# 2007
# WESTERN SOUTH DAKOTA
# HYDROLOGY CONFERENCE

## Program and Abstracts

---

**April 19, 2007**
**Rushmore Plaza Civic Center**
**Rapid City, South Dakota**

# TABLE OF CONTENTS

# 2007 Western South Dakota Hydrology Conference

This program and abstracts book has been produced in conjunction with the 2007 Western South Dakota Hydrology Conference, held at the Rushmore Plaza Civic Center on April 19, 2007. The purpose of this book is to provide summaries of the presentations made during the conference.

The purpose of the 2007 Western South Dakota Hydrology Conference is to bring together researchers from Federal, State, University, local government, and private organizations and provide a forum to discuss topics dealing with hydrology in western South Dakota. This conference provides an opportunity for hydrologists, geologists, engineers, scientists, students, and other interested individuals to meet and exchange ideas, discuss mutual problems, and summarize results of studies. The conference consists of four technical sessions and a keynote luncheon speaker. The topics of the technical sessions include drought and water availability; aquifer vulnerability; surface-water issues; ground-water issues, and environmental impacts.

## ACKNOWLEDGMENTS

Many people have contributed to this conference. The many presenters are thanked for their contributions. The moderators are thanked for their help in streamlining the technical sessions. The help by many students from the South Dakota School of Mines and Technology with presentations and lights is greatly appreciated. The keynote luncheon speaker, Dr. P. Christopher D. Milly, is thanked for his time and perspectives. Registration help by Sheri Meier (USGS) is greatly appreciated. Brenda Athow (USGS) provided computer support for the conference.

The sponsoring organizations are thanked for support: South Dakota Department of Environment and Natural Resources, South Dakota Engineering Society, South Dakota School of Mines and Technology, U.S. Geological Survey, and West Dakota Water Development District. Energy Laboratories, Inc., is thanked for partially sponsoring the morning refreshment break. The chairpersons for this conference were J. Foster Sawyer (South Dakota Department of Environment and Natural Resources), Arden D. Davis (South Dakota School of Mines and Technology), Scott J. Kenner (South Dakota School of Mines and Technology), Janet M. Carter (U.S. Geological Survey), Daniel G. Driscoll (U.S. Geological Survey), Van A. Lindquist (West Dakota Water Development District), and Jenifer Sorensen (South Dakota Engineering Society).

---

"Anyone who can solve the problems of water will be worthy of two Nobel prizes – one for peace and one for science" – John F. Kennedy

---

# 2007 Western South Dakota Hydrology Conference Program

**Thursday, April 19, 2007**
**Alpine/Ponderosa Rooms**
**Rushmore Plaza Civic Center**

| | | |
|---|---|---|
| **7:00 – 7:50 a.m.** | **REGISTRATION** | |
| **7:50 – 9:40 a.m.** | **Plenary Session 1 in Alpine and Ponderosa Rooms – Drought and Water Availability (1.5 PDH)**<br>**Moderator – Mark Anderson**, Director of the U.S. Geological Survey Water Science Center, Rapid City, SD | |
| 7:50 – 8:00 a.m. | Welcome, general information | **Mark Anderson** and **Daniel Driscoll**, U.S. Geological Survey |
| 8:00 – 8:20 a.m. | Status of drought in South Dakota | **Dennis Todey**, South Dakota State Climatologist, and **Matthew Bunkers**, National Weather Service |
| 8:20 – 8:40 a.m. | Ground-water levels in western South Dakota | **Ken Buhler**, Water Rights Program of the South Dakota Department of Environment and Natural Resources |
| 8:40 – 9:00 a.m. | Availability and access to U.S. Geological Survey water-resources data | **Joyce Williamson**, U.S. Geological Survey |
| 9:00 – 9:20 a.m. | Future water supplies for Rapid City | **Perry Rahn**, South Dakota School of Mines and Technology |
| 9:20 – 9:40 a.m. | "Safe yield" and water-right protection in the Madison aquifer—Are they compatible? | **Paula Cutillo** and **William Van Liew**, National Park Service |
| **9:40 – 10:05 a.m.** | **REFRESHMENT BREAK – Sponsored, in part, by Energy Laboratories, Inc.** | |
| **10:05 – 11:45 a.m.** | **Concurrent Session 2A in Alpine Room – Aquifer Vulnerability (1.5 PDH)**<br>**Moderator – Derric Iles,** State Geologist, South Dakota Department of Environment and Natural Resources, Geological Survey Program, Vermillion, SD | **Concurrent Session 2P in Ponderosa Room – Surface-Water Issues (1.5 PDH)**<br>**Moderator – Dan Driscoll,** Studies Chief, U.S. Geological Survey South Dakota Water Science Center, Rapid City, SD |
| 10:05 – 10:25 a.m. | *Vulnerability of the Madison aquifer, Hayward quadrangle, South Dakota* **– Crystal Hocking**, **Alvis Lisenbee**, and **Arden Davis**, South Dakota School of Mines and Technology | *Evaluation of compost as a stormwater best management practice* **– Russell Persyn**, South Dakota State University |
| 10:25 – 10:45 a.m. | *Aquifer characteristics of Precambrian basement rocks in the Pactola Dam quadrangle, South Dakota* **– Darren Johnson, Alvis Lisenbee,** and **Arden Davis**, South Dakota School of Mines and Technology | *Quarry Hill ravine and streambank stabilization* **– Jonathon Kusa** and **Chad Hanisch**, HR Green |
| 10:45 – 11:05 a.m. | *Vulnerability of the Inyan Kara aquifer, Hermosa and Hermosa NW quadrangles, Black Hills development corridor* **– Alvis Lisenbee**, **Elizabeth Francisco**, **Arden Davis**, and **Chris Pellowski**, South Dakota School of Mines and Technology | *Watershed assessment for the Lower Cheyenne River watershed* **– Cory Foreman**, RESPEC, and **Scott Kenner**, South Dakota School of Mines and Technology |
| 11:05 – 11:25 a.m. | *Aquifer vulnerability in the Blackhawk quadrangle, South Dakota* **– Elizabeth Francisco**, **Alvis Lisenbee**, and **Arden Davis**, South Dakota School of Mines and Technology | *Belle Fourche River watershed segment II strategic implementation plan* **– Jared Oswald** and **Dan Hoyer**, RESPEC |
| 11:25 – 11:45 a.m. | *Historic water pollution problems for Pactola Dam, Rapid City West, and the northern portion of Rockerville quadrangles* **– Matthew Minnick**, RESPEC, and **Alvis Lisenbee**, South Dakota School of Mines and Technology | *Environmental monitoring of the abandoned Belle Eldridge Mine near Deadwood, South Dakota* **– Arden Davis**, South Dakota School of Mines and Technology, **Cathleen Webb**, Western Kentucky University, **Jenifer Sorensen,** and **Joshua Valder**, South Dakota School of Mines and Technology |
| **11:45 a.m. – 1:15 p.m.** | **LUNCH with Keynote Speaker in Rushmore H Room – Dr. P. Christopher D. Milly (1.0 PDH)**<br>U.S. Geological Survey, Princeton, NJ<br>*Old state, new state; red state, blue state: Contrasting implications of climate change for streamflow across the United States* | |

