in Wyoming. Alfalfa yields reported in California are three times greater than those in Wyoming, even though, on average, the soil salinity values are nearly three times higher than those reported for the Wyoming counties. The values generated in this exercise suggest that environmental factors other than salinity, e.g., climate, may be dictating the obtainable degree of alfalfa yield produced. However, the data also suggest that the California-based 100 percent yield threshold of 2 dS/m may not be appropriate for even the chloritic soils of California. For

example, the historical average yield of alfalfa in Tulare County is 8.4 tons per acre with a corresponding average root zone EC of 2.8 dS/m. The yield from Tulare County is actually slightly greater than the yields from Fresno and Imperial Counties where the corresponding average root zone EC values are substantially higher at 6.7 and 6.7 dS/m, respectively. Regardless, there does not appear to be a substantial difference in yields reported by the California counties with soil EC values ranging from 2.8 to 6.7 dS/m.

Other field data from Wyoming have been reviewed that also suggest an alternative to the California-based salinity tolerance values. The Use Attainability Analysis (UAA) report for Cottonwood Creek (SWWRC et al., 2002) was downloaded from the Wyoming Department of Quality, Water Quality Division webpage. Cottonwood Creek is located in Hot Springs County within the Bighorn Basin of Wyoming. This is an area of extensive conventional oil and gas production. According to the UAA report, discharge of produced water from the Hamilton Dome oil field to Cottonwood Creek constitutes the majority of flow to the ephemeral stream and constitutes the only irrigation water source for approximately 35 ranching operations. The waters of Cottonwood Creek exhibit an EC_w between 4.1 and 4.5 dS/m. At an average EC_w of 4.3 dS/m, an average root zone soil EC_e value can be calculated using the widely accepted relationship: $EC_e = 1.5\ EC_w$ (Ayers and Wescot, 1985). This relationship is expressed in the draft Section 20 Agricultural Use Protection Policy. From this relationship, an average root zone soil EC value of 6.5 is estimated for the fields irrigated long-term with water from Cottonwood Creek. Average alfalfa hay yields reported in the UAA amount to 2.5 tons per acre. This yield is identical to the average of the three Wyoming counties reported in Table 2 above. This is compelling given that the average soil EC value for the three other Wyoming counties is 1.8 dS/m, while the estimated soil EC for the fields irrigated with water from Cottonwood Creek is 6.5.

Closing Statement

Based on the review summarized herein, we respectfully suggest that the WDEQ consider adopting an acceptable average root zone EC threshold of 4 dS/m for protection of alfalfa. This would equate to a default (Tier 1) effluent limit of 2.7 dS/m based on the 1.5 concentration factor cited by the draft Agricultural Use Protection Policy. Other species of concern, including western wheatgrass, should be given equal consideration due to the inherent differences in soil chemistry between the northern Great Plains and the California agricultural areas for which the ARS Salt Tolerance Database is based. Factors such as extreme climate, periodic drought, soil moisture regime, duration of growing season, soil depth, and fertility limitations can collectively exert an overriding regional influence on the yield potential of forage crops. Based on this, we ask that the WDEQ exercise caution interpreting the applicability of specific salinity tolerances outlined by the ARS Salt Tolerance Database and thoughtfully consider the difficulty in detecting a "measurable" change in plant production due to soil salinity alone.

References Cited

Ayers, R.S. and Wescot, D.W. 1985. Water quality for agriculture. FAO Irrigation and Drainage Paper, 29 (rev. 1).

Bernstein, L. 1975. Effects of salinity and sodicity on plant growth. p. 295-312. In: Baker, K.F., Zentmyer, G.A. and Cowling, E.B. (ed.) Annual Review of Phytopathology. Vol. 13. Palo Alto, California.

Bernstein, L. 1962. Salt affected soils and plants. Problems of the Arid Zones. Proc. UNESCO Symp. 18: 139-174. Paris, France.

Bernstein, L. and Francios, L.E. 1973. Leaching requirement studies: Sensitivity of alfalfa to salinity of irrigation and drainage waters. Proceedings, Soil Science Society of America. 37:931-943.

Bernstein, L. and Ogata, G. 1966. Effects of salinity on nodulation, nitrogen fixation, and growth of soybeans and alfalfa. Agronomy Journal. 58:201-203.

Bower, C.A., Ogata, G., and Tucker, G.M. 1969. Rootzone salt profiles and alfalfa growth as influenced by irrigation water salinity and leaching fraction. Agronomy Journal. 61:783-785.

Brady, N.C. 1974. The nature and properties of soils 8th ed. Macmillan Publishing Company, Incorporated, New York, NY.

Brown, J.W. and Hayward, H.E.. 1956. Salt tolerance of alfalfa varieties. Agronomy Journal. 48:18-20.

Britton, M.G., Buchannan, L.C. and Muir, W.E. 1977. Principles and practices of commercial farming (5th edition). Faculty of Agriculture, University of Manitoba. Winnipeg, Manitoba.

Cavers, C. 2002. Please don't pass the salt – Preventing and Managing Soil Salinity. Manitoba Agriculture & Food; Soils and Crops Branch. Accessed from the internet, 3/20/06 from; http://www.umanitoba.ca/afs/ agronomists_conf/2002/pdf/cavers.pdf.

Curtin, D., Steppuhn, H. and Selles, F. 1993. Plant responses to sulfate and chloride salinity: Growth and Ionic Relations. Soil Science Soc. Am. J. 57:1304-1310.

Dixon, J.B. and Weed, S.B., eds. 1989. Minerals in soil environment 2nd ed. SSSA book series no. 1.

Dodds, D.L. and Vasey, E. 1989. Forages for salt-affected soils. Bulletin R-584 Rev. Cooperative Extension Service, North Dakota State University; Fargo, North Dakota.

Francois, L.E. and Maas, E.V. (ed.). 1978. Plant responses to salinity: An indexed bibliography. USDA-SEA (Science and Education Admin.) Agric. Reviews and manuals, ARM-W-6. U.S. Gov. Print. Office, Washington, DC.

Gauch, H.C. and Magistad, O.C. 1943. Growth of strawberry clover varieties and of alfalfa and Ladino clover as affected by salt. Journal of American Society of Agronomy. 35:871-880.

Hanson, B., Grattan, S.R. and Fulton, A.F. 1999. Agricultural salinity and drainage. Division of Agriculture and Natural Resources Publication 3375. University of California Irrigation Program. University of California, Davis, California.

Hoffman, G.J., Maas, E.V. and Rawlins, S.L. 1975. Salinity-ozone interactive effects on alfalfa yield and water relations. Journal of Environmental Quality. 4:326-331.

