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Jim Ruby, Executive Secretary
Environmental Quality Council

**BEFORE THE ENVIRONMENTAL QUALITY COUNCIL
OF THE STATE OF WYOMING**

IN THE MATTER OF THE APPEAL OF)
POWDER RIVER BASIN RESOURCE)
COUNCIL, BERNADETTE BARLOW)
BERNADETTE BARLOW TRUST,) Docket No. 09-3802
WILLIAM L. BARLOW TRUST AND)
ERIC BARLOW FROM WYPDES)
PERMIT NO. WY0052299)

PROTESTANTS' DESIGNATION OF EXPERT WITNESS

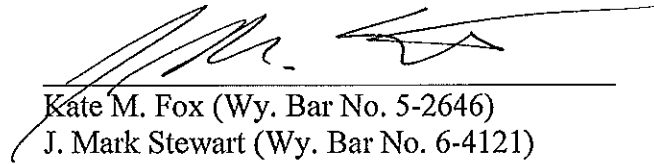
Protestants, POWDER RIVER BASIN RESOURCE COUNCIL, BERNADETTE
BARLOW, BERNADETTE BARLO TRUST, WILLIAM L. BARLOW TRUST AND ERIC
BARLOW serve herewith their designation of expert witnesses, as follows:

1. Dr. Ginger Paige
Department of Renewable Resources
University of Wyoming
P. O. Box 3354
Laramie, WY 82071-3354
Phone: 307-766-2200

The Curriculum Vitae of Dr. Ginger Paige is attached hereto as Exhibit 1 and includes a list of all publications authored by Dr. Paige. Dr. Paige has not charged a fee for her study and will not charge for her deposition testimony. A listing of cases in which Dr. Paige has testified as an expert, either at trial or by deposition, is attached hereto as Exhibit 2.

Dr. Paige's testimony will be consistent with her report which is attached hereto as Exhibit 3, and consistent with her deposition testimony, if any.

Dated this 18th day of December, 2009.



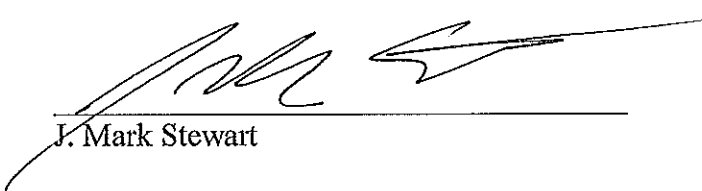
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CERTIFICATE OF SERVICE

I certify that on the 18th day of December, 2009, I served a true and correct copy of the foregoing by email or by hand delivery to:

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J. Mark Stewart

EXHIBIT 1

Dr. Ginger B. Paige
Assistant Professor
Department of Renewable Resources
University of Wyoming

EDUCATION

2000 Ph.D. Watershed Management, University of Arizona, Tucson, AZ
Minor: Agriculture and Biosystems Engineering
Dissertation: Measurement and modeling of the spatial variability of infiltration on rangelands.
1992 M.S. Soil Physics, University of Massachusetts, Amherst, MA
Thesis: Comparison of three methods for assessing soil hydraulic properties.
1984 B.A. Political Science, The Colorado College, Colorado Springs, CO

PROFESSIONAL EXPERIENCE

2004-present: Assistant Professor Water Resources, Department of Renewable Resources, University of Wyoming, Laramie, WY.
Direct and develop the Wyoming water resources extension program, provide training and extension services in the fields of water quality and quantity, and information services to researchers, State and Federal agencies and other interested parties. Conduct research on measurement and modeling of hydrologic and erosion processes on rangeland watersheds to address water resource and rangeland management issues important to Wyoming and regional states and of overall relevance to advancing the field of watershed hydrology.

2002-2004: Assistant Research Scientist, Department of Watershed Management, University of Arizona and USDA-ARS Southwest Watershed Research Center, Tucson, AZ.
Conducted research to measure and model hydrologic and erosion processes on rangeland watersheds at a variety of scales. Co-PI on Joint Fire Science Program funded project: Quantification of runoff and erosion processes on semi-arid rangelands following wildfires.

2000-2002: Research Associate, Department of Hydrology and Water Resources, University of Arizona and USDA-ARS Southwest Watershed Research Center, Tucson, AZ.
Conducted collaborative research as part of SAHRA (Semiarid Hydrology and Riparian Areas) NSF Science and Technology Center, to measure and model effects of the spatial variability of infiltration capacity on runoff and erosion on semi-arid rangelands at a variety of scales.

1996-2000: Senior Research Specialist, Department of Watershed Management, University of Arizona and USDA-ARS Southwest Watershed Research Center, Tucson, AZ.
Conducted research on measurement and modeling of hydrologic processes on rangeland watersheds at a variety of scales. Designed, built and tested computer controlled variable intensity rainfall simulator to measure hydrologic and erosion processes on rangeland watersheds.

1992-1996: Soil Scientist, GS-09, USDA-ARS Southwest Watershed Research Center, Tucson, AZ.
Developed a prototype Decision Support System to evaluate trench cap designs for low-level radioactive waste.

1992 (Jan. - May): Teaching Assistant, Soil Physics, Department of Plant and Soil Sciences, University of Massachusetts, Amherst, MA.
Co-taught class and taught laboratory section.

1988-1992: Research Assistant, Department of Plant and Soil Sciences, University of Massachusetts, Amherst, MA.

Managed Soil Physics Laboratory and conducted laboratory procedures. Designed and implemented study to characterize soil hydraulic properties.

1987 (June -Oct.): Peace Corps Training Co-coordinator, Ouezzendougou, Mali, West Africa
Co-coordinator for Appropriate Technology, Mali In-County Training. Developed curriculum for new program, wrote and implemented lesson plans, and evaluated trainees.

1986-1987: Peace Corps Agriculture Extension Agent, Dire, Mali, West Africa.

Designed and coordinated an irrigation project and introduced appropriate arid lands agriculture, soil and water management techniques.

1984-1986: Peace Corps Community Development Agent, Bougouni, Mali, West Africa.

Wrote project proposals and managed projects for the integration of appropriate technologies into schools and communities. Conducted training of trainer workshops and wrote proposal and managed project for the construction of reinforced wells for communities funded by U.S. AID.

RESEARCH EXPERTISE

Watershed and rangeland hydrology
Measurement and modeling hydrologic processes
Watershed and landuse management decision tools
Effects of fire on rangeland hydrologic and erosion processes
Characterization of soil hydraulic properties
Soil moisture measurement
Ecological site characterization and monitoring

HONORS AND AWARDS

Certificate of Appreciation, USDA-ARS SWRC, 2003
Outstanding Graduate Student, Dept. of Watershed Management, Univ. of Arizona, 2000
School of Renewable Natural Resources, University of Arizona, Superior Performance Award 1996, 1997, 1998, 1999, 2000
USDA-ARS, Outstanding Performance Award, 1996
USDA-ARS, Superior Performance Award, 1994 and 1995
Lotta Crabtree Fellowship for Agricultural Research 1991-1992

Professional Societies: American Water Resources Association, American Geophysical Union, Society for Range Management

EXTENSION PROGRAM

As State Water Quality Coordinator for Wyoming for the USDA CSREES National Water Quality Program, I have expanded the scope and impacts of Wyoming's water extension program to regional and national levels. The Mountain and Plains Regional project focuses on watershed planning, water quality assessment and water conservation in EPA Region 8 and is an integral component of my extension activities in Wyoming. A significant portion of my extension educational efforts target state decision makers who determine water resource policy for Wyoming. My extension activities address four major Wyoming water resource issues: 1) providing training and expertise in water quality and monitoring to the Wyoming Association of Conservation Districts (WACD), Wyoming Department of Environmental Quality (WDEQ) and the region; 2) assisting landowners, the Wyoming Environmental Quality Council (EQC) and the WDEQ in sound scientific guidance on impacts of Coalbed Methane (CBM) product water disposal; 3) improving statewide watershed monitoring by providing the hydrologic instrumentation and data network; and 4) responding to a variety of other water resource issues from state clientele. I have developed a website to provide water quality monitoring training course material, water quality and water resource information and programs, links to CBM information and information on the USDA-CSREES Regional and National Water Quality Programs http://www.uwyo.edu/water/default_text.asp. This website provides an immediate and accessible way to inform and update clientele across Wyoming.

Water Quality Monitoring and Assessment:

In 2005, I redesigned and expanded the WACD Water Quality Monitoring Training program and developed a Certification Program for state land and water managers. The program has grown to train more than 100 state resource managers, of which 48 have been certified, and eight Wyoming watersheds have undergone successful field audits. The program is divided into three training modules: 1) Watershed 101 and Water Quality 101; 2) Design and Implementation of a Water Quality Monitoring Program; and 3) Field Sampling Methods and Equipment, Data Analysis and Interpretation. The trainings form the base of Wyoming's Certification Program. I developed and teach the 3-day intensive Watershed 101 course for Module I, in addition to overseeing the entire training program. I teach or co-teach the courses with UW faculty and the NRCS state watershed coordinators. Since 2005, ten trainings have been conducted and Wyoming's Training and Certification Program is being used as a model for other states in the region; similar programs are being developed in Montana and North Dakota. I continually refine Wyoming's offerings, as the needs of Wyoming and the Conservation Districts change, and assist Conservation Districts (including Meeteetse, Dubois-Crowheart, and Laramie County) with watershed plans and data analysis. Results of these efforts are 1) knowledgeable and certified managers, 2) more effective monitoring and 3) scientifically credible water quality data.

