Water District Management and Governance

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Preface

The papers included in these Proceedings were presented during the Third International Conference on Irrigation and Drainage, held March 30 - April 2, 2005, in San Diego, California. The theme of the Conference, sponsored by the U.S. Committee on Irrigation and Drainage, was ***Water District Management and Governance.***

Water Districts are the most common vehicle for irrigation and drainage management in the U.S., Australia, New Zealand, Turkey, Mexico and a growing number of other countries. District management brings decision making to the level of the farmers the District serves, enhancing accountability, transparency and responsiveness. In the western U.S. and other industrialized countries, Districts are facing a long list of new management challenges related to increasing water scarcity, urbanization and expanding environmental awareness and concern. This Conference provided an opportunity for District managers, policymakers and others to share their experiences in dealing with these challenging issues.

As a part of a global trend toward decentralization, many countries worldwide are introducing and implementing District-based management of agricultural water supplies. A one-day **Symposium on District (Water User Association) Formation and Strengthening** brought together District managers and staff from the U.S., and their counterparts and supporters from countries where this form of management is just getting underway.

Papers included in the Proceedings were accepted in response to a call for papers and were peer-reviewed prior to preparation of the final papers by the authors. The authors are professionals from academia; federal, state and local government agencies; foreign ministries, international lending organizations, water districts and the private sector.

USCID and the Conference Co-Chairmen express gratitude to the authors, session moderators and participants for their contributions.

The Office of International Affairs, **Bureau of Reclamation** sponsored the Conference Proceedings and this support is acknowledged with appreciation.

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Conference Co-Chairmen

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THE CHANGING FACE OF WESTERN IRRIGATED AGRICULTURE: STRUCTURE, WATER MANAGEMENT, AND POLICY IMPLICATIONS

Rhonda Skaggs[1]
Zohrab Samani[2]

ABSTRACT

The structure of U.S. agriculture is dualistic and likely to become more so in the future. A small percentage of farms produce the majority of output, and almost three-fourths of U.S. farms sell less than $50,000 worth of goods annually. Farms in the lower sales categories tend to have chronic negative net farm incomes, and many have no intention of earning a living from agriculture. Much of this residential, lifestyle, or retirement agriculture occurs on the urban fringe and in rural areas just beyond the urban fringe. In the arid western U.S., much of it is located in irrigated river valleys, which are also centers of population and economic activity.

New Mexico's Elephant Butte Irrigation District (EBID) is located in one of the fastest growing counties in the United States. The region is experiencing water rights adjudication, rapid population growth, economic diversification, and increased competition for water resources. Recent research in the District found large differences in irrigation practices, efficiencies, and on-farm infrastructure relative to farm size. The small, residential, lifestyle, or retirement farms are notably different from the larger, commercially oriented farms. Many small producers view irrigation as a recreational, social, or lifestyle activity, rather than an income generating pursuit. The small farms have limited on-farm infrastructure, low irrigation efficiencies, and little interest in making irrigation improvements. Large, commercially oriented farms have high levels of on-farm irrigation efficiency due to deficit irrigation practices and investments in infrastructure.

The Elephant Butte research led to questions about changes in agricultural structure, water management, and water resource policy implications in other western U.S. irrigated districts. We hypothesized that the trends in agricultural structure found in the EBID would appear in other irrigated areas in the West. Analysis of limited U.S. Census of Agriculture data for a sample of western counties supports this hypothesis for some regions. The water policy implications of the findings are discussed.

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INTRODUCTION

The Structure of U.S. Agriculture

The U.S. current dual structure agriculture is one where approximately 7% of farms (with annual sales over $250,000) produce more than 76% of the total value of output, while 93% of farms are responsible for the remaining 24% of output (U.S. Dept. of Agriculture, 2004). A "farm" is defined by the U.S. Census of Agriculture as any place from which $1,000 or more of agricultural products were produced and sold, or normally would have been sold, in a given year. In 2002, the United States had 2.1 million farms comprising an extremely diverse farm sector. Fifty-nine percent of farms had less than $10,000 in annual sales of farm products. Approximately 43% of all U.S. farm operators do not consider farming to be their principal occupation and 55% of farms report some off-farm work (U.S. Dept. of Agriculture, 2004). Fifty-four percent of all U.S. farms are retirement or residential/lifestyle operations, which account for 7.8% of the value of U.S. agricultural production (Hoppe, 2001).

Almost 80% of all U.S. farms sell less than $50,000 worth of goods yearly (U.S. Dept. of Agriculture, 2004). The 1.6 million farms in the lower sales categories tend to have chronic negative net farm incomes. For these people, crop or livestock production is a consumption activity which is subsidized with non-farm earnings.

Much of the residential/lifestyle and retirement agricultural activity occurs on the urban fringe and in rural areas just beyond the urban fringe.[3] In the arid western United States, retirement and residential/lifestyle farming is often located in irrigated river valleys, which also tend to be rapidly growing in population and increasing in economic diversity. Agricultural irrigation accounted for 92% of total consumptive water use in the eleven western states in 1995, and market transfers of water from agriculture are viewed as the most likely way to accommodate growing municipal and industrial demands for water supplies (Gollehon, 1999). It is often assumed that improving low irrigation efficiencies will release water from agriculture to other uses, while at the same time allowing agricultural production to continue. The economic, lifestyle, environmental, open space, and preservation values of urban fringe agriculture could thus be maintained.

[3]"Urban fringe" is defined as the rural parts of metropolitan counties not settled densely enough to be called urban, while "beyond the urban fringe" refers to the rural countryside beyond the edge of existing urban areas in metro counties and often in adjacent nonmetro counties (Heimlich and Anderson, 2001).

Increased irrigation efficiency implies a change in technology (e.g., adoption of drip irrigation, canal lining), management practices (e.g., irrigation scheduling), or both. It is usually assumed that incentives to increase irrigation efficiency will work because agricultural water users have traditional business-like objectives (e.g., increased revenues and profits, and reduced costs). However, a significant percentage of farm operators throughout the United States and in the West are not strongly motivated by business or commercial objectives.

New Mexico's Elephant Butte Irrigation District

New Mexico's Lower Rio Grande Valley is experiencing rapid population growth, development of the rural countryside, and decreasing municipal groundwater supplies. Plans are underway to transfer some of the surface water from agriculture to municipal and industrial use in Doña Ana County, where most of the Elephant Butte Irrigation District (EBID) is located. Lifestyle agriculture is widespread in the county, where the number of irrigated farms increased by 70% between 1974 and 1997 (U.S. Dept. of Commerce, 1981; U.S. Dept. of Agriculture, 1999). Irrigated acreage in the Elephant Butte Irrigation District has been stable over that period of time (approximately 75,000 acres), while numbers of farms in the smallest acreage categories grew dramatically as a result of land splits. For instance, there were 150 farms between one and nine acres in 1974 and 691 of these farms in 1997 (U.S. Dept. of Commerce, 1981; U.S. Dept. of Agriculture, 1999). Farms between one and nine acres were 54% of all Doña Ana County farms in 1997.

Irrigation practices, irrigation efficiencies, crop yields, and crop quality vary dramatically between farms of different sizes. Skaggs and Samani (2005a) analyzed data provided by the EBID and conducted extensive fieldwork in the region in 2002 and 2003. These authors found striking differences in amounts of water applied, irrigation duration, irrigation timing (relative to crop water needs) and on-farm water delivery infrastructure on farms producing pecans, alfalfa, and cotton. The research found that applied water per acre was inversely related to farm size. Pecans, alfalfa, and cotton account for ~75% of the District's irrigated acreage. The research is summarized in Skaggs and Samani (2005b).

Agricultural Structure in Other Western U.S. Irrigated Areas

The structure of agriculture refers to the number and size of farms, ownership and control of resources, and the managerial, technological, and capital organization of farming (Knutson et al., 1995). The EBID research led the authors to question whether or not agricultural structure in other western U.S. irrigation districts has changed in ways similar to those found in New Mexico. There are limited county or district level data available to analyze these changes, however, the U.S. Census of Agriculture provides some insight into the questions. Thus, Census of Agriculture county-level data for a sample of western U.S. irrigation districts were collected for the years 1982, 1987, 1992, and 1997[4]. Data for 94 counties in Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, New Mexico, Oregon, Utah, Washington, and Wyoming were analyzed. Irrigation districts in these counties had previously been surveyed by McGuckin (2003). Census data for the counties were analyzed using Excel™. Results for selected variables are discussed below.

Change in Irrigated Farm Numbers and Irrigated Acreage. As discussed above, irrigated farm numbers in New Mexico's EBID increased dramatically through the 1980s and 1990s. Census data show a 43% increase from 1982 to 1997. All Arizona, California, Idaho, Nebraska, Nevada, and Washington counties in the sample showed net decreases or no change in irrigated farm numbers from 1982-1997. Counties which showed the largest increases in irrigated farm numbers were in Colorado, New Mexico, and Oregon. Results for counties in other states were mixed. Total irrigated acreage increased notably in some states over the period analyzed. There was limited consistency for the counties when comparing the 1982-1997 changes in total irrigated farm numbers and changes in total irrigated acreage. In several Colorado counties irrigated farm numbers increased while total irrigated acreage decreased between 1982 and 1997.

Farm Operators Working Off-Farm. As indicated above, more than half of all U.S. farms report off-farm work. Four-fifths of all U.S. farms have gross annual sales of agricultural products of less than $50,000 (and 59% of farms have less than $10,000 in annual sales). Using a rule of thumb that $1.00 in gross sales results in approximately 20-25¢ of net farm income, then the majority of "farm" households are dependent on non-farm income. County data for the EBID region show a 23% increase in farm operators reporting 200+ days/year of off-farm work over the period 1982-1997. Large decreases in the percentage of farm operators working 200+ days off-farm were reported for all the Arizona and California counties, and for many of those in Washington and Utah. Large increases were noted for most of the selected counties in Colorado, Montana, Nebraska, and Oregon. Results for the New Mexico counties were mixed. These results may reflect a movement of full-time farm operators to off-farm work due to unsatisfactory farm financial conditions. However, it is interesting to note that Colorado and Oregon county data both show growing numbers of farms and farm operators working 200+ days off-farm. Unfortunately, Census data cannot be used to identify farm operators who are retired to farming from some other occupation, and who thus may not report off-farm work.

Farm Enterprise Choices. Some research has been conducted into the relationships between off-farm employment and on-farm production decisions;

[4]These Census years were chosen because of the consistency of data reporting across all years.

however, attention has been limited (Phimister and Roberts, 2002). Anosike and Coughenour (1990) found that farm diversification was negatively and significantly associated with off-farm work. Carlin and Ghelfi (1979) concluded that part-time farmers must adjust their farm enterprises to off-farm labor requirements and do so by adopting less labor intensive farm enterprises. These authors indicated that operators of animal specialty farms, livestock enterprises, fruit and tree nut farms, and meadow production all have higher levels of off-farm employment and that these enterprises are all better suited to part-time farming than other crops or enterprises. Census data do not provide much ability to test these hypotheses. However, the Census of Agriculture does contain information for numbers of farms with orchards and numbers of farms producing hay crops. Review of these data for 1982-1997 for the selected counties revealed decreased numbers of farms with orchards in the Arizona, California, Colorado, and Oregon counties, while orchard numbers increased in several Washington counties. There was a greater than 100% increase in orchard numbers in the county where EBID is primarily located, although other New Mexico counties saw decreases in farms with land in orchards over the period analyzed.

Numbers of farms producing hay in the selected counties was also examined. These farm numbers tended to show consistent decreases from 1982-1997 in the Arizona, California, Idaho, and Washington counties. Results for New Mexico, Oregon, and Utah were mixed with no obvious tendencies over time, while the majority of the Colorado counties examined had increases in the numbers of farms producing hay between 1982 and 1997.

<u>Summary of Census of Agriculture Comparisons.</u> This review of Census data for the period 1982-1997 leads the authors to conclude that the structural changes in the irrigated agricultural sector the authors have found in New Mexico's Rio Grande Basin may be more unusual than hypothesized. As noted above, the data obtained through the Census of Agriculture point toward similar structural changes in Colorado and Oregon, although additional research is needed to confirm or reject this observation. If primary data could be obtained from irrigation districts in those states, as well as other western states, additional insight into changes in the structure of agriculture would be available.

IRRIGATION SYSTEM IMPLICATIONS OF CHANGING AGRICULTURAL STRUCTURE

Irrigation in New Mexico has a very long history, which predates European settlement. Irrigation customs are part of the social, cultural, and historic fabric of Rio Grande corridor communities. A wide range of social values related to water are held by Anglos, Hispanics, and Native Americans alike. Water plays an important role in defining the landscape for both long-term residents and newcomers. New Mexico may represent an extreme case of increasing numbers of people entering into agricultural lifestyles as a result of unique socio-cultural factors; however, our limited review of Census data leads us to believe that some other regions in the West are experiencing similar phenomena.

The visible presence of water in a landscape has been found to have beneficial psychological and physiological effects (Burmil et al.,1999). These beneficial effects of water (perceived or actual) and the aesthetic desirability of the oasis-type landscape are especially important in arid areas. The sight, movement, and sound of water all have value to humans, and surface irrigation activities allow people to directly experience these values. Large lot housing development gives homeowners the opportunity to have an irrigated agricultural lifestyle on the urban fringe.

The economic value of water is typically defined around consumptive use. Consumptive uses are usually classified as agricultural, industry, and household (primarily culinary and residential landscaping) applications of water. Water is also valued economically as a public good (i.e., in recreational uses, wildlife habitat, in-stream flows for environmental purposes, scenic values, etcetera). The value of water used in agricultural irrigation is a measure of the net economic contribution of water to the value of agricultural production (Young, 1996). According to economic theory, the value of an input or factor of production is the upper bound of a firm's ability to pay for the input. Profit maximizers will use inputs to the point where the price of the input is equal to the marginal value product of the output. Marginal value product is defined as the input's marginal product multiplied by the price of the output. Demand for an input (water, in this case) is based on these concepts and valuations of irrigation water estimated with them are used in economic feasibility tests for new irrigation projects as well as investments in rehabilitation of existing systems. Discussions of water reallocations between competing sectors generally incorporate valuations that have been derived using some version of the "residual" method described above. When markets for outputs such as environmental improvements do not exist, shadow values or prices for the water are estimated.

In agricultural policy debates unrelated to water resource use, the question is often raised as to whether or not agriculture is a "way of life" or a business (Blank, 2002). The "way of life" claim is used to support agricultural policies which directly or indirectly subsidize the farm sector. Farmers have historically been afforded a relatively high degree of protection from environmental regulations and been rewarded with a variety of cost reducing and/or income enhancing subsidies. Agriculture's status as a special industry in need of government support and protection is a well established tradition (and is maintained through a very complex policy structure).

The dictionary defines a "business" as a "commercial or industrial establishment" and notes that a "business" connotes a "profit motive." A "hobby" is defined as "something one likes to do in one's spare time; a favorite pastime or avocation."

As noted by Blank (2002), a hobby is a leisure activity that people do in order to increase their personal happiness, or utility. Hobbies come in all types, and with a range of costs that a hobbyist must pay to in order to have or increase happiness. The term “hobby farm” carries with it certain negative connotations (i.e., the belief that hobby farm operators aren’t *real* farmers), and is being replaced by the terms “lifestyle,” “retirement,” and “rural residential” farms. The United States is now at the point where more than half of all farms fall into these pastime or avocation categories.

Valuation of irrigation water continues to be based on the profit maximizer model, yet, many water users in the district intensively studied by the authors are clearly not profit maximizers. Skaggs and Samani (2005) hypothesize that many smaller water users seek to minimize the costs or risks of operating their small farms (regardless of the impacts on irrigation water productivity, yields, or total agricultural output). Smaller water users also appear to have maximizing their utility or satisfaction from the small farm generally (and irrigation activities in particular) as a key objective. These objective functions are not compatible with the notion that water users are interested in increasing irrigation efficiency through changes in technology, increases in management intensity, and responding to financial incentives to release surface water from agriculture for other competing uses.

A key water policy question is how water used in a “hobby” should be valued for the purposes of resource reallocation, irrigation infrastructure investments, and other policy questions. Traditional residual estimates of the value of water used in irrigation are likely to provide biased estimates of “lifestyle” irrigators’ true willingness to pay for water. Lifestyle irrigators may be willing to pay higher prices for the water resource than commercial farm operations, where levels of input use are driven by profit maximizing criteria. In this scenario, lifestyle irrigation water could be priced in a manner similar to other hobbies (golf, for example). Some lifestyle irrigators would be unwilling to “pay to play” and thus be priced out of the activity. However, it could take a relatively high price (or offer) to encourage some lifestyle irrigators to reduce their use of irrigation water. The price at which many small farm operators would be inclined to change their irrigation practices may be very high, because for them, irrigation is a revered recreational, social, or lifestyle activity.

Also, should investments in irrigation system rehabilitation be subsidized for lifestyle irrigators? Extensive public money is (and will be) dedicated to improving existing U.S. irrigation systems. Does it make good sense for taxpayers to subsidize building new irrigation structures to serve increasing numbers of lifestyle irrigators? If parcels in an irrigated area become so fractioned as to make irrigation technically very difficult, how should lifestyle irrigators be “bought out”? Should a commercial farm value or a hobby value be used? How should irrigation system technical inefficiencies be dealt with when they are a result of large-lot housing development and accompanying common property and easement disputes? Should remedies for these technical problems treat (and request payment from) the irrigators as commercial farmers or lifestyle irrigators? How do regulations governing the subdivision of farm land affect irrigation systems?

Agricultural structure in the United States will continue to evolve with urbanization, population growth, and economic development. As a result, compatibility between irrigation infrastructure, water policies, and agricultural structure does not currently exist. Furthermore, such compatibility is not a static target, given the dynamic nature of urban fringe agriculture. Irrigation system investments and public policies are currently designed for the commercial, profit maximizing model of farmer/irrigator behavior. Changes in agricultural structure and the diversity of irrigator motivations are not being incorporated in water valuation studies, infrastructure investment decisions, or water resource policy formulation. This situation needs to change!

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PROVEN INSTITUTIONAL, FINANCING AND PRICING PRINCIPLES FOR RURAL WATER SERVICES

Harald D. Frederiksen[1]

ABSTRACT

The International Commission on Irrigation and Drainage created a Committee in 2001 to prepare a Position Paper in response to the World Water Vision's proposed "full pricing" of services to ensure sustainability. International experience in the structuring of service entities, cost recovery and financing investments was considered in the adopted response. Historically, beneficiaries formed what have proved to be self-sufficient service entities for urban supply, irrigation and agricultural and storm drainage. Rapid expansion of services by governments after 1945, resulted in services that were not self-sufficient and systems having serious physical deficiencies in design and construction. Under-funding of O&M due to inadequate cost recovery and insufficient subsidies resulted in mounting obligations. Structuring system transfers to beneficiaries has proven difficult at best.

INTRODUCTION

The Hague's World Water Vision proposed 'full pricing' of water-related services as essential to the socio-economic sustainability of the services. In response, ICID charged the Task Force Committee (TC3) to prepare a Position Paper on the subject. The final Position Paper, *Irrigation and Drainage Services; Some Principles and Issues Toward Sustainability*, is available at www.icid.org

Long-term sustainability of services – irrigation, drainage and flood control – is not possible without full payment of the financial costs incurred. The relevant question posed is; who among the beneficiaries and national and local taxpayers is going to pay what share of the cost of each of these services? This is a highly emotional and politically charged issue with a range of philosophical views. The question is of particular interest where governments are subsidizing such services and by people who wish to influence water-use through pricing or distribute costs broadly within the local economy. The unreliability and inadequacy of subsidies as other demands on the government's budget grow poses increasingly serious risks to the sustainability of services as evident in too many countries.

The ICID Position Paper includes an Annex describing institutions, financial mechanisms and pricing principles utilized by existing successful entities providing these services. Many fully self-sustaining service entities continue under practices devised in the 1800s and early 1900s -- some several centuries

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earlier – well before major involvements by governments and international agencies. Countries and people that deal with the issues of financial sustainability would find it prudent to examine what has proved successful before imposing unproven concepts on farmers and taxpayers.

This paper provides a highly condensed summary of some key feature of long-established services described in the Annex to the Position paper. But first a summary of the TC3 Principles is provided as background to this discussion.

SYNOPSIS OF PRINCIPLES IN TC3 POSITION PAPER

A draft TC3 Position Paper, reflecting discussions at the 2003 Montpellier ICID meetings and modifications obtained from later exchanges among ICID members, was addressed in the Moscow meeting in 2004. Five principles are recommended to guide measures to improve the sustainability of water-related service agencies.

Principle 1 – Transparency of Cost Recovery TF3 advises to carefully define the scope of the services, identify all beneficiaries, and enter a contract stating responsibilities, accountability and charges; key elements towards sustainability.

Principle 2 – User empowerment TF3 advises to define formal means for agency/customer meetings, maintain a government oversight in the decision making on services consistent with its responsibility to represent the interest of society as a whole and the marginalised in society in particular.

Principle 3 – The "Sustainability Cost Recovery", a first ambitious Step TF3 advises to place service entity's budget priority on maintenance and renewal of the services infrastructure to guarantee the sustainability of the service and customer satisfaction, ahead of capital repayment coupled with staff constraints.

Principle 4 – Economic incentives towards "best practices" TF3 advises to keep a discussion of economic incentives as a last step for irrigation services until the services reach maturity, because such pricing systems are efficient only if they are understood by customers that are able to adjust their behavior in response to the incentive.

Principle 5 – Clear Policies TF3 advises to emphasize to the public that irrigated agriculture is governed by two policy areas – agricultural and water -- with conflicting rules and objectives. These conflicts should be explained in discussions with people in other water sub-sectors so their leaders may understand the complex nature of measures to ensure the sustainability in irrigated agriculture.

PERSPECTIVE FROM EXPERIENCES WITH SUSTAINABLE WATER-RELATED SERVICES

Reasons for Sustainability and Self-Financing

The concept of socio-economic sustainability of irrigation, drainage and flood control services is not new. Sustainability has been, and continues to be, the fundamental characteristic that rural societies seek in all factors important to their primary economic activity -- agriculture. The extent of services required differs from one area to another, but their effectiveness is a primary determinant of the farmers' success. In turn, the adequacies of the associated institutions and financial mechanisms have been critical to achieving 'sustainability'. The same may be said of urban residents and their services -- and has held true for centuries.

Accordingly, those engaged in the field and political leaders responsible for the welfare of their people should consider what prior generations did to create self-sustaining services. Most of the service problems today reflect the investment and institutional actions of governments during the previous 70 years. During this period, organizational and financial principles were determined mostly by politics and good intentions, discarding many principles devised much earlier. The governments in developing countries made the decisions on constructing services, including the extent and means for financing. Prior to the recent burst of development, farmers and rural communities largely made those decisions.

Further limiting today's options are the increasing demands on government budgets to support the rapidly expanding urban population. The needs for improved health, education and infrastructure, are forcing governments to reconsider their financial support for rural services. Political influence is shifting from the rural to the urban areas reducing the rural sector's ability to maintain its historic share of the budget. As a consequence, countries are rushing to transfer to the farmers the responsibility for most, if not all, O&M and facilities rehabilitation of the governments' recently-built systems.

Water-related Services

The scope of water-related services provided by agricultural service providers is far more extensive than implied in much of today's discussions that dwells on irrigation. Farmers (and ICID) also deal with agricultural drainage, storm water drainage and flood control, which are not 'water uses' nor easily measured services. Though covering a far greater farm area than irrigation, the sustainability of these agricultural water-related services is not adequately addressed in deliberations or literature – either within ICID or within the larger public debate. They are seldom mentioned in discussions of cost-recovery for services. Nevertheless, these services must be just as sustainable, in every measure, as irrigation. The failure of any one of the non-irrigation services in an area will directly affect the sustainability of the area's irrigation.

A second omission in discussions is the fact that most successful government and farmer-owned service entities provide more than one of the identified services as dictated by the farmers' needs. Most irrigated rice areas in the world also have storm drainage problems. Most irrigated arid regions have agricultural drainage needs. Agricultural drainage was taught in conjunction with irrigation for a reason. Thus, the form of service provider and the method of cost recovery and financial self-sustainability must be tailored to the situation.

A third omission is the need to deal with the growing situation where one water services entity will provide both village and agricultural services. This is forced by constraints on the area's water supply and the need for drainage and local flood protection by expanding villages. At the same time, village waste disposal may affect costs of both water supply and the drainage services. Obviously, there are differences in the supply reliability and annual service period required by villages compared to irrigation that should be reflected in service charges and cost-recovery mechanisms.

Water-related Service Entities

In this document, the term Water Service Entity (WSE) is used to denote the service provider, whether the service is irrigation, agricultural drainage, storm drainage, flood control, a mix of them (which is the scope of ICID) or even a joint service with villages. The organizational form of the WSE may be a government agency; a quasi-government customer-owned; a non-profit customer–owned mutual; or an investor-owned organization. The concepts of financial sustainability, financial self-sufficiency, financing mechanisms, service charges and fundamental responsibilities are similar. The form of WSE, however, appears to directly influence its ability to become self-sufficient.

One class of WSE warrants particular attention. Quasi-government entities have very limited government powers, but play a major role in providing services to rural customers. These entities have none of the traditional powers of civil government and do not report to other government agencies, except where a local body may administer such a WSE, for example a 'country' drainage district.

Their classification stems from their power, granted by legislation, to levy property taxes – a government-only power. They may secure loans and issue general obligation bonds backed by the power to tax all members. In the case where a bulk water supply or irrigation WSE constructs hydro-generation facilities, it may also issue revenue bonds backed by power sales. These powers make this class uniquely advantaged to assure financial self-sufficiency – equal to the capability of financially isolated subunits of local government that provide urban water, sanitation and storm drainage services.

Service, Institutional and Lending Principles that Affect WSE Financing

All water-related services provide economic and social benefits directly to identifiable beneficiaries. It has been historical practice and a basic policy of social equity that groups within society who directly benefit from a service, particularly if it supports economic activity, should pay the resulting costs. This holds true for urban and rural services in the developed and most developing countries. In countries where the government's social policies do not require beneficiaries to pay full costs of services, the government should explicitly, by a legal document, identify the sources of the replacement funds and the mechanism and schedule for full payment to the WSE funds sufficient to cover the full cost of the services. Anything less precludes sustainability.

Increasingly, WSEs – new, existing and transfers – will need access to commercial bank loan and bond financing. Such arrangements are common in countries where WSEs are financially self-sufficient, particularly for the larger schemes. The legislation would be most effective in lowering borrowing costs if it includes the means to create quasi-government WSEs and the mandate and means for auditing the WSEs.

The policies of lenders may directly determine cost-recovery mechanisms and other characteristics required of the WSE, regardless of its form or its service. Lenders will insist upon reliable and fully adequate sources of revenues for the period of the loans or bonds. Government subsidies to the WSE should be explicit in legal documents, since lenders discount the reliability of subsidies subject to politics. For long-term financing of new or rehabilitation of existing works, lenders will require full cost recovery and usually that the WSE has powers of taxation and an adequate emergency reserve fund or like means to carry it though periods of lower revenues caused by drought or economic downturns.

Lenders want to ensure that there is an adequately reliable service to the beneficiaries to better guarantee their repayment capacity over time. During inevitable low revenue periods for a WSE, most lenders stipulate the priority of WSE expenditures using the funds available. Routine O&M is first priority, replacement of reserve fund is second, emergency funds is third, interest on loans and bonds is fourth and capital repayment last. (The WSE itself should have the same polices relating to its cash flow.) Lender provisions will require automatic increases in charge rates if a prolonged revenue deficiency develops.

Lenders will require that a WSE providing water supply has been granted a legal, recorded permanent water-use right to the required quantity, quality and reliability of supply. This is as important to the lender as an assured revenue stream and for the same reason – sustainability of the service, the agriculture and the WSE. And the farmers' expenditures to improve their agriculture, including irrigation technology, depend on permanent rights.

Governments need to establish a professional government audit/regulatory 'utilities' agency to review WSE borrowing plans and revenue assumptions, particularly if they involve bonds. This is essential to help assure the lenders and bond purchasers that the specific WSE's program is viable. Equally, such examinations will instill confidence in the broader use of this form of financing within the entire country.

Finally as earlier inferred, two other features of rural services may affect the form of WSE, service pricing and financing policies and mechanisms. These are the specific mix of services to farmers and the joint but different content of services that may be provided by a WSE serving both villages and farmers.

Considerations in Discussing Service Charge Practices

There must be both the political will to adopt and society's acceptance of the mechanisms for any service charge policy to survive. The policies and mechanisms for assessing and recovering charges must be simple, easily understood by the customer/beneficiary and judged to be obviously fair. The term used in this document is 'service charges' covering all methods of assessment – service tariffs, property taxes, routine labor assessment and one-time assessments.

'Market pricing' and 'opportunity-cost pricing' are not found in established WSEs or in discussions of their irrigation, drainage and flood control services. 'Market pricing' has very limited validity in formal transactions in irrigation (or urban) services. The prices of bulk water supply to San Francisco are a fraction of those in most neighboring irrigated areas and are not marked up to 'market' prices. Indeed, the San Francisco bulk water is not made available to any 'markets'. The physical, institutional, political and social restraints to market pricing in developing countries make it infeasible. 'Opportunity-cost pricing' is not utilized for any services in developed or developing countries.

As shown in the report, "ICID Survey on Funding of Operation, Maintenance and Management of Irrigation and Drainage Projects," (Lee, 2002), those WSEs obtaining customer payments close to full funding of O&M rely on both tariffs and some form of property taxes. These may be paid in labor, common in many developing countries, particularly on customer/beneficiary-owned schemes.

By far the most common basis for charges for rural and urban services – and found in utility principles – is full financial cost of services. Costs include investments, replacement, O&M and repayment of any borrowing. The calculation to collect all costs on a consistent basis from all beneficiaries is straightforward and the customer/beneficiary can understand the principle as being equitable.

There are strong economic and social equity arguments for countries to have consistent policies for the recovery of the costs for all services in both the rural and urban sectors. Discussions in any one sector should be within the transparent framework of policies that the country applies to all water-related services in all sectors. Then all beneficiaries will feel they are treated equally, garnering the political support so necessary for consistent payment of the charges.

Farmers in the adjacent areas of rainfed agriculture do not believe subsidizing irrigation is equitable when they receive neither a service nor a subsidy. Rarely is it judged equitable to assess any irrigation costs to adjacent villages any more than assessing those farmers for village services.

Gaps in Information on Polices and Practices

ICID has developed considerable information regarding service charges (Lee (2000). The findings are based on data from schemes representing 'best practices' secured by the respective National Committees of ICID in twenty-three countries. Fifty WSEs are 'public /semi-public' entities where the government sets conditions of service, sets charges and usually subsidizes the service agency. Twenty-three WSEs are government departments that provide the service and a budget subsidy to augment customer payments, if any.

Unfortunately, there is inadequate information on customer-owned and managed service entities. Very few belong to the National Committees of ICID, essentially none in the developing countries. Country water departments have little information on this class of WSE and other organizations have conducted only limited investigations. Yet, very significant areas of developed and developing countries are served by farmer-constructed and owned irrigation and drainage systems that have proved over many decades to be financially and physically self-sustaining.

Customer/beneficiary-owned WSEs provide the majority of urban and rural water-related services in the world. These include sub-units of local government with taxing powers governed by a council that is elected by the customers, quasi-government with a customer-elected board of directors, and similarly organized non-profit WSEs without taxing powers. Typically, these are the best managed WSEs precisely because the customers agree to the service objectives and elect their representatives to the management body that has the power to hire and fire the administration and their workforce. The customers have a continuing 'regulatory' oversight with direct communications to WSE board members or governing council.

There is another characteristic common among self-sufficient irrigation WSEs; they retains the entire water right and do not distribute it among the members. The water right is the most important asset of these WSEs. The membership cannot afford to have some members sell their portion of the water right outside the WSE since it affects the financial viability of the WSE and the operational utility of the infrastructure for remaining members. As mentioned, lenders rely upon this asset remaining in full with the WSE.

Obviously, there are a numerous examples where government agencies at the state or central level provide very efficient, high quality, reasonably priced services. Caution should be exercised before judgment is rendered concerning such WSEs. There are good reasons why village, town, county and city services are largely provided by subunits of local government in developed and many developing countries. Nevertheless, sustainability of such WSEs depend upon sound politics, comprehensive staffing rules and fiduciary oversight.

Information on performance and financing mechanisms, including any government subsidies and grants, for both urban and rural WSEs should be available in a common format to engender trust, transparency and equity.

A SYNOPSIS OF INTERNATIONAL EXPERIENCE WITH FINANCING AND COST-RECOVERY

A range of historical information is required to properly analyze options and formulate equitable, practical, financing and service pricing policies. Only a few of those cited in the Position Paper Annex are offered in this paper.

Full financial cost recovery discussed earlier largely held true in Europe and North America prior to the early 1900s and have been applied in many of the more recent agricultural projects. Prior to the era of international lending, construction and O&M of many existing irrigation systems in developing countries were entirely funded by the farmers organized as customer/beneficiary-owned WSEs. The approximate percentages of typical examples in 1995 amounted to; Nepal (65%), Indonesia (20%) and Morocco (55%).

The world-famous Valencia Water Court in Spain is but part of a very comprehensive WSE structure established by the Arab Cordoba Caliphate more than 1,000 years ago and respected by all subsequent governments. Provisions include water rights tied to the land and not permitted to be sold separately; firm operating rules and equitable full cost-recovery with an internal enforcement mechanism. This WSE has been fully sustainable through all matters of rule, adversities and economic conditions.

In widely separated countries, people living in areas prone to inundation by storm water organized and dealt with flooding in the same manner. In the Netherlands local rural communities in 1100, in Germany in 1200 and England shortly thereafter established what became customer-owned WSEs. To the many thousands of such WSEs in these countries may be added even more in North America. Earlier irrigation, drainage and flood control developments of similar structure are found in Asia, the Middle East and North Africa.

Today, government irrigation agencies apply some level of cost recovery through service charges on the recently constructed schemes. The greatest variation regards recovery of the capital cost component. Most developing, but also recent 'privatization' in developed countries such as Australia and UK have foregone recovery of past capital costs. Australia and UK policy is to recover costs on new investments – in the case of UK by the for-profit companies now operating the facilities. Through the assessment of labor input to constructing facilities from the potential local beneficiaries, the Chinese governments avoided a majority of the costs of building irrigation and agricultural drainage and even major components of regional flood control works. The policy of the US government is to recovery all capital costs of urban and power services. The only subsidies to federal irrigation projects is forgone interest on the initial construction. The full capital costs of irrigation is included in service charges, though ownership remains with the government. Taxes on farm produce are assessed in some countries. But it is difficult to ascertain the portion credited to the associated water-related services.

The recovery of capital costs of local flood control facilities varies greatly. Local storm drainage, agricultural drainage and flood control services typically protect all property within an area. Varying portions of capital costs are collected through a property tax or a required contribution of labor. Some countries assess costs for such services to all beneficiaries (occasionally prorated among zones of different benefits). Local government councils and their tax collection units often function as the management agency since O&M is low and intermittent, hence, no permanent WSE administration staff is required. Typically there is no cost recovery for regional drainage or flood control, though some, such as the China, may require adjacent beneficiaries to provide labor for maintenance.

Developed and the developing countries may subsidize construction to accelerate the completion of facilities – particularly for pollution control. All countries assist the most poverty stricken with access to services for purposes of basic health and those activities that they pursue for economic survival. It is in the later vein that countries justify irrigation and drainage subsidies.

An increasing number of developing countries that face rapidly increasing demands on their national budgets will have to require beneficiaries of irrigation and drainage services to pay full O&M, as a minimum, in labor or fees for the services. Otherwise there the services will wither.

Privatization has been touted as the solution. One can argue its virtues, but that doesn't alter the need for cost-recovery.

FINDINGS

The international experiences from this investigation indicate that:

1. Irrigation and drainage systems constructed by farmers prior to the era of major government involvement and with firm water rights, remain physically and financially self-sufficient.
2. One characteristic of self-sufficient WSEs is that service charges are levied to all direct beneficiaries at a rate that recovers all financial costs of service and nothing more. The only excluded cost might be recovery of investment if facilities ownership does not remain with the WSE. None include a component to provide for 'profits'.
3. Charges to a distribution WSE for bulk water supply provided by another WSE are incorporated together with the distribution WSE's costs into the customer service charges.
4. There are no example WSEs that base service charges upon the free market, opportunity costs, marginal costs or economic costs. This is also true of urban services except where WSEs charge a modified marginal cost to urban areas located outside of the WSE's legal service area.
5. The great majority of the world's WSEs that have proven to be self-sustainable are directly or indirectly owned and governed by local customers/beneficiaries of the service(s) structured as quasi-governmental WSEs or local government subunits governed by the beneficiaries' elected representatives.
6. Successful, for-profit, irrigation WSEs in developing countries are typically small, serving a cluster of farmers from wells or low lift pumps from channels.
7. Successful, farmer-owned WSEs for irrigation as a part of government projects were created simultaneously with or before the major works were constructed and are of the quasi-government form of organization. These receive bulk supply that may be subsidized or at full cost from a government system, but the WSE charges typically cover all internal distribution costs.
8. A majority of central or provincial government-operated irrigation WSEs in developing countries base charge rates on the recovery of a portion of service costs augmented by unreliable subsidies or are under-funding.
9. Irrigation WSEs recently created by the transfer of service responsibility from government in developing countries usually levy charges based on O&M cost with mixed results; many are deteriorating from lack of funds to rehabilitate facilities. Water rights are often found to be questionable.
10. Self-sustaining storm drainage WSEs continue to be constructed by beneficiaries in developed countries utilizing quasi-governmental forms of organization without government financial support.
11. Local and regional flood control has a mixed history with governments assuming increased responsibility and costs as the protected area increases.

REFERENCES

Lee, P. (2000), "ICID Survey on Funding of Operation, Maintenance and Management of Irrigation and Drainage Projects." ICID Central Office, New Delhi. www.icid.org

A UNIQUE SYSTEM OF RESOURCE GOVERNANCE: NEBRASKA'S NATURAL RESOURCES DISTRICTS

Dean E. Edson[1]

INTRODUCTION

Nebraska's system of local natural resources management is unique in the United States. Unlike the county-wide districts found in most states, Nebraska's Natural Resources Districts (NRDs) are based on river basin boundaries, enabling them to approach natural resources management on a watershed basis. NRDs are unique to Nebraska, a state which has a long history of political innovation including the nonpartisan, single-house legislature and all power generation plants in the state are owned by the public. A map of the NRDs and contact information is attached at the end of this document.

Created in 1972, NRDs are local government entities with broad responsibilities to protect out natural resources. Major Nebraska river basins form the boundaries, enabling districts to respond best to local needs.

Elected boards of directors govern NRDs. Individuals are elected on the general election ballot and any citizen can run for office. NRDs have the choice to divide into sub-districts, elect all directors at-large or a combination thereof. If a NRD has sub-districts, no sub-district can have a population greater than 3 times the smallest populated sub-district. Most districts are at or near equal population per sub-district and adjusted every census.

Prior to the creation of the NRDs, not all local citizens had input on the direction and governance of the political subdivisions involved in resource management. For example only farmers were allowed to vote on election of the old county conservation districts and drainage districts. Some other resource management districts were appointed by county officials. All of these districts were merged into the NRDs in 1972.

Much of their funding comes from local property taxes. In many cases, local natural resources districts use from 1% to 2% of all property taxes collected in the county. The districts' taxing authority is 4.5 cents/$100 valuation. An additional 1.5 cents/$100 valuation for water management programs is allowed. The sum of property tax collection for all districts was $28 million in 2003.

NRDs help Nebraskans respond to natural resource challenges with local control and local solutions. Often, they build partnerships with other agencies and

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organizations, including the USDA Natural Resources Conservation Service, the Nebraska Natural Resources Commission, other state and federal agencies, municipalities, counties and private organizations.

Many NRD projects leave permanent results: dams, terraces, drainage ditches, windbreaks, reservoirs and recreational trails.

In the quarter century since they were created, NRDs have experienced tremendous growth in the responsibilities given to them by state statute, especially in protecting groundwater. With information, education and outreach efforts, NRDs also touch Nebraska's future generations, the young people who will watch over the state's resources in the 21st Century.

NRD RESPONSIBILITIES

Nebraska's NRDs are involved in many projects and programs to conserve and protect the state's natural resources. NRDs are charged under state law with 12 areas of responsibility:

- erosion prevention and control
- prevention of damages from flood water and sediment
- flood prevention and control
- soil conservation
- water supply for any beneficial uses
- development, management, utilization, and conservation of groundwater and surface water
- pollution control
- solid waste disposal and drainage
- drainage improvement and channel rectification
- development and management of fish and wildlife habitat
- development and management of recreational and park facilities
- forestry and range management

While all NRDs share these responsibilities, each district sets its own priorities and develops its own programs to best serve local needs. Districts are required by law to establish long-range plans and modify them on a timely basis. This requirement assists the districts in prioritizing activities and projects

Nebraska's major river basins include the Missouri, Platte, Niobrara, Loup, Republican, Elkhorn, Nemaha and Blue. Though it is plentiful and usable, Nebraska's water is neither infinite nor immune from pollution. Irrigators, cities and villages, industries and wildlife all compete for the resource. Contamination may come from sediment, farming chemicals, urban runoff and industrial sources.

Natural resources districts have local leadership responsibilities for protecting ground water from overuse and pollution. Each district also has a plan to protect groundwater. State law has given districts a variety of regulatory tools, to address contamination, shortages or user conflicts.

NRDs encourage stewardship by providing financial assistance to landowners for irrigation water management and best-management practices to protect water quality. NRDs are not just water protectors; in some cases they are providers. A number of NRDs operate water systems for rural customers and small communities.

Natural Resources Districts try to offset these natural forces by promoting conservation, educating the public, and working with other agencies such as the USDA Natural Resources Conservation Service and the Nebraska Department of Natural Resources to implement best management practices.