Holm, H.M. 1983. Soil salinity, a study in crop tolerances and cropping practices. Sask. Agriculture, Plant Industries Branch, Publ. 25M/3/83.

Holzworth, L.K. and Wiesner, L.E. 1990. Principles of establishment and seedling year management. p. 170-228. In: Baldridge, D.E. and Lohmiller, R.G. (ed.) Montana Interagency Plant Materials Handbook for Forage Production, Conservation, Reclamation and Wildlife. Montana State University, Bozeman, Montana.

Johnson, E.A. 1993. Depositional history of triassic rocks in the area of the powder river basin, northeastern Wyoming and southeastern Montana. U.S. Geological Survey Bulletin 1917 Chapter P.

Maas, E.V. 1990. Crop salt tolerance. p. 262-304. In: K.K. Tanji (ed.) Agricultural salinity assessment and management. ASCE Manuals Rep. Eng. Practive no.71. Am. Soc. Civ. Eng., New York, NY.

Maas, E.V. and Hoffman, G.H. 1977. Crop salt tolerance – current assessment. J. Irrigation and Drainage Div., Am. Soc. Civil Eng. 103(IR2):115-134.

McKenzie, R.C. 1988. Tolerance of plants to soil salinity. Soil and water program, 1987. Alberta Special Crops and Horticultural Research Centre Pamphlet 88-10. Brooks, AB.

Milne, R.A. and Rapp, E. 1968. Soil salinity and drainage problems; causes, effects, management. Publication 1314; Canadian Department of Agriculture.

Schafer, W.D. 1983. Salinity control under irrigation. Montguide Document MT 8382. Cooperative Extension Service, Montana State University; Bozeman, Montana.

Soil Survey Staff. 2006. National Soil Survey Characterization Data; Soil Survey Laboratory, National Soil Survey Center USDA-NRCS - Lincoln, NE. Saturday, March 11, 2006.

Springer, G., Wienhold, B.J., Richardson, J.L. and Disrud, L.A. 1999. Salinity and sodicity changes in dispersive clay and saturated hydraulic conductivity in sulfatic soils. Communications in soil science and plant analysis. 30(15&16), 2211-2220.

States West Water Resources Corporation, Western EcoSystems Technology, Inc., Blankenship Consulting LLC. 2002. Merit Energy Company Use Attainability Analysis to Accompany Petition to Change Use Criteria on Cottonwood Creek Near Hamilton Dome, Hot Springs County, Wyoming as Provided Under Wyoming Surface Water Standards, Chapter 1.

Trooien, T.P. 2001. Salinity down under. In: Proceedings of the South Dakota No-Till Association Meeting. pp. 35-38.

U.S. Census of Agriculture. 1997. Accessed from the U.S. Census Bureau website: http://www.census.gov/prod/www/abs/agric.html

U.S. Census of Agriculture. 2002. Accessed from the USDA National Agricultural Statistics Service website: http://www.nass.usda.gov/Census_of_Agriculture/index.asp.

U.S.D.A. Agricultural Research Service. 2006. Salt Tolerance Database. Relative Salt Tolerance of Herbaceous Crops. George E. Brown, Jr. Salinity Laboratory. Riverside, California.

U.S. Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA Agric. Handbook no. 60, Washington, D.C.

Wentz, D. 2001. Salt tolerance of plants. Alberta Agriculture, Food and Rural Development. Accessed from the internet, 3/25/06 from; http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex3303

* * * * *

Thank you very much for your time and consideration of this review and the recommendations stemming from it. If you, your WDEQ colleagues, or the members of the Water and Waste Advisory Board have any questions or comments regarding our findings, please contact me.

Sincerely,

Kevin C. Harvey, M.Sc., CPSSc.
Principal Soil Scientist

KC HARVEY, LLC
SOIL AND WATER RESOURCE CONSULTANTS

May 4, 2006

Mr. Bill DiRienzo
Wyoming Department of Environmental Quality
Water Quality Division
Herschler Building, 4th Floor West
122 West 25th Street
Cheyenne, Wyoming 82002

Subject: Comments pertaining to the proposed default SAR effluent limit cap of 10 in the Draft Section 20 Agricultural Use Protection Policy.

Dear Mr. DiRienzo:

I respectfully submit for your consideration the following comments regarding the fourth draft of the Section 20 Agricultural Use Protection Policy as it pertains to the derivation of effluent limits for SAR, particularly the proposed SAR cap of 10. These comments are being submitted on behalf of Yates Petroleum Company, Williams Production RMT Company, Petro-Canada Resources (USA) Inc., Marathon Oil Company, Lance Oil & Gas Company, Inc., Fidelity Exploration & Production Company, Devon Energy Production Company L.P., Bill Barrett Corporation, and Anadarko Petroleum Corporation. I have submitted additional comments regarding the derivation of EC limits in a separate letter.

By way of introduction, I am a board-certified professional soil scientist having practiced as an environmental consultant in Montana and Wyoming, and throughout the world, for nearly 25 years. For the past seven years, my practice has focused on water management and soil and water salinity/sodicity issues associated with oil and gas development. I am credited as the first to research, develop, and apply managed irrigation techniques for the beneficial use of coalbed natural gas produced water. I have directed or participated in over 75 separate projects related to produced water management, WPDES permitting, soil and water chemistry investigations, and reclamation for coalbed and conventional natural gas projects in Wyoming, Colorado, and Montana. I have a M.S. degree in land rehabilitation (soil science emphasis) from Montana State University and a B.S. in Resource Conservation (soil science emphasis) from the University of Montana.

I would like to comment on the proposed changes made to the Agricultural Use Protection Policy by the WDEQ subsequent to the January 26, 2006 meeting of the Water and Waste Advisory Board. My comments will focus on the comments provided by Dr. Larry Munn in his letter to the DEQ dated December 5, 2005. It is my understanding that Dr. Munn's comments resulted in the changes made to the proposed Policy. Specifically, I comment on Dr. Munn's proposal that all WPDES default effluent limits for SAR be capped at 10 under the Tier 1 process.

233 EDELWEISS DRIVE, UNIT 11, BOZEMAN, MONTANA 59718
VOICE: 406/585-7402, FAX: 406/585-7428, EMAIL: INFO@KCHARVEY.COM

Summary of Findings

The fourth draft of the Agricultural Use Protection Policy describes a 3-tiered decision making process for deriving appropriate effluent limits for EC and SAR whenever a proposed discharge may reach irrigated lands. The Tier 1 process would be followed for deriving "default" limits, and as such, this procedure would require a minimum of background information from the applicant. The default SAR limits would be extrapolated from the Hanson et al. (1999) chart relating the established EC effluent limit to SAR, up to a maximum default value of 10. The effluent limit for SAR will be determined in conjunction with EC so that the relationship of SAR to EC remains within the "no reduction in rate of infiltration" zone of the Hanson et al. (1999) diagram.