In collaboration with Utah State colleagues and the Regional Water Program, I have developed a "Best Management Practices" guidance document to assist agency and local water quality personnel to implement effective monitoring programs for streams. The guide has been very well received at national water meetings and trainings in Wyoming and Utah. Version 2.0 is now available on the web. These efforts have resulted in a Symposium "Effective Monitoring of Water Quality on Stream Systems" that I will co-chair at the National Water Meeting in Hilton Head, SC in February 2010.

Coalbed Methane (CBM) Product Water:

Since June of 2005, I have been an active member of the WDEQ Advisory Working Group to revise Wyoming Water Quality Standards Chapter 1 - section 20 that address Coalbed methane product water disposal. Though the new standards proposed by WDEQ have recently been withdrawn for consideration as rule, I continue to work extensively with WDEQ, EQC, landowners and Department of Renewable Resources colleagues to integrate sound science into the state's water quality policy regarding CBM produced water. I have testified before the EQC four times and have been subpoenaed three times for legal cases regarding CBM water quality policy. In 2008, I put together 2 workshops for landowners in the Powder River Basin and Rawlins to address their concerns with CBM issues. The workshops

included presentations from WDEQ on the permitting process, legal issues associated with CBM development, as evaluation of the watershed permitting process, and an introduction of the CBM Landowner's Manual. Regionally, I am working with Montana and Colorado colleagues in the Mountain and Plains Regional Project to assess the impacts of our CBM educational and extension materials and programs. Nationally, I organized and chaired the 2008 "Energy Development and Water Issues" Symposium that was held at the USDA-CSREES, National Water Quality Conference in Reno, NV. (Feb 2008).

Hydrologic Instrumentation:

In collaboration with the State Climatologist Office and the Wyoming Department of Agriculture (WDA), I took a leadership role to improve the hydrologic instrumentation network across the state. Hydrologic data collection equipment has been greatly upgraded and new sites were added to the prior soil moisture network (Kelleners et al., 2009; Paige et al., 2008). Real time soil moisture monitoring is now in operation at a National Weather Service (NWS) Stations at Mammoth Hot Springs, WY and Wapiti, WY and we will expand soil moisture monitoring with the NWS to additional sites in 2010.

Committees and Presentations:

I continually respond to requests from field extension agents and clients regarding water resource and water quality issues. I have developed long-term relationships with ranchers and impacted agriculture producers in the Powder River Basin and across Wyoming, to assist in issues derived from CBM product water discharge. I continue to be an active member of several state water-related committees: Wyoming Water Forum (State Engineers Office), WDEQ TMDL Workgroup, NRCS State Technical Advisory Committee, and the WDEQ Advisory Work Group to revise Chapter 1 - Section 20 (Wyoming Water Quality Standards). I currently serve as southeast representative to the Wyoming Section of the Society for Range Management. In spring of 2008, I joined the newly developed UW Cooperative Extension Service Reclamation Issue Team. I am active in efforts to document Ecological Site Descriptions on rangelands. I have presented invited talks and workshops on water resources, watershed hydrology and CBM water issues across Wyoming, work in eXtension programs and in leadership teams developing the Community of Practice (CoP) "Water Conservation for the Lawn and Landscape" and the Rangelands CoP to assist with the rangeland water issues.

PUBLICATIONS

(*Collaboration with graduate student)

Refereed Journals:

*Patterson, M.M., G.B. Paige, and K.J. Reddy. 20XX. Selenium in surface and irrigation water in the Kendrick Irrigation District, Wyoming. *Environmental Monitoring and Assessment* (accepted).

Kelleners, T.J., G.B. Paige and S.T. Gray. 2009. Measurement of the dielectric properties of Wyoming soils using electromagnetic sensors. *Soil Science Society of America Journal* 73:1626-1637.

Kelleners T.J., E. Ferre-Pikal, M.G. Schaap, and G.B. Paige. 2009. Calibration of hydra impedance probes using electric circuit theory. *Soil Science Society of America Journal* 73:453-465.

Moran, M.S., R.L. Scott, T.O. Keefer, W.E. Emmerich, M. Hernandez, G.S. Nearing, G.B. Paige, M.H. Cosh and P.E. O'Neill. 2009. Partitioning evapotranspiration in semiarid grassland and shrubland ecosystems using time series of soil surface temperature. *Agriculture and Forest Meteorology* 149:59-72.

Stone, J.J., G.B. Paige, and R.H. Hawkins. 2008. Rainfall intensity dependent infiltration rates on rangeland rainfall simulator plots. *Transactions of the ASABE* 51(1):45-53.

Paige, G.B. and T.O. Keefer. 2008. Field application performance of multiple soil moisture sensors. *Journal of American Water Resources Association* 44(1):122-135.

Keefer, T.O., M.S. Moran and G.B. Paige. 2008. Long-term meteorological and soil-dynamics database WGEW, Arizona, USA. *Water Resources Research* 44, W05S07, doi:10.1029/2006WR005702. 8 p.

Clay, D., C. Ren, C. Reese, R. Waskom, J. Bauder, N. Mesner, B. Seelig, G.B. Paige, K.J. Reddy, M. Neibauer, and R. Mahler. 2007. Linking public attitudes with perceptions of factors impacting water quality and attending learning activities. *Journal of Natural Resources and Life Sciences Education* (36):36-44.

Paige, G.B., J.J. Stone, J.R. Smith, and J.R. Kennedy. 2003. The Walnut Gulch Rainfall Simulator: A computer controlled variable intensity rainfall simulator. *Applied Engineering in Agriculture* 20(1):25-31.

Paige, G.B., J.J. Stone, D.P. Guertin, and L.J. Lane. 2002. A strip model approach to parameterize a coupled Green-Ampt kinematic wave model. *Journal of American Water Resources Association* 38(5):1363-1378.

Paige, G.B., J.J. Stone, and L.J. Lane. 1996. Calibration and testing of simulation models for evaluation of trench cap designs. *Journal of Environmental Quality* 26(1):136-144.

Paige, G.B., J.J. Stone, D.S. Yakowitz, and L.J. Lane. 1996. Evaluation of a prototype decision support system for selecting trench cap designs. *Journal of Environmental Quality* 26(1):127-135.

Paige, G.B. and D. Hillel. 1993. Comparison of three methods for assessing soil hydraulic properties. *Soil Science* 155:175-189.

In Review:

*Sharma, M., G.B. Paige, and S.N. Miller. Development of DEMs from ground-based LiDAR: A method to remove non surface objects. *Remote Sensing* (*in review*).

*Williams, M.I., G.B. Paige, T.L. Thurow, A.L. Hild, and K.G. Gerow. Ecological sites and wildlife habitat: development and assessment of an integrated framework to monitor and manage shrub steppe ecosystems. *Journal of Wildlife Management* (*in review*).

*Patterson, M.M., K.J. Reddy, G.B. Paige, and M. Bedessem. Removal of selenium oxyanions from a sulfate-containing synthetic waste stream using a rotating biological contractor and indigenous microorganisms. *Environmental Technology* (*in review*).

Paige, G.B., J.J. Stone, and D.P. Guertin. Three approaches to configure and parameterize a distributed hydrologic model. *Journal of American Water Resources Association* (*in revision*).

Books and Book Chapters:

Paige, G.B. and L.C. Munn. 2010. Chapter 15: Water Quality Standards and Policies for Coalbed Natural Gas Produced Water In Wyoming (*Invited*). In: K.J. Reddy. (ed.) *Coalbed Natural Gas: Energy and Environment*, Nova Science Publishers, New York. ~pp200 (*in press*)

Paige, G.B. 2000. Measurement and modeling of the spatial variability of infiltration on rangeland watersheds. Ph.D. Dissertation. University of Arizona. pp. 283.

Refereed Proceedings:

Hild, A.L., N.L. Shaw, G.B. Paige, and M.I. Williams. 2009. Integrated Reclamation: Moving toward ecological function. National Meeting of the American Society of Mining and Reclamation, Billings, MT In R.I. Barnhisel (Ed.) Revitalizing the Environment: Proven Solutions and Innovative Approaches, May 30 –June 5, 2009. Published by ASMR, Lexington, KY. pp 578-596 (*Invited*)

Paige, G.B. S.N. Miller, T.J. Kelleners and S.T. Gray. 2008. Hydrologic instrumentation and data collection in Wyoming. Proceedings of the Third Interagency Conference on Research in the Watersheds, September 8-11, 2008, Estes Park, CO. pp. 4.

Moran, M.S., T.O. Keefer, G.B. Paige, R.L. Scott, W.E. Emmerich, M.H. Cosh, P.E. O'Neill. 2006. Partitioning evapotranspiration using diurnal surface temperature variation. Second Interagency Conference on Research in the Watersheds, May 17-19, 2006, USDA SRS Coweeta Hydrologic Laboratory, Otto, NC. pp. 10

Paige, G.B., J.J. Stone, and D.P. Guertin. 2005. Evaluation of post-wildfire runoff and erosion on semiarid ecological sites. Biodiversity and Management of the Madrean Archipelago II: Connecting Mountain Islands and Desert Seas, May 11-14, 2004, Tucson, AZ. pp. 8.

Paige, G.B. and J.J. Stone. 2003. Infiltration and runoff: Point and plot scale. In Renard, K.G., McElroy, S.A., Gburek, W.J., Canfield, H. E. and Scott, R. L., (Eds.) First Interagency Conference on Research in the Watersheds, October 27-30, 2003. U.S. Department of Agriculture, Agricultural Research Service. pp. 186-191.

Stone, J.J. and G.B. Paige. 2003. Variable rainfall intensity rainfall simulator experiments on semi-arid rangelands. Renard, K.G., McElroy, S.A., Gburek, W.J., Canfield, H.E. and Scott, R.L., eds. First Interagency Conference on Research in the Watersheds, October 27-30, 2003. U.S. Department of Agriculture, Agricultural Research Service. pp. 83-88.

