2003
WESTERN SOUTH DAKOTA
HYDROLOGY CONFERENCE

Program and Abstracts

April 9-10, 2003
Rushmore Plaza Civic Center
Rapid City, South Dakota

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2003 Western South Dakota Hydrology Conference

This program and abstracts book has been produced in conjunction with the 2003 Western South Dakota Hydrology Conference, held at the Rushmore Plaza Civic Center during April 9-10, 2003. The purpose of this book is to provide summaries of the presentations made during the conference.

The purpose of the 2003 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, students, and other interested individuals to meet and exchange ideas, discuss mutual problems, and summarize results of studies. The conference consists of seven technical sessions, a keynote luncheon speaker, and a panel discussion of on-site wastewater treatment systems (septic tanks) and related issues. The topics of the technical sessions include the Black Hills Hydrology Study, geologic mapping, hydrologic budgets, surface-water issues, flooding, geologic hazards, contaminants, aquifer vulnerability, source-water assessment, water contamination issues, geochemistry, hydrogeology, karst hydrology, mining issues, modeling, regulatory issues, water quality, water supply, resources, and management.

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. Keynote speaker, Dr. Larry Agenbroad, and the panelists for the on-site wastewater treatment system discussion, Dan Bjerke, Norma Diede, Connie Douglas, Jeanne Goodman, Lyle Hendrickson, Scott Kenner, Grace Mickelson, Gary Renner, and Ed Striebel, also are thanked for their time and perspectives.

Registration help by Sheri Meier (USGS) is greatly appreciated. Brenda Athow (USGS) and Joyce Williamson (USGS) provided computer support for the conference. Connie Ross (USGS) designed the conference web site, and Ella Decker (USGS) provided assistance in publishing this program and abstracts book. Jenny Sorensen (South Dakota Engineering Society) is thanked for her help in coordinating the professional development hours.

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. 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), and Van A. Lindquist (West Dakota Water Development District).

Conference Program

Wednesday, April 9, 2003

7:30 - 8:00 a.m. . . . . Registration opens
8:00 - 8:20 a.m. . . . . Welcome, general information
8:20 - 8:40 a.m . . . . Black Hills Hydrology Study introduction

Session 1 – Major findings of the Black Hills Hydrology Study (1.5 PDH)
8:40 - 10:00 a.m.

Moderator: **J. Foster Sawyer**, Hydrologist, South Dakota Department of Environment and Natural Resources, Rapid City, SD

Presentations

8:40 - 9:00 a.m. - [1-1] Carter and Driscoll, *Overview of the Black Hills Hydrology Study and Associated Products*

9:00 - 9:20 a.m. - [1-2] Carter and Driscoll, *Overview of the hydrogeology in the Black Hills area, South Dakota*

9:20 - 9:40 a.m. - [1-3] Kenner, *Historical and spatial characterization of precipitation data for the Black Hills area*

9:40 - 10:00 a.m. - [1-4] Buhler, *Water Right's observation well network: Trends and discussion*

10:00 - 10:20 a.m. . . . . Refreshment break

Session 2 – Major findings of the Black Hills Hydrology Study—Continued (1.5 PDH)
10:20 - 12:00 p.m.

Moderator: **Van A. Lindquist**, Administrative Manager, West Dakota Water Development District, Rapid City, SD

Presentations

10:20 - 10:40 a.m. - [2-1] Driscoll and Carter, *Factors affecting streamflow characteristics in the Black Hills area, South Dakota*

10:40 - 11:00 a.m. - [2-2] Teller, *Recent streamflow conditions in South Dakota*

11:00 - 11:20 a.m. - [2-3] Williamson and Carter, *Water-quality characteristics in the Black Hills area, South Dakota*

11:20 - 11:40 a.m. - [2-4] Carter and Hayes, *Role of artesian springs in regional hydrogeology in the Black Hills area, South Dakota*

11:40 - 12:00 p.m. - [2-5] Naus and Driscoll, G*eochemistry of the Madison and Minnelusa aquifers in the Black Hills area, South Dakota*

12:00 - 1:20 p.m. . . . . Luncheon

Keynote speaker: Dr. Larry D. Agenbroad (1.0 PDH)

Principal investigator of the Mammoth Site of Hot Springs, South Dakota

Title: ***The Hot Springs Mammoth Site: A hydrogeologic natural trap***

Session 3 – Hydrologic budgets and geologic mapping (2.0 PDH)
1:20 - 3:20 p.m.

Moderator: **Dr. Arden D. Davis**, Professor and Chairman, Geology and Geological Engineering Department, South Dakota School of Mines and Technology, Rapid City, SD

Presentations

1:20 – 1:40 p.m. - [3-1] Carter and Driscoll, *Hydrologic budgets for the Madison and Minnelusa aquifers in the Black Hills area, South Dakota and Wyoming, water years 1987-96*

1:40 – 2:00 p.m. - [3-2] Driscoll and Carter, *Ground-water and surface-water budgets for the Black Hills area, water years 1950-98*

2:00 – 2:20 p.m. - [3-3] Rahn, *Black Hills water budget*

2:20 – 2:40 p.m. - [3-4] Putnam and Long, *Flow-system analysis of the Madison and Minnelusa aquifers in the Rapid City area*

2:40 – 3:00 p.m. - [3-5] Epstein, *Karst in the Black Hills of South Dakota, an example for the proposed national karst map*

3:00 – 3:20 p.m. - [3-6] Iles, *Geologic mapping at 1:24,000 scale in the Black Hills*

3:20 - 3:40 p.m. . . . . Refreshment break

Session 4 – Surface-water biology and flooding (1.5 PDH)
3:40 - 5:20 p.m.

Moderator: **Joyce E. Williamson**, Hydrologist, U.S. Geological Survey, Rapid City, SD

Presentations

3:40 - 4:00 p.m. - [4-1] Heakin, *Evaluation of water quality, physical habitat, and biological diversity in selected wadeable streams in South Dakota*

4:00 - 4:20 p.m. - [4-2] Larson, *Biological communities as indicators of water quality for total maximum daily load (TMDL) studies*

4:20 - 4:40 p.m. - [4-3] Fontaine and Tinant, *Improved flood frequency analysis*

4:40 - 5:00 p.m. - [4-4] Teller, Williams, Murphy, and Buck, *Rapid-deployment data-collection networks for wildland fire applications*

5:00 - 5:20 p.m. - [4-5] Liou, *Methodologies for determining flood hazards in the alluvial fan areas*

Thursday, April 10, 2003

7:30 - 8:00 a.m. . . . . Registration opens
8:00 - 8:10 a.m. . . . . Announcements, general information

Session 5 – Contaminants and aquifer vulnerability (1.5 PDH)
8:10 - 9:50 a.m.

Moderator: **Daniel G. Driscoll**, Chief of Hydrologic Studies, South Dakota District, U.S. Geological Survey, Rapid City, SD

Presentations

8:10 - 8:30 a.m. - [5-1] Anderson, *Water availability and emerging contaminant issues: challenges for science and implications for the Black Hills area*

8:30 - 8:50 a.m. - [5-2] Royse, *Piedmont Valley water quality assessment study*

8:50 - 9:10 a.m. - [5-3] Putnam, *Mapping the sensitivity of aquifers to contamination in Lawrence County*

9:10 - 9:30 a.m. - [5-4] Davis, Lisenbee, and Stetler, *Ground-water vulnerability mapping at 1:24,000-scale in the Rapid City area, South Dakota*

9:30 - 9:50 a.m. - [5-5] Stetler, Lisenbee, Davis, Miller, and Hargrave, *Geological hazards, resources, aquifer vulnerability, and engineering maps for the Rapid City West 7.5′ Quadrangle: A pilot project of the I-90 Development Corridor*

9:50 - 10:10 a.m. . . . . Refreshment break

Session 6 – On-site wastewater treatment systems and source-water assessment (2.0 PDH)
10:10 - 12:10 p.m.

Moderator: **Dr. Perry Rahn**, Professor Emeritus, South Dakota School of Mines and Technology, Rapid City, SD

Presentations

10:10 - 10:30 a.m. - [6-1] Anderson, *On-site waste disposal: Septic tanks and the alternatives*

10:30 - 10:50 a.m. - [6-2] Sawyer and Lindquist, *Identification of onsite wastewater treatment systems in the central Black Hills, South Dakota*

10:50 - 11:10 a.m. - [6-3] Kenner, *Biological water quality issues in the Black Hills area*

11:10 - 11:30 a.m. - [6-4] Goodman, *South Dakota requirements for on-site wastewater treatment systems*

11:30 - 11:50 a.m. - [6-5] Yan, *Source water assessment and protection program: South Dakota statewide overview*

11:50 - 12:10 p.m. - [6-6] Sawyer and Lester, *Delineating source water areas for public water supply systems in the Black Hills region*

12:10 - 2:50 p.m.. . . . . Luncheon and panel discussion

Panel discussion

***Pros and cons of on-site wastewater treatment systems (septic tanks) in areas of growing population density* (2.0 PDH)**

Moderator: **Derric Iles**, State Geologist, South Dakota Department of Environment and Natural Resources, Geological Survey Program, Vermillion, SD

[Panelists will each have 5 minutes to provide a perspective regarding on-site wastewater treatment systems, followed by question & answer discussion]

Panelists:

Jeanne Goodman, South Dakota Department of Environment and Natural Resources

Dr. Grace Mickelson, Former chairperson of Rapid City/Pennington County Safe Drinking Water Committee

Lyle Hendrickson, Pennington County Commissioner

Connie Douglas, Lawrence County Commissioner

Dan Bjerke, Rapid City Public Works Director

Norma Diede, Chairperson of Black Hills Resource, Conservation & Development Association

Gary Renner, Local consultant

Ed Striebel, Local consultant

Dr. Scott Kenner, South Dakota School of Mines and Technology

2:50 - 3:10 p.m.. . . . . Refreshment break

Session 7 – Water contamination issues (2.0 PDH)
3:10 - 5:10 p.m.