| **1:15 – 2:55 p.m.** | **Concurrent Session 3A in Alpine Room – Ground-Water Issues (1.5 PDH)**<br>**Moderator – Dr. Arden Davis**, Professor, South Dakota School of Mines and Technology, Rapid City, SD | **Concurrent Session 3P in Ponderosa Room – Hydrology Potpourri (1.5 PDH)**<br>**Moderator – Janet Carter,** Hydrologist, U.S. Geological Survey South Dakota Water Science Center, Rapid City, SD |
|---|---|---|
| 1:15 – 1:35 p.m. | *Pumping tests in the Deadwood aquifer at Jewel Cave National Monument, Custer County, South Dakota* **– Joshua Valder** and **Arden Davis**, South Dakota School of Mines and Technology | *Unique methods for stratigraphic correlation: Pierre Shale Formation, South Dakota* **– Doreena Patrick**, **Paul Wegleitner**, Geochemical Solutions LLC, and **James Martin**, South Dakota School of Mines and Technology |
| 1:35 – 1:55 p.m. | *Estimating ground-water ages and relative flow fractions of karst flow components in the Madison aquifer* **– Andy Long** and **Larry Putnam**, U.S. Geological Survey | *Occurrence of organic wastewater compounds in wastewater effluent and the Big Sioux River Basin, South Dakota, 2001-2004* **– Roy Bartholomay and Steven Sando,** U.S. Geological Survey |
| 1:55 – 2:15 p.m. | *Angle wells under the Missouri River* **– James Landenberger**, Bartlett & West Engineers, Inc. | *Further testing of limestone-based material for arsenic removal from small water systems* **– Jenifer Sorensen**, **Arden Davis**, **David Dixon**, and **Crystal Hocking**, South Dakota School of Mines and Technology |
| 2:15 – 2:35 p.m. | *Protecting ground water in the oil patch* **– Fred Steece**, South Dakota Department of Environment and Natural Resources, and **Kristine Murphy,** South Dakota School of Mines and Technology | *Susceptibility for slope failure due to future development and land use along Highway 79 in the Hermosa NW quadrangle, Pennington County* **– Matthew Minnick**, RESPEC, **Larry Stetler**, South Dakota School of Mines and Technology, and **Cory Foreman**, RESPEC |
| 2:35 – 2:55 p.m. | *Infantile methemoglobinemia and nitrate contaminated wells—Has the role of bacteria been overlooked?* **– Michael Meyer**, GeoTek Engineering & Testing Services | *Geologic mapping of the Hermosa and Hermosa NW quadrangles, Black Hills development corridor* **– Christopher Pellowski**, **Alvis Lisenbee**, and **Darren Johnson**, South Dakota School of Mines and Technology |
| **2:55 – 3:20 p.m.** | **REFRESHMENT BREAK** | |
| **3:20 – 5:10 p.m.** | **Plenary Session 4 in Alpine and Ponderosa Rooms – Environmental Impacts (1.5 PDH)**<br>**Moderator – Dr. John Zogorski**, Chief of the National Water Quality Assessment Program's National Synthesis on Volatile Organic Compounds, U.S. Geological Survey, Rapid City, SD | |
| 3:20 – 3:40 p.m. | Environmental impacts from the North Cave Hills abandoned uranium mines, Harding County, South Dakota | **James Stone**, **Larry Stetler**, South Dakota School of Mines and Technology, and **Albrecht Schwalm**, Oglala Lakota College |
| 3:40 – 4:00 p.m. | Aerosol dust transport, deposition, and composition around abandoned uranium mines in the North Cave Hills, Harding County, South Dakota | **Kyrian Onyeukwu**, **Larry Stetler**, and **James Stone,** South Dakota School of Mines and Technology |
| 4:00 – 4:20 p.m. | Groundwater quality near abandoned uranium mines in the North Cave Hills, Harding County, South Dakota | **Larry Stetler** and **James Stone**, South Dakota School of Mines and Technology |
| 4:20 – 4:40 p.m. | Characterization of effects of on-site wastewater disposal systems overlying fractured or solution-enhanced aquifers, Black Hills of South Dakota | **Larry Putnam**, **Andrew Long**, U.S. Geological Survey, and **J. Foster Sawyer**, South Dakota Department of Environment and Natural Resources |
| 4:40 – 5:00 p.m. | Effects of nuisance blooms of *Didymosphenia geminata* on benthic community composition in Rapid Creek, South Dakota | **Aaron Larson**, South Dakota Department of Environment and Natural Resources |
| 5:00 – 5:10 p.m. | Closing remarks | **Janet Carter,** U.S. Geological Survey |

## THURSDAY, APRIL 19, 2007
## SESSION 1
## 7:50 – 9:40 A.M.

## DROUGHT AND WATER AVAILABILITY

# Status of Drought in South Dakota

**Dennis Todey**
South Dakota State Climatologist, Ag & Biosystems Engineering, South Dakota State University, Brookings, SD 57007, email: *dennis.todey@sdstate.edu*

**Matthew J. Bunkers**
NOAA/National Weather Service, 300 E. Signal Dr., Rapid City, SD 57701, email: *matthew.bunkers@noaa.gov*

As drought enters its 6th to 8th year in western South Dakota (depending on your measure of drought), many current conditions indicate the severity of the situation including low reservoir and river levels, stressed rangeland, soil moisture animations, and increasing fire danger. The outlook for the spring and summer of 2007 does not hold a great deal of promise for much improvement. Many questions regarding this drought are posed, including how does this compare with other serious droughts (i.e., the 1930s), how long could this drought last, and what will future climate changes bring. We will compare the severity of this drought with other drought periods based on long-term precipitation totals. We will review current literature about longer term climate issues for the Plains to help guide how long this drought could last, particularly in regard to recent studies about the 20th century having been a wetter century with respect to the last several centuries.

# Ground-Water Levels in Western South Dakota

**Ken Buhler**
Water Rights Program, South Dakota Department of Environment and Natural Resources, Foss Building, 523 Capitol Avenue, Pierre, SD 57501, email: *ken.buhler@state.sd.us*

South Dakota Codified Law 46-2-14 authorizes the Water Management Board to establish experimental and observation stations. To fulfill this statute, a statewide of observation well network has been developed and maintained by the Department of Environment and Natural Resources-Water Rights Program. This observation well network consists of over 1,600 wells installed specifically for the purpose of collecting water-level data throughout South Dakota, a few with records dating back to 1949. Although the network contains around 90 observation wells instrumented with some type of continuous recorder, the strength of the network comes from the nearly 15,000 manual water level measurements taken annually.

The Water Rights Program monitors 240 observation wells, ranging in depth from 12 feet to 2,239 feet, completed into 13 aquifers in western South Dakota. Initially, these west river wells were installed in the late 1950s primarily to address ground water/surface water interactions along several major drainages. Observation wells installed in the 1960s were typically constructed in areas of greater water usage to address water availability issues. The 1970s saw a period of observation well construction to monitor the effects of irrigation development. The focus of observation well construction shifted in the mid 1980s from specific issues (i.e. problem areas) to more general issues (i.e. a regional geohydrologic information). Observation wells were completed with the goal of obtaining representative water levels from the different aquifers. These observation wells are routinely maintained to ensure accuracy of data collected.

Temporal trends for observation wells with the longest-term records generally show seasonal and annual fluctuations in response to climatic conditions; however, no long-term water-level declines are apparent west river. Ground water development appears to have not caused significant drawdown nor adversely affected the water supply from any South Dakota aquifer.

# Availability and Access to U.S. Geological Survey Water-Resources Data

**Joyce E. Williamson**
U.S. Geological Survey, 1608 Mountain View Road, Rapid City, SD 57702, email: *jewillia@usgs.gov*

An important mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the Nation's water resources. The USGS operates and maintains a network of hydrologic stations and compiles the data collected for public use. Databases are maintained by the USGS to manage and permanently archive the data. Recent advances in technology now permit easier access to the data via public Web pages created and maintained by the USGS. This effort began by providing site information, near-realtime streamflow data, and ground-water levels on the internet through a Web portal named NWISWeb (*http://waterdata.usgs.gov/nwis*). NWISWeb was expanded to include daily hydrologic data as well as historical surface-water discharges, water-quality analyses, and realtime continuous water-quality data. In 2007, the USGS will provide the Annual Data Report as an online version only and provide a Web page with an annual summary of streamflow for the Nation. In addition, USGS will implement access to continuous ground-water levels and instantaneous data values for selected surface-water sites.

The USGS hosts a wide variety of data on the Internet. Finding and retrieving the data in the desired format is not always easy because of the various types and levels of data available. Obtaining USGS data from the new system is much easier with the knowledge of a few tips and explanations. This presentation will describe the new USGS system, provide links to the databases, and tips on how to easily access the data of interest.

# Future Water Supplies for Rapid City

**Dr. Perry H. Rahn**
Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, SD 57701, email: *perry.rahn@sdsmt.edu*

Municipal water use for Rapid City from 2000 to 2005 averaged 22.92 cubic feet per second (cfs). This water was derived from eight wells largely withdrawing from the Madison Limestone (9.95 cfs), two galleries in alluvium along Rapid Creek (2.75 cfs), Jackson Spring (9.23 cfs), and Rapid Creek (0.99 cfs). In the next 40 years, municipal water demand may double.

In 2006, Rapid City acquired the surface-water rights to Rapid Creek. Through the USBR Pactola Reservoir storage agreement, 77 cfs can be obtained, although during years of normal precipitation Rapid Creek discharge is approximately 50 cfs. Because of this acquisition of water rights for Rapid Creek, Rapid City has an adequate water supply for the next 40 years, not considering droughts.

The long-term availability of ground water is in doubt because there are local competing uses for ground water and there is the threat of contamination such as increasing nitrate from onsite wastewater systems. The most ominous factor that casts a shadow on an increased use of ground water, particularly from Madison wells, is the fact that large-scale development would diminish artesian springflow. For example, since 2004, Madison well RC-6 has most likely dried up “City Spring,” which was once the source of municipal water. More wells in the Madison and Minnelusa aquifers could theoretically supply an additional 26 cfs, but these withdrawals would compromise local springs, e.g. the Cleghorn/Jackson Spring complex.

