COLORADO WATER

Newsletter of the Colorado Water Resources Research Institute, Fort Collins, Colorado 80523

WATER ITEMS AND ISSUES . . . July, 1989

CALLS FOR PAPERS

COLORADO GROUNDWATER ENGINEERING AND MANAGEMENT CONFERENCE, February 26-27, 1990, Denver, CO. Sponsored by CWRRI and the Colorado Division of Water Resources. See Page 3.

CONSERV 90, THE NATIONAL CONFERENCE AND EXPOSITION OFFERING WATER SUPPLY SOLUTIONS FOR THE 1990s, August 12-15, 1990, Phoenix, AZ. See Page 4.

NOTES

The WATER ISSUES FORUM will not meet in the Summer. Meetings will resume in the Fall.

HEC-2 USERS CONFERENCE, August 10-11, 1989, Denver. Cosponsored by FEMA, the Colorado Section of ASCE, Resource Consultants, Inc. and CWRRI. See Page 15.

A copy of Evaluating Water Use Efficiency, a paper given by Marvin E. Jensen at the Colorado Water Engineering and Management Conference, is provided as an attachment to COLORADO WATER.

Colorado State University

COLORADO GROUNDWATER ENGINEERING AND MANAGEMENT CONFERENCE
FEBRUARY 26-27, 1990 (tentative date)
DENVER, COLORADO

CALL FOR PAPERS

Conference Objective

The purpose of the Colorado Groundwater Engineering and Management Conference is to evaluate technical management methods necessary to solve state groundwater problems. The Conference will involve the presentation of contributed papers, invited papers and discussion about groundwater issues.

Audience

The Conference will be of interest to engineers, attorneys, hydrologists, geologists, well drillers, government officials, water managers, water users, utility contractors, researchers and citizens with a general interest in Colorado water.

Conference Topics

- Groundwater Management Techniques
- Determination of Aquifer Characteristics
- Aquifer Restoration Techniques
- Groundwater Quality Monitoring
- Hydrogeology
- Modeling and Computer Applications
- Legal and Institutional Factors and Role of Governments
- Groundwater Recharge and Conjunctive Use
- Management of Nontributary Aquifers
- Protection of Aquifers From Contamination
- Groundwater Classification Systems
- Well Technology
- High Plains Issues

Cosponsors Sought

The Conference is organized by the Colorado Division of Water Resources and the Water Resources Research Institute. Other agencies or public organizations or associations with an interest in groundwater are invited to cosponsor.

To Submit a Paper for Consideration

Send a 200-word abstract by **1 November 1989** to:

Water Resources Research Institute
Colorado State University
Fort Collins, CO 80523
(303) 491-6308

CONSERV 90

The National Conference and Exposition offering Water Supply Solutions for the 1990s

August 12–15, 1990 • Phoenix Civic Plaza • Phoenix, Arizona

CALL FOR CONTRIBUTORS

Recent occurrences have forced the American public to take a closer look at the issue of water supply in the United States. Increasing drought cycles, potential changes in temperature resulting from the widely reported greenhouse effect, inadequate surface and ground water supplies in some regions and localities, and lost water sources resulting from pollution deemed irreversible or economically infeasible to remediate have given the general public the impression that there is an impending water crisis. Knowledgeable authorities in water supply agree that these are serious issues facing the country.

CONSERV 90 is a multifaceted meeting that will address water supply concerns and examine more closely beneficial conservation and improved management solutions. The conference is being jointly sponsored by: American Society of Civil Engineers, American Water Resources Association, American Water Works Association, and the National Water Well Association. CONSERV 90 will help **you** prepare for the unavoidable changes in demand and distribution of water resources in the 1990s.

If you would like to take an active part in this monumental program, send for a program brochure that includes guidelines for contributors. Following is a program overview.

Issues That Will Be Addressed

CONSERV 90 will focus on water supply issues in relationship to 11 areas of interest (below). Under each heading, there are as many as 20 suggested topics to provide ideas for submissions. The "Call for Contributors" brochure contains a complete list of program topics.

Agricultural
Municipal
Industrial
Residential
Educational
Reuse
Drought Management
Watershed Management
Planning
Water Transfer
Water Resource Management

Educational Modes

CONSERV 90 will feature many types of presentations. With 11 educational modes, water supply issues will be discussed and examined from many perspectives. Listed below are the educational modes.

20-Minute Technical Presentations
- **Case studies**
- **State-of-the-art technologies**
- **Innovative management techniques**
- **Political strategies**
- **Socio-economic considerations**
- **Conflict management**

Workshops (one, two and three hours)

Short Courses (half-day and full-day)

Panel Discussions

Discussion Sessions

Poster Sessions

Software Displays/Software Exchange

Water Conservation Film Festival

Book Fair

Field Trips

Regional Sessions

Note — The program brochure contains a brief description of each educational mode.

Instructions for Submissions

To make a submission for any segment of the meeting, a 250-word summary must be forwarded to the CONSERV 90 Program Committee along with the Summary Submission Form. The submission form can be found on the "Call for Contributors" brochure. Deadline for submissions is **October 16, 1989.**

Additional Information

The "Call for Contributors" brochure contains detailed information about CONSERV 90. To receive a copy, contact: CONSERV 90, 6375 Riverside Dr., Dublin, OH 43017, (614) 761-1711.

Early registration fees: Members $195; Non-members $245. **Persons belonging to a sponsoring organization or a promotional partner will receive the member rate.**

THE CHANGING WATER AGENDA

by
Neil S. Grigg

The national network of water research institutes celebrated its 25th anniversary in April. The commemorative brochure produced for the anniversary credits President Emeritus William E. Morgan of Colorado State with strong help in establishing the program. Henry P. Caulfield, Jr., Professor Emeritus at Colorado State, also receives credit. The main proponent of the program was Senator Clinton P. Anderson of New Mexico. Reading about Senator Anderson's career in a new book, Conservation Politics (University of New Mexico Press, 1985), reveals a lot about how our water agenda has changed in just 25 years.

Senator Anderson, in the tradition of Teddy Roosevelt, was a staunch advocate of resource conservation. The Water Resources Research Act was passed in 1964 during the Eighty-eighth Congress, which Senator Anderson called "the most conservation-minded Congress in U.S. history." Accomplishments of this Congress also included the Wilderness Act, the Land and Water Conservation Act, the Outdoor Recreation Act, the Public Land Law Review Commission, and measures establishing new national parklands.

In the past conservation had a somewhat different meaning than it does today. The agenda has changed continually. It was widespread water shortages in the 1950s that spurred the nation to action in the water resources field. As a result, Montana's Senator Mike Mansfield introduced legislation to create the Senate Select Committee on National Water Resources, and it was this committee that gave impetus to the Water Resources Research Act.

The Select Committee's charge was to survey the "amount, the character, and the timing of water resources development necessary to meet the national requirements by 1980." The committee's report recommended construction of new storage facilities, more effective conservation and use of existing supplies, and development of new sources through desalting and weather modification. Desalting and weather modification have not lived up to expectations, but the combination of new storage and more effective use of existing supplies should ring a bell for those interested in a balanced approach to water resources development.

Since the time of the Select Committee the range and diversity of water research topics has expanded to an incredible extent. In 1988 the national institute network allocated 46 percent of its funds to groundwater research. After groundwater, the following topics received funding in the order shown: irrigation; heavy metals; wastewater treatment; policy; eutrophication; non-point sources; drought and conservation; acid precipitation and flooding. Surprisingly this research agenda does not concentrate on developing water supply, in spite of recent droughts and shortages. It does, however, focus on protecting water supplies.

Water policy and management has turned out to be more complex and politically difficult than some expected. There are many more issues to deal with than simply providing water supply, but supply and contamination still dominate lists of critical issues.

The national water agenda has clearly changed. I can't think of a more appropriate subject for research, debate and testing of the democratic process than finding solutions to our many water resources management problems.

NAWID CELEBRATES PROGRAM'S 25TH ANNIVERSARY AT ANNUAL MEETING

The National Association of Water Institute Directors (NAWID) celebrated the 25th anniversary of the Water Resources Research Act and the institute program at its annual meeting in Washington, D.C. April 26-28, 1989.

Prepared especially for the meeting and anniversary were a pamphlet, "Water Resources Research Institutes at U.S. Universities" (NAWID); and two publications, A Guide to the National Water Research Institute Program (NAWID) and The Water Resources Research Program: Lessons from the Past, Perspective on the Future (prepared for NAWID by the Montana Water Resources Center). The Texas Water Resources Institute prepared a 12-minute video tape, "Water--The Life-Giving Resource," which documents the contributions of state institutes and centers to water resources management throughout the nation.

The Water Resources Research Program: Lessons from the Past, Perspective on the Future, notes that approximately 250 projects addressing water problems of national, state and local concern are completed each year. A summary of the program's first ten years, prepared at the request of the Senate Interior Committee in 1976, found that 30-40 percent of the technical literature published in the water resources field during that time came from the water institute program. Yet, the program only

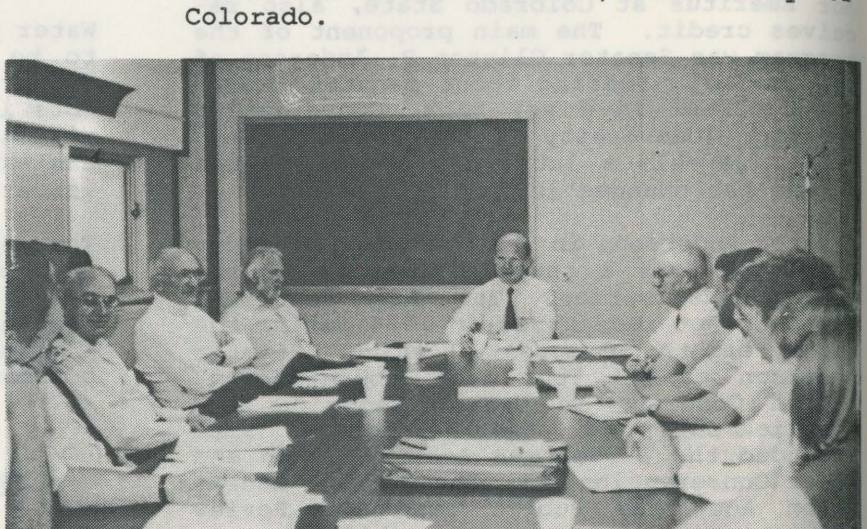
accounted for approximately ten percent of the total expenditures on water research during that period. Another important accomplishment is the training of scientists and engineers throughout the program's 25-year history.

