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AGRICULTURAL WATER MANAGEMENT

RESEARCH WORKSHOP

October 1992

U.S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
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Research and Laboratory Services Division
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16. ABSTRACT

A water management research workshop was sponsored by Reclamation with assistance from the Texas Water Commission, Texas Water Development Board, and the Lower Colorado River Authority. The workshop was formatted to identify needed research to promote better agricultural water management. The workshop presented an overview of water management from the Federal, State, and private perspectives; a series of technical case studies of current agricultural water management efforts; and resulted in the development of research prospectuses by the participants.

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by

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Hydraulics Branch
Research and Laboratory Services Division
Denver Office
Denver, Colorado

October 1992

UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION

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Many participants from the various organizations assisted in conducting and organizing the workshop. Of special recognition were:

Nick Palacios–Reclamation's Austin Office
Pam Denyer–Reclamation's Oklahoma City Office
Kariann Sokulsky and Comer Tuck–Texas Water Commission
Bruce Hicks, Jobaid Kabir, and Mike Personett–Lower Colorado River Authority
Philip Burgi and Fran Haefele– Reclamation's Denver Office

Ms. Pam Denyer and Ms. Fran Haefele assisted greatly with the organizational planning and running of the workshop.

Mission: As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.

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REPORT OF FINDINGS
Agricultural Water Management Research Workshop

Workshop Origin

In October 1987 Reclamation announced a redirection of agency goals. The focus was to move from water resources development to improved resource management. Reclamation, in their 1988 annual report, described the new direction as follows:

> *The original mission of constructing large federally financed water resource projects soon will be fulfilled. Of increasing importance is the Nation's demand for high quality water and the necessity for more effective, efficient water resources conservation and management. Current objectives are to improve management and use of resources which, for the most part, already are in place.*

The new direction was further defined by emphasizing priorities in 13 key areas. Among the identified priorities was *Research*. The 1988 Reclamation Annual Report states:

> *Research is one of Reclamation's great strengths and has been essential to the success of its mission. The focus of research will shift to resource management issues, technology transfer efforts, and cost-shared activities as this program receives increased emphasis.*

In response to the agencies move to meet changing needs within water resources, the Hydraulics Branch in 1990 initiated a new research program entitled "Water Management Research." As the generic title suggests management of water resources is an extremely broad and complex task. A perspective on how research should focus efforts to provide new tools for improving water management was needed. That perspective was the impetus behind the organizing of an Agricultural Water Management Research Workshop.

Because of considerable interest from Reclamation's Austin, Texas, Office, the State of Texas, and a local water conservancy district, the workshop was held in Austin, Texas, in October 1991. The workshop was sponsored by Reclamation with assistance from the Texas Water Commission, Texas Water Development Board, and the Lower Colorado River Authority. Representatives from these organizations met several months prior to the workshop to set the workshop format and scope.

Workshop Format

The organizing committee felt a workshop with the objective of improving water management required a cooperative effort of both governmental agencies and private water users. Therefore, a strong effort was made to invite a diverse group of knowledgeable participants with a common

goal of promoting beneficial and environmentally sound use of water in agriculture. The workshop agenda was split into three sessions: panel presentation, technical case studies, and group workshops. Session 1 focused on nontechnical, program management issues facing agricultural water use. Sessions 2 and 3 addressed technical research areas. These areas were subdivided into four broad research topics:

- Water Measurement and Accounting
- Projectwide Water Utilization
- Onfarm Water Conservation
- Agricultural Drainage Flows and Nonpoint Source Pollution

Summary–The Workshop Perspective of Agricultural Water Management Research

Reclamation historically has served as a water development organization. Therefore, an important perspective obtained by Reclamation from the workshop is a better understanding of water management problems facing agricultural water users. The workshop provided a melding of problems facing agricultural water users, an exchange of current research initiatives, and many proposals for needed research in agricultural water management. The complexity and diversity of the research presented and, most importantly, the research needs identified cannot be adequately covered in a summary. Therefore, summaries of case study presentations and research prospectuses developed by workshop groups are included in the body of this report. However, several broad research needs were identified that can be summarized:

- **The need for better water measurement data**. Many irrigation projects are now charging for the water delivered to a field based on volume of water and not land acreage. Therefore, billing the end user requires accurate and reliable water measurement data. Obviously, new innovation leading to more accurate, lower cost, and more reliable water measurement devices is needed. In addition, better methods of calibrating water measurement devices, in place, and on a regular basis are needed. However, problems giving rise to poor water measurement often do not result from a lack of technology. The problems arise as a result of improper application of devices, a lack of understanding by the user of how devices work, and poor maintenance. These causes are evidence of the increasing need for educating and transferring research technology to the end user.

- **The need for optimization tools that apply across the water project—farm interface.** Efficient agricultural water management requires good prediction of soil moisture, crop requirements, weather conditions, and the response time of the water delivery system. The greater the response time between calling for water and delivery, the more important the data used for determining water needs become. Some tools are available to optimize delivery systems or farm application systems but few serve both. Water management tools such as geographical information systems (GIS) need to be developed with a focus on improving management data available for both water projects and farm irrigation. Highly efficient delivery systems providing water to poor efficiency farm systems or vice versa result in little, if any, potential benefits.

- **The need for better information on the processes involved as agricultural chemicals enter the soil-water environment.** The solution to agri-chemical contamination of water, needs to be refocused from banning their use to understanding the processes that occur once a chemical type enters the soil-water zone. Research is urgently needed on controlling, breaking down, and sampling chemical contamination.

- **The need for legislation to remove many of the legal barriers which currently block investing in efficient water management.** A workshop on water management research can not avoid recognizing the many barriers to efficient water management associated with western water rights. Present laws in many States do not encourage or in some cases even permit efficient water management without loss of right. Research can again play a role by providing the technical data government bodies will need to address removing such barriers.

Workshop Session No. 1–Panel Presentations

The opening session was formatted to present a perspective on agricultural water use as viewed by Federal and State agencies and private irrigators. The Federal perspective was presented by Charley Calhoun[1], Acting Assistant Regional Director, Great Plains Region, Bureau of Reclamation.

The State perspective was prepared by Mr. James Kowis, Assistant Director, Water Rights and Uses Division, Texas Water Commission. Ms. Kariann Sokulsky, also with the Texas Water Commission, presented Mr. Kowis' speech in his absence.

The irrigator perspective was presented by Mr. Edd Fifer, General Manager, El Paso Irrigation District, El Paso, Texas.

Full transcripts of Mr. Calhoun's and Ms. Sokulsky's presentations are given in section 1 of this report. A transcript of Mr. Fifer's presentation was not available for inclusion in this report.

Workshop Session No. 2–Technical Case Studies

Session 2 of the workshop presented case studies of current research and technology transfer in each of the 4 technical areas. These case studies were presented by experts working in both the government and private sector. Case studies were selected by the organizing committee to emphasize the state-of-the-art, cooperative efforts between governmental agencies at all levels and the private sector, and the importance of transferring research to the end user.

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[1] Presently Assistant Regional Director, Lower Colorado Regional Office.

A summary of each case study is included in section 2 of this report.

Topic Area No. 1–Water Measurement and Accounting.–Case studies for the Water Measurement and Accounting session were chosen to present efforts in technology transfer and implementation. Technology transfer across professional disciplines is an essential component of research and is especially important in the field of water measurement. In most cases, adequate agricultural water measurement accuracy is attainable through the use of existing flow measurement methods and devices if properly applied. However, frequently the importance of operation and maintenance requirements of water measurement technology are not sufficiently transferred to end users. In these cases, attempts to improve water management often suffer from poor quality flow measurement data. Addressing this problem, the State of Montana has undertaken an aggressive water measurement technology transfer program. Mr. Greg Ames, Head, Hydro-Science Section, Department of Natural Resources and Conservation, State of Montana, presented an overview of Montana's unique program.

The second case study focused on implementing a cost-effective water measurement program in an existing water district. Mr. Bruce Hicks, Irrigation Operations Manager, Lower Colorado River Authority (LCRA), provided a presentation on many of the problems they faced including calibrating and using existing turnouts as flow measurement devices.

Topic Area No. 2–Projectwide Water Utilization.–The second topic area was termed Projectwide Water Utilization. This topic area encompassed research for improving water management at the project or water district level. Historically, Reclamation has been an active participant in this area of research. In particular, Reclamation's research efforts in canal automation and lining and more recently GIS have been extensive. Two case studies on Reclamation's efforts in these areas were presented at the workshop.

Today's rapid technology advances in the areas of electronics and materials science are being employed by engineers to achieve greater water and cost savings in water delivery systems. Several examples were presented by Mr. Dave Rogers, Water Conveyance Branch, Division of Civil Engineering, in an overview of Reclamation's long standing research in canal automation and lining.

GIS is an acronym used to describe geographically referenced computer data base systems. Data such as soil types, land ownership, irrigation status, crop types, etc. are stored in a multilayered hierarchy. Layering of the data provides a highly efficient method of recalling, correlating, and processing interrelated site data. Mr. Michael Pucherelli, Head of Reclamation's Remote Sensing Section, Research and Laboratory Services Division, presented a summary of GIS and the value of remotely sensed data for GIS based water management programs.

Topic Area No. 3–Onfarm Water Conservation.–Presentations were given discussing two highly noted and very different onfarm research projects. The first presentation was given by

Dr. Earl Stegman, North Dakota State University, on the Oakes Test Area, a full-scale irrigation test project in North Dakota. The Oakes Test Area was constructed as part of Reclamation's Garrison Diversion Project. Although the Garrison Project has been significantly scaled down from its original scope, the Oakes Test Area has continued to be operated as a unique irrigated agricultural research facility.

The second onfarm case study was presented by Mr. Wayne Wyatt, General Manager, High Plains Underground Water Conservation District No. 1, Lubbock, Texas. The High Plains area relies on natural precipitation and ground water pumped from the underlying Ogallala Aquifer to irrigate crops. The cost of pumping and depletion of ground water are major concerns to irrigated agriculture in the area. The High Plains District No. 1 recognized these problems and has become a leader in efficient use of water through improved irrigation techniques and good water-management practices.

Topic Area No. 4–Agricultural Drainage Flows and Nonpoint Source Pollution.–The issues of agricultural practices and their effects on water quality are "highly visible" concerns in today's environmentally conscious society. Farmers and the general public are questioning the long term effects of many traditional farm practices on both water and soil quality. Both improved management practices and better methods of removing agricultural contaminants are needed. One form of treatment currently under study for agricultural return flows is the use of wetlands. Dr. Rick Nelson, Reclamation's Missouri-Souris Projects Office, North Dakota, presented a research case study of this often controversial issue.

Workshop Session No.3–Needed Agricultural Water Management Research

Workshop participants were separated into four groups based on interest in each of the topic areas. Initially, they were asked as a group to identify and prioritize problems confronting efficient water management under two of the four topic areas. Each group was asked to work on only two topic areas to provide adequate time for group discussion of ideas raised. After each group prioritized problems identified based on importance, the problems identified under each topic area were combined from the groups and given to a single group. Groups were then asked to discuss each problem, consolidate listed problems as appropriate, and then write a research prospectus addressing possible research needed to solve each. These prospectuses are given in section 3 of this report. The groups were asked to provide research goals, methods of approach, barriers to implementation, and expected benefits of the research. In addition, estimates of time, costs, funding sources, and who should do the research were made.

SECTION 1–PANEL PRESENTATIONS

Federal Perspective
by Charley Calhoun[2]
Acting Assistant Regional Director, Great Plains Region
October 10, 1991, Austin, Texas

It's a pleasure to be with you this morning. I feel very strongly that what we discuss here today and tomorrow is extremely important to the future of water management in the West.

My task is to provide a Federal perspective on water conservation and water quality issues. Of course, I can really only speak from the perspective of one water management agency. However, as you know, the Bureau of Reclamation is the single largest provider of agricultural water in the 17 Western States. In 1989, our 355 dams and 254 diversions delivered nearly 26 million acre-feet of water to nearly 10 million acres of cropland. This farmland produced just under $9 billion worth of crops. Obviously, we are a major player in the western water game.

Although the general public often confuses us with the Bureau of Land Management for some reason, those who are familiar with water development in the West know of Reclamation's work. Over the years we have developed a reputation as a top-notch engineering and construction agency. And perhaps that reputation has worked against us somewhat as we shift away from our traditional construction role and begin using our technical expertise to accomplish additional goals in water management.