In the last decade, many South Dakota municipalities have focused on the Missouri River as a source of water. Aqueducts are being constructed easterly to Sioux Falls. The Mni Wiconi Project, currently under construction, will pump Missouri River water to western South Dakota, including Red Shirt just downstream from Hermosa. In the 1980s, the “West River Aqueduct” was proposed that would deliver Missouri River water to Rapid City. In view of the good quality and seeming abundance of water in Rapid Creek, these schemes seem remote. However, the future needs of Rapid City may ultimately entail the Missouri River.

# “Safe Yield” and Water-Right Protection in the Madison Aquifer – Are they Compatible?

**Paula A. Cutillo, Ph.D.**
National Park Service, Water Resources Division, 1201 Oakridge Drive, Suite 250, Fort Collins, CO 80525, email: *paula_cutillo@nps.gov*

**William P. Van Liew, P.E.**
National Park Service, Water Resources Division, 1201 Oakridge Drive, Suite 250, Fort Collins, CO 80525, email: *william_p_van_liew@nps.gov*

South Dakota Water Law limits ground-water withdrawals to the rate of natural recharge to prevent ground-water “mining.” This concept is often referred to as “safe yield”; however, it is an oversimplification of the information needed to determine the amount of ground water that can be pumped by wells without producing undesired consequences. For example, it is estimated that natural recharge to the Madison aquifer in South Dakota and Wyoming is about 140,000 acre-feet per year, mainly through infiltration of precipitation and streamflow losses on outcrop areas. Natural discharge from the aquifer includes springflow and leakage to other aquifers, and is on average approximately equal to natural recharge. Ultimately, water withdrawn by wells must come from somewhere, and the long-term response of the Madison aquifer to large-scale ground-water development will be depletion of natural discharge. Unfortunately, pumping wells along the southeastern flank of the Black Hills can deplete nearby artesian springflow for which water rights have been appropriated, or impact critical aquatic habitats at pumping rates far less than the rate of natural recharge. The amount of natural recharge to the Madison aquifer is, therefore, of limited use when evaluating the threshold above which changes to the ground-water system become undesirable. The determination of this threshold needs to be made by the public, water users, and decision-makers with the knowledge that aquifer response to pumping is a function not only of the amount of natural recharge to the aquifer, but also of the distance to areas of ground-water discharge and the ability of the aquifer to store and transmit water. Well-designed data collection programs and ground-water models are effective tools for synthesizing the information needed to evaluate more sustainable approaches to ground-water management. Hypothetical and field examples are given to illustrate these concepts.

## THURSDAY, APRIL 19, 2007
## SESSION 2A
## 10:05 A.M. - 11:45 A.M.

## AQUIFER VULNERABILITY

# Vulnerability of the Madison Aquifer, Hayward Quadrangle, South Dakota

**Crystal Hocking**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *crystal.hocking@hardrockers.sdsmt.edu*

**Dr. Alvis L. Lisenbee**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *alvis.lisenbee@sdsmt.edu*

**Dr. Arden Davis**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *arden.davis@sdsmt.edu*

Urban development affects large portions of the Hayward quadrangle west of Hermosa, SD, some in the recharge area of the principal aquifer of the eastern Black Hills, the Madison (Pahasapa) Limestone. This formation extends the entire eight-mile north-south length of the quadrangle, but is locally covered by channel deposits of the White River Formation or Quaternary alluvial aquifers. The Madison aquifer consists of gently east-dipping, karstic limestone and dolomite 240 to 300 feet thick. The aquifer overlies mudstone of the Englewood Limestone and is overlain by the Minnelusa Formation.

Depth to this aquifer varies from 0 feet on the west to as much as 2,300 feet along the southeastern edge of the quadrangle. Only seven wells utilize the Madison aquifer, and the static water level in the artesian wells varies from 130 to 420 feet below the surface, depending upon location.

Recharge of the aquifer occurs through direct influx to the outcrop (~1/3) and inflow from streams (~2/3) (U.S.G.S.). Aquifer susceptibility is considered to be high. Aquifer vulnerability varies from moderate to very high, depending upon location and type of overburden. Much of the southern outcrop area lies within Custer State Park and lacks development, other than two paved roads. In the northern portion, home sites on the Madison outcrop increased from one in 1998 to 16 in 2004 and vulnerability due to potential septic tank malfunction, lawn fertilizer, toxic spills along roads, etc. suggests a rating of high.

The area of greatest risk is along streams where water enters the aquifer directly through sink holes or through the overlying alluvium. Stream water has the potential to carry pollutants collected from throughout the drainage basin upstream of the area of inflow (33 $mi^2$ for Grace Coolidge and 76 $mi^2$ for Battle Creek). Aquifer vulnerability in these areas is considered to be extremely high.

# Aquifer Characteristics of Precambrian Basement Rocks in the Pactola Dam Quadrangle, South Dakota

**Darren Johnson**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *darren.johnson@hardrockers.sdsmt.edu*

**Dr. Alvis L. Lisenbee**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *alvis.lisenbee@sdsmt.edu*

**Dr. Arden Davis**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *arden.davis@sdsmt.edu*

Aquifer characteristics, susceptibility, and vulnerability of Precambrian basement rocks in the Pactola Dam Quadrangle (central Black Hills) were studied by members of the Department of Geology and Geological Engineering at SDSMT, under sponsorship of the West Dakota Water Development District. North-trending units (phyllite, quartzite, tholeiitic metabasalt, slate, and meta-arkose) lack primary porosity and permeability; secondary porosity has been created by fractures, which are not consistent throughout the rock bodies.

For 88 water wells the study found: (a) initial flow rates from 0 to 100 gal/min; (b) flow rates of 100 gal/min to depths of 300 feet; (c) 85% of the wells delivered 30 gal/min or less; (d) wells greater than 300 feet deep produced 10 gal/min or less; and (e) of the 88 wells, six produced 60 gal/min or more; twelve wells produced more than 40 gal/min; 64 wells delivered 20 gal/min or less; and 33 produced 5 gal/min or less; (f) no indication that rock type controls production rates; and (g) 53% drilled within Buck Mountain Formation phyllite and quartzite in development areas adjacent to Rapid Creek.

There is no visual correlation of flow rates and degree of fracturing (Anderson, 2002) in nearby outcrops, although no well is located at the exact area of measurements. Near Hisega, rates of 1 gal/min to 20 gal/min occur in areas of strongest (13 to 17 fractures per linear meter – {lm}) fracture intensity; 5 to 30 gal/min in areas with moderate to strong fracture densities (5 to 13 fractures/lm). Near Johnson Siding, fracture intensity is 2 to13 fractures/lm, where initial discharge (possibly including water from the Rapid Creek alluvial aquifer) was 1 to 75 gal/min. The two wells with 100 gal/min initial production are suspected to intersect “fractures traces.”

Lack of a qualitative rating system, based upon rock type, porosity, ground-water flow paths, hydraulic conductivity, transmissivity, and storage coefficient, prevented preparation of an aquifer susceptibility map, thereby preventing preparation of an aquifer vulnerability (risk) map for the entire area. Based upon the location of roads (with a 100-foot buffer) and on-site waste water systems (with a one-acre buffer), the greatest risk for ground-water contamination occurs in urbanized areas along Rapid Creek and Bogus Jim Creek.

# Vulnerability of the Inyan Kara Aquifer, Hermosa and Hermosa NW Quadrangles, Black Hills Development Corridor

**Dr. Alvis L. Lisenbee**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *alvis.lisenbee@sdsmt.edu*

**Elizabeth Francisco**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *azile_mari@yahoo.com*

**Dr. Arden Davis**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *arden.davis@sdsmt.edu*

**Chris Pellowski**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *christopher.pellowski@hardrockers.sdsmt.edu*

In the Hermosa and Hermosa NW Quadrangles the Inyan Kara aquifer recharge area is exposed in pine-tree covered ridges along their western margins. The outcrop area is about 1 mile wide (~16 $mi^2$ total) and extends from 2 miles south of the Rapid City limits to 6 miles southwest of Hermosa. This aquifer consists of gently east-dipping sandstone lenses and mudstone of the Fall River Formation and underlying Lakota Formation (500 ft to 750 feet thick). Mudstone aquitards of the underlying Morrison Formation and the overlying Skull Creek Shale encapsulate the aquifer. Locally, the eroded Inyan Kara is overlain by ancient channel and flood plain deposits of the Oligocene White River Formation on uplands or by Quaternary alluvial aquifers along the creeks.

Depth to this aquifer is 100 feet or less near exposed sandstone on the west, but increases to as much as 1,800 feet along the eastern edge of the quadrangle. Initial pumping rates vary from 20 to 95 gpm, and the static water level in these artesian wells varies from 100 to 300 feet, depending upon location.