CWRRI 1989-90 PROGRAM WILL INCLUDE ELEVEN NEW WATER PROJECTS

The Institute's 1989-90 program consists of 11 research projects that address high-priority Colorado water problems. Four projects involve groundwater issues concerning drinking water, agriculture, industry, and biological indicators; two projects address Front Range water issues; two projects concern models of groundwater and surface-water interaction; and the other three projects will examine the issues of streamflow in the Colorado River, water transfers and acid mine drainage. The projects, selected after review by CWRRI's Research Planning Advisory Committee and Technical Advisory Committee, are briefly described below.

Screening Methods for Groundwater Pollution Potential from Pesticide Use in Colorado Agriculture. The Environmental Protection Agency recently reported finding residues of 46 different pesticides in the groundwater of 26 states. EPA proposes state action to restrict pesticide use at the local and regional level based upon soil/aquifer vulnerability to pollution. This project will compare the abilities of several screening models to predict groundwater pollution from pesticide use in Colorado agriculture. Investigators: Deanna S. Durnford, Jim C. Loftis and Kenneth W. Knutson, Colorado State University.

Field Demonstration of Biological Denitrification of Polluted Groundwater. The water supplies of numerous Colorado communities are polluted with nitrates. In most shallow wells along the South Platte River nitrate concentrations exceed the maximum level allowed by federal Safe Drinking Water primary standards. Laboratory research has demonstrated that nitrates can be removed by biological denitrification. In this project a previously developed reactor will be installed at a field site to test its performance under operating conditions typical of a small Colorado community. Investigators: JoAnn Silverstein and Nevis E. Cook, University of Colorado.



CWRRI Technical Advisory Committee Reviews Proposals, April 20, 1989.

Adsorption of Copper, Cadmium and Zinc on Suspended Sediments in a Stream Contaminated by Acid Mine Drainage: The Effect of Seasonal Changes in Dissolved Organic Carbon. The release of cadmium into the Upper Arkansas River near Leadville may prevent trout from maturing, which seriously impacts the Upper Arkansas fishery. An important factor in metal adsorption is the amount of dissolved organic carbon adsorbed onto suspended particulates. This project will determine the extent of dissolved organic carbon adsorption onto suspended particulates and the subsequent or competitive adsorption of copper, cadmium and zinc. This information is critical to the development of a mathematical model that describes metal transport in the Arkansas River. Investigators: Donald L. Macalady and Stephen R. Daniel, Colorado School of Mines.

Enhanced Microbial Reclamation of Water Polluted with Toxic Organic Chemicals. Groundwater quality protection and the

reclamation of polluted groundwaters are major concerns in Colorado and throughout the West. This project is developing a microbiological system to reclaim groundwater degraded by toxic organics (PCP, TCE and DPE) and to optimize conditions for the maximal possible rate of toxic chemical biodegradation. Another consideration is the removal of trace concentrations of toxic organic chemicals from contaminated water. Investigator: Steven K. Schmidt, University of Colorado.

Potential Role of the South Platte Tributary Aquifer for Solving Front Range Drought Water Supply Problems: Hydrologic and Economic Considerations. Improved management of surface and groundwater supplies will become even more imperative in Colorado as prospects lessen for storage projects. This project will determine if some modifications to Colorado water law and administrative practice, combined with investments in pumping and recharge facilities, can be used to provide water for peak requirements brought on by drought. In addition, it will provide economic input for a parallel study of the Denver deep-aquifer potential at the Colorado School of Mines. Investigator: Robert A. Young, Colorado State University.

Hydrologic Aspects of Revegetation Following Water Transfers from Irrigated Agriculture. As Front Range cities acquire water rights from Colorado's agricultural sector, maintaining formerly irrigated farms and ranches will require a long-term solution. This project will study the hydrology of revegetation including water balance, soil-moisture retention, evapotranspiration measures and possible irrigation scheduling for stand establishment. The research will be incorporated with a project developed by the City of Aurora to revegetate formerly irrigated farmland in the Arkansas Valley. Investigator: J. Ernest Flack, University of Colorado.

Investigation of Groundwater Management Practices in the Denver Basin. Natural and artificial recharge of groundwater in the Denver basin may provide a water management alternative during drought. This project will use a previously developed three-dimensional flow model of the Denver Basin to evaluate the net impact of alternative water management plans under a variety of climatic conditions. It will include current water use in the Denver Basin, potential future annual use of groundwater, and additional groundwater use in times of drought accompanied by varying degrees of artificial recharge. Investigator: Eileen Poeter, Colorado School of Mines.

Development of a Soil-Stream Multiple Aquifers Interaction Three-Dimensional Model for Conjunctive Management. Compact requirements on surface water rights may severely limit Colorado's available water supply at critical times. A good example of this is the Rio Grande compact. Full integration of groundwater pumping with surface water management could reduce this problem. This project will improve the existing SAMSON Model, recently chosen by the South Platte Basin Water Management Committee for its river basin study, by incorporating a multiple-aquifers model as an optional module, and also a realistic description of the unsaturated zone that links the surface water supplies with the groundwater. Investigator: H.J. Morel-Seytoux, Colorado State University.

Improving Streamflow Forecasts for Colorado River Systems. Colorado water officials need accurate streamflow forecasts to achieve maximum storage and deliver water supplies with a minimum of waste, in accordance with water right seniority. They also need forecasts of inflows to reservoirs during the spring and summer to plan supplemental releases for irrigation, domestic and hydropower demands. This project will develop technology for Colorado's satellite stream monitoring system to forecast daily streamflow in selected Colorado river systems and compare the new forecasting methods with approaches currently used by agencies that administer Colorado's water resources. Investigator: Jose D. Salas, Colorado State University.

Development and Laboratory Verification of Models of Surface-Subsurface Water Quality Interaction. Pollutants from irrigation practices and urban runoff are affecting the water quality in almost all of Colorado's rivers. They can also affect groundwater due to interaction between surface and groundwater systems. This project will develop numerical models of solute transport between surface-groundwater systems that are in dynamic interaction, verify them in the laboratory and then conduct a case study in Colorado. Investigator: Tissa Illangasekare, University of Colorado.

Response of Groundwater Faunas to Groundwater Quality Degradation. Colorado relies on groundwater as a source of drinking water and to irrigate crops, and nowhere is this more important than in the South Platte River Basin. Previous Institute research revealed the existence of a diverse and abundant groundwater fauna in the alluvial aquifer of the South Platte River system. This project will evaluate

the use of these groundwater animals as an early-warning system to detect water quality degradation and to measure the success of groundwater reclamation efforts. Investigator: James V. Ward, Colorado State University.

The CWRRI 1989-90 research program will provide training and partial funding for 14 undergraduate, masters and doctoral students who will work on the projects.

HOUSE PASSES REAUTHORIZATION BILL

On Tuesday, June 6, H.R. 1101 passed the U.S. House of Representatives by a roll call vote of 336 to 74. The bill extends the authorization of the Water Resources Research Act through FY1993. It passed despite a position paper circulated to Congressional offices by the Administration, which sought to cut the authorization from $41 million to $5 million. The bill has been delivered to the Senate Committee on Environment and Public Works.

WATER INTERIM COMMITTEE SCHEDULES MEETINGS

Created by the Colorado Legislature in its 1989 session (H.J.R. 1030), the Water Interim Committee's primary task is to conduct a comprehensive study of water issues including water resources, water rights administration, water quality, water quantity, and water conservation measures. Senator Tilman Bishop, Committee Chairman, has announced the following schedule of six meeting dates:

July 12, Wednesday
August 3, Thursday
August 24, Thursday
September 14, Thursday
October 5, Thursday
October 26, Thursday

The first meeting will focus on drought conditions across the state. The committee will also discuss potential agenda topics for future meetings. If you are interested in the committee's activities, contact Marilyn Salazar, Council staff, at (303)866-3521.

WATER SUPPLY OUTLOOK

This year's June snowpack is only 51 percent of last year, and precipitation totals also average below normal across the state, although some areas received amounts greater than average for May. Streamflow volumes of less than 65 percent of normal are forecast for the Gunnison, Yampa, White, Arkansas and North and South Platte River Basins. Remaining Basins can expect volumes of 65-75 percent of normal, with the highest forecasts in the headwaters of the Rio Grande Basin at nearly 80 percent of average flows. Forecasts of only 50 percent of normal are projected for the main stem of the Gunnison and Arkansas Rivers.

Attached to this newsletter is a tabulation of the annual runoff for the period of record for seven of Colorado's major rivers. It was prepared by Leonard Rice Consulting Water Engineers, Inc. Mr. Rice noted that this is the second year in a row that the forecast is for below-average runoff in all seven basins.

Source: USDA, Soil Conservation Service

SOUTHWEST COLORADO SUFFERS WORST DROUGHT IN DECADE

The town of Dove Creek in southwest Colorado calls itself the "Pinto Bean capital of the world." Many farmers in the region practice dryland farming, relying only on Mother Nature to water their crops. Bob Seaton, Extension Agent for the area's Dolores and Montezuma counties, says a dry fall, winter and spring killed 15,000 acres of alfalfa in the counties, and in some areas two-thirds of the wheat crop also has been ruined. He said 1.8 inches of moisture, in contrast to the usual nine to 10 inches, has caused the worst drought he's seen in 15 years. And if rain doesn't come soon, the region's thousands of acres of pinto bean crops will be in trouble.