To help understand how we got here, to understand the present Federal perspective on water management, a quick overview of our history is important. As settlement west of the Mississippi was getting underway, it became clear that farmland was of little value without a stable supply of water. As you well know, Mother Nature does not provide rainfall in equal abundance from location to location and from year to year, especially in the West.

Reclamation was created to help reclaim arid lands through irrigation. As outlined by Congress, our program was to have the effect of stimulating further settlement and providing for economic development and stability. We feel it has accomplished that very well.

But because the Reclamation program was successful in fostering settlement and economic development, new public needs for water arose. Eventually, the single purpose mandate of the Bureau was expanded to include other beneficial purposes like hydroelectric power, flood control, municipal and industrial water, water quality, recreation, and fish and wildlife protection and enhancement.

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[2] Presently Assistant Regional Director, Lower Colorado Regional Office.

It's easy to describe this evolution in one quick sentence, but the changes haven't come quickly or easily. They are the result of a number of social, economic, demographic, and physical forces which have quite literally reshaped the West.

Our society is paying much more attention to the consequences of our actions. People are taking a closer look at how water is being developed and used and how that use affects or influences other resources. And we are looking much more carefully at what water development costs.

We have seen major shifts in our population. People have moved in droves to the far West and Southwest, and at the same time there has been a tremendous shift off the farm and into town. We are not a rural population any more.

With the resulting population growth and shift has come an ever-increasing demand for water. And this has happened at a time we have been experiencing some pretty dry years in most of the West.

When you combine increased attention to environmental issues, more fiscal conservatism, increasing demand for water, and shrinking supplies, the stage is set for conflict. And if demand exceeds supply, for whatever reason, the conflict intensifies. As Benjamin Franklin said, "When the well's dry, we know the worth of water."

Conflict over water is certainly not a new phenomenon in the West, but in the past it was mostly an issue of who owned and controlled the abundant supplies. Now it's more complicated than that.

Those who represent what we might call the more nontraditional water uses such as in-stream flows, wildlife habitat, wetlands, or recreation are saying they were not adequately considered or were not considered at all during the original water allocation process.

Just during the last year in Reclamation's Great Plains Region alone there have been a number of examples.

The three States which encompass the upper end of the Missouri River Basin filed suit against the Army Corps of Engineers contending recreation and its economic benefits have not been considered in decisions affecting the way the river is managed. The States in the lower part of the basin strongly disagree. The Attorney General for Missouri said, "When the Federal Government built the six dams between Fort Peck, Montana, and Sioux City, Iowa, its intention was not to subsidize the tourist industry."

In Kansas and Nebraska this summer there was protracted public debate over the dropping supply of water in a reservoir. There were reservoirs dropping all over the State, but the debate at this particular reservoir centered on whether irrigation was getting an unfair proportion of the available supply at the expense of recreation and the lake's fishery.

Another point of confrontation is between agricultural and municipal water users. Where city populations continue to expand and even encroach on agricultural land, there is tremendous pressure to move some of the agricultural water rights over to municipal use. There is a move afoot by some members of the California congressional delegation, for example, to enact laws which would divert a considerable amount of water from agricultural uses in the Central Valley to municipal use and for the protection of fish and wildlife. At the same time, the General Accounting Office (GAO) issued a report urging the Federal Government to declare a moratorium on all renewal of contracts for water delivery in the Central Valley. GAO said allocation of too much water to agriculture has hurt California wetlands and contributes to excessive accumulation of salts in the San Joaquin Valley.

And it's not always an issue of traditional versus nontraditional uses. Near Aspen, Colorado, residents who use a Reclamation lake for boating this summer were fighting a decision to release water into the Colorado River drainage to help protect threatened and endangered fish.

These are just a few of the examples of battles taking place all over the West. The long-standing traditions and laws regarding water in the West are being called into question. Nontraditional water users are going to court and winning the right to water that previously was held by more traditional uses like irrigation or hydroelectric power.

I don't want to sound a cry of doom and gloom, but rather just want to suggest that the very reason we are here to consider research opportunities in water conservation and water quality is very crucial in light of the forces coming to play.

But where does the Bureau of Reclamation fit into all of this? People often associate us with water storage and delivery and assume our role ends there. In fact, there are those who feel that because the job of building major water projects in the West has essentially been completed, Reclamation has exceeded its useful life. We would disagree. We feel there is still a major role for Reclamation in water issues in the West.

Because we own and are involved to varying degrees in the operation of so many water storage and delivery systems, and because the rights to a great deal of water were secured for these projects, we will, of necessity, remain in the middle of the fray. But we feel we are in a good position to use our technical and professional experience and expertise to address new water conflicts and challenges.

Most of these conflicts and challenges do not respect jurisdictional boundaries. They are not Federal problems alone. They are not solely State problems. And local agencies and individual irrigation districts need not be left to sort out the problems themselves.

We can all pool our human, technical, and financial resources to address issues of mutual interest through long-term partnerships. And I think it's important to point out this should not involve only the traditional water users. We should be reaching out to develop partnerships with the environmental community that might not even have been considered before.

Let me use the balance of my time to briefly describe how Reclamation is already addressing some of these issues. You will quickly notice the important common element in all of the examples is their cooperative nature.

Rehabilitation and Betterment

The concept of water conservation, contrary to what some may think, is not new to Reclamation. Over the years we have helped irrigation districts conserve a considerable amount of water by accomplishing rehabilitation work under the auspices of the Rehabilitation and Betterment or R&B program.

Some of the irrigation and drainage systems in operation today are between 80 and 90 years old. Even though the most up-to-date technology for the time was utilized in their construction, they just are not as efficient as the projects that are built with today's technology. In addition to being less efficient overall, their advanced age has led to deterioration and obsolescence. In many cases, funds that could be banked for a long-term capital improvement program are used to make costly annual repairs just to keep the system operating.

The Rehabilitation and Betterment Act, passed by Congress in 1949, was designed to provide a way of correcting inefficiencies in water collection, delivery, and drainage systems on Reclamation projects. Another law was passed in 1975 which expanded the R&B program to include funds for the rehabilitation of projects that provide for the needs of other water users and may alleviate conflict.

It's important to mention here, since we are talking of the Federal perspective, that the R&B program has been the subject of considerable attention by the Administration, particularly the Office of Management and Budget, and some individuals in Congress. There is concern that the program is putting too much Federal money, under terms that are too favorable, into projects where there should be more local and State responsibility.

Along those lines, a recent audit report by the Interior Department Inspector General suggests the Bureau's repayment policies do not provide for a way to charge users to help fund capital improvements to the aging water delivery infrastructure. The Inspector General has

recommended we change our policy to address funding requirements for capital improvements and to develop a user charge policy. Reclamation will soon be addressing those recommendations.

RRA Water Conservation Plans

Another area where we work closely with irrigation districts in water conservation is under RRA. Section 210 of the Reclamation Reform Act of 1982 formalized the requirement for irrigation districts receiving Reclamation water to develop and implement water conservation plans. We have found districts to be very supportive in this endeavor, and many are taking creative approaches. Many districts have been installing measuring devices or are otherwise trying to increase their ability to measure water distribution.

Many have embarked on projects to repair linings, pipes, and gates, or to change from open to closed distribution systems. Some have implemented ambitious education programs. Reclamation will continue to emphasize this requirement under Reclamation law and will make available expertise, especially through the new water conservation advisory centers, to help in the effort.

Research can help find ways for irrigation districts to economically make their systems and onfarm operations more efficient.

When the kinds of conflicts I mentioned a few moments ago begin to develop between irrigators and other users of water, the other users will immediately point to any wasteful and inefficient operations they see. As with rehabilitation and betterment projects, the water saved through active conservation programs might be all that's needed to meet the needs of these other uses.

Water Transfers, Leases, or Sales

While there are a number of policy and legal issues that must be sorted out, there is a tremendous opportunity around the West to get water where it is needed most through transfers, leases, or sales.

Our policy is to be a facilitator in transfers that potentially affect Federal projects or federally owned water rights. Primacy in water allocation and management rests with the States, and because they all have differing water laws, it is essential that our role be that of a facilitator.

We see the opportunity for moving water around to its best use at the time as a way to provide incentives for conserving water. If, for example, conservation creates water that is surplus to an irrigation district's needs, Reclamation can facilitate marketing between willing sellers and buyers.

Sometimes water may be conserved because of a technical solution. I see research playing a key role in identifying these technical solutions. Other times water may be conserved through a creative management approach. Or it could be a combination of both. We are seeing and participating in a lot of creative endeavors to get water either temporarily or permanently shifted to its best use.

At Box Butte Reservoir in northwest Nebraska, for example, annual irrigation releases were drawing the reservoir to such low levels the fish population was flushed out and lost. It was impossible to maintain a viable fishery in the reservoir and recreation was severely hampered because boat ramps were left high and dry.

The solution to the water supply problem was a unique agreement signed by the Mirage Flats Irrigation District, which operates the reservoir, the Nebraska Game and Parks Commission, which is responsible for its recreation, and the Bureau of Reclamation.

The irrigation district agreed to maintain the reservoir at a level adequate to protect fisheries and recreation. The Game and Parks Commission agreed to pay the district $294,530 to compensate for water lost because of the evaporation off the larger reservoir surface during the 30-year life of the agreement.

The district will use those funds to upgrade its delivery system. The water saved by the rehabilitation will offset that lost from increased reservoir evaporation. It was what Reclamation Commissioner Dennis Underwood called a "Win-Win" situation.

Sometimes there's a need to make a permanent change in the use of a particular project's water. Because authorizing legislation normally spells out how a project's water supply can be used, new legislation is needed to permanently change that use.

Reclamation has been working with the State of Kansas and the Cedar Bluff Irrigation District to effect a change in the allocation of water from Cedar Bluff Reservoir in the north central part of the State. Where the project was originally designed primarily for irrigation, declining reservoir levels have made irrigation deliveries impossible. Legislation is pending which would authorize reallocation of the existing conservation storage capacity to fish, wildlife, recreation, ground-water recharge, and other purposes.

Under the terms of the legislation, Kansas would make an up-front payment to satisfy all reimbursable irrigation costs and will share in the reservoir's annual operation and maintenance costs in return for the use and control of the reallocated reservoir. The irrigation district contract with the United States will be terminated and irrigation facilities closed.

For an irrigator this may seem like a grim example. I'm not trying to suggest that irrigation facilities are going to be shut down and the water devoted to other uses. I use the example only to suggest permanent shifts in the use of water are sometimes necessary.

High Plains States Ground Water Demonstration

Another method of conserving water resources is through ground-water recharge. Considerable research has and will continue to be done on how to deal with declining ground-water supplies, particularly in the plains States overlying the Ogallala Aquifer.

Reclamation has been involved since 1986 in a cooperative effort with the U.S. Geological Survey, Fish and Wildlife Service, EPA, and State and local agencies in carrying out the High Plains States Ground Water Demonstration Program. This program is designed to demonstrate the effectiveness of a variety of methods of recharging declining ground water supplies.

The actual project phase of the program got underway in 1989 with the first demonstration projects becoming operational this year. The 17 projects range from capturing snowmelt to recharging an aquifer with treated effluent from a municipal wastewater treatment facility.

One of the projects on the drawing boards awaiting further program funding is in the Lubbock/Crosby County area of the Texas Panhandle. The project will demonstrate the potential for collecting precipitation runoff in playa basins and then economically cleaning it of suspended particles so it can be stored in a near-surface geologic formation for future use. The partner in this effort is Texas Tech University.

Water Quality Initiatives

In addition to water quantity and conservation issues, the other major area of concern being addressed in this conference is water quality research. There are already many cooperative efforts taking place, but more research opportunities exist.

You'll hear about this in great detail later, but we are proud of the research underway at the Oakes Research Test Area in North Dakota. This is a cooperative effort among Federal, State, and local entities, and the State university system to determine how various farm management practices affect the quality of ground water and surface flows.

Even more important than the agencies and universities involved, however, is the involvement of farmers who are assisting by incorporating best management practices on actual commercial farming operations.

We also started working this year in partnership with the University of Nebraska on a program to study how to reduce nitrate concentrates in ground water. The project is being cost-shared 50-50.

I should also mention the Lake-Andes Wagner/Marty II Project in South Dakota. This is a 45,000-acre irrigation development in the southeast corner of the State. Because of concerns about potential selenium contamination from irrigation return flows in the project, Reclamation cooperated with South Dakota and the U.S. Geological Survey in 1989 in an evaluation which concluded there is a likelihood of selenium contamination.