Bryant, R., D. Thoma, M.S. Moran, C.D. Holifield, D.C. Goodrich, T.O. Keefer, G.B. Paige, D. William, and S.M. Skirvin. 2003. Evaluation of hyperspectral, infrared temperature and radar measurements for monitoring surface soil moisture. Renard, K.G., McElroy, S.A., Gburek, W.J., Canfield, H.E. and Scott, R.L., eds. First Interagency Conference on Research in the Watersheds, October 27-30, 2003. USDA,, Agricultural Research Service. pp. 528-533.

Kennedy, J.R., T.O. Keefer, G.B. Paige, and F. Barnes. 2003. Evaluation of dielectric constant-based soil moisture sensors in a semi-arid rangeland. Renard, K.G., McElroy, S.A., Gburek, W.J., Canfield, H.E. and Scott, R.L., eds. First Interagency Conference on Research in the Watersheds, October 27-30, 2003. USDA, Agricultural Research Service. pp. 503-508.

Paige, G.B., J.J. Stone, L.J. Lane, and D.S. Yakowitz. 1998. Overview of a Decision Support System for the Evaluation of Landfill Cover Designs. El-Swaify, S. and Yakowitz, D.S. eds. Multiple Objective Decision Making in Land, Water, and Environmental Management. Proc. of 1st International Conference on Multiple Objective Decision Support Systems for Land, Water and Environmental Management: Concepts, Approaches, and Applications. Honolulu, HI. July, 1995. St. Lucie Press, FL. pp. 153-165.

Proceedings:

*Baker, T.J., S.N. Miller, and G.B Paige, 2009. The Spatial Environmental and Agricultural Decision Support System (SEADS). Proceedings of the SUMAWA Mau Forest Complex Conference, April 27-29, 2009, Njoro, Kenya. pp. 71-75.

*Williams, M.I., T.L. Thurow, G.B. Paige, A.L. Hild and K. Gerow. 2009. Sagebrush-Obligate Passerine Response to Ecological Site Characteristics. Proceedings of the 15th Wildland Shrub Symposium, June 17-29, 2008, Boseman, MT. (*in press*)

*Church, M.M., M.I. Williams, A.L. Hild, and G.B. Paige. 2009. Comparing Vegetation Monitoring Methods in Shrublands: How Valuable is Grant's Methods in Shrub Communities? Proceedings of the 15th Wildland Shrub Symposium, June 17-29, 2008, Boseman, MT. (*in press*)

*Baldyga, T.J., S.N. Miller, W.A. Shivoga, F. Lelo, M.W. Jenkins, G.B. Paige, and S. Mooney. 2007. Development of a participatory spatial decision support system for East African rural planning, AfricaGIS 2007, September 17-21, 2007, Ouagadougou, Burkina Faso. pp. 14.

*Baldyga, T.J., S.N. Miller, W.A. Shivoga, F. Lelo, M.W. Jenkins, G.B. Paige, and S. Mooney. 2007. Rural Planning in East Africa Using a Participatory Spatial Decision Support System. Proceedings of the Environmental Systems Research Institute Eastern Africa User Conference, September 13 - 14 2007, Kampala, Uganda. pp.14.

Stone J.J., J. Wickre, G.B. Paige, D.P. Guertin, and G. Gottfried. 2007. Post wildfire runoff and erosion response on grassland and oak woodlands in southeastern Arizona. Biodiversity and Management of the Madrean Archipelago III. May 4, 2006, Tucson, AZ. pp. 5.

Paige, G.B., J.J. Stone, D. P. Guertin, R. McGee, and H. Blumenfeld. 2003. Runoff and erosion on a semi-arid grassland after a wildfire. Second International Wildfire Ecology and Fire Management Congress and Fifth Symposium on Fire and Forest Meteorology, November 16-20, 2003. Orlando, Florida. American Meteorological Society. pp. 7.

Paige, G.B., J.J. Stone, L.J. Lane, and D.P. Guertin. 2000. Infiltration and runoff response on a complex soil plot. Proceedings American Society of Civil Engineers Watershed Management 2000, June 21- 24, 2000, Fort Collins, CO. pp. 11.

Stone, J.J., G.B. Paige, and I. Sanchez Cohen. 1999. Planeacion de investigacion con simuladores de lluvia. Sanchez Cohen, I., J.J. Stone, and R. Jasso Ibarra eds. Uso de lluvia artificial para parametrizar modelos de procesos hidrológicos. SAGAR- INIFAP- CENID RASPA, Mexico, pp 7-14.

Paige, G.B. and J.J. Stone. 1996. Spatial and temporal variability of infiltration on rangelands. Proceedings USDA-ARS Workshop on Real World Infiltration. Pingree Park, CO. July 23-26, 1996, Colorado Water Resources Research Institute, Information Series No. 86, pp. 109-122.

Stone, J.J. and G.B. Paige. 1996. Rangeland rainfall simulator experiments. Proceedings USDA-ARS Workshop on Real World Infiltration. July 23-26, 1996, Pingree Park, CO. Colorado Water Resources Research Institute, Information Series No. 86, pp. 6-24.

Goodrich, D.C., R.E. Smith, D.D. Bosch, J.J. Stone, G.B. Paige, J.R. Simanton, W.E. Emmerich, T.O. Keefer, R.A. Shillito, C.L. Unkrich. 1996. Infiltration-scale interactions. Proceedings USDA-ARS Workshop on Real World Infiltration. July 23-26.1996, Pingree Park, CO. Colorado Water Resources Research Institute, Information Series No. 86, pp. 122-129.

Paige, G.B., J.J. Stone, T.E. Hakonson, and L.J. Lane. 1995. A decision tool for selecting trench cap designs. Proceedings of the 17th Annual Department of Energy Low-Level Radioactive Waste Management Conference, December 12-14, 1995, Phoenix, AZ, Idaho National Engineering Laboratory, Idaho Falls, ID. pp. 14.

Lane, L.J., M.H. Nichols, and G.B. Paige. 1995. Modeling erosion on hillslopes: Concepts, theory, and data. Binning, P., H. Bridgman, and B. Williams eds. Proceedings of the International Congress on Modelling and Simulation (MODSIM '95) November 27-30, 1995, University of Newcastle, Newcastle, Australia. Uniprint, Perth Australia.

Paige, G.B., T.E. Hakonson, D.S. Yakowitz, L.J. Lane, and J.J. Stone. 1994. A prototype decision support system for the evaluation of shallow land waste disposal trench cap designs. Proceedings ER '93 Environmental Remediation Conference, October 22-25, 1993, Augusta, GA, pp. 1111-1117.

Paige, G.B. and P.L.M. Veneman. 1993. Percolation tests and hydraulic conductivity. Soil Survey Horizons 34(1):1-3.

Manuals and Reports:

Mesner, N., A. Walker, G.B. Paige. 2008. Best Management Practices Monitoring Guidance Document for Stream Systems (Version 2.0). USDA-CSREES Northern Plains and Mountains Region. 43 p.

Mesner, N., A. Walker, G.B. Paige. 2008. Best Management Practices Monitoring Guidance Document for Stream Systems (Version 1.0). USDA-CSREES Northern Plains and Mountains Region. 21 p.

Paige, G.B. S.T. Gray and T.J. Kelleners. 2008. Soil Moisture Project Update. Wyoming Department of Agriculture. 9 p.

Paige, G.B. and T.O. Keefer. 2005. Soil moisture measurement at Walnut Gulch Experimental Watershed in support of: NASA-JPL Microwave Observatory of Subcanopy and Subsurface (MOSS) Project. Final Report, February 2005. 9 p.

Paige, G.B. 2002. Walnut Gulch Rainfall Simulator: User Manual and Operating Instructions (version 1). USDA-ARS, Southwest Watershed Research Center. 15 p.

Stone, J.J., Paige, G., Hakonson, T.E., Lane, L.J. 1994. Design document for landfill capping prototype decision support system. Los Alamos National Laboratory, LA-UR-94-570, 41 p.

Articles:

Paige, G.B. 2008. Wyoming's Water Information Network. Wyoming Section Society for Rangeland Management, Newsletter, July, 2008.

Paige, G.B. 2006. Water Quality and Erosion Following Wildfires. After the Fire, Casper Star Tribune, October 2006.

Fact Sheets:

Waskom, R., J. Bauder, T. Bauder, D. Clay, N. Mesner, G.B. Paige, K.J. Reddy, T. Scherer, and M. Neibauer. 2006. The National Integrated Water Quality Program, Highlighted Research, Education and Extension Projects in the Northern Plains and Mountains Region. (<http://region8water.colostate.edu/>)

Reddy, K.J., T. Roth, G.B. Paige, R. Waskom, J. Bauder, T. Bauder, D. Clay, N. Mesner and T. Scherer. 2006. Arsenic in Drinking Water: A regional assessment of Ground Water Wells. (<http://region8water.colostate.edu/>)

PRESENTATIONS

(*Collaboration with graduate student)

Invited:

Paige, G.B. 2009. Challenging Assumptions: Emerging research in rangeland hydrology. Research Across Disciplines Seminar, University of Wyoming, Laramie, WY December 4, 2009.

Paige, G.B. 2009. Wyoming Water: Watershed Hydrology and Management Programs Wyoming Association of Conservation Districts, Annual Meeting, Cheyenne, WY. November 19, 2009.

*Swallow, A. and G.B. Paige, 2009. Hydrologic Impacts of Vegetation Treatments in Bates Creek Watershed, Wyoming. Wyoming Association of Conservation Districts, Annual Meeting, Cheyenne, WY. November 19, 2009.

