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by

Wyoming Water Research Center  
University of Wyoming  
Laramie, WY 82071

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## ABSTRACT

Three research projects were funded under the FY 1985 program which covered topic areas in water quality problems in which organic contaminant transport between groundwater and surface waters was considered, recreational problems in which the effects of reservoir eutrophication on recreational activities and values is being assessed, and groundwater recharge through stream-aquifer interaction along fault zones. Information transfer was done principally through a symposium on Wyoming water problems, extension activities, mailings on available publications, through a newsletter, and participation at several meetings held by groups in the State of Wyoming on water issues.

A field study on the movement of organic contaminants through groundwater to surface streams created by a wood-treating facility and an oil refinery indicated that oily seeps occur into the surface stream and adversely affect the biological activity in the stream. Use of ambient toxicity tests were found to be sensitive enough to detect migration of contaminated groundwater into surface streams.

A recreational based valuation method was developed and sample tested to estimate the effects of change in water quality due to eutrophication of a reservoir on recreational benefits and uses. The method used sampled recreationalists on direct and indirect contact at the reservoir site with a follow-up questionnaire. The sample data indicate a change in user recreational activities due to eutrophication.

A field study is being conducted to investigate stream-aquifer interaction phenomena in fracture permeable Paleozoic rock outcrops. Using streamflow discharge measurements above and below the fracture permeable rock outcrop areas along with well level measurements, quantification of recharge due to streamflow during the entire year has shown that the groundwater system is being recharged directly from the stream at different rates during different times of the year.

## WATER PROBLEMS AND ISSUES OF WYOMING

Wyoming's heritage stems from her abundance of natural resources. Vast areas of range and pastureland interspersed with fertile, irrigable stream valleys have enabled the agricultural and livestock industry to become a major driving force of the State's economy. The recreation and tourism industry thrives in Wyoming as visitors come to share our wealth of scenic beauty. Beneath the land surface lies such mineral resources as coal, oil and gas, uranium, oil shale, trona, gypsum, and iron ore. Their abundance has enabled Wyoming to become a national leader in mineral production.

Water is the key natural resource controlling the development of each of these industries. As the saying goes, "in Wyoming, water is life". The rancher could not survive our semi-arid climate without water for livestock and irrigation. Without our streams, lakes and reservoirs, the quality of the recreationists' experience could be diminished. If the mineral industry is to continue to provide a major source of income in the State, water will be required. As our cities and towns continue to grow, adequate supplies of good quality water must be available.

Water availability and allocation for agriculture, mineral extraction, industrial development, recreation, and municipal consumption continue to be the center of water related problems in Wyoming. The development of new water resources through impoundment, while complying with existing interstate water compacts, is a challenge in planning and implementation. Once additional surface and groundwater supplies are

available, the equitable distribution, conservation and maintenance of quality are important and complex issues facing the State.

The State of Wyoming is considered to be a water producing state to the Colorado River Basin, the Snake River Basin, and the Missouri River Basin. Approximately 15.5 million acre feet of water is produced in Wyoming annually, with approximately 12 million acre feet obligated for downstream use through compacts and treaties. Wyoming has embarked on a large-scale water development program with the intended purpose of capturing for its use as much of the excess water produced as possible. The problems associated with the capture, diversion, dispersal, and re-use of these water resources are encompassing. In addition, being better able to forecast quantity and quality of water availability to downstream users is extremely important.

To address the problems and generate needed information associated with water conservation, development, and re-use, a truly interdisciplinary effort, well-managed and coordinated, is essential. The Wyoming Water Research Center is organized in such a manner and can call upon the diverse set of disciplinary expertise necessary to address key issues for the state and the region.

## PROGRAM GOALS AND PRIORITIES

In an attempt to address those problems most critical to the State, the Wyoming Water Research Center (WWRC), in consultation with its Research Review and Priorities Advisory Committee, established the following three major areas of water research: 1) evaluation of historical and current water use practices; 2) demand analysis and water resources planning and 3) development of water resources. These three major areas include water quality and quantity, as well as the economic and social aspects of water research. We believe this emphasis provides a very logical, step-wise approach to addressing water research needs in the State of Wyoming. Certainly, projects dealing with the economic, technical and legal aspects of historical and current water use practices are necessary for the proper analysis of need for additional water resources development, and the appropriate development of water resources can best be determined with information resulting from efforts under items 1 and 2 above. This framework should allow for a meaningful priority structure that can lead to information development germane to the needs of the State and the western United States.

In keeping with the Center's attempt to implement priority research, we have indicated how our projects relate to the various subjects falling under our three major priorities. Figure 1 is a schematic of how our federal projects meet some of our state priorities.

Figure 2 illustrates the categories of research under which specific projects fall for the federal program. These categories are based on the five-year plan and priorities set under the OWP program and are reflective of our continuous priority listing.