Such a discovery would normally be a death knell for a project like this, but it has evolved into a course of action to further investigate the selenium issue and how to deal with it. Legislation to authorize the project provides for an irrigation/drainage field demonstration on the project site to study return flows, best management practices, and wetlands effects. There has been wide support in Congress for the project. It is included in an omnibus bill that was stalled in the last session and again this year by other controversies.

This project suggests an interest in Congress with providing authorization and funding for projects that get at some of the environmental, conservation, and water quality issues. This and the other examples I've outlined also suggest it is possible to put together cooperative research and demonstration efforts.

Information and Education

I would also like to mention the role of education in all of this. There are two aspects of this topic. First, we can do all the research we want and yet, if we don't get the information and results to the people who need it and use it, it really doesn't do much good. Second, it is our youth who will inherit either the benefits of the research we do today or the results of our failures.

In an effort to promote more effective dissemination of information about water conservation, each of the Reclamation regions and the Denver Office is forming a water conservation advisory center. These centers are designed to get water conservation issues and information into the forefront. Each center will draw upon the expertise of that office's employees, State university systems, water users, and others to formulate strategies that will result in more efficient use of water and to develop techniques of getting information where it needs to be.

We expect all of the centers will operate in much the same way while allowing for individuality to address the needs of the particular locale. They will all be gathering and cataloging clearinghouses of information on water conservation. They will draw upon the technical skills and knowledge of a variety of disciplines to provide technical water conservation assistance to water users, and they will develop educational outreach efforts to get this knowledge and information disseminated.

In fact, I hope the data generated from the research efforts identified in this meeting is the kind of information that will be made available to end users through these advisory centers.

I also want to mention that the Bureau of Reclamation is taking the lead in an effort to develop a national program to teach youth about water conservation and water quality issues. The Great Plains and Pacific Northwest Regions developed a pilot program in cooperation with Montana State University.

Project WET, or "Water Education for Teachers," was implemented successfully in Montana and Idaho using materials and methods developed in North Dakota. The program is designed to get educational materials and ideas about water resources into the hands of public and private school teachers so they can adopt it into their curriculum.

The Commissioner of Reclamation has endorsed Bureau-wide implementation of Project WET, and funding will be provided to help this happen. Nationwide implementation will be accomplished through the Western Regional Environmental Education Council, the organization responsible for the extremely successful Project WILD and Project Learning Tree environmental education efforts.

Individually, none of us have all the answers about water conservation and water quality. Collectively, however, we just might find some solutions. The bywords in this process must be creativity, cooperation, and adaptability.

State Perspective

by James Kowis
Assistant Director
Water Rights and Uses Division, Texas Water Commission
October 10, 1991, Austin, Texas

New Problems, New Solutions

As the number of water management issues has broadened from simple consideration of water quantity to concerns regarding quality, increasing competition, protection of instream flows, and so forth, the "management" of the State's water resources has become more complex. Two fundamental water management issues facing Texas today are: (1) increasing water demands vis a vis almost full development of water supplies; and (2) determination of how to best allocate water resources so as to supply demands, maintain or improve water quality, and protect aquatic systems.

Given the increasing water demands in Texas, the first issue leads to: **"From where could additional water be obtained?"** One source is water conservation. In the State water plan, water conservation plays a significant role in calculating water demands for the planning horizon 1990 through 2040. For the agricultural sector, the plan assumes a decrease in agricultural water use from 8 million acre-feet in 1990 to 6.7 acre-feet (or less) by the year 2040. The plan states that the reduction in irrigated agricultural water use will occur because of reductions in water requirements from water conservation and increased use efficiencies. This leads to a subsequent question: "How do we manage so as to realize this decrease in agricultural water demands?"

In Texas, there are two State agencies which have responsibilities related to water management: the Texas Water Development Board (TWDB) and the Texas Water Commission (TWC). The TWDB is responsible for the development of a State water plan, and for providing State financial assistance for water supply, water quality, agricultural conservation, and other water projects. The TWC is the State agency which regulates water quantity, water quality, hazardous waste, solid waste, and other environmental programs. Texas, however, has historically limited the ability of "STATE" agencies from controlling natural resources, especially water. This policy of limiting State power reflects a populist mentality which promotes the individual or individual entity as the "best" and preferred manager for any public policy program or resource especially water resources despite a statute which declares all surface waters the property of the State.

So, especially in a State as geographically diverse and large as Texas, a critical question to ask in regards to water management is: **"Who is the 'State'?"** Is it the State agencies just mentioned, the local and regional water supply entities, or is it the individual end-users who depend upon the water resources of Texas on a day-to-day basis? This is the same as saying how do we effect policy goals and objectives.

Promoting Water Conservation

In the past, the answer to projected water shortages was to build additional water supply projects. But the 1990s is the decade of the environment, and people are beginning to ask today whether the building of more reservoirs is really the answer. They are not only asking the question in relation to the effects on the environment, but also in relation to "how much is it going to cost me the user?" Economics at the personal level is beginning to pressure water managers into looking for more or different cost-effective alternatives to increasing supply. More and more, conservation is touted as a solution for "supplying" increasing water demands. In the agricultural sector, water conservation is touted as a tool not only for addressing water demands in that sector, but in the municipal sector as well. In the lower Rio Grande valley, for example, municipalities are now considering the possibility of investing in agricultural water conservation measures in order that they, the municipalities, may capture the conserved water in order to supply their growing populations.

Six years ago, the Texas Legislature passed a bill which established a new direction in the State's water policy. For the first time, water conservation was not only defined as the development of water resources, but also as the use of those practices, techniques, and technologies that will reduce the consumption of water, reduce the loss or waste of water, improve the efficiency in the use of water, or increase the recycling and reuse of water so that a water supply is made available for the future or alternative uses.

The TWDB has promoted water conservation since the original legislation was passed with three distinct strategies. First, any political subdivision of the State requesting to borrow money through the TWDB is required to develop and implement a water conservation plan before funds may be released. Second, the TWDB administers a $5 million agricultural loan program for investments in water conservation equipment. Finally, upon request, the TWDB provides technical assistance for water conservation measures to both the agricultural and other sectors.

The TWC is currently developing a new strategic plan for all its program areas. The Commission has established as one of its goals to reduce water use in all sectors by 20 percent below 1990 levels by the year 2000. This is an ambitious goal, but one that I think is attainable.

In order to encourage conservation strategies within Texas, the TWC has just developed policies which require water right applicants to submit and implement effective and meaningful conservation plans. Currently, TWC staff are defining both the standards for such plans and the evaluation criteria for reviewing these plans. For agricultural users, the strategy of TWC staff is to primarily target the efficiency of an irrigation system rather than dictate either the type of technology or "best" practices. Technology is continually changing, but what we are really targeting in water conservation is efficiency, for, by definition, an improvement in efficiency is conservation. Most agricultural producers hate it when someone tells them exactly what they can or cannot do. I have found, however, that most agricultural producers are willing to work with you if you will give them a goal and then let them decide for themselves how to accomplish it. This strategy allows the agricultural user to be innovative in determining the "how to"—a

flexibility which economists have recognized to lead to cost-effective measures and greater economic efficiency.

The TWC is also committed to providing technical advice to water users in order to help them identify and implement appropriate conservation measures. The TWC is currently developing strategies for providing assistance and information to water users regarding water conservation measures.

Challenges

The attainment of agricultural water conservation goals will not be without its own barriers. For one, most irrigators will not be able to accomplish conservation without some cost. Also, since many ground water and most surface water users in Texas are individuals, another challenge will be in determining how to expose the irrigator to conservation techniques which are available and then how to encourage adoption of those techniques. For example, in the Brazos River basin 70 percent of the total surface water rights for irrigation collectively account for only 6 percent of the total volume of water appropriated for irrigation use; moreover, each of these rights represents only 100 acre-feet or less.

What are the solutions for effecting conservation in the agricultural sector? One way to cover the cost of implementing conservation measures is to use the water saved through conservation for either an expansion of the farmer's operation or to market or transfer that water to another or new user. Water rights are transferable in Texas. In fact, we process about 400-500 ownership changes a year. Currently in Texas, most marketing of water rights takes place in the Rio Grande Valley—the reason being is that the Rio Grande is over-appropriated so the only way to obtain a right is to buy all or a portion of another right.

Another way to possibly realize large savings of water would be to focus on the water districts. Districts and irrigation companies typically manage and/or control large volumes of water, especially in regards to surface water. These districts can be assisted in the development and adoption of comprehensive water conservation plans for their districts. In some areas of the State certain water districts have already done a tremendous job in providing their constituency with the latest and best technology that is available. Not only have they provided information, they also have been able to implement demonstration projects. In this State, as well as the country, we will have to continuously address the method of providing the agricultural producer with information and other assistance in order to change certain "wasteful" habits.

SECTION 2–TECHNICAL CASE STUDIES
Topic Area No. 1–Water Measurement and Accounting

Water Measurement Training and Technology Transfer Program

Mr. Gregory H. Ames, Head, Hydro-Science Section
Department of Natural Resources and Conservation
State of Montana

The 1989 Montana Legislature enacted House Bill 463 (85-5-111, Montana Code Annotated), which initiated the development of an education program for water commissioners and mediators in the state of Montana. The purpose of the program is to educate current and potential water commissioners and mediators on their respective duties, mediation techniques, and water measuring techniques. The bill also required the preparation and, as necessary, revision of a water commissioner and mediator manual, along with the development of an outreach program to identify potential water commissioners or mediators.

The Department of Natural Resources and Conservation (DNRC) was directed to develop and initiate the program in cooperation with the Montana Supreme Court, the Montana water courts, the district courts of Montana, the Montana university system, and other appropriate State and Federal agencies. With the assistance of these entities, along with the U.S. Department of the Interior, Bureau of Reclamation, Montana Projects Office, DNRC has successfully initiated this program.

Although Montana is generally a water-rich State, certain areas experience occasional or chronic water supply problems. Through the development of this educational (technology transfer) program, the wise use of water will be promoted, and the public will be educated on proper water measuring techniques.

The training program focuses on identification of water commissioner and mediator duties, location of water resource information, water measurement, units and techniques, and water measuring and metering devices. The program also presents an explanation and the status of the Statewide adjudication process.

This well-received program has been quite successful. The concept of presenting the physical and legal aspects of water measuring together, involving each of the various water-related entities, has worked well. Program participants will receive the complete picture of each aspect of water through a single training program.

Lower Colorado River Authority Water Measurement Program

Mr. Bruce Hicks, Irrigation Operations Manager,
and Jobaid Kabir,
Lower Colorado River Authority
Eagle Lake, Texas

Introduction

Rice irrigation is the largest user of water within the area served by the Lower Colorado River Authority (LCRA), accounting for approximately 75 percent of total annual surface and ground water demand. In an average year, about 30 percent of surface water supplied to rice irrigation is satisfied with water released from the storage in the Highland Lakes located at the upstream reaches of the Lower Colorado River and its tributaries. During a severe drought, the demand for stored water could be as much as 70 percent of annual rice irrigation demand.

LCRA owns and operates two irrigation canal systems which together supply water to irrigate 60,000 acres of rice in Texas each year. These irrigation systems are the Lakeside and Gulf Coast Irrigation Divisions. The Lakeside system is located in Colorado and Wharton Counties and the Gulf Coast system is located in Wharton and Matagorda Counties.

In October of 1989, the Lower Colorado River Authority Board of Directors authorized implementation and funding for the Phase I of the Irrigation Water Measurement Project. This water measurement project is a key initiative to agricultural water conservation goals established in the LCRA Water Management Plan and Water Conservation Policy.

During the 1990 rice irrigation season, LCRA field tested a system to measure the amount of water delivered to individual farms. In this Phase I of the Irrigation Water Measurement Project, three test sections were identified within the two irrigation districts of LCRA with approximately 3,000 acres in the Lakeside Irrigation System and 6,000 acres in the Gulf Coast Irrigation system.

Project Scope

The objective of Phase I of the Irrigation Water Measurement Project was to fully evaluate the technical and economic feasibility of measuring the amount of water delivered to the individual rice farmers of Lakeside and Gulf Coast Irrigation Division. The final goal of this project is to implement a full scale measurement system for both Lakeside and Gulf Coast Irrigation Divisions, if technically and economically feasible.

The purpose of this project is also to revise irrigation water rates to recover a portion of the LCRA irrigation operation costs through volumetric charges. The expected water conservation benefits of this project include improved canal operation efficiency and reduced onfarm water

use in response to water pricing incentives. The objective of this report is to evaluate technical feasibility of volumetric water measurement of farm delivery water.