Two key concerns arise from Dr. Munn's letter regarding sodicity and the discharge of CBNG produced water in the Powder River Basin: (1) the potential impacts on the hydraulic function of irrigated soils during produced water discharge; and (2) the potential impacts of residual adsorbed sodium on the hydraulic function of irrigated fields after produced water discharge has ceased and rainfall/snowmelt leaches salts from the upper root zone. It is assumed that these concerns led Dr. Munn and the WDEQ to propose the SAR effluent limit cap of 10 under the Tier 1 process.

In addressing these concerns, I performed a considerable amount of research, including three months searching and reviewing the relevant scientific literature, and compiling and analyzing available and relevant soil, plant, and water data. The key conclusions of the literature review and data analysis are presented below and will be substantiated by the discussion that follows.

Review of Soil Sodicity

- Plant growth problems associated with excess sodium adsorption are in response to negative changes in soil structure resulting in reduced air exchange, water infiltration and hydraulic conductivity.

- The universally applied sodic soil threshold is an exchangeable sodium percentage (ESP) greater than 15.

- SAR is a measure of the sodicity risk in irrigation water. The higher the salinity of irrigation water, the higher the SAR can be without impacting soil structure and impairing soil infiltration and permeability.

The ESP-SAR Relationship for Soils in Northeastern Wyoming

- Using regression analysis, the relationship between ESP and soil SAR was determined for the Powder River Basin (n=382, R^2=.74).

- A 1:1 relationship of soil SAR to water SAR exists for soils in equilibrium with irrigation water. This relationship is widely accepted and confirmed by recent research led by Dr.

James Bauder at Montana State University. The relationship of ESP to soil SAR is therefore equivalent to the relationship of ESP to water SAR.

- Based on the regional specific relationship of ESP and SAR, an effluent limit of SAR = 16 corresponds to an ESP of 10, and provides a 33% margin of safety against the formation of sodic conditions (i.e., exceeding an ESP of 15). The proposed default SAR cap of 10 is, therefore, unnecessarily conservative.

The Effect of Rainwater Leaching on Soils Irrigated with Produced Water

- Concern has been raised that subsequent rainfall/snowmelt leaching of residual soil salinity may lower the electrolyte concentration and naturally raise the ESP past the dispersive sodic soil threshold.

- Research demonstrates that arid land soils can release 0.3 to 0.5 dS/m of Ca and Mg to solution as a result of the dissolution of primary minerals and the inherent calcium carbonate content of surface soils. Shainberg et al. (1981) indicates that these concentrations are sufficient to counter the deleterious effects of exchangeable sodium, even when the soil is leached with rainwater.

A Review of Soil Sodicity

The physical and chemical phenomena associated with soil sodicity are complex. Therefore, a brief summary is provided regarding the soil and water chemistry associated with the physical affects of soil sodicity.

A large body of research concerning sodic, or "black alkali" soils has been generated in response to the negative effects of high sodium concentrations on soils. Toxicity effects of sodium are rarely expressed in forage and grass crops, but do cause injury to selected woody plants (Lilleand et al., 1945; Ayers et al., 1951; Brown et al., 1953). Plant growth problems associated with high concentrations of sodium are generally a response to negative changes in soil structure. Sodic soils are "nonsaline soils containing sufficient exchangeable sodium to adversely affect crop production and soil structure (Soil Science Society of America, 2001)." High levels of adsorbed sodium tend to disperse soil particles thereby sealing the soil. The result can produce clogged soil pores, hard surface crusts, reduced infiltration, reduced permeability, and reduced oxygen diffusion rates, all of which interfere with or prevent plant growth. By definition, sodic soils are those that have an exchangeable sodium percentage (ESP) greater than 15. The universally applied ESP threshold of 15 percent is acknowledged in numerous publications, including Levy et al. (1998), Abrol et al., (1988), Evangelou (1998), McNeal and Coleman (1966), Sparks (1995), Sumner et al. (1998), Shainberg et al. (1971), the Soil Improvement Committee (2002), university extension publications, etc.

Clay minerals are the most physically and chemically reactive components of the sand, silt, and clay matrix in soil. The structural arrangement of clay minerals in soil is akin to a deck of cards; the clay mineral itself can be thought of as the deck, and the cards as individual layers. The

properties of the deck depend upon the arrangement of the cards and the electrochemical interlayer forces holding the cards together.

Clay minerals in soils are negatively charged and consequently attract ions with a positive charge such as calcium, magnesium, potassium, and sodium. Positively charged ions are called cations. Each cation competes with others in the soil solution for access to the bonding sites based on its valence and hydrated size. Every soil has a definite capacity to adsorb the positively charged cations. This is termed the cation exchange capacity (CEC). The various adsorbed cations (such as calcium and sodium) can be exchanged one for another and the extent of exchange depends upon their relative concentrations in the soil solution (dissolved), the ionic charge (valence), the nature and amount of other cations, etc. ESP is, accordingly, the amount of adsorbed sodium on the soil exchange complex expressed in percent of the cation exchange capacity in milliequivalents per 100 grams of soil (meq/100 g). Thus,

$$ESP = (\text{exchangeable sodium} / \text{cation exchange capacity}) \times 100.$$

Sodic soil conditions arise when greater than 15 percent of the ions bonded to the deck are sodium, which has a +1 valence and a large hydrated radius. When the ESP exceeds 15, the large hydrated sodium ions can wedge in-between the individual cards and cause "swelling" of the deck (Levy et al., 1998). This causes negative effects on the physical structure of the soil. Upon re-wetting, the individual decks may disperse and settle into soil pores, effectively clogging them and reducing the efficiency of air exchange, water infiltration, and permeability (i.e., hydraulic conductivity). In general, soils with moderately high, to high, clay contents are at higher risk.

Excessive adsorbed or exchangeable sodium can result from sustained use of irrigation water that is high in sodium and low in calcium and magnesium. Consequently, the ratio of sodium to calcium and magnesium ions in water is an important property affecting the infiltration and permeability hazard. The water quality index used to measure the hazard related to sodium abundance or sodicity in irrigation water is the sodium adsorption ratio or SAR.

The SAR is the ratio of the dissolved sodium concentration in water divided by the square root of the average calcium plus magnesium concentration. The SAR can be calculated from the sodium, calcium and magnesium concentrations via the formula:

$$SAR = [\text{sodium}] / (([\text{calcium}] + [\text{magnesium}])/2)^{1/2}$$

where the concentrations are in milliequivalents per liter (meq/L).