Moderator: **Mark T. Anderson**, Chief of Hydrologic Investigations and Research Program, Arizona District, U.S. Geological Survey, Tucson, AZ

Presentations

3:10 - 3:30 p.m. - [7-1] Putnam and Long, *Use of environmental tracers to characterize ground-water flow in the Madison aquifer*

3:30 - 3:50 p.m. - [7-2] Driscoll and Putnam, *Concept for study of contamination potential of bedrock aquifers in the Black Hills area*

3:50 - 4:10 p.m. - [7-3] Erickson and Kenner, *Seasonal response of brown trout in Rapid Creek to urbanization*

4:10 - 4:30 p.m. - [7-4] Nelson, *Circumneutral pH contaminant mobility at Black Hills gold mines: Environmental concerns and long-term mine closure liability*

4:30 - 4:50 p.m. - [7-5] Sorensen, Davis, Dixon, Webb, and Fivecoate, *The potential for using limestone to remove arsenic from drinking water*

4:50 - 5:10 p.m. - [7-6] Das, Nebelsick, Capehart, and Mott, *A coupled approach towards estimating mitigating effects of CRP practices on regional sediment loading*

5:10 - 5:20 p.m. . . . . Closing remarks

WEDNESDAY, APRIL 9, 2003
SESSION 1
8:40 - 10:00 A.M.

MAJOR FINDINGS OF THE BLACK HILLS HYDROLOGY STUDY

Overview of the Black Hills Hydrology Study and Associated Products

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The Black Hills Hydrology Study was initiated in 1990 to assess the quantity, quality, and distribution of surface- and ground-water resources in the Black Hills. The study was a cooperative effort between the U.S. Geological Survey, the South Dakota Department of Environment and Natural Resources, and the West Dakota Water Development District, which represented various local cooperators. The first phase of the study focused on data collection activities, and the second phase focused on interpretive activities.

This regional study was necessitated by the complex hydrogeology of the Black Hills area, which is a recharge area for numerous local and regional aquifers. A wide variety of interactions occur between surface- and ground-water systems in the area. Headwater springs in high elevations provide base flow for many streams; however, most streams lose significant flow in crossing outcrops of the Madison Limestone and Minnelusa Formation. Further downgradient, some streams are rejuvenated by artesian springs from these aquifers.

A series of 11 maps and 21 reports have been published as part of the study. Hydrologic data collected during the study have been published in various data reports. Maps have included a hydrogeologic unit map for the study area, structure-contour maps for five geologic formations that contain major aquifers (Deadwood, Madison, Minnelusa, Minnekahta, and Inyan Kara aquifers), and potentiometric maps for these major aquifers. Interpretive reports have addressed a variety of subject matter for surface water and ground water, including quantitative hydrologic considerations and water-quality characteristics. Many of the interpretive reports have dealt specifically with the Madison and Minnelusa aquifers, which have been a primary focus of the study.

Overview of the Hydrogeology in the Black Hills Area, South Dakota

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The hydrogeology of the Black Hills area is very complex. Throughout geologic time, the area experienced periods of multiple inundations by seas, extended erosion, mountain building, and intrusion by igneous rocks. As a result, complex ground-water and surface-water interactions involving the Madison and Minnelusa aquifers influence ground-water and surface-water flow in the Black Hills area of South Dakota. Investigations of these interactions and general hydrogeology have been major components of the recently completed Black Hills Hydrology Study. Numerous headwater springs occur along the western flank of the Black Hills in the Limestone Plateau area, which is an important recharge and discharge area for aquifers in the Paleozoic rock interval, especially for the Madison aquifer. The headwater springs provide substantial base flow for several streams that flow across the crystalline core area of the Black Hills. After crossing the crystalline core, most streams generally lose all or part of their flow as they cross the outcrop of the Madison Limestone along the eastern flank of the Black Hills. Karst features of the Madison Limestone, including sinkholes, collapse features, solution cavities, and caves, result in the Madison aquifer's large capacity to receive recharge from streamflow. Large streamflow losses also occur in many locations within the outcrop of the Minnelusa Formation. Artesian springs originating from the Madison and Minnelusa aquifers occur in many locations downgradient from these streamflow loss zones. These springs provide stable base flow to many streams beyond the periphery of the Black Hills and are extremely important in supporting a variety of beneficial uses, including municipal supply, irrigation, and recreation.

Historical and Spatial Characterization of Precipitation Data for the Black Hills Area

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Precipitation over the Black Hills region is essential to stream flow and groundwater recharge. The variability of precipitation leads to dry and wet periods that require management of the resulting water resources. Understanding the long-term characteristics of precipitation provides information to better understand precipitation variability and water resources management issues. The information presented here is published as part of the Black Hills Hydrology Study in Summary of Precipitation Data for the Black Hills Area of South Dakota, Water Years 1931-98[1]. Long-term precipitation records are summarized for the Black Hills area of South Dakota. Precipitation Data are available for numerous gaging locations; however, few gages have continuous, long-term records, and periods of missing record are common. Thus, a geographic information system (GIS) utilizing an inverse-distance weighting method was developed to generate spatial precipitation for distributions from point precipitation data for the Black Hills area, based on available monthly records. The spatial distributions were used to estimate periods of missing record for all 94 gages considered. The resulting monthly records of measured or estimated precipitation are tabulated for water years 1931-98. Average values for water years 1961-90, which is the period used for calculation of climatic normals, were used to develop an isohyetal map of normal annual precipitation for the Black Hills area.

Temporal trends in precipitation for the Black Hills area also were examined. Sustained periods of deficit precipitation occurred during 1931-40 and 1948-61. Sustained periods of surplus precipitation occurred during 1941-47, 1962-68, and 1991-98, with the late 1990's identified as the wettest period since 1931. The driest 30-year period was 1931-60, when the annual precipitation averaged 17.17 inches for the study area. The wettest 30-year period was 1969-98, when annual precipitation averaged 19.61 inches. Normal annual precipitation (1961-90) for the study area is 19.06 inches, compared with the long-term (1931-98) annual average of 18.61 inches. Annual extremes for the study area have ranged from 10.22 inches in water year 1936 to 27.39 inches in water year 1995.

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[1]Driscoll, D.G., Hamade, G.R. and S.J. Kenner, 2000. "Summary of Precipitation Data for the Black Hills Area of South Dakota, Water Years 1931-98". Open-File Report 00-329, U.S. Department of the Interior, U.S. Geological Survey, Rapid City, S.D.

Water Right's Observation Well Network: Trends and Discussion

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The Water Rights' Observation Well Network is an important tool in understanding and managing South Dakota's ground water resources. The network (a) provides basic hydrogeologic data, (b) is used to determine long-term effects of recharge/discharge, (c) is used to assess the availability of ground water, (d) provides a basis for handling disputes/complaints, (e) provides general information to the public, (f) is valuable for research and water supply studies, and (g) fulfills statutory requirements. The observation well network, with records for some wells dating back as far as 1949, consists of over 1,600 wells installed specifically for the purpose of collecting water-level data throughout South Dakota. Although the network contains around 90 observation wells instrumented with some type of continuous recorder, the strength of the network comes from the over 12,000 manual water level measurements taken annually.

There are 240 observation wells, completed into 13 aquifers in western South Dakota. Initially, these west river wells were installed in the late 1950's primarily to address ground water/surface water interactions along several major drainages. Observation wells installed in the 1960's were typically constructed in areas of high water usage to address water availability issues. The 1970's saw a period of observation well construction to monitor the effects of irrigation development. Water Rights' staff shifted the focus of our observation well construction in the mid 1980's from specific issues "problem areas" to more general issues "big picture view." Observation wells were completed in favorable geohydrologic areas; at least cost (least depth); in locations that, when possible, would not free flow at the land surface; located away from major pumping diversions; regionally representative; with ease of access; and away from major geologic structural influences.

Much information has been obtained in the planning, constructing and monitoring of these wells. In many cases, data from the wells has confirmed accepted ideas such as the hydraulic relationships between aquifers and the general flow paths of the aquifers. The data has also brought about a certain amount of enlightenment on things, especially the magnitude of fluctuation of the water levels in the bedrock aquifers both seasonally and historically. 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 were apparent. Ground water development appears to have not caused significant drawdown nor adversely affected the water supply from any South Dakota aquifer.

WEDNESDAY, APRIL 9, 2003
SESSION 2
10:20 - 12:00 P.M.

MAJOR FINDINGS OF THE BLACK HILLS HYDROLOGY STUDY—CONTINUED

Factors Affecting Streamflow Characteristics in the Black Hills Area, South Dakota

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Streamflow in the Black Hills area is heavily influenced by geologic and climatic conditions. Characterizing responses of streamflow to hydrogeologic and climatic factors is important for managing the water resources in the Black Hills area. As part of the Black Hills Hydrology Study, precipitation and streamflow conditions for the Black Hills area were summarized and relations between these hydrologic variables were explored.