Instrumentation and Structure Modification

The water flow control structures of the Lakeside and Gulf Coast irrigation Systems can be divided into two general groups: main canal structures and farm delivery structures. While the main canal structures are used for the flow control in the canal distribution system, farm delivery structures are used for regulating the flow of water to individual farms from the canal system. Historically, both these two types of structures were used for regulating flow only and thus the design of these structures did not consider their possible application as flow measurement devices.

A wide variation of main canal structures and farm delivery structures exists throughout the two irrigation systems. The test sections selected for this study provided a good representation of different types of structures available in the two irrigation systems. Minor modifications were made to the flow control structures within the test sections to use them for flow measurement in addition to their primary application of flow control.

Because of the diverse nature of the main canal structures and farm delivery structures, two types of electronic water level recorders were used for flow measurement of these structures. For overshot main canal structures, electronic water level recorders were installed to measure depth of flow only at the upstream side of the structures. For undershot main canal structures, both upstream and downstream water depths were recorded by the water level recorder. In addition to the electronic water level recorders, staff gages were installed for recording water surface elevation in the canal.

For the farm delivery structures, two types of instrumentation were used for the flow measurements. For farm delivery structures with pipe turnouts from the main canal system, direct flow measurement through the pipe was made by propeller-type meters. Depth of flow measurements through the concrete and wooden water boxes were made by measuring depths of flow near the box by using staff gages. For overshot boxes, depth of flow was measured at the upstream side of the box and for the undershot structures depth measurements were made at both upstream and downstream sides of the box.

Additional Parshall flumes were installed immediately downstream of selected farm delivery structures for determining the accuracy of estimating flow using measurement from the structure itself. An electronic water level recorder was installed at each Parshall Flume site to record water depths. Electronic water level recorders equipped with two input channels were used for Parshall Flumes to record two depths of flows.

Weir blades were installed in all undershot and overshot water boxes used for farm delivery for accurate flow measurement. An attempt was made to install similar weir blades in main canal

structures. But because of employee safety concerns, after 3 weeks of data collection the weir blades were removed.

Structure Calibration

The U.S. Department of the Interior, Bureau of Reclamation (Reclamation), Hydraulics Laboratory at Denver, Colorado, conducted physical model studies of the different measurement approaches under various flow conditions of LCRA water boxes. Using the results of these model studies, formulas were developed for computing flow rates through these structures using the measured values of water surface elevations and orifice openings. Separate relationships were developed for overshot and undershot flow conditions.

Parshall Flumes were installed downstream of designated water boxes during the 1990 irrigation season within the test sections of Lakeside and Gulf Coast Irrigation districts. Electronic water level recorders installed at the Parshall Flumes measured water surface elevations at two key locations every 30 minutes. Using this data, flows through Parshall Flumes were computed and compared with estimated flows through the farm delivery structures. Results of these comparisons revealed that flows computed for the farm delivery water boxes agreed very well with the Parshall flume measurements.

Main canal structures were calibrated by comparing estimated flows through these structures with the measured flows using current meters. U.S. Geological Survey (USGS) conducted these current meter measurements, which were funded by Reclamation. Because the geometry of the main canal structures is poorly defined, calibration developed using USGS current meter measurements was not valid throughout the irrigation season.

Data Collection and Analysis

Various types of farm delivery structures were included in the test sections of this study. Because of the different varieties of the farm delivery structures within the study area, data needs for computing flow through these structures were also different. While for some farm delivery structures it was necessary to measure water depths at specific locations, other structures called for direct flow rate measurements using propeller-type devices.

Lotus 1-2-3 spreadsheets were developed for each farm delivery structure for storing field data and for performing hydraulic computations. These spreadsheets included the geometric features of the structures itself and formulas for flow computations. Formulas developed by Reclamation were used in the development of these spreadsheets for water boxes. Since the farm delivery structures are of different types, the spreadsheets used to compute their flows were also different. Because of the large volume of data, spreadsheet computation of flow was very slow at occasions, particularly for the main canal structures.

Accuracy of farm delivery structures in measuring flow was checked by comparing estimated flow with the measured flow using a Parshall Flume installed immediately downstream of selected water boxes. Computed cumulative volumes from the Parshall Flume were compared with the corresponding cumulative volumes computed from the data collected from the farm delivery structure located immediately upstream of the Parshall Flume. In general, cumulative volumes computed from Parshall Flume data were within 5 percent of the measured volumes for the farm delivery structures.

Data collected for the main canal structures included water surface elevation upstream of the structure, and elevation of the top board or weir blade. Elevation of the weir blade was recorded at the time it was changed and also measured at every site inspection. All main canal lock sites were inspected at least once a day. Water surface elevations were recorded by the electronic water level recorders. These electronic water level recorders measured water surface elevation at every 30-minute interval.

Main canal structures used in this study are different from one another. While some of the structures are made of one gate others are made of several gates of various widths. For some of the structures flow through these structures approaches at an angle complicating the hydraulic computations.

Accuracy of estimating flow through a main canal structure was checked by comparing estimated flows with the directly measured flow by using current meters. This analysis revealed that estimated flows for the farm delivery structures varied from –12.68 to 11.13 percent compared to the directly measured flows by USGS using current meters. This large error in estimating flow through these main canal structures had several causes, including large leaks between flash boards, poorly defined structures, and absence of weir blades. Also, analysis of the data collected thorough the irrigation season indicates that the leakage through the flash boards increased with time until some type corrective measure was taken by the water boss.

An attempt was made to develop a water balance to account for all water delivered to the field between two main canal structures. Results of this water balance analysis were not consistent. While some of these analyses demonstrated close comparisons others showed large error in the accounting process. These inaccuracies in water balance analysis resulted from the inaccuracy of estimating flow through main canal structures because of unpredictable leakage through the flash board joints, absence of weir blade, and undefined structure geometry. Another reason for such inaccuracy was the failure of the main canal structures in maintaining calibration for the entire length of irrigation season.

Before the initiation of the Water Measurement Project, it was observed that canal water surface fluctuated about 1 foot through the period of a day. During this study, attempts were made to minimize water surface fluctuation in the main canals to facilitate accurate estimation of flow though the farm delivery structures. Observation of the data collected by the electronic water level recorders reveals that although the canal water surface in the main canals fluctuates somewhat, it is small. Recorded daily fluctuations in the canal water surface were of

the order of 2 to 3 inches. The water surface fluctuations were small as a result of improved canal operations. The installation of several staff gages at strategic locations in the canal system provides a good reference to water bosses for maintaining the water surface fairly steady in the canals.

Conclusions

Based on the analysis of this data collected during the 1990 irrigation season from Lakeside and Gulf Coast irrigation systems the following conclusions are made:

1. Use of farm delivery structures for flow measurement is technically feasible.

2. Parshall flume measurements agree closely with the flow from the farm delivery structure.

3. Daily water surface fluctuations in the canals could be contained within 2 to 3 inches by providing staff gages at strategic locations in the canal system.

4. Spreadsheet computation of flow is slow because of the need for processing large volumes of data.

5. Use of main canal structures for the estimation of flow in the main canal is not technically feasible.

6. Water balance for canal sections is not technically feasible.

Recommendations

Based on the above conclusions, the following recommendations are made for future actions:

1. If economically feasible, implement water measurement for farm delivery in both Lakeside and Gulf Coast Irrigation systems of LCRA to have a volumetric water rate for irrigation achieving agricultural water conservation goals established in the LCRA Water Management Plan and Water Conservation Policy.

2. Gradually convert all farm delivery structures to standard concrete boxes for uniformity and for more accurate flow measurements.

3. Make flow measurements at the farm delivery structures every time there is a change in the flow conditions caused by either the change in water surface in the canal or any change in the orifice opening of the structure.

4. To expedite data processing time, develop a data base manager for performing all hydraulic computations and accounting. This data base manager should have the capability to generate reports for individual farmers, farms, and farm delivery. This data base manager also should be able to prepare summary reports for either the entire system or a part of the system for using as a tool for managing the canal system.

5. As long term activities, redesign the main canal structures for achieving improved control of flow and for flow measurement in the main canals. Improved main canal structures will help develop a water balance approach of accounting for flows for sections of the canal.

Topic Area No. 2–Projectwide Water Utilization

Water Delivery Efficiency Improvement Automation and Canal Lining

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Irrigation represents about 85 percent of the total water resource demand in the western United States. As the demand for water increases, operating efficiency of water conveyance systems needs to improve. Typically, irrigation canal systems have an overall efficiency of about 40 percent; i.e., only about 40 percent of the water entering the canal system becomes available for consumptive use.[3] Automating and lining irrigation canals can improve delivery efficiency significantly.

Canal Automation

In recent years, the rapid advancement of automatic control equipment has greatly expanded the field of canal operation and control. The improved operations afforded by an automated control system have many benefits, including increased crop production, reduced water use and waste, improved service to water users, and better response to emergencies. When automatic control was applied on the Corning Canal in California, benefits exceeded costs by a factor of two.[4] Automation can increase canal operating efficiency 10 percent or more.[5] In addition, farmers can see an increase of 15 percent or more in crop yields.[6]

Canal automation may vary from simple devices at check structures to complex systems of sensors, computers, and communication equipment. Typically, local automatic control includes control of an individual check structure using on-site equipment without human intervention. Check gates are adjusted automatically to maintain a target depth in the canal. Within each local controller, a set of logical equations–known as a control algorithm–receives and interprets data and computes appropriate control responses.

Local automatic control systems often include a one-way communication channel to transmit alarm signals to a central site to alert operators of potential problems.

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[3] Bos and Nutgeren, "Irrigation Efficiencies," International Institute for Land Reclamation and Improvement, Publication 19, 1978.
[4] Buyalski, "Automatic Downstream Control of Corning Canal Check Gates by the EL–Flo Plus Reset Control System," 1979.
[5] Clemmens, "Canal Capacities for Demand Under Surface Irrigation," Journal of Irrigation and Drainage Division, ASCE Vol. 112, No. 4, November 1986, pp. 331-246.
[6] Merrian, "Introduction to the Need for Flexibility and Automation," Planning, Operation, Rehabilitation, and Automation of Irrigation Water Delivery Systems, 1987, Proceedings of a Symposium ASCE.

Supervisory control involves monitoring and control of the canal from a central site, giving the operator a global view of the entire canal system. A remote terminal unit (RTU) is located at each data collection and control site–such as check structures, pumping plants, and major turnouts-throughout the canal system. Data from RTUs are communicated, stored, and displayed graphically at the central site for use by the operator.

Supervisory control requires a master station. The master station is a computer-based system that manages system communications, stores and manipulates data, and provides operator interface. A communication system is required between the master station and RTUs located at the remote sites. The communication system allows two-way transmission of digital data. Possible types of communication systems are metallic cable, single channel VHF or UHF radio, microwave, or optical fiber.

Canal Lining

Seepage losses average 25 percent of the water transported in unlined canals[7]. In some areas, as much as 60 percent of the total water diverted into canals is lost through seepage. Lining irrigation canals helps reduce seepage, conserving water and preventing detrimental effects to adjacent lands. Also, lined canals may be more efficient hydraulically. A smoother canal surface increases flow capacity and may allow a smaller canal section to be used.

The most prevalent canal linings fall into three categories: compacted earth, concrete, and plastic membrane. If good soils are available locally, compacted earth lining often is the lowest cost alternative. Earth lining material should have adequate impermeability, should be free from shrinkage and swelling, and should be stable and erosion-resistant when placed on a canal slope.

Portland cement concrete is widely used to line irrigation canals. Concrete lining is highly resistant to erosion, permits a smaller canal section with high flow velocities and steeper side slopes, reduces weed growth, and prevents damage from burrowing animals. Concrete linings may be reinforced or unreinforced.

Plastic linings–also called geomembranes or flexible membrane linings–are now widely used to line irrigation canals. These materials are tough, impermeable plastic or elastomeric films ranging in thickness from 10 to 100 mils (1 mil = 0.001 inch). The most common plastic linings are polyvinyl chloride (PVC) and polyethylene. PVC lining is buried under a protective cover of gravel, concrete, or shotcrete. Several different types of polyethylene have been used. Polyethylene does not require a protective cover, but is more difficult to work with than PVC.

[7] Lining Irrigation Canals, Portland Cement Association, Skokie, Illinois, 1957.