What is not apparent from the SAR formula is the fact that the higher the salinity of the water, the higher the SAR can be without impacting soil structure and impairing soil infiltration and permeability. Put another way, for a given SAR, infiltration rates generally increase as salinity (measured by the EC) increases. The changes in soil infiltration and permeability occur at varying SAR levels, higher if the salinity is high, and lower if the salinity is low. Therefore, in order to evaluate the sodicity risk of irrigation water, the EC must be considered. To this end,

the SAR-EC guidelines presented in Ayers and Westcot (1985) and Hanson et al. (1999) are used to assess the potential sodicity risk of irrigation water.

The ESP-SAR Relationship for Soils in Northeastern Wyoming

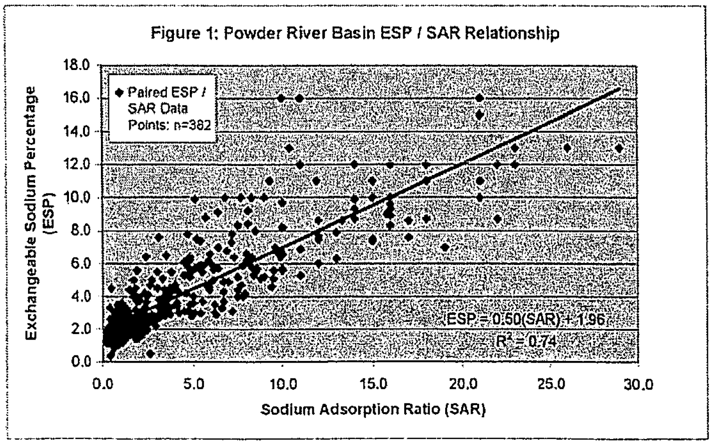
In addition to measuring the SAR of irrigation water, one can also measure the SAR of the soil solution via a saturated paste extract (i.e., the dissolved concentrations of sodium, calcium, and magnesium are measured in a saturated paste extract and applied via the SAR formula presented above). The soil SAR was developed to serve as a rapid and relatively inexpensive index of ESP. It is widely accepted that the SAR of the soil in equilibrium with the SAR of the irrigation water is equal to the long-term average SAR of the irrigation water.

The fourth draft of the Agricultural Use Protection Policy includes a proposed SAR cap of 10 for Tier 1 default effluent limits. To evaluate the appropriateness of the proposed cap, an analysis was performed using 382 ESP-SAR data pairs generated from ongoing soils assessment work in the Powder River Basin of Wyoming (KC Harvey LLC, 2006). This database represents flood plain soils associated with tributaries to the Powder River and the Tongue River, including spreader dike irrigated fields. This database represents baseline soil chemical conditions. In no case were any of these soils irrigated with or influenced by coalbed natural gas produced water. The soil samples from which the analyses were made were collected during soil profile descriptions to five feet, and with a Giddings hydraulic probe up to eight feet in depth. The numerous soil investigations involved were required for various coalbed natural gas water management planning, permitting, and design purposes.

The ESP-SAR data pairs were graphed in Microsoft Excel using simple scatter-plot and trend line analysis. The best fit line resulted in a linear regression which yielded the equation:

$$ESP = 0.5(SAR) + 1.96, \text{ with an } R^2 \text{ value of } 0.74.$$

The regional-specific "Powder River Basin" relationship, based on 382 soil samples, is shown on Figure 1. According to the Powder River Basin equation, a soil SAR of 26 corresponds to the critical ESP threshold of 15 percent.



It is widely accepted that the SAR of soil in equilibrium with irrigation water equals the long-term average SAR of irrigation water. Recent Department of Energy funded research directed by Dr. James Bauder at Montana State University (Robinson and Bauder, 2003) confirms this relationship. Their research, which is related to the potential effects of coalbed natural gas produced water on soils, reports that in general, soil solution SAR

represents the SAR of the applied water. The 1:1 soil SAR to water SAR relationship allows one to relate the SAR of discharge water to the SAR of the soil in the Powder River Basin ESP-SAR graph and equation described above. For example, after long-term irrigation with water exhibiting an SAR of 15, the equilibrated ESP of the irrigated soil would be approximately 9.5 percent. The proposed SAR cap of 10 would equate to a corresponding ESP of 7. An ESP cap of 7 appears to be unnecessarily conservative given the regional specific relationship of ESP and SAR. While an ESP threshold of 15 is widely accepted to be the point at which clay swelling and dispersion occurs, we respectfully suggest that the WDEQ consider establishing a Tier 1 default SAR effluent limit cap of 16, which corresponds to an ESP of 10. An ESP value of 10 provides a 33 percent margin of safety.

The Effect of Rainwater Leaching on Soils Irrigated with Produced Water

In his December 5, 2005 letter, Dr. Munn indicates his concern about the potential effects of rainwater leaching of fields that had received produced water due to upstream permitted discharges. In particular, what is the effect of leaching on the sodicity status and hydraulic function of soils after discharge and irrigation with produced water ceases? Fortunately, the considerable research on this subject has been well documented in the scientific literature.

Discontinuation of produced water discharge in the Powder River Basin will effectively reduce the EC and SAR of irrigation waters from tributaries and mainstems so long as the surface water is of higher quality than the produced water. In the case of fields that are irrigated opportunistically (e.g., in response to runoff events that are captured behind spreader dike systems), there can be three sources of water supplying soil moisture: (1) meteoric water (rain and snowmelt); (2) natural runoff water; and (3) subirrigation from a shallow aquifer. In the case of rainfall and snowmelt, the EC of these waters will be similar to that of distilled water, i.e., they will exhibit very low dissolved solids. Owing to the dissolution of soluble constituents within the watershed, natural runoff EC values can range up to 5 dS/m or higher. Regarding subirrigation, shallow aquifers can be relatively saline due to the entrainment of dissolved minerals along the groundwater flowpath.

The concern arises from leaching of residual surface soil salinity with rainfall and snowmelt. Intermittent rainfall and snowmelt may lower the electrolyte concentration (i.e., EC) sufficiently to promote clay dispersion, depending on soil properties (Levy et al., 1998). Conversely, when the electrolyte concentration in the soil solution reaches a moderate level (1-2 dS/m), high sodicity levels (ESP between 10 and 30) cause only small to moderate changes in the physical and hydraulic properties of the soils, which are mostly reversible (Levy et al., 1998). Shainberg et al. (1981) showed that a major factor causing differences among various sodic soils in their susceptibility to hydraulic failure when leached with low electrolyte concentrations (i.e., a low EC) was their rate of salt release from mineral dissolution.