*Swallow, A. and G.B. Paige, 2009. Hydrologic Impacts of Vegetation Treatments in Bates Creek Watershed, Wyoming. Wyoming Water Development Commission Annual Meeting, Casper, WY. August 21, 2009.

*Baker, T.J., S.N. Miller, and G.B Paige, 2009. The Spatial Environmental and Agricultural Decision Support System (SEADS). SUMAWA Mau Forest Complex Conference, Njoro, Kenya, April 27-29, 2009.

Paige, G.B., Mesner, N and A. Walker. 2009. Guidance Document for Monitoring Water Quality Associated with BMPs for Stream Systems. WACD BMP Training, Buffalo, WY. July 24, 2009

Paige, G.B. 2009. Measurement and Modeling of Surface Water Processes on Rangeland Watersheds. Colorado State University Water Resources Program. Fort Collins, CO. April 2, 2009.

Paige, G.B. 2009. CBM Water Product Water: Water and Reclamation Issues. Restoration and Reclamation Seminar, Laramie, WY. March 6, 2009.

Paige, G.B. 2008. Water Resource Programs. US Forest Service Coordination Meeting, Laramie, WY. November 17, 2008.

Paige, G.B. 2008. Water Quality Issues: Coal Bed Methane Development. Water Quality Division, Chapter 1, Section 20, Rules and Regulations Hearing, Cheyenne, WY. October 24, 2008.

Paige, G.B. 2008. Wyoming Water Issues: Watershed Management and Coalbed Methane Water. French Embassy Visit, School of Energy Resources and Ruckelshaus Institute, Laramie, WY. August 19, 2008.

Paige, G.B. 2008. Water Quality and Coal Bed Methane Development. Wyoming Water Law Conference. CLE International, Cheyenne, WY. April 25, 2008.

Paige, G.B. 2008. CBM Product Water: Downstream Water Quality Issues. North Platte River Basin Water Policy Conference, Scottsbluff, NE. March 11, 2008.

Paige, G.B. 2008. Ecological Sites: Using site descriptions for habitat management. Ecological Site Workshop, Pinedale, WY February 29, 2008.

Paige, G.B. 2007. Water Resources Extension and Research Program. Profitable and Sustainable Agriculture Systems, Wyoming Cooperative Extension Service. Laramie, WY. December 13, 2007.

- Paige, G.B. 2007. Ecological site descriptions and state and transition models. Ecological Sites as Management Tools, Society for Range Management workshop Park City, UT. October 23, 2007.
- Paige, G.B. 2007. Coal bed methane production, drought, climate. Western Region Joint Summer Meetings, Jackson, WY. July 16, 2007.
- Paige, G.B. and G. Gade. 2007. Post wildfire: Watershed water quality issues, runoff and erosion. American Public Works Association, Spring Conference. Casper, WY. April 5, 2007.
- Paige, G.B. 2007. Watershed health: Decision making & watershed assessment tools. Wyoming Association of Conservation Districts Workshop on Watershed Health. Cody, WY. March 9, 2007.
- Paige, G.B. 2007. Watershed health: Its not just the water. Wyoming Association of Conservation Districts Workshop on Watershed Health. Cody, WY. March 9, 2007.
- Paige, G.B. 2007. Watershed planning: Why watersheds? Wyoming Association of Conservation Districts Workshop on Watershed Health. Cody, WY. March 9, 2007.
- Paige, G.B. 2006. Drought in Wyoming: Risk & planning. Wyoming Women in Agriculture, Annual meeting. Casper, WY. November 17, 2006.
- Paige, G.B. 2006. Water issues in Wyoming: Survey of public attitudes. Ruckelshaus Institute Water Planning Group Meeting. Cheyenne, WY. May 11, 2006.
- Paige, G.B. 2006. Post wildfire effects on rangeland soils and vegetation. Land Reclamation Seminar, Dept. of Renewable Resources, University of Wyoming, Laramie. April 14, 2006.
- *Roth, T.R., K.J. Reddy, and G.B. Paige. 2006. Regional assessment of arsenic in domestic wells of small communities in region 8 states. National Association of State Universities and Land-Grant Colleges (NASULGC) Eighth Annual Food and Agricultural Science and Education Exhibition and Capitol Hill Reception. Washington, DC. February 28, 2006.
- Paige, G.B., J.J. Stone, D. P. Guertin, G.J. Gottfried, and J. Wickre. 2005. Runoff and erosion on a semi-arid grassland after a wildfire. 2005 Joint Fire Science Program Principal Investigator Workshop, San Diego, CA. November 1-3, 2005.
- Paige, G.B. 2005. Using ground based lidar for rangeland hydrology. WY Geographic Information Systems Center Seminar Series. University of Wyoming, Laramie. October 27, 2005.
- Paige, G.B. and T. L. Thurow. 2005. Rangeland water research: A complex agenda for a changing society. 58th Annual Meeting Society for Range Management, Fort Worth, TX Feb 5-11, 2005.
- Paige, G.B. 2004. Measurement of runoff and erosion on semi-arid rangelands. Department of Renewable Resources, Research Across Disciplines Seminar Series, University of Wyoming, Laramie. October 29, 2004.
- Conferences and Symposia:**
- *Swallow, A., G.B. Paige, and K. Dwire. 2009. Hydrologic Impacts of Vegetation Treatments in Bates Creek Watershed, Wyoming. AGU Chapman Conference: Examining Ecohydrological Feedbacks of Landscape Change Along Elevation Gradients in Semiarid Regions. October 4-8, 2009, Boise and Sun Valley, ID. *poster paper*

*Vithanage, J., S.N. Miller, A. Perlinski, and G.B Paige, 2009. Land Cover Characterization of Remotely Sensed Data using Fourier Algorithms for Hydrologic Modeling. GIS in the Rockies Conference. Sept. 25-28, 2009, Loveland, CO. *oral paper*

Hild, A.L., N.L. Shaw, G.B. Paige, and M.I. Williams. 2009. Integrated Reclamation: Moving Toward Ecological Function. 2009 National Meeting of the American Society of Mining and Reclamation, Revitalizing the Environment: Proven Solutions and Innovative Approaches. May 30–June 5, 2009, Billings, MT. *oral paper*

Paige, G.B., N. Mesner and A. Walker, 2009. Guidance Document for Monitoring Water Quality Associated with BMPs for stream systems. 2009 National Monitoring Conference. May 22, 2009. San Antonio, TX. *oral paper*

*Vithanage, J.C., A. Perlinski, S.N. Miller, and G.B. Paige, 2009. Land cover characterization of remotely sensed data using Fourier algorithms for hydrologic modeling of ungaged basins. First Forest and Plains Research Symposium: Building collaboration between researchers and forest and grassland scientists and managers through increased sharing of research findings. Laramie, WY, March 10, 2009. *poster paper*

*Perlinski, A.T., J. Vithanage, G.B. Paige, and S.N. Miller, 2009. Utilization of the Automated Geospatial Watershed Assessment Tool to Estimate Runoff and Sediment Yield from a Small Watershed in Southeastern Wyoming. First Forest and Plains Research Symposium: Building collaboration between researchers and forest and grassland scientists and managers through increased sharing of research findings. March 10, 2009, Laramie, WY. *oral paper*

Paige, G.B., S.N. Miller, A. Perlinski, J. Vithanage, D.P. Guertin, D. Goodrich, M. Nearing, P. Heilman, J. Stone, and G. Ruyle, 2009. Rangeland Automated Geospatial Watershed Assessment Tool. 2009 USDA-CSREES National Water Conference. Feb. 8, 2009, St. Louis, MO. *poster paper*

Paige G.B. and L.C. Munn. 2008. Impacts of coalbed methane development on water quantity and quality in the Powder River Basin Third Interagency Conference on Research in the Watersheds. September 8-11, 2008, Estes Park, CO. *oral paper*

Paige, G.B. S.N. Miller, T.J. Kelleners and S.T. Gray. 2008. Hydrologic instrumentation and data collection in Wyoming. Third Interagency Conference on Research in the Watersheds. September 8-11, 2008, Estes Park, CO. *poster paper*

*Williams, M.I., T L. Thurow, G.B. Paige, and A.L. Hild. 2008. Shrubland passerine bird density patterns in relation to ecological sites. 15th Wildland Shrub Symposium. June, 17-29, 2008, Boseman, MT. *oral paper*

*Church, M.M., M.I. Williams, A.L. Hild, and G.B. Paige. 2008. Comparing Vegetation Monitoring Methods in Shrublands: How Valuable is Grant's Methods in Shrub Communities? 15th Wildland Shrub Symposium. June 17-29, 2008, Boseman, MT. *oral paper*

Paige, G.B., N. Mesner and A. Walker, 2008. Designing monitoring programs to evaluate BMP effectiveness. 2008 National Monitoring Conference. May 21, 2008, Atlantic City, NJ. *oral paper*

Paige, G.B., S.N. Miller, and M. Sharma. 2008. Effects of DEM Resolution and Storm Characteristics on Hydrologic Modeling. AWRA GIS and Water Resources V. March 17, 2008, San Mateo, CA. *oral paper*

*Mulligan C., G.B. Paige, and K.J. Reddy. 2008. Monitoring the quality of CBNG produced water and determining the beneficial uses across the Power River Basin, WY. 2008 USDA National Water Conference. February 6, 2008, Sparks, NV. *oral paper*

Mesner, N., A. Walker, and G.B. Paige. 2008. Designing monitoring programs to evaluate BMP effectiveness. 2008 USDA National Water Conference. February 6, 2008, Sparks, NV. *oral paper*

*Williams, M.I., G.B. Paige, A.L. Hild, and T.L. Thurow. 2008. Use of ecological site indicators to describe upland passerine habitat. Society for Range Management 61st Annual Meeting. Jan 27- Feb 2, 2008, Louisville, KY. *oral paper*