Source: Denver Post, June 26, 1989.

JUNE RAINS HELP, BUT WATER SHORTAGES STILL FORECAST

- Northern Colorado farmers got a reprieve from near-drought with June rains, but still streamflow levels are about 50 percent below normal.

- By July 4, Horsetooth Reservoir at Fort Collins will be about 29 feet below capacity and year-end projections for September put the lake level at about 62 feet below capacity.

- In Aurora, mandatory water restrictions may come next year if the snowfall is as sparse as that of the 1988-89 winter. Aurora can't use 16,000 acre-feet of Arkansas River water unless it can plant enough prairie grass to prevent dust-bowl conditions caused by the removal of water from irrigated farmland.

- Castle Rock's water supplies are so limited that town officials plan to impose conservation restrictions even if this summer is wetter than normal.

- The Metro Denver area's biggest water shortage would occur in Westminster if it suffered a drought as drastic as those of 1953, 1954 or 1955.

- Farmers in seven Colorado counties already have requested federal disaster assistance. Farmers in six southeastern Colorado counties (Baca, Prowers, Kiowa, Cheyenne, Kit Carson and Bent) abandoned more than 60 percent of the wheat crop this year.

- Federal officials say Colorado's lowest-flowing rivers this summer will probably be the South Platte, Yampa, Gunnison and Dolores. No Colorado river is expected to contain more than 90 percent of its typical streamflow.

- A joint federal-state Drought Water Availability Task Force will identify and monitor Colorado's driest counties to expedite relief if drought conditions worsen. Both municipal and agricultural water supplies will be monitored.

- Some areas of the Western Slope had been without rain for more than 60 days in early June. The state's Division of Disaster Emergency Services said a continuing dry period could threaten wildlife and fish habitat as well as small towns that depend on direct streamflows for their water.

- Directors of the Northern Colorado Water Conservancy District will deliver a 100-percent quota of Colorado-Big Thompson water this year, providing an additional 93,000 acre-feet of water to northeast Colorado. Since 1957 the district has set 100-percent deliveries only four times and increased the delivery to 100 percent only three times.

- In Colorado's San Juan Basin, the overall rangeland rating is 48 percent of optimum conditions. A year ago at this time the figure was 80 percent, and the five-year average is 84 percent.

Sources: Coloradoan, May 26, 30, 1989 and June 7, 15, 1989. Denver Post, May 7,10,11 and June 2,9,10, 1989.

DROUGHT NETWORK NEWS

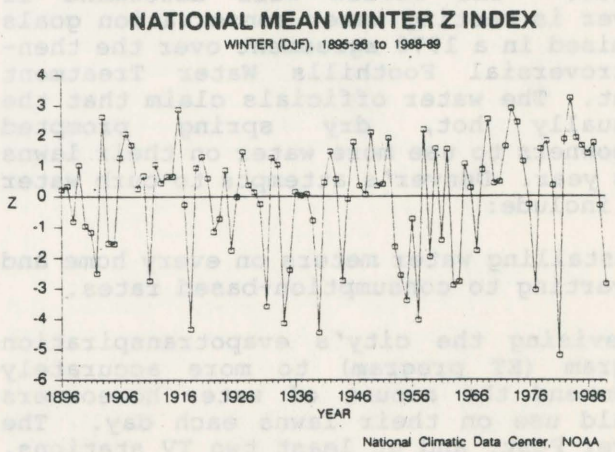
In January, 1989, the first issue of "Drought Network News" was distributed. The newsletter is published by the International Drought Information Center at the University of Nebraska in cooperation with the World Climate Program Office of NOAA. In each issue a principal drought region is featured. The second issue, May 1989, concentrates on Australia and some of the activities in progress there, but there are also articles on Hungary, Central India, China, and Ethiopia. Information on the continuing drought in the United States is included.

Subscriptions to "Drought Network News" may be obtained, free of charge, by writing to Jan Schinstock, Center for Agricultural Meteorology and Climatology, 236 L.W. Chase Hall, University of Nebraska-Lincoln, Lincoln, NE 68583-0728.

"Drought Network News" encourages readers to submit information on drought and its impacts.

HISTORICAL PERSPECTIVE: DROUGHT IN THE U.S.

Winter 1989 was the fourteenth driest since 1895, and the fifth consecutive winter with precipitation below the long-term mean. The Palmer Z index is a measure of short-term drought. It evaluates the temperature and precipitation for a given month to determine if the observed precipitation is enough to meet the resulting evapotranspiration demand. Positive values indicate that sufficient moisture was available to meet demand, while negative values indicate drought conditions. The Z index values for the contiguous United States have been predominantly negative since April 1987, and they give little indication that the drought is over. Winter 1988-89 was the tenth driest for the West.



Source: Richard R. Heim, Jr., National Climatic Data Center

DROUGHT GOES TO THE STATE FAIR

An educational exhibit, "Drought: A Colorado Problem with a Century of Solutions," has been developed by the Colorado Climate Center (Department of Atmospheric Science, Colorado State University). It was first displayed at the 1988 Colorado State Fair in Pueblo. Since then it has been displayed at a number of locations, including the rotunda of the Colorado State Capitol, and more exhibits are planned.

The exhibit has photographs, maps, graphs, and narrative describing many aspects of drought, from its impact on the early settlement of Colorado to current research about water management and conservation. Graphs show historical fluctuations in precipitation, snow accumulation and streamflow, balanced with photographs depicting a variety of drought impacts.

Inquiries about the display should be directed to Nolan J. Doesken, Colorado Climate Center, Department of Atmospheric Science, Colorado State University, Fort Collins, CO 80523.

Source: Colorado Climate Center

DENVER IMPLEMENTS WATER MEASURES, BUT PROBABLY WILL FAIL EPA REVIEW

Denver water officials are trying to cut residents' water consumption this summer, but admit that the city probably will not pass an Environmental Protection Agency review. The review will determine if Denver is meeting water conservation goals promised in a 1978 agreement over the then-controversial Foothills Water Treatment Plant. The water officials claim that the unusually hot, dry spring prompted homeowners to use more water on their lawns this year. Denver's attempts to curb water use include:

- Installing water meters on every home and converting to consumption-based rates.

- Revising the city's evapotranspiration program (ET program) to more accurately recommend the amount of water homeowners should use on their lawns each day. The Denver Post, and at least two TV stations, KCNC Channel 4 and KUSA Channel 9, provide the watering information daily.

- Hiring five water inspectors to cite water wasters -- residents who water their lawns during a rainstorm or when water restrictions are in effect.

Source: Denver Post, May 17, 1989; June 1, 2 & 7, 1989.

NCWCD DRAFTS PLAN OF STUDY ON REGIONAL COOPERATION

The Northern Colorado Water Conservancy District has drafted a plan of study on regional cooperation for northeastern Colorado. The study's two objectives are to provide the NCWCD and Municipal Subdistrict with information needed to establish plans and policies that will maintain stable water supplies for northeastern Colorado, and to enhance water availability and water quality at the lowest cost for municipal and industrial water users. The focus of the study for regional cooperation will be on enhancing the supplies, distribution capabilities, and overall efficiencies of existing water systems.

The study plan will address the following six key issues:

- Long-term future municipal and industrial water demand within and adjacent to Boulder, Larimer, Morgan and Weld Counties (principal growth areas);

- Alternative storage, distribution, and treatment facilities needed to provide adequate year-round supplies of treated or untreated water;

- Cost and long-term benefits of constructing regional distribution and one or more treatment facilities to provide treated or untreated water supplies to municipal and industrial users (including facilities to increase utilization of Windy Gap water);

- Alternative institutional and financial arrangements to obtain the needed treated or untreated water supplies, including associated legal issues;

- Potential long-term future demand from within the principal growth counties by municipal and industrial entities south of the District's boundaries, particularly those in Adams, Arapahoe and Jefferson Counties; and

- Alternative institutional and financial arrangements for municipal and industrial entities south of the District's boundaries to manage water supplies needed in the future, and to participate in regional distribution and treatment with entities in the principal growth counties.

Representatives from the area's municipalities, water districts, water user associations, conservancy districts, water supply companies, power supply companies and others will be invited to participate via the study's Advisory Committee for Regional Cooperation.

Source: Northern Colorado Water Conservancy District.

USFWS TRYING TO PROTECT RARE NON-GAME FISH IN COLORADO RIVER

U.S. Fish and Wildlife Service attempts to protect four rare fish species -- the Colorado squawfish, the humpback chub, the bonytail chub and the razorback sucker -- could stop or significantly change the Animas-LaPlata water project because it would lower stream flows in the species' breeding habitat. But, USFWS officials also say they may endorse new dams on the upper Colorado River to help the Colorado squawfish. The new dams would improve habitat for the endangered fish by regulating stream flows. Meanwhile, the Fish and Wildlife Service has asked the Bureau of Reclamation to release 10,000 acre-feet of water from the Reudi Reservoir later this summer to increase stream flows for the fish in the Colorado River near Grand Junction.

Source: Denver Post, May 15, 1989 & The Coloradoan, June 7, 1989

EPA ANNOUNCES NEW DRINKING WATER REGULATIONS

Aimed at reducing risk of illness from microorganisms, the Environmental Protection Agency announced new regulations for communities that obtain drinking water from surface sources such as rivers and streams. The new regulations require these public systems to use prescribed disinfectants or filtration to meet high standards of purity. The regulations also establish new monitoring and reporting requirements for treatment plant operators.

Source: The Coloradoan, June 23, 1989

STRETCH OF POUDRE RIVER CONSIDERED FOR NATIONAL RECREATION AREA

An 18.5 mile section of the Poudre River, from north Taft Hill Road to the Weld County line, was the focus of a recent federally funded, national recreation area study. If it is declared a national recreation area, the stretch of river could be protected for fishing, hiking, bicycling, picnicking and wildlife conservation. At a June 13 public hearing, 30 residents of the area expressed concerns about loss of potential revenue, vandalism, wildlife extinction, population increases, property tax changes, legal liability and property condemnation.