FIGURE 1

STATE OF WYOMING RESEARCH PRIORITIES AND PROJECTS  
FUNDED BY USGS THROUGH THE WYOMING WATER RESEARCH CENTER  
Fiscal Year 1985

RESEARCH PROJECTS FY85	STATE OF WYOMING RESEARCH PRIORITIES												
	Stream Structure & Management	Water Quality	Watershed Development & Management	Agricul- tural Uses	Information Coordination & Transfer	Underground Water Resources	Hydroelectric & Geothermal Potential	Water Quantity	Waterways Construction & Development	Economic Analysis	Trans- basin Diversion	Water Law in Wyoming	Multiple Uses
Project No. 02 - Organic Contaminant Transport in Groundwater		X				X							
Project No. 03 - Reservoir Eutrophication - Flaming Gorge		X	X						X	X			X
Project No. 04 - Stream Aquifer Interaction - Laramie Mountains	X		X			X		X					

FIGURE 2

FEDERAL RESEARCH PRIORITIES AND PROJECTS  
FUNDED BY USGS THROUGH THE WYOMING WATER RESEARCH CENTER  
Fiscal Year 1985

FEDERAL RESEARCH PRIORITIES									
	Hydrologic Processes					Legal, Institutional & Economic Consideration in Water Management & Development			
RESEARCH PROJECTS FY85	Montane Zones	Stream Systems	Groundwater/ Groundwater Recharge	Agriculture/ Conservation	Water Quality	Trans-basin Diversions Legal, Institutional and Economic Concerns	Financial Alternatives for Water Development Efficiency/Equity Consideration	Conservation/ High Energy Cost Adjustments in Agriculture	Water Planning Models
Project No. 02 - Organic Contaminant Transport in Groundwater			X		X				
Project No. 03 - Reservoir Eutrophication - Flaming Gorge					X				X
Project No. 04 - Stream Aquifer Interaction - Laramie Mountains		X	X						



RESEARCH PROJECT SYNOPSES

## SYNOPSIS

PROJECT NUMBER: 02

Start: 5/15/85  
End: 6/30/87

TITLE: Evaluation of Ambient Toxicity Tests for Detecting Ground-Water Pollution Entering Streams and Rivers

PRINCIPAL INVESTIGATORS: Harold L. Bergman and Joseph S. Meyer,  
Department of Zoology and Physiology, University of Wyoming, Laramie, WY

COWRR: 05B

CONGRESSIONAL DISTRICT: One

DESCRIPTORS: ground water, surface water, sediment, contamination, pollution sources, creosote, ammonia, ambient toxicity tests, fathead minnow, Pimephales promelas, Ceriodaphnia dubia, survival, growth, reproduction, mini-piezometers

### PROBLEM AND RESEARCH OBJECTIVES

Groundwater pollution is an emerging environmental concern in the Rocky Mountain region. Chemical analyses of water from monitoring wells can be used to trace the transport of groundwater pollutants. However, identifying and quantifying all potential inorganic and organic pollutants can be time-consuming and expensive. And a major question still arises: Do contaminant levels identified in those analyses pose environmental hazards in receiving waters?

We have adopted two relatively quick, sublethal toxicity tests using fish and invertebrates to evaluate potential effects of contaminated ground water. These tests were recently developed by the U.S. Environmental Protection Agency (EPA) for monitoring effects of industrial and municipal effluents discharged into surface waters. Our objectives in this study are to: (1) evaluate EPA ambient toxicity tests as monitors of effects of groundwater pollutants, (2) compare the sensitivity of those biological tests to the sensitivity of chemical

analyses for detecting the presence of groundwater contaminants, and (3) assess temporal variability of groundwater and surface water contamination in two Wyoming streams and rivers.

#### METHODOLOGY

During Year 1 of this two-year study, we tested water samples from two study sites: (1) the Laramie River as it flowed past a former railroad tie treating plant south of Laramie, Wyoming, from June 1985 to October 1985; and (2) Crow Creek as it flowed past an oil refinery in Cheyenne, Wyoming, from June 1985 to April 1986. Water samples were collected from five locations at each study site, and ground water adjacent to the tie treating plant was collected using Teflon mini-piezometers. Each water sample was tested for its effects on survival and growth of fathead minnow (Pimephales promelas) larvae and survival and reproduction of Ceriodaphnia dubia (an aquatic invertebrate). Chemical analyses of water samples included routine water chemistry parameters, major inorganic ions, 13 trace elements, dissolved organic carbon, reverse-phase HPLC gradients, and GC-MS analyses of organics.

#### PRINCIPAL FINDINGS TO DATE

At the Laramie River, interstitial water drawn from a piezometer set 1 m into the river sediments and just above a creosote oil seep killed all fathead minnow larvae and Ceriodaphnia adults in June 1985 and significantly reduced fathead minnow growth ( $P < 0.05$ ) in July and August 1985, compared to the upstream control. River water flowing

directly over the oil seep and at two downstream locations did not adversely affect survival, growth or reproduction compared to the upstream control during those three months. The Laramie River was rechanneled in September 1985 to avoid oil seeps and contaminated ground water. Ground water and river water collected at corresponding locations in the new river channel in October 1985 did not adversely affect survival, growth or reproduction, but river water below the downstream confluence with Spring Creek significantly decreased fathead minnow growth relative to the upstream control. Low concentrations of anthracene, phenanthrene and chrysene were detected in the toxic piezometer water in June 1985, using reverse-phase HPLC gradients. However, organics were not detected using HPLC on the other sampling dates. And no trace elements, major inorganic ions or routine water chemistry parameters differed considerably from the upstream control on any sampling date.