Recharge of the aquifer occurs through direct precipitation and through inflow from streams crossing the outcrop area. Aquifer susceptibility is medium to high. Areas of high risk (vulnerability) are: (1) a 1.5-$mi^2$ area west of Hermosa where septic tank numbers increased from seven in 1952 to 62 in 2005; and (2) canyon bottoms where the Inyan Kara is overlain by alluvium of Spring Creek (~182 $mi^2$ drainage basin, including the Hill City area) and Battle Creek and Grace Coolidge Creek (~158 $mi^2$ drainage basin).

Urban development on the overlying shale poses no threat to the Inyan Kara aquifer. Hart Ranch development is served by a waste water treatment plant, but the effects of road runoff, lawn fertilizer, and pet waste on the alluvial and underlying Inyan Kara aquifers are unknown.

# Aquifer Vulnerability in the Blackhawk Quadrangle, South Dakota

**Elizabeth Francisco**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *azile_mari@yahoo.com*

**Dr. Alvis L. Lisenbee**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *alvis.lisenbee@sdsmt.edu*

**Dr. Arden Davis**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *arden.davis@sdsmt.edu*

The Blackhawk area is experiencing the fastest urban growth in western South Dakota. Based on published topographic maps and aerial photographs, an average of 85 residential structures were added per year from 1972 to 2004 in the Blackhawk quadrangle, although much of this increase occurred between 1990 and 2004. The favored direction of urban sprawl appears to be the hilly regions, which are the outcrop areas of three major aquifers. These three aquifers are the Madison (Pahasapa), Minnelusa, and Inyan Kara.

Recent urban development in these recharge zones make the ground-water resources of the area vulnerable to contamination. Aquifer datasets have been identified and created in recognition of the need to protect and provide appropriate management of these ground-water resources. This information includes: the delineation of recharge areas of the major aquifers in the Blackhawk quadrangle; structural contour and depth-to-aquifer maps that present a subsurface image of the top of the aquifer; aquifer susceptibility, which evaluates the natural tendency of each hydrologic unit to receive and transmit fluids and contaminants; and aquifer vulnerability, which identifies the presence of a possible contaminant source in recharge areas, such as septic systems and roads. These datasets are presented in 1:24,000-scale maps, relevant and useful for local planning and management purposes.

Drilling depths to the various aquifers increase from the outcrop on the west to as much as 3,300 feet (Madison), 2,900 feet (Minnelusa), and 1,200 feet (Inyan Kara) in the northeast, but are reduced along the crest of the north-trending Piedmont anticline through the middle of the quadrangle. Aquifer susceptibility ratings are high to very high (Madison) and medium to high (Minnelusa and Inyan Kara). Aquifer vulnerability ratings are variable, but high in areas of roads, abundant septic tanks and alluvium overlying the formations.

# Historic Water Pollution Problems for Pactola Dam, Rapid City West, and the Northern Portion of Rockerville Quadrangles

**Matthew D. Minnick**
RESPEC, P.O. Box 725, Rapid City, SD 57709-0725, email: *matthew.minnick@respec.com*

**Dr. Alvis L. Lisenbee**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *alvis.lisenbee@sdsmt.edu*

Because of rapid urbanization of Pennington County and the eastern Black Hills in general, it is important to document examples of historic ground water pollution events which may affect the ground water. This study, funded by the West Dakota Water Development District, focused on potential pollution in an area of ~580 $mi^2$, including outcrops of Madison Limestone and Minnelusa Formation aquifers in the Pactola Dam, Rapid City West and the northern portion of the Rockerville 1:25,000-scale quadrangles. This area encompasses portions of the Rapid Creek, Spring Creek, and Box Elder Creek drainage basins including Pactola Reservoir and Sheridan Lake.

Data concerning toxic spills and on-site waste water treatment facilities were acquired from state and federal agency data bases and interviews of individuals in government agencies, engineering firms, and the general public. Over 400 instances were retrieved, the locations noted by latitude/longitude coordinates and/or site descriptions. The results were plotted on eight maps using a Geographic Information System (GIS). The maps show 68 hits of fecal and or total coliform bacteria and 104 hits of nitrates in drinking water systems. Over 3,700 septic tank systems are present in the study area with 379 in the Madison recharge area and 1,400 in the Minnelusa recharge area. Data for 203 hazardous spills were collected in the study area and 137 were mapped. Of the 137 mapped spills, one was in the Madison recharge area and four were in the Minnelusa recharge area.

The visual representation on a map of the information gathered provides insight into the potential of development to have a significant impact on our drinking water quality. This study does not show direct effects on ground water, but areas of probable effects. Such documentation will help strengthen the concerns of future development in susceptible areas.

## THURSDAY, APRIL 19, 2007
## SESSION 2P
## 10:05 A.M. - 11:45 A.M.

## SURFACE-WATER ISSUES

# Evaluation of Compost as a Stormwater Best Management Practice

**Dr. Russell A. Persyn, P.E., Assistant Professor/Environmental Quality Engineer**
Department of Agricultural & Biosystems Engineering, South Dakota State University, Box 2120, Brookings, SD 57007, email: *russell.persyn@sdstate.edu*

Construction activities can lead to challenges when attempting to re-establish vegetation and control runoff and soil erosion. This presentation evaluates two studies: a field-scale study and a laboratory scale study. The field scale study evaluated interrill erosion, rill erosion, and water quality implications between various types of compost and two soil conditions on a 3:1 highway embankment. Composts were applied at 5 and 10 cm blankets on the surface of the control, and topsoil was placed on the surface of the control at a depth of 15 cm. Rainfall was applied at a target rate of 100 mm/hr using a rainfall simulator. The laboratory scale study evaluated interrill runoff and erosion on three compost mixtures applied at 1.3 and 5 cm depths and were compared to a control soil and hydroseed treatment. In the field scale evaluation, all composts were effective at reducing interrill erosion rates for conditions simulated in this study. Heavy metals and nutrients leaving the site from interrill erosion and runoff did not pose additional water quality concerns. Rill erosion mechanics in compost blankets performed differently from the two soil treatments, which might pose additional challenges and considerations on some sites. The laboratory scale study showed that erosion control compost at 1.3 cm was adequate for erosion protection; however, runoff from general use compost was different as compared to soils and composts mixed with wood chips.

# Quarry Hill Ravine and Streambank Stabilization

**Jonathan Kusa, P.E.**
HRGreen, Court International Building, 2500 University Ave. W., Suite 400N, St. Paul, MN 55114, email: *jkusa@hrgreen.com*

**Chad Hanisch, P.E.**
HRGreen, 6010 S. Minnesota Ave., Sioux Falls, SD 57108, email: *chanisch@hrgreen.com*

The presentation provides an overview of an ongoing design project to resolve erosion issues in an urban stream environment with karst geology. The City of Rochester contracted Howard R. Green Company to resolve ravine and streambank stabilization problems located within Quarry Hill Park after significant erosion issues were discovered in ravines downstream from residential areas. The primary problems associated with the main stem of and tributaries to the stream in Quarry Hill Park include bank erosion, head cuts, incision, and sediment transport. These issues are inter-related and can be simultaneously addressed with various design solutions including bioengineered bank stabilization, wet and dry ponds, and storm sewer. The project included XPSWMM design of the system hydrology and hydraulics. The project is currently in construction and will be completed by June 2007.

# Watershed Assessment for the Lower Cheyenne River Watershed

**Cory S. Foreman, Water Resources Engineer**
Water & Natural Resources, RESPEC, P.O. Box 725, Rapid City, SD 57709; e-mail: *Cory.Foreman@respec.com*

**Dr. Scott J. Kenner, Professor of Civil Engineering**
Department of Civil and Environmental Engineering, South Dakota School of Mines and Technology, 501 East Saint Joseph Street, Rapid City, SD 57701, e-mail: *Scott.Kenner@sdsmt.edu*

A Phase I Total Maximum Daily Load (TMDL) assessment project for the Cheyenne River Watershed in western South Dakota was completed in the summer of 2006. The focus area of this project was the Cheyenne River Watershed below Angostura Reservoir, near Hot Springs, South Dakota, to the mouth of the river where it meets Oahe Reservoir. The Cheyenne River is currently listed as impaired for total suspended solids (TSS) and fecal coliform bacteria.

The Cheyenne River has four distinct reaches. The first reach, from Angostura Dam to Cedar Creek near Redshirt Table, has relatively low loading for both TSS and fecal coliforms. The second reach, from Cedar Creek to near Wasta, is a critical reach of river for both TSS and fecal coliforms, where the loading increases dramatically. The third reach, from Wasta to the confluence of the Belle Fourche River, is a transition reach for stream morphology and sediment transport processes. The final reach, from the Belle Fourche River to the mouth, sees continued increases in both TSS and fecal coliform loading.