Available precipitation data for water years 1931-98 for the Black Hills area were summarized for the study. Spatial precipitation patterns are highly influenced by orography and regional climatic patterns. The response of streamflow to precipitation influences is different for five different hydrogeologic settings that were identified for the study. In the limestone headwater setting, which is dominated by outcrops of the Madison Limestone and Minnelusa Formation, direct runoff is uncommon and streamflow consists almost entirely of base flow originating as ground-water discharge from headwater springs. In this setting, variability in daily, monthly, and annual flow is small, and annual streamflow correlates poorly with precipitation. In the crystalline core area, which is dominated by igneous and metamorphic rocks, streamflow correlates well with annual precipitation. In the loss zone setting, where streamflow losses occur to outcrops of the Madison Limestone and Minnelusa Formation, zero-flow conditions are common and relations between streamflow and precipitation were defined for only two streams. Streamflow characteristics for the artesian spring setting generally have small variability and poor correlations with annual precipitation because of large influence from relatively stable ground-water discharge. In the exterior setting, which is downgradient from the outcrop of the Inyan Kara Group, large flow variability is characteristic and base flow generally is smaller than for other settings. Positive correlations were identified between annual streamflow and precipitation in the exterior setting; however, correlations were weaker than for the crystalline core setting.

Basin yield is highly variable within the study area, with the largest yields generally occurring in high-altitude areas that receive large annual precipitation. Basin yields for several streamflow-gaging stations in the limestone headwater setting were shown to be influenced by differences between contributing ground-water and surface-water areas.

Recent Streamflow Conditions in South Dakota

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Hydrologic conditions in South Dakota for water year 2002 were markedly different than for the previous 9 years. Precipitation for water year 2002 generally was below normal in all of the State's nine weather divisions. Cumulative precipitation totals were below normal at the end of all four quarters of the water year at four of the nine divisions. Cumulative precipitation for the nine divisions ranged from 9.46 inches in the Northwest division to 20.82 inches in the Southeast division. Deficits ranged from 6.56 inches below normal in the Northwest division to 1.51 inches below normal in the Northeast division.

Correspondingly, streamflow generally was well below normal especially in the northwest part of the State. This followed flooding during 1993, 1995, 1997, and 2000, when numerous streamflow-gaging stations had peak flows approaching or exceeding the 100-hundred year recurrence interval at one time or another during this period. Also during this period the annual mean streamflows for several stations were at or near the highest on record. During typical climatic conditions, approximately 25 percent of the gaging stations would be expected to experience below-normal flow conditions. Based on streamflow data collected since April 7, 2001, at 28 selected gaging stations, the percentage of gaging stations below the 25th percentile exceeded 25 percent for most of the summer of 2002. The number of stations below the 25th percentile peaked at over 45 percent during the month of August.

Annual streamflow in South Dakota for water year 2002, as recorded at five representative gaging stations, averaged about 89 percent of the long-term median (normal) streamflow. Annual streamflow ranged from 132 percent of the median for Castle Creek above Deerfield Reservoir, near Hill City, to 6.3 percent of the median for the Moreau River near Whitehorse. Monthly mean streamflows for the Moreau River near Whitehorse were near-normal through February and then declined significantly in March. During the last 20 days of June and during July and August, there was no flow at this site. The annual mean of 8.85 cubic feet per second (ft^3/s) for this site was the second lowest on record. The annual mean of 12.7 ft^3/s, recorded at the Moreau River near Faith, also was the second lowest on record.

Water-Quality Characteristics in the Black Hills Area, South Dakota

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Water quality of the major aquifers generally is very good in and near outcrop areas but deteriorates progressively with distance from the outcrops. High concentrations of iron and manganese may limit the use of water from Precambrian aquifers. The principal deterrents to use of water from the Deadwood aquifer are high concentrations of radionuclides, iron, and manganese. Iron, manganese, and hardness concentrations as well as dissolved solids and sulfate concentrations may deter use of water in downgradient wells from the Madison and Minnelusa aquifers. Water from the Minnekahta aquifer ranges from hard to very hard although it generally is suitable for all water uses. High concentrations of dissolved solids, iron, sulfate, and manganese may limit the use of water from the Inyan Kara aquifer. In the southern Black Hills, radium-226 and uranium concentrations also may preclude use of water from the Inyan Kara aquifer for public supply.

For most streams, concentrations of dissolved solids increase as streamflow decreases. However, for streams in the limestone headwater and artesian spring settings, which are dominated by ground-water discharge, concentrations of dissolved solids have little variability. For streams in the crystalline core setting, trace element concentrations generally are low with the exception of arsenic. Iron and manganese concentrations that exceed the Secondary Maximum Contaminate Levels (SMCLs) also occur at some crystalline core sites. Samples from streams in the artesian spring setting commonly exceed the SMCLs for dissolved solids and sulfate. About 66 percent of the sulfate concentrations from streams in the exterior setting exceed 1,000 milligrams per liter. Higher uranium concentrations are found for streams located in areas exterior to the Inyan Kara Group outcrop.

Role of Artesian Springs in Regional Hydrogeology in the Black Hills Area, South Dakota

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In the Black Hills area, artesian springs originate primarily from the Madison and Minnelusa aquifers and occur in many locations downgradient from streamflow loss zones. Most artesian springs occur within or near the outcrop belt of the Spearfish Formation, which acts as a confining unit to the underlying bedrock aquifers. These artesian springs are an important source of base flow in many streams beyond the periphery of the Black Hills and were studied extensively for the recently completed Black Hills Hydrology Study.

Interactions between the Madison and Minnelusa aquifers have been identified as a probable factor in the development of artesian springs. Higher hydraulic head in the Madison aquifer relative to the Minnelusa aquifer creates potential for upward leakage in many locations. Water with low dissolved sulfate concentrations leaking upward from the Madison aquifer dissolves anhydrite in the Minnelusa Formation. Breccia pipes then form by gravity collapse. Exposed breccia pipes are believed to be the throats of abandoned artesian springs. Artesian springs probably develop preferentially in locations with large secondary porosity and high permeability. Dissolution then further enhances porosity and permeability in somewhat of a self-perpetuating process. Artesian springflow and general leakage are important factors in governing water levels in the Madison and Minnelusa aquifers. Artesian springs act as a relief mechanism that provides an upper limit for hydraulic head, with springflow increasing in response to rising water levels. Artesian springs have migrated outward over periods of tens of thousands of years in response to declining water levels in the Madison and Minnelusa aquifers, essentially keeping pace with regional erosion.

Cascade Springs, which is a group of artesian springs that originate primarily from the Madison aquifer, provides an example of hydrogeologic interactions in the southern Black Hills. Water from Cascade Springs normally is quite clear; however, periodic discharges of red, suspended sediment have been documented. The red sediment originated as the fine-grained fraction of Minnelusa aquifer rocks and is probably released in collapse brecciation episodes.

Geochemistry of the Madison and Minnelusa Aquifers in the Black Hills Area, South Dakota

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As part of the Black Hills Hydrology Study, geochemical information was examined to better understand the complex ground-water flow systems within the Madison and Minnelusa aquifers and movement of ground water between these aquifers in the Black Hills area of South Dakota. Water chemistry and isotopic information was used to evaluate ground-water evolutionary processes, flowpaths, ages, and mixing conditions for the Madison and Minnelusa aquifers.

Major-ion chemistry of water from these aquifers indicates that dissolution and precipitation of calcite, dolomite, and anhydrite are important. Upward leakage of water from the Madison aquifer, which generally has low dissolved sulfate concentrations, creates potential for dissolution of anhydrite in the overlying Minnelusa Formation.

Distinctive patterns exist in the distribution of stable isotopes of oxygen and hydrogen in precipitation for the Black Hills area; thus, stable isotopes are useful as natural tracers in this area. Comparison of isotope ratios in samples from wells and springs near regional and local recharge areas indicates that regional flowpaths in the Madison and Minnelusa aquifers are largely deflected around the Black Hills area. Extensive isotopic data sets are available for evaluation of mixing conditions and general ground-water ages in the Rapid City area, where a large amount of recharge occurs from infiltration of streamflow along Boxelder, Rapid, and Spring Creeks. Each source of recharge has distinctively different isotopic values for oxygen and hydrogen, allowing for tracing of ground water from each source. A distinct division of lighter isotopic values to the north and heavier values to the south occurs in the Madison aquifer along Rapid Creek. The isotope values indicate a general convergence of flowpaths from the three streamflow recharge areas along Rapid Creek, a strong northerly component of ground-water flow from the Spring Creek area, and dominance of recharge from Spring Creek in areas south of Rapid Creek.

Tritium concentrations were used in conjunction with three lumped-parameter models to evaluate mixing conditions and general ground-water ages. Headwater springs, located in or near outcrop areas, have the highest tritium concentrations, which generally indicate relatively high proportions of modern water (less than 50 years old). Samples from wells, as a group, have the lowest tritium concentrations, which generally indicates long traveltimes to wells, although there can be large variability in traveltimes within short distances. Artesian springs generally have higher tritium concentrations than water from most wells, which indicates that artesian springs preferentially occur along high-permeability flowpaths that have relatively fast traveltimes.