Crow Creek water 50 m downstream from the oil refinery's NPDES discharge either killed all fathead minnows and Ceriodaphnia or significantly reduced fathead minnow growth and Ceriodaphnia reproduction relative to upstream control ( $P < 0.05$ ) on every sampling date. This toxicity was predominantly caused by high ammonia concentrations allowed in the NPDES permit for that discharge. Waters collected in August 1985 upstream from the NPDES discharge, but still adjacent to the oil refinery property, were toxic to Ceriodaphnia. Those samples were collected one week after Crow Creek flooded because of intense hail and rain storms in August 1985; hence, the toxicity may have been caused by

contaminated ground water or storm-sewer runoff. However, no inorganic or organic contaminants could be identified as possible toxicants.

These results indicate that (1) ambient toxicity tests can be used in alkaline surface waters of the western U.S.; (2) they are sensitive enough to detect migration of contaminated ground water into surface waters; (3) they may be more sensitive in some cases than routine, inexpensive chemical analyses for detecting the presence of contaminants; and (4) instream toxicity of contaminated ground water and an industrial discharge varied considerably during Year 1. In the summer of Year 2 we will collect surface-water and groundwater samples adjacent to the oil refinery on Crow Creek, in order to more accurately identify potential sources of groundwater toxicity found in Year 1 and correlate instream toxicity with stream flow rate.

#### PUBLICATIONS AND PROFESSIONAL PRESENTATIONS

Crossey, M.J., A. Boelter and J.S. Meyer. 1986. Toxicological and chemical detection of contaminated ground water flowing into streams and rivers. Presented at the Eighth Annual Rocky Mountain Regional Meeting of the American Chemical Society. Denver, CO. June 8-12.

Crossey, M.J., A. Boelter and J.S. Meyer. 1986. Temporal variability of toxicity in a stream receiving industrial discharge. Submitted for presentation at the Seventh Annual Meeting of the Society of Environmental Toxicology and Chemistry. Alexandria, VA. November 2-5.

#### PH.D. DISSERTATION

Crossey, M.J. Determination of contaminated ground water using chemical and toxicological parameters. (Expected completion date: December 1986.)

## SYNOPSIS

PROJECT NUMBER: 03

Start Date: 5/15/85

End Date: 6/30/87

TITLE: Reservoir Eutrophication and the Value of Recreational  
Activities: A Case Study of Flaming Gorge Reservoir

PRINCIPAL INVESTIGATORS: David T. Taylor, James J. Jacobs, Edward B. Bradley, Department of Agricultural Economics, University of Wyoming, Laramie

COWRR: 05C

CONGRESSIONAL DISTRICT: One

DESCRIPTORS: eutrophication, recreation, economic benefits, travel cost method

### PROBLEM AND RESEARCH OBJECTIVES

The U.S. Environmental Protection Agency's National Eutrophication Survey indicated that most large reservoirs in the United States have encountered nutrient loading. The major concern on the part of water planners is that an excess amount of nutrients in a reservoir may result in unwanted algae blooms. The undesirable algae resulting from nutrient loading is known as Aphanizomenon, or bluegreen algae. This process of nutrient enrichment and increased algae production is called eutrophication. In most cases eutrophication of reservoirs has been associated with increased phosphorous levels. The highest percentage of phosphorous loading in most reservoirs is attributable to natural and man-made erosion.

Flaming Gorge Reservoir, located in southwestern Wyoming and northeastern Utah, is experiencing eutrophication problems. Phosphorous has been identified as the primary nutrient responsible for the dense bluegreen algae blooms at the northern end of the reservoir in late

summer and early fall. Some potential consequences of bluegreen algae growth are a degradation of fish habitat, a risk of fish mortality due to oxygen depletion, an increase in municipal water treatment costs, and a reduction in use of the reservoir for recreational purposes.

Numerous measures for controlling the symptoms of eutrophication have been proposed. The possibility of control would be enhanced if further investigation were to find that the cost of control actions are less than the value of recreational activities affected by eutrophication. Estimating the costs imposed by eutrophication is synonymous to estimating the benefits from controlling eutrophication.

The overall objective of this study is to estimate the value of recreational activity at Flaming Gorge Reservoir. With this value, the economic loss from any reduction in recreational activity associated with eutrophication can be assessed. Specific objectives required to facilitate the estimation of the value of recreational activity at Flaming Gorge include:

1. To review and evaluate alternative valuation methods that have been used to estimate the benefits from recreational activities.
2. Selection of a particular valuation method appropriate for the water quality and recreational situation at Flaming Gorge Reservoir.
3. To develop survey procedures for determining the current and potential impact of eutrophication on water-based recreation.

## PRINCIPAL FINDINGS AND SIGNIFICANCE

The literature on alternative valuation methods for outdoor recreation was reviewed and a survey instrument for identifying and valuing recreational activities on Flaming Gorge Reservoir was developed and pretested. The valuation method chosen to estimate the benefits from recreational activity at Flaming Gorge was the travel cost method. The travel cost method is developed by using actual observations on use and user characteristics from various origins to the recreational site. The wide range of costs facing individuals at different distances from a site provides considerable information about the influence of costs on participation. This information can be used to generate a demand curve from which the benefits from recreation can be derived.

The travel cost method was chosen for the following reasons. First, the literature indicated that, historically, the travel cost method has been preferred by most economists when estimating recreational benefits because it is based on observed market behavior, therefore, generating more accurate results. Second, it is an acceptable approach for estimating the effect on recreational benefits of a change in the quality of the resource. Third, information from the pretest indicates that the site characteristics of Flaming Gorge are consistent with the travel cost approach.