*Church, M.M., M.I. Williams, A.L. Hild, and G.B. Paige. 2008. Impacts of removal and seeding treatments on vegetative structure in greasewood (*Sarcobatus vermiculatus*) and smooth brome (*Bromus inermis*) dominated bottomlands. Society for Range Management 61st Annual Meeting. Jan 27- Feb 2, 2008, Louisville, KY. *poster paper*

*Williams, M.I., G.B. Paige, A.L. Hild, and T.L. Thurow. 2007. Linking ecological site indicators to upland bird density and diversity. WY Society for Range Management Annual meeting. Nov. 26-28, 2007, Lander, WY. *oral paper*

*Baldyga, T.J., S.N. Miller, W.A. Shivoga, F. Lelo, M.W. Jenkins, G.B. Paige, and S. Mooney. 2007. Development of a participatory spatial decision support system for East African rural planning. AfricaGIS 2007 September 17-21, 2007, Ouagadougou, Burkina Faso. *oral paper*

*Williams, M.I., G.B. Paige, A.L. Hild and T.L. Thurow. 2007. Linking ecological site indicators to upland passerine bird habitat. UW Graduate Student Symposium. April 3-4, Laramie, WY. *oral paper*

*Williams, M.I., G.B. Paige, A.L. Hild, T.L. Thurow and R. Laubhan. 2007. Linking ecological site monitoring techniques to upland breeding bird habitat. Society for Range Management Annual meeting. Feb 12-16, Reno, NV. *poster paper*

*McGee, R., G.B. Paige, J.J. Stone, and G. Ruyle. 2007. Evaluation of three rangeland monitoring methods as indicators of runoff and erosion on ecological sites. Society for Range Management Annual meeting. Feb 12-16, Reno, NV. *poster paper*

*Sharma, M., G.B. Paige and D.C. Goodrich. 2006. Watershed characterization and modeling at different scales using LIDAR data collected at two different spatial resolutions. AWRA Spring Specialty Conference on GIS and Water Resources IV. May 8-10, 2006, Houston, TX. *oral paper*

Stone J.J., J. Wickre, G.B. Paige, D.P. Guertin, and G. Gottfried. 2006. Post wildfire runoff and erosion response on grassland and oak woodlands in southeastern Arizona. Biodiversity and Management of the Madrean Archipelago III. May 4, 2006, Tucson, AZ. *oral paper*

*Williams, M.I., G.B. Paige, A.L. Hild and T.L. Thurow. 2006. Spatial database and decision tool to evaluate habitat monitoring and management at Browns Park National Wildlife Refuge. UW Graduate Student Symposium. April 3-4, Laramie, WY. *poster paper*

*Sharma, M. and G. B Paige. 2006. High resolution bare earth DEM from ground based lidar data for watershed characterization and modeling. UW Graduate Student Symposium. April 3-4, Laramie, WY. *poster paper*

Paige G.B., D. Clay, C. Reese, C. Ren, M. Neibauer, J. Bauder, N. Mesner, R. Waskom, B. Seelig, K. Reddy, R. Mahler. 2006. Priority Water Issues in the Northern Plains and Mountains Region. USDA – CSREES National Water Quality Meeting. February 5-9, San Antonio, TX. *poster paper*

*Wickre, J., J.J. Stone, G.B. Paige, D.P. Guertin, G.J. Gottfried. 2005. Parameterizing the WEPP model for post fire conditions using a rainfall simulator. 4th USGS Wildland Fire Science Workshop. December 5-7, Tucson, AZ. *poster paper*

Reddy, K.J., G.B. Paige, and Q. D. Skinner. 2005. Best management options for coalbed methane produced water in semi-arid environments. USDA CSREES 2005 Annual Water Quality Meeting. Feb. 5-10, La Jolla, CA. *poster paper*

Paige, G.B. J. J. Stone, and D. P. Guertin. 2004. Evaluation of post-wildfire runoff and erosion on semiarid ecological sites. Biodiversity and Management of the Madrean Archipelago II: Connecting Mountain Islands and Desert Seas. May 11-14, Tucson, AZ. *poster paper*

Paige, G.B., J.J. Stone, D. P. Guertin, R. McGee, and H. Blumenfeld. 2003. Runoff and erosion on a semi-arid grassland after a wildfire. Second International Wildfire Ecology and Fire Management Congress and Fifth Symposium on Fire and Forest Meteorology. November 16-20, Orlando, FL. *oral paper*

Paige, G.B. and J.J. Stone. 2003. Infiltration and runoff: Point and plot scale. First Interagency Conference on Research in the Watersheds. October 27-30, Benson, AZ. *oral paper*

Stone, J.J. and G.B. Paige. 2003. Variable rainfall intensity rainfall simulator experiments on semi-arid rangelands. First Interagency Conference on Research in the Watersheds. October 27-30, Benson, AZ. *oral paper*

Paige, G.B., J.J. Stone, and D.P. Guertin. 2001. Spatial variability of infiltration on semi-arid rangelands. NRCS-ARS-CSREES Partnering Workshop. November 26-30, Tucson, AZ. *oral paper*

Paige, G.B., Stone, J.J., and Guertin, D.P. 2001. Rainfall simulator experiments to parameterize a distributed hydrologic model. American Water Resources Association. Annual Water Resources Conference. November 12-15, Albuquerque, NM. *oral paper*

Paige, G.B., J.J. Stone, L.J. Lane, and D.P. Guertin. 2000. Infiltration and runoff response on a complex soil plot. ASCE Watershed Management 2000. June 21- 24, 2000, Fort Collins, CO. *oral paper*

Paige, G.B. and J.J. Stone. 1996. Spatial and temporal variability of infiltration on rangelands. USDA-ARS Workshop on Real World Infiltration. July 23-26, 1996, Pingree Park, CO. *oral paper*

Paige, G.B., J.J. Stone, T.E. Hakonson, and L.J. Lane. 1995. A decision tool for selecting trench cap designs. 17th Annual Department of Energy Low-Level Radioactive Waste Management Conference. December 12-14, 1995, Phoenix, AZ. *oral paper*

Paige, G.B., T.E. Hakonson, D.S. Yakowitz, L.J. Lane, and J.J. Stone. 1993. A prototype decision support system for the evaluation of shallow land waste disposal trench cap designs. ER '93 Environmental Remediation Conference. October 23-25, Augusta, GA. *poster paper*

Paige, G. B. and D. Hillel. 1991. Comparison of methods for assessing soil hydraulic properties. American Society of Agronomy Annual Meetings. October 17-20, Denver, CO. *poster paper*

Baker, R.S. and G.B. Paige. 1990. Site suitability assessment for on site sewage disposal. Soil Science Society of Southern New England Conference. November 14, 1990, Sturbridge, MA. *oral paper*

Workshops/Trainings:

Restoration 101: Introduction to restoration issues in Wyoming. October 22, 2009 Rawlins, WY
1 oral presentation: "Reclamation: Surface Water and Erosion"
17 attendees

Watershed 101 & Water Quality 101. Wyoming Water Quality Monitoring Training Module I. October 5-8, 2009. Laramie, WY.

Training Leader and Facilitator:
8 oral presentations (Watershed 101)
3 Attendees

Field Sampling Methods and Equipment; Data Analysis and Interpretation. Wyoming Water Quality Monitoring Training Module III. June 1 - 3, 2009. Casper, WY.

Training Leader and Facilitator:
3 oral presentations
2 day field demonstrations
6 Attendees

Watershed 101 & Water Quality 101. Wyoming Water Quality Monitoring Training Module I. October 10-14, 2008. Laramie, WY.

Training Leader and Facilitator:
8 oral presentations (Watershed 101)
6 Attendees

Workshop for Landowners in Areas of CBM Development. March 29, 2008. Rawlins, WY

Organized and Facilitated Workshop
6 Attendees

Workshop for Landowners in Areas of CBM Development. March 7, 2008 Sheridan, WY

Organized and Facilitated Workshop
1 oral presentation
65 Attendees

Ecological Sites for wildlife management. University of Wyoming Dept. of Renewable Resources and Jonah Interagency Office. February 29, 2008, Pinedale, WY.

Co-organizer
1 invited presentation
28 Attendees

Ecological Site Descriptions as a Management Tool: Understanding and Improving Applications for Wildlife Habitat Management in Sagebrush Ecosystems. Society for Range Management, Western Governors' Association, Western Association of Fish and Wildlife Agencies, The Wildlife Society, October 23 - 25, 2007, Park City UT.

1 oral presentation
invited "ecological site expert" facilitator.
250 Attendees.

Field Sampling Methods and Equipment; Data Analysis and Interpretation. Wyoming Water Quality Monitoring Training Module III. June 19-21, 2007. Casper, WY.

Training Leader and Facilitator:
2 oral presentations
2 day field demonstrations
Course wrap-up and evaluation
14 Attendees

Design and Implementation of a Water Quality Monitoring Program. Wyoming Water Quality Monitoring Training. Module II. March 27-29, 2007. Lander, WY.

Training Leader and Facilitator:
4 oral presentations
Course Final Exam
Course wrap-up and evaluation
14 Attendees

Predicting Post Wildfire Hydrology and Erosion on Semi-Arid Grasslands and Oak Woodlands. USDA-ARS and US Forest Service, Joint Fire Science Program Workshop. August 18-20, 2006. Sierra Vista, AZ.

Training Facilitator
4 oral presentations
1 field demonstration
Course wrap-up and evaluation
25 Attendees

Field Sampling Methods and Equipment; Data Analysis and Interpretation. Wyoming Water Quality Monitoring Training. Module III: Casper, WY June 12-15, 2006.