Cost-share incentives such as the Nebraska Soil and Water Conservation Program and programs specific to each District give landowners financial assistance. Erosion is controlled by installing terraces, grassed waterways, grade stabilization structures and dams, planting windbreaks and improving range management.

When soil erosion becomes a threat to neighboring property, Districts have the legal authority to mediate a solution under the Erosion and Sediment Control Act

In this paper, I describe three of the 12 areas of responsibility: 1) Groundwater Quality; 2) Groundwater Quantity; and 3) Flood Control and Urban Conservation.

GROUNDWATER ISSUES

Water management is vital to Nebraska's agriculture, economy and environment. The NRD is the primary agency for managing groundwater quantity and quality. With approximately half of the state's cropland under irrigation, agriculture, by far, is the leading consumer of water. Water is essential for other uses as well: communities, power generation, tourism and manufacturing.

Groundwater provides approximately 85% of Nebraska's drinking water. Fortunately, Nebraska has excellent water resources - ground and surface. Probably the best known is the Ogallala/High Plains Aquifer, which lies beneath much of the state. Not as well known is that Nebraska ranks 10th nationally in miles of rivers and streams.

Unfortunately, we have not always managed our water resources well prior to the development of the NRD system. Nor have we done the things needed to ensure long-term quality. Nitrate contamination is a major concern for NRDs. Although we do have some naturally occurring nitrate contamination, the primary cause is from production agriculture. The local producers share this concern and have teamed up with the NRDs on several demonstration and education efforts. However, regulation is still necessary to reduce the level of contamination.

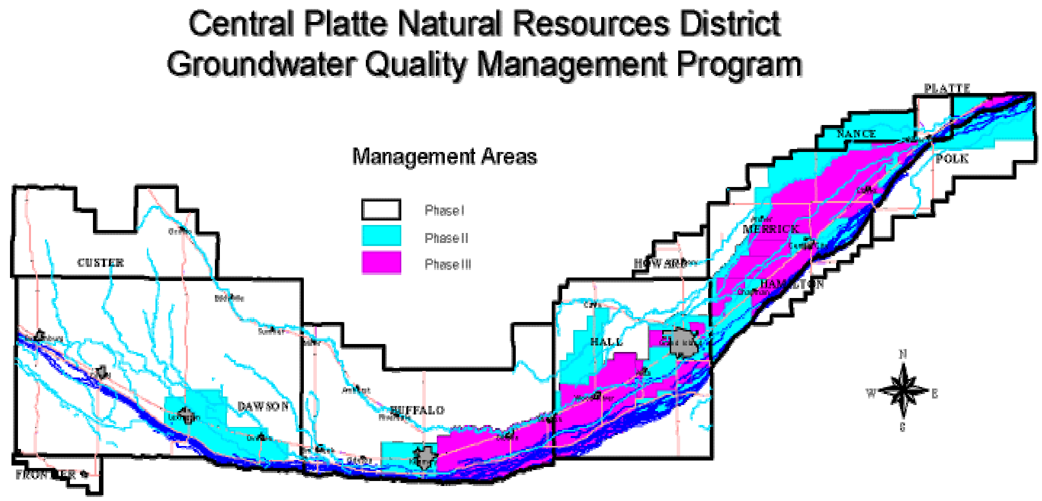
Central Platte NRD, located in Grand Island, has been the leader in correcting this nitrate problem.

GW Quality Issues

Until the Central Platte NRD Groundwater Quality Management Program was adopted in the mid-1980's, the nitrate level in the High Nitrate Area of the District had increased at a rate of about 0.5 ppm (parts per million) per year to 19.24 ppm. The Environmental Protection Agency's Maximum Contaminant Level for nitrate in drinking water is 10 ppm. At the end of the first crop year under the program, the nitrate level dropped by 0.3 ppm and continued to drop through the 1993 crop year. Adverse weather conditions resulted in increases during the 1994 and 1995 crop years, but, a lowering of the nitrate rate occurred again after the 1996 and 1997 crop years.

Nitrate levels in the NRD's high-nitrate area dropped from 17.41 ppm in spring 1998 to 16.62 ppm in spring 1999. The drop is credited to landowners in the District using better management practices recommended by the NRD and the University of Nebraska- Lincoln. Farmers from throughout the District, with varying soils and conditions, were recruited to work with the NRD in using the best management practices to demonstrate that nitrates can be managed efficiently and effectively while maintaining crop yields. In addition, many of the tools needed by the farmers to establish best management practices, including fertilizer calibration meters, irrigation well hour meters, surge valves, vertical dam manifolds, irrigation flow meters and reuse pits, were encouraged through the availability of cost sharing by the District Research indicated that most farmers did not know how much water they were using during irrigation, so the Board decided to make mandatory the practice of monitoring well outputs in Phases II and III. A well measuring program was adopted, and later revised, that could determine how much water is being used. Wells measurements began in 1998 for Phase III and in 2000 for Phase II. (See Table 1 for more explanation on Phase I-IV)

Table 1: Central Platte Natural Resource District GWQMP*



Phase I is generally the portion of the District in which the average nitrates are from 0 to 7.5 ppm
Phase II is generally those areas that have an average nitrate concentration of 7.6 to 15 ppm
Phase III is generally those areas with an average nitrate concentration of 15.1 ppm and higher.
Phase IV: Area where nitrate levels are not declining at an acceptable rate.

*Because the phases are implemented by area, individual wells in a Phase Area may be higher or lower than the designated range of nitrate concentrations. Other factors, including proximity to a municipal water supply and vadose zone nitrates, are also used in determining the Phase Areas.

To facilitate increased water management, the District developed its Splash program to provide one-on-one education for producers who voluntarily participate. The producers receive weekly irrigation assistance on one field and a complete evaluation of an irrigation system. In return, producers are expected to share the experience with other producers and consider improved irrigation techniques. To supplement these education and cost-share funding portions of the program, the NRD adopted rules and regulations to assure that certain minimum changes occur.

The district's goal is to assure an adequate supply of water for feasible and beneficial uses through proper management, conservation, development and utilization of the District's water resources. CPNRD is involved in groundwater level observations, administering irrigation runoff regulations, groundwater quantity and quality management, groundwater modeling and development of a surface water flow model. Together, these efforts form a complete groundwater and surface water management program.

<u>Example – Fertilize or Not</u>

In the mid-1990's, CPNRD entered into a 5-year contractual agreement with a landowner for a demonstration plot. The quarter-section of ground, 160 acres, was divided into two 80-acre parcels. The groundwater was contaminated with nitrates at a very high level. The multi-year agreement required the producer to fertilize one of the 80-acre parcels as he always has done, with about 200 pounds of N. The other 80-acre parcel received no commercial fertilizer. Both fields received the same planting rates and irrigation schedule. The district paid a fee for the demonstration plot and it agreed to compensate the landowner for any reduction in crop yield.

After the first two years of even yields, both the district and the producer realized there was enough nitrate in the irrigation water to provide the crop with all the nitrogen needed. The ironic twist was the producer wanted out of the contract for future years so he could cut back on fertilizer costs and improve profitability. However, the district made the producer complete the remaining years on the contract. At the end of year 5, the non-fertilized ground still had nitrogen content at least as high as the fertilized field.

News of the results has spread throughout the district and many farmers are now testing wells voluntarily and using the available nitrates in the irrigation water. This is helping reduce the contamination, but we still have a long way to go to reverse 60 years of over-application of fertilizer.

Nebraska's other 22 NRDs have followed the lead of Central Platte NRD and are seeing similar results.

<u>GW Quantity Issues</u>

Local NRDs have experience in managing ground water levels and have a proven track record on reacting to declines and developing management plans for ground water users. Current law in Nebraska places ground water under the correlative rights doctrine, which allows users the right to groundwater on the over-lying land as long as it does not harm another. In times of shortage, all users share equally in the shortage. Local NRD regulations allocate the shortages.

In 2004, the Nebraska Legislature passed comprehensive legislation to overhaul water law in Nebraska. Although surface water remains on the prior appropriation doctrine and ground water remains on the correlative rights doctrine, NRDs and the Department of Natural Resources are required to develop integrated management plans for both when a basin in determined to be fully appropriated or over-appropriated. Here are the key components to the law:

- The Department of Natural Resources is required to make an annual determination of which basins, sub-basins or river reaches are fully appropriated. If a basin is declared over appropriated or fully appropriated there shall be an immediate suspension of all new uses until the NDNR or the NRD decide more can be allowed.

- In basins declared over appropriated or fully appropriated, NDNR and NRDs are required to jointly develop and implement an integrated surface water and groundwater management plan within 3 to 5 years of the determination.

- One goal of the Integrated Management Plan is to manage all hydrologically connected groundwater and surface water to sustain a balance between water uses and water supplies so that the economic viability, social and environmental health, safety and welfare of the basin, sub-basin or reach can be achieved and maintained for both the near and long term.

- Integrated management plans will include managing new groundwater uses for surface water rights granted to fish and wildlife. Managing existing groundwater would be up to the local natural resources district.

- The Integrated Management Plan may use a number of voluntary measures as well as the controls in current law, such as allocation of withdrawals, rotation of use, reduction of irrigated acres, and other measures.

- Any disputes between the NDNR and NRDs over the development or implementation of the joint action plan will go to a dispute resolution process. If the dispute is still unresolved, the disputed issues will be presented to a five member Interrelated Water Review Board, which will make the final decision on which components to put into the plan or how the plan shall be implemented. The Board will consist of five members including the Governor or his or her appointee, one additional member of the Governor's choosing and three additional members appointed by the Governor from a list of at least six persons nominated by the Nebraska Natural Resources Commission.

- Transfers of surface water rights from one location to another will continue to be allowed. In some cases NDNR is authorized to issue temporary and permanent permits that either change the purpose for which water is used or change from one type of permit to another. No permanent transfers or changes are allowed if they involve a change to a different preference category. Safeguards are added to ensure changes in type of permits or changes in use will not adversely impact existing users.

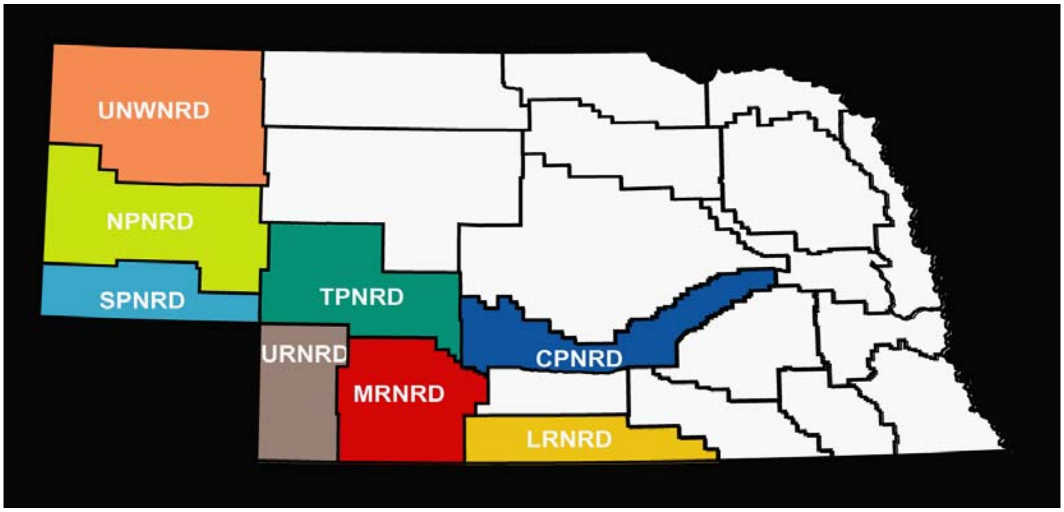
- The period of allowable non-use of surface water rights before cancellation without excuses is extended from 3 years to 5 years. If there are excusable reasons for nonuse, the allowable period of non-use without cancellation is extended from 10 years to as many as 15 years. The period of allowable non-use before cancellation when water unavailability is the reason is extended from 10 years to as many as 30 years or, upon petition by the appropriator, even longer if the permit is in a basin that has been determined to be over appropriated or fully appropriated and water is expected to be restored for use in accordance with an integrated management plan. When an appropriation held in the name of an irrigation district or company is cancelled, the district shall have up to 5 years to assign the right to another use.

- A Natural Resources District may require as a Management Area Control: 1) District approval of transfers of groundwater off the land where it is withdrawn, and 2) District approval of transfers of rights to use groundwater that result from District allocations imposed under the Groundwater Management and Protection Act. Require the District to deny or condition the approval of transfers if needed to: 1) ensure consistency of the transfer with the purposes of the Management Area, 2) prevent adverse impacts on groundwater users, surface water appropriators, or the state's ability to comply with an interstate compact, decree, or agreement, and 3) otherwise protect public interest and prevent detriment to the public welfare.

- Natural Resources Districts may grant groundwater transfers off the overlying land to augment supplies in wetlands or natural streams to benefit fish or wildlife or to provide other environmental benefits. The determination of whether to grant a permit is to be based upon stated factors, including whether the use is a beneficial use, the availability of alternative supplies, negative effects of the proposed withdrawal, cumulative effects of the proposed withdrawal, and consistency with groundwater management plans and integrated management plans.

Since the passage of the law this year, declarations of fully or over-appropriated resources have been made in more than 1/3 of the state and the local NRDs are actively developing management plans. These areas are shown in Table 2.

Table 2 – Nebraska NRDs either Fully or Over-Appropriated



FLOOD CONTROL & URBAN CONSERVATION

Natural Resources Districts work with landowners and other agencies to minimize the damages that floods cause. Often, flood control projects provide an avenue for recreational opportunities. Trails can be found along waterways or atop levees. Flood control reservoirs provide good sites for land and water recreation. Districts also aid communities in planning flood control and mitigation projects, bringing many interested agencies to work together toward a common goal.

NRDs also assist in development of Stormwater Management Plans required by the Clean Water Act. Districts are actively working with communities across the state to develop and implement stormwater management plans.

The Papio-Missouri River NRD has made a strong commitment to its citizens - protecting ground and surface water, slowing the effects of soil erosion, reducing flood threats, creating and protecting wildlife habitat, and planting trees.

Flood control is a major issue for the Omaha area, which is in the Papio Missouri River NRD. Every year the city grows by about 3 square miles, adding substantially to the surface area covered in concrete and roof tops. Runoff becomes a larger problem if planning is not done in advance.

The district has been working with local community leaders for the past 32 years to plan and build flood control structures. The high cost of the land, plus high construction costs, makes it difficult to obtain the public dollars to finance a project alone.

The Papio-Missouri River NRD has taken a new approach, incorporating public/private ventures for the newest of six flood control reservoirs surrounding the Omaha metro area. Dam Site 6, near Bennington, NE, was originally identified by the Corps of Engineers as one of 21 flood control dams needed to control floods in the Papillion Creek Watershed following major floods in 1964 and 1965. Six of the originally proposed 21 flood control dams were built, four by the Corps with the Papio-Missouri River NRD and City of Omaha sponsorship: Standing Bear, Cunningham, Wehrspann, and Zorinsky Lakes.

Federal funding for flood control reservoirs is no longer available for this watershed. One of the dams in the original plan, Lake Candlewood, was built by a private developer and offers flood control but no public recreation. Walnut Creek Lake and Recreation Area, west of Papillion, opened to the public in 1999. This site was built primarily for flood control but also offers numerous recreation benefits. Walnut Creek was built by the NRD with State of Nebraska funding assistance.

Dam Site 6 is the first public/private partnership created to meet flood control needs while offering limited public access for recreation. This partnership between the NRD and Horgan Development Company will provide additional flood protection for residents and businesses along the Big Papio Creek.

Dam Site 6 will control rainfall runoff from approximately five square miles of Big Papillion Creek Watershed - the most flood-prone watershed in the Omaha metro area. The flood control and public recreation facilities proposed at Dam Site 6 (including land acquisition and engineering), would cost over $10 million if constructed separately as an NRD project. A Wehrspann Lake/Chalco Hills type project would cost $10-$15 million.

The NRD is contributing $2.8 million for this public/private partnership. NRD dollars will be used only for actual engineering and construction costs associated with flood control and public recreation features.

Public Recreation Benefits of the Dam Site 6 Flood Control Project:

1. A hiking/bicycling trail encircling the development will be available for public use (a parking area will be built). This trail will eventually tie into the Papio Trails system being constructed throughout the Omaha metro area.
2. Public fishing will be permitted in an area along the face of the dam.
3. An 83-acre public use recreation area will feature boating, fishing, hiking and more
4. An 80-acre tract of land, adjacent to the Site 6 Reservoir, will be used by the City Of Bennington and the school district for park development and a new school site.

CONCLUSION

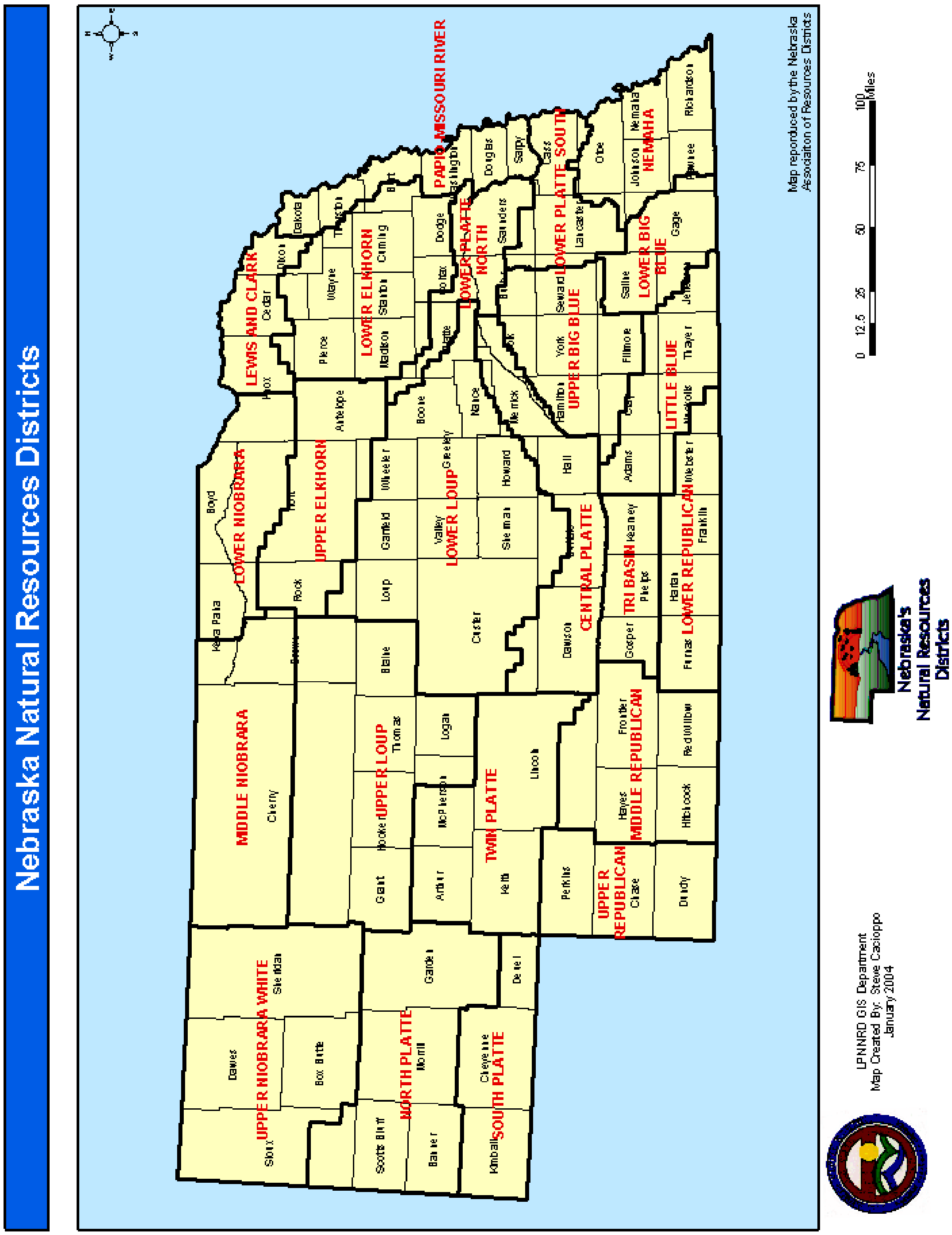
Although this report focuses on just three of twelve areas of responsibilities, it is clear that the local control concept has empowered Nebraskan's to address issues locally. Local NRDs have demonstrated great success in addressing the nitrate contamination while still improving productivity and profitability in the agriculture sector. Other NRDs and producers have copied and improved the best management practices adopted by the Central Platte NRD, turning the tide on nitrate contamination in other Nebraska basins.

Local NRDs are working with the local water users to address water quantity concerns. With the input of the local citizens, several districts have adopted allocation systems, or have pending proposals for groundwater allocations. The local municipal, agriculture, manufacturing and environmental interests are working together with the NRDs and the Nebraska Department of Natural Resources to develop integrated management plans to share this limited resource.

Locally driven flood control projects have turned to multi-purpose, joint ventures with the private sector to provide benefits to the public, while reducing the costs to the taxpayer.

Back in the pre-NRD era, many individuals argued this would never work because it took too much power away for the local citizens when 154 local political subdivisions were merged to form the 23 NRDs in 1972. However, it has probably done just the opposite, as candidates for local NRD boards campaign on the local issues and are elected by all registered voters. Prior to the creation of the NRDs, not all local citizens had input on the direction and governance of the political subdivisions involved in resource management. For example only farmers were allowed to vote on election of the old county conservation districts and drainage districts. Some other resource management districts were appointed by county officials. Now all registered voters have a voice in the goals, objectives and programs of the district.

Resource management and governance is a difficult task. However, when all local citizens have input on the process the difficult task of sharing the resource can become obtainable.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LOWER ELKHORN
PAPIO MISSOURI RIVER
LOWER PLATTE NORTH
LOWER PLATTE SOUTH
NEMAHA
LOWER BIG BLUE
UPPER BIG BLUE
LITTLE BLUE
LOWER REPUBLICAN
TRI BASIN
CENTRAL PLATTE
LOWER LOUP
UPPER LOUP
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NORTH PLATTE
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January 2004

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INVOLVING STAKEHOLDERS IN IRRIGATION AND DRAINAGE DISTRICT DECISIONS: WHO, WHAT, WHEN, WHERE, WHY, HOW

Lisa Beutler[1]

ABSTRACT

Many believe the public and other stakeholders should be considered in developing governance structures. Early engagement with stakeholders can provide an irrigation and drainage district with insight into their concerns and priorities, and outline relevant sustainability issues. Engagement also allows a district to manage expectations and concerns as well as assess strategic issues, opportunities and threats. Districts may utilize a variety of methods to identify stakeholders, discern when and where collaborative work should occur, and define the types of things stakeholders should or should not assist with.

INTRODUCTION

"Business as usual, government as usual, and perhaps even protest as usual are not giving us the progress needed to achieve sustainable development. Let's see if we can't work together to find better paths forward" (Hohnen 2001)[2]

In recent years numerous organizations, from government agencies to for-profit business, have realized the importance of engaging stakeholders in situation assessment and governance. The international community and particularly the United Nations (UN) have similarly embraced multi-stakeholder processes "to address issues that need public debate and stakeholder involvement and contentious issues of political, economic and technological development."[3]

Multi-stakeholder processes (MSPs) are *processes which aim to bring together all major stakeholders* in a different form of communication, fact finding, and possibly decision-making, on a particular issue."[4]

Stakeholder processes are often utilized when decision bodies acknowledge a need for systemic, sustainable, and inclusive approaches. Although complex

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[2] Hohnen, Paul, 2001 NGOs : Challenges and Opportunities. Presentation to UNEP Multi -stakeholder Workshop on "UNEP Today and Tomorrow", Nairobi, 1-2 February, 2001
[3] Hemmati, Minu, Multi-Stakeholder Processes for Governance and Sustainability - Beyond Deadlock and Conflict**,** London, Earthscan 2001
[4] Ibid

stakeholder processes can require large amounts of financial and human resources, some argue that stakeholder based process are also more efficient and effective because they result in faster, less contested implementation of the resulting policies or projects, Many agencies have found it difficult to implement decisions without first gaining stakeholder buy-in.

WHO ARE STAKEHOLDERS?

Stakeholders are individuals or groups who can affect or be affected by an organization's activities. This may include communities concerned with environmental impacts, consumers who want product information, and employees or investors who wish to see a company prosper.

Stakeholders are also those with a stake in what happens as a result of any decision or action. In less generous terms, some who find stakeholders difficult to work with define them as "someone who can mess with your business."

With such broad definitions decision makers and project managers will need to distinguish between influencers and stakeholders. Some individuals with a real stake in an enterprise may have no influence, e.g. a job applicant, while some influencers of an organization may have no stake, e.g. the media.[5] In some cases stakeholders also have influence (for example Board Members). In general, stakeholders are the appropriate parties to engage in situations involving governance and decision making issues.

Stakeholder identification begins with and is directly tied to project scoping. Many of the tools used to define stakeholders parallel those used to define customers. For example, there are several defined governmental sector customers, - ones who use or consume services, ones who regulate it (Judicial and Legislative), ones who authorize it (Executive Branch and Legislature), ones who manage public approval (Executive), and ones affected by the exercise of authority. Stakeholders may include representatives of affected environments or constituencies, such as formal advocacy groups, industry councils, and public interest groups.

In looking at particular issues it is useful to create a comprehensive map or outline of stakeholders needed to help clarify the desired policy outcomes. One approach includes expressing desired outcomes in terms of the impact on key stakeholder groups. From the initial stakeholder map, a more sophisticated analysis of

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[5] Donaldson, T. and Preston, L.E. (1995), The Stakeholder Theory of the corporation: concepts, evidence and implications, *Academy of Management Review*, **20**(1) 65-91.

interests and influence is needed to help assess whether or not to utilize some form of stakeholder group as part of decision-making.

CHARACTERISTICS OF STAKEHOLDER GROUPS

Wide use of stakeholder processes is relatively new and evolving. Methods are continually being adapted based on cultures and desired group products. Even so, while each stakeholder process contains unique features based on purpose and other factors, there are a number of common elements most collaborative efforts share. Table 1 outlines some of those elements.

Table 1. Sample Characteristics of Stakeholder Groups

Features	▪ Equity and accountability in communication between stakeholders ▪ Equitable representation of three or more stakeholder groups and their views ▪ Democratic principles of transparency and participation
Methods	Dependent on issues, objectives, participants, scope, time lines, etc. may include: ▪ Dialogues on policy ▪ Information sharing ▪ Consensus-building, decision-making ▪ Implementation of practical solutions
Outcomes	▪ Strengthened networks among and between stakeholders to achieve better system outcomes ▪ Accountability of decision-makers to the public and to key stakeholders
Sample Products	▪ Policy statements ▪ Response to agency prepared proposals ▪ Strategic plans ▪ Program plans ▪ Litigation settlements and/or agreements reached via alternative dispute resolution ▪ Site specific plans and agreements

As an example of products, the Extractive Industries Review, an entity within the World Bank, utilizes a multi-stakeholder approach to develop future policy on extractive industries, including oil, gas and mining. The objectives of this group were to record the positions of the stakeholders, assess consensus and dissent in selected pivotal issues, and to document them for political decision-makers. Where consensus existed the process aimed at formulating recommendations for the implementation of specific policies.

SELECTING A STAKEHOLDER PROCESS

Various studies have assessed stakeholder engagement methods. A United States Environmental Protection Agency (EPA) review of agency public involvement found, “Some stakeholder involvement activities appear to be conducted because they are considered a good thing but it might not be clear how the activities contribute to actual Agency decisions. This can lead to frustration as participant expectations do not coincide with Agency actions.[6]” EPA also found that because regulatory, non-regulatory, and voluntary program activities had become more extensive and interwoven, “there is not always an understanding of the type of stakeholder involvement that is most appropriate in a particular situation and the model selected might not produce the type of results that are needed.”

Indeed, agencies may involve stakeholders at many levels. One size or method does not fit all. The degree of engagement should be determined by the scope of the issue, needs of decision makers, interest of stakeholders and expertise of the stakeholders.

Management writer Paula Bloom, in her research on internal stakeholders, focuses on the issues of interest and expertise. Bloom recommends designing strategies that match stakeholder interest and expertise with specific outreach methods. Bloom prescribes the following:[7]

- Low interest, low expertise —avoid involvement
- Low interest, high expertise—consult
- High interest, low expertise—consult. The goal of the agency may be to lower resistance among the stakeholders, but this will require great care, sensitivity, and skilled leadership.
- High interest, high expertise—involve as early as possible, and given as much freedom as possible to define the problem and set objectives either as a delegated approach or a collaborative approach.

The International Association for Public Participation (IAP2) has created a Public Participation Spectrum[8] that defines stakeholder methods by degrees of involvement, increasing level of impact, goals of outreach, public expectations, and tools and methods. The model framework ranges from inform, consult, and involve, to collaborate and empower.

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[6] EPA Stakeholder Involvement, *Action Plan,* December 1, 1998, http://www.epa.gov/publicinvolvement/siap1298.htm

[7] Bloom, Paula Jorde. 2000. Circle of Influence: Implementing Shared Decision Making and Participative Management. Lake Forest, IL: New Horizons.

[8] http://iap2.org/practitionertools/index.shtml, IAP2 Headquarters, 11166 Huron St. Suite 27, Denver, CO 80234 USA, E-mail-iap2@iap2.org

Based on research of effective processes, EPA created a template of participation models by type of issue and degree of desired engagement. Table 2 illustrates the framework.

Table 2. US EPA Typology Of Stakeholder Involvement Techniques[9]

ROLE OF THE AGENCY		ROLE OF PARTICIPANTS: EXCHANGE INFORMATION	ROLE OF PARTICIPANTS: DEVELOP RECOMMENDATIONS	ROLE OF PARTICIPANTS: DEVELOP AGREEMENTS
ROLE OF THE AGENCY	**DECISION MAKER**	▪ Hearings ▪ Public comment periods ▪ Town meetings ▪ Open houses ▪ Interviews ▪ Focus groups	▪ Advisory group or task force ▪ Workshops	▪ Negotiated rule-making ▪ Consensus permits ▪ Mediation ▪ Negotiation
ROLE OF THE AGENCY	**PARTNER**	▪ Conferences ▪ Technical workshops ▪ Roundtables	▪ Task force ▪ Workshops ▪ Community visioning process ▪ Roundtables	▪ Partnering ▪ Memorandum of Cooperation
ROLE OF THE AGENCY	**CAPACIT Y BUILDER**	▪ Community Profiling Interviews ▪ Technical assistance grants	▪ Community consensus group ▪ Community visioning process ▪ Technical assistance grants	▪ Technical Assistance Grants

Both the EPA model and IAP2 spectrum are useful in selecting potential public involvement methods. In addressing complex issues it is not uncommon for organizations to utilize several different participation methods. An organization embarking on a very large, complex project may use many methods. For example, the public engagement process may include numerous and ongoing information exchanges with the general public, a focused stakeholder negotiation over environmental documents, technical assistance grants to a community to create capacity for managing new requirements created by the project, workshops to better define specific issues and use of an on-going stakeholder advisory group.

If, after analysis, an agency determines collaboration is the right approach to resolve an issue or develop a proposed action, the Center for Collaborative Policy, Sacramento State University defines eleven specific conditions[10] that should be assessed before moving into a formal collaborative process.

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[9] EPA Stakeholder Involvement, *Action Plan,* December 1, 1998,
[10] http://www.csus.edu/ccp/collaborative/sustain.htm, Center for Collaborative Policy, Sacramento State University, 1303 J Street :: Sacramento, CA 95814

1. Clear Role and Purpose: Participants understand their role, their responsibilities, and the purpose of the effort.

2. Transparency of Decision-Making: How decisions will be made is discussed and identified in the first stages of a stakeholder process. This does not mean that stakeholders, as contrasted with authorized governmental bodies, need to be the ultimate decision-makers. Rather, it means that stakeholders understand the decision-making ground rules before they invest their time in the process. Based on their evaluation on the decision-making rules, they can choose to participate or not participate. This transparency extends to how the ultimate decision will be made as well as to how decisions, including advisory decisions, will be made within the stakeholder group itself.

3. Interest-Based Decision-Making: If consensus-building or collaboration among historical adversaries is a goal of the stakeholder effort, then the decision-making structure needs to reflect this goal. This would mean that for the outcome of process to be considered collaborative, the major interest groupings as defined by the collaborative would need to be supportive of the decision or recommendation.

4. Every Effort to Bring Affected Stakeholders into the Process: At the beginning of any process, a conscious and serious effort is made to identify and recruit stakeholders whose interests are affected by the discussions. This requires a thorough stakeholder analysis process at the start up of a collaborative process or advisory board process. Inclusiveness enhances the legitimacy of the process.

5. Stakeholders Represent Organized Constituencies: When organizing stakeholder processes, as a general rule the participants should represent and be accountable to established organizations, or communities of interest rather than serving as individual citizens.

6. Upfront Exploration of Interests: During the initial stages of a process, a genuine effort is made to explore and communicate the underlying concerns and needs (interests) of the stakeholders participating in the process.

7. Common Understanding of Problems and Joint Fact Finding: Time and resources are devoted to developing a common information base among stakeholders.

8. Policy and Technical Expertise: Meaningful stakeholder processes require some level of external policy and technical support to accomplish their goals.

9. Respectful and Authentic Process: The process is managed so that all are heard and respected. A key role of the collaborative specialist / facilitator is to

manage the dialogue so that the conditions of accuracy, comprehensibility, sincerity, and legitimacy are protected.

10. Transparency of Products: The product needs to accurately reflect the outcome of the stakeholder discussion, in terms of the level of stakeholder support expressed as well as the stakeholder rationale for their recommendation. Specifically, the policy recommendations developed by the stakeholder group clearly state those who support the recommendation, those who oppose and why, those who conditionally support and why, and those who abstain or did not comment and why.

11. Resources: Stakeholder processes need to be funded such that there are appropriate resources to accomplish the above objectives.

If an assessment indicates less than optimal conditions for collaboration, decision makers should either mitigate to improve conditions or select a less intense form of stakeholder engagement. If all indicators point to use of a stakeholder group the next step involves stakeholder selection.

Stakeholder Selection and Criteria

A variety of criteria may be used to select members of a stakeholder group. After creating a stakeholder map to identify the range of interests, several screening questions such as the following may be applied:

- What stakeholders will need to be present for the process to be considered credible?
- To what extent can one set of stakeholders represent the broader interests of others?
- To what extent will this set of stakeholders be needed to achieve a sustainable outcome?

In his recent review of research on successful, effective public participation and stakeholder involvement,[11] William Leach outlined findings on key participant traits. The following is excerpted directly from his report.

Active support and participation by agency staff. Several studies suggest support should from the highest possible levels of the agency. Regular attendance by organization leadership helps legitimize the group and indicates to participants that their contributions will be taken seriously.

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[11] Leach, William D., *Public Involvement and Facilitation Assistanc*e, Center for Collaborative Policy, Sacramento State University, Oct. 2004

Cooperative, enthusiastic, and committed participants. Personal qualities that are especially valued in collaborative settings include honesty and humility, perseverance, a community spirit, a willingness to take risks, to compromise, to listen and learn from others, to keep an open mind, to take criticism gracefully, to respect those with differing opinions, and to avoid attacking others personally.

Trust and social capital. According to stakeholders surveyed in one study, the keys to successful public participation include helping participants "gain insight about others' views and values" and "improving communication among participants."

Continuity in participants over time.

Sense of place—a heartfelt affection for and commitment to a geographic location such as a watershed or town. Several studies conclude that it is easier to sustain a successful public participation process when the participants share a strong sense of place.

Strong motivation to resolve the conflict. This motivation can stem from a significant resource problem or crisis, or from a shared recognition that the participants' interests are interdependent. Motivation is also heightened when participants perceive a political stalemate in which they each lack viable alternatives to the collaborative process.

In addition to the research by Leach our field experience and other studies such as the ones by EPA indicate a few other traits that increase participant effectiveness:

1. Collaborative skills
2. Other skills or expertise useful to the process
3. Leadership ability
4. Degree of legitimacy as a spokesperson for a specific stakeholder community
5. Ability to represent more than one interest
6. Appropriate time and resources to commit
7. Ability to make commitments and reach decisions

A list of desired participant traits may be used by organizations as part of a participant selection processes.

BEST PRACTICES FROM SUCCESSFUL PROCESSES

Leach's literature review[12] also explored key features of successful stakeholder process and found substantial consistency among all the studies for the following:

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[12] Leach, William D., *Public Involvement and Facilitation Assistance*, Center for Collaborative Policy, Sacramento State University, Oct. 2004

- *Effective facilitator and/or coordinator.*
- *Focused scope and realistic objectives.* Have clear purpose, goals and objectives. Focus on measurable, quantifiable, or tangible goals. Demonstrate action and not just talk. Work with a manageable number and complexity of projects, having a well-defined geographic scope and making sure that the focus is sufficiently compelling to sustain the participant's motivation
- *Tractability of the disputes*. Careful selection of issues that are appropriate for collaborative planning. Disputes must be negotiable and not driven exclusively by value conflicts.
- *Early successes*. Early in a process focus on a few easily attainable goals to build momentum, confidence, and reputation. Set both short term and long term goals, and celebrate achieved milestones.
- *Early engagement.* Act early to receive the public's comments. Participants are more satisfied when involved in pre-decisional scoping activities, rather then simply commenting on fully formed policy proposals. Use conflict management methods as early in the planning process as possible. Periodically set new goals to maintain the momentum of a partnership.
- *Pay attention to the big picture.* Focus on more than project implementation. Conduct frequent meetings and frequent communication outside of meetings to maintain relationships.
- *Pre-work.* Allow facilitators sufficient time to help participants identify their underlying interests and avoid focusing solely on stated policy positions. Successful public participation takes time. Assert the importance of abstaining from judging collaborative processes prematurely.
- *Funding***.** Convening agencies can improve the likelihood of success by ensuring adequate funding is available for various startup costs such as retaining skilled facilitators or conducting situation assessments or public outreach. On the individual participant level, success requires that agencies and organizations and agencies earmark funding to support consistent staff attendance and participation.
- *Broad and inclusive participation* is desirable. At the same time emphasize the importance of having the right *mix* of participants to ensure compatible personalities and a diversity of skills and resources.
- *Adequate scientific and technical information.* To the extent information is beyond the control of the participants, this factor is contextual. However, several process design choices will influence how well any public participation process avails itself of available information. Conveners should solicit both expert knowledge and local knowledge, the latter being frequently overlooked and undervalued. Provide information to help participants achieve

common understanding in areas of scientific uncertainty, and design suitable protocols for monitoring and evaluating the outcomes of the process.

- *Collaboration skills training* is another frequent theme in the literature. Convening staff and other stakeholders are urged to seek out training for participants in communication, outreach, leadership, & collaborative problem solving skills
- *Well-defined decision rules and process rules.* Some suggestions include: rights and responsibilities of all participants clearly articulated from the beginning; effective process rules, communication rules, or bylaws; a predictable schedule of meetings; and clear duration of the process.

Based on the literature review and anecdotal experiences, not convening a stakeholder process is preferable to a poorly run process. This is because a poorly run process creates unmet expectations that often lead to cynicism and damaged relationships.

SUMMARY

Stakeholder processes continue to be used in growing numbers and in various settings ranging from local irrigation and drainage districts to issues of the United Nations. Modern leaders recognize the importance of stakeholders and collaborative process. A variety of techniques, features and criteria may be used to determine the best course for a collaborative. Four primary recommendations can be drawn from this paper:

1. Engage the right stakeholders as early as possible
2. Select the appropriate public processes
3. Use best practices drawn from other successful efforts
4. Adequately support the process.

IMPLEMENTING DISTRICT LEVEL INTEGRATED WATER MANAGEMENT WITH STAKEHOLDER PARTICIPATION

Moamen El-Sharkawy[1]
Amira El-Diasty[1]
Essam Barakat[2]

ABSTRACT

Increasingly it is understood that water management is best served by an integrated package of services and practices delivered at the local level. The Egyptian Ministry of Water Resources and Irrigation (MWRI) is decentralizing its internal functions and devolving its authority to the local level. Consolidation of MWRI district offices and integration of water management functions at this level supports the decentralized management goal.

Forming Branch Canal Water Users' Associations (BCWUA) promotes stakeholders' participation. Historically, teams from the MWRI headquarters established water users' associations in Egypt. A change initiated under this project was to build the participatory management skills of the Integrated Water Management Districts (IWMD) and to delegate to them the responsibility for implementing the program establishing BCWUAs in their district. This approach enhances the potential for sustainability because of the close working relations built between farmers and IWMD staff; project districts are seeing a significant reduction in the number of formal complaints from farmers.

Memoranda of understanding defining the roles and responsibilities of the respective signatories are signed by the MWRI and the established BCWUAs. This approach has been used to establish 94 BCWUAs, covering all branch canals within the command areas of four IWMDs, about 145,000 acres.

INTRODUCTION

In recent years, water managers around the world have concluded that water management is best served through an integrated package of services and practices. It is also widely accepted that more effective water management policies can be made by decentralizing operation to local coordination entities. The MWRI, the primary agency charged with management of water resources in Egypt, has a long-term goal to reorganize its internal functions and operations

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through a process of local consolidation and ministry-wide decentralization, including devolution of authority to the local level. The MWRI has adopted a policy to integrate all water management functions at the district level to support decentralized management. To support implementation of the policy, the MWRI formed the Integrated Water Management Unit (IWMU) in December 2003.

The US Agency for International Development (USAID) and the MRWI jointly designed a Water Policy Results Package that integrated water policy and institutional reforms through privatization and decentralization. These policy reforms resulted in an improved environment for private sector participation through the formation of BCWUAs and established a solid basis for MWRI decentralization through the formation of IWMDs.