Two types of sampling procedures were tested: one involving indirect contact with recreationalists, the other involving direct contact. The indirect approach consisted of leaving the survey form and a return envelope on the windshields of vehicles parked along the



reservoir. While this approach proved to be an efficient use of interviewer time, the response rate was lower than desired. The direct approach consisted of personally interviewing users at various sites along the reservoir. Each interviewee was asked several questions regarding the effects of algae on his recreational use of the reservoir and given a set of questions regarding recreational use patterns to complete after he returned home. This approach improved response rate. The surveying procedure used subsequently in this study consists of both a personal interview with recreational users at Flaming Gorge Reservoir and a follow-up mail questionnaire.

The data collected in the pretest confirmed that algae growth had been a problem for some recreational users, particularly at the upper end of the reservoir. Boating, fishing, and swimming activities had been changed due to the presence of algae, generally during July and August. In addition, the number of users reporting problems with algae had increased consistently since 1980. Overall, the data from the pretest supports the basic premise that eutrophication has had a negative impact on recreational activities at the upper end of the reservoir. The actual surveying and estimation of the economic benefits from recreation at Flaming Gorge Reservoir will be completed during 1986-87.

#### PUBLICATIONS AND PROFESSIONAL PRESENTATIONS

None

#### THESES

None

## SYNOPSIS

PROJECT NUMBER: 04

Start: 5/15/85

End: 6/30/87

TITLE: Stream Aquifer Interaction as a Possible Source of Recharge to the Paleozoic Aquifer Along the Laramie Mountains, Laramie County, Wyoming

INVESTIGATORS: Steve A. Mizell, Wyoming Water Research Center and Department of Geology, University of Wyoming, Laramie.

COWRR: 2A

CONGRESSIONAL DISTRICT: One

DESCRIPTORS: surface-groundwater relations, natural recharge, groundwater, surface water, groundwater recharge, stream discharges, effluent streams, groundwater level

### PROBLEM AND RESEARCH OBJECTIVES

Development of a ground-water resource requires complete characterization of the hydrologic system in order to facilitate proper management. Resource characterization must include quantification of groundwater flow parameters, recharge and discharge. The Paleozoic Aquifer, which has been identified as a potential water resource in Laramie County, has not been fully characterized, particularly with regard to recharge. Infiltration from perennial streams is likely to be a significant portion of recharge to the aquifer that crops out in a narrow band of steeply dipping rock on the west edge of the Denver-Julesburg Basin. This work quantifies recharge to an aquifer from streams crossing the aquifer outcrop.

This work has three objectives:

1. Quantify recharge to the Paleozoic Aquifer where streams cross the outcrop in western Laramie County.
2. Map the Paleozoic rock outcrop in the study area.

3. Investigate stream-aquifer interaction phenomena when the aquifer is fracture permeable.

#### METHODOLOGY

Ground-water recharge is quantified by characterizing ground-water fluctuations and stream flow variability at a location where a perennial stream crosses the aquifer outcrop. A stream flow monitoring station was established at each end of the study reach. Stream stage was monitored continuously using a servo-manometer design developed by the U.S. Geological Survey. Manual readings of stream stage were made weekly. During site visits stream discharge was measured to produce a stage-discharge rating curve. Five shallow ground-water level monitoring wells were installed near the downstream stage recorder. One well was instrumented with a continuous float-type recorder, and all wells were measured weekly to determine ground-water levels. Precipitation was measured near the downstream stage recorder and at a location in the stream headwaters using continuously recording gages. As data were collected it was reduced to permit comparison of (1) discharge at the two stream gages, (2) stream stage and ground-water levels, and (3) precipitation and discharge.

#### PRINCIPAL FINDINGS AND SIGNIFICANCE

Stream discharge determined at the downstream site was consistently lower than discharge at the upstream site during the period December through March. In April and May discharge at the two sites was about the same and neither site was consistently higher than the other. Stream discharge appears to respond to local precipitation or short-term

snowmelt events. Seasonal runoff trends are seen in increased discharges observed initially in late February and becoming quite obvious after late March.

Comparison of ground-water levels and stream stage makes two points clear. First, the well hydrographs clearly mimic the stream stage elevations. Secondly, ground-water levels are consistently 1 ft. to 1.25 ft. lower than stage in the stream. This implies a vertical downward gradient of about 0.1.

The initial observations of upstream and downstream discharge hydrographs and of stream and shallow ground-water levels suggests that the ground-water system is being recharged by stream losses in the study reach.

During the second year of funding data collection will be continued. Additional work will be conducted to locate the principal areas of stream loss and consider the relationship between stream loss and fractured rock outcrop. Surface and shallow ground-water will be sampled for chemical analysis as an additional check on the recharge from stream losses.

#### PUBLICATIONS AND PROFESSIONAL PRESENTATIONS

None

#### M.S. THESES

This project forms part of the research for Ursula M. Wiersma's Master of Science degree. Her research will continue through the second year of the project. All her thesis and degree work is expected to be completed by August 1987.

## INFORMATION TRANSFER ACTIVITIES

### DISSEMINATION OF RESEARCH RESULTS

#### Wyoming Water '85: A Symposium on Water Resource Problems and Research in Wyoming.

Sponsored by the Wyoming Water Research Center at the University of Wyoming, May 2-3, 1985. 118 attendees. Proceedings are available.