Training Leader and Facilitator:
2 oral presentations
2 day field demonstrations
Course wrap-up and evaluation
15 Attendees

Design and Implementation of a Water Quality Monitoring Program. Wyoming Water Quality Monitoring Training. Module II: Lander, WY March 5-9, 2006.

Training Leader and Facilitator:
4 oral presentations
Course Final Exam
Course wrap-up and evaluation
15 Attendees

Soil Erosion Network: Soil erosion under climate change. USDA-ARS, SWRC /ISCO Workshop. Tombstone, AZ. November, 2003

Field Demonstration: variable intensity rainfall simulator for quantifying hydrologic and erosion processes on ecological sites in semi-arid rangeland watersheds.
20 Attendees

First Interagency Conference on Research in the Watersheds. Benson, AZ. October 29, 2003.

Field Demonstration: variable intensity rainfall simulator for quantifying hydrologic and erosion processes on ecological sites in semi-arid rangeland watersheds.
60 Attendees

Linking Physical and Ecological Processes on Southwest Watersheds. University of Arizona Cooperative Extension In-Service. Tombstone, AZ. October, 2001.

Field Demonstration: variable intensity rainfall simulator for quantifying hydrologic and erosion processes on ecological sites in semi-arid rangeland watersheds.

35 Attendees

RESEARCH

I am lead PI on 6 grants with funding from USDA CSREES 406 Water program, Wyoming Game and Fish, Wyoming Department of Agriculture (WDA), US Fish and Wildlife Service, Wyoming Association of Conservation Districts, and UW Agriculture Experiment Station/ Research Office. In addition, I serve as Co-PI on an additional 7 grants with funding from WDA, USDA CSREES, F.E. Warren Air Force Base, USDA CSREES Rangelands, UW Faculty Grant-in-Aid, US Fish and Wildlife Service, and USDA CSREES. Two new research projects in Wyoming were added to my program in 2009 that directly complement my water quality monitoring extension program.

Watershed Hydrology and Water Quality:

My current Wyoming research focuses on measurement and modeling of hydrologic and erosion processes on rangeland watersheds to address water resource and rangeland management issues. I have 3 research projects that are focused on water quality monitoring issues (selenium, *E-coli*, and effectiveness of BMPs) in Wyoming watersheds. My Wyoming research efforts have resulted in 1) quantifying spatial variability of infiltration on ecological sites, 2) quantifying effects of wildfire and land management practices on runoff and erosion processes on rangelands and 3) evaluating soil moisture measurement methods. These efforts have culminated in eight peer-reviewed publications, three published, one accepted and four additional papers in review. These efforts benefit from parallel research efforts in other western states.

LiDAR Research:

Light Detection and Ranging technology (LiDAR) research has now been applied to a new Wyoming research project using LiDAR to characterize sagebrush habitat for Greater Sage Grouse, a critical species for many western rangelands. This research examines sagebrush vegetative characteristics on ecological sites in the Upper Green Basin, an area that contains habitat altered by energy extraction on the Pinedale Anticline. This is a new Wyoming application of earlier research that I initiated in Arizona to evaluate pre and post fire rangeland watershed (topographic and vegetation) characteristics. In 2007, I completed a MS student in REWM who used high resolution ground based LiDAR to assess topographic scale on hydrologic experiment sites (Sharma et al., 20XX, in review).

Watershed Hydrology Decision Support Tools:

I continue to work toward improved decision support tools for water resource, watershed and rangeland managers. This approach allows me to unify spatial databases and decision tools to evaluate rangeland monitoring and management practices in a documented and clearly delineated manner. This project applies my expertise in rangeland assessments to collaborations to form decision support systems for East African watersheds (Baldyga et al., 2007; Baker et al., 2009) and a new USDA-CSREES funded project "Development of a Rangeland Decision Support Tool to Improve Rangeland Watershed Management Decisions" currently underway (two Ph.D. students hired and two seasons of data collected).

University of Wyoming Environmental Simulation Laboratory:

The UW Environmental Simulation Laboratory (ESL) is a large, mesocosm-scale experimental chamber designed to investigate biophysical and hydrologic processes underlying ecosystem dynamics and change. The UW ESL is one of few such facilities in the world and is a platform for manipulative experimentation using constructed ecosystems. When used in conjunction with complementary field, greenhouse and

laboratory research, the ESL will facilitate integration of conceptual and quantitative models across different scales of space and time. Since 2006, I have led the renovation of the UW ESL which has moved forward significantly over the past year. The renovation of the heating and cooling system has been completed, testing of the system successful and the first research project is currently being installed. It is anticipated that the ESL will strengthen and complement the planned outdoor observatory network Forest Steppe Ecosystem Research - FoSTER) which is proposed in UW's most recent NSF EPSCoR proposal by serving as a testing and calibration facility.

GRANTS:

Total funding 2004-2009 (since coming to UW): **\$2,237,105.**

In Progress and Completed:

UW Agriculture Experiment Station 2009. Effect of drought on rangeland productivity in Wyoming. PIs. T.J. Kelleners, G.B. Paige, S.T. Gray. (2.7 years) \$60,000.

USDA CSREES 2009. Coordinated Regional Water Resources Programming for the Northern Plains and Mountain Region to Address Water Resource Issues. PD: R.M. Waskom (CSU), Wyoming PI: G.B. Paige (2008-2012) \$67,033 (10/2009 – 9/2010) *to be renewed annually.*

Tom Thorne Conservation Fund 2009. Quantifying Sagebrush Structure on Ecological Sites in the Upper Green River Basin. PIs. G.B. Paige, M. Holloran, and A.L. Hild. (6/2009-12/2010) \$80,372.

USDA CSREES 2008. Coordinated Regional Water Resources Programming for the Northern Plains and Mountain Region to Address Water Resource Issues. PD: R.M. Waskom (CSU), Wyoming PI: G.B. Paige (2008-2012) \$64,490 (10/2008 – 9/2009) *to be renewed annually.*

Wyoming Department of Agriculture 2008. Wyoming Soil Moisture Monitoring Network. PIs S.T. Gray and G.B. Paige (7/2008-6/2010) \$25,000.

Wyoming Game and Fish 2008. Structural and Spatial Characteristics of Sage-Grouse Nesting and Early Brood-Rearing Habitat Suitability of Wyoming Basin Ecological Sites. PIs. G.B. Paige, M. Holloran, and A.L. Hild. (9/2008-6/2010) \$99,822.

Wyoming Department of Agriculture 2008. Greybull River Streambed Processes & *E. coli* Distribution PIs G.B Paige and S. Jones. (9/2008-5/2011) \$80,430.

Wyoming Association of Conservation Districts 2008. Wyoming Water Quality Monitoring and Certification Program P.I. G.B. Paige (7/2008- 12/2009) \$65,068.

USDA CSREES 2008. Economic and environmental sustainability of conventional, reduced-input, and organic approaches on western crop-range-livestock farms. PIs. Norton, J.B., Franc, G.D., Hess, B.W., Hewlett, J.P., Kelleners, T.J., Krall, J.M., Latchininsky, A.V., Mount, D.E., Paige, G.B., Paisley, S., Kniss, A.R., Peck, D.E., Rashford, B., Smith, R.D., Stahl, P.D., Ward, N.L., Wilson, D.W., Press, M.D., Arnould, E.J. (1/2009-12/2012) \$500,000.

USDA CSREES 2007. Development of a rangeland decision support tool to improve rangeland watershed management decisions. PIs. D.P. Guertin, G.B. Paige, G. Ruyle, S.N. Miller, D.C. Goodrich, J.J. Stone, M.A. Nearing, P. Heilman. (2007-2010) \$384,554 (\$282,184 – Wyoming)

F.E. Warren Air Force Base 2007. Colorado butterfly plant and Prebles jumping mouse riparian habitat at F. E. Warren AFB, Cheyenne, WY. PIs A.L. Hild, T. Collier and G.B. Paige. (2007-2009) \$64,796.

US Fish & Wildlife Service 2007. Monitoring of grass and shrub communities in bottomlands at Browns Park National Wildlife Refuge, Co. PIs. G.B. Paige and A.L. Hild. (2007-2009) \$99,226.

UW Faculty Grant-in-Aid 2007. Soil moisture Sally Creek Watershed. PIs. T. Kelleners, G.B. Paige, S.N. Miller. \$7,400.

UW AES-Special RFP for Equipment 2006. Modernization of the Environmental Simulation Laboratory. PIs. G.B. Paige, D. Williams, P. Stahl, A.L. Hild and T. Collier. Submitted jointly to UW Research Office Equipment Grants. \$117,000.

UW College of Agriculture 2006. Instrumentation of Experimental Watershed. PIs. S.N. Miller and G.B. Paige \$11,308

US Fish & Wildlife Service and USGS 2005. Spatial database and decision tool to develop and evaluate habitat monitoring and management practices at Browns Park National Wildlife Refuge. PIs: A. Hild and G.B. Paige (2005-2008) \$208,521.

USDA CSREES Water Quality Regional Project 2005. Regional Assessment of Arsenic in Domestic Wells of Small Communities in Region 8 States. PIs: K.J. Reddy and G.B. Paige \$15,000.

NASA Space Grant Consortium 2005. Remotely Sensed LIDAR Data to Characterize Semiarid Watersheds at Different Scales. PI: G.B. Paige \$10,640.

USDA CSREES 2004. Coordinated Agriculture Water Quality Programming for the Northern Plains and Mountains Region. PD: R.M. Waskom (CSU) Wyoming PIs: Q.D. Skinner, K.J. Reddy, G.B. Paige (2004-2008) \$2,561,862 (\$254,105-Wyoming).

Wyoming Association of Conservation Districts 2004. Water Quality Monitoring Certification Program. PIs: G.B. Paige, Q.D. Skinner and K.J. Reddy. (2004-2007) \$129,200.