Remote Sensing and Geographical Information Systems for Efficient Water Management

Mr. Mike Pucherelli
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A variety of remotely sensed data is available to support Reclamation project studies, as well as irrigation district managers. More specifically, satellite imagery, aerial photography, airborne scanner data, thermography, and airborne video have all been used in one form or another to assist water managers. On the Newlands Irrigation Project, for example, Reclamation scientists have developed a Geographic Information System (GIS) for irrigation water rights management. The data base consists of six data layers, including the Public Land Survey System, water rights records, soils types, land ownership, irrigation district boundaries, and cultivated field boundaries. Each year, satellite imagery is used to define the irrigation status of every cultivated field in the project. Two to three different images are acquired at different dates during the growing season and registered to a common Universal Transverse Mercator (UTM) map project grid and are processed to produce a pixel-by-pixel map of irrigated areas. These data are merged with field boundary information from a GIS to improve the accuracy of the data base.

Irrigation overlays are intersected with updated water rights overlays to yield total irrigated area with water rights. This area is then multiplied by the appropriate bench or bottom-land water duty to yield total water use. This value is adjusted to reflect planned changes in irrigation for the coming season and becomes the target project diversion for the coming year.

Reclamation uses this technology on various other river basin areas, such as the Colorado River Basin, to prepare annual consumptive uses and losses. The key to these reports are reliable acreage tabulations prepared from aerial photographs and compiled via GIS.

GIS data bases have been prepared for planning, inventory, and mitigation. Such studies were undertaken on a large area in North Dakota (Garrison Project) for new construction, as well as project rehabilitation work on existing earth-lined canals in western Colorado (Grand Valley) and southern California (Coachella Canal).

In each case, aerial photography and GIS were used to prepare land use and land cover resources maps. From this information, planners can make educated decisions on canal alignments to minimize environmental impacts. In the case of rehabilitation studies, such as lining earth canals, buffers can be applied to existing project features to determine impacts. By performing a multitemporal analysis, historic conditions can be entered into the data base via preconstruction photographs to show trends in land use/land cover changes.

Seepage studies have been performed using airborne scanner data in the visible wavelength, as well as the thermal infrared portion of the spectrum. Greenness and coolness can be mapped and used as an indication of seepage areas along remote areas of canals. The method becomes an excellent tool for monitoring project features on a regular basis.

Airborne video has been researched and determined to be a cost-effective tool for mapping and monitoring aquatic weeds in canals. Surface areas of nuisance weeds can be reported by canal reach, using the airborne video data analyzed from a PC-based image processing system.

Water quality studies have been performed on various reservoirs by correlating imagery with limnological parameters. Chlorophyll *a*, temperature, and turbidity are mapped from several bands of the Thematic Mapper Imagery. Since the satellite passes the same area every 18 days, this tool becomes an effective source of monitoring. In addition, satellite data are available from 1972, thereby allowing researchers to derive trend information and show changes in water quality over many years.

Snow mapping techniques have been refined to provide surface areas of snowpack by basin. By applying water equivalency information, runoff can be predicted.

Remotely sensed data and overlay analyses from GIS are proven valuable tools for the water manager at all levels, from Federal and State agencies to the local water districts.

More research is needed in the following areas:

1. GIS data bases for irrigated lands need to be converted to PC-based systems to facilitate use and cost effectiveness.

2. Sensors should be developed to detect underground seepage before it surfaces.

3. Research is needed on the interaction of ground water and surface water, using GIS and three-dimensional modeling, coupled with land use and land cover information. A comprehensive data base could be used to model pre- and postirrigation projects to show how the utilization of water for irrigation could benefit wildlife, wetlands, and other environmental conditions.

Topic Area No. 3–Onfarm Water Conservation Research
Reclamation's Oakes Research Project

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North Dakota State University, Fargo, North Dakota
Mr. Michael Marohl, Bureau of Reclamation
Missouri-Souris Projects Office, Bismarck, North Dakota

Location

The Oakes Test Area (OTA) is located in southeastern North Dakota immediately south of the town of Oakes, adjacent to the James River. The OTA was constructed as part of the Oakes Area of the Garrison Diversion Unit Project.

Purpose and Objectives

Development of the OTA was based on recommendations of the International Joint Commission in their report dated August 12, 1977, "Transboundary Implications of the Garrison Diversion Unit." The OTA is to serve as an irrigation test facility to address concerns relative to the effects of a full-scale irrigation development and water resources.

The primary objectives are to:

(1) monitor return flows and evaluate model predictions
(2) implement Best Management Practices for irrigated agriculture
(3) test the operation of a closed wasteway system
(4) monitor the effect of irrigation on wetlands and wildlife

Authority

Authority for the construction of a test area was provided in the House of Representatives Committee on Appropriation Report No. 95-1247, June 1, 1979, which accompanied H.R. 12928. This authority was reaffirmed by H.R. 1116, the "Garrison Diversion Unit Reformulation Act of 1986."

Background

Investigations to select a site and delineate the OTA boundary were completed in 1980. Soils in the OTA are representative of the lands to be irrigated on the project. The geological characteristics of the OTA allow for the isolation and collection of return flows for monitoring purposes. The OTA includes sufficient lands suitable for irrigation to typify operations of a full-scale irrigation development; 5,000 acres was proposed to be irrigated.

A study plan was developed in 1980 by the Bureau of Reclamation in cooperation with State and other Federal agencies. The program outlined studies in the following areas:

(1) surface water monitoring
(2) drain and ground water monitoring
(3) irrigation management practices
(4) soils and leachate monitoring
(5) denitrification in drains, wetlands, and streams
(7) wildlife

Collection of baseline data and monitoring began in 1980 to document predevelopment conditions.

Construction of the OTA drains and water distribution system began in 1982 and were completed in 1988. The control system, an integral part of the closed wasteway system, was installed in 1989.

The acreage to be irrigated in the OTA will be less than the 5,000 acres originally proposed until such time the project's principal supply works are completed. During the interim, the water supply for the OTA is limited to storage water in Jamestown Reservoir and/or by developing a supply using artificial aquifer recharge/recovery practices. Surface reservoirs and expanded aquifer recharge facilities which would provide additional water supply capabilities have been evaluated, however, further reviews and approvals are necessary before such facilities may be constructed.

Initial water deliveries were made in 1988 to 899 acres using stored water from Jamestown Reservoir. In 1989 through 1991, 565, 824, and 851 acres, respectively, were irrigated using aquifer recharge water. During the spring of 1989 and 1990, excess flows were diverted from the James River and used to recharge the aquifer in the OTA. Later in the season (in 1989, 1990 and 1991) this water was recovered from the pipe drains and ground-water walls for irrigation.

Status of Studies

(1) Surface-Water Monitoring

- USGS gauging stations on the James River, quantity and quality sampling
- Recording quantities diverted by the Oakes Pumping Plant and delivered to each individual irrigator

(2) Drain- and Ground-Water Monitoring

- Quantity and quality sampling of return flows at sites on the drainage system since construction completion in 1984
- Recording ground-water levels and quality sampling from 94 observation wells in a 1/2-mile grid throughout the OTA since 1981

(3) Irrigation Management Practices

- Oakes Irrigation Field Trials Established in 1970
- Irrigation Advisory Program established in 1972
- Agricultural Practices Inventory initiated in 1986
- Best Management Practices Manual adopted in 1988
- Applied Nitrogen Distribution Studies initiated in 1989
- Best Management Practices Field Studies initiated in 1989

(4) Soils and Leachate Monitoring

- Completed soil surveys, land classification and drainage investigations across entire OTA
- Defined and sampled four soil master sites to characterize the soils in the OTA
- Conducted lysimeter research from May 1981 to present

High Plains Project

Mr. Wayne Wyatt, General Manager
High Plains Underground Water Conservation District
Lubbock, Texas

As a brief introduction, the High Plains Underground Water Conservation District No. 1 was created in 1951. It serves approximately 5-1/2 million acres in the Central Southern High Plains of Texas. There are approximately 50,000 large-capacity irrigation wells in our District.

Ground water is produced from the Ogallala Formation. We currently have a little less than 100 million acre-feet of ground water in storage in our Water District service area. Ground water use has historically been between 1-1/2 to 2-1/2 million acre-feet annually in our District. Recent studies indicate that annual natural recharge ranges from 1/2 to 3-1/2 inches per surface acre. Using the average of 2 inches per surface acre, natural recharge would be a little less than 1 million acre-feet in our 5-1/2 million-acre District.

When pumpage exceeds natural recharge, it is easy to understand why ground water depletion has historically been the number one concern in our District. My presentation today will be to outline how we have addressed the issue of water depletion and what has been accomplished.

First, the area receives between 16 and 18 inches of precipitation annually. Approximately 60 percent of the precipitation occurs prior to and during the principal crop-growing season. The soils are 4 to 6 feet thick, generally having a total water-holding capacity of 8 to 10 inches. Our number one objective was to maximize the utilization of the precipitation which occurs in the area. Certainly, anyone can understand that if you have soils that will hold a large amount of water and Mother Nature provides a substantial portion of the crop water needs, then it is just good business to store the precipitation in the soil until the crops need it. Maximum use of precipitation ultimately resulted in the necessity of supplemental irrigation only.

Most everyone is familiar with terraces, bench leveling, and those types of water-management techniques. One technique which some of you may not be acquainted with is the use of furrow dikes. A small dam is constructed in the furrow every few feet to hold precipitation in place until it has time to soak into the soil. Most of our precipitation events occur as high-intensity/short-duration events. The soils cannot absorb the water as fast as it falls; therefore, it is necessary to hold it in place until it has time to soak into the soil.

Before you can implement good water-management practices, it is necessary to identify bad water-management practices. In essence, where are water losses occurring?

In the early days of irrigation, we drilled wells on the high point of a farm and conveyed the water in open, unlined ditches from the well to the field. Ditch losses ranged from 10 to 30 percent per 1,000 feet, the variances being caused by the different soil types. We ran the water

through the field, generally for 12 hours. The water would reach the end of the field in about eight hours and then continue to flow out the end of the field into the borrow ditch. From there, it would flow into a depression which we call al playa basin, and most of the water would evaporate. We measured these irrigation tailwater losses to equal approximately 20 percent of the water being pumped.

Additional losses were occurring in the field. Water was evaporating from the free-water surface as it flowed through the field. Also, water was lost to penetration below the root zone because of the long period of time that water was being applied to the upper end of the field. Coupled with these losses was the fact that many irrigators were applying from 4 to 8 inches during an irrigation application when the soils needed only 2 to 4 inches to bring it to field capacity. Not only were we over-irrigating, but we were also punching below the root zone water which was already in storage and could been used by the crop.

These are the major water-loss areas as they relate to furrow irrigation. In order to eliminate the water-conveyance losses associated with open ditches, our irrigators have installed more than 12,000 miles of underground pipeline. More than 3,000 tailwater return puts have been constructed to catch the tailwater, and thousands of surge valves are being used which alternate the flow of water between sets of furrows, allowing the application of smaller amounts of water more uniformly throughout the field without tailwater losses and without over-watering the soil profile.

Water losses have been reduced from about 50 percent to about 25 percent by our furrow irrigators. Some irrigators have done even better.

Additionally, soil moisture monitoring programs have been put in place to help guide the irrigator in determining when and how much water must be applied to the soil to meet the water needs of the growing crops. We have two soil-moisture programs. The first is a preplant regional soil-moisture survey, and the second involves the use of soil-moisture monitoring equipment by the farmers during the growing season.

About 60 percent of our area is still furrow irrigated. The remainder of the area is now irrigated with sprinkler systems.

Several generations of sprinkler systems were introduced and used, which were very inefficient. The first were the hand-moved systems, which then evolved to side-roll systems. Next were the high-pressure above-line discharge center pivot irrigation systems. Sixty-percent efficiency was tops for most of these old systems.

Onfarm irrigation-efficiency evaluations and demonstrations of the best available technology have been credited with causing better water management by our irrigators. The Water District, working in a cooperative program with the USDA Soil Conservation Service, designed

mobile field water conservation labs and trained its employees to go onto a farm at the request of the irrigator and make a total evaluation of the irrigation system. Both application and distribution efficiencies were evaluated. A written report was provided within 2 working days to the operator; as a result, the operators became keenly aware of their losses and how they were occurring. Through their disappointment with the equipment in use and their demand that more efficient equipment be made available, the irrigation industry responded to the demands with the help of local research people. Most of these old systems have now been replaced with the center pivot systems with partial drop lines, which are about 80 percent efficient; the remainder have been converted to what we call the LEPA system, which stands for Low Energy Precision Application, developed by Dr. Bill Lyle at the Texas Agricultural Experiment Station in Lubbock. Water losses have been reduced to as little as five percent with the LEPA systems. Additionally, excellent uniformity is achieved throughout the field when these systems are used in conjunction with furrow dikes. His "LEPA" system is common place throughout our area.