Topics included: Water Issues and Problems--the Industrial, Municipal, Agricultural and Environmental Viewpoints; Water Economics; Water Management; Water Law; Water Development; Water Quality; Ground Water; and the Federal Role in Federal-State Relationships in Water Development Projects. Three of the presentations were the results of research funded by the U.S. Geological Survey 1984 federal program and two from state-funded projects through the Wyoming Water Research Center.

Speakers were selected from: Wyoming Mining Association, Cheyenne Board of Public Utilities, Wyoming Farm Bureau Federation, Wyoming Game and Fish, U.S. Department of Agriculture, Consulting Chemical Engineer, Casper Parks and Recreation Department, Colorado State University, Wyoming State Attorney General's Office, private law firm, Wyoming State Engineer, Powder River Basin Resource Council, Wyoming Oil and Gas Commission, Casper-Alcova Irrigation District, U.S. Forest Service, U.S. Geological Survey, former Wyoming congressman, and representatives from U.W. Departments of Geology, Range Management, Agricultural Economics, Agricultural Engineering, Mathematics, Plant Science.

Wyoming Water '86 and Streamside Zones Conference: Wyoming's Water  
Doesn't Wait While We Debate:

Sponsored by the Wyoming Water Research Center and the UW  
Agricultural Extension Service, the Wyoming Water '86 Conference was  
held in Casper, Wyoming, April 28-30, 1986.

Water and streamside zones are critical to the future of Wyoming.  
Both the state's economy and its renowned lifestyle depend upon positive  
decision-making and constructive public policy toward water and related  
sources.

This 1986 conference was the first time such a diverse subject has  
been addressed in Wyoming related to water and riparian zones. But this  
diversity reflects the wide interest within Wyoming and the breadth of  
on-going research and concern by rangeland managers and water  
administrators.

More than 200 participants from Wyoming and the West enjoyed the  
presentations first hand and took advantage of the opportunity to  
question the speakers and study more than 20 exhibits of current  
activities in Wyoming.

The proceedings provide a record of the excellent presentations  
both for the conference participants and for those who could not attend.  
Hopefully the conference has contributed to better informed public  
opinion so necessary to productive public debate concerning the future  
of Wyoming.

Topics included:

Riparian (Streamside) Systems  
Legislation and Laws  
Federal Land Management Responsibilities

Wyoming's Use and Needs of Riparian Areas  
Research Highlights

Participating Organizations were:

Wyoming Wool Growers Association  
Wyoming Department of Environmental Quality  
Governor's State Planning Coordinator's Office  
Wyoming State Grazing Board  
Wyoming Section-Society for Range Management  
Wyoming Stockgrowers Association  
Wyoming Farm Bureau Federation  
Wyoming Conservation Commission  
U.S. Bureau of Land Management  
Forest Service, USDA  
Wyoming Game and Fish Department  
Wyoming Association of Municipalities  
Chevron Corporation-Petroleum Association of Wyoming  
Wyoming State Treasurer  
Jackson Hole Alliance  
Wyoming Water Development Association  
U.S. Army Corps of Engineers  
University Departments of:  
    Range Management  
    Agricultural Economics  
    Geology  
    Zoology and Physiology  
    Cooperative Wildlife and Fisheries Research Unit  
    Forest and Range Experiment Station  
    Agricultural Engineering  
    Botany  
Montana State University  
Wyoming Department of Agriculture  
Association of Conservation Districts  
Wyoming Chapter-Soil Conservation Society of America  
Wyoming Public Lands Council  
Fish and Wildlife Service, USDI  
National Park Service, USDI  
Soil Conservation Service, USDA  
Wyoming Heritage Center

### Water Resources Data System

The Water Resources Data System (WRDS) has provided water related data to Wyoming researchers for over a decade. The system, through the years, has developed into the most comprehensive single source of surface and ground water quantity and quality, snow quantity, well levels and climatological data available for Wyoming. The broad applicability of the system is attested to by the variety of its users. The system has provided information to many state, federal, county and municipal agencies and private firms.

### Wyoming Water Bibliography

The Wyoming Water Bibliography, a service project requested by the State, is one of the most comprehensive, multidisciplinary, computer-based bibliographic storage and retrieval systems regarding Wyoming's water resources. Currently operational, the WWB contains approximately 12,500 citations which can be searched, free of charge, on a request basis. The User's Manual for the system is available and has been mailed to over 1,000 people in the State involved with water issues, including legislators, agency personnel, representatives of county and municipal governments, libraries, special interest groups and interested members of the private sector. Seminars have been given at all of the regional community colleges.

In the Fall of 1985, the Wyoming Water Research Center provided the Economic Development and Stabilization Board (EDSB) access to the Wyoming Water Bibliography via the establishment of a computer account and monies to purchase computer equipment. The EDSB now has the



capability to provide search and retrieval on the Wyoming Water Bibliography for other state agencies in addition to updating the data base itself with state documents. The Water Center can also route requests processed on the Water Resources Data System and the Wyoming Water Bibliography to EDSB, who in turn can provide depot service to WRDS or WWB requestors.

In February, Dr. Carroll Burke of the Connecticut Institute of Water Resources visited the Wyoming Water Research Center. During her visit she was given a demonstration of both systems.

Thomas A. Wesche, creator of the Wyoming Water Bibliography, has received requests for information on the development of the system and is now in the process of preparing a "package" to be distributed to interested sister Water Institutes upon request.