WEDNESDAY, APRIL 9, 2003
SESSION 3
1:20 - 3:20 P.M.

HYDROLOGIC BUDGETS AND GEOLOGIC MAPPING

Hydrologic Budgets for the Madison and Minnelusa Aquifers in the Black Hills Area, South Dakota and Wyoming, Water Years 1987-96

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The Madison and Minnelusa aquifers are two of the most important aquifers in the Black Hills area of South Dakota and Wyoming. Quantification and evaluation of hydrologic budget components are important for managing and understanding these aquifers, and have been a major component of the recently completed Black Hills Hydrology Study.

An average hydrologic budget for the two aquifers in the study area was computed for water years 1987-96, for which change in storage in the aquifers was assumed to be approximately equal to zero. A combined budget for both aquifers was developed because most budget components could not be quantified individually for the aquifers. Inflow components include recharge from infiltration of precipitation and streamflow losses, leakage from adjacent aquifers, and ground-water inflows across the study area boundary. Outflow components include springflow (headwater and artesian), well withdrawals, leakage to adjacent aquifers, and ground-water outflows across the study area boundary. Leakage, ground-water inflows, and ground-water outflows are difficult to quantify and cannot be distinguished from one another. These components were grouped as net ground-water flow, which was calculated as the residual by using estimates for the other budget components. Estimates of average combined budget components were: 395 ft^3/s (cubic feet per second) for recharge, 78 ft^3/s for headwater springflow, 189 ft^3/s for artesian springflow, 28 ft^3/s for well withdrawals, and 100 ft^3/s for net ground-water outflow.

For nine subareas, detailed annual budgets that considered periods of decreasing storage (1987-92) and increasing storage (1993-96) also were developed. Detailed budgets in areas with complex ground-water flowpaths were useful in evaluating budget components developed for the overall budget.

Ground-Water and Surface-Water Budgets for the Black Hills Area, Water Years 1950-98

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Quantification of ground-water and surface-water budgets is important for managing water resources in the Black Hills area. For the Black Hills Hydrology Study, ground-water and surface-water budgets were developed for water years 1950-98. For the entire study area, annual precipitation averaged 18.98 inches. Of this annual average, evapotranspiration accounted for about 92 percent, surface runoff accounted for about 5 percent, and recharge to bedrock aquifers through infiltration of precipitation on outcrops accounted for about 3 percent.

Average ground-water budgets were developed for the five major bedrock aquifers (Deadwood, Madison, Minnelusa, Minnekahta, and Inyan Kara aquifers) and several minor bedrock aquifers. The overall ground-water budgets are dominated by the Madison and Minnelusa aquifers, which have the largest outcrop areas of the major aquifers in the study area. Annual recharge to all bedrock aquifers was estimated as 348 cubic feet per second (ft^3/s), of which 292 ft^3/s is recharge to the Madison and Minnelusa aquifers. Discharge of all wells and springs is about 259 ft^3/s, of which the Madison and Minnelusa aquifers account for 206 ft^3/s of springflow and 28 ft^3/s of well withdrawals. Estimated springflow and well withdrawals from the Deadwood aquifer are 12.6 ft^3/s and 1.4 ft^3/s, respectively. Estimated well withdrawals from other aquifers account for about 11 ft^3/s. Springflow also occurs from other aquifers; however, discharge rates generally are small and variable and have not been quantified.

For surface-water budgets, inflows to the study area were estimated as 252 ft^3/s and outflows were estimated as 553 ft^3/s. Storage in major reservoirs increased by about 7 ft^3/s during 1950-98; thus, net tributary flows (flows less depletions) generated within the study area were estimated as 308 ft^3/s. Consideration of combined ground- and surface-water budgets was used to estimate consumptive streamflow withdrawals of 140 ft^3/s. Total consumptive use within the study area was estimated as 218 ft^3/s, which includes estimates of reservoir evaporation and storage changes (38 ft^3/s) and well withdrawals (40 ft^3/s).

Black Hills Water Budget

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A basic premise for a hydrogeological water budget is that over a period of years the rate of water recharging an aquifer is equal to the rate of water discharging from it. For the Black Hills area of South Dakota and Wyoming, a budget analysis was originally presented by Rahn and Gries (1973) and more recently by U. S. Geological Survey personnel.

In 1973 Rahn and Gries showed an approximate water budget for the Paleozoic carbonate aquifer in the Black Hills. The largest streams were gaged approximately once per month during the years 1968 to 1970. Disappearing streams were found to recharge the aquifer at 44 cfs. Large "resurgent" springs discharged from the aquifer at 190 cfs. Some water ("x") also left the Black Hills area as "deep ground water loss". The difference between the discharge (springs plus deep ground water loss) and the stream recharge was the recharge from precipitation which would be 146 cfs + x.

The U.S. Geological Survey has completed a ten-year intensive Black Hills hydrology study and has refined our calculations. Their reports are published as a series of Water-Resources Investigations Reports. The Paleozoic carbonate aquifer in our report is essentially the same unit as the Madison and Minnelusa aquifer in their studies. Their studies included headwater spring discharge (78 cfs) from the high limestone region. For years 1987 to 1996 they found the stream recharge to the Madison and Minnelusa to be 104 cfs. This is much higher than our value of 44 cfs and probably reflects drier than normal years when our measurements were made. It also reflects the fact that they measured some small streams which we did not include. Also, because they used continuous gaging stations in many cases, their numbers are more accurate. They found the resurgent springs discharge 189 cfs. This is very close to our value of 190 cfs. Based on a theoretical infiltration model, they estimated precipitation recharge to be 291 cfs over the entire Black Hills. Since disappearing streams recharged the aquifer at 104 cfs, the total recharge = 291 + 104 = 395 cfs. Water discharge was determined as headwater springs (78 cfs), resurgent springs (189 cfs), well discharge (28 cfs), and deep loss. Thus the total discharge is: 78 + 189 + 28 + deep loss = 295 cfs + deep loss. To balance the budget so that discharge (295 cfs + deep loss) is the same as recharge (395 cfs), then the deep loss must be 100 cfs.

Our ability to understand complex hydrogeological situations improves as data collection and analysis becomes more rigorous and complete. This is the way science advances.

Flow-System Analysis of the Madison and Minnelusa Aquifers in the Rapid City Area

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The conceptual model of the Madison and Minnelusa aquifers in the Rapid City area synthesizes the physical geography, hydraulic properties, and ground-water flow components of these important aquifers. The Madison and Minnelusa hydrogeologic units outcrop in the study area on the eastern flank of the Black Hills where recharge occurs from streamflow losses and areal recharge.

Effective transmissivities estimated for the Madison aquifer range from 500 to 20,000 feet squared per day and for the Minnelusa aquifer from 500 to 10,000 feet squared per day. Localized anisotropic transmissivity in the Madison aquifer has tensor ratios as high as 45:1. Vertical hydraulic conductivities for the Minnelusa confining unit determined from aquifer tests range from 1.3×10^{-3} to 3.0×10^{-1} foot per day. The confined storage coefficient of the Madison and Minnelusa hydrogeologic units was estimated as 3×10^{-4} foot per day. Specific yield was estimated as 0.09 for the Madison and Minnelusa aquifers and 0.03 for the Madison and Minnelusa confining units. Potentiometric surfaces for the Madison and Minnelusa aquifers have a general easterly gradient of about 70 feet per mile with local variations. Temporal change in hydraulic head in the Madison and Minnelusa aquifers ranged from about 5 to 95 feet during water years 1988-97.

Dye-tracer tests, stable isotopes, and hydrogeologic features were analyzed conjunctively to estimate generalized ground-water flowpaths in the Madison aquifer and their influences on the Minnelusa aquifer. The western Rapid City area between Boxelder Creek and Spring Creek was characterized as having undergone extensive tectonic activity, greater brecciation in the Minnelusa Formation, large transmissivities, generally upward hydraulic gradients from the Madison aquifer to the Minnelusa aquifer, many karst springs, and converging flowpaths.

Water-budget analysis included: (1) a dry-period budget for declining water levels; October 1, 1987, to March 31, 1993; (2) a wet-period budget for rising water levels, April 1, 1993, to September 30, 1997; and (3) a full 10-year period budget for water years 1988-97. By simultaneously balancing these water budgets, initial estimates of recharge, discharge, change in storage, and hydraulic properties were refined. Inflow rates for the 10-year budget included streamflow recharge of about 45 cubic feet per second or 61 percent of the total budget and areal recharge of 22 cubic feet per second or 30 percent and seepage from the Deadwood aquifer 6 cubic feet per second or 9 percent. Streamflow recharge to the Madison hydrogeologic unit was about 86 percent of the total streamflow recharge. Outflow for the 10-year budget included springflow of 31 cubic feet per second or 42 percent of the total budget, water use of about 10 cubic feet per second or 14 percent, and regional outflow of 22 cubic feet per second or 30 percent. Ground-water storage increased about 8 cubic feet per second or 11 percent during the 10-year period and leakage to overlying units was about 2 cubic feet per second or 3 percent.