Eliminating the water losses through refinement of irrigation systems has accomplished tremendous water savings in the High Plains. The net depletion of the aquifer in our District averaged about 1.4 million acre-feet annually in the mid-1970s. It dropped to about 1/2 million acre-feet per year in the first half of the 1980s, then to an average of about 200,000 acre-feet annually for the last half of the 1980s.

While the water use has dropped, crop yields have not dropped. Cotton, which had an average yield of 336 pounds of lint per acre during the first half of the 1980s, had an average yield of 447 pounds of lint per acre during the last half of the decade. Corn yields remained relatively constant through the entire period, as did the other crops. In addition to the water-use equipment, management of fertility programs and other chemicals to improve water-use efficiency has been incorporated into most of our producers' farming systems.

Not all of our farmers have yet upgraded their equipment and technology to accomplish maximum water-use efficiency; therefore, we will continue to work toward this end.

Topic Area No. 4–Agricultural Drainage Flows and Nonpoint Source Pollution

Wetlands Treatment of Return Flows

Dr. Rick Nelson, U.S. Bureau of Reclamation
Missouri-Souris Projects Office, North Dakota

Freshwater wetlands have received a great deal of attention because of the ability of some of these systems to provide benefits to water quality. However, freshwater wetlands are extremely complex systems with a diverse set of interactions that provide numerous values to the ecosystem. The terms—functions, values, and functional values have been used to describe the importance of wetlands. However, rarely are these terms adequately defined and confusion often persists regarding a wetland function versus a wetland value and the interactions that produce desirable values.

Wetland functions can be divided into three broad categories: hydrologic, chemical, and biological. The functioning of wetlands depends on the interactions between components of the hydrologic, chemical, and biological setting of a particular wetland or wetland complex. These functions and their interactions provide the values associated with wetlands and wetland complexes. Several examples will be presented to illustrate the definitions of these terms and the corresponding function and value relationships.

The term "water quality" must be delimited in terms of the specified use of the water. The ability of wetland basins to improve water quality depends on the status of the water source and the intended use of the treated water. Not all pollutants can be totally removed from a water source or removed adequately enough for the treated water to be used for all purposes. For example, irrigation return flows high in nitrates may be successfully treated and the water used by fish and wildlife. However, return flows with significant loads of organic pollutants may be treated but not to a level sufficient for use by aquatic organisms. In this example, the intended use of the water is for fish and wildlife. A unique definition of water quality is needed if water will be used for other objectives.

At the Oakes Test Area, data collected in the Riverdale March indicate that this wetland is providing water quality benefits via nitrate removal. This 70-acre wetland provides chemical and biological mechanisms that denitrify and uptake significant quantities of nitrate. Limited data have been collected on other parameters such as phosphorus and trace elements, but little analysis has been undertaken to examine the potential for interaction and synergism. Further research is needed to more fully document the functioning of this wetland with regard to treatment of return flows from the tests area.

Future research should be directed at determining metrics that provide a distinctive mechanism for evaluating wetland as treatments for return flows. Specifically, data are needed that can be used to efficiently and economically determine the integrity of wetland systems, and provide management options for maintaining the integrity of these systems.

SECTION 3–WORK GROUP PROSPECTUS REPORTS ON AGRICULTURAL WATER MANAGEMENT RESEARCH NEEDS

Water Measurement and Accountability

- Development of New Measuring Devices
- Data Base Manager Development for Accounting and Billing
- Barriers to Commercialization of Low-Cost Meters
- Flowmeter Calibration Using Computational Fluid Dynamics

Projectwide Water Utilization

- Development of an Affordable Data Acquisition and Transmission System to Track Projectwide Water Use
- Link Onfarm and Project Utilization to Maximize Project Efficiency
- Water Delivery Measurement Devices for Real World Conditions
- Develop Methodology to Determine Marginal Values and Priorities for Uses of Conserved Water
- Interactive, Spatially Distributed (GIS) Water Resource Model
- Examine Water Rights and Legislation Barriers and Needs Related to Water Conservation

Onfarm Water Conservation

- Most Effective Means of Educational/Informational Dissemination to Decision Makers
- Verification of Crop Water Use as a Function of Measurement and Local Environment
- Water Measurement Technology for Farm Use
- Verification of Water Savings from Water Conservation Measures
- Water Management in a Farming System Context
- Socioeconomic Risks Associated with Technology or Management Changes Required to Conserve Water
- Delivery Flexibility and its Relationship to Onfarm Irrigation Scheduling

Agricultural Drainage Flows and Nonpoint Source Pollution

- Best Management Practices
- Fate Transformation and Transport Process of Agricultural Chemicals in Agricultural Drainage Systems
- Monitoring Agricultural Chemical Use
- Process–Movement/Transport of Agricultural Chemicals into Waters (Ground and Surface)
- Treatment of Chemicals from Drainage Waters *in situ* (Controlled Drainage) and Offsite (e.g., Wetlands)

Prospectus No. 1
Study Area–Water Measurement and Accountability

1. **Title**: Development of New Measuring Devices.

2. **Problem Description**: Many flow measurement conditions exist under which existing water measurement devices are not acceptable. Field conditions cause problems related to accuracy, construction cost, difficulty in making accurate readings, etc. New theories in water measurement have not yet been applied to irrigated agriculture, e.g., vortex shedding.

3. **Recommended Action**:

A. **Overall Goals**: To develop new devices or modify existing devices for water measurement which can be applied under difficult hydraulic conditions at low cost which are realistic and simple to read.

B. **Method of Approach**:

- Research should focus on exploiting basic physical principles of water flow
- Re-examination of existing devices and principles and development of devices using new theories
- Both laboratory and field research are needed
- Emphasis should be placed on development of secondary devices for convenient display and accumulation of flow

C. **Barriers to Implementation**: Barriers vary with the type of device; development of secondary device readouts is a major barrier. Technology transfer mechanisms are not in place. Acceptance of new devices by users can be a problem.

4. **Expected Benefits**: The availability of a wider array of accurate, inexpensive measuring devices will result in fewer locations where flow measurement is difficult to apply.

5. **Time Schedule, Funds, Who should do the work**: These questions should involve an ongoing effort. However, with the recent advances in sensors and microprocessor electronics, the next 2 to 3 years is a prime time to re-evaluate existing devices. Two to three research scientists, one-half time, with support would be needed ($100 to $200 K/yr). ARS (Agricultural Research Service) and Reclamation currently have research facilities and are active in this area and should work together on this research.

6. **Related Issues**: Technology transfer efforts are needed to identify weakness in existing devices and conditions under which existing devices are difficult to apply.

7. **References**: BOR Water Measurement Manual, Discharge Measurement Structures by Bos, Advances in Irrigation Water Measurement (book chapter by Replogle, Clemmens, Bos), etc.

8. **Prepared by**: Bert Clemmens, USDA/ARS.

Prospectus No. 2
Study Area–Water Measurement and Accountability

1. **Title**: Data base Manager Development for Accounting and Billing.

2. **Problem Description**: Need better accounting and billing methods and procedures because of the need and competition for water.

3. **Recommended Action**:

A. Overall Goals: Development of software for water users that is easily operated by noncomputer oriented users, for PC computers.

B. **Method of Approach**:

- Wide distribution of questionnaires to Government, private, and water users to identify needs and what is available
- Build software, field test
- Education of users with pamphlets, VCR tapes, and demonstration of software

C. **Barriers to Implementation**:

- May be a conflict with private sector vendors.
- Some limited programs are available. They are costly, hard to use, and cost a lot to have the vendor modify.

4. **Expected Benefits**: Water savings will result from better tracking of water and district revenue will likely increase from better billing. This procedure will aid timely billing and water use reports. Would be a good management tool for district managers.

5. **Time Schedule, Funds, Who should do the work**:

Time Schedule = First year, develop questionnaires and compile results. Following 2 years, develop software and field test.
Who should do the work = Work should be done by Reclamation in conjunction with SCS (Soil Conservation Service) and experienced users.

6. **Related Issues**: Irrigation system scheduling will be closely associated and would be an integral part of this issue.

7. **References**: Bureau of Reclamation/LCRA Data Base Manager, Austin, Texas. WMC Program Package, Lower Colorado Region, Terry Taylor, or Mike Stuver, UC-433.

8. **Prepared by**: Terry Taylor and Jobaid Kabir.

Prospectus No. 3
Study Area–Water Measurement and Accountability

1. **Title**: Barriers to Commercialization of Low-Cost Meters.

2. **Problem Description**: Several low-cost water measurement devices were developed in the past few years. Economic and cultural reasons prevented the use of these low-cost devices for water measurement.

3. **Recommended Action**:

A. Overall Goals: Identify barriers and assist the private sector development and commercialization of low-cost devices.

B. **Method of Approach**:

- Seek a cooperative agreement with the private sector for use of Federal facilities
- Identify all low-cost water measurement devices
- Develop a priority listing based on cost and applicability
- Develop documentation and training program
- Provide training

C. **Barriers to Implementation**: Low profit, limited market.

4. **Expected Benefits**: Efficient and economic water measurement and promotes conservation.

5. **Time Schedule, Funds, Who should do the work**:

Time = 2 years
Funds = $100 K/year
Who should do the work = Federal, State, and irrigation districts, cooperatively.

6. **Related Issues**: Provide incentive to Federal researchers to gain source profit. Make U.S. manufacturers competitive in international market. Can be coordinated with technology transfer.

7. **References**: Reclamation, Agricultural Research Service, University publications.

8. **Prepared by**: Philip Burgi and Jobaid Kabir.

Prospectus No. 4
Study Area–Water Measurement and Accountability

1. **Title**: Flow Meter Calibration Using Computational Fluid Dynamics.

2. **Problem Description**: Nonstandard devices are a common problem and are costly to calibrate. A computer-aided calibration would expedite the process and be more economical.

3. **Recommended Action**:

A. Overall Goals: Develop a computer algorithm which can be used to calibrate nonstandard devices.

B. **Method of Approach**:

- Begin with devices which can be modeled with two-dimensional flow equations
- Use physical models to verify and identify the computer algorithms
- Gather field data to assist in verifying the model performance for large-scale structures under field conditions

C. **Barriers to Implementation**:

- Technology transfer to irrigation districts
- Gaining acceptance to computer simulation
- Nonstandard verification

4. **Expected Benefits**:

- Reduced costs in calibration of nonstandard devices
- Develop new, simplified devices which can be computer calibrated
- Aid in converting existing canal structures to flow measuring structures

5. **Time Schedule, Funds, Who should do the work**:

Time = 2 years to develop code
= 4 years to verify and debug model
Who should do the work = Work should be done by a university which has computer and hydraulic laboratory facilities.

6. **Related Issues**:

- Hydraulic structure modeling, both physical and computer modeling techniques

- Existing codes which might be modified for this purpose

7. **References**: None.

8. **Prepared by**: Tracy Vermeyen.

Prospectus No. 1
Study Area–Projectwide Water Utilization

1. **Title**: Development of an Affordable Data Acquisition and Transmission System to Track Projectwide Water Use.

2. **Problem Description**: Most water projects lack sufficient information on water distribution, which inhibits the ability to operate the system accurately on a real-time basis. Inability to match supply to demand results in inefficiencies, additional maintenance, and water waste.

3. **Recommended Action**:

A. Overall Goals:

- Affordable, dependable, accurate, and standardized hardware systems for data acquisition and transmission
- Generally applicable software to use system-wide data to manage the water distribution system

B. **Method of Approach**:

- Survey existing data acquisition systems
- Test, evaluate, and select hardware
- Identify additional hardware needed and unnecessary features of existing hardware
- Identify methods to accommodate future needs and expandability
- Develop generalized software
- Apply software and hardware on a demonstration project
- Advertise and transfer technology to the water community

C. Barriers to Implementation:

- Small users cannot afford experimental development
- User intimidation from high tech solutions

4. **Expected Benefits**: Improved water system operations; economic savings.