#### Other

Wyoming Climate Atlas. Following technical reviews, the manuscript for the Wyoming Climate Atlas has been accepted for publication by the University of Nebraska Press. The 432-page hard-cover book written by Brooks Martner of the University of Wyoming's Department of Atmospheric Science, with a foreword by University President, Donald Veal, is currently "in press". It is expected to be available for purchase by the public in Wyoming bookstores and by direct mail order from the publisher by January 1987. A selling price has not yet been established by the publisher, but it will be less than \$35 a copy. News releases and circulars announcing the availability of the Atlas will be forthcoming. Data compilation, analysis and manuscript preparation

aspects of the project conducted by Martner were funded by a grant from the Wyoming Water Research Center.

The Atlas is a reference book and a compendium of data and information on all facets of the state's climate. It provides a comprehensive summary of Wyoming's climatology. Data are presented in the form of maps, graphs and tables with accompanying narrative text. Most data compilations in the book are completely new, but it also offers previously published data heretofore difficult to obtain. The information is expected to be useful to scientists and laymen alike, especially those involved in such fields as agriculture, construction, architecture, engineering, hydrology, water management, transportation, tourism, education and research, government planning, wildlife management, surface mining and utilities operations.

State Research Activities. The Wyoming Water Research Center uses several networks to inform the public and private sector of research activities in the State. UW faculty, working through the Wyoming Water Research Center, have reported their research results in professional journals and at conferences. Research results are also disseminated through technology transfer efforts by organized workshops, seminars, etc.

Specific documents are circulated among users in the State. These are:

1. Information brochure: An information brochure on the Wyoming Water Research Center was designed to inform the public, state, and federal agencies, faculty and students of the mission, organizational

structure, and programs of the WWRC. To date, the brochure has been distributed to universities, industry, state and federal agencies, industrial organizations, and many other private and public entities.

2. "WWRC News": In "Wyoming Water Flow Newsletter", published monthly by the Wyoming Water Development Association. Subscriptions total approximately 700.

3. WWRC Progress Reports. Distributed annually to advisory committees and to Wyoming State Legislature.

4. Water Center Series Publications List.

5. Directory of Water Resources Expertise, Wyoming Water Research Center and University of Wyoming, Issue No. 1, September 1985.

6. Capsule reports on each project funded with monies available through the Center are in progress.

In addition to the above activities, the following meetings were attended and presentations made by the Water Center director, associate directors and/or staff as listed below. This past year has been extremely busy with these activities and oriented toward transferring information to potential users as well as making individuals and organizations aware of the WWRC and its activities and products.

#### 1985

- College Days, Fremont County Extension Service, February, 1985, Central Wyoming Community College, Riverton, Wyoming.
- Universities Council on Water Resources, February 4-6, 1985, Chevy Chase, Maryland.
- Wyoming Water '85, A Symposium on Water Resource Problems and Research in Wyoming, University of Wyoming, May 2-3, 1985, Laramie.

- Nonpoint Source Pollution Conference, May 19-22, 1985, Kansas City, Kansas.
- NATO Advanced Study Institute on Engineering Reliability and Risk in Water Resources, May 19-June 2, 1985, Tucson, Arizona.
- Wyoming Affairs Meeting, June 3, 1985, Cheyenne, Wyoming.
- University of Wyoming Forest Service Coordination Commission, June 7, 1985, Laramie, Wyoming.
- Governor's 1985 Resource Tour, Teton and Lincoln Counties, June 19-21, 1985, Wyoming.
- Western Acid Deposition Task Force Meeting, July 10-12, 1985, Colorado Springs, Colorado.
- Citizens Acid Rain Coordination Committee, appointed by Governor, July 22, Cheyenne and September 11, 1985, Laramie, Wyoming.
- Third International Symposium on Regulated Streams, August 4-8, 1985, Alberta, Canada.
- ASCE Hydraulic Division Specialty Conference, August 12-17, 1985, Orlando, Florida.
- Cooperative Research on Acid Deposition in the West Planning Meeting, August 23, 1985, Idaho Falls, Idaho.
- American Fisheries Society National Meeting, September, 1985, Sun Valley, Idaho.
- Mitigation of Acidification Effects Symposium, Muskoka Conference '85. Sponsored by the Federal and Provincial Governments of Canada. September 15-20, 1985, Toronto, Ontario, Canada.
- Missouri River Basin Directors Meeting, September 18-19, 1985, Denver, Colorado.
- Wyoming Water Development Association Annual Meeting, October, 1985, Casper, Wyoming.
- Upper Missouri Water Users Association Annual Meeting, October, 1985, Rapid City, South Dakota.

- Great Plains Symposium on Transition to Dryland Agriculture. Sponsored by Water Resources Committee of the Great Plains Agricultural Council and the Nebraska Water Resources Center. October 29-31, 1985, Denver, Colorado.
- Fifth Annual Georgia State Energy Advocacy Conference. Sponsored by the Citizens Advisory Council on Energy, November 6-8, 1985, Athens, Georgia.
- Wyoming Farm Bureau Federation Meeting, November, 1985, Lander, Wyoming.
- Wyoming Woolgrowers Association Annual Meeting, November, 1985, Sheridan, Wyoming.
- Colorado Water Users Association Annual Convention, December, 1985, Las Vegas, Nevada.
- Wyoming Stockgrowers Annual Convention, December, 1985, Cheyenne, Wyoming.
- National Association of Water Institute Directors Annual Meeting, December 4-5, 1985, Reston, Virginia.