In order to complete the TMDL process for the Cheyenne River Watershed, a sampling and data collection plan needs to be implemented to reduce data gaps associated with TSS and fecal coliform bacteria. A Phase II Assessment Project is set to begin in March 2007. A major emphasis of this project is to identify contributing areas to impairment to the Cheyenne River and Cherry Creek. This will be accomplished through analysis of new water-quality and stream-flow data, development of a watershed model using the program Hydrologic Simulation Program Fortran (HSPF), analysis of new biological data, and analysis of stream physical habitat data. A Phase III Assessment Project focusing on impaired lakes and Black Hills streams is being planned for 2008.

# Belle Fourche River Watershed Segment II Strategic Implementation Plan

**Jared K. Oswald**
Agricultural Engineer, Water & Natural Resources, RESPEC, P.O. Box 725, Rapid City, SD 57709, email: *Jared.Oswald@respec.com*

**Dan P. Hoyer**
Vice President, Water & Natural Resources, RESPEC, P.O. Box 725, Rapid City, SD 57709, email: *Daniel.Hoyer@respec.com*

The Belle Fourche River is a tributary to the Cheyenne River. The 4,614,400-acre Watershed is located in Hydrologic Units 10120201, 10120202, and 10120203. The Belle Fourche River is identified in the 1998 and 2002 South Dakota 303(d) Waterbody Lists and the 2004 and 2006 Integrated Report for Surface Water Quality Assessment as impaired because of elevated total suspended solids (TSS) and fecal coliform levels. The Belle Fourche River Watershed Management Project Segment II was sponsored by the Belle Fourche River Watershed Partnership (BFRWP) with support from agricultural organizations, federal and state agencies, local governments, and South Dakota School of Mines & Technology (SDSM&T). The objectives of this project segment were: continue implementation of Best Management Practices (BMPs) in the Watershed to reduce TSS (15.2 mg/L reduction below the Belle Fourche Reservoir (14 percent of goal), and 1.3 mg/L reduction above the Belle Fourche Reservoir), conduct public education and outreach to stakeholders within the Belle Fourche River Watershed, and track the progress made toward reaching the goals of the Total Maximum Daily Load (TMDL) to help ensure that BMPs are being implemented.

One focus for BMP implementation is on the Belle Fourche Irrigation District (BFID) to reduce unused irrigation water that enters the Belle Fourche River and Horse Creek. Several BMPs have been installed within the BFID. BMPs installed to date include 16 flow automation units; a water card/water ordering system; six portable and nine real-time stage/flow measuring devices; a canal operational model for the South Canal; replacement of canals, laterals, and/or ditches with pipelines; and installation of pipelines to deliver water from the BFID irrigation system to fields. As a result, the main canal delivery system has become much more efficient in delivering water, and preliminary estimates indicate that the amount of unused water has been reduced.

# Environmental Monitoring of the Abandoned Belle Eldridge Mine near Deadwood, South Dakota

**Dr. Arden Davis**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *arden.davis@sdsmt.edu*

**Cathleen J. Webb**
Western Kentucky University, 1 Big Red Way, Bowling Green, KY 42104, email: *cathleen.webb@wku.edu*

**Jenifer L. Sorensen**
South Dakota School of Mines and Technology, 501 East St. Joseph St., Rapid City, SD 57701, email: *jensorensen@rushmore.com*

**Joshua F. Valder**
South Dakota School of Mines and Technology, 501 East St. Joseph St., Rapid City, SD 57701, email: *valderj@rushmore.com*

The abandoned Belle Eldridge Mine near Deadwood, South Dakota, is on land controlled by the U.S. Bureau of Land Management (BLM). The mine produced lead and zinc during the first half of the 1900s and was abandoned before 1950. Because of acidic drainage and elevated levels of metals in tailings and waste rock, the site was evaluated in 1998 and 1999. After evaluation, the mine was remediated during 1999-2001 by the BLM. Since remediation, values of pH in water samples have been nearly neutral and specific conductance values have been lower than before remediation. The Grizzly Gulch forest fire of July, 2002, consumed much of the Belle Eldridge site and resulted in greater than normal erosion and sediment flushing during the months following the wildfire. If the site had not been remediated and the tailings emplaced within a capped repository, generation of acidity and off-site migration of heavy metals within sediments could have been severe at downstream locations.

**THURSDAY, APRIL 19, 2007**
**LUNCHEON**
**11:45 A.M. - 1:15 P.M.**

## OLD STATE, NEW STATE; RED STATE, BLUE STATE: CONTRASTING IMPLICATIONS OF CLIMATE CHANGE FOR STREAMFLOW ACROSS THE UNITED STATES

**(RUSHMORE H ROOM)**

**THURSDAY, APRIL 19, 2007**
**SESSION 3A**
**1:15 - 2:55 P.M.**

**GROUND-WATER ISSUES**
**(ALPINE ROOM)**

# Pumping Tests in the Deadwood Aquifer at Jewel Cave National Monument, Custer County, South Dakota

**Joshua F. Valder**
Geology and Geological Engineering Department, South Dakota School of Mines and Technology, 501 East St Joseph St, Rapid City, SD 57701, email: *valderj@rushmore.com*

**Dr. Arden Davis**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *arden.davis@sdsmt.edu*

Jewel Cave National Monument is 13 miles west of Custer, South Dakota. The park's two water-supply wells draw water from the Deadwood aquifer approximately 550 feet below the land surface. In a collaborative effort, South Dakota School of Mines and Technology and the National Park Service recognized the need for assessment of aquifer parameters and vulnerability.

Two pumping tests were conducted. The first had an average discharge of 13.1 gal/min with a total drawdown of about 26 feet in the pumped well. Water-level measurements were collected in the pumped well with a sonic water-level indicator and were analyzed manually and with curve-matching software. Techniques included the Theis method, Papadopulos-Cooper method, Hantush method, Moench method, and effects of casing storage. The average transmissivity was 600 gal/day-ft and the storage coefficient was about $10^{-3}$. The second aquifer test showed a low transmissivity because little or no drawdown was measured in the second well 800 feet away. A plot of water levels and barometric data showed an inverse correlation. Using the Theis equation to predict a drawdown value in the second well indicated that the maximum drawdown from pumping would have been about 0.1 foot. Parameters from the pumping tests indicated a ground-water velocity of 0.8 ft/day, using an effective porosity of 0.05.

Assessment showed that the aquifer has low to moderate susceptibility and vulnerability; however, aquifer-test analysis indicates a leaky confining layer above the aquifer. If heavy pumping of the aquifer continued over time, the leaky confining layer could potentially allow contaminants into the aquifer. Therefore, monitoring of potential contamination sources is essential to protecting the aquifer.

# Estimating Ground-Water Ages and Relative Flow Fractions of Karst Flow Components in the Madison Aquifer

**Andrew J. Long**
U.S. Geological Survey, 1608 Mt. View Road, Rapid City, SD 57702, email: *ajlong@usgs.gov*

**Larry D. Putnam**
U.S. Geological Survey, 1608 Mt. View Road, Rapid City, SD 57702, email: *ldputnam@usgs.gov*

Ground-water residence time, also known as “age,” for the karstic Madison aquifer on the northern and eastern flanks of the Black Hills of South Dakota was estimated based on chlorofluorocarbon (CFC) and tritium concentrations in samples collected from wells from 1991 to 2005. Karst conduits, which are pipe-like features through which ground-water flows quickly, are hydraulically connected to an annex system of smaller passages in many cases. The Madison aquifer is characterized by three distinct flow components (from youngest to oldest): conduit, annex system, and long-term flow, which occurs in the smallest passages. The ages of the two youngest flow components and the relative flow fractions for all three components were estimated. Mathematical models were developed that estimated the ages and relative flow fractions for samples based on observed and model-calculated sample concentrations and on a conceptual model for triple-porosity karst ground-water flow. Input data for the model included more than 50 years of record for concentrations of CFCs and tritium in the atmosphere, precipitation, and streamflow. The ages of water in conduit and annex system flow were estimated to be less than 1 year and 20-50 years, respectively, for most well samples. Long-term flow, which could not be specifically dated, was assumed to be greater than 50 years old. Based on the estimated ages, potential contamination is an immediate concern for conduit flow and a future concern for the annex system and long-term flow components because of slow transport of solutes.