Karst in the Black Hills of South Dakota, an Example for the Proposed National Karst Map

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The U.S. Geological Survey, in cooperation with State Geological Surveys, the National Cave and Karst Research Institute and the National Speleological Society is preparing a new national karst map and database which will update the "Engineering Aspects of Karst" (Davies and others, 1984; scale 1:7,500,000). New karst mapping in the Black Hills provides an opportunity to display a variety of karst features which do not appear on Davies map. The central Precambrian core is surrounded by zones of rock with contrasting lithologies and differing karstic features. These zones are, from center (and oldest) outwards: (1) In the Limestone Plateau in which the Madison (Pahasapa) Limestone contains world-class caves, such as Wind and Jewel Caves; the Minnelusa Formation contains as much as 250 feet of anhydrite at depth in which a variety of intrastratal dissolution features have developed; the Minnekahta Limestone has scattered karstic features; (2) the Red Valley, in which sinkholes and enlarged solution conduits have developed in gypsum in the Spearfish Formation red beds and the Gypsum Spring Formation; (3) the Dakota hogback containing Cretaceous clastic rocks in which breccia pipes have intruded as much as 1,000 feet above their source in the Minnelusa, and (4) the Great Plains with carbonate-bearing units of Cretaceous age in which there are no known karstic features. Climatic differences between the semi-arid west, as in the Black Hills, and the humid east has resulted in striking differences in karst development. Sinkhole plains are common in the east, whereas the development of extensive residual soil which leads to collapse producing the sinkholes, is rare or absent in the Black Hills. Sinkholes and enlarged fractures developed by dissolution of gypsum are fairly common in the Black Hills, but virtually absent in the east where any surface exposures of calcium sulfate would be rapidly dissolved away.

Geologic Mapping at 1:24,000 Scale in the Black Hills

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Current geologic map coverage at 1:24,000 scale is extremely variable for the Black Hills of South Dakota. There has been no long-term, organized effort to conduct geologic mapping and to publish geologic maps at this scale. Geologic information at 1:24,000 scale for most areas of the Black Hills is commonly represented by hand-drawn field maps in personal and corporate files that are seldom available to the public. However, geologic maps at this scale are an essential foundation for addressing issues related to water supply, water quality, urban expansion, rural housing expansion, geologic hazards, mineral exploration, mine reclamation, and state and national parks.

The Geological Survey Program, South Dakota Department of Environment and Natural Resources, is currently engaged in a process to produce quadrangle-based, geologic maps at 1:24,000 scale using published, unpublished, and newly acquired geologic data. Many areas of the Black Hills have been identified where the need for geologic maps at this scale is critical to allow government agencies, consultants, and private citizens to adequately address environmental issues. Map preparation is proceeding in quadrangles where urban and suburban development, mining, mine reclamation, and aquifer recharge areas are significant concerns.

Other organizations participating in the effort thus far are the South Dakota School of Mines and Technology, the West Dakota Water Development District, the U.S. Geological Survey EDMAP Program, the National Park Service, and the University of Missouri-Columbia. Four geologic maps have been published and 18 others are in various stages of completion. An additional 20 quadrangles, or parts thereof, have been identified as priorities for future mapping. Geologic maps at 1:24,000 scale are being produced in paper and digital format to maximize versatility and user access, and to complement the use and development of a statewide geographic information system.

WEDNESDAY, APRIL 9, 2003
SESSION 4
3:40 - 5:20 P.M.

SURFACE-WATER BIOLOGY AND FLOODING

Evaluation of Water Quality, Physical Habitat, and Biological Diversity in Selected Wadeable Streams in South Dakota

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In 2000, the U.S. Environmental Protection Agency (USEPA) initiated a 5-year study called the Environmental Monitoring and Assessment Program-Western Pilot (EMAP-WP). EMAP-WP was developed in order to assess the current condition of our nation's ecological resources on both regional and national scales. The goals of the study are to develop the monitoring techniques required to identify which environmental stressors (sedimentation, nutrients, etc.) are present in or near streams and rivers with poor water quality, and to determine the relative importance of potential stressors in streams and rivers across the western United States. The resource population of interest for EMAP-WP is all perennial streams and rivers represented in USEPA's River Reach File (RF3), with the exception of the "Great Rivers" (the Columbia, Snake, Colorado and Missouri Rivers). The study incorporates a probability design for selecting potential sites that are statistically representative of the resource population of interest.

In 2001, the South Dakota Department of Game, Fish and Parks and the U.S. Geological Survey (USGS) entered into a cooperative agreement to conduct assessments of wadeable streams in South Dakota for the EMAP-WP study. USGS personnel use several monitoring techniques developed by the USEPA for conducting the ecological assessments. A number of ecological indicators are assessed at selected sites and include water chemistry, physical habitat, periphyton assemblages, benthic macro-invertebrate assemblages, aquatic vertebrate communities, and fish tissue contaminants.

During 2001, EMAP-WP was expanded to include the selection and assessment of reference sites throughout South Dakota. Reference sites were not randomly selected but were specifically selected because they represented the best attainable aquatic conditions within the seven Level III Ecoregions present in South Dakota. Inclusion of reference sites into EMAP-WP will provide a valuable mechanism for assessing the overall health of sites selected randomly throughout the State by providing standards or benchmarks against which to compare existing aquatic conditions. A list of guidelines for selecting reference sites was developed to ensure that sites are representative of a variety of hydro-geological, ecological, and land-use settings found throughout South Dakota.

At the end of the 2002 field season, assessments had been completed at 59 randomly selected sites and 13 more assessments are scheduled for 2003. To date, 31 assessments have been conducted at selected reference sites and assessments for 15 to 18 reference sites are planned for both 2003 and 2004.

USEPA contract laboratories are currently analyzing samples collected during assessments, and results will be summarized by the USGS in a project completion report planned for 2004. Data will be archived in USEPA's WATSTORE database when the study is completed.

Biological Communities as Indicators of Water Quality for Total Maximum Daily Load (TMDL) Studies

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Section 303(d) of the Clean Water Act provides that states, territories, and authorized tribes are to compile a list of waterbodies that do not attain water quality standards. These agencies must establish total maximum daily loads (TMDLs) that will allow each listed waterbody to meet water quality standards. A TMDL is regarded as a tool for implementing water quality standards.

South Dakota's surface water quality standards include narrative criteria for the protection of biological integrity of waters and prohibit the discharge of materials that produce nuisance aquatic species. Therefore, biological monitoring is an essential component of the South Dakota Department of Environment and Natural Resources (SDDENR) TMDL program.

Biological integrity has been defined as "a balanced, integrated, adaptive, community of organisms having a species composition, diversity and functional organization comparable to that of the natural habitat of a region" (Karr, 1991). In order to assess biological integrity, the SDDENR Water Resource Assistance Program (WRAP) samples algal and aquatic macroinvertebrate communities. Currently, biological assemblage data is incorporated into an index to either examine the trophic state of the waterbody or to prioritize watershed areas for the implementation of management practices. Carlson's (1977) trophic state index (TSI) is used as an indicator of lake eutrophication and for determining beneficial use support status of lakes.

The SDDENR WRAP is also compiling biological data to locate reference sites for watershed assessments and to establish more specific biological criteria.

References Cited:

Carlson, R.E. 1977. A trophic state index for lakes. *Limnology and Oceanography* 22(2):361-369.

Karr, James R. 1991. Biological integrity: a long-neglected aspect of water resource management. *Ecological Applications* 1(1):66-84.

Improved Flood Frequency Analysis

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Flood frequency analyses (FFA) provide critical information for risk based hydrologic design, floodplain management, and for the analyses of contaminant or sediment transport during severe floods. Regional frequency analysis using L-moments is a relatively recent method that offers some advantages over more conventional methods. L-moment analyses provide more accurate estimates of rare floods and provide a way to check stream flow records for errors. Most importantly, regional L-moment analysis identifies sections of streams that respond similarly to rare precipitation events. This aspect of L-moment analysis is a significant breakthrough in FFA and can be of great use for agencies looking to develop efficient and accurate ways to predict flood volumes for ungaged watersheds. Stream flow data were analyzed to investigate the applicability of regional frequency analysis in South Dakota. After an initial screening, forty-six gaging stations were tested for errors. The method identified several stations with possible errors. Further investigation found these stations to have atypical watershed scales, infiltration capacities, or inaccuracies in their record from backwater or estimated peak discharges. The gaging records of all forty-six stations were normalized by their watershed area and grouped by their hydrologic response. Five homogenous groups of stations were identified. 100-year flood estimates by L-moments were compared to estimates by a conventional flood frequency analysis method. Comparison of estimates by the two methods shows differences of –38 to 108 percent. A conceptual model for estimating peak flows for ungaged watersheds is discussed. The model is based on using GIS software to relate spatial parameters of ungaged watersheds to those of homogenous watersheds identified by L-moments. The related spatial parameters can then be used to assign ungaged watersheds to homogenous groups. Flood frequency estimates can then be found by rescaling the homogenous group distribution by an appropriate scaling factor.

Rapid-Deployment Data-Collection Networks for Wildland Fire Applications

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The Missionary Ridge Complex Fire began June 9, 2002, near Durango, Colorado and was contained on July 14, after consuming 73,400 acres. Realizing the potential hazards, the Interagency Burned Area Emergency Rehabilitation (BAER) Team submitted a request to the U.S. Forest Service (USFS) for financial support to install a satellite-telemetered rapid-deployment precipitation network and received USFS approval the same day. On that same day, the BAER team requested assistance from the U.S. Geological Survey (USGS), which operates and maintains a similar type of precipitation data-collection network for the northern Black Hills area near Rapid City, South Dakota. Within 7 days of the start of the BAER team's investigation, the rapid-deployment data-collection network was designed and funded, and by day 17 all the gages were installed and operating. Subsequently, similar gage networks have been installed in burned areas of the Grizzly Gulch and Battle Creek fires in South Dakota.