#### 1986

- Water Management Seminar, January 7-8, 1986, Powell, Wyoming.
- Missouri River Basin Directors Meeting, March 21, 1986, Denver, Colorado.
- Wyoming Water '86 and Streamside Zones Conference, April, 1986, Casper, Wyoming.
- International Symposium on Flood Frequency and Risk Analysis. Sponsored by Civil Engineering Department, Louisiana State University. May 18-21, 1986, Baton Rouge, Louisiana.
- Colorado Stockgrowers Association Annual Meeting, June, 1986, Burlington, Colorado.
- Governor's 1986 Resource Tour, Natrona County, June 1986, Wyoming.

## COOPERATIVE ARRANGEMENTS

As specified in its charter, the Wyoming Water Research Center has been responsible for 1) Service, 2) Extension, 3) Research and 4) Instruction. The Director, in keeping with the Center's charter, and in cooperation with the State of Wyoming, has spent the majority of his time in organizing the following services.

### 1. Service:

#### Service to State Agencies

- Continual liaison with state agency officials. Table 1 lists cooperating state agencies and Table 2 lists specific projects performed in response to state requests.
- Basic technology transfer to state agencies and Wyoming water users and managers.
- Serve as advisor to Wyoming Water Development Commission.
- Continued attempts to integrate state and federal research programs.
- Attend Governor's Water Forum.
- Attend meetings regarding specific research projects.

#### University Service

- Serve on University committees.
- Continued effort to apprise faculty members of research needs and opportunities in water-related research.
- Work with academic standards committee on Water Resources curriculum.
- Serve on appropriate graduate student committees.
- Serve on appropriate national and international technical review panels.

TABLE 1  
COOPERATING WYOMING STATE AGENCIES

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Attorney General's Office
Conservation Commission
Department of Agriculture
Department of Environmental Quality Air, Land and Water Quality Divisions
Disaster and Civil Defense
Economic Development & Stabilization Board
Game & Fish Department
Governor's Office
Highway Department
Industrial Siting Administration
Legislative Services Office
Oil and Gas Conservation Commission
Recreation Commission
State Engineer's Office
State Planning & Coordination
Travel Commission
U.S. Geological Survey District Office
Water Development Commission
Wyoming Geological Survey

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TABLE 2

Service-to-State  
FY1985

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- Collection of field data involving evapotranspiration and associated climatic measurement--Upper Green River (Wyoming Water Development Commission and UW Agricultural Engineering) - continued financial support
  - Reconnaissance Survey: Trace Metals Concentrations in Wind River Glaciers (Western Wyoming College, Rock Springs) - continued financial support
  - Production of Input-Output Model, county-by-county water use in Wyoming (Economic Development and Stabilization Board, Wyoming Water Development Commission and Wyoming Recreation Commission) - continued financial support
  - Evaluation of Irrigation Diversions and Bank Storage Return Flows, Pinedale, Wyoming (Wyoming Water Development Commission and State Engineer's Office)
  - Development of Methodology to Determine Flushing Flow Requirements for Channel Maintenance Purposes (Wyoming Water Development Commission, Wyoming Game and Fish, and U.S. Forest Service)
  - Flood Design Frequencies for Drainage Basins in Wyoming (Wyoming Highway Department)
  - Snowy Range Watershed Laboratory - continued financial support
  - Riparian Zone Management, Muddy Creek, near Baggs, Wyoming (Ranchers, Water Quality Division of Department of Environmental Quality, U.S. Department of Agriculture, Bureau of Land Management, Soil Conservation Service)
  - Livestock Stocking Rates/Fifteen Mile Creek near Worland, Wyoming. (Ranchers, Water Quality Division of Department of Environmental Quality, U.S. Department of Agriculture, Bureau of Land Management, Soil Conservation Service)
  - Enhancement of Aquatic/Riparian Ecosystems (Pole Mountain) (Wyoming Water Development Commission, Wyoming Game and Fish, and U.S. Forest Service)
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TABLE 2  
(cont.)

Service-to-State  
FY1985

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- Conveyance Losses in Natural Stream Channels (Wyoming Water Development Commission, State Engineer's Office, Board of Control)
  - Nutrient Loading to Flaming Gorge Reservoir-Limnology Study (Bureau of Land Management, Department of Environmental Quality, State of Utah)
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### Service to Sister Institutes

- At request of Montana WRRI, Director was invited speaker before the Water Policy Committee of the Montana State Legislature to share success WWRC has had with Wyoming State Legislature.
- Director of Connecticut Institute of Water Resources visited with Wyoming Water Research Center personnel, toured facilities, and exchanged ideas and information.

### Other

- Continued effort to be cognizant of regional and national water issues and research opportunities.
- Transfer of research results to appropriate users.

## 2. Extension

One of the four major missions of the WWRC involves extension activities. The WWRC believes in a strong water resources extension effort. The Associate Director for Extension and Information works in cooperation with the UW Agricultural Extension Service to develop expanded education programs among researchers conducting water-related research. It is our intention that both state and federal research results be packaged and presented in a useful and satisfactory manner to maximize the utilization of research effort and results.

## 3. Research

### ● Federal Program FY85

Research accomplishments of the FY85 Federal Water Research Program were reviewed by the Director. The results of the projects sponsored with FY85 monies have been provided to the Center's advisory committees and presented at professional meetings.

- Federal Program FY86

The Director solicited proposals under the FY86 Federal Water Research Program from interested faculty on campus. Five proposals were received and reviewed by state agencies and regional Water Institute/Centers--four (three continuing, one new) were funded under the program.