With USAID and project contractor assistance the MWRI began implementing these policy reform measures in four irrigation districts. MWRI district offices were consolidated and tasks were integrated. Stakeholders' participation was promoted through the formation of BCWUAs.

Implementation included a process of planning and plan adjustment driven by site-specific conditions and available human and financial resources. Establishing four IWMDs and 94 BCWUAs was achieved in a nine-month period. This paper will discuss lessons learned from an accelerated implementation program and early plans for strengthening the four IWMDs and 94 BCWUAs formed and expanding the program to cover four directorates, covering about 1.1 million acres, comprising an additional 23 districts and about 1,000 branch canals.

INTEGRATED WATER MANAGEMENT DISTRICTS

Use of water resources at the district level is plagued by inefficiency: poor management of resources, lack of accurate and timely information, weak management institutions, and no user involvement all contributed to water quality and physical system problems.

A second major problem is that management of water resources use is not integrated. Districts work to match their Nile water allotment with the demand of the command area. The use of groundwater and reuse of drainage water are not considered in the district's water balance, even when these sources are used by farmers to supplement water from the Nile.

The MWRI is vertically organized in line departments with directives and functions flowing from MWRI headquarters to lower line offices at the directorate, inspectorate, and district levels. Policy reform objectives were to reorganize MWRI internal functions and operations and devolve authority to the district level. In the process, district offices become organizationally flatter and inefficiencies and redundancies are reduced. An operational IWMD is expected to achieve the following targets: improved water use efficiency, well-maintained irrigation and drainage systems, and improved service delivered to users.

An IWMD is defined as an entity that has sufficient manpower, material, and fiscal resources to operate and maintain all water resources and pertinent facilities under its jurisdiction to deliver water to users equitably. All divisions support the water distribution and maintenance process and all the various district water entities are merged to constitute a single entity referred to as an IWMD.

Consolidating the multiple MWRI offices within a district creates an Integrated Water Management District with one office, one staff, and one unified budget. Consolidation requires unification of authority and administrative boundaries, preparation of a new organizational structure, an intensive training program, and the development and installation of a database system to monitor and assist the newly established BCWUAs in the district.

Specific steps taken to form an IWMD are outlined below. Steps four and six through nine are also training clusters, indicated in bold type. Training program instructors came from the MWRI and had long experience with the subjects being taught; they could blend practical experience with theoretical knowledge. The program was comprised of formal courses and on-job-training (OJT).

1. Identify and decree administrative boundaries – For single office integrated management of all water resources within the new district, the boundaries for irrigation and drainage command areas must coincide as closely as possible.
2. Develop an organizational structure – The organization is headed by the District Officer and has four sections: water management and distribution, maintenance, planning and follow-up, and administration.
3. Orientation Training – Provides a basic background on IWRM concepts and activities to district engineers, technicians, and stakeholders.
4. **District Consolidation** – The IWMD concept requires consolidation of organizations, staff, equipment, facilities, transportation, budgets, and administrative plans. IWMD staff received a project orientation and training in administration, water management, and consolidated maintenance of the irrigation and drainage systems.
5. Comprehensive Assessment – Determine district's potential water resources and establish an integrated operations program for surface water, drainage water, groundwater, rain, and treated wastewater. IWMD staff should be able to assess and match water supply and demand.
6. **Water Monitoring** – Promote "measurement-based management", where information on water quantity and quality can be used for irrigation system management. Canal monitoring, groundwater monitoring, and water quality monitoring were included. Ten formal and five OJT courses were used.
7. **Information System** – Provide the capability to manage all data and information needed to support decentralized and integrated water management

decision-making at the district level including: data integration procedures, databases, electronic forms/reports, electronic-mapping system, and specialized software. Seven formal and three OJT courses were used. Private sector providers taught the basic computer skills courses, but MWRI staff taught the use of specialized software.

8. **Performance Monitoring and Evaluation** – Identify and document baseline conditions; develop procedures and protocols to assess changes resulting from the institutional reforms; and provide guidelines for computer-based monitoring systems established in the IWMDs. One formal course and one OJT course were presented wherein the staff conducted a survey of water users to assess benefits gained from the IWMD.
9. **Stakeholders' Participation** – Increase stakeholder and farmer awareness of opportunities to participate and to share responsibilities in the management of water resources. Nine formal courses and ten OJT courses were developed and used. These courses covered in-depth the procedures for establishing BCWUAs.
10. Commodity Procurement – Procure items that are essential to ensure implementation of integration activities and support IWMD establishment such as: computers and peripherals, communications & IT, specialized software, water monitoring equipment, training support equipment, and office equipment.

<u>Early results</u>

Considerable progress in decentralization of water resources management has been made. Over this short nine-month period of implementation there are reportable results.

- Integrating physical, institutional, and service aspects of water management at the district level has led to improved institutional and physical efficiencies and a significant decrease in the number of users complaints related to water.
- Training of IWMD staff has improved functional coordination at the local level for water allocation and distribution, drainage, and physical operation and maintenance.
- Guidelines and training materials prepared to implement institutional reorganization and decentralization of the MWRI at the local level are available for program expansion.
- The MWRI Irrigation Advisory Service (IAS) and IWMU, with project assistance, developed for each IWMD a database of information and prepared complete process documentation for each BCWUA established in the district.
- The government has come to realize that the authority of IWMD Officers must be defined and formalized and linkages with directorates redefined. The Minister has appointed a high level committee to address these issues.

- Installation of Internet capabilities at IWMD offices with links to directorates and MWRI headquarters has facilitated the flow of data and information.

FORMATION OF BCWUAS

A critical component of the IWMD is stakeholder participation in decision-making concerning the development and management of water resources. The MWRI recognizes that stakeholder participation strengthens fulfillment of public policies and contributes to transparency. It provides opportunities for cooperation and coordination between the government and stakeholders, which builds trust and collaborative relationships. Stakeholder participation was activated by establishing BCWUAs on all of the secondary canals in the four-targeted IWMDs. Documented benefits to users include increased productivity, positive changes in cropping intensity, improvement in financial impact performance indicators, resolution of water-related conflicts, and a positive environmental impact.

Historically, teams from the IAS established water users' associations in Egypt. Major changes initiated under this project were for the IAS, supported by the project and IWMU, to train and build the capabilities of the IWMD field staff in participatory irrigation management and they then establish branch canal water users' associations. This approach provided IWMD engineering and technical staff with the capabilities needed to take responsibility for establishing BCWUAs in their district. One engineer and 10 to 18 field technicians in each IWMD participated in the Stakeholder Participation activity and can assume IAS responsibilities in their respective districts if so assigned. The number of IAS staff assisting each of the IWMDs ranged from two to eleven. Each four- to five-person field team was strengthened with one female trainer and was responsible for specific branch canals, i.e., for a given branch canal, stakeholders interacted with the same team for the entire process. The MWRI Water Communication Unit, with project assistance, provided public awareness material to support the effort. The potential for sustainability is enhanced because of close working relationships built between farmers and IWMD staff.

The challenge was to establish BCWUAs on each of the 94 branch canals of the four IWMDs during a project time horizon of 13 months. This was the first time MWRI had attempted to form BCWUAs on all branch canals within a single district. Given limited financial resources and time it was necessary to develop a strategy that would provide replicable procedures to enable expansion vertically and horizontally; incorporate the MWRI policies of integration, decentralization, and gender; set the standards for similar stakeholder participation activities in Egypt; prepare modularized training and public awareness materials; and maintain a complete documentation of the process so that it could serve as a model for future efforts.

The Stakeholder Participation program was designed to establish BCWUAs through a comprehensive, stepwise training effort. The IAS team designed a ten-step process in three phases to establish the BCWUAs.

Entry Phase: Introduce the BCWUA concept to both district staff and water users and prepare for BCWUA organization building. The implementation plan had two activities for each step. First, train district staff so they could establish BCWUAs and continue their work in the district. This meant that district staff were forming BCWUAs while their district was undergoing the IWMD transformation. Second, train water users and organize the BCWUAs.

IAS staff was responsible for training district staff. Key steps and training included: staff recruitment and designation of district field staff to activate an IAS unit under the IWMD structure, water users' orientation, data collection, gender issues, stakeholder analysis and identification of key persons, and canal grouping for BCWUA representative elections. Immediately after training, the District staff went into the field to apply the training. The IAS accompanied the District staff in the initial practical applications to assure quality and to learn lessons for future work.

Organization Phase: District staff and water users, with central support, build the BCWUAs: issue IWMD and BCWUA initiation decrees, elect BCWUA representative assemblies and BCWUA boards, issue BCWUA establishment decrees. Formal and OJT courses were used. These courses covered: election of representative assembly, roles & responsibility of the representative assembly, election of the BCWUA board, roles & responsibility of the BCWUA board, exchange of experience among BCWUAs, and follow-up for water users (BCWUA board only).

Signing Memoranda of Understanding Phase: The memoranda of understanding (MOU) between the MWRI and the established BCWUAs is introduced and signed. The MOU defines the roles and responsibilities of each party. After completion of this phase, the BCWUA is ready to undertake the basic functions and to represent water user members on water issues with the IWMD. Training on roles and responsibilities was given during the preceding phase.

Completion of the MOU phase was accomplished in August 2004. Next year a period of institutional strengthening will ensure sustainability and full activation of the BCWUA. Activation will be followed by the transfer of selected responsibilities from the IWMD and MWRI to the BCWUA.

Institutional Strengthening: Capacity building for BCWUAs will consist of developing their administrative capabilities; improving their representation of user concerns to the IWMD, including effective expression of priorities for MWRI annual work plans; undertaking some canal operation and maintenance tasks; learning to monitor water deliveries and operation and maintenance implementation; and beginning to resolve allocation issues between mesqas.

Transfer: Capacity building continues as needed. BCWUAs share and/or replace IWMD staff for operation and maintenance activities, participate with MWRI in contracting decisions and contract performance monitoring, have transparent and organizational capacity to manage activities and funds, and have ability to resolve allocation issues between mesqas and to undertake technical tasks. This phase cannot happen until the amendments to Law 12/1984 Irrigation and Drainage[3] have been approved and the BCWUAs receive legal status. It is not envisioned that the BCWUAs will take over ownership of any irrigation or drainage infrastructure currently owned by the Government of Egypt. They will however be contracted to operate and maintain the infrastructure subject to MWRI supervision and inspection. It is expected that as the BCWUA gains experience in operations and maintenance the degree of MWRI oversight will diminish.

Four distinct products of the Stakeholder Participation activity enhance the capacity of MWRI headquarters and directorates and within IWMDs to support establishment and strengthening of future BCWUAs.

- A **BCWUA Database** was created, tested, and installed at each of the four districts. The database will help the IAS manage, monitor, and evaluate the progress of participatory activities in the IWMDs, and help the IWMDs provide coordination, documentation, and tracking of BCWUA activities.
- A **Monitoring and Evaluation (M&E) Knowledge Base** was developed by interviewing field and management staff. The M&E Knowledge Base includes: parameters for field team formation (age, experience, gender, team structure, performance rate), and BCWUA establishment process requirements (time, resources, planning, data collection, communications, and etc.). The M&E Knowledge Base provides a benchmark for planning other BCWUA formation efforts. This effort will be expanded with knowledge gained during the Institutional Strengthening and Transfer phases.
- During the implementation of each BCWUA complete **process documentation** was prepared. This information is being used to improve the BCWUA formation process. Process documentation will continue to be prepared during the Institutional Strengthening and Transfer phases.
- All training materials were prepared in modular format. These **training modules** are ready for use or adaptation for new projects.

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[3] Three amendments in the legislative process will: give water users' organizations at all levels of the delivery system legal status; permit them to obtain financial resources through service fees and grants; and to contract with the MWRI for the operation and maintenance of contractually defined parts of the irrigation and drainage networks.

Early Results

There are 94 BCWUAs covering about 145,000 acres with 64,583 water user members, of which 1,924 (about 3%) are voluntarily (no compensation) serving on a BCWUA board. These associations were established within a nine month period from December 2003 to August 2004.

About 13 percent of Assembly Representatives and Board Members are women.

"The Branch Canal Water User Associations Informative Handbook" is being provided to BCWUA boards and representative assembly members in the four pilot districts. The pamphlet "Frequently Asked Questions about Branch Canal Water Users Associations" is being prepared for all BCWUA members. In the future these materials will be distributed early in the establishment process.

The principal obstacle for stakeholder participation encountered in the four pilot IWMDs was stakeholder's lack of standing in negotiation with the MWRI. An important result of this project was signing MOUs between each BCWUA and the MWRI. This step also starts activation of BCWUA roles and responsibilities.

Decentralization of IAS activities to district staff was initiated and has proven effective for assisting water users.

Staff of the four IWMDs understand participatory concepts and have the capability to work with BCWUAs established under their jurisdiction.

Lessons Learned

From experience gained during the project and from the knowledge base survey, the Stakeholder Participation Task Group has learned lessons that can improve efficiency in forming future BCWUAs.

1. As replication proceeds, establishment of BCWUAs will become more efficient due to: previous investment in developing training materials and formats, transitioning from engineers to field staff as implementers, transitioning from field staff to farmers as trainers, and empowering BCWUAs and IWMDs to assist in the establishment process.
2. The principal planning parameters for replication of BCWUA establishment include the number of water users and the area covered, the level of effort for field activities (including training the trainers), and the number of training events. On average, a BCWUA with 687 members covering 1,771 acres required a District Field Team staff of 13 people and 115 person days of effort.
3. Establishment of BCWUAs is an integral part of district restructuring.

4. Implementation plans should be modified for site-specific conditions, e.g., canal/drain system layout and social conditions.
5. Establishing a BCWUA provides opportunities for regional and local stakeholders, including governmental and non-governmental organizations, to participate in the process.
6. Criteria developed in the Monitoring and Evaluation Knowledge Base should be used to form new BCWUAs.
7. Given the opportunity, women are able to participate fully as water users and as outreach staff. The degree of participation exceeded expectations.
8. Farmer participation was more enthusiastic than expected. There is an expectation by farmers that the BCWUAs will result in effective participation in decisions.

Recommendations

1. BCWUAs should be encouraged to assume operation and maintenance tasks, improve water delivery or drainage, reduce conflict over water, become effective representatives of farmers, become effective partners in support of agricultural development, and deliver other benefits to members.
2. Agriculture should remain the principal focus as BCWUAs assume operational tasks, with the environment, solid waste management and water quality improvement, as important secondary concerns.
3. Legal reform to recognize BCWUAs should be supported.
4. The institutional model based on IWMD reorganization, including recruitment of willing staff, providing support through the Activity Work Management Group, participation of governorate level undersecretaries, and limited amounts of outside technical support should be considered a sound model for larger projects and programs. Smaller efforts may not need as much regional or national managerial inputs.
5. The BCWUA database should be maintained and used for planning. This database should become the basic document source for planning agricultural, hydrological, and marketing efforts on each branch canal.
6. The Knowledge Base should continue its work to document the progression of costs for establishing BCWUAs and development of BCWUAs as they assume new functions. The Knowledge Base should be expanded to cover analysis of the impacts from the BCWUAs, IWMDs, and mesqa WUAs, cover other project areas (Integrated Irrigation Improvement and Management Project, Water Boards), and measure the multiple dimensions of BCWUA development. These dimensions include stakeholder participation in hydrological and related decisions, assumption of administration, operations and maintenance tasks by water users, and increased agricultural production and income associated with BCWUA operations.
7. Process documentation should be prepared and maintained for each BCWUA. Process documentation, and monitoring in general, should be continued for a

minimum of three years. The computerized BCWUA database is a requirement if MWRI is to implement its decentralization policy nationally.

8. Public awareness efforts should be expanded to facilitate replication of the BCWUA/IWMD model. To date, public awareness has been limited to the area wherein BCWUAs are being implemented. As they become more common and as their functions increase, their existence will be of importance to more people, and the public awareness effort becomes correspondingly more important.

Recognized Concerns

- Improve/formalize modes of coordination between the BCWUAs and the IWMDs. Approval of amendments to Law 12/1984 and refinement of the MOU will help define the relationship.
- Define a procedure or process for a BCWUA to take over full responsibilities for actual daily requirements for maintenance and operations.
- Address MWRI organizational and staffing issues, e.g., redundancy, arising as BCWUAs take over more responsibilities for operations and maintenance.
- Develop procedures for interministerial coordination to resolve overlapping authorities and responsibilities and to promote cooperation in the water sector.

REFERENCE

Integrated Water Management Unit. 2004. "Stakeholder participation activity in Integrated Water Management Districts." Red Sea Sustainable Development and Improved Water Resources Management Project, International Resources Group.

PITFALLS IN WATER DISTRICT MANAGEMENT AND ADMINISTRATION: EXAMPLES FROM THE 'REAL WORLD'

David G. Cone[1]

ABSTRACT

This paper illustrates several areas of water district management and administration that can lead to problems for the manager and the board of directors. The illustrations include conflicts, overselling water, special treatment for directors, directors involved in day-to-day management, manager problems, and embezzlement. These examples are from the "real world" of water district management. The manager and directors must continually review the operations of the water district to avoid these problems. Management, staff, and the board have the responsibility to provide service to water users.

INTRODUCTION

The author has been the manager of Broadview Water District for over 17 years. He has encountered real life problems of a water district on a day-to-day basis as well as observing other managers and water districts operations.

In this paper, several examples of actual problems will be discussed to help water district managers and directors avoid these situations. The examples are problems that have either happened to the author or are situations that he has personal knowledge of in other water districts.

REAL WORLD EXAMPLES

Conflicts

Due to the fact that water district management involves people, there will be conflicts. Some conflicts arise between water users, between canal operators and water users, between management and water users, etc. The conflicts can result from confusion over policies, miscommunications, unequal service, unfair treatment, etc. The staff of a water district must always remember they are employed to provide service to water users under the policies and guidelines of the district. Two examples of conflicts are:

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1. Water User and Canal Operator:
   A.) One day in late June a conflict developed between the canal operator and a water user. On this occasion, the canal operator told a water user that he could not have water delivery the next day as requested. The water user got very upset. In this case, the canal operator was incorrect in his statements and actions. All water users are entitled to receive water equally and fairly. The canal operator should have said that there was not sufficient capacity remaining in the canal to meet his request but he would reduce the delivery flows to all water users on the canal down to their equal pro-rata share of the canal capacity. The water user would be able to receive water delivery but not at his requested flow. He would be treated fairly and equally. The canal operator was reminded that he should never tell a water user that he could not receive service because of canal capacity. All water users will receive the same level of service and the flow will be shared equally.

   B.) On another occasion, a water user believed that the canal operator had reduced his delivery flow. The manager was called out to the field to resolve the conflict. In this case, the water user was unfamiliar with hydraulic principles. The water user (farmer) was monitoring the flow to his field by the water level in the canal. The canal water level had dropped and the farmer thought he no longer was receiving his desired flow rate. He did not understand that the delivery to the field depended on several factors such as the size of the opening on the turnout gate as well as the water elevation. If the farmer had checked the water delivery meter he could have determined the flow rate was correct as opening the gate further compensated for the lower water elevation. When the manager arrived, the farmer was so upset that he was not willing to listen to reason. The manager allowed the user to express his frustration. When the farmer calmed down, he was shown on the water delivery meter that he was receiving his desired flow rate. However, the farmer remained upset at the canal operator for a period of time.

   While these examples involved communication problems between canal operators and water users, canal operators sometimes make mistakes that impact water users. Management should work with canal operators to improve communication and operations.

2. Water User Supply Allocations and Use:
   Most water districts in the western United States have a limited annual water supply and as a result, they usually allocate water to individual water users. It is then up to the water user to manage his water supply. The district has the responsibility to maintain records to account for the allocation and water deliveries for each water user.

> Sometimes errors are made in accounting for water supplies. This can lead to significant conflicts with water users and district management. With the increasing scarcity of water and its higher cost, water users now must manage their water allocations to make sure they can farm at the maximum level. This can lead to emotional responses to errors in water accounting. Instead of responding to an emotional outburst by a water user, district staff should review the numbers with the water user to determine if there is an error and how it can be corrected.
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> When water supplies are allocated to water users, water district personnel have a responsibility to all water users to not allow water users to exceed their supply allocations. Most districts have policies for the termination of water deliveries to water users when either the water allocation is completely used or when the water user has not paid his water bill. If a water district does not have such policies, management should recommend policies to the board to establish procedures regarding the assignment and enforcement of water allocations.
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> The issue of terminating water deliveries to water users who have not paid their service fees is an important issue that is raised often during training workshops for water user associations (WUA) in many countries. Usually the WUA does not have the physical ability to shut off deliveries. If a WUA allows water users to receive water when they have not paid their fees, the WUA will eventually fail. WUAs must collect fees to perform proper maintenance required for them to function and be sustainable.

Overselling Water

There are several situations that a water district manager fears. One is that the district will run short of operating funds and another is that water supplies will be oversold or over allocated. While the author has not been short of operating funds or over allocating water, he has oversold the district's water supply. Based on discussions with other managers, some of them have been in this situation.

Before the Broadview Water District began allocating water supplies to individual water users, the district would transfer (sell) to other water districts any water supply that was considered in excess of the amount needed to meet irrigation demands within the district. In 1990, when estimating water demands within the district, the manager made an error that resulted in overselling 500 acre-feet (616,800 m^3) of water. While the manager had to purchase 500 acre-feet from another water district, at the time the cost of the water sold and the water purchased were virtually the same. If this were to occur today, there might be a significant difference in water costs. Not only would it be embarrassing to the manager, it could be costly to the district. In addition, water may not be available to purchase in order to replace the water sold. If the district had exhausted its water supply before all water users had used their allocations, the manager might have been dismissed.

Special Treatment for Directors

There are occasions when water users seek to be on the board of directors of a water district in order to obtain special treatment. Obviously they do not say this but their actions while on the board reveal their intentions.

These board members seek to get special treatment and are in a position to require the manager to give them that special treatment. Special treatment might involve: 1) weed control in excess of normal efforts on ditches serving their farm fields, 2) priority of water service, 3) cleaning their canals and/or drains more frequently, 4) bending of rules, policies, practices, and procedures for their benefit, and 5) delivering water without recording the delivery. While it is appropriate for a water user to seek to become a board member to have input regarding district policies, practices, and procedures, it is not appropriate for a board member to pressure management for special treatment. All members of a water district should receive equal service and be treated fairly. Water users should be treated the same regardless of the acreage they farm.

It is difficult for a manager to confront a board member when he or she requests special treatment. During the author’s 17 years as manager of Broadview Water District, none of his directors has requested special treatment. However, he has observed directors getting special treatment in other districts. In addition, he has had discussions with other managers who must work under these circumstances. Any special treatment makes district management more difficult and subject to criticism by other water users. Directors need to recognize that their actions could lead to a conflict of interest situation or a formal complaint.

Directors Involved in Day-to-day Management

In addition to seeking special treatment, directors sometimes get involved with the day-to-day management of a district. This makes it difficult for a manager to effectively manage the district. He is never sure what the district’s employees should be doing or what projects they should be working on because one or more of the directors might overrule his decision. More confusion or indecision develops if input from different directors is contradictory.

A former employee of the author became the manager of a mutual water company. That water company had a reputation concerning board members getting involved in day-to-day management and decisions. The board members were always looking over the manager’s shoulder second-guessing decisions or directing him to do something else. While the board of directors is responsible for approving the operation and maintenance plan and the budget, it is the manager's responsibility to carry out day-to-day activities.

The author has worked in the Republic of Georgia preparing training materials for establishing and developing water user associations (WUA). These associations are organized under Georgian Law regarding "Legal Person under Public Law" (Republic of Georgia, 1999), which describes the following duties and responsibilities of the manager:

1. The manager acts independently within the limits of appropriate law, Presidential Degree, the association's Charter, and the internal policies and regulations established by the Assembly.
2. The manager personally manages the activities. He/she is authorized to represent the association and is personally responsible for the proper management of the activities.
3. If the association is established on state property, the manager is appointed and dismissed by the Assembly.
4. The manager is personally responsible for the property owned by the association and for the proper disbursement of funds for the purpose intended.

While Georgian law makes it clear that the manager is to act independently for day-to-day activities, California law does not provide such clear guidance. Basically, in California, the manager's independence is determined by the individual district.

The chairman (president) and other board members should not interfere with the manager as he conducts his day-to-day management of the district. Except in cases of emergency, they should not direct staff in work projects or instruct staff to do certain work. If there is a problem with the manager doing his job appropriately, the board should work directly with the manager to correct the problem or take steps to replace him. The direct interference in day-to-day management by any member of the board is one of the signs of a poorly functioning district.

While it is inappropriate for directors to direct day-to-day activities, it is not inappropriate or unusual for the manager to float potential ideas, solutions, etc., off board members individually to get early comments, but not a decision.

Manager and/or Staff becoming Arrogant or Dictatorial

The longer a person serves as manager of a water district the greater the chance that he will become arrogant and/or dictatorial. This is not necessarily the result of some personality trait but rather it arises from the fact that over time the manager knows more about the district and its activities than anyone on the board.

Also, most of the time the board members do not want to spend the time required to learn about the details of various issues or to participate in the many meetings required of modern districts. The manager is the only person providing specific input that will enable board members to make decisions. The district becomes the manager's life and it is hard to separate who he is from the district because of his involvement in all aspects of managing the district.

An example of the difficulty of separating the manager from the district and policy decisions occurred earlier this year. After the author presented the details of a specific issue on which the board needed to take action, the president of the board asked the manager (the author) if he was going to make a motion on the matter. The manager reminded him that he was not on the board and could not make the motion. The president realized his error and requested a member of the board to make the motion.

The manager is left to make so many decisions in conducting district business and representing the district that over a long period of time, he might begin making decisions that are policy decisions that the board should be making. In addition, the manager might "take ownership" of the district and begin acting like it belongs to him. The U. S. National Park Service has recognized this problem for park rangers. When management detects that a ranger is beginning to view the park as his own property, rather than belonging to the visitors, they transfer him to another park (Cone, 1977).

The author is very familiar with this problem. A previous manager of the Broadview Water District had taken 'ownership' of the district and had become a dictator. He not only dictated the activities of all employees to the point where they no longer had any initiative but he was dictatorial to board members. As an example of his behavior, when one of the water users (even a board member!) parked a tractor on a district right-of-way even for a day or two, he would call them and tell them to get their tractor off 'his' right-of-way. Although he did not own the right-of-way, he acted as if he had taken ownership.

The 'last straw' for that manager occurred when he introduced the president of the board at a conference as 'his' board president. The way it was said conveyed the idea that the president was subservient to the manager. The president of the board was so offended that he left the conference and then brought the matter up at the next board meeting. The board eventually suggested that the manager consider retirement (Cone, 1987).

The author has to continually remember whom he works for and who determines the policies, practices, and procedures of the district. The manager's responsibility is to implement those policies.

Embezzlement

Embezzlement is one of the most damaging things that can happen to a water district. In addition to the loss of money, the district suffers a great deal of embarrassment. Not only is the embezzler embarrassed, but the shame also touches the management and the board. While procedures can be and should be established to reduce embezzlement and to make embezzlement difficult, there is always the chance that embezzling might occur and when it occurs, it is usually discovered. Auditors can review district financial operations and make recommendations regarding procedures to reduce the chances of embezzlement.

Once the author received a telephone call from the manager of another water district. The manager was calling to inform the author that he had his bookkeeper arrested for embezzlement. The manager wanted to ensure that the other local managers knew the details so the correct story would be circulated in the area.

The bookkeeper had embezzled about $50,000 over a period of 2 to 4 years (Cone, 1999). She eventually pled guilty and was placed in home confinement for 2 years wearing an ankle bracelet. She had to get permission to leave her home for such things as doctor's appointments, etc. She and her husband had to pay the money back. A lien was placed against their home to assure payment.

Two major errors contributed to this embezzlement. The first one involved the past history of the bookkeeper, who had been arrested and convicted of embezzlement once before. She did not show the arrest or conviction on her application and the manager did not request an arrest/conviction check on her. The second error involved a simple procedure for the processing of payments and the signing of checks. The manager did not review all checks prior to signature to determine if the payment was correct and appropriate. The invoice (back up material) should have been paper clipped to the check so that those signing the checks could have reviewed the appropriateness of the payment. If this procedure had been followed, the embezzlement could have easily been discovered.

Since most water districts have a limited staff, it may be difficult to fully implement procedures designed to reduce the risk of embezzlement. The following procedures have been recommended to the author by the auditors of Broadview Water District (Baker, et al., 2004):

> Internal controls are designed to safeguard assets and to detect losses from employee dishonesty or error. A fundamental concept in a good system of internal control is the segregation of duties. Although the size of the District's accounting staff prohibits complete adherence to this concept, we believe the following practices could be implemented to improve existing internal control without impairing efficiency:

- Cash receipts should be deposited intact daily. Holding receipts for periodic deposit exposes the District to loss.

- Bank statements, canceled checks, and appropriate advices should be received by someone other than employees maintaining cash records. Such items could be periodically reviewed prior to turning them over for reconciliation. Unusual items noted during the review should be investigated promptly.

- Cash receipts from customers are received primarily through the mail, which is opened by the bookkeeper, the District's only accounting staff. She then prepares the deposit slip and keys the cash receipts into the computer accounting system. We recommend that management review the deposits and compare them to monthly bank statements to ensure that all checks received are deposited. A listing of the deposit should be printed and attached to the daily deposit slip as support for the deposited balance.

- Management should review supporting documents for normal recurring disbursements (not usually reviewed) on a spot-check basis. Non-routine testing would aid in ensuring compliance with District policy for all disbursement.

- Non-standard journal entries should be approved by an employee other than the one who prepared the entry. All entries should be initialed by the preparer and the individual approving them in order to attribute responsibility to the appropriate individuals. All journal entries should be accompanied by full explanation and by reference to adequate supporting data.

While some of these items are currently part of the district's accounting process, some items are difficult to implement with a 2-person office in a rural setting, 7 miles from the bank and post office. The principles underlining the recommendations are appropriate and should be implemented where possible.

CONCLUSIONS

Management and staff, as well as the boards of directors of water districts, must always remember that the primary purpose of a district is to provide water service. Employees are hired to provide that service on a day-to-day basis. The board of directors should remember that its function is to provide policies, practices, and procedures that promote effective functioning of the district. The manager is hired by the board to manage and administer the district under those guidelines without inappropriate daily interference. Following these guidelines will enable a water district to minimize the probability of encountering some of the problems described in this paper.

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HOW 32 LOCAL WATER AGENCIES GOT TOGETHER TO ASSUME OPERATIONS & MAINTENANCE OF REGIONAL FEDERAL CENTRAL VALLEY PROJECT FACILITIES
(The San Luis & Delta-Mendota Water Authority Experience)

Daniel G. Nelson[1]

ABSTRACT

The San Luis & Delta-Mendota Water Authority (Water Authority) is a California Joint Powers Authority that consists of 32 water agencies and represents approximately 1,200,000 acres (486,000 ha) of agricultural lands, about 100,000 acres of wildlife refuges and a population of over 1,000,000. A map of the Water Authority is attached. The Water Authority was formed in 1991 for two primary purposes: to assume the operation and maintenance (O&M) responsibilities of certain United States Bureau of Reclamation (USBR) Central Valley Project (CVP) facilities; and, to represent it's member's common interests on issues such as water rights and water resource public policy. Key formation issues included governance and cost allocation issues.

Motivation for assuming the O&M responsibilities arose from two sources: 1) water user concerns regarding the costs and reliability of the federal facilities that they rely on for delivery of water supplies; and 2) a desire by the federal government to reduce its role in operating and maintaining water supply facilities. In 1992, the Water Authority initiated the cooperative transfer of O&M of selected facilities that serve its member agencies. The transfer was phased in over several years. Key facilities include the Delta-Mendota Canal, Tracy Pumping Plant, O'Neill Pumping Plant, Delta Cross Channel Gates, and San Luis Drain.

This paper will describe the issues involved in the transfer of operation and maintenance of these facilities from the federal government to the Water Authority. Key issues include formation of the Water Authority, structure of the organization, governance, cost allocation, the relationship of the Water Authority with the CVP and federal government, internal conflict avoidance/resolution, and the relationship between water users, member agencies and the Water Authority.

BACKGROUND

Central Valley Project (CVP)

Initial CVP features were constructed between 1937 and 1951. Other facilities were added later and by 1990, the project included 20 dams and reservoirs

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capable of storing 11 million acre-feet of water, 11 powerplants, some 500 miles of major canals or aqueducts, three fish hatcheries, and assorted tunnels, conduits, power transmission grids and distribution systems.

CVP Facilities Servicing the Water Authority. The Tracy Pumping Plant (TPP) and the Delta-Mendota Canal (DMC) were completed in 1951. The canal begins at the Tracy Pumping Plant and follows the Coast Range south to the Mendota Pool on the San Joaquin River. The TPP/DMC is the primary source of water supply for the area within the Water Authority.

The San Luis Dam and Reservoir are joint-use facilities built and used by the state and federal governments to store water diverted from the Delta through the TPP/DMC. The reservoir can store over 2 million acre-feet of water. Authorized in 1960 and completed in 1968, the offstream dam and associated facilities allowed expansion of CVP service for the San Luis Unit.

The San Felipe Division was authorized in 1967 and completed in 1988. The San Felipe Unit provides water to Santa Clara and San Benito counties from San Luis Reservoir both for urban and agricultural uses.

CVP Operation and Maintenance (O&M). The CVP was constructed primarily under the supervision of the USBR. Once constructed, the USBR provided for the O&M of all CVP facilities. The USBR provided quality O&M service to its contractors for many years.

USBR O&M Cost Allocation. USBR costs for O&M are included in the water rates charged to CVP contractors under the provisions of their contracts. Initially the O&M costs were projected and incorporated in long term fixed rate contracts. That approach was replaced by collection of all O&M costs on an annual basis. Annual O&M deficits (underpayments) are accounted for and collected with interest. Therefore, in effect, water users/contractors are responsible to pay all USBR costs for O&M in each and every year.

California Water Resources Management Changes

In the late 1980’s and early 1990’s management of California’s water resources was under scrutiny. Congress was redefining how the CVP would be operated through its development and passage of the Central Valley Project Improvement Act of 1992 (CVPIA). Other federal regulatory statutes including the Endangered Species Act (ESA) and the Clean Water Act (CWA) also changed the way the two major California water projects, the State Water Project (SWP) and the CVP were operated.

USBR Changes. The USBR was evaluating its role as a water purveyor. An illustration of the change was a statement by a USBR official that the historical role of the USBR was to represent their water users/contractors to Washington D.C. and that now their role was to represent Washington D.C. to the water users. CVP water users were confronted with reduced supplies, increased costs and a tremendous amount of uncertainty.

MOTIVATION FOR ASSUMING RESPONSIBILITY FOR O&M

There were several factors that led to CVP contractors assuming responsibility for O&M of the regional CVP facilities that served them. Reliability, costs, inefficient federal budgeting and funding mechanisms and the perceived deterioration of a 50 year-old facility. These issues coupled with a federal administration with a tendency toward downsizing and privatization provided more than ample motivation for the change.

Reliability

Agriculture in the San Joaquin Valley is entirely reliant upon irrigation. Rainfall within the Water Authority region averages about 9 inches per year. Groundwater availability and quality is spotty. Water Authority members are almost entirely reliant on the supplies they receive through their CVP contract.

Water Authority members are served by CVP facilities that allow the project to store water in northern California and to move that water from northern California through the Sacramento/San Joaquin River Delta (The Delta) by the TPP for use within the Water Authority area. The Delta is a sensitive region for fisheries, wildlife habitat and water quality. CVP operations have been altered and the Delta became a bottleneck in the movement of CVP water from northern California reservoirs to regions south of The Delta. This bottleneck is the result of reduced windows of opportunity for pumping at the TPP.

The windows of opportunities for pumping at the TPP have narrowed. When those opportunities present themselves, there can’t be any downtime. Facilities must be in a reliable condition and must be ready for immediate operation. Proper O&M is essential to assure that the facilities can be relied upon when needed. The water users that rely on their supplies from these facilities have a lot at stake since interruptions in operations reduce their supplies. Curtailed pumping at the TPP has a direct affect on water supplies within the Authority.

CVP contractors are highly motivated to make sure that the O&M of the CVP facilities are done in such a way that the facilities are operationally reliable.

Cost Containment / Budgets / Rate Control

Cost, Budget Controls. As discussed above, all USBR expenditures for O&M of CVP facilities are passed on to CVP water users & contractors through an O&M

component in their water rates. Opportunities for water user input to budgets were minimal. Budgets and expenditure priorities didn't necessarily reflect the needs of the facilities.

CVP contractors are highly motivated to make sure that the O&M of the CVP is done in a cost-effective manner.

Rate Control Flexibility. CVP O&M costs are allocated annually and are collected through water deliveries to contractors. Annual water allocations are volatile, therefore costs/acre foot are volatile as well. Water user control over budgets can provide the flexibility to implement long term O&M projects during higher allocation year types, and forego those projects in lower allocation years. This is a helpful tool for rate stabilization and an example of one of the many opportunities for the Authority to better structure the O&M and O&M financing to meet a broad array of objectives.

Funding

The USBR is reliant for all of its funding through the United States Congress appropriations legislative process. This includes those funds needed for the O&M of the CVP facilities. Congressional Appropriations are traditionally political and inconsistent. Levels of funding, activities funded and priorities of appropriations don't always reflect what's needed in the field. Furthermore, CVP water user/contractor payments to USBR for the O&M of the CVP go directly to the general federal treasury. This, in affect delinks the federal appropriations process with the payments and payers of the projects.

Federal Work Force Reduction Program.

In the mid 1980's, President Reagon established a directive (A95) which mandated the federal Office of Management and Budget (OMB) to administrate an evaluation by all federal agencies. These evaluations were to determine if work could be done more efficiently and cost effective by either contracting for those services to private or more localized governmental agencies. This approach was a part of a broader "less government is better" principle held by President Reagon.

In the late 1980's, the CVP Mid Pacific Region's Regional Director David Houston embraced this principle and initiated discussions with CVP contractors to take over the O & M of the CVP.

The timing was right. Federal Directive A95 complimented CVP water user interests to assume more responsibility over the O&M and the O&M funding of the CVP.

SAN LUIS & DELTA-MENDOTA WATER AUTHORITY

Formation

As outlined above, there were a lot of reasons and incentives for the CVP water users and contractors to assume responsibility for the O&M of the CVP facilities that served them. The next hurdle was to develop an agency that had the authority to contract with the federal government to provide O&M services. It was decided that a Joint Powers Authority would be the best way for the CVP contracting agencies to organize for that purpose. Initial issues to be dealt with were classic organizational formation issues: Who has authority to make decisions on behalf of the agency, (governance issues); and who pays / how much, (cost allocation issues).

In addressing these formation issues the CVP contractors in the region were fortunate because they had already developed a relationship among themselves through an informal association, the San Luis & Delta-Mendota Water Users Association. This organization provided the forum to develop a formal regional governmental agency through a Joint Powers Authority.

The Parent Organization, San Luis & Delta-Mendota Water Users Association. The San Luis & Delta-Mendota Water Users Association (The Association) was formed in 1977 to provide an informal forum for water agencies which contracted with the CVP and received their water through the Tracy Pumping Plant (TPP) and Delta-Mendota Canal (DMC).

The Association Board of Directors met monthly at one of its member agencies office, the San Luis Water District in Los Banos, California. The San Luis Water District provided their general manager as Secretary–Treasurer and sole staff member of the Association. Bill (CW) Jones Sr., a farmer south of Firebaugh, California acted as Chairman of the Board the entire active life span of the Association, (1977-1992).

The Association provided a useful service to the region. Its monthly meetings were well attended and provided an opportunity for member agency board of directors and managers to compare notes on the operations of their agencies as well as regional water right and water policy issues. It also held larger forums for its membership board of directors and farmers. This forum was used to update the broader community on current issues.

The Association provided a great platform from which the Water Authority was formed. The Association created a Formation Committee that took the lead in the formation of the Water Authority. Formation activities included the development of the Joint Powers Authority Agreement, negotiations with USBR for assuming O&M responsibility for the CVP facilities s. of the delta, the initiation of discussions with USBR employees currently employed by USBR, executive director hiring, etc.

Joint Powers Authority. Under California's Government Code, two or more governmental agencies are authorized to join together to form a separate and distinct organization to carry out defined common interests.

A Joint Powers Authority has proven to be a very functional organizational tool for a group of governmental agencies with common interests and projects. It also provides for subgroups of member agencies (Activity Agreements) under the umbrella of the overall Authority. This provides for flexibility in participation and cost allocation based on need and benefits.

Governance. "Who is authorized to make decisions on behalf of the organization", and "how are those decisions going to be made", are fundamental questions when developing a new organization. The challenge for the Water Authority was to develop a governance structure that would provide for adequate representation of all of the 32 member agencies, but yet be functional. This was accomplished through the development of 5 divisions within the Authority for the purposes of electing a Board of Directors.

The Authority developed a 19 member Board of Directors. Four divisions were delegated four board directors each, and the fifth division was delegated three.

A simple majority of the Board constitutes a quorum. Endorsement or support for legislation and participation in any lawsuit requires an 85% vote of the directors present. All other actions including O&M actions require a simple majority of the directors present.

Committees. The Water Authority addresses a broad scope of issues and represents a variety of water uses over a large geographic area. A committee structure was developed to allow opportunities for board members to focus on specific issues in detail and allowed for a broader delegation of responsibilities. The three core policy committees that were established are the Water Resource Committee, the Financial & Administration Committee and the O&M Committee. The O&M Committee has been established to oversee O&M budgeting, develop long term O&M strategies, and in general work with staff to develop the O&M program for the Water Authority. The O&M Committee allows members the opportunity to direct O&M activities.

Several committees have also been developed to oversee specific projects or activities. A good example of this is the Grassland Basin Steering Committee that oversees efforts by a subgroup of Water Authority members to address their agricultural drainage issues.