5. **Time Schedule, Funds, Who should do the work**:

Time = Three to five years to develop, test, and demonstrate.
Funds = Project to cost $100,000 plus additional funds for the demonstration project. (Demonstration project funds partially supplied by project receiving the data acquisition system.)
Who should do the work = Work by Reclamation in conjunction with project and field office personnel and hardware suppliers.

6. **Related Issues**: None.

7. **References**: None.

8. **Prepared by**: Dave Rogers and Cliff Pugh.

Prospectus No. 2
Study Area–Projectwide Water Utilization

1. **Title**: Link Onfarm and Project Utilization to Maximize Project Efficiency.

2. **Problem Description**: Software and programs have been developed at the onfarm and project level but have not been linked. Optimizing system delivery often is not compatible with the farmer's scheduling needs. This incompatibility results in less than optimum water utilization for the project, reduced yields and net income for the farmer, and increased hazard to the environment.

3. **Recommended Action**:

A. Overall Goals: Develop a software package to link onfarm and project scheduling that gives precedence to crop needs. Schedule on farm, then the lateral, then the system. Develop a balance between facility's capability and farmer's needs. Develop a GIS to analyze and modify system and to manage water delivery.

B. Method of Approach:

- Use real-time climatic data for onfarm scheduling
- Use software that links onfarm demand to lateral deliveries for entire project
- Develop GIS and data base (soils, crops, etc.) to analyze, modify, and manage the system
- Package for use on a PC for project and district managers
- Use document and training modules

C. **Barriers to Implementation**:

4. **Expected Benefits**: More efficient use of water, increased yields, reduction of environmental degradation, reduced operating cost throughout the project.

5. **Time Schedule, Funds, Who should do the work**: Agricultural Research Service and/or universities in close collaboration with Reclamation, Soil Conversation Service, and selected districts.

6. **Related Issues**: If properly developed, this tool could be used to manage irrigation delivery systems throughout the world.

7. **References**: SCS computerized scheduling program, Phoenix; ARS P.I.P. Project; Utah State Scheduling package; ARS EPIC model; GRASS (GIS); ARCINFO (GIS).

8. **Prepared by**: Carmack and Dickey.

Prospectus No. 3
Study Area–Projectwide Water Utilization

1. **Title**: Water Delivery Measurement Devices for Real World Conditions.

2. **Problem Description**: Accurate measurement of irrigation water to irrigators is critical to improving both delivery system and onfarm efficiencies; however, presently available devices (weirs, flumes, and constant head orifices) are not always adaptable to existing conditions (low lead, open to closed pipe systems, back water conditions, entrance conditions).

3. **Recommended Action**:

A. Overall Goals: To develop reasonably cheap, reasonably accurate, reliable, easy for field to use, easy to construct for above conditions.

B. **Method of Approach**:

- Start by identifying needs in the field
- Assessment of common problems
- Development of specific solutions for each condition

C. **Barriers to Implementation**:

- Multitude of existing devices available that fall short of the mark
- Cost of installation

4. **Expected Benefits**: Water savings to delivery systems and essential information to irrigators for better management of water resulting in reduced water use and higher crop yields.

5. **Time Schedule, Funds, Who should do the work**: Federal agencies

6. **Related Issues**:

- Onfarm efficiency improvements
- Irrigation scheduling
- Efficiency evaluations of existing projects

7. **References**: None.

8. **Prepared by**: Eldon Johns and Lenny Duberstein.

Prospectus No. 4
Study Area–Projectwide Water Utilization

1. **Title**: Develop Methodology to Determine Marginal Values and Priorities for Uses of Conserved Water.

2. **Problem Description:** Water conservation can be enhanced or made feasible if the benefits are obvious to the responsible parties. Methodology to determine marginal values and address priorities of use are needed to justify water conservation.

3. **Recommended Action**:

   A. Overall Goals: Develop methodology to fix marginal values and assign priorities to available water supplies.

   B. **Method of Approach**: Marketplace approach that fixes realistic values and priorities to all uses of conserved water including in-stream flows and endangered species habitat considerations.

   C. **Barriers to Implementation**: Economic analysis balanced with ecological constraints.

4. **Expected Benefits**: Quantification of economic and biological values to incremental water supplies.

5. **Time Schedule, Funds, Who should do the work**:

   Three-year program to complete:

   First year–develop economic and biological components
   Second year–merge two components into methodology
   Third year–test package on Platte River System, Colorado/Nebraska

6. **Related Issues**: Possible amendments to Endangered Species Act may affect outcome of methodological development

7. **References**: Professor C. Howe, University of Colorado, Jim LaBounty, U.S. Bureau of Reclamation.

8. **Prepared by**: C. A. Calhoun.

Prospectus No. 5
Study Area–Projectwide Water Utilization

1. **Title**: Interactive, Spatially Distributed (GIS) Water Resource Model.

2. **Problem Description**: An integrated, spatially distributed (GIS) water resource model is needed that can be interactively used to plan and manage basin or project water balance by incorporating irrigation, drainage, conjunctive use and return flows.

3. **Recommended Action**:

   A. Overall Goals: Comprehensive water resource planning and management

   B. **Method of Approach**: Adapt or develop water resource models into an integrated, advanced decision support system.

   C. **Barriers to Implementation**: Method must be appropriately generic to enable adaption to specific basins, or projects, and sufficiently user friendly to facilitate user interaction.

4. Expected Benefits: More efficient and higher economical uses of renewable water supplies, and more efficient project management.

5. Time Schedule, Funds, Who should do the work:

Time = Three to 5 years for development and implementation
Funds = $450,000 to $750,000
Who should do the work = Multidisciplinary team effort

6. **Related Issues**: Hardware and software requirements, data base requirements, training and technology transfer.

7. **References**: Ongoing related projects and available model documentation.

8. **Prepared by**: Marvin Jensen and Allen Powers.

Prospectus No. 6
Study Area–Projectwide Water Utilization

1. **Title**: Examine Water Rights and Legislation Barriers and Needs Related to Water Conservation.

2. **Problem Description**: Existing water rights laws and historic water use practices frequently limit the use of conserved water to historic uses. Thus, the effects of water conservation practices affect existing uses and water rights through current dependency of non-District uses of return flows and/or seepage currently benefiting estuaries, endangered species, and historical ground-water recharge historically being used by others. New "working and legislative tools" are needed to allow for and promote new and/or alternative uses of conserved water.

3. **Recommended Action**:

   A. **Overall Goals**: Identify critical barriers to water conservation and develop generic legislation to promote needed flexibilities and current user benefits from water to be conserved.

   B. **Method of Approach**: Each State's water right and related legislation and policies need to be collected and evaluated to identify barriers and flexibility needs.

   C. **Barriers to Implementation**: From 3B above, a generic proposal must be developed to encourage and assist States in making (promoting) changes to overcome barriers.

4. **Expected Benefits**: Water project reformulation (allowing new uses of conserved water) could be optimized if constraints are reduced and current users are not injured legally and/or financially.

5. **Time Schedule, Funds, Who should do the work**:

6. **Related Issues**: Water values and use priorities need to be evaluated to determine need, legislative and institutional changes.

7. **References**: None.

8. **Prepared by**: Darold Arbuthnot.

Prospectus No. 1
Study Area–Onfarm Water Conservation

1. **Title**: Most Effective Means of Educational/Informational Dissemination to Decision Makers.

2. **Problem Description**: Research most effective methods to communicate/educate the decisionmakers on concepts and technologies concerning water conservation. Decisionmakers are everyone involved with deciding what changes should be made.

3. **Recommended Action**:

A. **Overall Goals**: To make decisionmakers aware of water conservation technologies.

B. **Method of Approach**:

- Gather information from field personnel, especially those from other agencies, concerning methods to inform/educate decisionmakers.
- Compare these methods looking for common threads between the successful/unsuccessful methods.
- Establish a "clearing house" for materials and methods used to communicate/educate the decisionmakers.

C. **Barriers to Implementation**:

- Geographical/cultural differences between areas
- "Turf battles" concerning who will do this and have control

4. **Expected Benefits**: More successful acceptance of water conservation.

5. **Time Schedule, Funds, Who should do the work**: This work should be contracted out to a university for 2 years at $50,000/year to set up the system. At the end of the 2 years, the Bureau of Reclamation would take over and operate it in the Water Conservation Center as an ongoing program.

6. **Related Issues**: Prospectus entitled "Socioeconomic Risks Associated with Technology Changes to Conserve Water."

7. **References**: Other agencies that are educating the decision makers. Soil Conservation Service, irrigation and conservation districts, State extension services.

8. **Prepared by**: Harvey Everhart, Michael Madigan.

Prospectus No. 2
Study Area–Onfarm Water Conservation

1. **Title**: Verification of Crop Water Use as a Function of Measurement and Local Environment

2. **Problem Description**: Transferability of existing methods and knowledge is hampered by a lack of standardized methods for measuring and computing components of the energy balance for ET (evapotransporation) and crop development when influenced by water and chemical conserving management practices.

3. **Recommended Action**:

A. **Overall Goals**: Develop within western United States unified procedures and necessary modules for predicting or estimating crop evaporative water use and yield in response to climatic, soil, water, and agronomic management conditions.

B. **Method of Approach**: Develop multilocation research teams to:

- Develop standardized/appropriate ET methods
- Develop improved measurement systems and/or sensors for measuring ET
- Improve quantitative methods to describe/model effects of salinity, shallow water table, nonuniform irrigation, deficit irrigation, etc.

C. **Barriers to Implementation**:

- Weather data networks
- Lack of standard methods/sites for measuring ET
- Lack of modularized and/or standardized crop development models

4. **Expected Benefits**: Improved ET methodologies and crop development models for real-time decision makers for such needs as irrigation scheduling, prediction of irrigation requirements, estimating irrigation system effects on environment, etc.

5. **Time Schedule, Funds, Who should do the work**: Five to 10 years; one research team per U. S. Bureau of Reclamation region; $300,000/year per research team. Research teams: University, USDA–ARS/SCS, USBR, U.S. Department of the Interior, user-level cooperators.

6. **Related Issues**:

- Weather and resource data networks for real-time application of models
- Development of improved measurement systems and sensors
- Interfacing to technology transfer/application methods

7. **References**: R. Allen, Utah State University; E. Stegman, North Dakota State University; T. Howell, USDA-ARS, Bushland, Texas; J. Wright, USDA-ARS, Kimberly, Idaho; E. Johns, USBR, Denver, Colorado.

8. **Prepared by**: E. Stegman, North Dakota State University.

Prospectus No. 3
Study Area–Onfarm Water Conservation

1. **Title**: Water Measurement Technology for Farm Use

2. **Problem Description**: Need less expensive equipment or methods to measure water use, well discharges, etc.

3. **Recommended Action**:

A. **Overall Goals**: Simple device(s), easy to install and maintain, relatively inexpensive, appropriate level of accuracy, possibly portable.

B. **Method of Approach**:

- Survey of available equipment and equipment being researched or developed
- Brainstorming to identify new approaches, selection of ideas for research and development
- Laboratory testing
- Field demonstration
- Publications

C. **Barriers to Implementation**:

- General resistance of water users to water measurement
- Costs of measuring devices
- Lack of incentive

4. **Expected Benefits**: Improved onfarm water management, which cannot happen without water measurement. Higher crop yields, lower operating costs, improved water quality, etc., which result from improved management.

5. **Time Schedule, Funds, Who should do the work**:

- **Time/funds** = Year 1 – survey of current technology, brainstorming/$50K
  = Year 2 – laboratory testing/$200K
  = Year 3 – complete laboratory testing, begin demonstration/$300K
  = Year 4 – complete and evaluate demonstration publications/$200K
- **Who should do the work** = Cooperative program among SCS, ARS, and Reclamation. Cooperative research and development with private firms.

6. **Related Issues**: ARS in Phoenix has some research underway. Would need an effective technology transfer approach.

7. **References**: Bureau of Reclamation's Water Measurement Manual, ARS book by Clemmens et al., other water measurement publications.

8. **Prepared by**: Danny King.

Prospectus No. 4
Study Area–Onfarm Water Conservation

1. **Title**: Verification of Water Savings from Water Conservation Measures.

2. **Problem Description**: Quantitative evaluation of practices believed to provide water conservation is needed to assist irrigators in management decisions for practice implementation.

3. **Recommended Action**:

A. **Overall Goals**: Develop data which can be used in journal articles, technical papers, presentations, and literature.