Hydrologic data-collection networks, such as the ones installed in Colorado and South Dakota, are comprised of a series of field sensors, GOES/DOMSAT satellite transmitters, ground-readout delivery systems, and solar-power modules packaged for rapid-deployment. The field sensors collect data for a variety of hydrologic measurements selected by the BAER teams to meet specific needs. Precipitation and stream stage are the most frequently acquired measurements, but other water-quality and quantity data can be collected. The data from the sensors are processed in a field data-collection platform (DCP) and transmitted to the GOES weather satellite. The processed GOES data are distributed for local use to ground-readout stations by way of the DOMSAT satellite.

The rapid-deployment network developed for BAER applications is a precipitation-gage network designed to record precipitation over the burned area in near-real time. Where feasible, the network is laid out in a pattern that will facilitate tracking the path of storms across the burned area. The DCP will accumulate and transmit data to the satellite every 4 hours. However, threshold limits are programmed into the DCP that, when exceeded, initiate an immediate "forced-random" transmission. These forced-random transmissions are used to deliver near-real time data to the user. Also, high data-rate transmitters are available now that transmit DCP data hourly. The NWS and the USGS use separate data-collection networks, which provide redundancy for the system. This type of satellite-telemetered network is also uniquely suited for mountainous terrain unlike radio-based systems that require line-of-site transmission.

Methodologies for Determining Flood Hazards in the Alluvial Fan Areas

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Alluvial fan flooding occurs on the surface of an alluvial fan area which originates at the apex and is characterized by high-velocity and two-dimensional flows; active processes of erosion, high sediment transport, and deposition; and unpredictable flow paths within the fan areas. The hydraulics of flow in the fans is different from the conventional riverine channel flow and the analysis procedures are far more complex than the channel flow. The potential of the development in the fan areas is very high but the flooding hazards in those areas are high also due to the high flow velocity, erosion potential, and mudflow. This presentation is trying to introduce the methodologies to define the flooding hazard boundary, inundation depth and flow velocity zones in the alluvial fan areas.

THURSDAY, APRIL 10, 2003
SESSION 5
8:10 - 9:50 A.M.

CONTAMINANTS AND AQUIFER VULNERABILITY

Water Availability and Emerging Contaminant Issues: Challenges for Science and Implications for the Black Hills Area

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In the American West, the task of securing sustainable water supplies for agricultural, industrial, or municipal use without adverse effects to the environment has become a daunting challenge. Aquifers near many cities are fully developed and, in some cases, ground water is being rapidly depleted. Many communities in the West are dependent upon water drawn from ground-water storage, which is unsustainable in the long term. Surface-water supplies in some areas are fully to over allocated leaving little water for stream ecosystems. Conjunctive use of surface water and ground water has become a common water-use strategy to cope with declining water availability. Treated wastewater effluent and imported surface water are the common sources of water for artificial ground-water recharge. Recent work, however, has shown that conventional wastewater treatment does not remove all organic wastewater contaminants or pathogens. In a column experiment designed to simulate artificial recharge, some organic compounds and pathogenic organisms were found to survive percolation through soil. The human health significance of organic wastewater contaminants at low concentrations in drinking water is unknown but of concern to many water consumers.

Science plays an important role in the solution of such problems by first raising the awareness of problems and, as alternative solutions are proposed, describing the potential hydrologic and environmental consequences. Water availability no longer applies to water supply only, but now, also means securing water for ecosystems and endangered species. Integrated science is being called upon to help achieve sustainability, find a developable amount of water with minimal consequences to the environment, define the physical-habitat requirements of stream and riparian ecosystems, and quantify the specific needs of individual species.

Piedmont Valley Water Quality Assessment Study

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The Piedmont Valley Water Quality Assessment Study (hereafter Study) represents a local, state, and Federal partnership effort to identify and quantify parameters which may be adversely affecting area water supplies.

The Study was conducted in an approximate 104 km^2 (40 mi^2) 'corridor' lying between Blackhawk, SD and Sturgis, SD (all in Meade County, SD). The area essentially paralleled I-90 and was contained within a valley formed by high ridge areas located on both the east and west sides of the Interstate.

To assess and to quantify this problem the Study undertook several major tasks. One task was a 'door to door' survey of private septic systems. Another significant aspect of the Study involved surface and groundwater testing. Surface water testing occurred generally with all major streams of the project area. Groundwater tests were taken at approximately 428 separate well locations. Water testing involved an analysis for nitrates, total coliforms, and fecal coliforms. The data collected by the septic survey and the water quality testing was used in the Study as a part of an overall vulnerability analysis of area water sources.

Vulnerability, for the purposes of this Study, was divided into factors of susceptibility (i.e. man-imposed factors) and of sensitivity (i.e. naturally occurring factors). Susceptibility factors included not only the septic data, and water quality data, but also parameters of land use, population density, well depth, and well density. Sensitivity factors included parameters of aquifer characteristics, soil conditions, flood plain conditions, aquifer depth, and geologic conditions.

To facilitate this analysis a GIS (Geographical Information System) program was used, which provided a graphical diagram and data base of each parameter. The vulnerability ranking of the various tracts within the project area yielded a 'picture' of areas of low, moderate, and high susceptibility, sensitivity, and vulnerability. As site conditions may change in the future, a new analysis can easily be made reflecting the effects of such changes and the revised vulnerability ranking which may result.

This presentation offers a brief review and summary of the 4 primary aspects of the Project: Septic System Reviews; Surface Water Testing; Ground Water Testing; and Vulnerability Determinations.

Mapping the Sensitivity of Aquifers to Contamination in Lawrence County

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Ground-water supplies in Lawrence County, South Dakota, can be contaminated by agricultural, urban, suburban, commercial, and industrial land uses. To address this issue, the U.S. Geological Survey in cooperation with Lawrence County and the City of Spearfish mapped the sensitivity of ground water to contamination in Lawrence County.

Sensitivity of ground water to contamination was determined by delineating hydrogeologic settings with common hydrogeologic characteristics as described in the DRASTIC method, developed by the U.S. Environmental Protection Agency and the National Water Well Association. Within the framework of 11 hydrogeologic settings, sensitivity to contamination was ranked for six intrinsic hydrogeologic characteristics: (1) aquifer media, (2) unsaturated media (3) hydraulic conductivity, (4) recharge rate, (5) depth to water, and (6) land-surface slope. The rating conventions of DRASTIC were modified to provide a relative ranking of hydrogeologic characteristics without assignment of a combined numerical score. Soil characteristics were not included because detailed digital data were not available; however, the general distribution of two soil characteristics were shown. The most sensitive hydrogeologic units included the limestones, alluvium, unconsolidated sands and gravels, and some sandstones. The least sensitive units included shales or units with interbedded shales.

Nine hundred fifty six polygons were delineated and assigned a sensitivity-unit code that represented unique groups of sensitivity rank for the six intrinsic hydrogeologic characteristics. The polygons were created by overlaying and intersecting maps that describe the geology, precipitation, land-surface elevation, and depth to water using a geographic information system. Thirty drainage areas upstream from potential streamflow-loss zones were delineated to describe an additional mechanism of transport of potential contamination. The sensitivity of ground water to contamination was presented on a 1:100,000-scale map with code and label explanations. Limitations of the sensitivity map are described to facilitate appropriate use of the map as a screening tool to compare sensitivity to contamination.

Ground-Water Vulnerability Mapping at 1:24,000-scale in the Rapid City Area, South Dakota

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Ground water in aquifers of the Black Hills region is potentially vulnerable to contamination from the land surface. In the Rapid City area, most of the population relies on water supplies that are obtained from shallow alluvium or from bedrock aquifers whose recharge areas are exposed nearby. Among these aquifers, the Madison Limestone is vitally important because it currently supplies more than half of Rapid City's drinking water. The City of Rapid City has expanded its extensive use of the Madison aquifer because of insufficient and vulnerable water supplies from shallower aquifers. Residential development is encroaching on the recharge area of the karstic Madison aquifer west of Rapid City. Previous aquifer vulnerability mapping has encompassed the entire area of the Rapid Creek watershed above Rapid City, including the Boxelder Creek and Spring Creek watersheds above Madison sinkholes. However, that basin-scale vulnerability mapping was primarily a screening tool and was not meant to delineate sensitive areas at a site-specific scale. As part of the Black Hills Mapping Initiative at South Dakota School of Mines and Technology, aquifer vulnerability mapping will be undertaken at a scale of 1:24,000, for improved resolution. The resulting vulnerability maps will be a combination of sensitivity mapping and human influences. The sensitivity mapping will include intrinsic characteristics of the aquifer materials and overlying soils. A geographic information system will be used to overlay human influences such as locations of septic tanks and drain fields, industrial sites, roads, and other factors. The overall goal is to produce vulnerability maps that delineate areas of highest hazard to ground water for 1:24,000 quadrangles along the Interstate 90 development corridor from Rapid City to Spearfish, South Dakota.