Although the board of directors maintains the ultimate authority and all of the formal actions of the Water Authority are funneled through the board, it relies heavily upon the work and recommendations of the committees.

The committee process has worked well for the Water Authority. It has provided broad representation and participation by the member agencies. It also provides an opportunity to maximize the use and share the expertise of member agencies and staff.

Cost Allocation. Another key formation issue was "Who pays/how much" (Cost Allocation Issues). The Board adopted the simple guiding principle that costs should follow benefits, and that water users should not have to pay for services that don't benefit them.

The O&M services provided by the Water Authority are recovered through a charge on water delivered to each member agency. These costs are broken down by region so water users generally only pay for the O&M of facilities that they use. Water right and water policy representation activities are normally recovered through annual dues based on the prorated water supply contract amounts.

Given that the Water Authority works on a wide variety of issues and delivers water to a diverse and broad area, linking costs to benefits is an administrative challenge. The Water Authority currently administrates about 15 separate funds with different member participants and cost allocations. Although complicated, once formatted the cost allocation accounting isn't overly burdensome to administrate and is considered fair and worthwhile by the membership.

OPERATIONS AND MAINTENANCE TRANSITION

The transfer of O&M of CVP federal facilities south of the delta to the Water Authority was a major undertaking. Issues included: establishing the relationship between the USBR, the owner of the facilities, and the Authority; developing a work force; developing O&M plans, both short and long term; acquiring equipment and supplies; development of an array of guiding principles/policies to guide the transition.

Phasing

It became evident that given the complexities and up front costs of the transfer of O&M responsibilities that a phased approach would allow for a smoother transition. The Delta-Mendota Canal was targeted for the first phase. The second phase was scheduled for one year later and included the addition of the Tracy Pumping Plant, O'Neill Pumping/Generating Plant, Tracy O&M facilities, and the San Luis Drain. The Delta Cross Channel Facilities, Mendota Pool and Kesterson Reservoir O&M were also transferred in subsequent years.

In retrospect, the phasing of the transfer of O&M responsibilities was important to the overall success of the transition. It allowed the Water Authority the opportunity to ease into its new role and provided the opportunity for a gradual and smoother expansion of work force and equipment.

Contracts / Agreements With USBR

Cooperative Agreement. The initial relationship between the Water Authority and USBR was a Cooperative Agreement. The purpose of this agreement was to provide the personnel, materials, supplies and equipment necessary to properly operate, maintain and repair specific CVP facilities. A cooperative agreement is in effect a contract between the USBR and the Water Authority to provide O&M services.

The funding for this contract came from federal appropriations to the USBR. The USBR paid the Water Authority to provide the O&M services. USBR then charged the CVP contractors/water users for this O&M expenditure as a component of its water rate.

Transfer Agreement. After several years of operating under a cooperative agreement, the Water Authority entered into a Transfer Agreement with USBR wherein all O&M costs related to the transferred facilities were funded directly by the contractors/water users themselves.

Through the Transfer Agreement, the Water Authority develops the O&M budget, forecasts deliveries and develops a water rate for delivered water. This rate is collected from the member agencies through an O&M charge per acre foot on actual water deliveries. The Transfer Agreement therefore removes the reliance on the Congressional appropriations process and gives the Authority more direct control over funding, budgets and cost allocation.

Work Force

The Authority adopted a few guiding principles to assist it in developing a work force. 1) Target key USBR employees in key positions and encourage them to continue their position with the Authority. Keep them well informed of transition activities and include them in decision making; 2) Offer first right of refusal for USBR employees qualified for positions offered by the Authority; 3) Establish good open relationship with employees and potential employees throughout the recruitment process. Keep them well informed of transition process and recruitment activities; 4) Gradually build out the work force, error on the side of a minimal work force. Expansion of the work force can be done as the need is determined and is easier than reducing the work force. If needed, some work can be contracted out temporarily to fill any gaps, as you determine the needs for the work force.

Equipment Acquisition

Providing the necessary equipment and tools to enable the work force to be able to carry out their jobs is critical and an expensive up front cost. The Authority had good cooperation from the USBR and was able to obtain from them some vital surplus equipment & supplies. Notwithstanding, the Authority was faced with acquiring most of its needed equipment & supplies. Initially, equipment was either funded over a short period of time (5 – 10 years) or was leased. Annual debt service was folded into the O&M budgets. The Authority's approach was to gradually build out its equipment and supplies. The phasing in of the transfer of facilities complimented this approach. Once the equipment and supplies were established, a long term replacement program was established with an equipment and supplies revolving fund.

Organization Policy Development

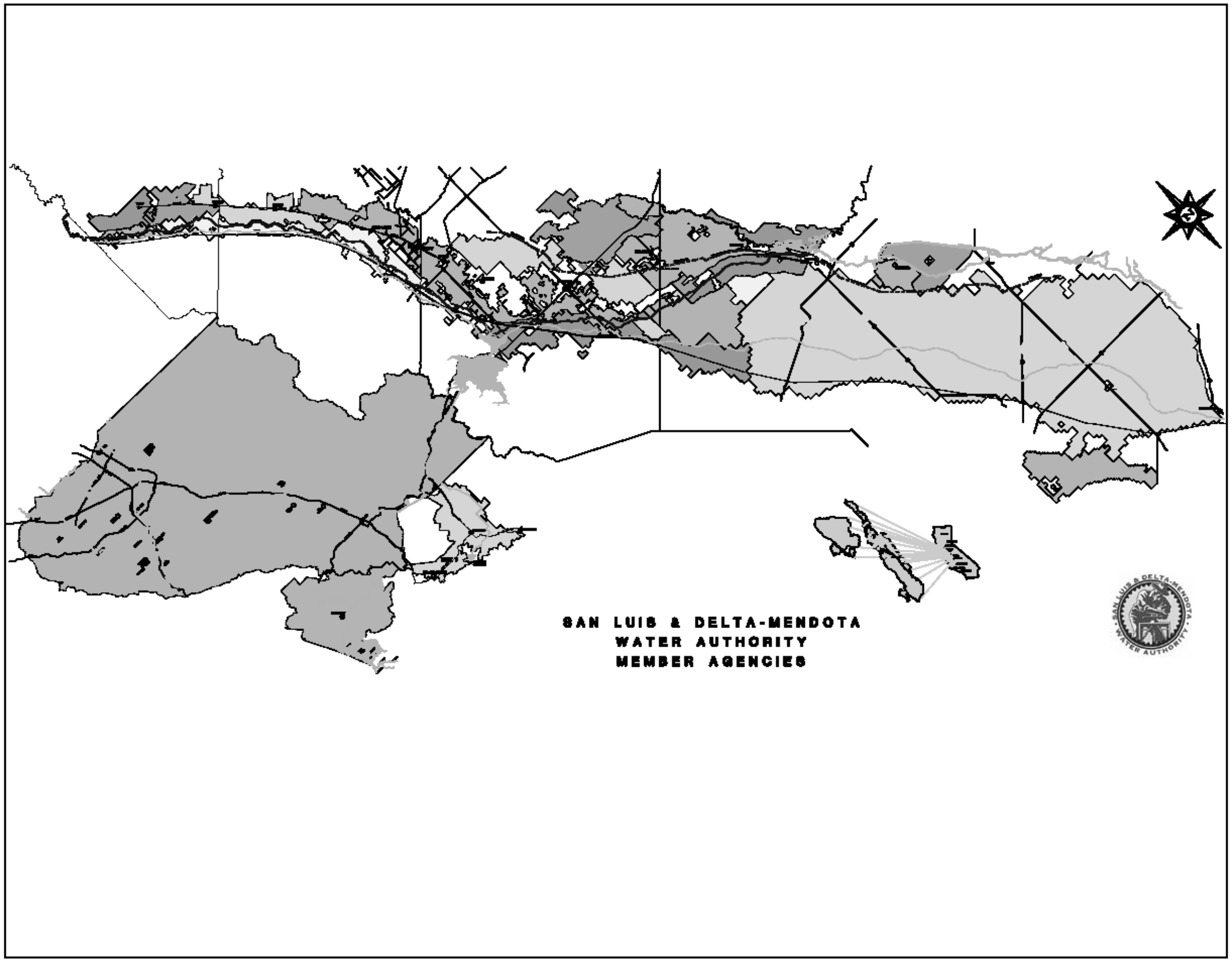
Organizational policies assist in defining and clarifying organizational goals and processes for achieving those goals. Some of the policies can be developed as needed while for others it was important to establish as early as possible.

Work Force Policies. It was critical to establish policies regarding the work force immediately. Policies such as salary level, salary adjustment process, labor relations, health and retirement benefits, vacation and sick leave, and overall structure of the work force such as organizational charts, all needed to be established prior to being able to recruit a work force.

Cost Allocation Policies. An important role of California water agencies is to allocate costs for the services it provides appropriately and fairly. This can be done with broad discretion by the agency. It is important that the process to develop a cost allocation policy is open, is supported by its members and is considered equitable.

CONCLUSION

The Water Authority has been operating and maintaining all CVP facilities south of the delta for over 12 years. There is a consensus that the condition and reliability of the facilities has improved. There is also a consensus that the facilities are being operated and maintained in a more cost-effective manner. CVP water users / contractors south of the delta continue to support their expanded role. The USBR continues to be supportive of the changes as well and acknowledges the benefits to the federal government.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WATER AUTHORITY
MEMBER AGENCIES

WUA DEVELOPMENT AND STRENGTHENING IN THE KYRGYZ REPUBLIC

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ABSTRACT

Under the On-Farm Irrigation Project (OIP), the Department of Water Resources (DWR) of the Kyrgyz Republic is to rehabilitate tertiary irrigation infrastructure. Rehabilitation on infrastructure serving 50,000 ha is underway; infrastructure serving 160,000 ha is to be rehabilitated over the six-year life of the project. To replace the role of irrigation brigades on former state farms, the Government has promoted establishment of Water User Associations (WUAs) to take over on-farm irrigation O&M. Initially, WUAs were formed under a Presidential Decree but with project assistance, in 2002 the Republic passed a WUA Law that superseded the decree. Under the law 350 WUAs have been registered. As part of OIP, WUA Support Units at the central (1), provincial (7) and district (26) level have been formed to develop and strengthen WUAs. During the first three years of the project, these units have provided training to almost 11,000 trainees as well as assisting with WUA re-registration under the new law. Although still too low, fees paid by members to cover WUA O&M and administration as well as pay the DWR for water supplied have increased in every province since 2000. A resolution just passed by the Government now gives WUAs legal ownership of their on-farm irrigation infrastructure.

INTRODUCTION

After the breakup of the Soviet Union the economy of the Kyrgyz Republic went into a serious decline. As a result irrigation systems suffered from poor or no maintenance due to lack of financial resources. When the state and collective farms were disbanded, and land was distributed to individual growers, farms immediately faced a problem with on-farm irrigation[3] O&M. Without farm brigades there was no internal organization responsible for taking water from the farm head gate and delivering it to fields of thousands and thousands of small farmers. As a result of the decline in irrigation service, there was a significant decline in agricultural output in the first half of the 1990s.

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[3] On-farm irrigation is defined as the irrigation distribution system within the boundaries of the former state and collective farms.

Given that the majority of the population lives in the rural area, the Government has placed high priority on growth in the agricultural sector. Progress has been made in implementing agricultural reform such as price deregulation, trade liberalization, land reform, and privatization of agro-industrial enterprises. However, in order to ensure increased agricultural production the Government recognized it must address problems in the irrigation sub-sector.

With a lack of public funding the Government decided that the only way to sustain the irrigation infrastructure was for users of irrigation water to pay for water delivery services. As a result of the irrigation service fee introduced in 1995, water users are now contributing directly to the operational budget of the DWR. More importantly, the Government instituted a new policy to encourage the formation of WUAs to take responsibility for on-farm irrigation O&M, including collecting irrigation service fees for payment to the DWR. This included the passing of a strong WUA Law in 2002 as well as a recent resolution transferring ownership of on-farm infrastructure to WUAs.

WATER AND IRRIGATION IN THE KYRGYZ REPUBLIC

The Kyrgyz Republic is a landlocked country, surrounded by Kazakhstan, Uzbekistan, Tajikistan and China (see Figure 1). The Republic covers a total area of approximately 200,000 km^2, although mountains occupy more than 70% of the territory. The climate is continental with cold winters and hot dry summers. The frost-free season in the south is 8 months while the frost-free season in the mountainous provinces is less than 5 months. Annual precipitation in the north of the Republic fluctuates from 200 to 600 mm and in the south from 350 to 700 mm. During the potential growing season the mean precipitation in the south is around 170 mm while the mean reference crop ET during the same period is approximately 900 mm. Consequently, irrigation is critical for sustained agricultural production.

Dominated by high mountains, the majority of water resources in the Kyrgyz Republic originate from snow and glacier melt. Average annual runoff in the country is 47.4 billion m^3. Although, under international agreements the Republic can only use a maximum of 12 billion m^3, with the reminder flowing to neighboring states, especially the cotton producing countries of Uzbekistan and Turkmenistan. About 90% of this water is used for agriculture, 7% for industry, and 3% for other needs including municipal water supplies.

Figure 1. Map of the Kyrgyz Republic

<u>Irrigation Development</u>

Irrigation development, especially in the Ferghana Valley in the south, can be traced to primitive intake structures and canals developed by earliest inhabitants. In 1922 the area served by irrigation in the Kyrgyz Republic was 180,000 ha. This increased to 300,000 ha by the end of World War I and 530,000 ha in 1935. Just before World War II the irrigated area was approximately 740,000 ha. By 1990, prior to the collapse of the Soviet Union, there were 1.07 million ha of irrigated land, or 80% of the arable land in the country.

This included a total of 631 irrigation systems, which varied from less than 100 to 50,000 ha in size. Of these systems 373 were government-owned and served approximately 765,000 ha. Another 156 systems under 100 ha and 102 systems over 100 ha had independent intake structures, often owned by former state and collective farms. The Government controls intake structures that serve main and inter-farm canals under the responsibility of the DWR while the other 258 systems have intakes managed by the users (Asian Development Bank, 1997).

Water used for irrigation over the period 1985-1992 averaged 10.5 billion m^3. However, after the breakup of the Soviet Union, and the financial crisis in the Kyrgyz Republic, water delivered to irrigation declined significantly. As a result of deterioration in the irrigation infrastructure and a reduction in area under cultivation, as well as farmers reducing their costs for irrigation water by reducing the quantity used, only 8.19 billion m^3 was delivered in 1995. This was further reduced to 7.19 billion m^3 by 2001, 6.5 billion m^3 in 2002, and 5.93 billion m^3 in 2003, although the last two years were relatively wet which partially explains the lower intake values.

Reservoirs and irrigation infrastructure that provided water for irrigated land within a province, but across more than one district, were the responsibility of the Provincial DWR (P-DWR), with all O&M costs paid for with state funds. Within a district all O&M of the main and secondary canals was also paid by the state budget through the District DWR (D-DWR) offices (Kostiuk, 1999). Although it is estimated that at least $11.5 million are required to operate the off-farm system under the management of the DWR, the budget for 1998 was only $7 million and for 1999 had declined to $3.2 million. The drastic decline in DWR budget means that the additional funds (in excess of $1 million) paid by WUAs for irrigation service fees are very important for O&M of the off-farm system.

During the Soviet period, tertiary irrigation networks belonged to former state and collective farms. D-DWRs were only responsible for providing water to the head gate of the state and collective farms. From this point on irrigation was the responsibility of state and collective farm irrigation brigades as they were expected to operate, maintain and repair the system using their own resources. With slightly more than 1 million irrigated ha, at the time of the breakup the average on-farm irrigation system was just less than 2,000 ha (Johnson III, Stoutjesdijk and Djailobayev, 2002).

AGRICULTURAL AND IRRIGATION REFORM

Following independence in August 1991 the Kyrgyz Republic was one of the first of the Central Asian Republics to opt for a market economy and adopt measures to privatize agriculture, including a comprehensive land reform program. Former state and collective farms were liquidated and the land and other assets were divided among the previous tenants. The amount of land allocated to each individual depended upon the number of people living in the village, the size of the farm and the years of experience of the farm workers. Throughout the Republic land holdings vary from 1 ha/person to 0.1 ha/person, with the smallest holdings being in the more densely populated Ferghana Valley in the south.

Ownership of the on-farm irrigation infrastructure on the former state farms was previously property of the state, while irrigation facilities on collective farms were owned by the members of the collective. The collapse of the USSR, and ensuing financial chaos, resulted in a lack of public funds to maintain the off-farm system while the breakup of the state and collective farms created a situation where no organization was clearly responsible for operating and maintaining the on-farm system. In 1995 the Government instituted an irrigation service fee (ISF) to be paid by the users to the water supplier (usually the D-DWR) with all funds to be used to cover costs of irrigation service to the farm head gate. The level of the fee is established by the Parliament and is a political decision rather than an economic one. This fee was increased by Parliament to 30 Kyrgyz Som (KS) per 1,000 m^3 in 1999 and it is still at that same level even though by legislation irrigation tariffs should be reviewed annually. Based on the exchange rate for April 2004 (43 KS =

US$1.00), the ISF is approximately 70 US cents per 1,000 m^3 of water. DWR continues to push for an increase in the ISF to at least 60 KS per 1,000 m^3 to reflect a more realistic cost of delivery, but that has been resisted by Parliament.

A decree on the establishment of WUAs was signed by the Prime Minister on August 13, 1997 (Presidential Decree, 1997). This resolution allows for the legal establishment of WUAs and stipulates the procedures for creating WUAs, their membership, activities, rights and duties, etc. Based on this resolution, on-farm irrigation infrastructure could be transferred to legally established WUAs. Yet, with no previous experience in independent participatory farmer organizations, the on-farm system irrigation users were uncertain how to form and operate a sustainable WUA.

IRRIGATION REHABILITATION

Recognizing the critical need to rehabilitate the off-farm irrigation systems as well as major storage and diversion works, in 1997 the Government requested financial assistance from the World Bank to address the immediate problems in the off-farm system. As a result the Irrigation Rehabilitation Project (IRP) was designed to provide low-cost rehabilitation of off-farm irrigation infrastructure in order to ensure irrigation systems can supply adequate quantities of irrigation water to the head gates of the on-farm irrigation systems. This $46.8 million ($35 million from IDA) project was initiated in mid-1998 and will, by the end of 2005, eventually rehabilitate off-farm irrigation infrastructure serving about 270,000 ha as well as four dams commanding over 400,000 ha.

On-Farm Irrigation Project (OIP)

When completed IRP will ensure a more dependable supply of water. However, it is equally important to rehabilitate on-farm irrigation infrastructure in order to ensure that the water can be used more efficiently on the agricultural land to improve production. Yet, this rehabilitation is only justified if there is a management system responsible for on-farm water distribution and deliveries and the maintenance of the system under the management of WUAs. In order to achieve this, the Government has recognized the importance of developing and strengthening WUAs as the central organization responsible for on-farm O&M. Given the need to form in excess of 500 WUAs in the Kyrgz Republic, the ability to train and strengthen WUAs is not just a short-term project activity but instead is a permanent requirement if effective WUAs are to be a part of a sustainable irrigation delivery system.

The OIP, effective since December 2000, is a $29 million project ($20 million from IDA) with two main components: (1) rehabilitation of on-farm irrigation infrastructure serving a minimum of 160,000 ha; and (2) development and strengthening of the associated WUAs to ensure the on-farm system is operated properly and maintained (World Bank, 2000). In order to ensure WUAs accept responsibility for the on-farm irrigation system they are expected to repay 25% of the rehabilitation costs, spread over 7 years with interest not to exceed inflation as well as a four year grace period. In addition to collecting service fees from their members to cover the costs of O&M of the on-farm irrigation infrastructure and the WUAs share of repayment for rehabilitation, WUAs are expected to collect the ISF that is to be paid to the water service provider.

Since it is unlikely that all WUAs will mature at the same rate, it was recognized that the project would have to work with more than 160 WUAs to ensure that at least 80 WUAs (responsible for 160,000 ha) are ready for rehabilitation activities.

WUA Support Units

There will continue to be a need to form and sustain additional WUAs in the Kyrgyz Republic after OIP is completed. In order to establish the institutional capability to develop and register in excess of 500 WUAs, as well as to ensure that the Government has the long-term technical capacity to support these WUAs, the project was designed to form WUA Support Units (WSUs) in the central office of DWR (C-WSU) and all seven Provincial Water Resources Departments (P-WSUs) as well as 17 District Water Resources Departments (D-WSUs) that serve the project area. In 2002, reflecting the success of WSU activities the Government decided to increase to 26 D-WSUs. At the request of the Government the project plans to further increase to 34 D-WSUs.

C-WSU. Since 2001 the C-WSU has been operational and is staffed with a WUA Specialist, an Engineer, a Training Specialist, a Lawyer and an Economist-Financial Management Specialist. In addition, international consultants have provided technical assistance with the formation and strengthening of this unit. Under OIP the C-WSU has responsibility to ensure sustainable WUAs are created and strengthened. More importantly, it is the responsibility of the C-WSU to develop institutional capacity within the DWR in order to form additional WUAs as required as well as support the existing WUAs. Staff members have developed training materials needed to strengthen the WUAs and, working with local trainers, established courses needed to strengthen WUAs.

P-WSUs. Seven P-WSUs have been established to provide strong political and technical support within Provincial DWR offices. P-WSUs are working to develop a strategy for WUA development as well as a program for helping WUAs to determine their system improvement requirements. These units are also responsible for formulating a long-term program to strengthen WUAs and are working with the C-WSU as well as the D-WSUs to ensure sustainable WUAs. Each P-WSU has a small team comprised of a WUA Support Specialist, Water Management Specialist, and an Engineer.

D-WSUs. D-DWRs have become bulk sellers of water and drainage services with the WUAs as their primary clients. With this type of relationship it is very important that D-DWRs have the technical and institutional ability to support their WUAs to ensure they are viable customers. Therefore, with support from OIP, D-DWRs in the project have established 26 D-WSUs to provide assistance with the formation of WUAs, including helping them become legally registered under the new WUA Law. D-WSUs have a support team with the same technical composition as the P-WSUs. D-WSUs schedule training courses so that WUA staff gain skills needed to properly operate and maintain their irrigation system. Technical capabilities of D-WSUs' staff members and their ability to transfer those technical skills to WUAs are critical to long-term sustainability of WUAs.

WATER USER ASSOCIATIONS

Soon after the state and collective farms were dissolved the fact that there was no organization responsible for on-farm irrigation became obvious to the farmers. In some locations spontaneous unions of water users called hydro-services were formed. In other locations unofficial WUAs were formed to try to solve the problems farmers faced with on-farm irrigation O&M. Most of these WUAs were formed without any technical assistance and had no real idea how a participatory farmer organization actually functioned. As a result many of the associations simply selected the former chairman of the state or collective farm as Chairman of the WUA and he managed the WUA in the same manner in which he had managed the state or collective farm before.

Over time WUAs recognized problems associated with this Chairman-dominated approach. Consequently, WUAs have responded to guidance from D-WSUs to help WUAs reorganize (and reregister) under the new WUA Law to a more participatory WUA model. The speed with which WUAs have been formed and registered under the law in the Kyrgyz Republic, is illustrated in Table 1.

Table 1. Trend of WUA Establishment, 1999-2003

Province	**Registered 1999**	**Registered 2000**	**Registered 2001**	**Registered Dec 2002**	**Registered Dec 2003**
Osh	26	26	26	46	63
Batken	16	16	17	21	23
Jalal-A.	11	18	27	41	50
Talas	5	13	30	47	52
Issyk-K.	7	10	11	21	28
Naryn	1	3	5	20	42
Chui	9	24	53	68	79
Totals	75	115	169	264	337

Source: Field data collected by OIP staff

Given the difficulties faced by other Central Asian Republics, the speed of formation of WUAs in the Kyrgyz Republic is a positive sign as it clearly indicates farmers have recognized the need for farm-level water users associations.

Table 2 illustrates that already 60% of the total irrigated land in the country is served by WUAs with over 70% of the irrigated area having assistance provided through WSUs. Now the important task is for the WSUs to help these WUAs become financially viable associations that can provide reliable irrigation O&M for their members.

Table 2. Number Registered WUAs and Service Area (ha)

Province	No. of Districts	No. of WUAs	Reg. WUAs	Re-Reg. WUA	District Irrig. Area (ha)	WUA Irrig. Area (ha)	WSU Area (ha)
Batken	4	24	23	21	57,489	41,339	40,454
Jalal-Abad	8	53	50	45	127,933	81,147	90,933
Issyk-Kul	5	31	28	25	163,398	59,243	99,176
Naryn	5	44	42	38	120,241	58,886	76,982
Osh	6	64	63	60	134,393	91,405	112,913
Talas	4	54	52	41	114,900	89,468	56,656
Chui	8	80	79	70	328,875	182,580	253,122
TOTAL	**40**	**350**	**337**	**325**	**1,047,229**	**604,063**	**730,236**

WUA Training

Given that farmers in the Kyrgyz Republic have not had previous experience with participatory farmer associations, training is a critical factor. Working with international consultants and staff from the C-WSU, training courses have been organized for P-WSUs and D-WSUs. In turn, all of the WSUs have taken the responsibility for organizing and conducting training courses for WUAs. To date training has been provided for approximately 11,000 trainees (see Table 3). Success of the WUA development program is directly related to OIP training activities.

Table 3. C-WSU, DWR, P-WSU and D-WSU Staff trained 2001-2003

Level	Staff	Plan (2001)	Done (2001)	Plan (2002)	Done (2002)	Plan (2003)	Done (2003)
DWR	PIU-DWR			4			
Provinces	P-WSUs		266		100	63	119
Districts	D-WSUs			633	569	1,013	710
WUAs	WUA				4,052	9,086	10,126
TOTAL			266	637	4,726	10,162	10,955

Training materials for six core courses have been developed and regularly refined. These courses include: (i) WUA formation and development; (ii) general administration and financial management; (iii) monitoring and evaluation (M&E); (iv) engineering; (v) legal aspects; and (vi) water management. Courses on training methods, and environmental management have also been developed during the past year. For 2004 the C-WSU has organized a training course along with the Kyrgyz Association of Accountants for WUA bookkeepers. The project has also developed two excellent training videos along with a large supply of handouts and training materials.

WUA MILESTONES AND SERVICE FEES

Under OIP a system of milestones were created to determine the progress WUAs were making toward sustainability. As WUAs were established and strengthened they were able to attain higher milestones. Only WUAs that reached the upper milestones were considered to be strong enough to take responsibility for their rehabilitated on-farm infrastructure.

In addition, one of the most critical indicators of WUA performance and sustainability is its ability to establish and collect an irrigation service fee that will cover all the necessary O&M costs, administrative costs and pay the required water service fees to the DWR.

Milestones for WUA Performance

Donor-supported irrigation projects often simply create paper WUAs in order to justify disbursement of rehabilitation funds. However, under OIP as a majority of members of WUAs have to sign an agreement to repay their 25% percent of the rehabilitation costs, WUAs must be actually formed and functioning. In order to ensure WUAs are more than paper entities, credits for rehabilitation will only be granted when they have passed a series of milestones. These include:

- **Milestone 1:** WUA establishment, including legal registration and bank account opened.
- **Milestone 2:** Recruitment of WUA staff and necessary training.
- **Milestone 3:** WUA Board has prepared a plan of O&M and the general assembly has approved this plan—this includes setting a sustainable fee to cover O&M and ISF costs.
- **Milestone 4:** WUA members have paid O&M costs and ISF payment to water supplier.
- **Milestone 5:** WUA and DWR have developed alternatives for rehabilitation and determined their costs with WUA members involved in these discussions.
- **Milestone 6:** WUA members have selected an alternative for rehabilitation.

- **Milestone 7:** A majority of water users in the WUA have agreed to borrow the credit for rehabilitation and to repayment under OIP terms and the WUA Board officially requests the credit and signs for repayment.

It has been demonstrated in the Kyrgyz Republic that WUAs can accomplish all milestones within a year. Obviously, some WUAs take longer and therefore under OIP the plan was to work with a larger set of WUAs (approximately 160) than was required to actually rehabilitate the 160,000 ha of on-farm irrigation area. As can be seen in Tables 1 and 2 the project has already exceeded 160 WUAs. Given such a large number of WUAs, milestones have proven a good way to track WUA performance. Table 4 shows the status of WUAs in the country with respect to reaching milestones as of 1 April 2004.

Table 4. Number of WUAs at Different Milestones-By Province

Mile-Stone	**Batken**	**Chui**	**Issyk-Kul**	**Jalal-Abad**	**Osh**	**Naryn**	**Talas**	**Total**
0	1	6	0	4	0	2	0	13
1	2	9	7	6	9	8	13	54
2	0	6	6	24	11	13	0	60
3	1	36	1	1	15	5	0	60
4	10	18	10	6	18	9	33	104
5	6	3	0	1	1	1	3	14
6	0	0	1	1	1	0	0	3
7	3	5	5	9	8	5	5	40
Total	23	77	31	52	63	43	54	344

Qualification for rehabilitation is first come-first served although there is some pressure to ensure funds will be spread around the seven provinces. As can be seen already there are more than enough qualified WUAs to utilize all the OIP rehabilitation funds. In fact, the project is already in the process of working with around 60 WUAs for rehabilitation and the project will identify the remaining WUAs for rehabilitation during 2004.

WUA Irrigation Service Fees

As can be seen in Table 5 irrigation service fees have been increasing in all the provinces, but are still too low to ensure sustainability. One of the main tasks of WUA leaders and P-WSUs and D-WSUs is to persuade WUA members that they need to increase their irrigation service fees. Of these fees, a percentage has to go to the D-DWR to pay for water services delivered to the WUA while the remainder of fees collected is used for O&M.

Table 5. Irrigation Fee Changes-2000, 2001, 2002, 2003 ($/1,000m^3)

Province	2000	2001	2002	2003
	($/1000m^3)	**($/1000m^3)**	**($/1000m^3)**	**($/1000m^3)**
Osh	.70	.86	.90	.97
Jalal-Abad	.86	.87	.87	.94
Naryn		.22	.26	.27
Talas		.77	.78	.80
Batken		.53	.60	.73
Isyk-kul		.48	.54	.86
Chui		.86	.90	1.03
AVERAGE	NA	.66	.70	.80

KS 43 = US$1.00

Table 6 illustrates the approved 2004 WUA budgets for O&M and repair costs by province.

Table 6. Planned WUA Budgets for O&M and Repairs-2004

No.	Province	Area Irrig	WUA Budget (US$)		O&M and Repairs (US$)		
		(ha)	Total	Per ha	O&M	Repairs	Repairs per ha
1	Osh	91,274	239,998	2.63	187,979	52,018	0.57
2	Jalal-Abad	79,437	213,798	2.69	137,228	76,570	0.96
3	Naryn	58,886	77,527	1.32	56,957	20,594	0.35
4	Talas	88,677	110,827	1.25	81,585	29,242	0.33
5	Batken	41,339	115,010	2.78	98,160	16,850	0.41
6	Isyk-kul	60,903	80,173	1.32	60,904	19,269	0.32
7	Chui	193,279	279,107	1.44	234,300	44,807	0.23
	TOTAL	613,795	1,116,439	1.82	857,090	259,349	0.42

Source: Data collected by District WSUs. KS 43 = $1.00

Osh, Jalal-Abad and Batken are planning on collecting around $3/ha for WUA O&M and repairs while the remaining provinces are collecting about half this amount. Over the next few years P-WSUs and D-WSUs need to work closely with WUA leaders to educate them on the need to provide sufficient resources to sustainably maintain and operate the irrigation infrastructure. This means that irrigation fees need to be about three times what they are at present in Osh, Jalal-Abad and Batken and around six times what they are in the other provinces.

An associated problem along with low payment is the tendency for members to pay in kind. This costs both WUAs and D-DWRs and is a continuing source of financial difficulty. Working with D-WSUs and WUA leaders, P-WSUs need to start a program for gradually weaning WUAs away from payment in kind. In fact, D-DWRs have already issued a memo instructing WUAs to pay at least 70% of their irrigation service fees in cash.

WUA Debts to DWR

When the project started former collective and state farms as well as WUAs had very large debts to the DWR for irrigation service. This was a serious burden on D-DWRs as a significant percentage of their budget was to come from irrigation service fees. A sign of improvements in the situation, as well as a reflection in the maturation of WUAs, is the reduction in debts owed to D-DWRs. In January 1998, when OIP was being designed, debts to the D-DWRs were around $1.55 million. In contrast debts owed to D-DWRs by the WUAs in January 2004 are $0.54 million. Thus, over the life of the project to date not only have WUAs increased the percentage of payments to D-DWRs, they have also paid off more than 60% of their debt to D-DWRs.

OIP INFRASTRUCTURE REHABILITATION

Despite the slow start to rehabilitation activities, considerable progress has been accomplished during the past year and useful experience gained from initial rehabilitation contracts. A total of 80 WUAs have now been identified serving an irrigated area of about 155,000 ha, or 97 percent of the project target. Table 7 details the status of rehabilitation work under the project. One sub-project has been completed, 23 are under construction, and another 24 sub-projects are contracted. D-WSUs are working with another 20 WUAs that are moving into the rehabilitation phase.

Table 7. OIP Rehabilitation Status

Status	No. Sub-Proj's	Irrigated Area (ha)	Costs ($ '000)	Cost Increase	Cost/ha ($/ha)	Percent Complete
Complete	1	3,268	83	37%	25	100%
On-going	23	47,303	5,309	10%	112	35%
Design						
-complete	13	24,160	1,897			
-ongoing	23	41,397				
Proposed	20	38,939				
TOTAL	80	155,067				

FUTURE ACTIVITIES

After some confusion about legal ownership of on-farm irrigation infrastructure, the Government has now passed a resolution that clearly gives ownership to WUAs. Over the next year it is important that all WUAs inventory and register their infrastructure with the State Agency on Registrations of Rights for

Immovable Property. With assistance from the World Bank and USAID, the Kyrgyz Republic is in the process of passing a national Water Code. Water contracts and water rights established under the Code will have an impact on the way WUAs operate. In addition, authority to establish irrigation service fees will be moved from Parliament to a transparent process between the water provider (DWR) and WUAs.

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VARIATIONS IN IRRIGATION DISTRICT VOTING AND ELECTION PROCEDURES

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ABSTRACT

Fair and clear voting and election procedures are necessary for an effective water users association, but these procedures have considerable variety. Voting may be limited to owners of irrigated land, or may also include tenants and sharecroppers. Decisions must be made on how voting privileges will be allocated for situations like multiple owners, corporations, municipalities, and lands held in trust. The weight given to each vote is another major consideration. "One person-one vote" is common. Or votes may be proportional to the amount of irrigated land owned or number of shares owned in the corporation. The "one person-one vote" method may lead to unfair domination by small landowners, which in the United States and similar countries may lead to domination by non-farmers. However, voting power in proportion to land owned or shares owned may lead to domination by a few powerful individuals. An example compromise system is irrigation district law in the State of Oregon, USA, which provides for one vote for up to 40 acres (16 hectares), two votes for 40 to 160 acres (16 to 65 hectares), and three votes for more than 160 acres (65 hectares). An example "blended" system generally uses acreage-based voting, but uses "one person-one vote" for "at-large" directors. Elections require procedures on notification, nomination of candidates, maintenance of voter registers, proxy voting, quorums, and conducting the election. Maintenance of secrecy is pretty much essential for effective elections. Where voting power varies with the amount of irrigated land owned or shares owned in the corporation, use of colored ballots representing different numbers of votes can be an effective method of maintaining secrecy.

INTRODUCTION

Reforming the election process within WUAs... is the single most effective way to substantially improve small-scale farmers' inclusion in the WUAs. (IWMI, 2004)

Fair and clear voting and election procedures are necessary for an effective water users association (WUA), but these procedures often have considerable variety. Some of this variety may be appropriate, based on local conditions, but some procedures are more effective than others. Those involved in writing legislation or bylaws for irrigation associations will have an interest in reading what others have used or proposed. The examples cover a range of types of organization, but should not be considered a random sample. Examples are listed by subject and

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source, sometimes with commentary. Some are direct quotes as indicated by quotation marks; some are paraphrased. Sources are described by organization name or government law, sometimes in association with the source author. Examples were selected to illustrate the variety and range of practices. A complete list of sources is in the References section.

QUALIFICATIONS FOR VOTING MEMBERSHIP

General

"Most bylaws restrict membership of the WUA to the registered land owners in the hydraulic unit, who are engaged on a full-time basis in farming". Some countries extend the right to tenants and sharecroppers. (World Bank, 2001)

Examples where membership is limited to landowners: East Bench, Folsom, Maricopa, Greenfields, and Kyrghyz (Hagan). But for Kyrghyz, model bylaws provide: “Holders of land-use rights who lease their land, may delegate their voting-rights to their tenants.”

Examples where membership can also include tenants or operators: Sidney, State of Maharashtra - India (World Bank, 2001), and Andhra Pradesh - India. (Lok Satta, 2000)

Voting may also be limited to those over 18 years of age, such as at Greenfields or as specified by State of Washington irrigation district law.
Two Leggins: “Shares may be voted by the guardian of an owner”.
Kyrghyz (Hagan): “Minor members will be represented in the General Assembly by their trustees who will exercise the voting rights in their name.”

Palo Verde: Voting membership is open to “Any person, firm or corporation owning any real property or improvements or any assessable interest in such”.

In the case of canal companies (corporations), voting membership is restricted to shareholders, such as at Big Ditch: “Every stockholder who is not delinquent... for assessments made against said stockholder’s stock is entitled to cast one vote for each share of stock”.

Non-voting memberships may be extended to representatives of associated organizations with an interest in the irrigation system, such as local communities, non-governmental organizations, supply or marketing organizations, or extension workers.

Multiple Owners

If there are co-owners on a particular parcel of land, a common requirement is that the co-owners must designate in writing one person who will vote for them at meetings.

Folsom bylaws, Section 1: "Only one (1) person of any number of such co-owners shall be a member of this Company. Such co-owners shall be required to designate in writing to the Company who shall represent them at Company meetings."

Greenfields: "A man and wife co-ownership must provide acknowledgment from both partners to cast a vote", or "a Designation of Voting Authority can be filed at the District to grant the voting privilege to one or the other." "Corporation - If all shareholders are not identified in the title of the corporation, a corporate resolution, or similar, must be presented which designates the voting agent." "Partnerships - If all partners are not identified in the title... an appropriate legal document... must be presented to illustrate all names of the partnership." "Trusts - Trustees, not beneficiaries, will have the voting privilege."

Two Leggins: Shares owned by another corporation "may be voted by such officer, agent or proxy as the bylaws of such corporation may prescribe, or, ... as the Board of Directors of such other corporation may determine." "Shares of its own stock belonging to the (Two Leggins) corporation ... shall not be voted."

Washington: "when land is held as community property, the accumulated votes may be divided equally between husband and wife." "An agent of an entity owning land in the district, duly authorized in writing, may vote on behalf of the entity by filing with the election officers his or her instrument of authority."

Salt River Project Agricultural Improvement and Power District: Land held in trust or partnership, or owned by corporations or municipalities, cannot be voted.

Voting Restriction to Those Who Have Paid Their Assessments

This restriction encourages payment of assessments.

Commonly, the general body consists of "all registered members who are current in the payment of their dues, as in Mexico, Nepal," and some Indian states. (World Bank, 2001).

Big Ditch: "Every stockholder who is not delinquent... for assessments made against said stockholder's stock is entitled to cast one vote for each share of stock".

Sidney: "Members not delinquent in the payment of membership fees and assessments shall be entitled to vote".

Kyrghyz (Hagan): "Only members which have paid their dues to the association, and not in arrears, are voting members and have the right to vote in the General Assembly." "The Secretary of the Association will circulate a list of members who are not entitled to exercise their voting rights, due to non-payment of dues one week before the scheduled meeting of the General Assembly. The defaulters listed may recover their voting rights if they pay their dues before the beginning of the General Assembly."

Bylaws proposed for the State of Karnataka, India: "If any Member becomes defaulting to the Society in any manner, such Member shall not be eligible to vote in the General Body Meeting". (Saciwaters, 2004.)

Weighting of Votes

Some examples of methods:

1. One vote per member: An advantage of this method is simplicity. A small landowner's vote is given the same weight as that of a large landowner, which may be an advantage or disadvantage. "Under most WUAs, each member of the WUA has one vote" (World Bank, 2001). This method may encourage small farmers to participate in the WUA. However, in the United States and similar countries, it may lead to domination by non-farmers.

2. One vote per share of stock owned. Shares are typically in proportion to the area of land owned in the service area. Most canal companies use this method.

3. One vote per acre, or one vote per 40 acres. This method is most common on irrigation districts. Voting power is thus proportional to the amount of irrigated land owned on the system. In the United States, "weighted voting, either by acres or shares of stock, is generally favored. According to irrigation enterprise representatives, this is because weighted voting better reflects the cost borne by individual water users, relative to the overall cost of operating the enterprise." (Wilkins-Wells, 1999).

4. State of Oregon irrigation district law provides for one vote for up to 40 acres, two votes for 40 to 160 acres, and three votes for more than 160 acres. This simplifies voting, but still partially reflects the amount of irrigated land owned on the system.

For fractional shares or fractional areas, sometimes the number of votes will be rounded up to a whole number, sometimes not. Most systems guarantee at least one vote, no matter how little land is owned.

A variation is practiced by the Salt River Project Agricultural Improvement and Power District. Voting is primarily in proportion to acreage of land owned. However, the four ‘at-large’ Board members (of the 14 total) are elected on a “one-landowner, one vote” basis.

Palo Verde Irrigation District specifies “one vote for each $100 of assessed valuation.”

Weighting the votes by the amount of land or shares owned can lead to dominance by a few large powerful landowners. The author knows of an irrigation district that is dominated by three farmers, and another system where one landowner owns 40% of the land. To prevent domination by a few, individuals could be restricted to no more than a specified percentage of the votes. State of Washington irrigation law specifies “No one ownership may accumulate more than forty-nine percent of the votes in one district.” In Germany, a member of a Water and Soil Association is limited to no more than 40% of all votes (Monsees, 2004). These limits are very high, and could still lead to domination by a few.