B. **Method of Approach**:

- Review of previous research results to identify available data on various practices, crops, soils, geographic regions, and types of irrigation systems
- Identify additional studies needed to fill in data for situations not already evaluated
- Develop research projects to provide needed data
- Conduct in-field research studies
- Prepare analysis of research data

C. **Barriers to Implementation**: The transfer of study results to the water user is expected to be a limitation.

4. **Expected Benefits**: Sufficient data to convince irrigators, Governmental planners and regulators, and financial institutions that conservation practices do "conserve" a specific amount of water.

5. **Time Schedule, Funds, Who should do the work**:

- **Time** = Six months to 1 year for review of available data and to identify needed studies. One year to develop proposed research projects. Two to three years of in-field research studies.
- **Funds** = $100,000 for review, $100,000 for research proposal
  $5 million over 3 years for research projects
- **Who should do the work** = Lead activity(ies) would be consortium of university departments with technical review and advisory committees of Federal/State agencies

6. **Related Issues**: Effective education programs for water users and as-input data for economic analysis of implementing conservation practices.

7. **References**: None.

8. **Prepared by:** Comer Tuck.

Prospectus No. 5
Study Area–Onfarm Water Conservation

1. **Title**: Water Management in a Farming System Context.

2. **Problem Description**: Emphasis needed on impacts of available water, water management alternatives, price support programs, labor and alternative crops on farm enterprise (firm level) profitability. Shift emphasis from irrigation of specific crop to value of water in optimizing profitability of whole enterprise, not just the one crop.

3. **Recommended Action**:

   A. **Overall Goals**: Maximize firm level profitability per unit of irrigation water used.

   B. **Method of Approach**:

   - Economic analyses of value of water use in specific cropping systems/combinations of systems representative of local regions in the West
   - Integration of specific cropping practices into firm level decision aid
   - Development of methods to optimize profitability across levels of water availability, Government programs, water management options

   C. Barriers to Implementation:

   - No economic incentive to conserve water
   - Government programs act as disincentive to water conservation
   - Bureau of Reclamation project limitations to providing water at the right time in proper amounts
   - Lack of technical or economic capability to apply conservation at firm level
   - Resistance to change at firm and project level

4. **Expected Benefits**:

   - Maximize efficiency of water use in agricultural enterprises in economic sense
   - Opportunity to reduce water use in an absolute sense for additional use within the firm
   - Enhance sustainability of agricultural enterprises

5. **Time Schedule, Funds, Who should do the work**:

   - **Time** = 5 years
   - **Funds** = $2.5 million/5 years
   - **Who should do the work** = Bureau of Reclamation personnel in cooperation with university and agency economists, policy analysts and water management professionals. Emphasize collaboration with irrigators to yield valid firm analyses across the West.

6. **Related Issues**:

- Continuing environmental concerns
- Increased competition for water
- Policy related to farm commodity programs
- Educational programs to transfer technology

7. **References**: Agricultural Economics Programs at Texas A&M, Nebraska, and New Mexico Universities.

8. **Prepared by**: Wayne R. Jordan and Richard S. Bowers.

Prospectus No. 6
Study Area–Onfarm Water Conservation

1. **Title**: Socioeconomic Risks Associated with Technology or Management Changes Required to Conserve Water.

2. **Problem Description**: Water users, operators, and managers often resist adopting new technology or management practices because of perceived economic risks or resistance to change.

3. **Recommended Action**:

A. **Overall Goals**: Overcome water user's, etc., reluctance to adopt new technology or management practices.

B. **Method of Approach**:

- Identify potential risks associated with water conservation
- Determine level of risk based upon reliability of procedure or technology
- Identify reasons for resistance to change
- Propose procedures for overcoming resistance to change

C. **Barriers to Implementation**: No standard procedures exist for evaluating risks.

4. **Expected Benefits**:

- Perceived risks will either be dispelled or adequately managed
- Programs can be formulated to minimize resistance to change

5. **Time Schedule, Funds, Who should do the work**:

- **Time**: One year would be required to identify and evaluate risks. Two years would be required to identify psychological reasons for resistance to change and then develop procedures for overcoming this resistance. A third year would be required for report preparation.
- **Funds**: Costs would be in the range of $450,000 for the first year, $500,000 for the second year, and $75,000 for the final year of report preparation.
- **Who should do the work**: An agricultural economist would conduct the risk analysis. A social psychologist would evaluate the problem of resistance to change. Non-Bureau of Reclamation expertise may be required through some form of cooperative program.

6. **Related Issues**: The agricultural community does not communicate within itself and the outside world.

7. **References**: None.

8. **Prepared by**: Michael Stuver.

Prospectus No. 7
Study Area–Onfarm Water Conservation

1. **Title**: Delivery Flexibility and its Relationship to Onfarm Irrigation Scheduling

2. **Problem Description**: Limited delivery flexibility impacts onfarm irrigation schedules and irrigation practices. Research into improved system flexibility in regard to theoretical, structural, and management approaches and applications needs to be conducted.

3. **Recommended Action**:

   A. **Overall Goals**: Development of flexible delivery systems and management techniques for optimal water utilization.

   B. **Method of Approach**:

   - Inventory of existing practices and approaches
   - Investigate structural changes and their proper application
   - Development of algorithms and models for testing of theoretical approaches
   - Development of approaches to implement management changes

   C. **Barriers to Implementation**:

   - Economics
   - Resistance to change
   - Each system will be unique

4. **Expected Benefits**: Improved onfarm water management resulting in increased profit to the water users. Potential improvement of water quality.

5. **Time Schedule, Funds, Who should do the work**:

   - **Time** = several years
   - **Funds** = expensive (millions)
   - **Who should do the work** = Cooperative research with university, district, consultants, and Bureau of Reclamation.

6. **Related Issues**:

   - Drainage
   - Labor requirements (extra training)

7. **References**: Maricopa-Stansfield Project with USDA–ARS, SCS, etc.

8. **Prepared by**: Tim O'Halloran, Ram Dhan Khalsa.

Prospectus No. 1
Study Area–Agricultural Drainage Flows and Nonpoint Source Pollution

1. **Title**: Best Management Practices.

2. **Problem Description**: We do not have the needed practices for controlling, absorbing, eliminating chemicals from agricultural drainage water. We cannot eliminate chemical use.

3. **Recommended Action**:

   A. **Overall Goals**: Develop practices not just to reduce chemical application, but also to control/eliminate/minimize chemicals from drainage water.

   B. **Method of Approach**:

   - Evaluate practices (current and new). Do/how practices effect water quality?
   - Evaluate economic impact of practices on individual users and society.

   C. **Barriers to Implementation**:

4. **Expected Benefits**: Predict impact of best management practices on water quality (modeling of).

5. **Time Schedule, Funds, Who should do the work**: Government and universities.

6. **Related Issues**: Economic value of agricultural chemicals.

7. **References**: None.

8. **Prepared by**: Group 4.

Prospectus No. 2
Study Area–Agricultural Drainage Flows and Nonpoint Source Pollution

1. **Title**: Fate Transformation and Transport Process of Agricultural Chemicals in Agricultural Drainage Systems.

2. **Problem Description**: The presence of agricultural chemicals in drainage water and irrigation return flows has been reported. Eliminating the use of agricultural chemicals would eliminate this problem, but this practice is not acceptable. Thus, if some chemicals are applied, we need to be able to predict what happens to the chemicals in the soil and water system and account for the total mass of the chemical applied. Chemical, biological, and hydrological processes must be integrated to establish the fate of agricultural chemicals in drainage systems.

3. **Recommended Action**:

A. **Overall Goals**: Establish an understanding of the integrated chemical, biological, and hydrological processes on the fate of the agricultural chemicals, and develop process oriented prediction models to predict the fate of the agricultural chemicals in response to various management practices.

B. **Method of Approach**: Establish an integrated laboratory, lysimeter, and field study at several sites with various climatic and geologic settings to study processes affecting fate of agricultural chemicals. The work at different sites should be coordinated from a central manager.

C. **Program Components**: Chemical, biological, hydrological, climatic sites, classes of agricultural chemicals, process studies, modeling studies, validation of models, field evaluation.

4. **Expected Benefits**: Have a process controlled model that can be used to evaluate best management practices for minimizing agricultural chemicals in drainage water. These models could be used by regulatory and management entities to establish best management practices for different climates, soils, geology, and regions.

5. **Time Schedule, Funds, Who should do the work**:

- Should be initiated immediately. The development and validation of models will require a 5- to 10-year timeframe for completion.
- Funds required for this area will be significant. Several entities should be involved. Estimate $1,000,000/yr for 10 years. Total cost $10,000,000.
- A Federal agency needs to be placed in charge to coordinate this effort. They should subcontract significant portions of the work to universities, experiment stations, and USDA-ARS. But, one entity needs to coordinate the total research program in this area.

6. **Related Issues**:

- Contaminant transport in ground water and soils
- Kinetics for chemical and biological transformation in both aerobic and anaerobic environments
- Bioremediation—*in situ* biotransformation of agricultural chemicals
- Reducing amount of agricultural chemicals applied to that just necessary to achieve desired production

7. **References**: None.

8. **Prepared by**: Group 4.

Prospectus No. 3
Study Area–Agricultural Drainage Flows and Nonpoint Source Pollution

1. **Title**: Monitoring Agricultural Chemical Use

2. **Problem Description**: Are chemicals there? Current monitoring is not real-time, is expensive, and is difficult to account for spatial diversity. How to detect chemicals needs to be a part of application specifications, especially in saturated vs. unsaturated zones.

3. **Recommended Action**:

A. **Overall Goals**:

- Establish baseline data on actual occurrence of agricultural chemicals in agricultural drainage into waters (surface and ground)
- Improve monitoring instrumentation to collect data on agricultural drainage water

B. **Method of Approach**:

- Categorize chemicals by chemical composition, use, health effects, crops, region
- Gather existing data
- Monitor needs for categories
- Collection: mobile labs and regional labs
- Develop documentation on how to detect chemicals

C. **Barriers to Implementation**:

- Chemical companies do not want to release information

4. **Expected Benefits**:

- Provide input in defining "best management practices"
- Provides data upon which to establish (or not establish) regulator legislation
- Lower-cost methods for monitoring

5. **Time Schedule, Funds, Who should do the work**: Immediate: ASAP. (Prevent legislation, policy not based on empirical data.)

6. **Related Issues**: Process.

7. **References**: None.

8. **Prepared by**: Group 4.

Prospectus No. 4
Study Area–Agricultural Drainage Flows and Nonpoint Source Pollution

1. **Title**: Process Movement/Transport of Agricultural Chemicals into Waters (Ground and Surface)

2. **Problem Description**: Agricultural chemicals in drainage water have been reported, but chemicals cannot realistically be eliminated from agricultural production.

3. **Recommended Action**:

   A. **Overall Goals**:

   - Need to investigate and develop models of the combined chemical, hydrological, and biological processes on the fate of the agricultural chemicals as they move through waters in both saturated and unsaturated states.
   - Models are to be developed for site-specific input.

   B. **Method of Approach**:

   - Categorize chemicals; gather and organize existing data
   - Develop an integrated approach and specify interaction of processes

   C. **Barriers to Implementation**: Need cooperation of chemical manufacturers.

4. **Expected Benefits**:

   - Provide input into defining best management practices for controlling, eliminating agricultural chemicals
   - Predict how chemicals concentrate in ground water

5. **Time Schedule, Funds, Who should do the work**:

   - Immediate and ongoing (catch-up)
   - Government initiated. Contract to university with users advisory committee, including municipalities

6. Related Issues: Monitoring.

7. **References**: None.

8. **Prepared by**: Group 4.

Prospectus No. 5
Study Area–Agricultural Drainage Flows and Nonpoint Source Pollution

1. **Title**: Treatment of Chemicals from Drainage Waters—*in situ* (controlled drainage) and offsite (e.g., wetlands).

2. **Problem Description**: Need to determine methods "tools" for removal of chemicals from drainage waters.

3. **Recommended Action**:

   A. **Overall Goals**: Establish alternatives for agricultural water treatment. (Will wetlands work? Will *in situ* methods work? Which is best for a given situation?)

   B. **Method of Approach**:

   - Quantify applicability of alternatives; differences between alternatives

   C. **Barriers to Implementation**: Some existing facilities will not enable easy implementation of controlled drainage, etc.

4. **Expected Benefits**: (Side) Way to preserve natural wetlands.

5. **Time Schedule, Funds, Who should do the work**: Three- to 6-year timeframe for answers.

6. **Related Issues**: Environmental concerns.

7. **References**: None.

8. **Prepared by**: Group 4.

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