Geological Hazards, Resources, Aquifer Vulnerability, and Engineering Maps for Rapid City West 7.5′ Quadrangle: A Pilot Project of the I-90 Development Corridor

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The Department of Geology and Geological Engineering at South Dakota School of Mines & Technology has initiated research focused on identification and mapping of geologic hazards, water and mineral resources, and engineering properties for rock and soil for the Rapid City West 7.5 minute quadrangle. The base map utilized for the project is the new digital Rapid City West 1:24,000 scale geologic map by the South Dakota Geological Survey. This project forms the first phase of a larger study to quantify the natural resource base and potential geological hazards along the I-90 development corridor that extends eastward from the South Dakota - Wyoming border to Rapid City and south to Hermosa. Rapid industrial, urban, and rural development along this corridor in portions of Pennington, Meade, and Lawrence Counties places an increased stress on resources including surface and groundwater availability and protection, slope stability, and protection from water and soil contamination. Such growth also challenges city, county, state, and federal agencies responsible for anticipating the short- and long-term effects of growth on natural resources. In addition, individual developers face challenges related to water sources, sewage disposal, and ground stability. Thus, it becomes paramount to adequately define, identify, and protect natural resources and any potential hazards to individuals and/or property that may arise from incorrect use. For much of the development corridor, existing maps at scales of 1:100,000 or smaller do not display the necessary detail to adequately define the geology, geologic hazards nor surface and ground water issues. Results of this study will be 1:24,000-scale digital- and paper-derivative overlays of geologic hazards, mineral resources, depth-to-water, structure contour, and aquifer vulnerability and susceptibility maps. Use of such maps, combined with the geologic map, may become an indispensable tool for planning commissions, local building inspectors, and property owners.

THURSDAY, APRIL 10, 2003
SESSION 6
10:10 - 12:10 P.M.

ON-SITE WASTEWATER TREATMENT SYSTEMS AND SOURCE-WATER ASSESSMENT

On-site Waste Disposal: Septic Tanks and the Alternatives

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Septic tanks are the most common on-site wastewater treatment systems used by individual homeowners, especially in rural areas. The treatment of wastes within a septic tank is mainly limited to primary sedimentation or simply separation of solids from liquids. Nutrients, organic wastewater contaminants, and pathogens are only partially removed. For example, removal efficiency for particulate solids may be 90 percent or greater; however, removal of total nitrogen ranges from about 10 to 20 percent, according to a U.S. Environmental Protection Agency "Onsite Wastewater Treatment Systems Manual" that is available at http://www.epa.gov/ORD/NRMRL/Pubs/625R00008/625R00008.htm. Most of the removal of dissolved constituents that is accomplished occurs within the soil horizon, after effluent is discharged from the septic tank. Thus, removal of many constituents may be extremely limited in situations where effluent contact with the soil horizon is limited by proximity to ground water or surface water. Factors influencing removal efficiency will be discussed as part of a general overview of septic tank function and performance.

The technology of aqueous-based waste disposal has changed only incrementally since the mid-1850's when the flush toilet was introduced into the United States. Alternative methods of on-site waste disposal are available today and in common use elsewhere in the world. Composting and incinerating toilets are two examples that will be discussed.

Identification of Onsite Wastewater Treatment Systems in the Central Black Hills, South Dakota

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The quantity and distribution of onsite wastewater treatment systems are important considerations in evaluating susceptibility to contamination of public drinking water supplies. This is especially true in the central Black Hills which serve as source water areas for the Minnekahta, Minnelusa, Madison, Deadwood, and Precambrian aquifers which supply drinking water to the majority of the population in the Black Hills area. Therefore, the South Dakota Geological Survey undertook a project to identify locations of onsite wastewater treatment systems within these significant source water areas. This project was an outgrowth of an earlier effort by the West Dakota Water Development District which identified onsite systems within Pennington County west of the Cheyenne River.

The first step in locating onsite wastewater treatment systems was to identify boundaries of municipal and community wastewater systems, and identify locations of onsite systems that occur within these boundaries. Subsequently, any dwelling that was identified outside of these municipal and community system boundaries was assumed to utilize an onsite system. Digital orthophoto quadrangles were employed to locate dwellings in the most efficient manner possible. A geographic information system was used to integrate a variety of base map layers with the onsite system locations, as well as to build a table of data pertaining to individual systems. Field verification of identified onsite systems was completed as time and resources allowed.

Approximately 9,000 onsite wastewater treatment systems were identified within source water areas in the central Black Hills. Concentrations of onsite systems are greatest in areas adjacent to cities, as well as along major stream valleys where roadways and private property are commonly located. These areas coincide with sensitive components of the source water areas such as stream reaches and locations where aquifers are exposed at land surface.

Biological Water Quality Issues in the Black Hills Area

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With increasing multi-use demands on water resources of the Black Hills, managing the water quantity and quality has become a prominent issue. Water quality regulatory initiatives such as Source Water Assessment and Total Maximum Daily Loads (TMDLs) programs are being implemented to protect, maintain and remediate water quality. Water quality criteria for streams and lakes in the Black Hills are established based on beneficial uses assigned to a waterbody. For most flowing streams in the Black Hills one of the typical beneficial uses is immersion recreation. One of the critical criteria for immersion recreation is fecal coliform bacteria. Fecal coliform bacteria come from the gut of warm blooded animals (humans and animals). The presents of fecal coliform indicate the possible presents of pathogens that are harmful to human health. The criterion for fecal coliform takes two forms 1) the geometric mean of a minimum of 5 samples during separate 24-hour periods for a 30-day period and may not exceed 200 CU/100ml in more than 20 percent of the samples examined in the same 30-day period and 2) may not exceed 400 CU/100 ml in any single sample.

Recent studies on streams in the Black Hills and historical water quality data show that the criteria for fecal coliform bacteria are being exceeded in several streams in the Black Hills. The exceedence of the single sample criteria usually occurs during runoff caused by snowmelt or rainstorms. There are several possible sources for fecal coliform and include domestic and wild animals and humans. The objective of a TMDL study is to identify pollution sources and the reduction in pollutant loads necessary to meet water quality criteria. The challenge for identifying and quantifying bacteriological pollutant sources is differentiating between the different animal and human bacteria. New methods have been developed based on DNA analysis that can differentiate between human and animal and with supplemental analysis specific animal types. Recent and historical bacteriological data will be presented from studies on Spring Creek, Rapid Creek and Whitewood Creek.

South Dakota Requirements for On-Site Wastewater Treatment Systems

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The design, construction, and use of on-site wastewater treatment systems have been regulated in South Dakota since 1952. The requirements for these systems have changed through the years and were last revised in 1997.

The Administrative Rules of South Dakota 74:53:01 specify proper construction for on-site systems. The South Dakota Department of Environment and Natural Resources administer these rules and are required to review plans and specifications for all on-site systems except those conventional systems used for a home. Local governments can adopt more stringent standards to meet local planning and zoning goals.

A number of state requirements apply statewide; a number of requirements are determined based on site-specific criteria. The rules also require on-site system installers to be certified through DENR.

A successful state regulatory program, installer certification, and strong county programs in high-growth counties, provide effective treatment of wastewater for rural South Dakota.

Source Water Assessment and Protection Program: South Dakota Statewide Overview

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The preparation of Source Water Assessments for each public drinking water system is federally-mandated by the 1996 amendments to the Safe Drinking Water Act. In South Dakota, the Department of Environment and Natural Resources has been tasked with the preparation of the Source Water Assessment reports for the public drinking water systems regulated by the State. A Source Water Assessment includes 1) defining the critical area that contributes water to a ground water well or surface water intake; 2) identifying the potential sources of contamination within the source water area; and 3) evaluating the susceptibility of the water system to becoming contaminated from those sources. The purpose of a source water assessment is to provide information to water systems and communities that may have a need to implement additional protection of their drinking water quality. The assessment results will provide a basis for communities to 1) understand the potential threats to their water supply, 2) identify priority needs for protecting the water from contamination, and 3) implement appropriate protection measures. The current status of the assessments in South Dakota will be presented, as well as the state-wide overview of the results.

Delineating Source Water Areas for Public Water Supply Systems in the Black Hills Region

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Source water areas were delineated for all public water supply systems in the Black Hills region as part of the Source Water Assessment and Protection Program. Public water supplies in the Black Hills obtain water from confined and unconfined aquifers, and surface water. Major confined aquifers in the Black Hills region include the Madison Group, the Minnelusa Formation, the Inyan Kara Group, the Deadwood Formation, and the Minnekahta Limestone. Unconfined aquifers include alluvium, terraces, eolian deposits, and fractured Precambrian lithologies. Surface water is supplied by streams, springs, and lakes.

Principal tools and information used to make the delineations were (a) land-surface topography and watershed divides, (b) stream locations, (c) lithology, structure, and spatial distribution of geologic units, (d) ground-water elevations and interpolated divides, (e) estimated ground water travel times, and (f) digital base maps. These data were utilized within a geographic information system to produce the final source water area maps. Because of the complex interaction between ground water and surface water in the Black Hills, as well as significant anisotropic subsurface flow in some aquifers, conjunctive delineation techniques were employed for many sources. In areas characterized by geologically complex structural settings, detailed geologic and structural data were incorporated into the delineation procedure where available. Data for each well or surface water intake was verified through cross referencing of existing databases, site investigations, and personal communications with system operators.

Delineations were completed for 311 public water supply systems which utilize 503 individual water sources. Approximately 400 separate maps were produced to show the delineated areas.