Proxy Voting

Folsom: “Members shall not be entitled to vote by proxy.” Proxy voting is also not allowed at Sidney.

Big Ditch: “Any person may vote the stock of another... by presenting a written proxy to the secretary at the time of the meeting.”

Two Leggins: “a stockholder may vote in person or by proxy executed in writing by the stockholder”. “Such proxy shall be filed with the Secretary... before or at the time of the meeting. No proxy shall be valid after eleven months from the date of its execution, unless otherwise provided in the proxy.”

Absentee voting is generally not allowed. Perhaps this is intentional to reduce the possibility of absentee landlords dominating elections. However, absentees may still be able to vote by proxy on systems where that is allowed.

Voting Registers

Irrigation organizations typically maintain voter registers, which list eligible voters and the number of votes each is entitled to cast.

Kyrghyz (Hagan): The Secretary “Maintains the records of the members of the association, of the voting rights of the members, and of the number of shares of each member.”

State of Arizona, 48-3015, Registration of Voters: "The registration books shall be opened for a period beginning on the thirtieth day after an election and closing on the fiftieth day before the date of the next election." "a qualified and registered elector who voted at the last preceding district election and who continues to possess the qualification of a qualified elector... shall not be required to reregister." "The election register shall denote the names of the holders of lands within the district, the number of acres held by each and the number of votes which they are entitled to cast."

Two Leggins: "The officer... shall keep a complete list of the stockholders entitled to vote at each meeting... with the address and the number of shares held by each, which list, for a period of ten (10) days prior to such meeting, shall be kept on file at the registered office of the corporation and shall be subject to inspection by any stockholder at any time during usual business hours. Such list shall also... be kept open at the time and place of the meeting and shall be subject to the inspection of any stockholder during the whole time of the meeting."

Lists of registered voters and vote entitlements may be required to be posted in public places, such as the district office and/or county courthouse(s) for a specified period before the election, to provide opportunities for corrections.

NOMINATION OF CANDIDATES FOR ELECTION

Officers of the Organization

Some officers may be elected by and represent specific territories in the organization. Others may be elected "at large" by members of the whole organization. Some organizations, like the Salt River Project mentioned earlier, have both types of officers.

Palo Verde: The Governing Board consists of 7 trustees, elected at large; all must be owners of real property in the district and a majority must be residents.

Big Ditch: "The corporate powers of this company shall be vested in a board of seven directors, each of whom at the time of his election, shall be a stockholder in the company and the owner of land located in the district from which said director is elected." Districts 1 (upper section of the canal system) and 2 (central section) are entitled to two directors each. District 3 (tail section) is entitled to three directors (section boundaries are specified in the bylaws). "The secretary and treasurer may or may not be directors or stockholders in the company."

Alberta, Canada: Where a district has electoral divisions, "an irrigator must vote in the electoral division in which that irrigator has irrigation acres, or if that irrigator has irrigation acres in more than one electoral division, the division in which the irrigator has the largest number of irrigation acres."

In Andhra Pradesh (India), every WUA has a Managing Committee, with one representative from each territory, and a President elected by the "farmers and tenants" of the whole association. (Lok Satta, 2000)

Kyrghyz (Hagan): A Commission for Conflict Resolution consisting of a Chairman and four other members will be elected by the General Assembly (with staggered terms of three years) to resolve conflicts between members. Decisions on conflicts must be made within one week, by majority vote of a quorum of at least three members. Rulings may be appealed to the General Assembly.

“The most favored number for a board of directors was 5.” “Boards are always odd-numbered to ensure a tie-breaking vote.” “All boards were found to be rotating boards, with elections every year for one or more board members.” (Wilkins-Wells, 1999. From a survey of 36 irrigation organizations in the United States)

Nomination Process

Midvale: There are five commissioner districts. A water user “may nominate any qualified landowner who is a resident of the Commissioner District... and who is qualified to vote by getting 10 signatures of qualified landowners upon a nominating petition. He must file the completed petition with the Bookkeeper not less than 10 days before the election to have that nominee placed on the official ballot.”

State of Oregon: “Openings for the board of directors of an irrigation district shall be advertised in a newspaper of general circulation within the boundaries of the district for which the candidate would be elected or posted in three public places within the district at least 60 days prior to the election. All nominations shall be filed with the secretary of the board not more than 75 nor less than 35 days before the date of the election.” “Nominations for candidates for the board of directors may be made by petition, signed by at least 10 electors in the proposed district or division who are qualified to vote for the directors nominated by them. Nominations may also be made at an assembly of not less than 25 electors.” “Nominations by petition or by assembly shall be filed with the county clerk at least 35 days next preceding the date of election.”

Greenfields: A commissioner “must be an owner of irrigable land within the division of the District he/she is to represent” and “be actively engaged in the actual farming of his/her own farmland and derive at least 50% of his/her net income from his/her farm operation.” “Candidates for the office of commissioner may be nominated by petition filed with the election administrator... at least 75 days before the election and signed by at least five electors of the district.” “If no nominations are made... the electors of the District may either accept nominations from the floor or write on the ballots the name of the person or persons for whom they desire to vote."

Alberta, Canada requires that nomination papers be signed by at least 2 irrigators, and "contain a signed statement by the candidate consenting to the nomination".

Two Leggins: "The Board of Directors shall consist of five (5) members. Each director shall be elected for a term of three years". "Directors must be a stockholder in the company and the owner of land located in the district from which said director is elected." "It shall be the duty of the Board of Directors to appoint, not less than thirty (30) days, nor more than sixty (60) days before the date of meeting... a committee on nominations consisting of not less than three (3) stockholders. The Committee shall prepare a list of nominations for directors... at least thirty (30) days before the annual meeting. At least two candidates shall be nominated for each district" where a director needs to be elected. In addition, nominees "may be nominated from the floor during the annual meeting."

ELECTION PROCEDURES

Notification of Elections

Big Ditch: Notice of the annual meeting "shall be mailed to each stockholder at his last known address...at least twenty days before the date of said meeting".

Two Leggins: "Written notice... of annual meeting shall be delivered not less than ten (10) days before the date of the meeting. Said notices shall be delivered either personally or by mail... to each stockholder of record entitled to vote at such meeting. If mailed, such notice shall be deemed delivered when deposited in the United States Mail". "Notice of the Annual Meeting of the Stockholders shall be published at least once a week for the three consecutive calender weeks preceding the date of the meeting, in one or more newspapers published and of general circulation" in the area.

Folsom: "The failure of any member to receive notice of an annual or special meeting of the membership shall not invalidate any action which may be taken by the members at any such meeting."

In the State of Karnataka, India, model bylaws specify "Notice of the meeting shall be sent to the Members 15 days before the Annual or Special General Body Meeting. The meeting notice shall include the agenda, venue, time, and date of the meeting." (Saciwaters, 2004)

Notices may allow an opportunity to update the voting register, and an opportunity to pay by those who are delinquent in their assessments.

Quorums

Big Ditch: "A majority of the outstanding stock of this company represented, in person or by proxy, shall constitute a quorum at any... meeting of the stockholders."

Sidney: "Thirty per cent (30%) of members shall constitute a quorum". Folsom requires 10%; Two Leggins requires that 1/3 of the shares be represented. In the State of Karnataka, India, model bylaws state one fifth of the members or 25 members, whichever is less. (Saciwaters, 2004)

Kyrghyz (Hagan): "A quorum of more than half of its voting members" is required. "If there is no quorum, the session is postponed for one week. At the second session... decisions are taken irrespective of the number of its present members."

Conducting the Election

Officers are most commonly elected for three year terms, with the terms expiring on a "staggered" basis (not all the same year) to provide continuity of leadership.

Voting, at least in the United States, is typically done by secret ballot, particularly for election of directors. This reduces the chance of a director being hostile to those who did not vote for him. In a survey of 36 irrigation organizations in the United States, secret ballot elections were found to be the norm (Wilkins-Wells, 1999). Elections are sometimes conducted by an outside organization, or at least monitored by outside observers, to reduce the chance of election fraud.

East Bench: (A specific local legal firm) "is responsible for the administration of all procedures relating to the conduct of elections and will keep all records relating to the elections."

Greenfields: "The Teton County Clerk and Recorder is the election administrator and is responsible for the administration of all procedures relating to the conduct of elections and will keep all records relating to the elections. The commissioners may request the election administrator to appoint the District secretary, or any other person it desires, as deputy election administrator". "There shall be two or more election judges assigned to each" voting area. Election judges are appointed by the commissioners, and must be qualified electors in the District. "No election judge may be a candidate or a spouse, ascendant, descendant, brother, or sister of a candidate appearing on the ballot." "The names of all candidates printed upon the ballot shall be in type of the same size and character." "A sample ballot shall be posted near the entrance of the polling place". "Electors are entitled to one ballot per forty acres or major fraction thereof." After voting is completed, the election judges "shall immediately count the votes publicly without adjournment until completed and the result publicly declared". Greenfields has very detailed election procedures, from which the above provisions were selected.

Two Leggins: "The polls shall be opened and closed, the proxies received and taken charge of, and all ballots shall be received and counted by three inspectors, who shall be chosen from the stockholders, at each meeting... and shall, in writing, certify to the results. No candidate for election as director shall be named or act as inspector."

Alberta, Canada: The results of the election must be posted "in a conspicuous place showing the total number of votes for each candidate".

Ballot secrecy can be difficult to maintain when votes are proportional to the numbers of shares owned or area of land irrigated. To protect secrecy, State of Montana (United States) irrigation district law (Code 85-7-1710) provides that for "10 votes or less, separate ballots will be used; more than 10 votes, the elector shall vote in blocks of 10 using one ballot for each 10 votes and separate ballots for odd votes over multiples of 10." This is an alternative to each irrigator being given a ballot that includes the number of acres he owns and the number of votes being cast. East Bench uses this system, using one color of ballot for 1 vote and a second color for 10 votes.

Vacancies in Offices

At Tumalo, "When a vacancy exists in the office of Director, a majority of the remaining Directors shall appoint an eligible person from the electoral division in which the vacancy exists to serve until a successor shall be elected at the next regular election to fill out unexpired term." This is the most common method used by irrigation organizations. However for Kyrghyz (Hagan), the model bylaws provide that when a vacancy occurs, "an extraordinary meeting of the General Assembly will be called to elect a replacement for the rest of the tenure."

The Madhya Pradesh (India) Farmers' Participation in Irrigation Management Act of 1999 has a provision for recall of elected representatives. Recall can be initiated if more than one third of the members give written notice to that effect. The motion of recall is carried with the support of more than two-thirds of the general body members present and voting and representing over half of the electorate body, in a meeting specially convened for that purpose. As of 2003, this action had not yet been attempted (Arya, 2003). Recall of elected officials should not be easy, but not excessively difficult either. In Germany, members of the board may be dismissed by a two-thirds majority of the general assembly (Monsees, 2004).

OTHER

Most decisions are made by simple majority vote, but a two-thirds majority may be required for such things as borrowing money or changing the bylaws.

Sidney: "These bylaws, as well as any rules and regulations of the association may be amended at any time by a two-thirds (2/3) vote of the members present at any meeting according to one vote per member, the notice of call for said meeting having stated the amendment to be submitted thereat."

Kyrghyz (Hagan): "Decisions regarding the modification of the by-laws, the liquidation or the merger of the Association will have to be approved by 2/3 of the present voting members, provided that these 2/3 represent at least 50% of the members of the Association.

Two Leggins: "The Articles of Incorporation and these bylaws can be amended only by the shareholders, at a regular annual meeting, or at a special meeting called for such purpose, by a majority of the outstanding shares. The proposed amendment shall be delivered by mail to the stockholders... prior to the meeting at which the vote upon the proposed amendment is held" (not less than 10 days prior to the meeting).

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WATER USERS ASSOCIATION GOVERNANCE IN DEVELOPING COUNTRIES: FRAGILITY AND FUNCTION

L. Humberto Yap-Salinas[1]

ABSTRACT

Transfer of irrigation system management from government to water users has been taking place in developing countries for at least three decades. Various methods and degrees of transfer have been employed. Overall, the concept of transfer has been good, with benefits both to the central government and to the water users, who generally receive the transfer as members of organized water users associations (WUAs). Indeed, organizing water users into associations holds out much hope for farmers in developing countries. Similarly, modernizing agricultural technology is a must for these WUAs in order to produce competitively for global markets. However, technological modernization cannot be effective without robust water users association governance.

Many WUAs start out well, but some of them lose strength and/or become embroiled in debilitating problems later. This paper focuses on lessons learned in WUA organization and growth in developing countries, particularly those in which the International Irrigation Center of Utah State University has been involved during the last three decades. Underlying problems in irrigation system management transfer and in WUA organization and function are examined, along with post-project difficulties that can occur. Ways to make WUAs robust, effective in meeting production and community needs, efficient in management of water resources, and sustainable as functioning representative entities are discussed.

INTRODUCTION

Irrigation has long been viewed as the flagship of the rural agricultural sector in many developing countries because of its great adaptability and tremendous potential for increasing agricultural yield. In the first two-thirds of the twentieth century, a more structural approach to promoting agricultural production through irrigation took place through the construction of dams and irrigation systems; however, it was observed that building more and more systems finally began to yield diminishing results. A nonstructural, managerial approach, focusing on more effective use of the systems and limited water resources already available, was called for (Yap-Salinas 1983, Ostrom 1992). In many developing countries,

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irrigation traditionally had been the responsibility of the central, or national, government. By the latter half of the twentieth century, however, many of these governments, facing increasing debt loads, began to view transfer to water users of irrigation system management, including the financial responsibilities involved, as one way to lighten their economic burdens. Although often conceived for this purpose, water users associations (WUAs) have turned out in fact to be important tools for development of the rural sector in these countries because they address one of the weak factors for national growth: development of human capital. Now, however, with globalization, developing countries exporting agricultural products need to have agricultural production systems that are technologically and managerially efficient and competitive, ready to supply products when trade agreements open doors (Yap-Salinas 2003a, 2004). This means that WUAs need to become as efficient as possible in their management of irrigation and production.

Irrigation system management transfer has taken place in developing countries under a variety of internal and external conditions and often at points along continua. Such transfer has taken place at various speeds: "big bang;" very gradual, and even "de facto" previous to the present "wave." Transfer, similarly, has taken place under varying degrees of political will: governments in favor, governments reluctant, and governments of mixed interest and desire for the process depending on the level of bureaucracy. In addition, transfer has involved varying levels of development of human capital: some water users have very little real experience or even no knowledge of irrigation principles, and, at the other end of the continuum, some are agricultural entrepreneurs with a high level of education and irrigation and marketing experience. Accordingly, transfer has been seen under varying conditions of technological development: systems with a large quantity of available equipment and others with none.

Thus a variety of factors are involved in the unique form that irrigation system management transfer takes in each developing country. Furthermore, once transfer of irrigation system management has taken place, the WUAs in each developing country face a variety of similar factors that either promote or debilitate their growth and development. Such factors determine whether they will be robust or fragile, and whether they will be effective or not in meeting production and community needs, in managing their systems and water resources, and in achieving sustainability as functioning representative entities. External factors, such as internationally–financed projects, also enter into the equation. Because of these many factors, even though transfer and the formation of WUAs may start off magnificently, the associations and the process may later lose strength and/or become bogged down in complex problems.

There is a need to make WUAs robust, efficient, and competitive in agricultural production. This paper will examine the factors that contribute to this robustness and sustainability and will discuss underlying problems in the irrigation system management transfer process and water users organization formation and function, along with irrigation project and post-project difficulties, that can influence the achievement of optimal WUA objectives and function.

The analysis presented here derives from lessons learned by the International Irrigation Center/Utah State University (IIC/USU) irrigation projects in irrigation system management transfer and WUA formation and building in various developing countries during the past three decades, as well as from research in these areas in other countries in which USU has been indirectly involved.

BUILDING ROBUSTNESS IN WATER USERS ASSOCIATIONS

A Holistic View and Approach

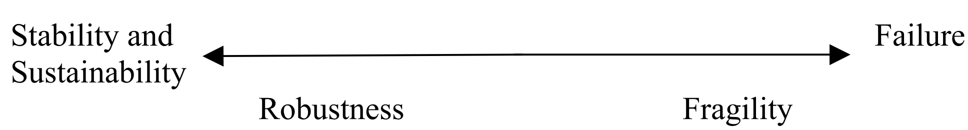
A WUA project in the irrigated agricultural subsector may be implemented by a government by itself or with international funding, and it may or may not involve irrigation consultants from other nations. Nevertheless, traditionally, and generally still, the stated aim of an irrigation project focuses on one or two main objectives. Such objectives may, for example, include bringing in advanced technology to improve agricultural production, or training water users in irrigation management at field and system levels, or guiding WUAs in institutional changes to promote true representation and a democratic process. However, while there may be only one or two objectives of a project, the approach must, because of the many factors involved in assuring sustainability, be an integrated, holistic approach that addresses these factors. A departmentalized, parochial approach that focuses only upon the desired main objective, ignoring contextual factors, will ultimately be hampered in its efforts to achieve a sustainable outcome and therefore be limited in its success.

Thus it is imperative that the factors that limit or promote success of irrigation system management transfer and the success of WUA formation and building be identified, examined, and taken into account in any irrigation project that involves any objective that is part of irrigation system management transfer or part of WUA formation and building. In other words, in approaching a transfer or WUA project, we must realize that a “simple” nonstructural irrigation development project with a limited objective is really more complex than it appears. For example, a WUA project that aims to bring in new technology for improved agricultural efficiency and production is really not only about water management and technology. Rather, such a project also involves institutional transformation in three aspects—i.e., really three “hidden” objectives—first, achieving effective acceptance by water users and by their WUA of the new technological modernization so that this technology will indeed be utilized; secondly, preparing water users and their WUA to understand and confront the fierce competitiveness of the global market and to see this technology as a tool to meet that goal; and thirdly, making water users and their WUA aware of the need to preserve the natural resources involved in their agricultural production and to see technology as part of this whole framework of production. Furthermore, institutional change in perception and commitment is necessary at other levels besides those of the individual water user and of the WUA entity; government district officials and top government ministry leaders also need to be made aware of and become committed to achievement of these so-called “hidden” objectives that affect the successful outcome of the technology that the project is importing (USU 2001). Thus a holistic, integrated perspective on any project objective is necessary, and a multilevel approach—at the individual water user level, at the WUA entity level, at the government district level, and at the top ministry level—is required.

A Conceptual Model and Equation for WUA Robustness

Through our experience, we have observed that WUAs generally follow the same evolutionary path as the society in which they are immersed. This is because a WUA, in the actions and functions required to form itself as an institutional, legal entity, confronts many of the same advantages and problems in its evolution and development that the society or country faces in its pursuit of development and growth. Thus it can be said that a WUA is often a microcosm of a country’s evolution toward development.

The robustness, or strength, of a given WUA as an institution exists as a continuum:



Various factors have been mentioned as affecting the irrigation system management transfer process and the formation and building of WUAs as part of that process. In the traditional perception of development, key factors are considered to include (1) human resources, (2) technological resources, (3) economic and financial resources, and (4) natural resources. This conceptual model includes an additional contemporaneous factor attached to the factor of economic resources: the need for agricultural production to be competitive in the new world order of international market conditions brought about by globalization.

Internal and external factors affect WUA governance and performance. Internal factors that determine the degree of robustness or fragility that a given WUA has can be represented by an equation of fragility in this conceptual model. External factors act upon the WUA and can be shown as a conceptual coefficient affecting the internal factors in the equation. Furthermore, this conceptual model equation behaves differently in each stage of development of the WUA, and the external factor coefficient affects the fragility function to different degrees.

Two key questions are (1) which factors, internal or external—and specifically, which ones—affect the fragility function for a WUA more, and (2) which one or ones of these factors can most easily be avoided or handled in the implementation strategy for WUA building.

Internal Factors Affecting WUA Development, Governance, and Performance: The main internal factors that can determine the fragility or robustness of a WUA are (1) human resources, (2) technological resources, (3) economic and financial resources, including (3a) competitiveness of agricultural production in the new international market conditions brought about by globalization, and (4) natural resources. Most of these factors are rather self-explanatory as to their meaning. However, the factor of human resources deserves a further explanation at this point.

In addition to the water users themselves, the factor of human resources involves other protagonists at other levels in the irrigation system management transfer process: chieftains and community leaders/local decision makers, local technocratic personnel, and local government bureaucracy at the district level. Within each level there are subfactors of general education, knowledge of good irrigation and management practices, sensitivity to natural resource conservation, and commitment to the success of the irrigation system management transfer process (also called "political will.") Similarly, subfactors of age and openness to ideas and new technology exist at each level. Furthermore, within the water users themselves, there are additional subfactors concerning generation gap and gender participation.

Thus the equation for robustness function of WUAs can be stated conceptually as:

$$R_0 = (w_0, x_0, y_0, z_0, \ldots n) \quad (1)$$

with R representing the robustness of the WUA at any given stage, and w, x, y, and z each of the main internal factors that determine fragility. Within each main internal factor, there are subfactors, mentioned above, that determine the composition of each main internal factor.

Because each stage of development will show varying development in each of the internal factors, the robustness of a WUA at any given stage of development can be represented as a function of:

Stage 1: $$R_1 = (w_1, x_1, y_1, z_1, \ldots n) \quad (2)$$

Stage 2: $$R_2 = (w_2, x_2, y_2, z_2, \ldots n) \quad (3)$$

Stage 3: $$R_3 = (w_3, x_3, y_3, z_3, \ldots n) \quad (4)$$

External Factors Affecting WUA Development, Governance, and Performance: This model of WUA robustness/fragility is incomplete without the external factors that affect a WUA's development. The WUA is immersed in a socio-political environment of underdevelopment, along with a natural environment.

This equation can be shown as existing within a "soup" of external factors that condition and ultimately affect the development of the WUA. While there are many such external factors, the most important include:

1. Political will and stratification of political will, as opposed to "state policy." In a developing society, perception of the transfer process and the development of WUAs is often affected by social strata of the country's decision-making structure and the fear of change (and loss of position that may result from change) in the administrative structure governing irrigation. While government ministry officials may see the clear benefits of transfer and WUA development, the people "on the ground" may often have different perceptions, partially conditioned by age, degree of professional participation and awareness of trends, and openness to new ideas. District officials often feel threatened by WUAs taking over irrigation system management responsibilities; it is often difficult for them to perceive new roles for themselves as advisors and collaborators in the process. Consequently, this lack of political will is manifested by blocking the transfer/WUA development process at many steps. This is an extreme and perhaps is the greatest difficulty facing those directing a transfer project. Lack of political will is the most negative and constant factor that must be avoided and combated from project inception.

2. Political bias and paternalism. In a developing society, politicization of the WUA can occur, often starting in the leadership; WUA goals and resources may be diverted to support a given party's goals and financial needs. This can be a very serious factor leading to WUA fragility and failure (Yap-Salinas 1994b).

3. Political change as a result of elections. In a developing society, elections may cause temporary project discontinuity or project termination; often an incoming political party feels no obligation to continue programs and projects started by the government structure of the outgoing political party. Furthermore, personnel from top to bottom, from ministry to district level generally change if there is a change in governing party in an election. This means that every time a new administration comes in, the full cadre of professional personnel, including technical personnel, is changed. This is generally a serious setback due to several negative effects: (1) time lag in resuming activities due to the replacement of previous personnel with new and often inexperienced personnel (sometimes political appointees with no

experience and little interest) who must be brought “up to speed.” Project consultants also often need to induce a positive political will toward the transfer/WUA development process and the goals of the project. (2) loss of “institutional memory” of what has worked and what has not during the life of the project.

4. Coordination and cooperation. In a developing society, there is often a lack of coordination and cooperation among local government units administering water resources. This situation can be improved when there is political will from the top downward.

5. Regulations and procedures. In a developing society, there is often a lack of efficient regulations, and burdensome regulations may exist. Cumbersome procedures often exist for obtaining legal status for the WUA, causing serious project delays and postponement of project objectives; unfortunately unorthodox payment methods (sometimes bribes) are sometimes necessary to accelerate this process. Again, political will can cut through red tape.

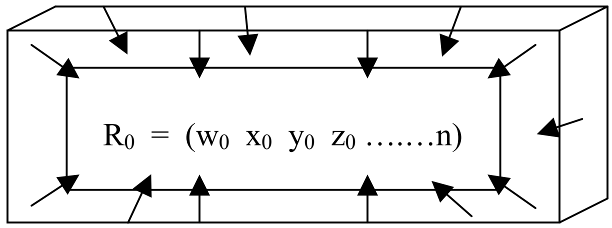
6. Definition of land ownership, property rights, and water laws. In a developing society, these are often weak and cause conflicts among users, inefficient property registration, and difficulty in trading and obtaining credit. Furthermore, the water laws of many countries are obsolete. New versions are being written, but few are being improved because of conflicts of interest among sectors.

7. Continuity factor. As mentioned above, elections may affect the continuity of a project. Furthermore, at the end of a project, which, simply for lack of sufficient time, generally never ends in a stage of complete stability and sustainability for the WUAs, the delay until a follow-up project is contracted and implemented can be a serious setback. In terms of progressive steps of building managerial, institutional, and technical skills, the development of WUAs is often incomplete. As a result, WUAs are not optimally strong, and are even more subject to some of the negative external factors resulting in fragility.

This “soup” of external factors has great bearing upon the success of the irrigation system management transfer process and development of the WUAs as strong, legal, representative institutional entities. These external factors can be shown as:

$$R_0 = (w_0, x_0, y_0, z_0, \ldots n) E_f \tag{5}$$

or, more visually, as a three-dimensional box around the fragility/robustness conceptual equation:



(6)

Ways to Promote Robustness of WUAs

Understanding the internal and external factors involved in development of WUAs, and understanding the fact that these factors each evolve according to stages of development of the WUAs are key to determining ways to promote strength of WUAs at each stage.

Some key actions are based on this analysis of internal and external factors.

1. Develop human resources: If water users do not evolve in their managerial, institutional, and technical abilities and skills, they cannot adequately assume the responsibilities of irrigation system management. Some developing countries used a "big bang" approach of transferring these responsibilities without providing the necessary training, and serious problems, including loss of agricultural production, resulted. Some governments used a gradual approach, incorporating training with gradual transfer of irrigation system management responsibilities. Other governments used a "big bang" approach, but they followed it immediately with projects providing training.

   Training for effective transfer involves at least three main areas: irrigation system management and technology, institutional innovation, agricultural production and marketing. Water users need to be "chaperoned" into a new way of managing their systems and water resources, gradually showing them the advantages of new methods and technology and building their confidence in their abilities. Similarly, the representative governance that WUAs entail is often new in countries where paternalistic governments previously were in charge of all aspects of irrigation. This involves training in institutional changes that involve representation, equity, and responsibility; as farmers see reduction in conflicts and fairness to all, not just to a few, they become convinced that indeed community cooperation through their WUA is worthwhile and effective. The third area of training that is essential for water users is that of increasing agricultural production and using effective marketing; in the end, if transfer and WUA formation does not result in increased farmer income and an improved standard of living, water users will view the whole concept as useless. WUAs gain greater strength as they function as their own middlemen in the marketplace (USU 1997-2001). The formation of national federations of WUAs, such as those now taking place in

Ecuador, Peru, El Salvador, Dominican Republic, and Mexico, increases the collective strength and bargaining power of water users, not only in marketing but in all areas. This area of training in production and marketing now gains even greater importance as globalization increases the need for competitiveness in the international marketplace (Yap-Salinas 2004).

2. Build political will: Because of the problems of lack of political will and interest, training must be provided to government administrative and technical personnel at all levels of transfer—not just the water users. A significant amount of time must be spent "converting" all those to be involved in transfer, up to the ministerial level, to a commitment to the goals of the irrigation transfer project so that decisions can be made smoothly, in a timely manner, with minimal encumbrances. In practice this has meant a great deal of time at the beginning of the project spent on educating people about the project; ongoing seminars and discussions throughout the project life are necessary to keep the project on task and accomplishing its objectives (USU 2001).

3. Build legal status of WUAs and land ownership of water users: One of the first steps in building strong WUAs is obtaining legal status for the WUAs for their operation as legal, negotiating entities (USU 1997-2001). Water users' properties must also be clearly demarcated. Digitalized mapping of irrigation parcels through GPS has contributed to definition of property in the USU projects in the Dominican Republic. Accurate land tenure maps give WUAs a basic tool for management decisions for their irrigation systems.

4. Demonstrate results and reduce risks: Water users in developing countries tend to live marginally. The results of proposed actions must be shown in order for water users to take risks. It is important to reduce the risks involved (Yap-Salinas 1994a, 1994c). One example involved the use of a farmer's land as a pilot area in the Dominican Republic to demonstrate rehabilitation and drainage; although farmers were reluctant at first, soon all were clamoring to have work done on their fields (Yap-Salinas 1994b). Another example is the use of artisan greenhouses that enabled tomato production at high altitudes in the Ecuadorian Andes; once a few had tried these and obtained astounding results, greenhouses began sprouting up all over, even in non-project areas (USU 1997-2001).

   As farmers become convinced of the possibilities, their commitment to their WUAs strengthens, and they are willing to pay the water tariffs and learn to manage their water resources. As they begin to see that they can actually manage their own systems without a paternalistic government, they become willing to learn how to do so more efficiently and eagerly take the training classes. The idea of actually managing their own system is often a "eureka" revelation when it jumps off the paper and becomes a reality because it goes against decades and even centuries of agricultural tradition of dependence upon the government for everything.

5. Build continuity: Because of delays within projects due to elections or changes of government leadership, and because of delays between projects, one way to ensure that water users and their WUAs are not just "dropped" is to build continuity through training in the WUAs and to build a technical cadre of engineers that in some types of delays can continue working. This was done in Ecuador (USU 2001).

CONCLUSION

Internal and external factors affect the development of WUAs and their progress toward the goal of stability and sustainability. The internal factors involve resources: (1) human, (2) technological, (3) economic and financial, and (4) natural. The robustness of a WUA will depend on development in each of these areas.

However, external factors in a country also affect this process of WUA strengthening and progress toward robust stability and sustainability. These effects can be positive or negative. To summarize, some of these external factors involve (1) political will, as opposed to "state policy," (2) political bias and paternalism, (3) political change, (4) coordination and cooperation, (5) regulations and procedures, (6) definition of land ownership, property rights, and water laws, and (7) the continuity factor.

These internal and external factors have been described in this paper, and the conceptual model and equation presented enable visualization of the factors.

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VIET NAM: CREATING CONDITIONS FOR IMPROVED IRRIGATION SERVICE DELIVERY — THE CASE OF THE PHUOC HOA WATER RESOURCES PROJECT[1]

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ABSTRACT

About one third of the Vietnamese population live below the poverty line, of whom 85% live in rural areas, and 70% of the labor force depends on agriculture. To help improve rural incomes, the Government of Viet Nam continues to place high priority on investments in water resource infrastructure to increase agricultural productivity and reduce rural poverty.

At present, more than 2.6 million ha of agricultural land in Viet Nam are irrigated through 75 large and medium-scales schemes and thousands of small-scale systems. These systems are managed by state-owned Irrigation Management Companies (IMCs) and thousands of agricultural cooperatives and water user groups (WUGs). The country's irrigation systems realize only about 50-60% of the design targets as a result of a number of constraints that limit performance.

The Government has recognized that a new strategy is needed to improve system performance in Viet Nam. Hence, policies on water service delivery have shifted to a more decentralized and participatory approach. Government policy now promotes autonomy for the IMCs and establishing/ strengthening of WUGs at the local level. Under the Phuoc Hoa Water Resources Project, an irrigation project recently initiated by the Ministry of Agriculture and Rural Development, it is intended to operationalize the Government's new approach. This project offers a

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[1] The views expressed in this paper are those expressed by the authors and do not necessarily reflect the official positions of ADB, AFD and MARD.

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unique opportunity to do this as local irrigation institutions are still to be developed. A "road map" for achieving sustainable management of the project's irrigation system is presented.

SETTING THE SCENE: SECTOR BACKGROUND

About one third of the Vietnamese population live below the poverty line, of whom 85% live in rural areas, while 70% of the country's labor force depends on agriculture. In line with the Government's Comprehensive Poverty Reduction and Growth Strategy adopted in 2003, the Government continues to emphasize the importance of rural development in reducing poverty. Investments in water resource infrastructure to increase agricultural productivity are an integral part of this strategy.

At present, more than 2.6 million ha of agricultural land in Viet Nam are irrigated through 75 large and medium-scales schemes and thousands of small-scale systems. These systems are managed by 130 public sector Irrigation Management Companies (IMCs) and more than 10,000 agricultural cooperatives and local water users organizations. The IMCs, established at the end of the 1980s manage headworks and main outfall structures and the main and secondary canal and drainage systems. The IMC managed systems cover about 70 percent of the country's irrigated areas. Within the IMC managed systems, agricultural cooperatives, associations and groups providing water services at the lower system level. In some provinces, Irrigation Management Enterprises (IME) manage the secondary system with the IMC managing the main system. IMCs are usually established on the basis of hydraulic boundaries whereas IMEs and local-level irrigation institutions within IMC managed systems are usually based on administrative (district and commune) boundaries.

Irrigation service fees are high in Viet Nam compared with the other countries in the region. However, IMCs continue to receive subsidies from the central and provincial governments for operation and maintenance (O&M) as they do not generate sufficient revenue from the irrigation fees while they have many internal inefficiencies. Typically, irrigation fees cover about 50% of the routine O&M costs. Being public sector companies, IMCs have little incentive to improve their financial and operational performance.

The Ministry of Agriculture and Rural Development (MARD) – the Government agency responsible for irrigation and drainage at the central level - estimates that the country’s irrigation systems realize only about 50-60% of the design targets. Factors that contribute to this state of affairs include (i) incomplete or degraded infrastructure (especially at the farm level), (ii) underfunding of O&M, (iii) poor system management and unauthorized interference by farmers, (iv) an institutional framework that is not conducive for financial and management accountability, (v) a complex legal framework based on contradicting policies and strategies in a number of areas, (vi) the mismatch between hydraulic boundaries and the system management institutions at the lower level which continues to be based on administrative boundaries, and (vii) weak integration of water services with other agriculture-related support services.

Realizing the generally poor system performance, MARD with the assistance of external financing agencies and Non Governmental Organizations (NGOs), initiated a series of pilot projects for participatory irrigation management (PIM) since the mid-1990s. Results from these pilots suggest that PIM "works", i.e. that local water users groups (WUGs) can undertake O&M of tertiary canals within larger irrigation schemes and the O&M of small-scale stand-alone systems. These pilots also have demonstrated that WUGs based on hydraulic boundaries can effectively undertake tertiary system level management.

In order to improve the performance of public sector managed irrigation systems, the Government's strategy related to irrigation services has shifted to a more decentralized and participatory approach. This is fully in line with the Government's overall policy to encourage grassroots democracy. The approach also promotes autonomy for the IMCs and establishment and strengthening of local level water users organizations. In this context, one recent initiative taken by MARD is the finalization of its strategy to operationalize participatory irrigation management. This new approach towards irrigation services has been incorporated in the design of the Phuoc Hoa Water Resources Project, a large-scale $164.6 million multipurpose water infrastructure project recently initiated by MARD with financial assistance from the Asian Development Bank (ADB) and the Agence Francaise de Developpement (AFD).

PROJECT BACKGROUND

The Project is located in the Dong Nai river basin in South Viet Nam, see map. Dong Nai basin,[6] the third largest in Viet Nam, consists of four major subbasins: the Dong Nai, Be, Saigon, and Vam Co Dong rivers covering 10 provinces including Ho Chi Minh City (HCMC).[7] The basin contains the country's largest urban and industrial development areas that are fast expanding, and water demands have increased and will continue to increase. While there has been recent development of the water resources in the Dong Nai and Be river basins through construction of reservoirs, shortages in the Saigon and Vam Co Dong river basins have become more critical over recent years. It has already reached a stage where municipal water supply authorities of HCMC are experiencing unacceptable salinity levels at proposed intakes for new urban water supplies. With higher priority given to supplying water for urban and industrial uses in line with the 1998 Law on Water Resources, the current situation rules out the

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[6] The Dong Nai river has a catchment area of 47,300 square kilometers (km^2).

[7] HCMC was formerly known as Saigon.

potential for further agricultural development in rural provinces surrounding HCMC. Without the Phuoc Hoa Water Resources Project, further irrigation development would not proceed due to lack of fresh water.

To address the issue of increasing water demands in the Dong Nai basin, the Government adopted a holistic three-pronged strategy. Taking a basin perspective, it identified the key water-related issues constraining development of urban and industrial areas, and considered various options to transfer water from the Be subbasin to the Saigon subbasin. The basin approach is further strengthened through the Dong Nai river basin organization recently set up to coordinate and improve river basin planning and management. The second element of the strategy is the improvement of the efficiency of existing water resource systems. As part of this process, the Dau Tieng irrigation system (DTIS) will be upgraded and modernized with World Bank financial assistance to optimize water use and secure its dam safety. The third strategic element is the further regulation of the Be river and the transfer of water to the Saigon river to control salinity intrusion and provide water for urban, industrial, and agricultural uses. This will be achieved through the Phuoc Hoa Water Resources Project.

The Phuoc Hoa Water Resources Project (the Project) will develop water resources infrastructure comprising basin transfer facilities and provide irrigation systems for 48,130 ha of agricultural land, most of which is rainfed at present. Water from the Be river will be conveyed to the Dau Tieng reservoir on the neighboring Saigon river, see map. From there, releases will be controlled to supply water for various purposes. These include (i) releases to the Saigon river for water supply intakes and salinity control in the lower reaches; (ii) releases to the Vam Co Dong river via the existing DTIS canals and drains for salinity control; and (iii) releases for irrigation in DTIS and the new areas to be developed under the Project. The Project will be implemented over a 6.5-year period starting in early 2005.

While the Project's infrastructure provides the means for supplying additional water, it is recognized that the most challenging requirement for successful implementation of the Project and realization of the benefits is an integrated approach to develop institutional capacity for sustainable management of one of the country's most complex irrigation systems. In terms of system management, there will be three levels of O&M responsibility: national, provincial, and farm levels. The national level covers the interprovincial facilities (barrage and transfer canal, and main canals for each of the irrigation subsystems). These will be managed by MARD through the already existing Dau Tieng IMC. At the provincial level, provincial IMCs will manage the primary and secondary canals. Canals serving less than 150 ha, generally the tertiary units and lower, will be managed by local WUGs. The three-tiered system management is in line with the 2001 Ordinance on Exploitation and Protection of Hydraulic Works and the 2003 Decree No. 143. The Ordinance and the Decree provide the overall regulatory framework for O&M of IMC managed irrigation systems. Provinces have developed further guidelines for the implementation of these two legal instruments to suite local conditions and specific system requirements.

The current irrigation fee (IF) structure set by various government regulations is generally adequate to cover O&M costs. IFs are usually equivalent to 5-8 % of the value of agriculture crop production. The critical issue, however, is to ensure that the fees are collected and used effectively. Experience in Viet Nam shows that IFs can be readily collected if service delivery is satisfactory, which places the onus on the Project to ensure that the systems are operated properly and will be well managed. The Project aims to achieve this by emphasizing establishment of institutional arrangements that promote participation of the end-users in decision making during preparation and implementation.

ROADMAP FOR SUSTAINABLE SYSTEM MANAGEMENT: CREATING CONDITIONS FOR IMPROVED IRRIGATION SERVICE DELIVERY

Because local irrigation institutions do not yet exist in the area covered by the Project, it offers a unique opportunity to start with a clean slate to implement the Government's current sector strategy. Many system and institutional shortcomings prevailing in the existing systems can be avoided by creating the right conditions while the Project is being implemented. Recognizing this opportunity, MARD and the two external financiers, have agreed to a roadmap for "*sustainable system management*". [8] "*Sustainable*" system management is defined as:

> *IMCs and water user groups (WUGs) providing reliable water delivery services against agreed performance indicators to all users without having to resort to major rehabilitation interventions*.

The Project includes the following two important features that will facilitate the implementation of the roadmap.

(i) Provision of a Complete Irrigation System from Headworks to Tertiary Canals

– *Many public sector irrigation systems are only partly developed. Government financing is usually limited to the headworks and the main canal system. The development of the lower level system is left to generally fund-strapped provincial agencies and farmers. As a result, full irrigation services are usually possible for 50-60 % of the designed service area.*

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[8] System management includes O&M of the infrastructure and the associated financial and human resources.

– To ensure that full irrigation services can be delivered, the Project will provide a complete system including main canals, secondary and tertiary canals designed for full irrigation service in the entire Project area.

(ii) Creation of "upfront" Ownership

– *Irrigation development financed by government agencies has traditionally been planned, designed and implemented with limited local level involvement. As a result, there is limited ownership among farmers in terms of the irrigation infrastructure and its upkeep.*

– Under the Project, a comprehensive network of WUGs will be established from an early stage to enable farmers to participate in the local-level design process. Organizations such as social science institutes or nongovernment organizations (NGOs) will be contracted to provide the necessary community mobilization and social intermediation services. Tertiary facilities will be designed in a participatory manner involving farmer review of tertiary unit layouts prepared by engineers. Farmers will be mobilized to contribute to the construction of the tertiary units, mainly through labor for earthworks. During community mobilization and the formation of WUGs, the farmers will be informed about their responsibilities, the arrangements for the management of the tertiary system through their WUG, the design irrigation supply, the IF structure, and the principles of the service contract between the WUG and the IMC.

The Road Map

The roadmap includes measures to address current policy and legal issues, outlines specific actions related to systems to be managed by the IMCs and WUGs, and the management arrangements between them. It covers the period up to 2008 when the Project's irrigation system is expected to be fully commissioned.