Arid land soils can release 0.3 to 0.5 dS/m of calcium and magnesium to solution as a result of the dissolution of plagioclase, feldspars, hornblends and other sparingly soluble minerals within the soil matrix (Rhoades et al. 1968). The solution composition of a calcareous soil at a given ESP in contact with distilled water (i.e., rainwater or snowmelt) can be calculated (Shainberg et al., 1981). As calcium carbonate ($CaCO_3$) dissolves, the EC of the soil solution increases and

calcium replaces sodium on exchange sites until the solution is in equilibrium with the cation exchange system and the $CaCO_3$ solid phase. Shainberg et al. (1981) calculated that the EC values of solutions in equilibrium with soils having ESP values of 5, 10, and 20 are 0.4, 0.6, and 1.2 dS/m, respectively. Shainberg et al. (1981) indicates that these concentrations are sufficient to counter the deleterious effects of exchangeable sodium, even when the soil is leached with rainwater.

It is evident that water equilibrated with a calcareous soil can never be a very low salinity (Shainberg et al., 1981). Using the same database discussed above for evaluation of the ESP-SAR relationship in 382 soil samples from the Powder River Basin, we can compute an average percent lime ($CaCO_3$) content in surface soil samples (n=81), which is 5.1 percent. This represents a considerable reserve of calcium. Other sources of calcium include residual gypsum ($CaSO_4$) which we know to be prevalent in Wyoming soils.

Various soil SAR-EC relationships (not to be confused with irrigation water SAR-EC relationships) have been reported in the literature by introducing low electrolyte concentration waters to sodic soils. Felhendler et al. (1974) measured the hydraulic conductivity of two montmorillonitic soils as a function of the SAR and found that both were only slightly affected by the SAR of the percolating solution up to a SAR of 20 as long as the concentration of the percolating solution exceeded 1 dS/m. Shainberg et al. (1981) studied the effects of leaching a 1:1 sand-soil column with distilled water and increasing concentrations of a weak electrolyte solution. His findings concluded that an electrolyte concentration of 0.3 dS/m in the percolating solution was adequate to prevent the adverse effects of a SAR of 15 on the hydraulic conductivity of the soil-sand mixture. These findings are very similar to the conclusions of the U.S. Salinity Laboratory Staff (1954) who used electrolyte concentrations equal to or greater than 0.3 dS/m in their regression analysis to determine the sodic soils threshold of ESP = 15.

As a review, an electrolyte concentration of 0.3 dS/m is the minimum value of calcium and magnesium contributions to soil solution associated solely to arid soil weathering. This suggests that an arid Powder River Basin soil with a SAR of 16 (ESP = 10), will have no sodicity related impacts to the hydraulic conductivity, even when the salt concentration of the irrigation or rainwater is equal to that of distilled water.

Of course, irrigation water in the Powder River Basin has an intrinsic electrical conductivity greater than that of distilled water. Use of surface water for irrigation will actually supplement the inputs of calcium and magnesium from weathering and carbonate dissolution alone.

Using the aforementioned Powder River Basin soils assessment database (KC Harvey LLC, 2006), an average surface soil ECe of 1.64 dS/m was calculated from 81 individual surface soil samples. This value suggests that electrolyte concentrations in surface soils of the Powder River Basin, in equilibrium with mineral dissolution, the salinity of runoff irrigation water, and rainwater/snowmelt, is about 1.6 dS/m, or five times (1.6 dS/m divided by 0.3 dS/m) the concentration required to maintain the hydraulic conductivity of a soil at an ESP of 16.

Closing Statement

Results of the Powder River Basin regression analysis indicates that a relationship between ESP and soil/water SAR exists, which allows the calculation of one parameter from the other. Using the proposed, default ESP cap of 10 percent, the scientific literature indicates that water with a SAR of 16 can be effectively used for irrigation without adverse effects on the physical structure or hydraulic conductivity of Powder River Basin soils during irrigation. Furthermore, it has been shown that inputs of Ca and Mg from the natural dissolution of plagioclase, feldspars, hornblends and other sparingly soluble minerals, especially calcium carbonate and gypsum, will provide an effective buffer to residual soil sodicity after the discontinuation of produced water discharge and the transition back to native irrigation, precipitation, and runoff regimes.

References Cited

Abrol, I.P., Yadav, J.S.P. and Massoud, F.I. 1988. Salt-affected soils and their management. FAO Land and Water Management Division, Soils Bulletin 39.

Ayers, A.D., Aldrich, D.G. and Coony, J.J. 1951. Sodium chloride and injury of Fuerte avocado leafs. California Avocado Soc. Yearbook: 1951 174-178 illus.

Ayers, R.S. and Wescot, D.W. 1985. Water quality for agriculture. FAO Irrigation and Drainage Paper, 29 (rev. 1).

Brown, J.W., Wadleigh, C.H. and Hayward, H.E. 1953. Foliar analysis of stone fruit and almond trees on saline substrates. Amer. Soc. Hort. Proc. 61: 49-55.

Evangelou, V.P. 1998. Environmental soil and water chemistry principles and applications. John Wiley and Sons (Pub), New York, NY.

Felhendler, R.I., Shainberg, I. and Frenkel, H. 1974. Dispersion and hydraulic conductivity of soils in mixed solutions. Int. Congr. Soil Sci., Trans. 10th (Moscow) 1:103-112.

Hanson, B., Grattan, S.R. and Fulton, A.F. 1999. Agricultural salinity and drainage. Division of Agriculture and Natural Resources Publication 3375. University of California Irrigation Program. University of California, Davis, CA.

KC Harvey, LLC. 2006. Unpublished data. Compilation of various soil investigation sampling and analysis data from Sheridan, Johnson and Campbell Counties, Wyoming. Bozeman, MT.

Levy, G.J., Shainberg, I. and Miller, W.P. 1998. Physical Properties of Sodic Soils. In: Sumner, M.E. and Naidu, R. 1998. Sodic soils: Distribution, properties, management and environmental consequences. Oxford University Press, Inc. New York, NY.

Lilleand, O., Brown, J.G. and Swanson, C. 1945. Research shows sodium may cause leaf tip burn. Almond Facts 9 (2): 1, 5, illus.

McNeal, B.L and Coleman, N.T. 1966. Effect of solution composition on hydraulic conductivity. Soil Sci. Soc. Am. Proc., 30, 308-312.

Rhoades, L.D. 1968. Mineral weathering correction for estimating the sodium hazard of irrigation waters. Soil Sci. Soc. Am. Proc. 32:648-652.

Robinson, K.M. and Bauder, J.W. 2003. Soil behavior upon wetting with saline sodic water part 2: Soil chemical responses. Adapted from Robinson, K.M. 2003. Effects of saline-sodic water on EC, SAR, and water retention.