#### 4. Instruction

The Wyoming Water Research Center is cooperating with academic departments throughout the campus to provide master of science degree programs which contain high quality multidisciplinary training in water resources. The master of science degrees offered through these affiliations are awarded as specialty options within the existing master of science programs currently housed within the sponsoring departments. The water resources emphasis will be acknowledged on the graduate transcript and thereby certify to potential employers that the candidate has completed an attractive in-depth multidisciplinary course program in the broad area of water resources. There are five students enrolled in the program at present.

#### ADVISORY STRUCTURE

The organizational structure and operational procedures of WWRC for a high degree of accountability and relevance to state and regional water research seems to be working well. In 1982, the WWRC was restructured to include a Research Review and Priorities Committee (RRPC) appointed by the Governor of the State of Wyoming and the President of the University. The membership was designed to reflect the interests

and inputs of the Executive Office, the legislative branch of government, the academic community and the University administration (Table 3). The Committee meets at least three times annually to discuss Water Center activities, research needs as they may have been perceived to change, and to approve projects presented.

Prior to presentation of projects to the Advisory Committee, a review process that includes relevant state agencies, in addition to scientific peer review, has been completed. This process has insured good science directed toward issues meaningful to water research needs in the state and the region.

A Citizens Water Issues Advisory Council (CWIAC) was formed in January 1984 and consists of members selected by the Governor and the University of Wyoming President (Table 4). The Council was formulated to represent a) agriculture, b) recreation, c) municipalities, d) National Forest Service, Bureau of Land Management, Bureau of Reclamation, U.S. Fish and Wildlife Service, e) consulting engineers, f) State Legislature, g) industry, h) environmental interests, i) private citizens, j) legal profession, k) political action groups (e.g., League of Women Voters), l) Wyoming Higher Education System, and m) state agencies. The Council is charged with collecting input from constituencies, water experts within and outside the State, and other available sources, identifying water concerns and transmitting those concerns to the Research Review and Priorities Committee. The Council meets at least twice a year; one of which is a joint meeting with the Research Review and Priorities Committee.

TABLE 3

WYOMING WATER RESEARCH CENTER  
Research Review and Priorities Committee

Chairman:

Paul Schwieger  
Economic Development &  
Stabilization Board  
Water Division  
Herschler Building  
Cheyenne, Wyoming 82002  
(307) 777-7284

Executive Secretary:

Harold L. Bergman  
Acting Director  
Wyoming Water Research Center  
Room 151, VA Building  
University of Wyoming  
(307) 766-2143

U.W. Appointees:

Donald L. Veal, President  
Office of the President  
Old Main, Room 206  
(307) 766-4121

Dennis H. Knight  
Department of Botany  
Aven Nelson, Room 135  
(307) 766-3291

Ralph DeVries  
Vice President for Research  
Old Main  
(307) 766-5353

Quentin Skinner  
Range Management  
Agriculture Bldg., Room 2028  
(307) 766-4139

(All University of Wyoming, Laramie, Wyoming 82071)

Executive Appointees:

Governor Ed Herschler  
State Capitol Building  
Cheyenne, Wyoming 82002  
(307) 777-7434

Warren White  
State Planning Coordinator  
Herschler Building  
Cheyenne, Wyoming 82002  
(307) 777-7574

Willard Rhoads  
Water Development Commission  
P.O. Box 637  
Cody, Wyoming 82414  
(307) 587-3787

Legislative Appointees:

George R. Salisbury, Jr.  
Representative, Carbon County  
Savory, Wyoming 82331  
(307) 383-2430

Donald R. Cundall  
Senator, Goshen-Platte County  
Wendover Route  
Guernsey, Wyoming 82214  
(307) 322-3311

TABLE 4

## WYOMING WATER RESEARCH CENTER

## Research Review &amp; Priorities Committee

## CITIZENS WATER ISSUES ADVISORY COUNCIL

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Myron Goodson, Chairman  
Citizens Water Issues Advisory Council  
Box 429  
Sundance, WY 82729  
(307) 283-2407

Walter Yose, Jr.  
P.O. Box 94  
LaBarge, WY 82123  
(307) 386-2322

Beryl Churchill  
848 Road 10-A, Route 3  
Powell, WY 82435  
(307) 754-4865

Philip Hocker  
P.O. Box 458  
Wilson, Wyoming 83014  
(307) 733-6116 or 733-6345

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John Morris  
10401 Experimental Farm Road  
Cheyenne, WY 82009  
(307) 634-7561

Jim Rumery  
North Portal Road  
Riverton, WY 82501  
(307) 856-7477

Russell Michael  
Route #2  
Torrington, WY 82240  
(307) 788-1139

9/86

# TRAINING ACCOMPLISHMENTS

Shown by fields of study and training levels indicated, the numbers of individuals participating in projects financed in part through the Fiscal Year 1985 Program.

Training Category	Training Level				
	Under-Graduate	Graduate		Post-Ph.D.	Total
		Master's Degree	Ph.D. Degree		
Engineering Agricultural Civil Environmental					
Biology					
Ecology					
Fisheries, Wildlife and Forestry					
Agronomy					
Chemistry					
Hydrology		1			1
Resources Planning					
Law					
Economics			1		1
Geography					
Other - specify					
Environmental Toxicology	3		1		4
TOTAL	3	1	2		6