Policy and Legal Management Aspects:

(i) Review and adjustment of current policies and legal framework

– *The irrigation sector and its institutions are governed by several ordinances, decrees, decisions and regulations reflecting various sector and sector-related Government policies and strategies. The current policy and legal framework is therefore complex. On the one hand it contains inconsistencies while on the other hand still provides insufficient guidance on how to actually implement the sector policies and strategies. This situation makes it difficult for central and provincial authorities to provide clear guidance to IMCs, the WUGs and the district and commune authorities.*

- To address the complex policy and legal framework, current central and provincial level policies, strategies, and regulations relating to irrigation services will be reviewed early on during project implementation. The views of stakeholders within MARD, the provinces, and other ministries will be sought and the review will be lead by a high-level Task Force chaired by the vice-minister of MARD responsible for irrigation service delivery. The review is expected to recommend adjustments to the legal framework which will then be introduced according to an agreed time table.

Management of Systems under IMC responsibility:

(ii) Setting clear objectives for system management

- *Most large-scale public sector managed irrigation systems do not have specific management objectives. The management objectives of the IMCs are generally described as: (i) providing water for irrigation purposes for specific areas and (ii) ensure the functionality of the main and secondary drainage systems. These objectives, apart from being general, do not establish a clear linkage between irrigation service and agriculture and other income and livelihood providing sectors (like aquaculture). The current lack of system specific management objectives makes system performance assessment and monitoring virtually impossible.*

- To provide a clear benchmark to assess management services by the IMCs, the system's overall management objectives will be clearly defined early during project implementation with the participation of representatives of all stakeholders. The objectives will take into account the multipurpose nature of the Phuoc Hoa – Dau Tieng (PH-DT) system. The main objectives will therefore relate to agriculture production; domestic and industrial water supply; and environmental releases. In view of the highly dynamic character of the economic development in the Dong Nai basin and also in PH-DT service area, it is essential to review the performance objectives on a regular (perhaps five-year) basis. This review will be done in consultation with all stakeholders at the basin level through the Dong Nai River Basin Organization and the stakeholders at the system level.

(iii) Setting clear irrigation service delivery standards

- *Most IMC managed irrigation systems do not have clear service delivery standards. The service standards are usually loosely defined as providing "full" irrigation delivery to the entire service area. IMCs do not have an incentive to specify the service delivery standards as they operate as public sector companies with no formal accountability towards the end-users. IMCs therefore perceive end-users as customers under a monopolistic situation.*

- Once the performance objectives for the PH-DT have been defined, service delivery standards and associated indicators will be developed for the main system and subsystems with participation of all stakeholders. MARD, the provinces and other stakeholders will jointly develop the standards and indicators such as seasonal deliveries to primary canals and bulk water users (a delivery standard), and areas under irrigation contracts (an indicator). The standards will be adjusted regularly in line with the review of the system's performance objectives (see (ii) above).

(iv) Developing a system management plan

- *Most IMCs do not have a fully developed management plan with operational rules for various supply scenarios. In terms of the system's organization, standard norms are usually applied for management staff at different level with little regard for the actual requirements. Furthermore, most IMCs lack a systematic asset management system. Under the present situation of a paucity of maintenance funds, IMCs do not have an incentive to use such a system.*

- Considering the size and complexity of the PH-DT system, a comprehensive management plan is needed to ensure that the system will meet the agreed service delivery standard under different supply conditions, i.e. full "design" supply and various level of partial supply depending on crop water requirements and water availability. The management plan will include various operational rules for major structures and define the major O&M tasks and requirements (routine, annual, and replacement) for the main system and the subsystems. The management plan will need to be adjusted based on actual experience in managing the system.

(v) Developing a clear financing plan

- *In principle, IMCs have financial autonomy and are to be self-financing but with an entitlement for subsidies in case of extreme weather conditions. For most IMCs, however, various government policies make it difficult for them to become financially autonomous and reach self-financing. Provincial governments set guidelines for the IF structure based on the government's overall socio-economic development strategy with little regard for system's specific financing plans. As a result, IMCs are usually dependent to a substantially degree on government subsidies to finance their budget. Unfortunately, there are ambiguities in the subsidy entitlements and the subsidies therefore are unpredictable. Furthermore, the IMCs are usually not sure when they will receive the subsidies. The financial statements of many IMCs are incomplete as they do not provide all required accounting information based on the accounting standards for public sector service companies.*

- Based on the management plan (see (iv) above), MARD and the Provincial authorities in consultation with the IMCs, will prepare and reach an agreement on the system's financing plan. The plan will identify the various financing sources which include expected revenues generated from IFs; bulk water sale for domestic, urban and industrial use; reservoir releases for salinity control; and the subsidies eligible under the current government policies. Regarding the subsidy entitlements of the PH - DT system, MARD will remove the current ambiguities related to these entitlements. Furthermore, meeting system performance standards will be considered as an eligibility criterion for certain entitlements.

- Once the rehabilitation, modernization and expansion of the PH-DT system are complete (by 2008), the roadmap envisages that government subsidies will be minimized. The Project IMCs should then be in a position to generate sufficient revenues from IFs, bulk water sales and releases for environmental flows to fully finance the management plan.

- For efficient implementation of the management plan, the following systems will be developed and operationalized during the next two years: (i) a transparent accounting system using acceptable standards for public sector enterprises; (ii) an asset management and monitoring system (to keep track of maintenance and replacement works and their expenditures); (iii) human resource development system; and (iv) seasonal and annual reporting on system performance against the agreed performance standards and criteria; these reports will be made public.

Management of Lower-Level Systems by WUGs

(vi) Establishment of WUGs based on hydraulic boundaries

- *In most IMC managed irrigation systems, tertiary system management is undertaken through commune-level agricultural cooperatives. These cooperatives are part of the overall administrative system at the commune level. As a result, the service area of one tertiary canal typically belongs to more than one cooperative with two or more separate irrigation teams managing a relatively small canal. This situation of tertiary system management based on administrative boundaries and not on hydraulic boundaries makes efficient irrigation distribution and delivery virtually impossible.*

- In the Project area WUGs will be established for each tertiary canal on the basis of the hydraulic boundaries. MARD and the provinces have already provided the legal basis for this. The WUGs will be responsible for distribution of irrigation supplies delivered by the IMC at the tertiary canal outlet structure. Members of the WUG will elect their own management committee. They may seek the assistance of commune authorities or the local judiciary in case individual members refuse to comply with WUG regulations. MARD and the provinces will develop model regulations for the management of the tertiary canal system for adoption by WUGs. The role of the commune authorities and the judiciary for dispute resolution among WUG members will also be defined.

(vii) Mobilizing resources for system management

- *In IMC managed irrigation systems, IMCs usually receive the IF payments from the agriculture cooperative while the cooperative collect the IF payment from the farmers. The IMC and the agriculture cooperatives negotiate the IF amount to be paid by the cooperative. This negotiation is undertaken on the basis of the IF structure approved by the province, the service area within the commune receiving irrigation supplies through the system managed by the IMC and the level of service, i.e. full or partial service. With service standards not well defined and the inability to monitor irrigation delivery to the cooperatives because of the mismatch between the hydraulic and administrative boundaries, "bargaining" takes place in these negotiations and IMC are not in a position to fully capture the potential IF revenue.*

- *At the agriculture cooperative level, IFs are normally combined with other taxes levied by the commune authorities on the farmers. The cooperatives usually retain a certain percentage of the amount of IF collected to cover collection expenditures. Many cooperatives add an additional fee to recover the cost incurred by them in the operation of the tertiary systems and the O&M of other irrigation facilities managed by them such as local pump stations that recycle drainage water. In many areas under IMC management, the total annual tax payment by the farmers can reach the equivalent of 50 % of the value of the agriculture crop production. But farmers do usually not know which part of their tax payment is for irrigation service and for other services. As IFs are not separated from other tax revenues, there is no link between irrigation service delivery and IFs and between IFs and O&M expenditures at the cooperative level. In contrast to the IMCs, many cooperatives are able to balance their accounts.*

- Under the Project, WUGs will establish their own regulations and arrangements for mobilizing the resources for the O&M of their tertiary canals. WUG members could contribute labor for works like desilting of and weed removal from the tertiary canal. WUGs could receive government subsidies (such as subsidy for canal lining under the current government policy) but these subsidies should not replace regular maintenance.

- The IFs for the financing of the O&M of the higher level systems will be collected through the WUGs. The IF will be assessed jointly by the IMC and the WUG for each season taking into account the land use in the service area (in case the IF is differentiated between crops), and the use of groundwater by the WUG members. Commune authorities could pay IFs on behalf of farmer families recognized within the commune as poor. MARD will provide the legal basis for IF payment through WUGs.

- End-users are generally willing to pay IFs if they have confidence that the IFs collected are utilized efficiently for the O&M of the canal system delivering their irrigation supplies. The management plan will therefore include mechanisms for involvement of the WUGs in setting priorities for the maintenance of secondary and primary canals.

<u>IMC and WUGs Interaction:</u>

(viii) Service contract with IMC

- *MCs normally enter into seasonal contracts with the agriculture cooperatives. The main objective of these contracts is to agree on the seasonal IF amount to be paid by the cooperative to the IMC. As mentioned above, the amount is arrived at through negotiations between the two parties. Because irrigation deliveries can not be monitored, the contracts can not specify seasonal irrigation supplies in an enforceable way. As such, the contracts are not "service delivery" contracts.*

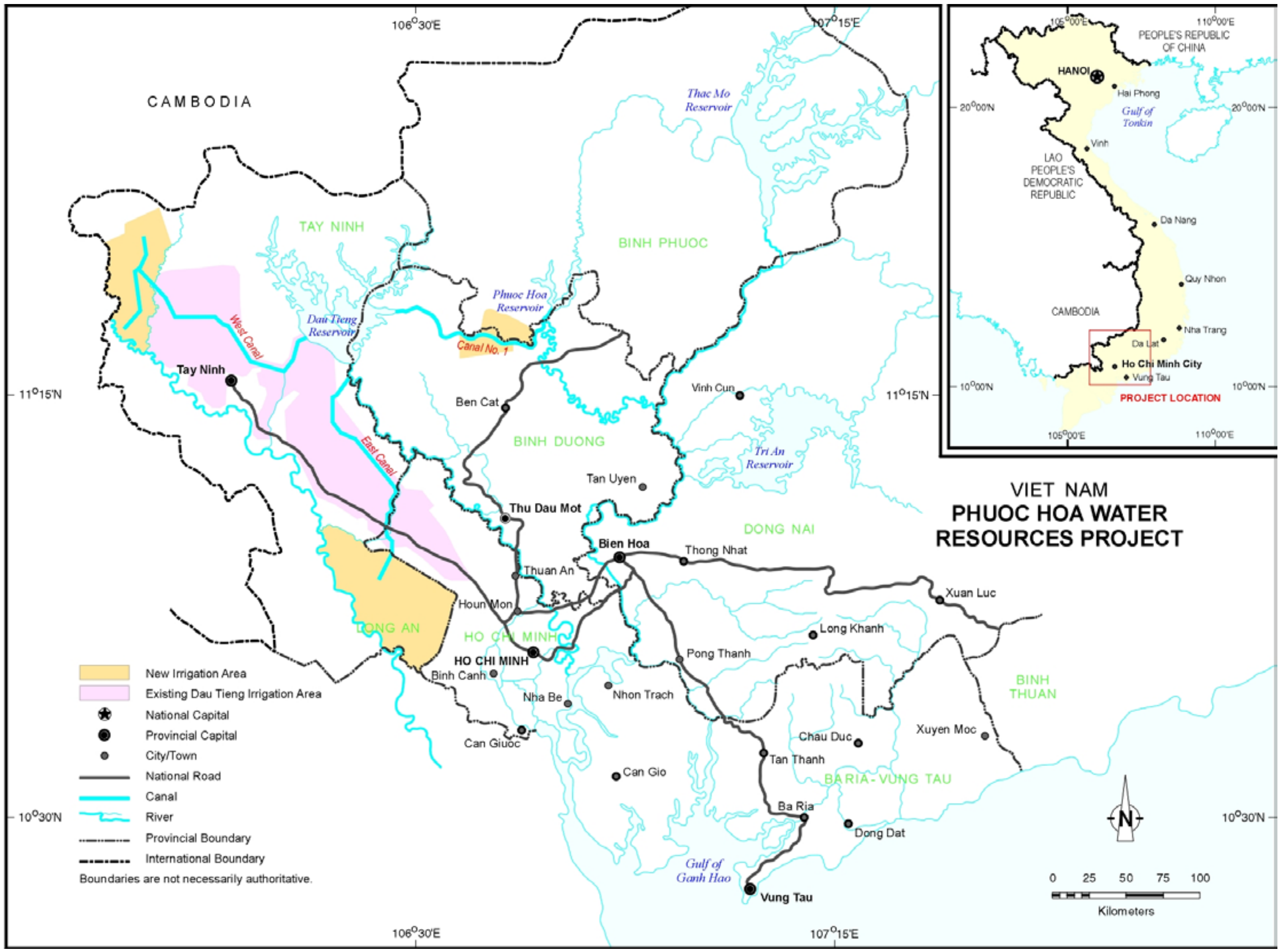
- With WUGs to be established on the basis of hydraulic boundaries with the tertiary turnout being the delivery transaction point between the IMC and the WUG, an opportunity will be created for a quasi "service delivery" contract.[9] These contracts will include a schedule of irrigation supplies to be delivered by the IMC to the WUGs. The contract will also include the amount of IF to be paid by the WUG and rebates in IF payment in case of failure by the IMC to adhere to the irrigation schedule. A dispute resolution mechanism will need to be developed to deal with disputes about the compliance with the service contract (including default in ISF payment by the WUG). This may require the involvement of commune, district, and provincial authorities, and the judiciary. MARD and the provinces will develop a “model” service contract to be adopted by the IMCs, and agree on dispute resolution mechanisms.

[9] This contract can not be treated as a full service contract as actual discharges into the tertiary canals will not be measured.

CONCLUDING COMMENTS

The roadmap described above is an indicative one because it will be further developed during the next three years in accordance with Viet Nam's national policies for management of water resources infrastructure with participation of central, provincial and local stakeholders.

The roadmap's further development and subsequent implementation will be a challenge as it requires a departure from the system management approach presently prevailing in most pubic sector managed irrigation system. However, the roadmap's direction is fully in line with the Government's policy towards greater participation by the end-users in irrigation system management and greater management and financial autonomy for public sector irrigation institutions.


VIET NAM
PHUOC HOA WATER
RESOURCES PROJECT
CAMBODIA
TAY NINH
BINH PHUOC
BINH DUONG
DONG NAI
LONG AN
HO CHI MINH
BINH THUAN
BA RIA - VUNG TAU
Tay Ninh
Ben Cat
Thu Dau Mot
Tan Uyen
Vinh Cun
Bien Hoa
Thong Nhat
Xuan Luc
Thuan An
Houn Mon
HO CHI MINH
Binh Canh
Nha Be
Nhon Trach
Can Giuoc
Can Gio
Pong Thanh
Long Khanh
Chau Duc
Tan Thanh
Xuyen Moc
Ba Ria
Dong Dat
Vung Tau
Phuoc Hoa Reservoir
Dau Tieng Reservoir
Thac Mo Reservoir
Tri An Reservoir
Gulf of Ganh Hao
West Canal
East Canal
Canal No. 1
106°30'E
107°15'E
11°15'N
10°30'N
New Irrigation Area
Existing Dau Tieng Irrigation Area
National Capital
Provincial Capital
City/Town
National Road
Canal
River
Provincial Boundary
International Boundary
Boundaries are not necessarily authoritative.
0 25 50 75 100
Kilometers
N
PEOPLE'S REPUBLIC OF CHINA
HANOI
Hai Phong
Gulf of Tonkin
Vinh
LAO PEOPLE'S DEMOCRATIC REPUBLIC
Da Nang
Quy Nhon
CAMBODIA
Nha Trang
Da Lat
Ho Chi Minh City
Vung Tau
PROJECT LOCATION
105°00'E
110°00'E
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10°00'N

03-2976 HR

MANAGEMENT TRANSFER OF IRRIGATION SYSTEMS TO WATER USER ORGANIZATIONS

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ABSTRACT

This paper describes the design and implementation of two concurrent and recently concluded irrigation management transfer projects in the Dominican Republic, the lessons learned, and the achievements to date. The projects included 36 irrigation systems and dealt with over one hundred water user organizations at different levels, with emphasis on organization and training of water users. Several hundred formal training events and related activities were held during the project implementation to strengthen existing water user organizations, and to foment the establishment and development of such organizations where they had not previously been found. Extensive informal follow-up advising and institutional support was also provided by the project team members. Three of the primary-level water user organizations have evolved to the point that they no longer require external assistance, and most of the others are far enough along in their development to be self-sufficient in the next few years.

INTRODUCTION

Irrigation management transfer has occurred in recent years in many countries (Geijer 1995). The management transfer of irrigation systems to water user organizations in the Dominican Republic was established as a national policy during the 1980s due to widespread recognition of the deterioration of water delivery infrastructure, resulting from less than optimal operation and maintenance (O&M) practices, in general. Other factors leading to this policy included the documentation of significant water distribution inequities in the irrigation delivery systems, frequent water shortages due to ineffective operations, low percentages of water use fee payments, and others. It was further recognized by INDRHI, the government agency responsible for water resources development, that an unfavorable predominance of centralized decision-making with regard to irrigation system O&M existed in most of the irrigation systems. It had become evident that in some regions, in spite of relative water abundance with respect to irrigation needs, the water users suffered from the consequences of inadequate

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O&M. For these reasons, in 1987 INDRHI decided to adopt a policy of irrigation system management transfer from state control to newly formed water user organizations which would assume responsibility for the O&M of their systems.

In 1985, the United States Agency for International Development (USAID) financed the On-Farm Water Management Project (PROMAF) in the Dominican Republic. A team from Utah State University (USU) worked with USAID and INDRHI to implement the management transfer aspects of the project. These aspects were strongly emphasized after a redesign of the original project work plan. The main objective of PROMAF was the management transfer of irrigation systems by means of three fundamental activities: (1) improvement of irrigation infrastructure; (2) on-farm water management improvements; and, (3) organization and institutional strengthening of water users. These activities were designed to allow the water users, through their own organizations, to progressively take greater responsibility for the O&M of their irrigation systems, eventually to the point at which they would operate and maintain most or all of the system, including the main canals. However, the main canal of each irrigation system in the project areas was never transferred to user control at the outset of the project because the budding water user organizations were not yet ready to operate at this level.

PROMAF was successful in creating two legally-recognized, nonprofit water user organizations in relatively large irrigation systems just two years after the program start. These two successes in the creation of viable water user organizations were highly visible and contributed to the later achievements under the project, and under follow-up projects in these and other irrigation systems.

By the end of the year 2000, the Dominican Republic had achieved significant success and experience in the formation of water user organizations within some of the most important irrigation systems in the country. Nevertheless, it was also recognized that in spite of the noteworthy advances in this area, the achievements to date had not been sufficient to solve all of the administrative problems in the management of the irrigation systems. Of particular consequence was the fact that a number of influential government agency representatives remained skeptical of the water user organizations' ability to assume responsibility for operation and maintenance of the irrigation systems, thereby posing a formidable practical obstacle to the continued development of these incipient organizations.

THE PROMATREC AND PROMASIR PROJECTS

PROMATREC (*Irrigated Lands and Watershed Management Project*) was conceived through a study which was completed in 1988. After numerous modifications to the original concept through collaborative interventions by specialist from IICA and FAO, in 1995 the World Bank (IBRD) and INDRHI jointly announced a new loan agreement for PROMATREC in which the

YSURA, Ulises Francisco Espaillat, and Nizao-Valdesia water user organizations would receive additional institutional strengthening and irrigation system infrastructure improvements.

To a large extent, PROMATREC was intended to be a continuation of the previous efforts to effect management transfer from INDRHI to the three water user organizations. Thus, the overall objective of PROMATREC was to further strengthen the water user organizations so that the management transfer might be successful in the long-term, directly benefiting over 10,000 people in farming communities. Part of the project design was to apply a technique recently used in management transfer efforts in other countries; that is, to concurrently strengthen the waters user organizations through training events and other activities, while making key improvements to the irrigation infrastructure. The component for training, institutional strengthening, and agricultural development began officially in October of 2000, and concluded in December 2003 after having negotiated extensions to the work plan and the time frame for implementation. Twelve years had passed from the project design to its termination in 2003, with somewhat uncoordinated implementation of the separate components, resulting in cycles of optimism and pessimism by the water users in the affected areas. Near the end of the project, many water users manifested overt indifference to most of the project activities, leading directly to water user apathy and frustration on the part of the personnel who implemented the project.

Like PROMATREC, PROMASIR (*Water User Irrigation System Administration Program*) also began within INDRHI, but was implemented through funding from the Interamerican Development Bank (IDB) and the government of the Dominican Republic. PROMASIR included four project components, many of which were, to a large extent, analogous to those in PROMATREC:

1. Organization and training of water users;
2. Special studies and irrigation system mapping;
3. Infrastructure rehabilitation; and,
4. Irrigation system operation and maintenance.

The *Organization and Training of Water Users* project component began at the same time as the corresponding component of PROMATREC, but ended in June 2004, six months after the completion of PROMATREC. The project proposed the inclusion of some 36 irrigation systems, covering 80,000 ha and 20,000 users. Beneficiary water user organizations fell into three categories: (1) Pre-existing with legal recognition, and at least partially self-sustaining; (2) Recently formed and unable to function independently; and, (3) Not yet formed. This gamut of organizational development levels was something not seen in PROMATREC, where each of the three pre-existing water user organizations were already well along in their respective paths of institutional development.

The pre-extant organizations had already undergone official management transfer by means of a signed agreement with INDRHI, even though in all but one or two cases the organizations were not yet capable of functioning without substantial external support. Also, those systems which had been officially transferred to the water user organizations included only the O&M of secondary and tertiary canals, not the main canal.

ORGANIZATION AND TRAINING IN PROMATREC AND PROMASIR

The respective organization and training components of the PROMATREC and PROMASIR projects were both implemented concurrently through separate contracts between INDRHI and Utah State University. The USU team, which had just completed an irrigation management transfer project in Ecuador, was mobilized to work with the water users and INDRHI to organize and train the water user organizations. The fundamental management transfer process was as given in Skogerboe, Merkley, and Rifenburg (2003), but with required modifications to accommodate local conditions and needs.

The *Organization and Training of Water Users* component of PROMASIR was modified extensively during the first year of implementation to include, for example, the institutional strengthening/formation of water user organizations at not only the primary level, but also at the lower levels (secondary and tertiary). This is something which was not required in the three PROMATREC organizations because they had already been awarded legal status by the Government of the Dominican Republic prior to the start of the project. In PROMASIR, an extensive and lengthy campaign was carried out to promote the project objectives among the beneficiaries (water users, principally), begin the organizational development process, and complete the requirements for legal recognition at both the secondary and primary levels in each of the 36 systems. A few of the irrigation systems were geographically isolated and small in area, so they were organized only at the secondary level.

The PROMATREC and PROMASIR activities began in October 2000 with the organization, training, and institutional strengthening of 16 water user organizations. A total of 38 irrigation systems were included between the two projects. Before the end of the project a total of 16 primary-level water user organizations were formed/strengthened, including 96 secondary-level organizations, all with legal status. Another six secondary-level organizations which fell outside of any of the primary-level organizations were established as independent entities but were also strengthened through project activities. A total of 102 secondary-level water user organizations were created and or strengthened, none of which had legal recognition before the projects began.

Table 1 presents a summary of the general project accomplishments in each independent water user organization, which in most cases was at the primary level, but also included isolated secondary-level organizations. The left-most four columns in the table show the different organizational levels (tertiary, intermediate, secondary, and primary) included in each independent water user organization.

Table 1. Organizational Level, Process Type, and Electoral Events in the Water User Organizations.

No.	Water Users Organization	Organizational Level				Process			Elections
		Tertiary	Intermediate	Secondary	Primary	Reorganization	Organization	Restructuring	
1	Dajabón	●	●	●	●	●		●	2
2	Fernando Valerio	●	●	●	●	●		●	2
3	Horacio Vásquez	●		●	●	●			2
4	Mao, Inc.	●		●	●	●			2
5	Ulises Francisco Espaillat	●	●	●	●	●		●	2
6	Ms. Bogaert	●	●	●	●		●		1
7	Presa de Rincón	●		●	●	●			2
8	Río Camú	●		●	●	●		●	2
9	Constanza	●		●	●		●		1
10	AGLIPO	●	●	●	●	●			1
11	Nizao-Valdesia	●	●	●	●	●		●	2
12	YSURA	●		●	●	●		●	2
13	Padre las Casas	●		●	●	●			2
14	Valle de San Juan	●	●	●	●	●		●	2
15	Valle de Neyba	●	●	●	●	●			1
16	Mijo	●	●	●		●			2
17	Carrera de Yeguas	●	●	●			●		1
18	San Rafael de Yuma	●	●	●		●			2
19	Boba	●	●	●	●		●		1
20	Anón Uvilla	●	●	●			●		1
21	Vicente Noble-Canoa	●	●	●			●		1
22	Uno Sur Cristóbal	●		●			●		1
23	National Irrigators Council	N/A	N/A	N/A	N/A		●		1

The development of each water user organizations during the projects was classified as belonging to one of three stages of progress: (1) no existing water user organization; (2) functioning, but not yet self-sustaining; and, (3) nearly independent of external assistance. Thus, although none of the water user organizations were completely self-sustaining at the program outset, some of them were on the road to being so. The O&M of those irrigation systems that had already been officially transferred to a water user organization was no longer the responsibility of the government agency (INDRHI), but to be handled by the water users, at least at levels below that of the main canal. When the projects began in the fall of 2000, eight water user organizations had already been formed, and the O&M of the respective irrigation systems had officially been transferred to the water users. All of the above are examples of water user organizations at the third stage of development.

Many other irrigation systems had recently-formed water user organizations, either already legally recognized at the primary level or in the process of obtaining said recognition. At the start of the projects, these systems were co-managed by the fledgling water user organizations and the regional INDRHI office which provided technical assistance, some O&M personnel, machinery, and partial funding for O&M activities. In these cases, the irrigation system manager, engineers, administrative and operations personnel were mostly provided by the regional office of INDRHI, although some of the personnel were directly hired by the water user organization.

A common occurrence was the sharing of the irrigation system manager's salary by INDRHI and the waters user organization, based on the premise that the latter would eventually assume 100% of the manager's salary, as well as the payments to other O&M and administrative personnel. Much of the O&M activities continued to be handled by INDRHI, especially at the main canal level of the irrigation systems, whereby the water user organizations only dealt with preventive maintenance in the smaller flow control structures, removal of vegetation from the channels, and other minor activities. Examples of the water user organizations at this second stage of development in the fall of 2000 include numerous irrigation systems distributed around the country: Horacio Vásquez, Valle de Constanza, Río Camú, Presa Rincón, Padre las Casas, and others.

The first stage of organizational development at the program start was essentially no identifiable water user organization at all. In these cases, INDRHI retained complete responsibility for all O&M activities, in addition to administration and conflict resolution among water users. The water users relied completely on INDRHI to take care of the distribution and delivery of water. INDRHI imposed somewhat arbitrary water use fees upon the users, usually amounting to only a small fraction of the real O&M costs, and many of the water users seldom (or never) paid those fees. Examples of irrigation systems in this situation at the beginning of the projects include: Boba, Amina, Guanajuma, and others.

Given the varying degrees of organizational development in the different irrigation systems covered by the two projects, the plan was to tailor project activities to each specific case, providing the types of support appropriate to the initial level of development, also realizing that the organizations would surely evolve at different rates. A diagnostic study of the organizational situation in each of the included irrigation systems was carried out early on in the project, according to the project design, whereby team members made multiple visits to each area to assess conditions. The team members worked jointly with the water users to determine the best approach to fomenting the water user organizations and their ability to take responsibility for O&M of the infrastructure. These initial actions resulted in the preparation of site-specific plans for each of the irrigation systems in the project areas.

Each of the site-specific plans included a list of required actions and a proposed timetable for implementation, but with sufficient flexibility to deal with unforeseen events and the unknown rates at which organizational development might occur in each of the irrigation systems. Historical context indicated a need for such flexibility, allowing for sometimes rapid progress, periodic developmental setbacks, and the need for a great deal of patience on the part of the project team members and the water users themselves. In those irrigations systems with some pre-existing level of water user organization, restructuring issues (Table 1) were visited with the water user representatives to determine where the predominant weaknesses might lie, and whether some degree of reorganization might be appropriate to enhance the effectiveness in terms of O&M and administrative capability. In one of the irrigation systems, the pre-project organization level had been completely lost before the projects started, and in this case the organization had to be started from scratch, as was the case in several irrigation systems which had never enjoyed any function level of water user organization. All project-supported activities were designed to promote lasting self-sufficiency within the water user organizations, as opposed to a quick official transfer of responsibilities from the government to the water users.

In this way, the activities of organization/reorganization and restructuring were defined. Organizational activities were limited to irrigation systems with no viable water user organizations, that is, where it was necessary to start from scratch. Reorganizational activities took place in those areas that already had functional water user organizations at the time the project began, and these included the continued formation of the different organizational levels. The highest independent organizational level in each irrigation system fell into either the "organizational" or "reorganizational" categories (Table 1), but not both.

The other category of activities was "restructuring," which was applied in those areas which needed a change in the number of lower-level organizations (secondary and tertiary). Reasons for such change were always for practical reasons and logistics, such as the ability and convenience for water users to travel to a meeting location, the number of users included in each lower-level organization, the organizational costs, and the completeness of representation for all areas served by the irrigation system. Thus, in some cases the number of lower-level organizations was decreased during the first year of project implementation, and in others the result was a subsequently greater number of organizations at this level. For example, in Dajabón, the number of secondary organizations was decreased from 16 to 4, and in Fernando Valerio from 17 down to 7, making administrative functions more efficient and cost effective. On the other hand, in Río Camú, Nizao-Valdesia, YSURA, and Valle de San Juan, the number of secondary organizations was increased to include irrigation system areas which had not previously been represented in the water user organization. Some primary-level organizations even decided to change their name to better reflect their constituency and area served.

Once the organization/reorganization and restructuring were achieved in each of the project areas, electoral issues were considered. Again, the conditions surrounding these issues were treated as unique for each site-specific case, as opposed to attempting to fit all under a single electoral template. However, there were, of course, many similarities in the handling of electoral processes overall. The electoral rules and regulations were studied and discussed through numerous collaborative meetings between water user representatives, community leaders, and project team members. This process included a review of all the organizational bylaws, originally developed by INDRHI for each irrigation system, and subsequent revisions, exclusions, and additions to the bylaws in general. Each primary-level organization ended up having its own unique set of bylaws, tailored to their conditions and preferences. Once the electoral portions of the bylaws were reviewed and modified, the process of holding elections for water user organization officers was initiated. These officers included a president, vice president, secretary, and treasurer at each organizational level, plus members-at-large and other representatives.

The right-most column of Table 1 shows that a total of 36 elections were held in the water user organizations during the implementation of PROMATREC and PROMASIR. The electoral process was monitored by the project team members in each case to help ensure adherence to the bylaws, and to explain the process to water users as necessary. Few processes within the water user organizations require greater follow-up, support, and monitoring than the elections for organizational officers, many of whom were entirely new to the job and lacked adequate preparation for their duties. Project team members found it necessary, in many occasions, to monitor the electoral process when it was observed that violations had occurred.

Table 2 presents a summary of many of the institutional strengthening activities in each primary-level (and secondary-level, in some cases) water user organization. It is also seen in Table 2 that all of the top-level organizations had bylaws at both the primary and secondary levels before the end of the projects. The second column shows that all but one of the primary-level organizations had reviewed and updated their bylaws by the time the projects ended.

The third and fourth columns in Table 2 show the attainment of legal recognition by the Government of the Dominican Republic for all secondary and primary organizational levels, respectively, except in the case of Presa de Rincón. As mentioned above, the legal status was granted to the water user organizations after having met all requirements and obtaining a presidential decree.

Each of the top-level water user organizations received training, repeated follow-up, and consultation by project team members in the preparation of three fundamental plans (columns 5, 6, and 7 in Table 2):

1. Strategic plan for sustainability;
2. Annual business plan and budget; and,
3. Water use fee collection plan.

Table 2. Summary of Institutional Strengthening Activities for each Independent Water User Organization.

		1	2	3	4	5	6	7	8
No.	Water Users Organization	Secondary-Level Bylaws	Primary-Level Bylaws	Legal Recognition: Secondary Level	Legal Recognition: Primary Level	Strategic Plan for Sustainability	Annual Business Plan and Budget	Water Use Fee Collection Plan	Regulations
1	Dajabón	●	●	●	●	●	●	●	●
2	Fernando Valerio	●	●	●	●	●	●	●	●
3	Horacio Vásquez	●	●	●	●	●	●	●	●
4	Mao, Inc.	●	●	●	●	●	●	●	●
5	Ulises Francisco Espaillat	●	●	●	●	●	●	●	●
6	Ms. Bogaert	●	●	●	●	●	●		
7	Presa de Rincón	●		●		●	●	●	●
8	Río Camú	●	●	●	●	●	●	●	●
9	Constanza	●	●	●	●	●	●		
10	AGLIPO	●	●	●	●	●	●	●	
11	Nizao-Valdesia	●	●	●	●	●	●	●	
12	YSURA	●	●	●	●	●	●	●	●
13	Padre las Casas	●	●	●	●	●	●		●
14	Valle de San Juan	●	●	●	●	●	●	●	●
15	Valle de Neyba	●	●	●	●	●	●		●
16	Mijo	●	N/A	●	N/A	●	●		●
17	Carrera de Yeguas	●	N/A	●	N/A	●	●		●
18	San Rafael de Yuma	●	N/A	●	N/A	●	●		●
19	Boba	●	●	●	●	●	●		
20	Anón Uvilla	●	N/A	●	N/A	N/A	N/A	N/A	
21	Vicente Noble-Canoa	●	N/A	●	N/A	N/A	N/A	N/A	
22	Uno Sur Cristóbal	●	N/A	●	N/A	N/A	N/A	N/A	
23	National Irrigators Council	N/A	●	N/A	●	N/A	N/A	N/A	●

Note: Column 8 includes bylaw attachments with rules for elections, the levying of sanctions, and payments to elected water user organization officers.

The first two plans were successfully prepared by the 19 top-level water user organizations in each irrigated area, whereby 16 were at the primary level and 3 were at the secondary level. The training and other project-sponsored support activities for the development of these three plans in the water user organizations were accomplished in two groups: one in the southern part of the country and the other in the north.

The Water Use Fee Collection Plan was prepared only for eleven of the District-level organizations by the end of the projects, but was in process for the remaining top-level organizations. The delay in preparing the Water Use Fee Collection Plans was due to the time required for each water user organization to complete its formation or restructuring at the lower levels.

PROJECT ACCOMPLISHMENTS

In addition to the activities and occurrences cited in the previous sections of this paper, a number of important contributions to the management transfer process in the Dominican Republic can be summarized. All of these accomplishments were a result of the PROMATREC and PROMASIR actions in the project domains, and they illustrate the level of development attained by the water user organizations from the year 2000 to June of 2004. Of major importance was the training, both formal and informal, which took place in a number of venues in the country, as well as in trips to other countries. The training was accompanied by the development of several dozen pamphlets, brochures, manuals, posters, banners, and other materials. All of these materials were left with the water user organizations and INDRHI.

A total of over 500 training events were held for water users themselves, waters user organization officials, engineers, field technicians, and others in the Dominican Republic, with over 13,000 participants in all. The training activities included numerous topics, many of which were repeated two or three times in the same areas to increase the number of trainees and to reinforce practice of the concepts put forth in the events. A great deal of informal follow-up training and assistance was provided by project team members, resulting in much stronger and more self-sustaining water user organizations.

The training events were augmented by several trips to Mexico, Chile, and Spain, where the participants visited farmer-managed irrigation systems and had the opportunity to share experiences with farmers and water user organization officers in each of these countries. Each of the visits was to locations where a successful management transfer had already occurred, and where the water user organizations were continuing to evolve and improve. Furthermore, the participants were able to converse freely in their own language without the need for interpreters. As a result of these trips, the participants, including government officials, farmers, and water user organization officers, gained confidence in their ability to achieve a successful and sustainable management transfer of the irrigation systems in the Dominican Republic.

Complementary to the training activities, a new financial accounting system was developed in the Spanish language specifically for application in water user organizations. The software was developed by a local firm who also installed the software and the computers upon which it operates in the top-level water user organizations, and provided training on its application. One of the important features of the software was the integration of a water users registry into the financial management routines, such that the water user organization staff could track water use fee payments and perform other important management functions. As a result of the development and introduction of this new software package, the top-level water user organizations had much greater control over their financial situation than ever before.

Another significant accomplishment was the formation of a National Irrigators Council (NIC) which represents all water user organizations in the country. The NIC began with substantial project support, eventually resulting in the preparation of bylaws specifically for the NIC, and the holding of national elections among the presidents of top-level water user organizations in the Dominican Republic. All of the NIC officers are also presidents of water user organizations and they deal with national issues of water rights, governmental liaison, and assistance to top-level water user organizations. For example, the NIC helps support the water user organizations with technical and institutional services that they all need, but cannot afford on an individual basis. INDRHI gave a seat on their advisory board to the president of the NIC, a significant gesture of continued collaboration and support in the development of water-user-managed irrigation systems.

The diagnostic surveys at the conclusion of the PROMATREC and PROMASIR projects indicated a high level of water user organization development since the initial diagnostics were undertaken in 2001. Many of the water user organizations had evolved to the point of selecting and hiring their own manager, support staff, and even technicians in some cases. Many of these organizations have also purchased vehicles to conduct the business of managing an irrigation system. All of the organizations have progressed significantly in following and enforcing the bylaws, even though a number of them were faced with resolving conflicts due to abuses by some elected officers. Overall, the dependence of the water users in the project areas on governmental support has decreased substantially from pre-project levels and the water users have attained a sense of self-sufficiency which had not been known before.

CONCLUSIONS

The PROMATREC and PROMASIR projects each had components for the organization and training of water user organizations, and each was implemented concurrently in the Dominican Republic. These projects followed earlier efforts via programs such as PROMAF, and resulted in the development of extant and newly-formed water user organizations in 36 irrigation systems around the country. More than 100 secondary-level water user organizations achieved legal recognition, as well as several primary-level organizations. Over 500 formal training events were held to support the sustainable development of the water user organizations. The authors believe that three of the primary-level organizations are now capable of autonomously managing their irrigation system, while the majority of the other primary-level organizations are well along in their own development, but still require some outside assistance from INDRHI, other government agencies, and non-governmental support organizations. With continued support, all of the primary-level water user organizations can become self-sustaining within a few years.

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IMPROVING GOVERNANCE IN NEPAL'S WATER RESOURCES SECTOR THROUGH INSTITUTIONAL CHANGES

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ABSTRACT

Principles of cooperative governance and collaborative management are increasingly becoming central to integrated and participatory water resources development and management. Several institutional measures, both in terms of tools and rules, have been introduced in most cases to make these principles effective. While some successful cases such as Murray-Darling basin in Australia and Northern-Colorado Water Conservation District in Colorado exhibit alluring examples, experiences from Nepal show a contrasting picture. Nepal has embarked on several national and local level institutional measures to improve governance in water resources sector. However, the evidences suggest that the results are far from what were expected at the outset.

Successful examples around the world indicate that "enabling environment", "genuine representation of the stakeholders", and "accountability" are key requirements for the success of such endeavors. How have these key requirements been addressed in case of Nepal? What are the achievements and shortcomings? What can be a promising way forward? Focusing on these questions, this case study presents findings and conclusions based on: 1) review of various institutional measures taken over time in Nepal's water resource sector; 2) analysis of achievements and shortcomings in achieving "enabling environment", "genuine representation of the stakeholders", and "accountability"; and 3) investigation of roles of external support agencies and allied government bodies.

INTRODUCTION

Despite being generously endowed with freshwater (10,043 m^3 per capita in 2000), Nepal faces challenges in exploiting its water resources for realizing the national objectives of: social development, economic development, and environmental sustainability (WECS, 2002). The recently proposed National Water Plan, 2004 asserts that the implementation of water related programs under good governance is vital for realizing the national goals and objectives. Clearly, this requires complementing institutional arrangements encompassing: legal framework, related policies, and organizational structures of the involved entities.

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INSTITUTIONAL MILIEU

The water resource sector in Nepal represents a combination of deep-rooted indigenous customary laws and a host of statutory laws and regulations promulgated and amended through time (WECS, 2002; Sharma and Onta, 2002). Agrarian communities of Nepal have been engaged in the development of irrigation and water supply schemes from the sixth century. Using local knowledge and skills they developed simple and rudimentary irrigation systems. Sporadic supports in these development endeavors were also made by incumbent kings in response to the pleas (*jaaheris*) made to the palace. Farmers managed and utilized water as per their individual or collective needs. Over time, such practices and associated norms, generally unwritten, became the guiding principles for managing water-related conflicts. The state literally had no role in development and management of water resources until the middle of nineteenth century.

With the expansion of paddy cultivation in both the hills and *terai* during the nineteenth and first half of twentieth century significant expansion of irrigation schemes (about 20,000 in number) occurred through the initiatives of the farming communities. Then the state came into the picture and promulgated the National Code of Conduct (*muluki ain BS1910*) in 1853. Its objective was to make the District Revenue Offices (*maal addas*) responsible for enforcing prior use water rights (primarily based on the customary practices); to develop irrigation in the plains (*terai)*; for constructing, operating and maintaining irrigation systems; and related conflict management. Occasional investments in developing irrigation canals through the interests of the king or prime minister are also found to have occurred. However, investments in other areas like hydropower or water supply schemes were largely non-existent. This trend of water resource development and management continued in the country's water sector until 1956 when the practices of undertaking planned development activities, in form of five-year development plans, started taking roots. This period from the ancient time till 1956, hence can be observed as initial efforts of commencing and streamlining activities related to governance of water resources, mainly for irrigation. Focused on irrigation development, this phase signifies an era of evolution of rules, norms or codes related to irrigation development and defining roles and responsibilities of the informal irrigator communities involved in the development of the irrigation infrastructures. This phase; with no formal linkages between stakeholders and the state's organ or external support agencies and allied government bodies; largely benefited the elites and the ones that were close to the state's power structure and the palace.