Source: The Coloradoan, June 14, 1989

COLORADO VS. U.S. FOREST SERVICE

The US Forest Service has initiated a court battle with the state of Colorado to guarantee minimum stream flow on federal lands. US Justice Department attorneys say an 1897 law gives the federal government the claim to up to 50 percent of the stream flow on Forest Service land. They say the water is needed to protect the health of the forest land. Conservationists say that minimum stream flow levels will protect native fish populations. Colorado water interests, including Denver, Public Service of Colorado and Adolph Coors Company, say the US Forest Service demand will threaten future economic development and cause extreme water shortages during dry years. The trial will begin in a Greeley water court in January 1990. Both sides expect the case to end up in the US Supreme Court.

Source: Denver Post, March 3, 1989

CONGRESS EARMARKS FUNDS FOR ANIMAS LA PLATA PROJECT

On June 15 the House Appropriations Subcommittee on Water and Power approved $7.1 million for the Animas La Plata project. The subcommittee also called for construction to commence in 1990. The Administration had recommended that the project only receive $2.1 million in the FY1990 budget which starts October 1. Representative Ben Nighthorse Campbell, whose district includes the project site, expressed delight. With Senate approval, he said, "we should be able to start moving dirt in 1990." Senators Armstrong and Wirth both back the project.

The Denver Post reported on June 21 that the House Appropriations Subcommittee on Interior designated $19.5 million to assist two Colorado Indian tribes, the Southern Ute and Ute Mountain tribes, with economic development plans for their reservations. The money is tied to construction of the Animas La Plata water project. The tribes are to use the funds for irrigation systems and related expenses that will allow them to utilize project water.

An Associated Press report says the Animas-La Plata Water Conservancy District has received signed petitions for more than 60 percent of the 36,535 acres of farmland that would be irrigated during the project's first phase.

Source: Denver Post, June 15, 21 and 26, 1989.

NATIONAL WATER ALLIANCE PROPOSES WHITE HOUSE CONFERENCE

The National Water Alliance (NWA) is urging President Bush to hold a White House Conference on Water Resources. The conference would focus on development of a national water policy to ensure the availability of water to present and future generations, according to Rep. Henry Nowak (D-NY), chairman of the NWA. The conference proposal followed the NWA's April submission of a report to the President and Congress outlining the nation's priority water issues. The report lists administration involvement in the debate on groundwater management and protection as the top issue for the 1990s. Rep. Nowak also said he would introduce a resolution into the House showing Congressional support for the proposed White House Conference.

Source: National Water Alliance Report, April 1989; US Water News, May 1989.

DELTA COUNTY TO BUY GUNNISON RIVER LAND

Delta County will buy the last remaining privately held land along a stretch of the Gunnison River. Landowner William McCluskey agreed to sell the county 844 acres near the Gunnison Gorge. This stretch of the Gunnison River is designated as "Gold Medal" fishing waters by the Colorado Division of Wildlife. Last year a real estate agent posted "no trespassing" signs on the property, cutting off public access to prime fishing waters.

Source: Denver Post, June 15, 1989.

KODAK ENGINEER APPOINTED TO COLORADO WATER QUALITY COMMISSION

Connie King of Fort Collins, an environmental engineer for Eastman Kodak Company in Windsor, has been appointed to the Colorado Water Quality Commission. King is a member of several water and engineering organizations, including the Colorado Water Congress State Affairs Legislative Committee and the Larimer-Weld Regional Council of Governments Water Quality Planning Committee. Senator Bob Schaffer of Fort Collins made the announcement.

Source: Coloradoan, May 1, 1989

COLORADO CONGRESSMEN WANT DOE TAILINGS PROGRAM AUTHORITY IN COLORADO

Colorado congressmen want authority for the uranium mill tailings disposal program transferred from the Department of Energy Albuquerque Projects Office to the Grand Junction Projects Office. Senator Bill Armstrong says he will look into the transfer, which may help facilitate the cleanup at Lowry Landfill. DOE estimates that more than 71 million gallons of wastes containing hazardous materials were dumped at Lowry.

Source: Denver Post, June 15, 1989

WATER RIGHTS DISPUTE OBSTRUCTS EFFORTS TO PROTECT NORTH ST. VRAIN

A dispute over federal reserve water rights may hinder an effort to have the North St. Vrain Creek designated as a Wild and Scenic River. Two such claims could be established: one by the Wild and Scenic designation, and the other by the U.S. Forest Service. The Forest Service claim would be to establish that stream flows within the forest land were promised by the creation of the national forest in 1907 and 1912. Colorado Congressman David Skaggs initiated a study of possible ways to protect the creek, but said he would like to see the Forest Service claim settled first. The St. Vrain and Left Hand Water Conservancy District and the Upper St. Vrain Water Users Association have adopted resolutions that call for a settlement to the Forest Service claim before any other decision is made.

Source: Coloradoan, June 19, 1989

FROM COOPERATIVE EXTENSION

Irrigated agriculture encompasses approximately 45 percent of Colorado's arable land, and there is concern about possible drought conditions this summer. At a meeting held by Dr. Dennis Lamm, Associate Director of Cooperative Extension, the State Climatologist and his assistant analyzed historic weather data and correlated it to future trends. One conclusion from this analysis is that there is no relationship between winter moisture and subsequent summer precipitation. Therefore, even though winter precipitation on the eastern plains was 50 percent of

normal, it doesn't mean that the summer will be as dry. However, if the dry trend continues, it is possible that a drought will occur. The consensus of participants at the meeting was that by using irrigation water management practices, less water will be used to satisfy crop consumptive use and a situation of limited water supply can be handled.

As a result of this meeting, Extension agents from eastern Colorado met in April to develop ideas and concepts for irrigation water management.

Participants agreed that irrigation scheduling is more feasible with sprinkler irrigation than with surface irrigation. And, water conservation is not the only benefit of water management. Reduced fertilizer leaching, better root zone aeration and less susceptibility to various diseases and pests are also benefits, in addition to increased yields and profits.

They also agreed that a demonstration comparing normally used irrigation practices with managed irrigation would show the merits and benefits of irrigation water management. A modified atmometer, using a simple table with direct reference ET, would be an easy and inexpensive water management practice. Wayne Shawcroft (Akron) is developing graphs of cumulative and daily reference ET to be publicly displayed so farmers will be able to see the maximum water use in the elapsed period.

Ditch companies will have limited water supplies and water will be delivered only a few times. By using the concept of critical growth stages, the ditch companies can schedule these infrequent water deliveries at the most needed periods.

Information about growth stages and when crops are most sensitive to water stress is available in the irrigation scheduling guide that was developed in cooperation with the Agricultural Research Service, Soil Conservation Service and Colorado Cooperative Extension. The guide is available from the Extension Agricultural Engineering Office at Colorado State University.

The second annual meeting of cooperators, Energy and Water Conservation by Improved Irrigation Practices Project, met at Colorado State University in January. The theme of the meeting was surge irrigation and cablegation. The meeting, as well as results and summaries from the demonstration sites, is described in the 1988 Annual Report. Copies can be obtained from the Extension Agricultural Engineering Office, Department of Agricultural and Chemical Engineering, Colorado State University, Fort Collins, CO 80523.

An important new demonstration site added to the project this year is the Piedmont Farm owned by Lew Grant. Approximately 60 varieties of vegetables are grown on the farm under several irrigation systems. Three types of drip systems have been installed and will be compared with furrow and sprinkler irrigation. This new site provides an opportunity to work with a vegetable grower on a variety of crops.

For a list of scheduled field days at the various demonstration sites or for more detailed information contact your County Cooperative Extension Office or call the Extension Agricultural Engineering Office (491-6172).

COLORADO STATE'S NREL MAINTAINS ACID RAIN DATA BASE

The Natural Resource Ecology Laboratory at Colorado State maintains the official national database on acid rain for the National Atmospheric Deposition Program (NADP). Precipitation samples are collected from more than 200 sites all over the country, and this data is then sent to NREL electronically. A small staff headed by James Gibson, Senior Research Scientist and NADP/NTN Coordinator, is responsible for compilation, quality assurance and dissemination of the collected data.

The NADP is a cooperative, interdisciplinary research effort, organized in 1978, to address the problem of atmospheric deposition and its effects on crops, soils, forests, surface waters and materials. In 1982, NADP assumed responsibility for coordinating the federally-supported National Trends Network (NTN) established under the National Acid Precipitation Assessment Program (NAPAP).

Samples are collected weekly and sent to the NADP/NTN Central Analytical Laboratory at the Illinois State Water Survey. When analyses are completed the results are stored in a central computer file, and this information is then transferred to NREL. Analysts at NREL prepare tables, graphs, maps and reports which are mailed regularly to more than 500 scientists and leaders in government and industry.

Currently the NADP/NTN staff is preparing national maps of acid deposition for congressional hearings concerning emissions controls.

CENTER PIVOT SPRINKLER DRAWS ATTENTION

A modified sprinkler system developed by Carl Butler, a Texas farmer, has resulted in a 99.6 percent irrigation efficiency rating. Butler's idea is drawing attention from both farmers and irrigation manufacturers. His system modification is described in the June 1989 **Cross Section**, as follows:

Butler modified his irrigation system with a series of pipes, joints and flanges. He rigged the pipes to connect from the original water outlet on top of the transmission line. He positioned drop lines to fall directly over the furrow row to be watered and to bring the water within two feet above the land surface. A 20", swiveling, adjustable tube positions the water in the center of the furrow. The tube is plugged with a plastic cap which has a precision-cut hole in it. The hole at each drop is a different size: smaller where water pressure is highest close to the tower at the water intake point and larger at the end of the line where pressure is lower. This allows the same amount of water to be released in each row. The plastic cap is covered with a flexible plastic pipe and a canvas sock which drags in the furrow.