# Angle Wells under the Missouri River

**James D. Landenberger, P.E., Assistant Project Manager**
Bartlett & West Engineers, Inc., 3456 E. Century Ave., Bismarck, ND 58501, email: *James.landenberger@bartwest.com*

South Central Regional Water District (SCWD) is a regional rural water system located in Burleigh County in south central North Dakota. Their system has seen exceptional growth in the last decade and as part of an expansion project, SCWD needed to build an intake on the Missouri River to supply water to a new water treatment plant facility, north of Bismarck.

After considering several options for developing a groundwater source with conventional wells or horizontal collector wells, SCWD decided to proceed with the installation of a series of angle wells under the Missouri River. The angle wells targeted a narrow band of sand and gravel under the Missouri River where the aquifer is hydraulically connected and directly influenced by the surface river water above. The first well was installed in August of 2005 and was installed at an angle of 23° from horizontal. As the next wells were installed, it was decided to decrease the angle to 14-15°. By doing this, the overall length of the well was increased, and the amount of screen in the targeted zone, increased as well to increase potential yield of the well.

Relatively new to water production, angle wells help balance four key constraints: transmissivity, drawdown, water quality, and installation cost. The Project was able to maximize the value of the water source by balancing these four constraints.

Another promising byproduct of angle wells is the river bank filtration aspect, which could allow SCWD to gain a 0.5-log credit for removal of potentially harmful waterborne pathogens. Also, this project is environmentally friendly in that a minimal area was disturbed, and no disturbance of the natural waterway of the Missouri River occurred during construction. A total of six (6) angle wells with a combined capacity of over 2,200 gpm, have been installed thus far. SCWD has plans to install up to three (3) additional angle wells in the near future.

# Protecting Ground Water in the Oil Patch

**Fred V. Steece**
South Dakota Department of Environment and Natural Resources,
2050 W. Main, Suite #1, Rapid City, SD 57702, email: *fred.steece@state.sd.us*

**Kristine Murphy**
South Dakota School of Mines and Technology, 501 E. Saint Joseph, Rapid City, SD 57701,
email: *kristine.murphy@gmail.com*

Ground water in subsurface formations in South Dakota has been protected from potential pollution by oil and gas exploration, production and development for more than 50 years. Although exploration for natural gas at Pierre began in the 1890s, ground water protection was not a serious problem because the gas was produced along with flowing water from the Dakota Sandstone. The surficial glacial and alluvial sediments, the only aquifers above the level of the Dakota, were protected by conductor pipe or surface casing. The Dakota, at depths of 1,800 to 2,200 feet, is the uppermost aquifer in the "Pierre Gas Field," a region about 60 miles in diameter, centered on the City of Pierre. The increased need for oil during World War II resulted in an accelerated search for the resource all across the United States, including South Dakota, in the post war years. As a result, the South Dakota Legislature in 1943 adopted statutes for the regulation of oil and gas exploration, motivated primarily by the efforts of E. P. Rockrock, State Geologist for 41 years. The primary focus of the new regulation was to ensure that oil and gas test wells were properly completed with casing and cement, or abandoned with the use of cement plugs and heavy bentonite slurries at intervals selected to isolate oil-bearing and water-bearing zones to prevent interaction between them. Wells plugged in Rothrock's time, as today, are supervised by an on-site representative of the Oil and Gas Section of the Department of Environment and Natural Resources. The present-day regulations are refinements of Rothrock's forward-looking accomplishments, and are enforced by the Department.

# Infantile Methemoglobinemia and Nitrate Contaminated Wells – Has the Role of Bacteria Been Overlooked?

**Michael R. Meyer, M.S.**
GeoTek Engineering & Testing Services, 909 E. 50th St. N, Sioux Falls, SD 57104, email: *mmeyer @geotekeneng.com*

The NO3-N limit of 10 mg/L for public drinking water was developed in 1945-50 based on many cases of infants suffering methemoglobinemia (blue baby disease) when given formula mixed with water from nitrate contaminated wells. The author participated in investigation of two cases in South Dakota in the 1980s and studies of nitrates in public and private wells in the State. While nitrate contaminated wells are common in the State, methemoglobinemia cases occur rarely. A review of the literature indicates that, in most cases, the infants were sick with diarrhea. Reduction of nitrates to nitrites requires the presence of nitrate reducing bacteria in the digestive tract. Both nitrate reducing and pathogenic bacteria thrive in less acid conditions. Persons with less acid stomachs include young infants and persons sick with diarrhea. Breast feeding imparts protective antibodies and minimizes diarrhea. Not a single reported case of methemoglobinemia has involved a breast fed infant. Only one public supply well has ever been documented and in this case the well was contaminated with sewage and the affected infant had diarrhea. In a Czech study, hundreds of cases were reported involving infant formulas. However, of the three formulas used, the one with a natural antibiotic had no reported cases. Disinfection efforts, and promotion of breast feeding, may be more effective at minimizing future cases than nitrate removal treatment.

**THURSDAY, APRIL 19, 2007**
**SESSION 3P**
**1:15 – 2:55 P.M.**

**HYDROLOGY POTPOURRI**
**(PONDEROSA ROOM)**

# Unique Methods for Stratigraphic Correlation: Pierre Shale Formation, South Dakota

**Doreena Patrick**
GeoChemical Solutions, LLC, email: *Doreena.Patrick@sdsmt.edu*

**Paul N. Wegleitner**
GeoChemical Solutions, LLC, Fort Pierre, SD 57532, email: *Pnw248@aol.com*

**James E. Martin**
Museum of Geology, South Dakota School of Mines and Technology, Rapid City, SD 57701, email: *James.Martin@sdsmt.edu*

A portion of our current research involves new methods for stratigraphic correlation, which includes Rare Earth Elements (REE) and other trace elements (TE) analyses of fossilized bone and associated sediments. These methods for REE and TE analyses use variations within these materials to identify unique signatures and distinguish packages within lithologic units. Since these intervals represent an averaging of periods within depositional environments, these distinct packages can be correlated laterally over a significant distance. REE and TE analyses of fossilized bone material and sediments also define a paleoenvironmental package. These package 'fingerprints" are determined through the use of multiple analytical techniques.

The REE signature and TE ratios of fossilized bone are dependent upon conditions of diagenesis. Through the use of sequential extraction of sediments, a unique REE signature and TE ratios are identified for each fraction. The signature associated with a fossilized bone sample is dependent on the conditions during fossilization and is obtained from one of these sediment fractions. Identification of the origin of the fraction that imparted the signature to the bone material was achieved though comparison of the REE signature and TE ratios in bone material and associated sediments. REE signatures and TE ratios in sediment fractions can be used with signatures of fossilized bones to correlate packages.

To test this theory, fossil vertebrates and incremental sediment samples were collected from the lower, middle and upper Sharon Springs, Gregory, Crow Creek, and lower and upper DeGrey Members of the Pierre Shale Formation in South Dakota. REE signatures and TE ratios were found to be consistent within the package(s) associated with each lithologic unit and are significantly different between the units. Therefore, REE signatures and TE ratios act as markers for these units and help discriminate between these units for purposes of stratigraphic correlation and natural resource exploration.

# Occurrence of Organic Wastewater Compounds in Wastewater Effluent and the Big Sioux River Basin, South Dakota, 2001-2004

**Roy Bartholomay**
U.S. Geological Survey, 111 Kansas Ave. SE, Huron, SD 57350, email: *rcbarth@usgs.gov*

**Steven K. Sando**
U.S. Geological Survey, 3162 Bozeman Ave., Helena, MT 59601, email: *sksando@usgs.gov*

Water samples were collected from wastewater effluent and the Big Sioux River in the vicinity of Watertown, Volga, and Brookings during 2003-2004 and in the vicinity of Sioux Falls during 2001-2004. The sampling was conducted as part of a reconnaissance-level assessment of organic wastewater compounds (OWCs) in the Big Sioux River Basin in eastern South Dakota by the U.S. Geological Survey in cooperation with the East Dakota Water Development District and the City of Sioux Falls. Water samples were collected during both base-flow and storm-runoff conditions from a total of 20 sites.

A total of 125 different compounds were analyzed for and were classified into the following six compound classes: human pharmaceutical compounds; human and veterinary antibiotic compounds; major agricultural herbicides; household, industrial, and minor agricultural compounds; polyaromatic hydrocarbons (PAHs); and sterol compounds. OWCs in all six classes were detected in water samples from sampling sites in the Watertown and Sioux Falls area. Compounds from all the classes except PAHs were detected in the Volga and Brookings areas. Some of the compounds detected at most of the sites are suspected endocrine disrupting compounds (EDCs), but none of the concentrations were large enough to be a concern for human health. EDC concentrations found in the Big Sioux River generally were less than concentrations reported to have substantial endocrine-disrupting effects on aquatic organisms, although there may be some cause for concern about the relatively large frequency of detection for atrazine.