Shainberg, I., Bresler, E., and Klausner, Y. 1971. Studies on Na/Ca montmorillonite systems, I: The swelling pressure. Soil Sci. 111:214-219.

Shainberg, I., Rhoades, J.D., Suarez, D.L. and Prather, R.J. 1981. Effect of mineral weathering on clay dispersion and hydraulic conductivity of sodic soils. Soil Sci. Soc. Am. J. 45:287-291.

Soil Improvement Committee, California Plant Health Association. 2002. Western Fertilizer Handbook, ninth edition. Interstate Publishers, Inc. Danville, Illinois.

Soil Science Society of America. 2001. Glossary of Soil Science Terms. Madison, WI.

Sparks, D.L. 1995. Environmental Soil Chemistry. Academic Press, San Diego, Ca.

Sumner, M.E., Rengasamy, P. and Naiud, R. 1998. Sodic soils: A reappraisal. In: Sumner, M.E and Naidu, R. 1998. Sodic soils: Distribution, properties, management and environmental consequences. Oxford University Press, Inc. New York, NY.

U.S. Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. USDA Agric. Handbook no. 60, Washington, D.C.

* * * * *

Thank you very much for your time and consideration of this review and the recommendations stemming from it. If you, your WDEQ colleagues, or the members of the Water and Waste Advisory Board have any questions or comments regarding our findings, please contact me.

Sincerely,

Kevin C. Harvey, M.Sc., CPSSc.
Principal Soil Scientist

ATTACHMENT 2

Williams Production RMT Company
Proposed Revisions to Appendix H
Agricultural Use Protection and Associated Language
in Section 20 of Chapter 1

Page H-1, Paragraph 3, "Measurable Decrease" – delete "prior to January 1, 1997"; insert "pursuant to a valid and existing permit issued prior to the date of the adoption of Appendix H"

Page H-3, Paragraph 1, "Naturally Irrigated Lands" – Insert at the end of the paragraph, "However, landowner testimony may be used only if the landowner provides the discharge permit applicant with reasonable access to the landowner's lands to determine the extent of the claimed naturally irrigated lands."

Page H-7, Paragraph 2, Final Sentence, "Reasonable Access Requirement" – 1) Insert at the beginning of the sentence "Since the applicant has the burden of proof under Tiers 2 and 3,"; 2) insert after "access" "to the applicant"; and 3) insert after "obtained" "by the applicant".

3722474_1.DOC

Appendix H

Agricultural Use Protection

(a) Purpose

All surface waters in Wyoming are protected to some extent for agricultural uses. "Agricultural uses" are described in Section 3 as being either stock watering or irrigation.

The purpose of this Appendix is to provide a benchmark against which a determination can be made as to whether a waterbody is impaired and requires some kind of corrective action and to provide a basis for establishing permit limits on regulated activities (WYPDES & Section 404 permits). The purpose of this Appendix is also to provide the criteria and procedures to be used by the Water Quality Division when translating the narrative goals expressed in the Section 20 standard into appropriate WYPDES permit limits where maintaining agricultural use of the receiving waters is an issue.

"Measurable Decrease"

The first part of translating the standard is defining what is meant by *"measurable decrease in crop or livestock production"*. The phrase implies that there is a pre-existing agricultural use of a stream or drainage prior to an application for a WYPDES discharge permit. For livestock watering purposes, a pre-existing use will always be assumed. For irrigation purposes, there needs to be either a current irrigation structure or mechanism in place for diverting water from the stream channel, or a substantial acreage of naturally sub-irrigated pasture within a stream floodplain. Where neither of these conditions exist, there can be no irrigation use, nor loss in crop production attributable to water quality.

Where there are pre-existing agricultural uses, it may often be impossible to measure a loss in crops or livestock that can be attributed to water quality because of the many other factors that will affect actual production. It is also important to be able to predict the probability of a measurable decrease in production rather than relying solely on after-the-fact measurements. Therefore, the implementation of the narrative criteria through WYPDES permits will always involve making reasonable judgments and assumptions.

Effluent limits on discharges of produced water that began ~~prior to January 1, 1997~~ will not be affected by this Appendix in relation to the protection of agricultural uses. Where discharges have been occurring for at least ten years with no prior indication or complaint of reduced agricultural production, it will be assumed that the discharge has had no adverse effect on production. Therefore, it is not necessary to modify those discharges in order to achieve the goal of "no measurable decrease" in crop or livestock production. It would only be necessary to maintain the existing quality of the discharge. It is important to note, however, that effluent limits on historic discharges may be made where the quality of the discharge is shown to constitute a hazard to humans, livestock or wildlife.

(b) **Livestock Watering**

(i) The following limits apply to discharges that will be used for livestock watering. Each limit must be achieved at the end-of-pipe prior to mixing with the receiving stream:

5000 mg/L TDS;
3000 mg/L Sulfate;
2000 mg/L Chloride;

In addition to the basic effluent limitations above, the following limits for livestock protection may be incorporated into WYPDES permits when there is reason to believe they may be associated with a discharge:

Selenium	50 µg/L	Total Recoverable
Fluoride	4000 µg/L	Dissolved
Arsenic	20 µg/L	Total Recoverable
Copper	500 µg/L	Dissolved
Cadmium	50 µg/L	Dissolved
Boron	5000 µg/L	Dissolved
Chromium	1000 µg/L	Dissolved
Lead	100 µg/L	Dissolved
Mercury	10 µg/L	Dissolved
Zinc	2500 µg/L	Dissolved

(ii) Livestock watering waiver - An exception to the limits above may be made whenever the background water quality of the receiving water is worse than the value listed for the associated pollutant or when the livestock producer requests use of the water and thereby accepts any potential risk to his livestock.

(c) **Irrigation**

Electrical conductivity (EC) and sodium adsorption rate (SAR) limits will be derived in permits where effluent discharges are used for irrigation. Each limit must be achieved at the end-of-pipe prior to mixing with the receiving stream.

(i) For the purposes of this rule, irrigated lands include the following:

(A) "Artificially Irrigated Lands" means the artificially irrigated lands where water is intentionally applied for agricultural purposes. Artificially irrigated lands will be identified by the presence of canals, ditches, spreader dikes, spray irrigation systems or any other constructed mechanism intended to divert water from a stream channel for application on adjacent lands.

(B) "Naturally Irrigated Lands" means lands along stream channels that have enhanced vegetative production due to periodic natural flooding or sub-irrigation. Naturally irrigated lands are those lands where a stream channel is underlain by unconsolidated material and on which the combination of stream flow and channel geometry provides for enhanced productivity of agriculturally significant plants. Naturally irrigated lands may be identified by an evaluation of infra-red aerial imagery, surficial geologic maps, wetland mapping, landowner testimony or any combination of that information.