This diffused distribution pattern prevents soil erosion and virtually eliminates loss to evaporation in the water application. Butler also plows his rows in a circle to conform to the center pivot's modified watering system. He farms two rows in and one out and delivers his water between the two rows. The pivot covers the entire section except the corners, which he furrow irrigates conventionally.

The Cross Section is published by the High Plains Underground Water Conservation District No. 1, Lubbock, TX.

USGS MARKS 100 YEARS OF STREAM GAGING

1989 is the 100th birthday of the Geological Survey program for measuring flows in the Nation's rivers and streams, begun at Embudo, New Mexico, on the Rio Grande. Since then, the USGS has established a nationwide network of more than 50,000 monitoring stations to keep tabs on the quality and quantity of our surface-water and groundwater resources.

John Wesley Powell, second director of the USGS from 1881 to 1894, was the force behind the founding of the Irrigation Survey (a new bureau within the USGS) which was responsible for assessing water resources of Western lands, and which also resulted in founding of the Embudo station. The Embudo site was chosen because of concern about downstream water needs for irrigation in the United States and Mexico, and because streams in northern areas were frozen at the time. It also had the advantage of rail access for moving the necessary scientific and camp equipment.

The first group of engineers at Embudo not only began the gaging station itself but were also hydrologists-in-training. Among their earliest scientific equipment was a cook's bread pan, a length of rope and a raft made of four empty barrels. The bread pan was used for measuring water evaporation and the rope and raft were used in the earliest stream-gaging efforts. They were soon replaced with a custom-designed evaporating pan, a steel cable and a boat. Embudo station records show an average streamflow of 13 billion gallons per day (bgd) for the 100-year period of record. Record high streamflow was 105 bgd on June 19, 1903. The record low, recorded less than a year earlier, was less than one million gallons per day.

Source: U.S. Geological Survey

"ENOUGH AND CLEAN ENOUGH" -- COLORADO WATER WORKSHOP FOCUSES ON WATER QUALITY/QUANTITY

The 14th Annual Colorado Water Workshop, scheduled for July 24-26, 1989, will center on the Colorado water quality/quantity debate. Topics for the three-day conference will be: **Water Quality and Water Rights--An Historical Perspective** (Day 1); **Water Quality/Quantity Conflicts** (Day 2); and **Seeking Effective Processes of Resolution and Accommodation** (Day 3).

This popular water workshop is held annually at Western State College, Gunnison, Colorado. Special features of the event are a raft trip-scenic float of the Upper Gunnison River and a visit to the Roaring Judy Fish Hatchery conducted by the Colorado Division of Wildlife. Academic credit and Continuing Legal Education credits are available.

For information contact conference director Tyler Martineau, Colorado Water Workshop, Western State College, Gunnison, CO 81231 (303)943-2082.

HEC-2 USERS CONFERENCE PLANNED

A conference for users of HEC-2 will be held in Denver August 10-11, 1989 at the Holiday Inn, I-70 East. The conference will feature speaker-users from the Federal Emergency Management Agency (FEMA), the Corps of Engineers and other government and private users. It will provide the opportunity for HEC-2 users to get together and share their experiences and applications of HEC-2.

The conference is for experienced users of the HEC-2 Model. It will be especially useful for those who have applied the HEC-2 Model to specific applications and have encountered specific problems. Cost of the conference is $75.00 including coffee breaks, lunches and notebook. It is sponsored by FEMA, the Colorado Section of ASCE, Resource Consultants, Inc. and CWRRI. Contact David Frick at 572-1806 for more information.

STREAMBANK EROSION AND FLUVIAL SYSTEM MANAGEMENT SYMPOSIUM PLANNED

This symposium, to be held in Snowmass, Colorado July 31-August 2, 1989, is jointly sponsored by the Colorado Soil Conservation Board and Colorado Association of Soil Conservation Districts. Its purpose is to examine low-cost Best Management Practices (BMP)) in use in the Western United States to control streambank erosion and which can be installed by the landowner or landuser. Speakers will include both professionals and landowners. There will be a balance between general sessions, small group discussions, and a field trip along the Roaring Fork River to observe and study BMPs installed and in operation. For further information contact the Colorado State Soil Conservation Board, 1313 Sherman St., Room 420, Denver, CO 80203, or call (303)866-3351. Cosponsors of the symposium include the Bureau of Land Management; Soil and Water Conservation Society of America, Colorado Chapter; Soil Conservation Service; and Colorado Riparian Association.

INFORMATION TRANSFER WORKSHOP SCHEDULED

A special workshop on information transfer will be held in conjunction with the 1989 annual meeting of The Universities Council on Water Resources, **Facing the Water Problems of the Nineties**, scheduled for August 8-11, 1989 in Minneapolis, MN. On August 8 a half-day session will feature speakers and discussions on national water quality initiatives, including opportunities and strategies for closer cooperation between Cooperative Extension and Water Institutes. On August 9 information transfer personnel will participate in a day-long technical session designed to improve communication skills.

Although targeted toward water institute-center personnel, the workshop is open to others as well. For information contact Joe Gelt or Susanna Eden, Water Resources Research Center, Geology Bldg., University of Arizona, Tucson, AZ 85721 (602) 621-7607. The workshop is sponsored by the National Association of Water Institute Directors, the Universities Council on Water Resources, and the Arizona Water Resources Research Center, with support from the U.S. Geological Survey.

CALLS FOR PAPERS

International Symposium on Planning, Management, and Research on Water Resources, Jan. 24-26, 1990, Merida, Yucatan, Mexico. Cosponsored by ASCE and IWRA. Submit two copies of one-page abstract including affiliation, position and address of author(s) to: Ing. Miguel Villasuso Pino, Facultad de Ingenieria, Universidad Autonoma de Yucatan, Calle 14x41, Ex-Fenix, Merida, Yucatan, MEXICO. Telephone: 99-27-45-23. U.S. authors also submit information copy to: Harold J. Day, Room ES 317, Univ. of Wisconsin, Green Bay, WI 54311-7001 (414)465-2369. Deadline: Sept. 11, 1989.

IWRA VIIth World Congress on Water Resources, May 13-18, 1991, Rabat, Morocco. The theme will be water's role in sustainable development, asking how societies can best manage their water resources to maintain growth in the next century. Deadline: July 31, 1990. For additional information contact: The Secretariat, VIIth IWRA World Congress on Water Resources, Administration de l'Hydraulique, Direction de la Recherche et de la Planification de l'Eau, Rue Hassan Ben Chekroun, AGDAL-RABAT, MOROCCO, Phone:(212)786-90; Telex: 310 82; Telefax: 766-58.

POSITIONS AVAILABLE

Project Specialist (Agroecosystem Ecologist)--Will function as a senior-level scientist in the Agroecosystem component of a national Environmental Monitoring and Assessment Program (EMAP), and be

responsible for developing and implementing a national program whose objectives are to determine the status and trends of United States' agroecosystem "health". Information obtained from this program will be used in making decisions regarding risk management and implementing regulatory actions, as well as informing the public about the "health" of the nation's agroecosystems.

Duties include: 1) development of an EMAP-Agroecosystem Research Plan; 2) active involvement with the EMAP-Agroecosystem Task Group; 3) implementation of an active research component in the incumbent's own area of expertise that will compliment the Program's objectives; 4) interaction and cooperation with other EMAP senior scientists (forests, wetlands, surface waters, near coastal) and senior staff from a variety of Federal and state agencies; and, 5) preparing briefings, technical reports and peer-reviewed publications.

QUALIFICATIONS: Ph.D degree in ecology, ecophysiology or a closely aligned discipline, with emphasis on agroecosystem structure and function. Must have a minimum of 5 years of applied ecological research experience (preferably relating to agroecosystems), plus a minimum of 2 years of research leadership experience. The research and leadership experience must demonstrate that the applicant possesses: 1) a thorough understanding of scientific principles and theories underlying ecology; 2) a broad knowledge of concepts, factors and conditions which influence the structure and function of ecosystems; 3) a high level of technical competence and creativity in original scientific inquiry in developing new methods or new insight addressing complex ecological problems; and, 4) the ability to organize, implement, direct and complete complex research programs, projects or studies.

Applicant should have demonstrated knowledge in the following areas related to the geographical, agronomic, economic and ecological considerations of U.S. agriculture: 1) major agroecoregions, including associated wildlife and natural vegetation; 2) natural and socioeconomic controlling factors; and, 3) natural-anthropogenic stressors and indicators or monitoring stressor effects. Applicant must have: 1) the ability to communicate scientific related information orally and in writing; 2) a record of publication in the peer-reviewed literature; 3) the ability to work in a team-oriented, research-management environment and deal effectively with complex, rapidly developing issues.

APPLICATION: Include cover letter (specifically relating your experience as it pertains to the duties and qualifications listed above), resume, transcripts (unofficial) and the names of three references. Initial review of the applications will begin July 1, 1989 and the position will remain open until filled. Susan Carey, NSI Technology Services Corporation, 1600 SW Western Blvd., Corvallis, OR 97333.

Water Resources Position, Extension-Information Transfer. The Wyoming Water Research Center is seeking an Associate Director for Extension and Information Transfer. This is a full-time temporary appointment (two years) with a possibility for continuation dependent upon availability of funding. Initial appointment may begin as soon after July 1, 1989 as practicable. The successful applicant may be appointed with faculty rank or as professional staff dependent upon qualifications.

POSITION RESPONSIBILITIES: The Associate Director for Extension and Information Transfer reports to the Director and is responsible for all communications activities of the WWRC. Current activities include publications, brochures, an annual report, research briefs and a newsletter; educational activities include a Summer Water Institute for Teachers, community College Seminars on Water Resources, Water Resources Workshop for State Legislature, Field Tours for Governor's Office; program development and implementation of statewide Water Quality Initiatives for Cooperative Extension including videotape programs on various water resource topics, radio shows, news releases, and public meeting presentations. The Associate Director for Extension and Information Transfer may be appointed for up to 25 percent research in his/her area of specialization.