# Further Testing of Limestone-Based Material for Arsenic Removal from Small Water Systems

**Jenifer Sorensen, P.E.**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *jsorensen@envisiondesigninc.com*

**Dr. Arden Davis**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *arden.davis@sdsmt.edu*

**Dr. David J. Dixon**
South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *david.dixon@sdsmt.edu*

**Crystal Hocking**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *crystal.hocking@hardrockers.sdsmt.edu*

During earlier phases of this research, manufactured limestone-based granules were shown to improve arsenic removal capacity in both batch and column studies over crushed limestone of equal diameter. Granules are made through the process of agglomeration, where fine materials are formed into larger, spherical granules through tumbling and use of a binder.

With the goal of further improving arsenic removal efficiency by granulated limestone, seven granule formulas were manufactured and tested that incorporated established arsenic adsorbents such as granulated activated carbon and granular ferric hydroxide, in addition to powdered limestone. Batch tests at 100 ppb and 500 ppb arsenic were run. In addition, well water from Keystone City Well No. 4 was also tested with the granules.

A column study with three columns in series using crushed limestone as the adsorbent was also run with the goal of engineering a scale-up design for future field application at a small water system. Keystone City Well No. 4 water was used for this study. Water quality analysis of both influent and effluent showed that limestone treatment had little impact on overall water quality while reducing arsenic concentrations.

A review and comparison of other innovative arsenic removal technologies was also completed and will be presented.

# Susceptibility for Slope Failure Due to Future Development and Land Use along Highway 79 in the Hermosa NW Quadrangle, Pennington County

**Matthew D. Minnick, Geological Engineer**
Water & Natural Resources, RESPEC, P.O. Box 725, Rapid City, SD 57709, email: *Matthew.Minnick@respec.com*

**Dr. Larry D. Stetler**
Department of Geology and Geological Engineering; South Dakota School of Mines & Technology, 501 East Saint Joseph Street, Rapid City, SD 57701, email: *larry.stetler@sdsmt.edu*

**Cory S. Foreman, Water Resources Engineer**
Water & Natural Resources, RESPEC, P.O. Box 725, Rapid City, SD 57709, email: *Cory.Foreman@respec.com*

A slope stability analysis was performed to create factor-of-safety maps to assess slope failure susceptibility due to future land use development in the Hermosa NW and Hermosa 7.5 minute quadrangles in Pennington County. Funding was provided by the Pennington County Commission in a partnership with the South Dakota School of Mines & Technology and RESPEC. The slope stability analysis included an existing slide inventory, soil core sampling, soils laboratory testing, limit equilibrium modeling, and Geographic Information System (GIS) spatial analysis. The existing slide inventory was needed to assess areas under current and past conditions that were prone to slope failures. Digital Orthoquad Imagery, a low-level plane survey, and extensive field Global Positioning System (GPS) mapping were used to produce the slide inventory. Eight suitable sampling sites were then selected based on geologic formation, accessibility, and land ownership approval. Shelby tube samples were collected up to 25 feet deep at each sample location. Geotechnical laboratory testing was performed, including unit weight, plasticity indices, and direct shear tests to acquire cohesion and friction angle values. Limit equilibrium models were built in Slope Stability Analysis Software (STABL) using profiles gathered from field GPS mapping and United States Geological Survey (USGS) 10-meter Digital Elevation Model data. Models were run for unsaturated and saturated conditions. Factor of Safety points were taken from the slope models to interpolate a slope failure susceptibility map. Spatial model accuracy was verified using the existing slide inventory. Results indicate Skull Creek Shale and Belle Fourche Shale are most susceptible to slope failure. Mowry Shale and Carlile Shale are susceptible with added stresses. Remaining tasks in this project include analyzing multiple spatial layers to determine site suitability and potential impacts due to future development.

# Geologic Mapping of the Hermosa and Hermosa NW Quadrangles, Black Hills Development Corridor

**Christopher Pellowski**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *Christopher.Pellowski@hardrockers.sdsmt.edu*

**Dr. Alvis L. Lisenbee**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *alvis.lisenbee@sdsmt.edu*

**Darren Johnson**
Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD, 57701, email: *djohnson904@rap.midco.net*

Urbanization south from Rapid City to Hermosa is accelerated by the expansion of U.S. Highway 79 to four-lanes. The geology of two quadrangles (Hermosa and Hermosa NW) in this area was mapped in 2004, 2005, and 2006 by geologists from the South Dakota School of Mines and Technology (partially funded by grants from West Dakota Water Development District and the U.S. Geological Survey EDMAP program) in order to serve as a basis for other studies, including aquifer vulnerability and susceptibility and rock slope characterization.

A gently east-dipping sequence of Cretaceous shale and limestone in seven formations, chiefly covered by prairie grasses, increases to a thickness of 1,800 feet along the eastern margin of the quadrangles: Sandstone of the underlying Cretaceous Fall River and Lakota Formations (the Inyan Kara aquifer), and the Jurassic Morrison Formation and Unkpapa Sandstone is exposed in pine-tree-covered ridges along the western edge.

The Cretaceous strata are folded by previously unrecognized, southeast-plunging, anticline-syncline pairs, some of which (e.g., the Hermosa and Spring Creek pairs) extend for more than seven miles cross the entire width of the quadrangles. North trending normal faults on the Hermosa NW quadrangle, a possible southern extension of the Spiken Ridge Fault, are present along the western edge of Murphy Ridge extending north from Billover Creek to south of Gobbler Knob.

Locally, older units are overlain by silica-cemented conglomeratic channels, flood plain deposits of tuffaceous mudstone, and freshwater lacustrine limestone of the Oligocene White River Group. The channels cause an inverted topography between present streams and parallel Laramide folds, which may have controlled the location of Oligocene streams. Quaternary alluvial aquifers and terraces occur along the present creeks.

Geologic hazards include landslides (especially the Skull Creek and Belle Fourche Shales), floodplains, expansive soils (gilgai), and clays poorly suited to act as septic tank drain fields (especially the Belle Fourche Shale).

**THURSDAY, APRIL 19, 2007**
**SESSION 4**
**3:20 - 5:10 P.M.**

**ENVIRONMENTAL IMPACTS**

# Environmental Impacts from the North Cave Hills Abandoned Uranium Mines, Harding County, South Dakota

**Dr. James Stone, PE, Assistant Professor**
Department of Civil and Environmental Engineering, South Dakota School of Mines and Technology, 501 E. Saint Joseph St., Rapid City, SD 57701, email: *james.stone@sdsmt.edu*

**Dr. Larry Stetler, Associate Professor**
Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. Saint Joseph St., Rapid City, SD 57701, email: *Larry.Stetler@sdsmt.edu*

**Dr. Albrecht Schwalm, Research Associate**
Oglala Lakota College, 490 Piya Wiconi, Kyle, SD 67752, email: *aschwalm@olc.edu*

Substantial prospecting and mining of uranium resources occurred from the early 1950s through the early 1970s throughout western South Dakota. Through US-EPA CERCLA funding, a Joint Venture Agreement between the USDA-Forest Service Northern Region and the South Dakota School of Mines (SDSM&T) has been established to evaluate uranium mining environmental impacts to soil, water, and air resources in northwestern (Custer National Forest) and southwestern (Black Hills National Forest) South Dakota. Historical mining activities have resulted in significant degradation of regional ecological and environmental resources through the transport and deposition of sediments and spoils containing As, Cu, Mo, Ra226, Th, U, and V. Results from the first project phase (North Cave Hills complex within Custer National Forest) completed during the 2006 field season suggests widespread contamination of heavy metals and radionuclides exists on private properties located adjacent to and down-gradient of USFS administered lands. Concentrations of As, Cu, Mo, U, and V exceeded established background concentrations within several streams flowing in the vicinity of the minesites, with several sampling sites containing total metal concentrations exceeding 35 times established background. The extent of surface water contamination was limited to approximately 27 km of stream length flowing from the abandoned mines. Stream sediment results show the formation of secondary mineral phases was typically limited to the upper depths of the sediment cores collected using a track-mounted GeoProbe. Re-mobilization of contaminants appears to be a significant concern due to seasonal changes to redox and pH environments, especially within several large sediment deposition zones where 50+ years of seasonal deposition has resulted in deposits to depths greater than 10 m. Mineral microscopy analysis of sediment cores and stream colloids using a newly acquired field emission scanning electron microscope (SEM), transmission electron microscopy (TEM) and powdered x-ray diffraction (XRD) confirm the occurrence of nanometer sized uraniferous lignite particles which may be directly attributable to historical mining activities.