THURSDAY, APRIL 10, 2003
SESSION 7
3:10 – 5:10 P.M.

WATER CONTAMINATION ISSUES

Use of Environmental Tracers to Characterize Ground-Water Flow in the Madison Aquifer

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Environmental tracers include natural or anthropogenic compounds or isotopes that can be measured or estimated in water that recharges aquifers. The abundance of these compounds or isotopes in water samples can be a useful tool for estimating pathways, traveltimes, and ground-water mixing. In fractured-rock aquifers, ground water moves through cracks and openings with highly variable permeability, and water samples often represent a complex mixture of recharge water. Mixing in the Madison aquifer is especially complex because of solution-enhanced openings and ground-water velocities that can exceed several hundred feet per day. Multiple tracers generally are needed for effective characterization of ground-water flow and mixing conditions.

Tritium, chlorofluorocarbons, and oxygen isotope time-series data were conjunctively analyzed for selected wells and springs in the Rapid City and Spearfish areas to estimate mixing and traveltimes in the Madison aquifer. Tritium concentrations in precipitation increased exponentially during atmospheric testing of nuclear devices in the late 1950's and 1960's and have decreased slowly ever since. Chlorofluorocarbons (CFCs) are stable, synthetic organic compounds that were developed in the early 1930's and have been used in a wide range of industrial and refrigerant applications. Historical atmospheric concentration curves have been developed for three CFCs; CFC-11, CFC-12, and CFC-113 that are commonly used as age-dating tracers with a range of about 50 years. Ratios of stable isotopes of oxygen in water are widely used as naturally-occurring tracers.

Analysis of CFCs at springs and wells where mixing and traveltimes have been estimated were used to illustrate the potential of CFCs to characterize ground-water flow. Tritium and CFCs were conjunctively analyzed at several production wells to illustrate the highly variable mixing conditions present in Madison aquifer. Oxygen isotope time-series data were used to characterize conduit and diffuse flow at a well in which tritium and CFCs indicated a large portion of young ground water. Changing oxygen isotope concentrations in streamflow recharge from Spring Creek were used as traceable input signal. Water samples were collected at about 6-week intervals over a 6-year period at the streamflow-loss zone and at a well about 1.5 miles down gradient. Linear-systems analysis of the time series data estimated a conduit flow velocity of about 1700 feet per day.

Additional environmental tracer data are needed in the Black Hills area for better understanding of ground-water flow and mixing conditions. This knowledge is especially important in evaluating water-quality trends in fractured and karstic aquifers.

Concept for Study of Contamination Potential of Bedrock Aquifers in the Black Hills Area

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Bedrock aquifers are the primary source of drinking water in the Black Hills area. Large secondary porosity and permeability from fracturing or solution enhancement creates potential in some aquifers for rapid infiltration and transport of contaminants. Extensive development in recharge areas has potential to impair the quality of important water supplies. Conversely, limiting growth and development in recharge areas also would have substantial economic implications. Thus, information regarding the potential for future contamination of bedrock aquifers in the area would be useful for water-resource managers and land-use planners.

The U.S. Geological Survey has developed a concept for performing such a study, and a preliminary concept paper is available at http://sd.water.usgs.gov/research/bedrock-contaminants. The conceptualized study would involve two primary components, including: 1) development of capabilities for estimating age (since recharge) and mixing conditions of ground water in area aquifers; and 2) collecting ground-water samples from selected locations in priority aquifers for determination of various constituents indicative of human influence (anthropogenic indicators). The highest priorities probably would be placed on the Madison and Minnelusa aquifers, which are extensively utilized and have especially large secondary porosity and permeability. High priorities also would be placed on the Minnekahta aquifer and on localized aquifers in Precambrian igneous and metamorphic rocks in the central core of the Black Hills. These aquifers also have relatively large secondary porosity and permeability and are utilized extensively for water supplies in many areas.

Extensive knowledge of ground-water ages and mixing conditions (component 1) would be needed for identification of potential sampling locations where detection of anthropogenic indicators (component 2) would be feasible. Current concentrations of anthropogenic indicators in ground water probably are extremely small in most locations because: 1) proportions of recharge influenced by current anthropogenic activities generally are small relative to total recharge; and 2) full effects of recent influences currently are not apparent because of ground-water travel times and mixing conditions. Proportions of recharge influenced by anthropogenic activities presumably will increase in some locations as population growth continues, which, in combination with ongoing displacement of relatively old ground water by younger water, eventually will increase concentrations of anthropogenic indicators in many locations. Thus, detection of extremely dilute concentrations of various constituents in ground water could provide early indications of potential water-quality problems in the future. Enhanced knowledge of ground-water ages and mixing conditions would be essential for interpretation of results.

Seasonal Response of Brown Trout in Rapid Creek to Urbanization

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Since the late 1960's and the early 1970's, the South Dakota Department of Game, Fish and Parks (SDGFP) has made several efforts to improve the brown trout fishery in Rapid Creek through Rapid City. In June of 1972, a flood with an estimated peak discharge of 50,000 cfs took the lives of 237 residents of Rapid City. Following this devastating flood, a greenway was established adjacent to the stream to minimize future damages. Since the establishment of the greenway along Rapid Creek, the City of Rapid City, SDGFP, the Bureau of Reclamation ad the South Dakota Department of Environment and Natural Resources have collaborated on bank stabilization and fish habitat improvement projects worth an estimated $750,000.

The SDGFP discontinued stocking brown trout in the reach of Rapid Creek below Canyon Lake in the early 1970’s and this wild brown trout supported approximately 1,800 to 2,000 brown trout per mile through the 1990’s. A decrease in the number of brown trout and an increase in the number of white suckers between 1985 and 1999 became a concern to SDGFP.

In 2000, SDGFP, the University of South Dakota (USD) and the South Dakota School of Mines (SDSMT) began a 3-year project to establish linkages between the health of the brown trout fishery (size, number, physiological response to environmental stressors) and current ecosystem characteristics.

We will be presenting some initial results from fish population surveys, and seasonal blood sampling surveys to quantify acute and chronic stress responses of brown trout in Rapid Creek.

Circumneutral pH Contaminant Mobility at Black Hills Gold Mines: Environmental Concerns and Long-Term Mine Closure Liability

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Continuing experience in the Black Hills, South Dakota, indicates the persistence of several natural contaminants in mine waste effluents under circumneutral pH conditions. Selenium and arsenic are the most problematic environmental contaminants observed in these effluents. The contaminants are present in ore and waste rock as naturally occurring trace elements, and under the physicochemical conditions of the mine waste repositories are mobilized by oxidation and desorption reactions into infiltrating meteoric water. Characteristics of the mine wastes, waste repository construction, and Black Hills climatic conditions, indicate these natural contaminants may persist well into the future causing long-term mine closure liabilities, a difficult challenge to both mine operators and regulators.

The Potential for Using Limestone to Remove Arsenic from Drinking Water

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Removal of arsenic from drinking water is a serious problem facing many water supply systems in the United States and the world. Arsenic is a persistent, bio-accumulative toxin. The U.S. EPA announced in November, 2001 that the drinking water standard for arsenic, formerly 50 parts per billion (ppb), will be lowered to 10 ppb by 2006 because of links to cancer. Current remediation technologies are expensive and are designed for large water treatment facilities. Lowering of the standard will put increased economic pressure on rural communities with high levels of arsenic in their drinking water. The American Water Works Association has estimated the cost of decreasing the arsenic standard to 10 ppb in South Dakota at $8.25 million.

Arsenic is readily soluble and transports easily through ground water. Observations of arsenic contamination from mining areas in the Black Hills indicate arsenic is retained by native limestone. Preliminary laboratory water treatment (batch and column) experiments with Minnekahta limestone indicate significant retention of arsenic. In batch experiments, a 100-mL volume of ~100 ppb arsenic solution was mixed with between 1 and 20 grams of limestone. Typically, 5 to 10 grams are sufficient for 80 to 90 percent arsenic removal. Generally, batch experiments are conducted for 48 hours, although batch tests conducted as a function of time show that 70 percent or more of the arsenic was removed within 2 hours. Greatest efficiency of arsenic removal is achieved with limestone of the smallest grain size and greatest surface area. Minnekahta limestone is successful in effectively removing arsenic regardless of the water's initial pH (pH 4 through 10).

A Coupled Approach Towards Estimating Mitigating Effects of CRP Practices on Regional Sediment Loading

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A combination of factor based empirical erosion model within a GIS environment and a process based field scale model is used to estimate mitigating effects of CRP practices on reduction of regional sediment loading. Topographic, land use/management and soil type data of South Dakota were collated into a usable database of factors from which the potential for soil loss via water erosion was computed using the Universal Soil Loss Equation. These magnitudes were collected into risk categories and used as the basis of a more detailed approach at the catchment scale and at the state scale. The USDA WEPP Model was used for these more detailed simulations. At the catchment scale, a specific basin's CRP strips were modulated by sub-catchment for a specific field assessment, while at the larger scale, a more generalized approach was used. Here, the previous risk categories were used as a framework by which to thematically divide these larger zones by climate, soil and slope parameters to create a distributed statistically derived estimate using iterative WEPP simulations. This approach demonstrates how local scale erosion models can be "scaled up" to provide large-scale sediment loading estimates as well as provide guidance for conservation policy.