QUALIFICATIONS: Ph.D and academic experience in water resources or closely related field or equivalent combination of M.S. degree and experience. Excellent writing and oral communications skills. Demonstrated ability to work effectively with diverse governmental, public interest, and commodity groups. Desk-top publishing and computer skills desirable.

SALARY: Commensurate with qualifications. TO APPLY: Send complete resume, letter of application, names and addresses of three references to: Dr. Steven P. Gloss, Director, Wyoming Water Research Center, P.O. Box 3067, University Station, Laramie, WY 82071-3067. Application Deadline: July 1, 1989.

Director, The University of British Columbia Faculty of Graduate Studies, Westwater Research Centre. Applications are invited for the position of Director, Westwater Research Centre, at the University of British columbia. The Centre conducts interdisciplinary research on problems concerning water resources and their associated lands. Its general objective is to provide an improved foundation for policy and institutional development through rigorous analysis of alternative courses of action. The Centre presently has a core of 3.25 full-time equivalent faculty members and numerous associates and graduates students.

The successful candidate will have a Ph.D or equivalent, and will be a recognized authority in a field of research that enhances the activities of the Centre. The Director will have a proven record of leadership and administrative ability and a demonstrated skill in coordinating interdisciplinary research and in raising and maintaining funds for that purpose.

The appointment as Director will be for an initial period of five years, and will take effect by January 1990 or as soon as possible thereafter. Rank and salary will be in accordance with qualifications and experience. The Director will hold a cross-appointment in an appropriate academic unit of the University; the appointment in the Centre will be half-time.

Applications with supporting documentation and names of three referees should be sent by August 31, 1989 to: Dr. S. Cherry, Associate Dean, Faculty of Graduate Studies, University of British Columbia, Vancouver, B.C. V6T 1Z3, Canada.

Research Geohydrologist, The Water Resources Research Institute, Mississippi State University. Position for a geo-hydrologist beginning August 1989. Should be a self-motivated individual with a background in groundwater geology as related to analysis and management. The position is non-tenure track for approximately two (2) years with continuation dependent upon research efforts and continued external funding. Salary dependent upon qualifications and experience. Duties include work on funded groundwater studies, development of proposals and securing of funded research.

Minimum qualifications include an M.S. in Geology/Geohydrology with emphasis in groundwater geology and 3 to 5 years experience in interpretation of geophysical data for groundwater studies.

To apply, send letter of application, resume, academic transcripts, list of publications and names and addresses of three references to: Dr. Marvin T. Bond, Director, Water Resources Research Institute, Mississippi State University, P.O. Drawer AD, Mississippi State, MS 39762. APPLICATION DEADLINE: This position will remain open until July 21, 1989 or until an acceptable applicant has applied.

Research Transfer Specialist-Assistant Director, Mississippi Water Resources Research Institute. Responsible for providing leadership in all phases of water resources research, training, and information transfer. This position has been classified by the University as a non-tenure track position to Research Scientist. The person holding this position will be part of a small professional Water Resources Institute staff. Primary responsibilities include the Institute's information dissemination/technology transfer activities and functioning as an assistant director. Technology transfer activities include (1) scheduling and organizing conferences, review of project reports for clarity prior to printing, (3) compilation of materials for annual reports, and (4) general promotion of the Institute and its programs.

Responsibilities include attending meetings with state and federal agencies when the Director has conflicting schedules and assisting in program development and project management. Qualified candidates must possess a master's degree in an appropriate discipline and demonstrate excellent communication skills. Salary commensurate with qualifications. This position will be open through July 21, 1989 or until such time as a satisfactory applicant has been identified. APPLICATION: Send resume with the names of three references to: Dr. Marvin T. Bond, Director, Mississippi WRRI, P.O. Drawer AD, Mississippi State, MS 39762.

WATER FACTS

- There are approximately one million miles of pipeline and aqueducts in the U.S. and Canada, enough to circle the earth 40 times. The first water pipes in the U.S. were made from fire-charred or bored logs.

- A birch tree gives off 70 gallons of evaporation per day.

- The average residence uses 107,000 gallons of water a year. An individual person uses 168 gallons per day.

COLORADO WATER RESEARCH

A summary of water research awards and projects recently initiated is given below for those who would like to contact the investigators to receive information.

Colorado State University, Fort Collins, CO 80523

Evaluation of Large-Scale and Long-Term Impacts of Changes in Management and Climate on Properties and Productivity of Great Plains Soils, Edward T. Elliott, Agronomy.

Tourism Tracking Index, Glenn E. Haas, Recreation Resources.

Local Government Severe Weather Information Processing, Thomas H. Vonderhaar, CIRA Administrative Unit.

Long-Term Ecological Research into the Effect of Atmospheric Desposition in the Rocky Mountains, James H. Gibson, Natural Resources Ecology Lab.

Application of Computer Modeling Techniques for Management of Water Resources, Marshall Flug, Civil Engineering.

Characterization of Soil Hydraulic Properties for Pesticide Study, Greg Butters, Agronomy.

Development & Application of Biological Assessment Tecniques to Water Resources, Terence P. Boyle, Recreation Resources.

Utility of the 6-class Dwarf Mistletoe Rating System for Quantifying Wildlife Habitat, Richard L. Knight, Fishery & Wildlife Biology.

Response of a Temperate Grassland Ecosystem to Climate Change, H. William Hunt, Natural Resources.

Soil Moisture and Temperature Data Base, Jan E. Cipra, Agronomy.

Development of Antidegradation Standards for Protecting High Quality Waters of the NPS, Duane C. Boes, Statistics.

Irrigation and Drainage Research - Fruita, Lee E. Sommers, Agronomy.

Interactions of Water and Nutrient Dynamics in a Pinyon - Juniper Woodland, Floyd W. Whicker, Radiation Biology.

Gas Phase Transport of Volatile Organic Compounds in the Vadose Zone, David McWhorter, Agricultural and Chemical Engineering.

Drought Control and Water Management in Humid Regions: Expanded Project, Neil S. Grigg, Civil Engineering.

Twin Lakes Entrainment Studies - Phase III - Monitoring, David Anderson, Fishery and Wildlife Biology.

Climatic Geomorphology, Stanley A. Schumm, Earth Resources.

Development of Improved Quality and HIG yield in Wheat Germplasm in Colorado, James S. Quick, Agronomy.

Integrated Forest Study on the Effects of Atmospheric Desposition, Daniel E. Binkley, Forest and Wood Science.

Phase II Crop Salt Tolerance Study, Parviz Soltanpour, Agronomy.

Current and Forecast Hydrometeorological Conditions, Thomas H. Vonderhaar, Atmospheric Science.

Areal Precipitation Estimates Using Satellites, Thomas H. Vonderhaar, Atmospheric Science.

LES and Mesoscale Observational Comparisons, William R. Cotton, Atmospheric Science.

LES and Mesoscale Model Simulation, William R. Cotton, Atmospheric Science.

Developing and Understanding a Sensor - Topographic Modeling, Thomas H. Vonderhaar, Atmospheric Science.

Testing of Hydrologic Model, Daryl B. Simons, Civil Engineering.

Persistence of a Pastoral Ecosystem, James Ellis, Natural Resources.

Analytical Techniques for Estimation of Velocity and Shear Stress at the Outer Bank in a River, Colin R. Thorne, Civil Engineering.

Chalk Creek, Eric P. Bergersen, Cooperative Fish & Wildlife Unit.

Long Term Ecological Research Program - Shortgrass Steppe, Robert G. Woodmansee, Natural Resources.

Monitor and Evaluate the Effect of Channel Bank Stabilization and Controlled Grazing, John D. Stednick, Earth Resources.

University of Colorado, Boulder, CO 80401

Brittle-Ductile Failure Mechanics of Mortar and Concrete, Stein Sture, Civil, Environmental and Architectural Engineering.

Natural Disturbance and the Dynamics of Subalpine Forests in the Central Rockies, Thomas Veblen, Geography.

Fracture Mechanics of Concrete Gravity Dam; Part I; Static Loading, Victor Saouma, Civil, Environmental and Architectural Engineering.

Technolgy Transfer Activities for Snowmelt Hydrology and Streamflow Forecasting, Hon-Yim Ko, Civil, Environmental and Architectural Engineering.

Comparative Lithological Mapping using Multipolarization, Multifrequency Imaging Radar and Multispectral Official Remote Sensing, Fred Kruse, Geological Sciences.