The next period from 1956 to 1970 can be characterized as an era of planned development in Nepal. Extensive development of water resources infrastructure took place under the joint initiatives of the state and bilateral donors. Three crucial laws related to governance of water resource sector were institutionalized during this period. Keeping the emphasis on irrigation development, but with the view of making it better planned, the Irrigation Act of 2018 was promulgated in 1961. This Act made explicit legal provisions for various water uses in addition to irrigation, distribution of water among aspiring water users, collection of water charges, sewerage disposal, etc. Another act, the Water Tax Act of 2023 was later enacted in 1966 to articulate provisions for water tax and licensing, including for drinking water. In 1967, a more comprehensive act, the Irrigation, Electricity and Related Water Resources Act of 2024 was brought in, particularly for providing a legal framework for the various uses of water. In all these Acts, the emphasis was on the state's lead roles in the governance of water sector. No provisions to involve the grass-root level stakeholders in the decision-making processes existed. Consequently, provisions for ensuring genuine representation of stakeholders in the governance of water sector, accountability, and enabling environment for participatory water resource management largely remained unaddressed.

The period from 1970 to 1985 mainly focused on the development of relatively large water projects, again with bilateral assistance. The sector concentrated on infrastructure development to achieve high economic growths. The state intensively developed large schemes and took charge of their management solely through its own bureaucracies. Promulgation of the Soil and Watershed Conservation Act in 1982; on the presumption that the state could check the prevalent mismanagement of watersheds leading to land degradation, through floods, water logging, salinity and siltation in the reservoirs; fostered the state's roles further in constructing and maintaining dams, embankments, improving terraces, constructing diversion channels and retaining walls as well as in protecting vegetation in landslide prone areas. Towards the end of this period, based on the experiences gained through pilot projects such as participatory water supply and sanitation projects (supported by UNICEF), Irrigation Management Project (supported by USAID), etc, which heavily emphasized organized stakeholders' participation in the development and management of the water related projects, a greater realization that the state-led, sectoral, and construction-oriented approach alone cannot produce the intended outputs began to take roots among the water sector policy makers.

As a consequence, the period after 1985 has been heavy on an integrated and participatory development approach in the water sector. The various laws and regulations (see Table 1) that have been enacted after 1985 stress on making congenial provisions for encouraging stakeholders' participation in the development and management of various water-related projects. Similar realizations can be seen to have evolved among the stakeholders' organizations and accordingly, initiatives have been made by them to be part of the governance process of the water resource sector in the country (e.g. formation of National Federation of Water Users' Association). Several new policies, laws, and regulations have been promulgated and interventions been made that exhibit efforts of various institutional measures taken in Nepal for improving the governance of water resources in the country.

Table 1: Chronology of Institutional Measures of Water Resources Governance

Year	Event/Activity	Rationale
1853	*National Code of Conduct 1910* (*Muluki Ain*)	To provide legal foundation for prior use water rights, to develop irrigation in the *terai,,* and to make District Revenue Offices responsible for construction, operation and maintenance of irrigation systems.
1961	*Irrigation Act, 2018.*	To make legal provisions for various water uses, construction and maintenance of irrigation canals, distribution of water, collection of water charges, sewerage disposal, etc.
1966	*Water Tax Act, 2023.*	To articulate provisions of water tax and licensing, including for drinking water sector.
1967	*Irrigation, Electricity and Related Water Resources Act, 2024.*	To provide legal framework for the use of water resources for irrigation, electricity production, and others uses.
1974	*Canal Operation Regulation.*	To govern water use for irrigation.
1975	Introduction of community participation approach in water supply and sanitation sub-sectors by UNICEF.	To promote community participation in the development of domestic water supplies and sanitation in rural areas.
1982	*Soil and Watershed Conservation Act*	To check mismanagement of watersheds that leads to land degradation, through floods, water-logging, salinity, and siltation in the reservoirs and to manage the government constructed embankments, terraces, diversion channels, and retaining walls as well as to protect vegetation in landslide prone areas.
1985	Initiation of the Irrigation Management Project (IMP).	To promote participatory irrigation management approach in the country.
1987	Organizational restructuring and formation of Department of Irrigation (DOI).	To bring all irrigation related activities under one umbrella.
1988	Adoption of a new working policy on irrigation development by HMG.	To institutionalize the participatory irrigation management approach.
1988	*Irrigation Regulation, 2045.*	To provide legal provisions for formation of water users' group, water distribution, realization of water charge etc. of a new working policy on irrigation development by HMG.
1992	Adoption of the *Irrigation Policy, 2049.*	To bring uniformity in implementation procedures of all institutions and to continue necessary reforms in the institutional structure and management for better service delivery.
1992	*Water Resources Act, 2049.*	To provide umbrella legislation for hydropower, irrigation, drinking water and other water uses and to establish District Water Resource Committees (DWRCs) for regulating use of water resources at the district level.
1992	*Electricity Act and Regulation, 2049.*	To facilitate and regulate the hydropower sector, with the main thrust on hydropower development.
1993	Introduction of the *Water Resources Regulation, 2050.*	To elaborate on the provisions made in the Water Resources Act, 2049.
1993	Social auditors organize the first public hearing in Nepal.	To discuss on the issues of Arun III Hydropower Project.

1996	First Amendment of *Irrigation Policy, 2049*.	To update irrigation policy for rapid and sustainable development of irrigation and to adapt river basin approach and greater participation of WUAs at all stages of irrigation development.
1997	*Environmental Protection Act, 2053*.	For ensuring environmental friendliness in various development efforts.
1998	Formation of National Federation of Water Users' Association (NFWUAN).	To develop a higher tier of organization of the water users' association enabling their representation at national level.
1998	Enactment of the Nepal Water Supply Sector Policy.	To devolve the management of water supply schemes to the users groups
1998	Formation of a committee for Private Sector Participation.	To lease Nepal Water Supply Committee to the private sector.
1999	*Local Self-Governance Act, 2055*.	To strengthen the decentralization governance process in the country.
2000	*Irrigation Regulation, 2056*.	To elaborate on the provisions made in the Water Resources Act, 2049.
2001	First election of NFWUAN	For democratic appointment of the executive body of NFWUAN.
2003	Adoption of Irrigation Policy, 2060.	To promote optimal use of available physical and institutional infrastructure for expanding year round irrigation services.
2004	Second election of NFWUAN	For appointment of democratically elected executive body of NFWUAN.
2004	*Irrigation (First Amendment) Regulation, 2060*.	To legalize the Irrigation Policy, 2060.

The main institutional elements that shape the governance of water sector in Nepal at present art the following:

Water Resources Act, 2049 (1992) vests ownership of all the country's water resources in the state. It establishes a hierarchy of water needs and sets the state as the licensor of water use. It also provides for levying a water charge, as prescribed by the state, to the licensee against the use of water resources. The Act allows a licensee to make available services from the use of water resources to any other person based on mutual terms and conditions and to collect charges for the delivered services. For the water resources developed by the state, the service charge would be assessed and realized for the services rendered to water users as prescribed by a tariff fixation committee. Services to any person can be stopped in case of non-payment of such charges, unauthorized use of the services, or for any act that may contravene the predefined terms and conditions. The Act also empowers the government to make necessary rules on matters relating to water fees, charges, etc payable to the state for utilizing water resource related services.

Similarly, ***Water Resources Regulation, 2050 (1993)*** delegates the power to recognize licensed users and resolve water related disputes to the district level. It also provides for a "District Water Resources Committee (DWRC)" in each district, under the chairmanship of Chief District Officer (CDO) comprising of the Local Development Officer and representatives from district level Agriculture

Development Office, Forest Office, Drinking Water Office, Irrigation Office, Electricity Project Office, offices related to utilization of water resources, and the District Development Committee.

Further, ***Irrigation Policy, 2049 (Second Amendment 2060) (2003)*** enforces the concept of decentralized, autonomous, and self-financed management of the irrigation schemes. In management-transferred surface or groundwater irrigation systems, the state would not collect irrigation service fees. The respective WUAs can collect such fees on their own from their beneficiaries as per the operation and maintenance need of the particular scheme.

As observed above, on the evolutionary path of improving governance of water sector, Nepal has come a long way in terms of decentralizing the related tasks and responsibilities. Particularly, after the re-advent of multi-party representation in the government structure in 1990, the process of various stakeholders' involvement in water sector governance (facilitated by institutional changes both in terms of rules and tools) has gained a faster pace and is slowly maturing.

Currently, the organizational structure of water administration in Nepal has three levels: coordination and policy; implementation and operational; and regulatory. At the level of coordination and policy, the organizations in place are: a) National Development Council; b) National Planning Commission; c) National Water Resources Development Council; d) Water and Energy Commission; and e) Environment Protection Council. Similarly, at the ministry level, six relevant ministries and the Water and Energy Commission Secretariat is involved.

At the implementation and operational level, seven government departments and semi government organizations like Nepal Electricity Authority and Nepal Water Supply Corporation are involved. The local government bodies such as District Development Committees (DDCs), Village Development Committees (VDCs) and Municipalities as well as NGOs like WUAs are also in place at the operational level. The prevalent policy and regulations have entrusted the governance of water at the local level to the Water Users' Associations (WUAs) formed by the representatives of the beneficiary. This institution of local organizations with a federation at the central level (viz. NFWUAN) has been projected as the key element at the operational level.

Achievements

Various institutional measures taken over time in Nepal clearly show a substantial shift in the country's approach for governing water resources toward decentralized and user-centered participatory management. Prevailing policies and legal provisions reveal that the government is attentive and willing to involve the stakeholders in the decision making process of governance of water resources. Several measures are dedicated to improving governance by empowering local organizations (Brunner et al, 2002). Such measures, favorable to a pluralistic system of conducting the affairs of the state, have aided behavioral changes in government institutions and strengthened of non-government institutions.

Recent legal provisions are focused towards creating an enabling environment. Irrigation Policy 1997, encompasses mechanisms for maintaining coordination between agriculture and irrigation related entities at various levels. Similarly, National Water Supply Sector Policy of 1998 visualizes a shift for the state organ responsible for water supplies from the traditional role of service provider to that of a facilitator owing to eventual handover of drinking water supply schemes to the users' committees and/or private sector management. Along the same line, the hydropower policies encourage private sector's involvement. The provisions related to authority delegation (decentralization of government functionaries; development of the beneficiaries' organizations; promotion of their active participation in planning, construction, operation and maintenance; water licensing, linkage with the allied agencies and local administration bodies, etc) are all crucial for creating an enabling environment for the evolution of self-governed beneficiaries' organizations (Freeman et al, 1989; Prasad, 1994). They are also essential for ensuring tripartite accountability among the beneficiaries, related state functionaries, and local government bodies (Shivakoti, 1991; Prasad, 1994; Starkloff et al, 1999).

Creation of numerous WUAs has made it possible to maintain organizational linkages among themselves as well as with other entities particularly for resource mobilization. Most WUAs face severe resource constraints but have been able to draw some resources from DDCs and VDCs. In addition to providing small-scale financial and material support for local infrastructures, VDCs are also involved in resolving disputes at the local level whenever problems arise between water uses.

Contributions of the DDCs in the development of water resources, especially in the micro-hydropower systems, have been encouraging. In many instances, the users' committees have initiated the development and management of micro-hydro schemes. The DWRCs have also slowly started undertaking several key activities as district level water management entities e.g. registering WUA for different uses of water, requesting DDC/VDC to resolve conflicts in case of complaints, and recommending government agencies for the construction of the new infrastructure at the request of the users.

Shortcomings

Despite all these various institutional measures, the practice for people-centered governance is not yet complete. There is a general lack of coordination among institutions related to water sector. Overlap of authority and confusion regarding responsibilities and accountability are prominent among different levels of organizations and institutions arising out of non-harmonization of relevant Acts, Regulations, and Procedures, particularly with regard to fees to be charged for a license, rates for royalty, registration of the WUAs, service fees and dispute settlement mechanisms and other regulatory provisions.

Many of the ideas introduced in the policy and related rules have not yet been tried. The ongoing disputes over the implementation of Melamchi water supply project that involves trans-basin diversion is an example such deficiency, where stakeholders have long been accusing the state of deliberately keeping them out of the decision-making process and thus, of undermining the principle of participatory governance in water sector (http://www.southasianmedia.net). Moreover, the compliance rate of the existing legal provisions is observed to be quite low (Sharma and Onta, 2002). The water use arrangements among various sectors are generally institutionalized through the agreement between the water use activities. However, customarily the irrigation receives first priority in Nepal. The development of new water use activity is often based on the informal arrangements among the water users of different sectors.

Recent studies indicate that the groundwater resources are not properly conserved and used due to lack of effective legal provisions (WECS, 2002). Discussions are still underway to include it in a more comprehensive water resources act, which will cover governance of groundwater use (in combination of surface water sources) for different purposes like drinking, industrial, commercial and other uses. Municipalities and private sector are expected to play a magnified role in optimal and sustainable use of groundwater.

Since no organization exists which looks after the overall water balance of the river basins and different departments are concerned only with their own specific use an integrated approach in the utilization of water resources has been limited only to theory. Among different water use activities, except for irrigation and electricity, most are administered privately.

The WUAs have been found to remain effective only during the construction of the irrigation or electricity scheme and become non-functional during the operation and maintenance phase (Sharma and Onta, 2002). The regular task of operation and maintenance does not seem to motivate the WUA members to actively get involved.

The government's intensions of involving the local governments in the management of natural resources (including water) is still far from being accomplished. The role of VDC in water resource management is generally confined to providing occasional financial support for constructing drinking water and maintenance of irrigation systems. VDCs are rarely proactive in managing water resources at local level, mainly due to their unclear role at present. Though, the Local Governance Act provided a sound foundation for an active role of the

DDCs, they hardly get involved in the WUA formation process or in the issuance of licenses to the private sector for water resources development.

The DWRCs are yet to start functioning in almost half of the 75 districts in Nepal. Most existing DWRCs do not meet even once a year. This was primarily due to low priority given to the task especially by the Chief District Officer (CDO), the ex-officio state-appointed chairman, who is hardly accountable to beneficiaries in water resources sector (Sharma and Onta, 2002). Most other members in DWRCs are appointed and not genuinely represented from among the beneficiaries.

The involvement of INGO/NGOs in water resource development is not evident except for the support of few organizations like Action Aid, International Development Enterprises (IDE), Farmer Managed Irrigation Systems Promotion Trust (FMISPT), etc.

DISCUSSIONS AND CONCLUSIONS

Institutional arrangements for improved water governance generally imply three mutually complementing constituents: beneficiaries' organization at different scales; rules and regulations of the organization; and relevant legislative arrangements of the state, or of the states (in trans-boundary cases) in which they operate. Most of the above-discussed institutional measures taken in Nepal have strong linkages with these key attributes of good governance in water resources sector, or for that matters, any natural resource sector (Brunner et al, 2002).

Most shortcomings either emerge from the present institutional weaknesses and/or require solutions that necessitate further institutional changes. The National Water Resource Strategy of Nepal (2002) also profoundly highlights the absence of an appropriate institutional framework for effective integrated water resources management in the country and highlights the need for creating new organizations and redefining functions and structures of some existing organizations to achieve the objectives enumerated in the strategy document.

In collaborative management of any natural resources, an effective beneficiaries' organization is strategic in securing the kind of collective action that defeats free-riding and secures control over resource appropriation and allocation to its members. Beneficiaries' organizations, articulated at different scales, provide a promising means for the resources users to adopt general rules to local contexts, with local knowledge, and mobilize local resources for common benefits (Freeman et al, 1989, Brunner, 2002). In addition, they create a space for authentic participation in the development of community and society, and conserve scarce resources by promoting local responsibility and accountability. State and allied external agencies are expected to support and assist in the growth of these beneficiaries' organizations (ibid).

Even though several of the adopted institutional measures in Nepal have these beneficiaries' organization at their core, appropriate importance has hardly been given to the key necessities of such organizations to perform effectively. If one turns to examples of effective beneficiaries' organizations around the world (e.g. Murray-Darling River Basin Commission, Northern Colorado Water Conservation District, etc), one tends to find four key features generally present (Freeman et al, 1989). Four key features were found to be common among all effective beneficiaries' organizations around the world. The first is the organizational self-autonomy which means that some form of local organization based on the principle of voting and checks and balances in the leadership structure exists. The representatives are accountable directly to the stakeholders and that these organizations are independent of any local or central government influence other than legal certification and auditing.

The second feature is the allocation of water and collection of service fees by shares, meaning that a beneficiary's water right in the association's collective service delivery is roughly proportional to the contributions made by that same individual to the cost of operating and maintaining the water resource system annually, in cash, produce, or labor equivalent. The third key feature is the presence of an organized water delivery work force, however small, appointed and supervised by the organization leadership to oversee the management of water in the coverage area of the resource system. The fourth feature is some form of organized record keeping, no matter how rudimentary, designed to maintain records on labor mobilization, donations and/or fees, water service delivery scheduling, organizational membership, and some rules about how water is to be managed and divided among beneficiaries during normal and unusual water supply conditions.

These key features are unimaginable in an organization without 'enabling environment', 'genuine stakeholders' representation in the organization', and 'accountability'. These characteristics are the building blocks for the decentralized management of common pool natural resource systems (Freeman et al, 1989; Ostrom, 1992).

Various institutional measures adopted in Nepal do reflect a vision for addressing these key characteristics but efforts to ensure that they are in place have largely been lacking. Instead, the focus has been on more and more additional institutional measures such as structuring and restructuring of state's different functionaries, defining and redefining their roles, promulgating one after another legislation, etc, without paying much needed attention to the aforesaid key characteristics at the local level. Most of the shortcomings discussed above substantiate this need in Nepal's context.

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TECHNICAL AND INSTITUTIONAL SUPPORT FOR WATER MANAGEMENT IN ALBANIAN IRRIGATION

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ABSTRACT

Since 2001, Société du Canal de Provence (SCP) has been asked by the French Ministry of Foreign Affairs to provide support in certain specialised fields to a vast program undertaken by the World Bank in Albania to rehabilitate the irrigation networks in collaboration with the Project Management Unit (PMU) of the Albanian Ministry of Agriculture and Food. The support contributed by this work concerns the aspects requiring the intervention of engineers and operators in the irrigation sector. SCP has adopted an approach jointly with Albanian partners and with the oldest Water Users' Association (WUA) in Provence, the Canal St Julien. The pilot command areas chosen for this project are located about 50 kms to the south of Tirana, in the area of Peqin Kavaje and Lushnije. These command areas are managed by 26 WUAs and 2 federations of WUAs (FWUAs). They represent a total irrigated area of 20,000 ha. Topographical data of the Peqin Kavaje main canal were then used to model the canal with SIC[7] software in order to simulate operation of canal in both steady and unsteady flow conditions so that the hydraulic constraints on operation of the facilities could be assessed.

The work undertaken relates to the following main aspects:
- Survey and monitoring of network hydraulic operation and delivery of irrigation water;

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[7]SIC: Simulation Irrigation Canals: computer model developed by the Montpellier CEMAGREF (France)

- Institutional and technical support to the WUAs and FWUAs;
- Training of the farmers and the members of WUAs;
- Technical visits in France.

As a result, the work highlighted the current malfunctions on the canal and led to proposals for solutions:
- On the physical level, concerning the rehabilitation program, in particular, the construction of control facilities of duckbill weir type;
- On the organizational and functional levels, a list of actions and the means to be implemented for ensuring the water service at long term.

This type of intervention is particularly remarkable insofar as it allows organisations with competences and complementary cultures to take part in a project of cooperation in which the institutional and human components have an essential role.

INTRODUCTION

Since the 90's Albania has made considerable efforts to reorganize the agricultural sector. Irrigation has now been completely reorganized through a simultaneous program of infrastructure rehabilitation and management transfer. Some 200 WUAs, each covering about 500 hectares, have been established and have been in operation since then. The WUAs usually manage the secondary canals, while groups of farmers operate the tertiary canals. For operation and maintenance of the main canals, the Albanian authorities decided to establish a FWUA.

The Albanian government sought the assistance of France due to the expertise developed by the French Regional Development Companies in the control of water conveyors and distributors and the long experience of France in the field of participative management of irrigation. In this context, the French Ministry of Foreign Affairs (MAE) included Albania in its programme of technical assistance and signed a four-year service contract with a partnership formed between the SCP and the Saint-Julien Canal WUA.

One of the pilot project carried out by French experts is the Federation of Peqin-Kavaje. This Federation was judged to be representative of the problems encountered by Albanian Federations in institutional and operational management. The purpose is to improve the water management capacities within the pilot project WUAs and the Federation. Specifically, the aim of the Federation is to improve its performance in terms of water distribution to WUAs by introducing and testing new management methods combined with suitable monitoring techniques.

A detailed inspection with an Albanian project team was made, from the intake in the Shkumbinit River to the downstream part of the Peqin Kavaje main canal, during the 2000-2001 closure period. This partly consisted of a topographical survey, in order to update the longitudinal profile of the canal, the position of the structures, and an overall survey of the condition of the canal and all its structures (bridges, footbridges, aqueducts, cross regulators, offtakings, etc). Following this analysis, physical modifications has been proposed in order to adapt the Peqin-Kavaje main canal capacities to the water requirements. The feasibility of implementing a water roster along the secondary canals and its consequences for the operation of the main canal was examined.

These are all contained in detailed and exhaustive Canal de Provence internal report. The paper shall only present highlights of the whole study. In the first section the pilot project and some of its hydraulic features are presented. The second section deals with our proposals for the modernization of water supply and their consequences in term of main canal modifications. The last section describes the capacity building program which has been organized by the team of the project.

THE PILOT PROJECT

The irrigation scheme

The Peqin-Kavaje main canal (see figure 1) is a 42-kilometer long conveyance and supply structure. It is fed from an intake situated upstream of the Cengelaj barrage on the Shkumbinit River. 15 km downstream of the head structure, the canal separates into two branches: the Karina Gose branch and the Peqin-Kavaje branch.

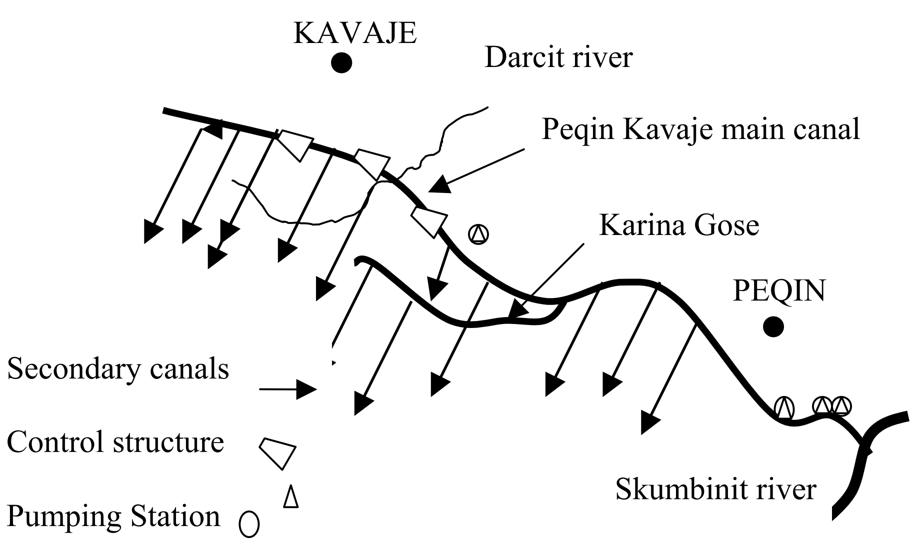

Figure 1. Pilot project irrigation scheme

The Peqin Kavaje federation was created in 1998 and consists of 12 WUAs: two WUAs located on the upstream part in Peqin district which use pumping stations, and ten WUAs located in Kavaje district which use a mixed system (gravity and pumping).

The Peqin-Kavaje main canal supplies 38 secondary canals on the left bank, a few direct irrigation offtakes and some pumping stations. The command area covers around 10,000 hectares. The pilot project has a drainage network which collects the surplus irrigation water and directs it towards Shkumbinit River or the sea. On the drainage network, some pumping takes place to supply some irrigation plots. The canal was designed in 1952 to convey a flow of 7 cumecs. In 1980, the capacity of the first 15 km of the canal was increased to 17 cumecs in order to supply the pumping stations. Due to urbanization, a canal bypass was built in 1998 for all the downstream part of the canal (around 8 km long).

Hydraulic analysis of the current condition of the Peqin-Kavaje main canal

The detailed inspection and the topographical surveys made it possible to model the Peqin-Kavaje main canal in order to assess the current hydraulic characteristics and the current water management. Using SIC simulation model, the analysis had the following objectives:

- To reproduce the waterline at maximum flow on hydraulic longitudinal profiles, in order to identify the current capacities of the main canal;
- To identify zones which limit the canal's capacity;
- To underline the hydraulic constraints for operation of the main canal;
- To check the actual water management methods;
- To link the hydraulic constraints of the main canal to current management methods.

With above tasks, the hydraulic characteristics of the main canal have been defined (maximum discharges, storage volumes, hydraulic delay, etc..). These enable the assessment of hydraulic constraints on operation of the main canal. Two methods were used to estimate the hydraulic delay needed to pass from one operating flow to a new flow on the canal:

- Steady flow computation using two waterlines (one set at the maximum flow and the other at 50% of the maximum flow) as presented in the table 1;
- Unsteady flow computation using the unsteady flow module of the SIC model.

Table1: steady flow estimation of the hydraulic delays

Reach	Ups (m)	Dws (m)	Qmax (l/s)	Max vol (m^3)	Qmax/2 (l/s)	Max Vol/2[8] (m^3)	Delay[9] (mn)
1 & 2	45	3,600	6,400	51,390	3,200	31,600	100’
3	3,600	5,600	5,800	20,800	2,900	12,200	50’
4	5,600	12,480	4,600	61,700	2,300	38,300	170’
5	12,480	15,720	3,000	24,500	1,500	16,100	90’
6	15,720	27,750	2,600	76,600	1,300	44,300	410’
7	27,750	34,570	2,000	31,100	1,000	18,600	210’
8	34,570	38,040	1,600	19,100	800	11,000	170’
9	38,040	41,200	500	3,100	250	2,000	70’
10	41,200	42,380	300	900	150	500	44’
						Total	**22 hours**

MODERNIZATION OF OPERATION

Water distribution

The strategy to distribute the water along the secondary canals

The federation project objective requires that its performances in terms of water supply to WUAs are improved by introducing and testing new management approaches associated with adapted control techniques. The purpose of this section is to analyze the feasibility of setting up rotational distribution along the secondary canals and to determine the consequences for the operation of the main canal.

Rotational distribution along the secondary canals consists in creating a roster on which the flow is successively distributed to tertiary canals. When the tertiary unit (irrigated area supplies by tertiary canal) is too small, which is the case in the Peqin-Kavaje irrigation project (12 ha), the roster can be prepared so that it supply several adjoining tertiary canals (2 or 3) at the same time.
The advantages of this method of distribution, which is widely used, are:

- Each plot is irrigated using the entire flow from the tertiary canal. As a result there is no need to share the flow inside the tertiary unit. The system of water

[8] Max Vol/2 = storage volume in each reach corresponds to the water line obtained with 50% of the maximum flow

[9] Hydraulic delay = $\dfrac{MaxVol - MaxVol/2}{Q\max - Q\max/2}$

allocation to the tertiary canal is based on time and is easy to control and implement.
- The irrigation program can be prepared in advance. This simplifies the work of farmers and operators.

The water requirements

Using the CROPWAT software, the water needs of the crops have been estimated in accordance with the cropping pattern. The curve in figure 2 shows the continuous flow required along the main canal in order to satisfy the needs of crops. This flow is expressed in l/s/ha.

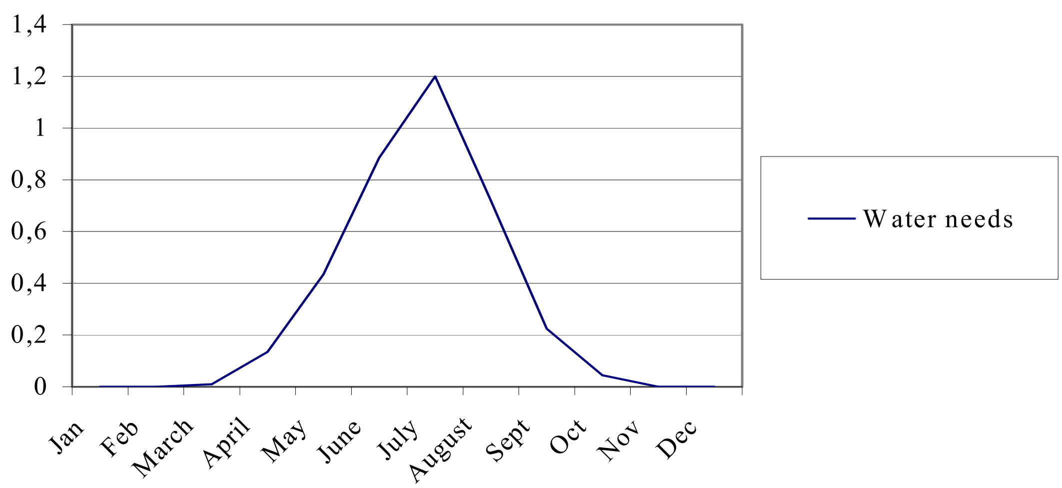

Figure 2. Water needs to supply the crops

The irrigation period can be broken down into three sub-periods:
- The peak period is between May 15 and September 15 when requirements are more than 0.6 l/s/ha.
- Two periods of two months, at the start and at the end of the irrigation season when the needs of crops are less than 0.6 l/s/ha.

The night irrigation issue

According to the federation, farmers do not want to irrigate at night and therefore the gates supplying the secondary canals are normally closed during the night. The issue of night irrigation is crucial to canal management. This controls the possibility of organizing a rotation of the secondary canals, to transfer flow towards the downstream users which are largely underfed by current practices. This strategy to distribute the water has been analyzed through two alternatives:
- Continuous distribution (24 hours a day) along the secondary canals;

- Discontinuous distribution along the secondary canals, allowing farmers to irrigate their plots only during the day (12 hours a day).

For each alternative, the consequences on both physical modernization and operation of the main canal have been analyzed. The conclusions on the ability to fulfill the requirements have been given.

Modernization of the main canal

Alternative 1: Continuous distribution (24 hours a day)

The secondary canals remain always open and the tertiary canals are operated based on the water roster. The time between two successive operations of a same tertiary canal correspond to the duration of the water roster. During a same water roster, the duration of the operation of a tertiary canal correspond to the time needed to satisfy the water needs for the crops.

Unless incidents occur, the networks will operate smoothly: Operation will be limited to simultaneous opening and closing of tertiary offtakes and some adjustments at the head regulator on some secondary canals. This organization of distribution is suitable for upstream control. Considering the small number of changes that would be required during the irrigation season, it would be possible to keep the existing structures after rehabilitation (cross regulators). However, to increase the flexibility of the operation and to limit the human intervention along the main canal, the implementation of duckbill weirs or longitudinal weirs has been proposed. In addition no electrical power, level detectors and controllers are needed.

The installation of control structures such as weirs will allow substantial head to be maintained in the canal and limit the level fluctuations at the offtakes. This has three major advantages:
- Easier supply to head gates of the secondary canals (more head at low flow);
- More accurate control of flows delivered to the secondary canals (limited level fluctuations in the canal);
- Reduction of the hydraulic delays along the main canal.

However, it should be specified that the weir setting is governed by the following points:
- The length of the weir depend on the head required at the weir with maximum discharge;
- The elevation of the weir crest must ensure that the structure operates with free flow;
- The number of weirs to be installed depend on the canal slope and the number of head gates of secondary canals affected by the structure;

- The presence of weirs will increase the sedimentation upstream of the structures. The presence of a gate at the end of the weir will facilitate cleaning and draining, and allow the operator to proceed to flushing operations.

Concerning the modernization of the head gates of the secondary canals, the best technical solution will consists in installing baffle distributors at each turnout. These baffle distributors are used to both control and measure flows. However, this is expensive equipment and requires the installation of civil works.

The application of the simulation model has determined the required settings for fourteen (14) weir crests. Each crest elevation was set in order to:
- Ensure that the weirs operate in free flow conditions,
- Allow correct supply to the baffle distributors (operation with +/-10%).

The site of the weirs on the canal was determined based on the position of the secondary canals, and to avoid further heightening of the banks. With regard to the baffle distributors:
- The nominal discharges chosen correspond to the values obtained for the water roster;
- They were all set in order to adjust their nominal discharge to within +/-10%.

The tables 2 and 3 below give example to adjust theses hydraulic structures.

Table 2. Weir settings – example

Location (m)	Flow max (cumecs)	Length (m)	weir elevation (m)	bottom elevation (m)	water level max (m)	Structure
33531	2.000	15	22.53	20.8	22.68	Duckbill
40088	0.5	3.6	13.5	12.78	13.66	Long weir

Table 3. Baffle settings - example

Baffle distributor	Nominal discharge (cumecs)	Nominal Head (m)	Maximun head (m)	Minimum head (m)	Head variation (m)
X2 150	125	22.65	22.68	22.62	0.06
XX2 360 X2 120	475	13.54 13.54	13.66	13.50	0.05

Alternative 2: Discontinuous distribution (12 hours a day)

Discontinuous distribution allows farmers to irrigate their plots only during the day (12 hours a day). Therefore the duration of a tertiary canal operation cannot exceed 12 hours consecutively and the operators are obliged to open the gates of all the secondary canals in the morning and close the gates in the evening. This operation will have an impact on the management of the main canal.

It appears clearly that implementing a water roster without night irrigation generates sharp variations in the flow regime on the main canal, and requires much greater transit discharges than with the previous alternative. For transit discharges, significant canal works would be required. In its current state, the Peqin-Kavaje main canal is unable to cope with the variations generated by this alternative. Additional works would consist in:

- Creating an intermediate reservoir in order to increase the storage capacity of the canal;
- Increasing the transit capacities on certain sections of the canals.

ORIENTATIONS OF THE MODERNIZATION

Based on our recommendations, the Albanians involved in the project decided to modernize the main canal following the strategy of the alternative 1. On this basis, an investment programme taking into account this strategy was prepared in close collaboration with the Albanian counterparts (PMU). Due to the significance of the work and the stakes that this work represented for future management of the main canals, the PMU was provided with technical support and consultancy services for the completion of this work. These services consisted of validating the detailed designs for the construction of the new control facilities realized by the Albanian partners, and defining with the PMU the list of priority works to be executed. In 2001, three duckbill weirs have been constructed. Their implementation in the field, which was financed by the World Bank, was completed under the supervision of Albanian consulting engineers. These facilities are now operational.

As the result of the project's physical modernization, a local consultant has been trained on the job in Albania and in France. The local consultant is now capable of identifying designing and supervising all physical improvement in irrigation canals.

CAPACITY BUILDING

It is deemed that without having a new generation of properly trained irrigation managers a successful modernization of the irrigation schemes in Albania is clearly at risk. The aim of this component of the project was to help Albania in undertaking a training and capacity building program in the field of irrigation management and canal operation, drawing from up-to-date hydraulic and flow control expertise as well as practical experience from irrigation scheme managed by farmers. The capacity building has been achieved through professional training modules and technical visits, both in France and Albania and by creating partnerships between professional from both sides. This partnership materialized in February 2002 with signatories enjoining Saint Julien WUA and the Federation of Peqin Kavaje, in the presence of the Albanian Minister of Agriculture in an official protocol.

In this context, training activities have been developed to enable Albanian farmers to benefit from French experience. Saint-Julien WUA in France was chosen due to its age (the canal was dug in 1171), the dynamism of its managers and representatives, as well as its hydraulic and agronomic characteristics and its area, which is comparable with the areas of the Albanian projects. Although there are notable differences between the contexts of the two countries, the associations' representatives noted many similarities in the operating constraints and practices used on the irrigation networks. The discussions related mainly to:
- Techniques for collecting irrigation fees and their effectiveness;
- Tariffs applied;
- Allocation of the income collected;
- Representativeness of farmers and the organisation of elections;
- The constraints due to operation and maintenance of the networks;
- The organisation of the technical and administrative team in charge of the operation and management of the networks;
- Relations between farmers and WUAs;
- The role of the State and the local authorities in the management of WUAs;

These meetings between the managers of irrigation associations led to a sharing of experience and exchanges on precise problems encountered in daily management

CONCLUSION

A list of activities and the means to be implemented has been developed. These recommendations, which are intended for the federations and Associations and also to all the players involved in irrigation in Albania, will:
- On a 3 to 5-year time frame, guarantee a reliable supply of water to the plots requiring a dependable resource, control conveyor and distribution infrastructure operations, and ensure equitable sharing of water between and within the associations,
- On a 5 to 10-year time frame, enable them to cope with an increase in demand for irrigation water which will require that the efficiency of the networks is improved, the operation of the conveyor and distribution infrastructures are even better controlled, and be able to accept more members,
- On a 10 to 15-year time frame, ensure the lasting quality of the water service by satisfying all the users equitably.

AN IRRIGATION DISTRICT PERSPECTIVE ON MANAGEMENT OF GROUNDWATER SUPPLIES FOR AGRICULTURAL, INDUSTRIAL AND MUNICIPAL USERS

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ABSTRACT

A fundamental issue of concern for Oakdale Irrigation District (OID) is maintaining a sustainable balance between groundwater use and groundwater recharge in the face of growing municipal and industrial water demands. Meanwhile, as groundwater use increases, key pathways for groundwater recharge are expected to decline due to the urbanization of farmland and conversion to irrigation methods which reduce the amount of deep percolation (i.e. surface to drip irrigation). All these issues are complex and interrelated and will require a coordinated regional effort to resolve. Furthermore, the coordination needs leadership and knowledge of water resources planning that only irrigation districts can provide. This paper discusses the development and activities of OID as it pertains to regional groundwater management, as well as the regional need for irrigation districts to coordinate the management of groundwater.

INTRODUCTION

The Oakdale Irrigation District (OID) was organized on November 1, 1909, under the Wright Act. In July 1910, the OID and the South San Joaquin Irrigation District purchased an established ditch system known as the Tulloch System. The Tulloch System had been developed in the 1880s by Charles H. Tulloch, primarily serving the Knights Ferry community with diverted water from the Stanislaus River. Since that time the OID has expanded its service area to encompass approximately 72,345 acres, of which an estimated 55,000 acres are irrigated to produce a variety of agricultural crops, largely irrigated pasture, nut crops, corn (silage) and rice.

Approximately sixty percent of OID's service area lies south of the Stanislaus River and is within the Modesto Groundwater Sub-basin. The remaining forty percent of the service area lies north of the Stanislaus River and is within the Eastern San Joaquin Groundwater Basin. OID operates and manages 27 agricultural deep wells and 43 reclamation pumps to supplement surface irrigation supplies, in addition to operating and maintaining 18 domestic wells. OID

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manages more groundwater well systems than any other single user within its service area, including the cities of Oakdale, Riverbank and Escalon combined. OID, in cooperation with other members of the Stanislaus-Tuolumne Rivers Groundwater Basin Association, is developing an Integrated Regional Groundwater Management Plan (IRGMP) for the Modesto Sub-basin. The IRGMP will address a number of priority basin issues.

PERSPECTIVE

Competing Interests

In the Central Valley region of California, as well as other regions in the Western United States, there has always been fierce competition for the control, distribution and utilization of water resources. The development of the State Water Project and the Central Valley Project has further intensified this struggle, especially for surface water resources. Pressures for water to meet the domestic, environmental, industrial, and other "high value" demands have led to increased competition between these sectors and agricultural users (Burke & Moench, 2000). With virtually all of the surface water resources allocated and new development projects halted, the dependence on groundwater resources is increasing. An estimated 30 percent of the total water demand in the San Joaquin River basin is met utilizing groundwater (DWR, 2003). It is anticipated that the largest growth in California in the next 25 years will be within the San Joaquin River Basin along the Highway 99 corridor. This growth will further intensify the taxing of groundwater resources. As this development occurs certain planning issues will have to be resolved. One of those major issues will certainly be water supply.

Information Deficiencies

Local planners and elected officials will be making decisions on zoning for residential, industrial and commercial growth and they will need and should take into consideration information available on groundwater resources. The information needed is not limited simply to the yield of the aquifer; water quality, land subsidence, and recharge potential are a few examples of the information that needs to be considered and evaluated prior to making decisions on growth. Unfortunately, local planners often do not have access to critical information, provided that the information is even available. Suburban and rural cities generally have strong public works departments who operate and maintain water distribution systems within defined areas; however they seldom employ designated technical staff capable of analyzing trends in data in regard to groundwater resources within an entire basin. The lack of information for proper planning, protection and production of groundwater clearly points out the importance of an irrigation district's role in the development and sustainability of groundwater resources. Irrigation districts are in the business of resource management and employ technical and managerial staff knowledgeable in water resource issues.

Plan, Protect, and Produce

OID utilizes a three step approach to resource management; Planning, Protection and Production. In regard to groundwater resources the planning effort OID is executing is the development of an Integrated Regional Groundwater Management Plan (IRGMP) for the Modesto Sub-basin. One of the key components of the IRGMP is the development of Basin Management Objectives (BMOs) for all stakeholders in the Sub-basin. The goal of the BMOs is to identify the issues that all stakeholders feel are essential in the protection of the groundwater resource. Table 1 outlines specific BMOs that have been identified thus far through the development of the IRGMP.