Joint Fire Science Program 2003. Quantification of Runoff and Erosion on Semi-arid Grasslands following a Wildfire. PIs: G.B. Paige, J.J. Stone, D.P. Guertin, G.J. Gottfried. (2003-2006) \$127,000.

Sustainability of Semi-arid Hydrology and Riparian Areas (NSF funded Science and Technology Center) 2000. Spatial Variability of Infiltration and Runoff Processes on Semiarid Watersheds. PIs. G.B. Paige, J.J. Stone, D.C. Goodrich and A.W. Warrick (2 year post doctorate position) \$100,000.

Unsuccessful:

Rocky Mountain Research Station 2008. Development of management tools for quantifying, tracking and visualizing the spatial arrangement of vegetation structure and habitat characteristics following disturbance. PIs. G.B. Paige, A.L. Hild. (2 years) \$80,000.

UW Agriculture Experiment Station 2008. Effect of drought on rangeland productivity in Wyoming. PIs. T.J. Kelleners, G.B. Paige, S.T. Gray. (2.7 years) \$60,000.

Wyoming Sage-Grouse Conservation Group 2008. Ecological Site Description, Mapping and Sage-Grouse Habitat Monitoring on the Mesa. PIs. G.B. Paige, A.L. Hild, M. Holloran (1 year) \$31,746

North Platte Decree Committee 2007. Quantifying Consumptive Water Use in the Upper North Platte River Basin. PIs. B. Ewers, F. Ogden, T. Kelleners, G. Paige. (2 years) \$704,317.

USDA CSREES 2006. Spatial Decision Support System for Rangeland Watershed Assessment PIs. G.B. Paige, S.N. Miller, D.P. Guertin, P. Heilman (3 years) \$486,841.

DOE – Ruckelshaus Institute ENR 2006. Effects of Coal Bed Natural Gas Co-Produced Water on Ephemeral and Intermittent Channels in the Powder River Basin. PIs. G.B. Paige, S. Neizgoda, N. Humphrey, S.N. Miller (2 years) \$293,105.

US EPA 2006. Spatial Decision Support System for Watershed Assessment. PIs. G.B. Paige, D.P. Guertin, P. Heilman. (1 year) \$79,671.

USDA National Research Initiative 2005. Methodology for Improved Water Quality Assessment of Watersheds: Linking water quality monitoring and watershed processes. PIs. G.B. Paige and S.N. Miller. (3 years) \$330,853.

USDA CSREES 2005. Spatial Decision Support System for Rangeland Watershed Assessment. PIs. G.B. Paige, S.N. Miller, D.P. Guertin, P. Heilman. (3 years) \$476,641.

Wyoming Water Resources Program 2005. Effect of CBM discharge water on ephemeral channels in the Powder River Basin. PIs. G. B. Paige, S. Neizgoda, N. Humphrey, S.N. Miller (2 years) \$106,789.

Wyoming Water Resources Program 2005. Quantification of hydrologic impacts of watershed management practices on Bates Creek Watershed. PIs. G.B. Paige, R. Vore, S.N. Miller (2 years) \$101,139.

Strategic Environmental Research And Development Program (SERDP) 2004. Distributed, Physically Based Models for Transport and Fate of Range Energetic Materials in Semiarid Environments. PIs. L.J. Lane, M. Wigmosta, G.B. Paige. (3 years) \$1,000,000.

TEACHING

The majority of my teaching appointment is devoted to mentoring graduate students. At UW, I have completed 4 graduate students (1 PhD and 3 MS) as chair and served on committees of 3 graduate students that completed; 2 MS and 1 Ph.D. I currently serve on 10 graduate student committees. I am chair of 3 MS committees, co-chair on 3 Ph.D. committees, and I am a member of 5 MS committees. In 2009, I mentored a McNair scholar, who has been conducting research assessing the effectiveness of one of our water quality extension program materials. In spring 2008, I co-taught Environmental Assessment ENR 4900/5900. I mentored a team of 4 students, participated in class discussions and gave a guest lecture on Decision Support Tools for Watershed Assessment. I continue to give regular guest lectures in many classes on campus.

GRADUATE STUDENTS

Current:

Williams, Mary I. PhD, Rangeland Ecology and Watershed Management. Recipient of Graduate School Women and Minority Fellowship. Co-Chair, A.L. Hild.

Perlinski, Anthony PhD, Rangeland Ecology and Watershed Management, Co-chair, S.N. Miller

Swallow, Aaron MS, Rangeland Ecology and Watershed Management, Recipient of the Water Resources Assistantship, Chair

Vithanage, Jagath, PhD, Rangeland Ecology and Watershed Management, Co-chair, S.N. Miller

Blain, Liberty MS, Rangeland Ecology and Watershed Management, Chair

Beaugh, Corey MS, Rangeland Ecology and Watershed Management, Chair

Tilaye, Abhishek MS, Rangeland Ecology and Watershed Management, committee member

Anderson, Kelsha MS, Rangeland Ecology and Watershed Management, committee member

Chitty, Carrie MS, Rangeland Ecology and Watershed Management, committee member

Schaffer, Gretchen, MS, Rangeland Ecology and Watershed Management, committee member

Completed:

Paterson, Michelle PhD, Rangeland Ecology and Watershed Management, Defended May, 2009. *Irrigation and climate effects on selenium in the Kendrick Irrigation District, WY, and a bioremediation strategy*. Co-chair, K.J. Reddy

Church, Matthew MS, Rangeland Ecology and Watershed Management, Defended July, 2009. *Vegetation management in a greasewood-dominated floodplain of the Green River, Colorado*. Co-chair, A.L. Hild

Banks, David MS, Zoology and Physiology, Defended December, 2008. *Population abundance and habitat selection of bluehead suckers and flannelmouth suckers in an isolated headwater tributary*. Graduate faculty representative.

Soltis, Jeff MS, Rangeland Ecology and Watershed Management, 2008. *Public involvement in natural resource decision making*. Committee member.

Baldyga, Tracy PhD, Rangeland Ecology and Watershed Management, 2008. *Spatially explicit multiple objective decision support for rural watersheds*. committee member. Currently with Texas A & M.

Sharma, Maneesh MS, Rangeland Ecology and Watershed Management, 2007. *Assessing effect of resolution and rainfall at plot and watershed scales in hydrologic modeling*. Chair. Currently with Coal Bed Methane Associates, Laramie, WY.

Zobell, Aaron MS, Rangeland Ecology and Watershed Management, 2006. *Water quality of the Bitter Creek and Killpecker Creek watersheds*. Co-chair, Q.D. Skinner. Currently with USFS, Utah.

Shrestha, Sudhir MS, Rangeland Ecology and Watershed Management, 2007. *Plan B*. Committee member.

Wickre, Jennifer MS, Watershed Management, University of Arizona, 2006. *Parameterizing the WEPP model for post-fire conditions in semi-arid environments using rainfall simulator*. Committee member.

McGee, Rachel MS, Watershed Management, University of Arizona, 2006. *Evaluation of three rangeland monitoring methods as indicators of runoff and erosion*. Committee member. Currently with USFS, Douglas, WY.

Blumenfeld, Hana MS, Watershed Management, University of Arizona, 2002. *Quantifying rangeland health indicators using runoff and sediment from rainfall simulator experiments*. Committee member. Currently with USFS, Oregon.

Guest Lectures:

Paige, G.B. Decision tools: Why talk about decision tools in rangeland management planning? Rangeland Management Planning, REWM 4900, Dept. of Renewable Resources, UW, November 17, 2009.

Paige, G.B. Decision Tools: Natural resource Management, REWM 5000, Dept. of Renewable Resources, UW, November 16, 2009.

Paige, G.B. Role of Soils in Watershed Hydrology, Genesis, Morphology and Classification of Soils, SOIL 4120, Dept. of Renewable Resources, UW, November 10, 2009.

Paige, G.B. Decision tools: Why talk about decision tools in rangeland management planning? Rangeland Management Planning, REWM 4900, Dept. of Renewable Resources, UW, April 23, 2009.

Paige, G.B. Landscape Night: Surface water issues. ENR 4900/5900, Haub School and Ruckelshaus Institute, March 11, 2009

Paige, G.B. Introduction to Watershed Hydrology and Management, ESS 1000, Dept. of Renewable Resources, November 10, 2008.

Paige, G.B. 2008. Decision Support Tools: Applications in Natural Resource Management, ENR 4900/5900, Haub School and Ruckelshaus Institute, March 12, 2008.

Paige, G.B. 2007. Infiltration. Wildland Hydrology, REWM 4285, Dept. of Renewable Resources, UW, September 25, 2007.

Paige, G.B. 2007. Decision tools: Why talk about decision tools in rangeland management planning? Rangeland Management Planning, REWM 4900, Dept. of Renewable Resources, UW, April 12, 2007.

Paige, G.B. 2007. Facilitator: Multi-objective DSS. Guest Speaker Spatial Decision Support System (DSS) Seminar, Wyoming Geographic Information Systems Center, UW, April 9, 2007.

Paige, G.B. 2006. Post wildfire runoff and Erosion Processes. Erosion and Sedimentation, Civil Engineering. October 21, 2006

Course:

Environmental Assessment ENR 4900/5900, Spring 2008. Mentored a team of 4 students, participated in class discussions and gave a guest lecture on Decision Support Tools for Watershed Assessment.

Mentor:

McNair Scholar, April Hadley 2009: Assessment of Water Quality Extension Product for the Northern Plains and Mountains Region Program.