CONFERENCES

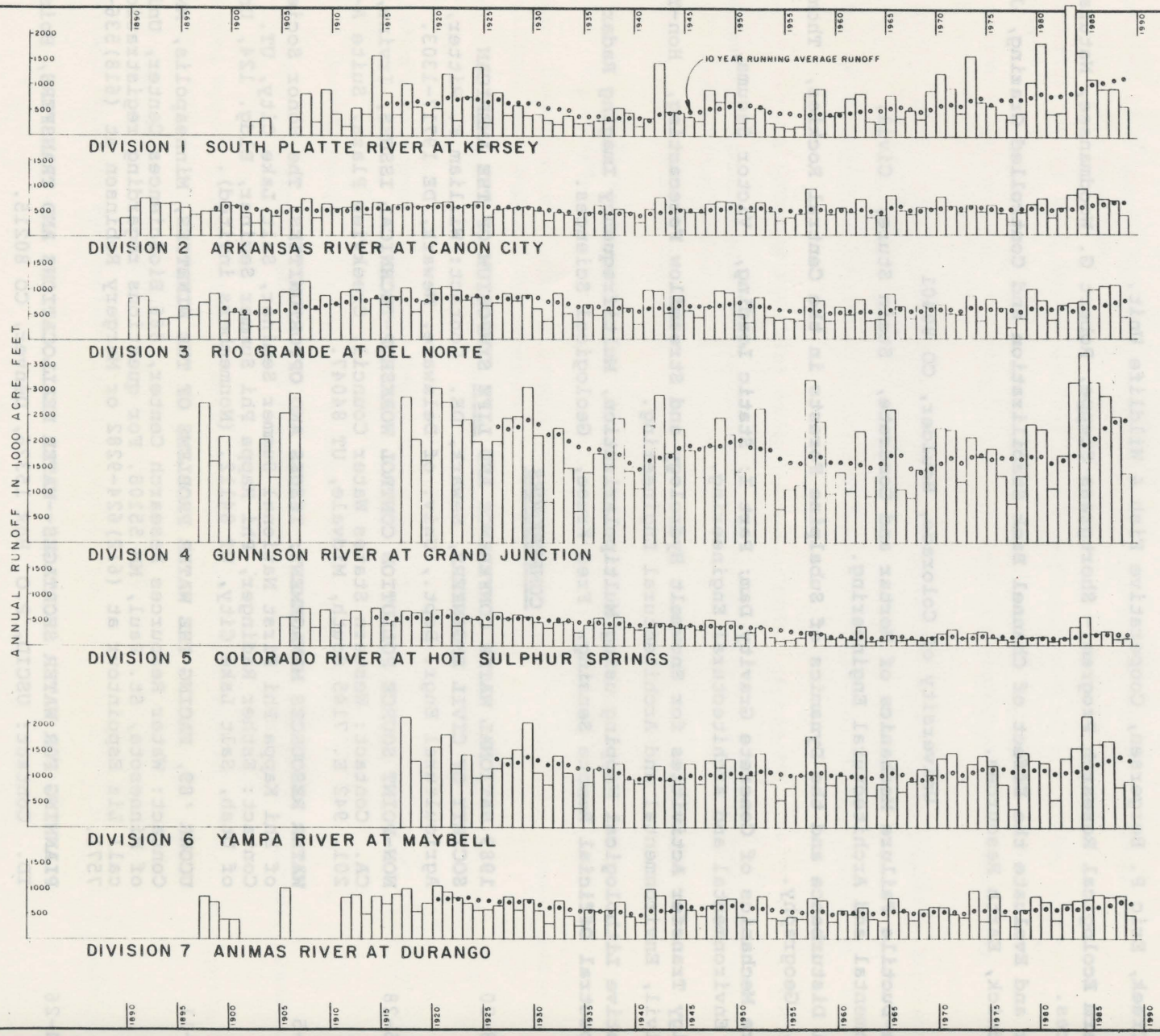
July 18-20 — **1989 NATIONAL WATER CONFERENCE AND LIFE SYMPOSIUM OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS,** Newark, DE. Contact: William F. Ritter, Agricultural Engr. Dept., Univ. of Delaware, Newark, DE 19717-1303.

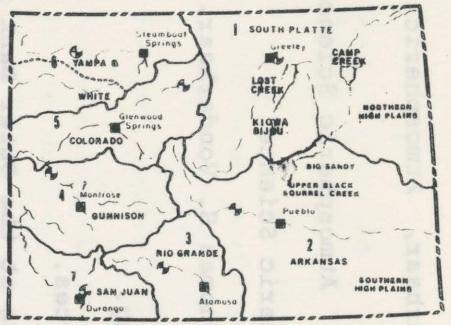
July 25-28 — **NON-POINT SOURCE POLLUTION CONTROL WORKSHOP-TECHNICAL ISSUES,** Irvine, CA. Contact: Western States Water Council, Creekview Plaza, Suite A-201, 942 E. 7145 South, Midvale, UT 84047.

Aug. 4-5 — **WATER RESOURCES MANAGEMENT; ISSUES AND OPPORTUNITIES,** The Honor Society of Phi Kappa Phi First National Summer Seminar, Salt Lake City, UT. Contact: Esther Radinger, Phi Kappa Phi Summer Seminar, Bldg. 124, Univ. of Utah, Salt Lake City, UT 84112. (Nonmembers invited).

Aug. 8-11 — **UCOWR '89, FACING THE WATER PROBLEMS OF THE NINETIES,** Minneapolis, MN. Contact: Water Resources Research Center, 866 BioSciences Center, Univ. of Minnesota, St. Paul, MN 55108. For questions regarding registration call Liz Espointour at (612)624-9282 or Margery Robinson at (618)536-7571.

Aug. 24-26 — **PLANNING FOR WATER SHORTAGES--WATER REALLOCATIONS AND TRANSFERS,** Boise, ID. Contact: USCID, P.O. Box 15326, Denver, CO 80215.





Map of Colorado Showing Water Divisions

- U.S.G.S. Surface Runoff Gauge
- Division Water Court
- Designated Ground Water Basin
- Water Division

COLORADO RIVERS HISTORICAL RUNOFF

Leonard Rice Consulting Water Engineers, Inc.
(303) 455-9589 / 2401 Fifteenth Street, Suite 300 / Denver, Colorado 80202-1143

APRIL 1989

EVALUATING WATER USE EFFICIENCY

Marvin E. Jensen

INTRODUCTION: The theme of this session is "State Water Issues." The subject I have been assigned is evaluating water use efficiency. My focus is on evaluating water use efficiency in agricultural areas.

The term "efficiency," when used by a specific technical group, usually has a very specific meaning and its use is well-understood. Speakers and writers outside the technical groups often use efficiency in a general sense without clearly defining what is meant. Unless efficiency is clearly defined it may be more effective to avoid its use entirely. For example, because there have been different interpretations of the term "irrigation efficiency," a recent Council on Science and Technology task force elected to avoid using this term if the specific meaning intended could be expressed explicitly without its use (CAST, 1988).

Since the theme of this brief presentation is evaluating "water use efficiency," we first need to define some key terms to be certain that we are communicating. Then, we can proceed to discuss some alternative approaches for evaluating water use efficiency. Evaluations may be either qualitative or quantitative. Quantitative evaluations are more meaningful, but they require measurements and definable indices. Quantitative evaluations generally are required to monitor the impacts of changes in policies or practices on water use efficiency.

DEFINITIONS: All water uses are either consumptive or non-consumptive, or a combination of these uses. Both uses usually have residual effects on the remaining water supply and hydrologic system.

Consumptive Use. Water that is used consumptively is evaporated or otherwise unavailable for other uses. It is a one-time use. Water evaporated from a reservoir or transpired by a growing crop are examples of consumptive uses.

Non-consumptive Use. A non-consumptive water use means that water used is available for other uses. Hydro-electric power generation and most in-stream water uses are examples of non-consumptive water uses.

Some uses of water involve both consumptive and non-consumptive uses. For example, water used in irrigated agriculture is mainly consumptive use. A fraction, which is used beneficially to leach the residual soluble salts from the soil, is a non-consumptive use. These salts, which were originally in the irrigation water, remain in the soil as pure water is transpired by plants or evaporated from the soil. Leaching is an essential process for sustained irrigated agriculture. Water used for cooling is mainly non-consumptive use except for increased evaporation due to the addition of heat energy.

Efficiency. The most common definition of efficiency is the ratio of output to input such as the ratio of effective work to energy input. Thus, efficiency is generally considered to be a dimensionless term. In general terms, efficiency means the ability to produce a desired effect with a minimum of effort, expense, or waste. The latter definition, when evaluated quantitatively, may require terms that are not dimensionless.

Farm Irrigation Efficiency. Farm irrigation efficiency (E_i) was defined by Israelsen (1950) as the ratio of irrigation water used in evapotranspiration (ET_i) to the water delivered to the farm (W_f).

$$E_i = ET_i/W_f \qquad (1)$$

Conveyance Efficiency. Conveyance efficiency (E_c) is the ration of water delivered to farms to the water diverted from the supply (W_s).

$$E_c = W_f/W_s \qquad (2)$$

Gross Water Supply. The gross water supply required for a given irrigated area depends

on the amount of water to be provided by irrigation (ET_i), and the conveyance and farm irrigation efficiencies.

$$W_s = ET_i/((W_f/W_s)\ (ET_i/W_f)) - ET_i/E_cE_i \qquad (3)$$

Net Water Supply. The net water supply required for a given irrigated area depends on the amount of excess water input that can be recovered for use within the farm or project.

$$W_{ns} = W_s - r((1 - E_i)\ W_f + (1 - E_c)\ W_s) \qquad (4)$$

where r is the fraction of excess water that is recovered for reuse within the project.

Overall Irrigation Efficiency. The overall irrigation efficiency (E_{io}) of a project is the product of conveyance and farm irrigation efficiencies.

$$E_{io} = E_cE_i \qquad (5)$$

Effective Irrigation Efficiency. The effective irrigation efficiency (E_{ie}) is the ratio to irrigation water used by the crops in ET to the net water supply:

$$E_{ie} = ET_i/W_{ns} \sim E_cE_i + r(1 - E_cE_i) \qquad (6)$$

Water Use Efficiency. The production of marketable crop per unit of water consumed is commonly called water efficiency (WUE) in agricultural publications. When expressed in units of mass/mass, it is dimensionless.

$$WUE = Y/ET \qquad (7)$$

EFFECT OF WATER USES ON THE ECONOMIC VALUE OF WATER

The economic value of a water use may be associated with only a single consumptive use. A unit of water used non-consumptively may have value for additional uses. Generally, the value of a unit of water used non-consumptively will have been reduced. The remaining water supply is generally affected by both consumptive and non-consumptive water uses. For example, the return flow from an irrigation project will contain a higher concentration of soluble salts than the original irrigation water because the soluble salts originally in the water have been concentrated by evaporation and transpiration. Likewise, water lowered in elevation to extract energy will have lost some of its intrinsic value (Jensen, 1983). Water used for cooling may be warmer than before which may affect its value for some uses. Water released for power production may not be available for other downstream uses if the releases do not coincide with downstream uses or it cannot be stored for later release and use. Likewise, water released for various instream uses may not be available for other uses if downstream water requirements do not coincide with upstream in-stream uses.