(ii) Appropriate effluent limits for EC and SAR will be calculated and applied to WYPDES discharge permits in all instances where the produced water discharge may reach any artificially irrigated lands.

(iii) EC and SAR limits will be applied to WYPDES permits where the produced water discharge may reach stream segments containing single parcels of naturally irrigated land greater than 20 acres in size or multiple parcels in near proximity that total more than 20 acres. In making this estimation, small drainage bottoms may be excluded from consideration. Two specific criteria which may be used to exclude lands include lack of a persistent active channel and unconsolidated floodplain deposits which are generally less than 50 feet in width.

(iv) If there are no pre-existing diversions within reach of a discharge, if the water will be impounded or managed so as not to reach a diversion during the irrigation season, or if the discharge will not reach an irrigated field, either because of natural conditions or water management techniques, then permit limits will be established to protect other relevant water uses (e.g. livestock watering, wildlife, aquatic life, etc.)

(v) Data and Information. A minimum amount of data must be collected to identify existing irrigation uses and to appropriately set effluent limits on discharges that may affect those uses. At a minimum, the following information must be obtained:

(A) Location(s) of irrigation diversions and/or naturally irrigated acreage;
(B) Crops grown under irrigation;
(C) Published tolerance values for the most sensitive crop;
(D) Season of use

Additional information may be required of the applicant to ensure that appropriate effluent limits are set to protect the receiving water.

(vi) - Establishing Effluent Limits. A 3-tiered decision making process will be used to establish appropriate effluent limits for EC and SAR whenever a proposed discharge will likely reach irrigated lands.

(A) Tier 1 -Default EC and SAR limits. Default limits for EC and SAR may be used where the quality of the discharge water is relatively good or the irrigated crops are salt-tolerant. The default values shall be based upon the published soil EC tolerance values for the most sensitive crop and shall be calculated as follows:

(I) Default EC limits will be based upon 100 percent yield threshold values for soil EC as reported by the USDA Agriculture Research Service (ARS) Salt Tolerance Database. In the event that the species of interest is not included in the ARS Salt Tolerant Database, then the following alternative references can be consulted:

(1.) Hanson et al. 1999. Agricultural Salinity and Drainage. DANR Pub. 3375, Univ. of Calif. Davis;

(2.) Ayers and Westcot. 1985. Water Quality for Agriculture. UN FAO Irrigation and Drainage Paper 29 (revised); and

(3.) CPHA. 2002. Western Fertilizer Handbook. 9th Edition. Interstate Pub., Inc., Danville, IL.

(II) The relationship between soil EC values and irrigation water EC values will be: EC (soil) = 1.5 EC (water), i.e., the published soil EC threshold obtained from the appropriate reference will be divided by the soil concentration factor of 1.5 to establish the discharge EC limit.

However, in circumstances where the background water quality of the receiving water(s) is known to be significantly better than would otherwise be required based on a theoretical 100% yield, effluent limits may be set to maintain that higher quality.

(III) Default limits will be set to ensure the relationship between SAR and EC remains within the designated zone of "no reduction in rate of infiltration" as depicted in Figure 1 at the end of this appendix. The following equation will be used to determine the default SAR limit: SAR = (7.10 x EC) – 2.48. If the actual EC concentration of the discharge is observed to be of higher quality than the published default concentration then the SAR limit may be adjusted to actual EC concentrations depending on site specific conditions. When the calculated default SAR value exceeds 10, the limit will be set at 10 as the maximum default limit. The maximum default limit is only intended to apply to calculating Tier 1 limits and may be modified according to the provisions of sections B and C below.

(IV) At a minimum, the EC and SAR limits will apply during the irrigation season and when flows are sufficient to support the use. For sub-irrigated lands and passively irrigated lands such as those under spreader dike systems, EC and SAR limits will generally apply year-round.

(B) Tier 2 - Background Water Quality. If sufficient data is available to demonstrate or calculate that the pre-existing background water quality at the point(s) of diversion is worse than the effluent quality, EC and SAR effluent limits may be based upon those background conditions rather than tolerance values for the most sensitive crop.

(I) Measured Data. Background water quality may be established based upon published pre-discharge historic data. Generally, this data only exists on larger, perennial, mainstem stream channels where historic gauging has taken place. Actual measured data is the most reliable means of establishing background and must be considered on those waters where it is available.

(II) Calculated Background. On intermittent and ephemeral stream channels, pre-discharge water quality data is usually scarce or non-existent and very difficult to collect. In these circumstances, background water quality can be estimated by conducting soil surveys on land that has been historically irrigated from the subject stream.

In the event that soil studies are used as a means to estimate baseline water quality for a given drainage, the following requirements apply:

(1.) Sample Site Selection. Soil samples shall be taken at semi-random sites within each contiguous irrigated segment downstream of the proposed discharge. "Semi-random" in this case is intended to mean that the applicant will identify the various major distinguishing terrain zones within each irrigated segment and select sample sites randomly within each terrain zone. For example, the channel bottom may constitute one terrain zone, the first small terrace above the channel bottom may be another terrain zone, and the adjacent meadow or field may be a single remaining terrain zone, or that meadow / field may actually be comprised of several other known zones such as discharge-affected soils vs. non-affected soils, sub-irrigated reaches vs. non-sub-irrigated reaches, etc.

(2.) Number of Sample Sites. Listed below are the minimum number of soil sample sites required for each of the identified terrain zones (based on zone area) within a contiguous irrigated segment:

Zone Area	**Minimum Number of Sample Sites**
0 – 5 acres	**3**
5 - 10 acres	**5**
10 + acres	**7**

(3.) Sample Collection. Sample sites must be located a minimum of 50 feet apart from one another. Each sample site shall be sampled at a minimum of four depths (0-12", 13-24", 25-36", 37-48"). If alfalfa is present within the terrain zone, each sample site within that terrain zone must be sampled at a total of 6 depths (at the above-noted depths, plus 49-60" and 61-72"). Each twelve inch sample increment must be analyzed either individually or combined (composited) with other corresponding depth samples from the other sample sites within the same terrain zone (e.g., all 0-12" samples from a given terrain zone bulked together and analyzed as a single composite sample).

(4.) Sample Analysis. At a minimum, a saturated paste extract for each sample shall be analyzed for EC. Though not necessary for the estimation of background water conductivity, it is advisable to also analyze the soil samples for pH, SAR, soil texture and exchangeable sodium percentage (ESP) to avoid having to duplicate the sampling if the results indicate that a "no harm analysis" *(item (C) below)* needs to be completed. Percent organic matter shall be analyzed in the surface 0-12 inch samples only. In addition, analyses to identify the clay mineralogy types present in the soils may also be warranted.