# Aerosol Dust Transport, Deposition, and Composition around Abandoned Uranium Mines in the North Cave Hills, Harding County, South Dakota

**Kyrian Onyeukwu**
Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. Saint Joseph St., Rapid City, SD 57701, email: *kyrianco1@yahoo.com*

**Dr. Larry Stetler, Associate Professor**
Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. Saint Joseph St., Rapid City, SD 57701, email: *Larry.Stetler@sdsmt.edu*

**Dr. James Stone, PE, Assistant Professor**
Department of Civil and Environmental Engineering, South Dakota School of Mines and Technology, 501 E. Saint Joseph St., Rapid City, SD 57701, email: *james.stone@sdsmt.edu*

Transport and depositional processes for aerosol dusts originating in the North Cave Hills area of Harding County, South Dakota were evaluated to determine potential metals contamination due to past uranium mining activity in the area. This work was funded by the US-EPA CERCLA program administered through the USFS Northern Region office. Field sampling and collection of dust at 30 sites included: (1) use of a portable wind tunnel to generate fine particulate matter liberated under ~40 mph winds, (2) an ambient atmospheric dust-fall monitoring network, and (3) collection of surface dust using a soil skimming technique. Bulk soil samples were also collected and later sieved to obtain grain size distributions. Particles less than 63 micrometers diameter were further analyzed using a laser particle sizer. All collected dust samples were analyzed by ICP/MS and specific samples were also analyzed by XRD. Target analytes were focused on uranium and arsenic with lesser emphasis placed on other metals. The basis for evaluation of impairment was by comparison to a statistical background concentration, computed as 2 times the Standard Deviation + mean of the background sites. The statistical background values for U and As were 0.74 and 11.93 mg/kg, respectively. Fifteen samples contained U in concentrations above the background value, were widely distributed throughout the area, and had a NW-SE directional spike in the predominant wind direction. All samples contained As and five were above the background value. As was widely distributed and contained a high concentration spike to the east and southeast of the mine sites. These data suggest that analyte metals are ubiquitous in occurrence and are a natural components of soil development in the region. Pre-erosion and pedogenic conditions placed uranium-bearing formations in a superior position and as the ground surface was let down, these metals were incorporated into the soils. Soil dusts do contain CERCLA metals but at concentrations that are orders of magnitude less than in surface soils located in impacted drainages.

# Groundwater Quality Near Abandoned Uranium Mines in the North Cave Hills, Harding County, South Dakota

**Dr. Larry Stetler, Associate Professor**
Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. Saint Joseph St., Rapid City, SD 57701, email: *Larry.Stetler@sdsmt.edu*

**Dr. James Stone, P.E., Assistant Professor**
Department of Civil and Environmental Engineering, South Dakota School of Mines and Technology, 501 E. Saint Joseph St., Rapid City, SD 57701, email: *james.stone@sdsmt.edu*

Geochemical and radiometric analysis of 34 wells from the North Cave Hills area in NW South Dakota were evaluated to determine the level of impact due to past uranium mining activity in the area. Through US-EPA CERCLA funding administered through the USFS Northern Region office, wells were selected to ensure that domestic and stock water supplies were evaluated and that the sampling network covered both up- and down-gradient wells. Well depths ranged from 50 to 840 feet deep, and aquifers were classified as either unconfined alluvial or confined deep sources. Water analyses included physical, inorganic, and nutrient parameters with the primary focus being placed on CERCLA radionuclide and metal testing including As, Cu, Mo, Se, Pb, Th, U, V, Ra, Ra-226, U-235, and gross alpha. Results indicate groundwater sources in the study area contain metals and radionuclides, some of which exceed the US EPA MCL. Species in exceedance of the MCLs were gross alpha (3 wells), uranium (1 well), and lead (2 wells). Gross alpha exceedance ranged from 3x to 1x the MCL, and all wells were being used as domestic sources at the time of sampling. The uranium exceedance well coincided with the 3x gross alpha well and was 2x the MCL. This well was discontinued after these results were provided to the landowner. Th, As, and V were not detected in any of the wells. The data suggest that the current metals and radionuclide levels in the groundwater are from natural sources and are ubiquitous in occurrence. Exceptions include 2 of the gross alpha exceedance wells which are sourced in shallow unconfined alluvium which most likely is recharged from runoff across mined lands. The confined deep systems are in the Fox Hills sandstone and are recharged away from the local area. Aquicludes above these aquifers most likely prevent deep percolation of any contaminates to the water table.

# Characterization of Effects of On-site Wastewater Disposal Systems Overlying Fractured or Solution-Enhanced Aquifers, Black Hills of South Dakota

**Larry D. Putnam**
U.S. Geological Survey, 1608 Mt. View Road, Rapid City, SD 57702, email: *ldputnam@usgs.gov*

**Andrew J. Long**
U.S. Geological Survey, 1608 Mt. View Road, Rapid City, SD 57702, email: *ajlong@usgs.gov*

**J. Foster Sawyer**
S.D. Department of Environment and Natural Resources, 2050 W. Main St., Rapid City, SD 57702, email: *Foster.Sawyer@state.sd.us*

The potential effects of on-site wastewater disposal systems (septic tanks with drain fields) on surface- and ground-water quality is an important water-resource concern for the Black Hills area of South Dakota. The hydrogeology of the area is complex, and many areas are characterized by fractured or solution-enhanced bedrock, which is less effective at attenuating contaminants than other formations. In 2006, the U.S. Geological Survey, in cooperation with the South Dakota Department of Environment and Natural Resources and West Dakota Water Development District, initiated a study to characterize the potential effects of on-site wastewater treatment systems. The study is intended to: (1) locate study areas overlying fractured or solution-enhanced rocks where high densities (clusters) of septic systems may affect water quality; (2) sample and analyze ground water and surface water for preliminary indicators of septic influence, including nitrate, chloride, bromide, boron, and fecal coliform; (3) sample a selected subset of sites for additional analysis of nitrogen isotopes, selected waste-water compounds, and microbiological indicators.

Selected study areas include clusters overlying the Minnekahta Limestone, terrace gravels and the underlying Spearfish Formation, Precambrian rocks, and stream alluvium. Concentrations of nitrate + nitrite ($NO_2$+$NO_3$) from preliminary screening in samples collected from seven wells completed in the Minnekahta Limestone ranged from 3.5 to 17.6 milligrams per liter (mg/L) compared to a concentration of 1.0 mg/L for a Minnekahta background well. Linear regression of boron concentrations with nitrate concentrations for the Minnekahta well samples indicates a relation between the two constituents ($r^2$ = 0.87) with a probable anthropogenic source. $NO_2$+$NO_3$ concentrations in samples from 2 of 3 wells completed in the Spearfish Formation underlying terrace gravels had nitrate concentrations of 4.1 and 11.6 mg/L. $NO_2$+$NO_3$ concentrations in water samples from four alluvial wells were less than 1.6 mg/L.

# Effects of Nuisance Blooms of *Didymosphenia Geminata* on Benthic Community Composition in Rapid Creek, South Dakota

**Aaron M. Larson**
South Dakota Department of Environment and Natural Resources, 2050 West Main Street, Suite #1, Rapid City, SD 57702, email: *Aaron.Larson@state.sd.us*

*Didymosphenia geminata*, an algal species historically inhabiting low-nutrient montane or northern boreal streams, appears to be expanding its geographic range. This diatom was recently identified as an invasive species in New Zealand – the first confirmed record of *D. geminata* in the southern hemisphere. In the United States, nuisance blooms of *D. geminata* are increasingly reported by the public and media. Nuisance blooms have been observed in Rapid Creek since 2002 with the greatest mat densities observed near Johnson Siding.

A stream assessment was conducted to determine the impact of *D. geminata* blooms on the benthic (stream bottom-dwelling) organisms in Rapid Creek. Biological and water quality samples were collected monthly from June through October of 2005 at four monitoring sites located between Pactola Reservoir and Canyon Lake. Monitoring sites were categorized as either "impacted" or "non-impacted" by established *D. geminata* mats based on visual observations of areal mat coverage. Nuisance-level growths covering up to 80% of the stream bottom and up to 10 cm thick were observed at sites classified as impacted (RC2 and RC3), while only small patchy growths of *D. geminata* were observed sporadically at sites classified as non-impacted (RC4 and RC5).

Several benthic macroinvertebrate and algal metrics were correlated with visual estimates of *D. geminata* areal coverage of the stream bottom, suggesting that impacts to biological communities are directly related to the spatial extent of nuisance blooms. Statistically significant differences in biological metric values were observed between impacted and non-impacted sites. Biological diversity and eveness are reduced at impacted sites. These results indicate that nuisance blooms of *D. geminata* have likely altered the taxonomic composition of benthic macroinvertebrate and algal communities in Rapid Creek. Consequently, higher trophic level organisms, such as brown trout, may be affected by shifts in benthic taxonomic composition through food web interactions.