EVALUATING WATER USE EFFICIENCY

Because of the different types of uses, different criteria are required to evaluate the efficiency of various water uses, systems and practices. Various water use efficiency indices have been used for decades to assess the effects of specific practices on physical production per unit of water consumed or on the net economic returns. Determining the integrated efficiency of various water uses can be complex because a universal system of evaluating integrated "water use efficiency" has not been developed.

Water Use Efficiency in Agriculture

In agriculture, water use efficiency (WUE) is commonly expressed as the marketable product produced per unit of water consumed in evapotranspiration (ET). For example, the WUE in producing wheat may be expressed as kilograms of grain per cubic meter (or bushels per acre-inch) of water consumed in ET. This index is used to assess the effects of different agronomic practices on production per unit of water where water is the primary limiting variable. It is used also to assess the value of water used in growing alternative crops in which case it may be referred to as average productivity. The net value of water used in production requires taking into account production costs or benefit/cost

relationships.

Numerous recent studies have shown that yield increases linearly with ET when soil water limits plant growth, and when plant water stress is distributed throughout the season (Howell and Musick, 1985; Davidoff and Hanks, 1989). Because of evaporation from the soil and because a crop must develop through the vegetative stage before the main marketable component is produced, the highest WUE typically occurs at the highest yields as illustrated in the next section.

Water Deficit. Crop Yield and WUE. The linear relationship between yield (Y) and ET may overly simplify complex soil-plant-environment relationships, but it does help agricultural specialists understand the effects that water deficit has on crop yields and water use efficiency. Yield can be related to ET as:

$$Y = a\ ET - b \qquad (8)$$

where a and b are constants. From Eq. 8, the relationship of water use efficiency, WUE, to ET is:

$$WUE = Y/ET - (a\ ET - b)/ET = a - b/ET \qquad (9)$$

With Y in metric tons per hectare and ET in mm (1 mm depth = 10 m^3), WUE in kg/m^3 is:

$$WUE = 100\ a - 100\ b/ET \qquad (10)$$

Data from Stewart et al. (1983) illustrate these typical relationships (Jensen, 1987). For grain sorghum grown in the high plains of Texas:

$$Y = 0.0154\ ET - 2.20, \quad \text{for } ET>225 \text{ mm} \qquad (11)$$

$$WUE = 1.54 - 220/ET, \quad \text{for } ET>225 \text{ mm} \qquad (12)$$

Equations 11 and 12 show that yield decreases as ET decreases and the highest WUE occurs at maximum ET, which is controlled by climate. This definition of WUE is not related to irrigation efficiency which relates increased ET to applied irrigation water. There is no similar, linear relationship between the amount of water applied and yield except for the first few increments of applied water.

Similar relationships have been found for other crops. Davidoff and Hanks (1989) recently reported sugar beet yield-ET relationships from which the following WUE relationship for full season irrigation was derived:

$$Y = 0.0166\ ET - 1.85, \quad \text{for } ET>375 \text{ mm} \qquad (13)$$

$$WUE = 1.66 - 185/ET, \quad \text{for } ET>375 \text{ mm} \qquad (14)$$

where Y is sucrose yield in metric tons per hectare and ET is in mm.

Musick and Dusek (1980) used WUE values to evaluate the effects of alternative irrigation practices on corn production. Particularly, they showed that water stress at different stages of growth had significant effects of production per unit of water used in ET. Also, they showed that corn is more sensitive to water stress than a drought tolerant crop like grain sorghum.

Integrated WUE Values. Evaluating an integrated WUE index when different crops are grown becomes more complex. An alternative approach is to evaluate the overall economic value, not the net value, of the individual crops produced and then express WUE in economic terms. This requires weighing the WUE values by the production and market value of each crop. For example, when considering only grain sorghum and sugar beets,

$$WUEecon = \frac{WUEgs(\$/unit)(ETgs) + WUEsb(\$/unit)(ETsb)}{\text{Total irrigation water consumed by crops}} \qquad (15)$$

where ETgs represents the units of irrigation water used in ET by grain sorghum and ETsb represents the units of irrigation water used by sugar beets. If an entire river basin is to be included in such an integrated index, then water uses that have little or no economic value also must be included. For example, if the wood produced is left to rot or has little or no economic value, water consumed by trees in flood plains and along rivers is a very low use. Procedures for estimating ET by low-value flood plain vegetation is not as well-established as for crops. An alternative approach is to estimate the potential economic loss by low vegetation to arrive at the net economic WUE excluding production costs.

$$\text{Net economic WUE} = \text{WUEecon}\left(1 - \frac{\text{Total available water} - \text{ETcrops}}{\text{Total water available}}\right) \quad (16)$$

A simple hypothetical example using the above relationships will illustrate how the economic water use efficiency might be evaluated for a two-crop system.

Given:
Area = 65 hectares (160 acres)
Crops, 50% grain sorghum and 50% sugar beets, or 32.5 ha (80 acres) grain sorghum and 32.5 ha sugar beets
ET: Grain sorghum = 560 mm (22 inches)
Sugar beets = 610 mm (24 inches)
Rainfall: For grain sorghum, 140 mm (5.5 inches)
140 mm = 0.140 x 10,000 x 32.5 = 45,500 m^3 (36.9 ac-ft)
For sugar beets, 180 mm (7.1 inches)
180 mm = 0.180 x 10,000 x 32.5 = 58,500 m^3 (47.4 ac-ft)
ET from irrigation water:
Grain sorghum, 560 - 140 = 420 mm (16.5 inches)
420 mm = 0.420 x 10,000 x 32.5 = 136,500 m^3
(110.7 ac-ft)
Sugar beets, 610 -180 = 430 mm (16.9 inches)
430 mm = 0.430 x 10,000 x 32.5 = 139,750 m^3
(113.4 ac-ft)
Total available irrigation water = 400,000 m^3 (324 ac-ft)

Assumptions:
Yields: Grain sorghum = 6.4 metric tons/ha (5,700 lb/acre)
Sugar beets (sucrose) = 8.3 metric tons/ha (7,400 lb/acre)
WUE, grain sorghum, 1.15 kg/m^3 (2.60 cwt/acre-inch)
WUE, sugar beets (sucrose), 1.36 kg/m^3 (0.154 ton/acre-inch)
Price: Grain sorghum, $0.10/kg ($4.55/cwt)
Sucrose, $0.14/kg ($0.064/lb)

Results:
Production:
Grain sorghum = 32.5 x 6.4 = 208 metric tons (229 tons)
= 208,000 kg
Sucrose = 32.5 x 8.3 = 270 metric tons (298 tons)
= 270,000 kg

$$\text{WUEecon} = \frac{1.15(0.10)(136{,}500) + 1.36(0.14)(139{,}750)}{136{,}500 + 139{,}750} = \$0.15/m^3$$

$$\text{Net economic WUE} = 0.15\left(1 - \frac{400{,}000 - (136{,}500 + 139{,}750)}{400{,}000}\right)$$

$$= \$0.104/m^3$$

An alternative approach to estimating WUEecon is to consider the total value of each crop produced divided by the total irrigation water and rainfall used in ET.

$$\text{WUEecon} = \frac{0.10(208{,}000) + 0.14(270{,}000)}{136{,}500 + 139{,}750 + 45{,}500 + 58{,}500} = \$0.15/m^3$$

Measurements or Estimates Required. In the first example, the amount of water consumed in ET by crops must be estimated. Common procedures for estimating ET are to first estimate

reference crop ET based on climatic data. Then, estimates of irrigation water used in ET for each crop are obtained using crop curves or coefficients which have derived experimentally and subtracting effective rainfall. WUE values are also determined experimentally for the crops involved in the region, and estimated crop yields are based on agricultural statistics. The alternative approach is to use only estimated crop yields and total water used by the crops in ET.

Evaluating Irrigation Efficiency

Another approach to assessing the effectiveness at which water is used is to evaluate effective irrigation efficiency based on Eg. 6. This approach does not involve crop yields and economic value of irrigation water use. It does require estimates of crop ET, water delivery to farms, and a more difficult problem of assessing the fraction of excess water applied and conveyance losses that is recovered for reuse within the boundaries of the study area. An example evaluation of the impacts of changes in irrigation practices on effective irrigation efficiencies in upstream and downstream projects was presented by Jensen (1984).
Evaluating Leakages.

Assessing the leakage in a water delivery system is commonly used to evaluate municipal water distribution systems. In river basins, uncontrollable tree growth with little or no economic value can be likened to leakage losses. Each tree that is allowed to grow and its wood is allowed to rot or is later burned in clearing an area is like a leak in the system. Each tree extracts water from the system and transfers it to the atmosphere.

Non-consumptive Water Uses

Non-consumptive uses of water usually lower the value of water for other uses. For example, water used for hydroelectric power generation is lowered in elevation in proportion to energy extracted. Lowering its elevation means that it may not be available for gravity diversion at higher levels. Likewise, excess water applied to the land in irrigation which percolates to the ground water will be decreased in value because reuse may require energy for pumping. Irrigation return flow may enable gravity diversion downstream. Excess water applied to some land areas may cause salt loading which decreases the quality and value of water for downstream water uses (Jensen, 1983).

SUMMARY

A discussion of evaluating water use efficiency requires a clear definition of terms that are used. Water use is either a consumptive, or a one time use, or a non-consumptive use, or a combination of these uses. Irrigation and conveyance efficiencies are used extensively by engineers in designing and operating water distribution and farm irrigation systems. Agriculturalists use an index called "water use efficiency" which is the production of marketable crop per unit of water consumed. This term can be used to evaluate the overall value of various agricultural water uses.

All uses of water affect the value of water. A water use either consumes the resource or affects its intrinsic value. Evaluating water use efficiency within a river basin may be a very complex process, but there are relatively simple cost effective ways to assess the relative value of alternative water uses or management practices. These indices can be used to monitor the effects of changes in policies and practices and to assess how effective available water is being managed in a river basin.

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