(III) Soil Report Preparation. At a minimum the applicant shall submit:

(1.) A map or diagram identifying where each of the soil sample sites is located. At a minimum, the map or diagram must show the basic topography and stream course, irrigation structures *(if present - such as spreader dams or head gates)*, estimated boundaries of the irrigated acreage, surface ownership of the irrigated acreage *(including downstream irrigated areas)* and section / township / range identification. This map must also show any delineated terrain zones, plus elevations of the terrain zones

(2.) An accompanying location table which includes the quarter / quarter, section, township, range, and latitude / longitude for each sample site

(3.) Summary data table showing the analytical results for each of the soil parameters listed above, for each depth, at each sample site

(4.) All associated lab sheets

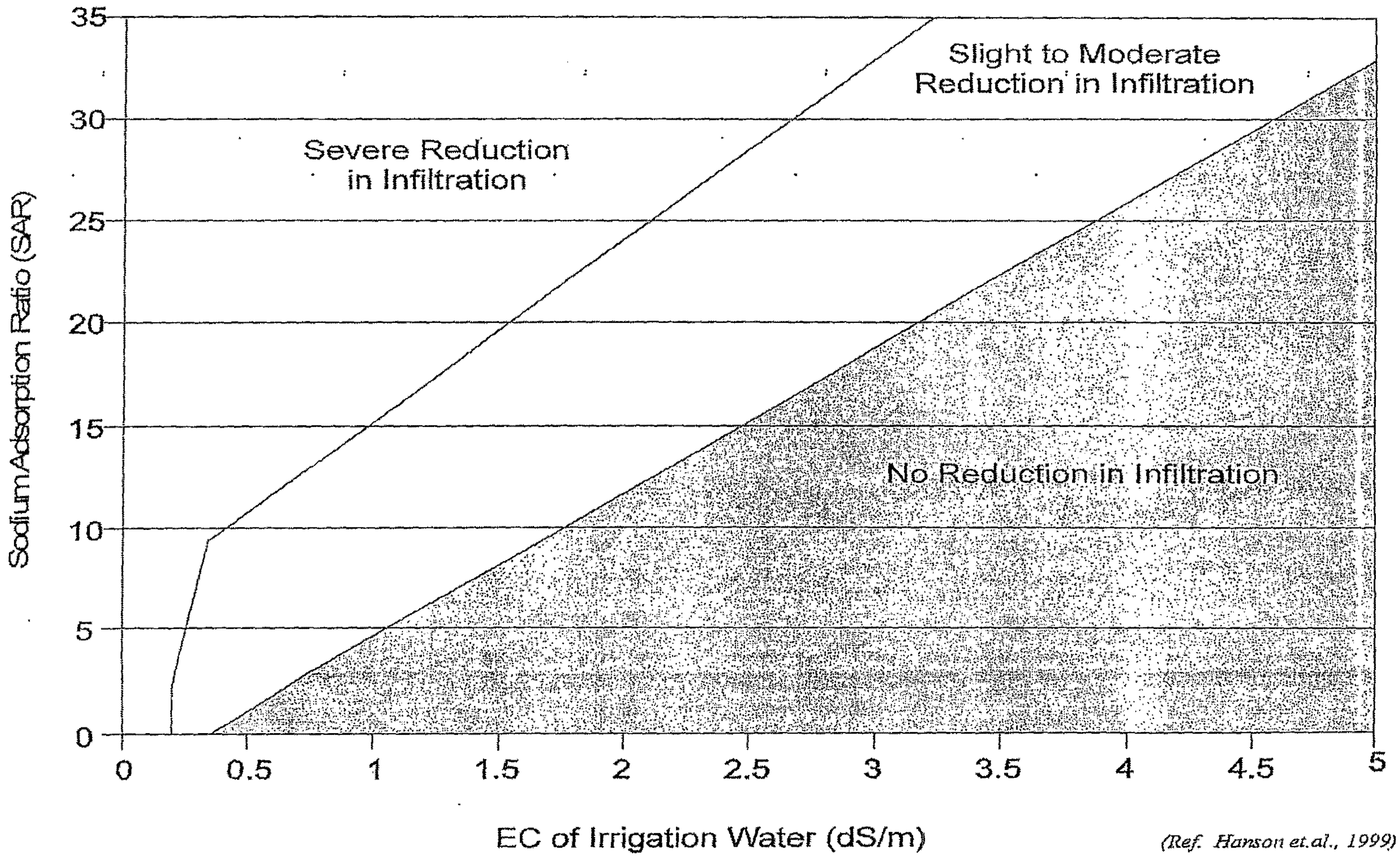
(C) Tier 3 - No Harm Analysis. The actual effects of EC and SAR on crop production are variable based upon soil type and chemistry and may be mitigated to some extent by managing irrigation practices. EC and SAR effluent limits may also be established based upon a scientifically defensible site specific study that examines local soil characteristics, natural water quality, expected crop yield, irrigation practices and/or other relevant factors related to crop production.

Because of the site-specific nature of this approach and the number and complexity of variables that may need to be considered, there is a burden of proof placed upon the applicant to demonstrate through a comprehensive study that levels of EC and/or SAR, higher than either the default values or estimated background water quality, would most likely not measurably harm an existing irrigation use. Refined limits for EC and SAR resulting from a "no harm" analysis should incorporate a reasonable margin of safety to account for variables that cannot be precisely measured or modeled.

(vii) Irrigation Waiver. An exception to EC or SAR limits established under the

Tier 1, 2 or 3 procedures may be made when affected landowners request use of the water and thereby accept any potential risk to crop production on their lands. Irrigation waivers will only be granted in association with an irrigation management plan that provides reasonable assurance that the lower quality water will be confined to the targeted lands.

(viii) Reasonable Access Requirement. The procedure for establishing default EC and SAR limits is intended to provide the ability to permit the discharge of high quality water without an obligation to conduct site specific studies. In practice, the use of the default procedure will only apply where permitted discharges are of exceptionally high quality. In many applications, appropriate limits for EC and SAR will be based on refined procedures rather than default. Because the refined procedures require the acquisition of site-specific data, it is necessary that permit applicants and/or the DEQ have reasonable access to obtain the required information. In circumstances where a landowner chooses to deny access for the purpose of developing a Section 20 analysis, EC and SAR limits will be based upon the best information that can be reasonably obtained and may be less stringent than Tier 1 default limits.



(Ref. Hanson et.al., 1999)