SERVICE

I currently serve on 8 University of Wyoming faculty committees, many focused on water resources and ecology issues. In addition, I regularly review articles for peer review journals including Hydrologic Processes and Journal of the American Water Resources. In addition, I serve on several state technical committees including the TMDL task force and the NRCS state technical committee. I often serve as an invited reviewer for the NRCS CEAP program and recently joined the WERA1011 for Rangeland and Watershed stewardship.

State, Regional and National:

- NSF Jornada Basin LTER V Site Review 2009
- Wyoming Water Quality Coordinator (USDA-CSREES, National Water Program) 2005–present
- WERA 1011 Rangeland and Watershed Stewardship 2008 - present
- Wyoming TMDL Committee 2005 – present
- NRCS state technical advisory committee 2005 – present
- Wyoming Water Quality Standards Revision Workgroup (Chapter 1- Section 20) 2005 – 2006
- Society for Range Management, Wyoming Section, Southeast Representative (elected) 2008-09
- USDA-CSREES and NRCS, CEAP Project, Invited reviewer, 2006, 2007, 2009
- Joint Fire Science Program, Invited reviewer, 2005

Peer Reviews:

- Journal of American Water Resources Association (2-3/year)
- Hydrologic Processes (2-3/year)
- Water Resources Research
- International Journal Wildfire Management
- Soil Science
- Rangeland Ecology & Management
- Water International
- USFS internal peer review for Catena

University of Wyoming:

- Faculty Development Committee 2006–present (chair 2009-2010)
- Ruckelshaus Institute for Environment and Natural Resources Water Committee 2006-present
- Climate Change Committee (C³) 2007-2009
- EPSCoR Forest Steppe Ecosystem Research Advisory Committee 2008-present
- Reclamation Issue Team 2008 - present
- Rangeland Systems Ecologist Search Committee 2009-present
- Ecological Climatologist (ATMOS/REWM) Faculty Search committee 2007-2009
- Soil Physics Faculty Search Committee 2006
- SAREC Director Search Committee 2006

EXHIBIT 2

Dr. Ginger B. Paige
Assistant Professor
Department of Renewable Resources
University of Wyoming

Coalbed Methane Product Water: Testimonies

June 23, 2006: Deposition, Laramie, WY

Matter of Appeal of William P. Maycock, Case No. 05-3803

November 20, 2007: Deposition, Laramie, WY

Matter of Appeal and Review of the WYPDES (Pumpkin and Willow Creek),
Docket Nos. 06-3815, 06-3816, 06-3817.

May 1, 2008: Oral testimony, WY EQC Hearing Cheyenne, WY

Matter of Appeal and Review of the WYPDES (Pumpkin and Willow Creek),
Docket Nos. 06-3815, 06-3816, 06-3817.

October 24, 2008: Oral testimony, WY EQC Hearing, Cheyenne, WY.

Assessment of Tier 2.

November 2, 2009: Written testimony, Expert Opinion, Appeal of WYPDES 0094056
(William F. West Ranch)

UNIVERSITY OF WYOMING

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December 17, 2009

J. Mark Stewart
Davis and Cannon, LLP
422 W. 26th Street
P.O. Box 43
Cheyenne, WY 82003

Re: Expert opinion on Tier-2.

Dear Mr. Stewart:

This letter is a response to your engagement letter of December 8th, 2009. The law firm of Davis and Cannon, LLP is working for the Powder River Basin Resource Council and the Barlows in connection with the Appeal of WYPDES WY0052299. In general, you have asked me to consult with you on the issue of whether the effluent limits established in WYPDES WY0052299, under the Wyoming DEQ Tier 2 methodology are protective of irrigation uses. Specifically, you asked for my expert opinion on two questions:

- 1) Whether Tier 2 is an appropriate scientific method for establishing numeric effluent limits for EC and SAR that ensure no measurable decrease in crop production; and
- 2) Whether Tier 2 is a reasonable and scientifically valid method for determining EC of water that can be discharged to an intermittent or ephemeral drainage so that degradation of the receiving water will not be of such an extent as to cause a measurable decrease in crop production.

My responses are as follows:

In general, effluent limits established for WYPDES 0052299 have not been determined using a scientifically appropriate method that results in scientifically defensible or reasonable limits for EC of discharge waters that are protective of agriculture uses. Wyoming DEQ established the effluent limits for the WYPDES 0052299 discharge

permit using a procedure outlined in their Agricultural Use Protection Policy. Chapter 1, Section 20 of the Wyoming Water Quality Standards prohibits degradation of waters to the extent that it would result in a ‘measurable decrease in production.’ The Agricultural Use Protection Policy allows for establishing effluent limits for salinity (EC_w) and sodicity (SAR, sodium absorption ratio) equal to historic background water quality if the product water does not meet Tier-1 standards. The methodology used in Tier 2 is to sample soils in the area of question and “backout” or calculate historic water quality (specifically electrical conductivity –EC_w) from the soil salinity (WY DEQ, 2008). This method was recently evaluated by Scientific Experts hired by the WY Environmental Quality Council (EQC) and found to be scientifically invalid (Hendrickx and Buchanan, 2009).

The movement of water and soluble salts in soils and ephemeral channels in semi-arid climates such as the Powder River Basin of Wyoming are very dynamic. The natural salinity that can be found in many of the soils is not a direct reflection or result of the quality of the water applied, but rather a reflection of the soil characteristics (e.g., texture and chemistry), the climate (high potential evapotranspiration potential), depth to ground water, and irrigation management (Hillel, 1998; Rose, 2004).

In general, as water infiltrates into soils it can accumulate salts from the weathering of the mineral soil. In semiarid climates, salts are continually moving and being redistributed in the soil with the soil water. These salts will often move with the wetting front up and down through soil profiles. To keep salts from accumulating large rainfall events or irrigation applications are necessary to move salts lower in the soil profile away from the root zone. In semi-arid and arid regions, there are often periods without significant downward movement (percolation) of water and no effective leaching, so salts can and often do accumulate in the soil profile (Hillel 1980; Hillel 2000; Hendrickx and Buchanan, 2009). Sampling of soil salinity at any given point in time will not reflect background water quality, but the historic movement of water and salts in the profile in response to rainfall, evapotranspiration, and any irrigation applications. This means that detailed sampling of the soil salinity and sodicity cannot be used to determine historic background or historic water quality.

Response to Question 1:

The assumption in the applied method of Tier-2 of a consistent, direct relationship between soil salinity and background water quality does not exist. This in itself means that the Tier-2 methodology, as it is being applied, is scientifically invalid and can not be used to establish numeric effluent limits for EC and SAR that ensure no measurable decrease in crop production. There is no adjustment or calibration procedure possible that would make the Tier-2 methodology scientifically valid. As stated above, soil salinity in semi-arid regions changes with time and is not a direct reflection of the background water quality. Soil salinity is primarily a result of the soil characteristics, depth to ground water, climate and irrigation management (Hendrickx and Buchanan, 2009; Rose 2004; Hillel, 1998.) It is not a direct result of the background water quality

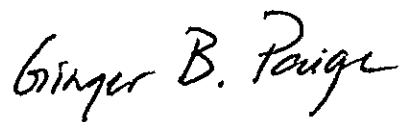
that has been applied to an area, and cannot be used to determine the quality of the water applied. This fact has also been presented to the WY EQC in oral testimony by me, Dr. Larry C. Munn and Dr. George F. Vance on October 24, 2008. As stated in the report to the WY EQC, Expert Scientific Opinion on the Tier-2 Methodology (Hendrickx and Buchanan, 2009), no evidence has been found in the peer-reviewed scientific literature that will support the methodology of Tier 2 to accurately determine background water quality. It is not an appropriate scientific method to establish effluent limits.

Response to Question 2:

The Tier 2 methodology will not support the establishment of scientifically defensible effluent limits for discharge permits that will not cause measurable decrease in crop production. Tier 2, as it is being applied, is simply scientifically invalid. This fact was well documented by Hendrickx and Buchanan (2009). Tier 2 does not provide a reasonable or scientifically defensible method to determine the quality of the water (ECw and SAR) that historically flowed within a given drainage system. Therefore it is not an appropriate scientific method and cannot be used to support the establishment of limits for discharge permits in that drainage that will not cause a measurable decrease in crop production.

In addition to the responses to your questions above, I have attached a copy of my CV which includes my publications, a list of testimonies and depositions related to CBM water issues and a list of my extension activities over the last 5 years that includes CBM related activities.

Sincerely,

A handwritten signature in black ink that reads "Ginger B. Paige". The signature is written in a cursive, flowing style.

Ginger B. Paige, Ph.D.
Water Resources Extension Specialist

References:

Dead Horse Creek, Section 20 Soil Investigation, KC Harvey, LLC., August 2007

Hendrickx, J.M.H.; Buchanan, B.A. Expert Scientific Opinion on the Tier-2 Methodology; Report to the Wyoming Environmental Quality Council. May 2009. [<http://deq.state.wy.us/eqc/Docket/08-3101%20WQD,%20Chpt.%201,%20Sect.%2020,%20Ag%20Water%20Supply/Consultants%20Final%20Report.Chpt.%201-Sect.%2020.5-09.pdf>].

Hillel, D. 2000. Salinity Management for Sustainable Irrigation: Integrating science, environment and economics. The World Bank, Washington, DC.

Hillel, D. 1998. Environmental Soil Physics. Academic Press, San Diego, CA.

Hillel, D. 1980. Applications of Soil Physics. Academic Press, New York, NY.

Rose, C. 2004. An Introduction to the Environmental Physics of Soil, Water and Watersheds. Cambridge University Press, Cambridge, UK.

WY DEQ, 2008. Agriculture Use Protection Policy. https://deq.state.wy.us/wqd/WYPDES_Permitting/WYPDES_cbm/downloads/Ag_Policy_Final_rev.pdf

WYPDES WY0052299, November 25, 2008