Table 1. Modesto Sub-basin Management Objectives

Basin Management Objective	**Intent**
Protection of Natural Recharge Areas	To develop specific planning actions that offer varying degrees of protection depending upon an area's significance as a source of recharge.
Development of a Water Budget	To provide essential baseline data on water needs and groundwater conditions and serve as a tool for assessing the likely impacts of proposed groundwater management actions, and enable evaluation of the impacts of ongoing changes in land use and water management on the basin's groundwater resources.
Evaluation of Artificial Recharge Areas	To identify those areas were recharge basins could be constructed if results from the water budget indicate that additional recharge is needed. In addition, converting agricultural users from groundwater to surface water in these specific areas.

Basin Management Objective	Intent
Optimization of Well Field Operations	To fully understand the operation of well fields and their interactions with other well fields within the basin. Primarily to minimize the overall cost of groundwater extraction, maintain groundwater levels, reduce or eliminate well interference, avoid migration of containment flumes, and water conservation through reduced spill of surface water conveyance systems.
Identification of Conjunctive Use Programs	To develop an integrated approach to balancing surface and groundwater use to support other BMOs
Support Public Health Programs	To assist local agencies in complying with public health standards in regard to the construction and demolition of wells
Water Quality Management	To conduct a detailed geologic assessment of the basin, focusing on the areas with poor quality water, to identify the sources of contaminants. In addition development of a GIS based map to identify recharge areas that would have significant impacts on the control of migrating contaminants.
Monitoring of Subsidence	To measure the rate of inelastic land surface subsidence within the basin. Doing so will provide information on the performance of the implemented BMOs as well as provide for prevention of property damage due to subsidence
Policy Assessment	To foster coordination and cooperation among participating agencies to manage the basin and provide a framework for formulation of regional policies for the protection and use of basin water resources. Moreover, to assist in the formulation of basin-wide water conservation measures, including incentive programs and water audits.

Consequently, the regional implementation of the BMOs by all stakeholders will lead to sustainable protection of the Modesto Sub-basin. The protection activities will ultimately revolve around water quality, recharge pathways, and conservation. The regional aspect of the protection activities is important; multiple agencies will need to insure that the protection methods have no agency boundaries and that the activities are consistent throughout the entire basin. Moreover, the production portion of groundwater resource management is essential to providing agricultural, environmental, industrial and municipal stakeholders the flexibility and knowledge required to maximize the effectiveness in management of the groundwater supply. Through solid planning and protection of this water resource, sustainable aquifer production and yields are attainable, and as a result, societal and economical growth within the basin can be accomplished.

Management

Management of a misunderstood and non-quantified resource is an extremely arduous task. When developing a management strategy for groundwater it is critical to address the physical constraints of the resource as well as the ability to adjust to the variability of that resource. In order to develop effective approaches and institutions for groundwater management, the underlying factors causing specific problems and limiting society's ability to respond to them have to be addressed (Burke & Moench, 2000). However, it is important to note that an exhaustive effort to monitor and analyze the physical aspects and interactions of the aquifer can often be expensive and time consuming, resulting in data that is out of date and effectively useless in making real-time management decisions. The ability to be flexible in management practices and approach will result in basin wide groundwater protection. Flexibility implies the development of policy frameworks that enable management approaches to be tailored to reflect the social, economic and physical resource conditions prevailing in different management areas (Moench, 1994). Moreover, all interests, ranging from industrial use for cooling water processes or municipal water for recreational facilities, need to realize that it is essential to be regionally adaptive and understanding of the issues that each of the individual stakeholders are operating under. A second dimension of flexibility has to do with the willingness of specialist and decision makers involved in groundwater management initiatives to accept participatory planning and to respect the perspectives and knowledge of all stakeholders-particularly local users (Burke & Moench, 2000). The flexibility in response to the burdens and limitations of the basin must be shared equitably among all substantial groundwater interests within the basin. Individual agricultural and rural domestic wells are often not substantial enough in the scheme of an entire groundwater basin to have significant negative impacts on the resource. However, it is important to be able to recognize that these users are present and account for their cultural and quantifiable uses of the resource. Groundwater management initiatives will fail unless they influence the behavior of stakeholders whose actions individually or as a group have major impact on the condition of the resource base (Burke & Moench, 2000). For this reason, during the development of the IRGMP the Stanislaus-Tuolumne Rivers Groundwater Basin Association has solicited the participation of all basin stakeholders.

Moreover, management of the Modesto Sub-basin will involve an ongoing wide spread education program. Groundwater interests in the basin will need to be updated regularly as to the status and conditions of certain aquifer parameters. While the importance of educating stakeholders is acknowledged, it is equally important to educate and raise awareness of the public and policy makers as a basic principle for effective groundwater management (Burke & Moench, 2000). As more information about the basin becomes available it will be an essential task of the Stanislaus-Tuolumne Rivers Groundwater Basin Association to insure that the data is presented properly and disseminated to the appropriate decision makers as well as the general public. Educating the general public on the conditions of their primary water supply will encourage water conservation practices as well as protection of water quality. By providing the public with an opportunity to have some understanding and recognition of the importance of groundwater resources, management activities within the basin will be accomplished with greater ease.

CONCLUSION

Through the development of the IRGMP the Stanislaus-Tuolumne Rivers Groundwater Basin Association hopes to achieve a plan for the long term sustainability and enhancement of the Modesto Sub-basin. Each member in the association has and will continue to be a vital resource in the protection of the basin. The efforts of all members should be recognized. Specifically, the cities of Modesto, Oakdale and Riverbank are recognized for their understanding of the importance of groundwater management. Each municipality has a unique interest in the groundwater resource; however a common thread among them is the need to protect water quality and quantity, which leads to sustaining key recharge pathways as well as the development of new ones. Sustaining key recharge pathways is also a goal of both the Modesto and Oakdale Irrigation Districts. The continued application of surface irrigation water provides recharge, protects surface water rights and promotes the production of agricultural commodities within the basin. The importance of the irrigation districts to the entire basin revolves around their knowledge of water resources. This knowledge when shared with policy makers within the basin can result in effective and thoughtful land use planning. Stanislaus County is ultimately a key contributor to the overall effectiveness of the management activities. If by preventing development of essential recharge areas within the basin and encouraging development to occur in areas with less impact, the basin management objectives will be more successful in their application.

Finally, although many of the agencies listed above are extremely adept on management activities only one type of agency is suited to oversee and truly manage the groundwater basin. This type of agency is an irrigation district. As previously stated irrigation districts have been involved in resource planning and management for more than 100 years in California. The social and economic impacts that poor management of such an essential resource endangers, would be devastating. Irrigation districts have a vested interest in the protection and development of water resources, as well as a vested interest in the social and economic well being of the communities in which they are situated. In many instances irrigation districts provided for the growth and development of the cities and towns that now rely on this resource. If irrigation districts were to manage basin wide groundwater programs and were afforded the opportunity to influence policy makers in regard to development and zoning decisions; sustainability and protection of groundwater resources should be realized.

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WATER USERS ASSOCIATIONS & THEIR RELEVANCE TO WATER GOVERNANCE IN SUB-SAHARAN AFRICA

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ABSTRACT

Over the past two decades a substantial body of knowledge has been generated in understanding how communities at local level organize and implement systems for managing water for agriculture—i.e., 'water users associations' (WUA). These have been implemented in many countries with varying degrees of success. However, there is now increasing emphasis on creating institutional mechanisms for river basin management, which adds considerable complexity to efforts to improve water management. Water scarcity and competition for water at basin level is largely driving this process. This emphasis on the basin level also has important implications for WUAs, who are being saddled with new and more complex roles before they are even coping with local water management.

This paper reviews recent experiences with WUAs in the context of river basin management, particularly in Asia and Africa, and synthesizes a few lessons and principles of significance to water governance. The focus is on Sub-Saharan Africa where the problems are especially difficult. Aspects discussed include indigenous and induced arrangements for water management at local levels and how they can be integrated with formal top-down legal and institutional arrangements; the sustainability, practicality and feasibility of selected governance concepts currently being promoted by the international community; and the policy measures necessary to improve the likelihood of success.

INTRODUCTION

Since the late 1970s, considerable efforts have been devoted to understand, develop and support the organizations associated with managing irrigation systems, that is, water users associations (WUA). In many forms these institutional arrangements are now responsible for managing the water delivered to much of the world's irrigated agriculture. Some institutional arrangements have been in place for decades and even centuries, whereas others are relatively new, either having been created as part of efforts to transfer management of the systems to the users, or, less common, developed with the construction of new irrigation systems.

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The overall goal of this paper is to take a critical look at the recent evolution of WUAs, particularly in Asia where much has been done over the past three decades, compare this with the present conditions and needs in sub-Saharan Africa, and draw lessons, particularly for sub-Saharan Africa. This is done from the perspective of managing water in a river basin context. Managing river basins has emerged as one of the major challenges facing all countries, but especially developing countries, in the 21st century (Vermillion & Merrey, 1998; Svendsen, ed., 2004).

Given that water governance is a large, complex and continuously evolving subject, this paper cannot be a comprehensive review. Rather, the aim is to determine and characterize selected water governance issues, especially in agriculture, and their implications for improving the governance of water in sub-Saharan Africa.

GOVERNANCE

Rogers and Hall (2003) define water governance as the range of political, social, economic and administrative systems established for the development and management of water resources and water services at all scales. It needs to be considered at basin and sub-basin scales, within sectors (e.g., agriculture), inter-sectorally, and should encompass the management of the land-use within a basin that affects the characteristics of the resource downstream. It includes establishment of the rules, responsibilities, operating mechanisms, policies, and user and official accountability systems. Effective governance is that which provides water for livelihoods and economic growth, yet maintains a sustainable environment.

All river basins already have, to some extent, some form of formal and informal governance systems in-place, which are characterized by the particular social, cultural and political setting of that basin (Rogers & Hall, 2003). Each river basin has its own unique physical, social, environmental and economic characteristics, is at its own unique level of development, and has its own unique administrative and institutional arrangements. A few basins are still “open,” i.e., there are still more water resources that have not been developed, but increasing numbers of river basins around the world are “closed,” i.e., have no more water available for development (Molden & Sakthivadivel, 1999). This issue has profound implications for basin governance.

The above said, it is important to qualify that in sub-Saharan Africa the concept of a 'closed' basin is not as pertinent as in other parts of the world. Many basins in this region, such as the Ewaso Njiro North in Kenya and the Ruaha in Tanzania, are experiencing intense competition for resources and are subjected to frequent shortages and in the broad sense of the concept, are “closed”. However, given the low level of physical development of these basins this is occurring at relatively low levels of utilization of the resource. If there were more storage capacity to capture wet season runoffs there would be a better capability to meet growing demands and reduce the impacts of the droughts.

The relative paucity of infrastructure development in sub-Saharan Africa is an important consideration when comparing its agricultural water management with that of Asia or elsewhere, and how it may develop in the future. The general development environment is not as favorable towards investing in agricultural water as it was in the "Green Revolution" era when considerable financial resources were available and helped drive the development of water infrastructure in Asia.

Water governance is inherently political, and politics determines the vision and the agenda as well as the extent to which institutions are actually put in place and made effective. The extent to which the necessary institutions are in place determines whether the vision is fulfilled and the day-to-day management is undertaken. Also, politics, as much as any thing, greatly affect the development trajectory of a given basin.

Improvements to governance are promoted to address a wide range of issues including: pollution, poverty, allocation regulation and development, i.e., construction of infrastructure (Sakthivadivel & Molden, 2002). Improved governance is also promoted where there is a perceived threat of conflict over water, and in other situations where water is considered to be an area for cooperation, i.e., where for example countries sharing a basin must come to agreement before the basin can be developed for mutual benefit, and, in some case, as a tool in maintaining and improving diplomatic relations between countries. Where improving the governance has been deemed necessary, the appropriate interventions have to be tailor-made for that basin, although a broad understanding of best practices from elsewhere is an important input to the process.

According to Rogers & Hall (2003), key principles for achieving and sustaining effective water governance are:

- stakeholders be involved in the governance of the systems at the relevant levels, and achieving this requires the institutional and policy environments to facilitate the necessary levels of participation;
- facilitation of action and removal of obstacles, and try to be inclusive, accountable, participatory, transparent, predictable and responsive. Without these elements the economic, social and political risks increase.
- institutional and administrative framework within which stakeholders from all levels can agree to coordinate and cooperate.

Governance of water for agriculture, which is the dominant water user in most basins in Asia and Africa, is essential to ensuring governance of water in general.

Indigenous local water management organizations have been forming and evolving throughout the world for centuries, including in Asia and Africa (Shah et al, 2001). For more than thirty years a substantial body of knowledge and community of practice has been generated in understanding how communities at local level organize and implement systems for managing water for agriculture—i.e., WUA. Based on this, there have been many attempts to replicate such organizations and, specifically, transfer the management of previously public-run irrigation systems to the water users. This process is referred to as "irrigation management transfer" (IMT).

In Asia, the focus of improving agricultural water management over the past three decades has largely been on the software, as much of the hardware had already been constructed. In fact, much of the motivation behind this effort was on the fact that top-down, hardware focused management of irrigation systems was performing poorly. It has also been driven by the need to reduce government budgets, and a belief, or perhaps hope, that the necessary capacity lies with the users or local non-government organizations. Efforts to improve water management in agriculture usually include a basic strategy for user participation in the management and transfer of responsibilities to the users (irrigation transfer).

Results have been mixed, either because the users still expect the public institution to manage the systems, or the enabling environment is not sufficiently supportive for the WUAs to implement their new responsibilities. There are a number of reported cases of failure of users to properly manage systems after they were transferred where the primary cause was missing elements from the enabling environment, such as lack of financial rigor, no clear water rights, and poor clarity regarding accountability for users and the government agency (Merrey, 1997; Vermillion & Garcés-Restrepo, 1998; and Samad & Vermillion, 1999).

Irrigation transfer has sometimes been successful, such as the case of the pilot transfer of small and medium irrigation systems to the users in Vietnam (Ringler, Cong, and Huy; 2002). The primary goal was to reduce the burden on the national budget, but it also improved the reliability of water supply, better tail-end performance, expanded the irrigated area, created more fiscally efficient O&M, and improved both the proportion and speed of fee collection. In some countries, governments have succeeded in reducing their costs through IMT, though farmers have not necessarily filled the gap (e.g., Sri Lanka, Indonesia, India); most of the 'success' cases in fact come from middle income countries with a strong commercial agricultural sector (e.g., Mexico, Turkey).

From Merrey (1997) and other literature basic prerequisites for the successful and sustainable transfer of irrigation systems to the users include:

- farmers must find ways to cover the costs of operation and maintenance;
- a long-term government commitment to a solid and practical policy;
- clear and transparent water rights and distribution arrangements;
- legal recognition of WUAs; and
- profitable agriculture.

The weakness of public institutions has long been recognized as a key constraint to governance, both for agricultural water and water in general. Poor performance, lack of a service orientation and slow adoption of innovation are symptoms of acute policy and management constraints within existing institutions. Despite considerable efforts in irrigation management, viable alternatives have been slow to emerge. Even in attempts to transfer management to the users, in many cases the responsibilities did not transfer; either the government department declines to let go of its authority, or the farmers themselves decline to accept what often seems a burden not an opportunity. Merrey (1997, 1996) considers that "radical decentralization" and even abolition of existing public organizations may have higher returns in the long-run rather than attempts at incremental reforms of rigid, ineffective, and, in some cases, corrupt institutions.

In Africa, the experience with IMT has been even less encouraging than in Asia. Shah, van Koppen, Merrey, de Lange, and Samad (2002) reviewed the evidence on irrigation management transfer in Africa and conclude that even where countries have gotten the 'process' of transfer right, the conditions are not conducive to success. Driven largely by financial pressures, governments throughout sub-Saharan Africa are in the process of transferring responsibility for irrigation management to farmers through WUAs or other farmer-based organizations. While large-scale commercial farmers have welcomed this reform, the result of government withdrawal from many of the smallholder schemes has been complete collapse. A review of international IMT experience shows that in the areas where IMT has worked, the irrigation system is central to a dynamic, high-performing agriculture; average farm size is large enough for a significant proportion of the farmers impacted to operate like agri-businessmen; backward linkages with input supply systems and forward linkages with output marketing systems are strong and well-developed; and the costs of self-managed irrigation are an insignificant part of the gross value of product of farming. These conditions characterize Mexico, Turkey, USA, and New Zealand—the countries from which IMT success stories emerge. These conditions are also found to varying degrees in parts of India, China, Indonesia, and other Asian countries—where IMT has had more limited success. In these situations, IMT worked because it made good economic sense to the farmers involved.

But these conditions are rarely found in sub-Saharan Africa. In much of Africa, irrigation schemes are designed to provide very small plots to many people, such that they are not the major source of household income. Schemes are often costly to operate and maintain, for example schemes based on imported pumps, or that require large numbers of people to cooperate effectively. Linkages to input markets, information and other support services are weak or non-existent, while output markets rarely work well, or transport costs are so high that the farmers' produce is not competitive.

BASIN PERSPECTIVE

Shah et al. (2001) describe three basic forms of institutional model for the management of basins. These are "hydrological", "administrative", and what is essentially a hybrid of the two. The hydrological model is where the area of responsibility of the primary authority is determined by the hydrological boundaries (i.e., the basin). In the administrative model either the province, state or other administrative unit is responsible for the governance of water resources with no regard for the hydrological boundaries. The hybrid is the administrative model with some form of coordination mechanism, such as a basin commission, overlaying the administrative boundaries. In reality, the governance of a basin is generally some hybrid, with a tendency either towards hydrological or administrative governance of the basin.

Water institutions in the developed world have, as the needs and resources have changed, evolved over a considerable time into formal and organized entities (Shah et al, 2001). Although many such basins do have some form of hydrological institutional arrangement, these are often not the primary institutions governing water. In fact, institutional arrangements are generally complex, as described by Svendsen (2001; 2004 forthcoming) for the Central Valley of California. In fact, for most rivers in the western United States any basin level institutional arrangement has a coordination role rather than an authority type role, and the overall management of the basin depends on relatively well resourced institutional arrangements at various administrative levels.

In the developing world, the governance arrangements are generally more administrative than hydrological, and efforts to either restructure or enhance the institutional arrangements towards a more hydrology-based model (e.g., river basin organization), with the assumption that this will lead to enhanced integration of the management, has had disappointing results (Shah et al, 2001). Despite significant encouragement, including conditionalities on financial assistance, development of basin organizations in the developing world is at best a slow process.

Shah, et al (2001) caution that experience has shown that there are "limits to leapfrogging", that is successful water governance models from developed countries cannot be transferred to developing countries, particularly given the problems facing developing countries (for example supporting agriculture carried out by large numbers of small and poor farmers) and the institutional capacities of these countries are too different from the rich countries. That said, there are some common themes that emerge from the evolution of governance arrangements.

The Brantas River in Indonesia has been developed over the past forty years. Initially the primary focus was flood control and then irrigation, but by the mid-1980s water supply for domestic and industrial needs became a major factor in planning and managing the basin. Now, with a relatively high level of infrastructure developed, the focus has become demand management and considering transfer of water from the agricultural sector to higher value uses. From the outset, the development had a basin level focus, yet the basin development agency did not have a mandate for operation and maintenance (Sunaryo, 2002), which was the responsibility of provincial water agency, i.e., an administrative institutional arrangement.

Despite Indonesia having a basin level perspective, a long history of indigenous user-managed systems and some recent history of developing WUAs, it is only in the current reforms, which include devolution of responsibilities for water management to the sub-Provincial level (Kabupaten), that recognition has been given that users should be included in the decision making. However, in larger basins this has meant that there are many different stakeholders to be coordinated (Sunaryo, 2002). Also, with the existing variety of responsibilities for aspects of water governance there already is duplication and confusion, which the decentralization process is not necessarily improving; this has raised concerns over governance and even the potential for conflict (Rodgers, Siregar, Sumaryanto, Wahida, Hendradjaja, Suprapto, and Zaafrano, 2002).

As with Indonesia, Ethiopia has a history with a basin approach to water development. In the 1960s Ethiopia, with support from the United States, developed a water resources development plan for the Blue Nile (Abbay) river. Also, a basin agency has been governing the Awash basin for the past few decades (Taddesse, McCornick and Peden, 2004). The present policy of the Ethiopian government is to establish basin organizations for the major basins, including the Awash and the Blue Nile that will, among other things, coordinate between the riparian Regions (Provinces) in a given basin, which have the primary authority for water governance. A major concern is that it is these are additional institutions that need public resources in a setting where funds are insufficient for the existing institutions. Large cost, capacity and even constitutional issues are raised in developing basin-level river basin management institutions; and this does not even begin to address the transboundary dimensions given the international nature of the Blue Nile.

SYNTHESIS & CONCLUSIONS

From the decades of work on agricultural water management, it is clear that creating effective WUAs takes time, particularly where no similar institutional arrangement exists, and it needs to have the right enabling environment.

In addition to the key principles for achieving and sustaining effective water governance, which were identified at the beginning of this paper, it is essential that the economic conditions be present that make irrigated agriculture a going concern for farmers. From the experience with WUAs, achieving this has been a tall order even in Asia where much of the physical development has been achieved.

In conditions where the infrastructure has yet to be well developed, such as most sub-Saharan African countries, the governance arrangements need to include the necessary enabling policy and economic environment, and capacity to effectively plan, implement and, perhaps most challenging, finance such developments. This is a tall order. While in Asia, WUAs have been promoted in conditions where much of the supporting infrastructure is more or less in place, and where there are markets that work, making agriculture potentially profitable, these conditions are less prevalent in Africa.

Effective management of river basins is a major challenge, and it is evident that this has to be done with a basin perspective. However, this does not necessarily require that there be an overall basin management organization. In the western United States, the institutional units with the majority of the authority and technical capacity are administrative (eg. States), as too is the case in Indonesia and in other parts of the world. Allowing that there are "… limitations to leap-frogging...", given the lessons from agricultural water management that it does take considerable time to develop new institutions and results are mixed, the promotion of basin level organizations needs to be done with due consideration for the existing administrative arrangements, including whether these agencies need to be strengthened, rather than replaced with new institutions.

A major consideration in all governance improvement efforts, whether it is associated with agricultural water management or the entire basin, is that stakeholder involvement in governance is not sufficient in itself and, as indicated in the case from Indonesia, can even further confuse the situation. Given the real costs of involving stakeholders in the governance of the greater basin, decisions with regard to stakeholder involvement need to be realistic, taking account of the resources available to maintain these arrangements and local institutional and financial capacities.

Despite facing enormous problems, many Asian countries are evolving institutional arrangements for water management at both local and basin levels that over time will lead to more sustainable and productive water management. These challenges are more daunting in sub-Saharan Africa where, in addition to the relative under-development of infrastructure, weak policies and limited institutional capacities, the general development environment is not as favorable towards investing in agricultural water as it was in the "Green Revolution" era which helped drive the development of water infrastructure in Asia.

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RECONCILING TRADITIONAL IRRIGATION MANAGEMENT WITH DEVELOPMENT OF MODERN IRRIGATION SYSTEMS: THE CHALLENGE FOR AFGHANISTAN

Thomas Panella[1]

ABSTRACT

This paper provides the following: (i) a background of water resources and irrigation in Afghanistan; (ii) an overview of the current status of irrigation in Afghanistan; and (iii) a set of issues that need to be addressed for sustainable outcomes in irrigation and water resources management and development in Afghanistan. In presenting the brief overview of the current state of irrigation, the paper identifies important factors affecting the future of irrigation management and development. An important challenge for Afghanistan is to maintain the strong tradition of community-based participation in irrigation while at the same time to respond to the massive need for system rehabilitation and new development of irrigation throughout Afghanistan.

OVERVIEW OF WATER RESOURCES IN AFGHANISTAN

Afghanistan is about 675,000 km^2 and landlocked. Over 75% of the terrain has mountainous features and 27% of Afghanistan lies at an elevation above 2,500 meters. Land resources are classified as the following: 3% forest; 12% arable land, 39% mountainous and barren, and 46% pasture. Afghanistan is generally arid. Precipitation varies from 75 millimeters (mm) in the southwest to 1,170 mm in the Hindu Kush Mountains (snowfall) in the northeast with about 200 to 400 mm falling over the majority of the country (Kabul averages about 300 mm). Precipitation is seasonal with the majority falling between November through May with February, March, and April receiving the greatest amounts.[2] In addition to being naturally arid, Afghanistan is a drought prone and one season of low precipitation can substantially impact water availability.[3]

The limited precipitation and its temporal variation and spatial concentration in the central highlands and northeastern mountains creates a seasonal water tower

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[2] The rainfall pattern is different from the South Asian monsoon although some eastern areas may be influenced by the monsoon resulting in a bimodal rainfall and runoff pattern.

[3] The drought conditions and growing desertification may also reflect changing climate patterns, which has serious long-term implications for water security.

effect with 80% of surface runoff in the form snow melt that originates above 2,000 m. These waters feed the major river basins in the country that flow north, south, east, and west (See Table 1). Most rivers exhibit and annual hydrograph that shadows the annual hyetograph with a one to three month lag depending on the elevation of their catchment (i.e. timing of snowmelt). In most rivers, the rainfall and snowmelt blend together for peak seasonal flows in the spring, so that good spring rains can compensate for poor winter snowfall. However, since most areas are irrigated with river diversions with no storage, this often means that discharge is excess in the spring and deficit in the summer to meet crop water requirements (AIMS, 2004 and FAO, 1997).

Table 1: Major River Basins, Major Rivers, and Mean Annual Runoff

River Basin	River Name	Mean Annual Volume (billion m^3)	Percent
Amu Darya	Ab-i Panja	36,420.00	43.35
Amu Darya	Kokcha	5,700.00	6.78
Amu Darya	Kunduz	6,000.00	7.14
Total Amu Darya		**48,120.00**	**57.28**
Kabul (Indus)	Panjshir	3,130.00	3.73
Kabul (Indus)	Kunar	15,250.00	18.15
Kabul (Indus)	Kabul (main)	2,520.00	3.00
Total Indus		**21,650.00**	**25.77**
Northern Basin	Balkh	1,650.00	1.96
Total Northern		**1,880.00**	**2.24**
Basin	Farah Rod	1,250.00	1.49
Helmand Basin	Helmand at Kajaki Dam	6,000.00	7.14
Helmand Basin	Arghandab	820.00	0.98
Total Helmand		**9,300.00**	**11.07**
Harirod - Murghab	Murghab	1,350.00	1.61
Harirod - Murghab	HariRod	1,600.00	1.90
Total Harirod - Murghab		**3,060.00**	**3.64**
	Total	**84,010.00**	**100**

Source: Note that only major rivers are listed while basin totals reflect all inflows.

Water security and irrigation are absolutely critical well being of the rural sector and the national economy as a whole since irrigated agriculture produces up to 85% of agricultural output (1978 data); makes up close to 70% of the total national economy; and employs around 80% of the population.[4] Agriculture uses

[4] Almost 35% of agriculture's contribution to the economy in 2004 came through production of opium poppy. If this is deducted from the gross domestic product, agriculture's contribution falls to between 50 and 60% (World Bank, 2004a).

95% of developed water supplies (Government of Afghanistan, 2004a and World Bank, 2004a). A drought from 1999 to 2001 devastated the agricultural sector with a near total failure of rainfed farming. Many traditionally irrigated lands were deprived of water, which destroyed long-standing orchards, and livestock was significantly impacted with herds and their associated rural wealth substantially reduced. By 2004, 70% of rural households had still not fully recovered income or asset losses. To cope, 40% of rural families decreased food consumption from already low levels, and many were forced to sell land for income rendering them permanently worse off and more poverty prone. In 2004, another deficit rainfall year was estimated to have caused a 25% decline in cereal output. The estimated 16% GDP growth was revised downwards to 8%, and an additional 2.5 million Afghans were faced with food insecurity. Any sustainable development strategy for the country must highlight water security and irrigation as critical components (World Bank, 2004b and IMF, 2005).

OVERVIEW OF IRRIGATION SYSTEMS IN AFGHANISTAN

Irrigation System Types

Hydrologic conditions render most surface irrigation to the major river valleys with seven provinces located in the main basins providing nearly one third of the total irrigated area (See Table 2). Total irrigated area in the country is around 2.5 million hectares although data is uncertain and many areas in many years may only have intermittent irrigation. There are five basic types of irrigation systems in Afghanistan: (i) *arhad* or Persian wheel, (ii) *karez*, (iii) traditional surface water systems, (iv) modern or formal surface water systems, and (v) pump systems. The scale and technical characteristics of each system type has different management implications. The vast majority of irrigation is considered traditional where local communities developed the infrastructure and are responsible for its management and operations and maintenance (O&M).

Arhad (Persian Wheel) System: Groundwater is lifted from shallow wells with the help of an *arhad* (Persian wheel) driven by beasts of burden supplying irrigation water to the fields of individual farmers. The size of irrigated area is generally not more than three hectares (ha). Persian wheels comprise no more than 1% of the total irrigated area in Afghanistan.

Karez Systems: Water is delivered by free flow via underground tunnels that are dug into the sides of hills or mountains to collect sub-surface flow. The horizontal tunnel is punctuated by vertical shafts and although the diameter of the tunnels is small (one or two meters), the *karez* may be tens of kilometers in length. The flow from a *karez* is typically between 10 to 200 liters per second (l/s), but may be up to 500 l/s, and may be able to irrigate anywhere between 10 and 200 ha. They are an important water source for both domestic supply and irrigation and are often used for high value crops and orchards. Approximately 7,000 *karez* may be found in Afghanistan and are concentrated on the eastern, southern, and western flanks of the Hindu Kush Mountains. Local villages typically had a *karezkan*, who was responsible for developing and maintaining the *karez*, which is perilous work. The *karez* systems may comprise 5 to 10% of total irrigated areas although their prevalence varies by location.

Table 2: Irrigated Areas in Afghanistan by Province

Province	Irrigated Area (ha)	Province	Irrigated Area (ha)
Badakhsh.	96,907	Kunar	17,044
Badghis	66,596	Kunduz	195,324
Baghlan	145,344	Laghman	34,742
Balkh	162,921	Logar	40,631
Bamyan	28,103	Nangarhar	85,707
Farah	49,051	Nimroz	76,475
Faryab	82,439	Oruzan	98,667
Ghazni	101,241	Paktia	49,919
Ghor	57,726	Paktika	39,648
Helmand	111,906	Parwan-Kapisa	100,094
Herat	259,552	Samangan	80,899
Jawzjan	100,089	Takhar	150,788
Kandahar	121,662	Wardak	29,127
Kabul	73,261	Zabul	64,260

Source: FAO, 1997. Table 2 reflects 1978 data, however, a decline in area is generally the norm since 1978. It is also difficult to accurately define irrigated areas since in many seasons irrigation may be intermittent. However, the statistics indicate the magnitude of distribution of irrigated area throughout the different provinces of the country.

Traditional Surface Irrigation Systems: Traditional surface irrigation systems may be classed as small, medium and large scale and all are surface water diversion systems or spring fed.[5] Many of these systems have been functioning for several centuries. The traditional irrigation systems generally have no or few formal control structures and use earthen canals that rely on brush, log, mud, stone, and some masonry water control structures. Intake structures are usually not engineered or permanent and rely on brush, logs, rock, and makeshift gabions. Given the annual flood hydrology and the fact that river channels often shift laterally and many have lowering beds levels, intakes structures need to be rebuilt on a frequent basis. Traditional irrigation systems are widely distributed and constitute about 80 to 90% of Afghanistan's irrigated area.

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[5] Artesian springs are common in many areas and a vital source of surface water that supply about 5 - 7% of all irrigation. Although the water source is different from surface diversions of traditional systems, the distribution and system management are the same.

Small-scale traditional systems, which vary in size (up to 100 ha) are often located in remote valleys along a stream or spring, and generally only one village is responsible for the O&M. Medium scale irrigation systems range from 100 to 2,000 ha, and several village communities may share the system, which has a common water source (usually river) and may have several temporary intakes. Large-scale traditional irrigation systems are supplied by river flow and may have tens of thousands of hectares of command area and hundreds of kilometers of canals. In general, the size of the traditional irrigation systems increases as one moves down the river valleys and out into the plains since the topography is more favorable for development, the land is more fertile, and flows generally larger. Using the same source of water through intakes along a river, the systems have main, secondary, distributary and even smaller canals and may include numerous villages in their command area. In addition to irrigation water, the traditional irrigation canal networks play an important role for livestock, domestic, and municipal water supply.

Modern (Formal) Surface Irrigation Systems: Ten modern irrigation systems have been developed over the last half-century. The systems were developed and managed until the late 1970s mainly through parastatal agencies (such as the Helmand Valley Authority or the Nangarhar Valley Authority). The modern systems are generally larger than 10,000 ha and some have storage (including multipurpose). These systems were designed to have modern control structures and canal networks. The majority of the modern schemes are located in three major river valleys: the Kunduz in the North, the Kabul in the East, and the Helmand in the South, which has the largest design command area of around 100,000 hectares. Together these systems have a combined command area of about 300,000 ha or almost 10% of the irrigated area (BCEOM, 2004; DAI, 2002; Sheladia, 2002; and FAO, 1997).

Groundwater Pump Systems: Groundwater pump systems have expanded rapidly in recent years and both shallow and deep wells are being developed depending on the hydrogeology of the area. Shallow wells are generally less than 20 meters with a discharge of around 4 to 20 liters per second, and deep tube-wells can be much deeper with much higher discharge of at least two to three times that of shallow tubewells. Currently, little data exists regarding groundwater development since it is almost all supported through private investment and no regulatory framework or monitoring capacity exist (Government of Afghanistan, 2004b).

Irrigation Practices and the Current State of Irrigation Systems

In the traditional and modern irrigation systems, the dominant irrigation methods are basin/border irrigation for cereals and furrow irrigation for cotton, vegetables and oilseeds. The main physical constraints to irrigation include the following: shortage of water after the peak snow melt in April to August (depending on location); poorly formed river intakes and water regulating structures; excessive seepage losses in some places; and deeply incised canals that are difficult to desilt. Average irrigation efficiency is considered to be about 25 to 30% due to high conveyance losses in traditional schemes; high operational losses in modern schemes with lined conveyance canals that are in poor condition; and high on-farm distribution losses due to poor command area development. In many of the river valleys, drainage is not a problem due to the fact that the fine to medium alluvial soils in the upper layers have course materials below facilitating percolation and leaching with adequate water application. In some areas outside river valleys, however, drainage is important to avoid water logging and salinazation (FAO, 1997 and Government of Afghanistan, 2004a).

Irrigation cropping intensity varies significantly depending on the particular system and location within a system. Intensities of 200% or greater are not uncommon in areas at the head reaches, yet this can only be achieved through rotation of downstream areas with as much as one third of the areas traditionally remaining fallow or through excessive abstractions by upstream users. In spite of the fact that most structures are rudimentary, Afghans are industrious farmers and once water is in the canal, it is relatively well managed within the physical constraints of the traditional systems.

Current State of Irrigation Infrastructure: About one third of Afghanistan's villages were damaged or destroyed during the first 10 years of war (1979-1989), and the war's impact of irrigation infrastructure stems partly from direct combat activities, however, degradation is mainly due to the exodus of farmers and dereliction of O&M. After the war in the 1990s, some communities were able to rehabilitate smaller traditional irrigation systems with rudimentary structures, however, in larger schemes with more complex designs and intakes from major rivers, greater problems were encountered including complete sedimentation of larger canals and dilapidation of major structures and canals.[6] An estimated 10% of systems were directly affected by combat, while another 40% of systems, particularly large-scale schemes, were damaged due to lack of O&M and uncontrolled flow entering the systems. It is estimated that in some areas access to irrigation water may have been reduced by more than 50% since the pre-war era, and irrigated area has declined by as much as 33%. In addition to the needs for rehabilitation, many of the traditionally developed schemes would benefit from improved river intakes; rationalization of canal networks; improved structures for water control and regulation; improved cross drainages; canal protection; and other improvements consistent with modern design and construction to increase water use efficiency; improve control over water distribution; and reduce annual

[6] Unexploded ordinance and land mines also pose significant challenges for irrigation development and rehabilitation in many areas.

maintenance needs (BCEOM, 2004; Government of Afghanistan, 2004b; and FAO, 1997).[7]

The large modern systems were severely degraded during the last decades of civil unrest, and many control structures are currently inoperable or looted. Generally, they have suffered much more than traditional systems since government agencies were not able to maintain facilities due to lack of staff, equipment, and funds. The maintenance of these large systems proved beyond the capability of local farmers who did not have the long tradition of community management. Consequently, only the upstream command areas now get proper irrigation in many cases. In some instances, makeshift structures have been fashioned using the existing canal network rendering these systems' O&M similar to traditional systems.

IRRIGATION MANAGEMENT IN AFGHANISTAN

Traditional Irrigation Management under the *Mirabs*

The Department of Irrigation, which was relocated to the Ministry of Energy and Water (MEW) in December 2004, is the agency responsible for irrigation management and development within the Government of the Islamic Republic of Afghanistan (the Government). However, one of the most salient features of irrigation in Afghanistan is the extent of the irrigation developed by local communities over hundreds of years and the ongoing community management that continues to be responsible for the majority of system O&M. Traditionally, local communities have selected *mirabs* who are the local water masters responsible for managing the system including water allocation and O&M with the support of community labor.[8] In larger irrigation systems, a *mirab bashi* is selected with responsibility for the entire irrigation system starting with the intake for the primary canal. A *mirab* is selected to manage the distribution from the secondary canals, while a *chak bashi* is selected at the tertiary and individual community level. In some instances, a timekeeper (*saatchi*) or assistants may be selected to oversee rotation.

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[7] The last decades of civil unrest were particularly devastating for the *karez* with many falling into disservice due to the disruption of traditional community O&M. The recent influx of groundwater pumps have also desiccated karez flows and without adequate groundwater management, this trend is likely to continue. This trend has significant equity concerns since *karez* water, which is traditionally a community resource, is being usurped for private use by individuals who can afford pumps and their operation.

[8] The discussion presents a generalized view based mainly on northern and western areas, and actual arrangements and terminology differ from system to system. In some areas, the term *wakil* is used to refer to the *mirab bashi,* or *wakil* will sometimes assist the *mirab* with defining allocation and distribution.

A village *shura* (council) usually selects the *mirab* for a one-year term although no term limit exists, and in many cases, the *mirab* will serve for the majority of his lifetime and sometimes pass the position on to his children, so long as the community is satisfied with performance. The *mirab*'s role may require full time service during a large portion of the year, and he receives an in kind fee from the harvest. The *mirabs* receive no formal assistance from the Government for their efforts although they may collaborate with the Department of Irrigation or other authorities to help execute projects. Generally, the financial and other resources at their disposal are meager, and O&M support is provided entirely by the community. However, *mirabs* are usually still able to mobilize significant community labor, sometimes hundreds of men in labor gangs, using manual methods for O&M in most systems (PCI, 2004b and Pain, 2004 and Lee, 2003).

Water Allocation: Irrigation in Afghanistan has a water allocation system based on irrigated area that dates back several centuries. In Northern Afghanistan, the *paikal* is the basic unit for water allocation, and it corresponds to both a unit of land as well as the measure of a flow of water for irrigation purposes.[9] *Paikal* land also refers to the agricultural land type (i.e. irrigated land), and historically specific taxes were paid on *paikal* land. The taxes paid corresponded to the size of the land holding and accordingly, the water allocation was also contingent on the *paikal* tax paid. A *paikal* does not always appear to be uniform, but is usually between 350 to about 500 *jeribs* of land (one *jerib* equals 1953 m^2), and its size may depend on whether it is located in the head or the tail of the irrigation system. A *paikal* is converted to a unit of water measure through a corresponding unit-width that allows water to pass through a control structure within the irrigation system, which is also called a *paikal* or *paikal* width.

Based on the *paikal* system, water allocation is proportional among different offtakes from a river as well as within the system at canal structures; each with a prescribed *paikal* allocation that corresponds to the area to be irrigated and a width of intake or division structure. The *paikal* system is based on continuous flow and does not account for changes of head in the river or in the canal, so volume of delivery is not constant, yet is roughly proportional. As one moves down the canal system, rotation is practiced in some systems with complex distribution schedules that involve hourly rotations on as high as a monthly rotation cycle in some lower level canals. In Northern Afghanistan, current *paikal* allocations were formalized into law in1925 and 1926 although the canals and practices go back several centuries as they do in many of the traditional systems throughout the country. However, many of the allocations today do not correspond to the traditional allocations and may also not reflect the on ground reality with respect to irrigation and land use. Strict adherence to the traditional allocation system has weakened in some cases. Even when the *paikal* system is

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[9] *Paikal* is used in Northern Afghanistan while in the west the basic unit for land and water is the *juftgau*, yet the concept and allocation methods are the same.

adhered to it is still imprecise, however, all *mirabs* and irrigated landholders are aware of it and at least superficially acknowledged the system and their particular *paikal* allocations and rotations.[10] Most importantly, most Afghan farmers understand how the system works and irrigate with the expectation of a prescribed allocation.

Traditionally, dispute resolution within an irrigation network is addressed by the *mirabs*, yet concerns may be referred to the *shura* for decision and possible sanction. At the community level, enforcement appears to be addressed through public reprimands with shame as the main coercive measure. In some instances, however, *mirabs* or irrigators may bring issues to the attention of the Department of Irrigation or other district or provincial authorities, including the governor's office, for assistance to resolve a situation, especially allocation conflicts between different irrigation systems, and the *mirabs* act as system advocates (ADB, 2004; PCI, 2004b; BCEOM, 2004, Pain, 2004, and Lee, 2004).

Current State of the Traditional Management: Like the physical infrastructure, the institutional structure for community management has degraded during the last 25 years of civil unrest. In many communities, *mirabs* are no longer able to enforce the water allocation schedules or mobilize substantial labor to maintain the irrigation systems. The rise of many local commanders in the rural power vacuum created after the fall of the Taliban along with the influx of weapons over the last two decades has made it difficult to stop unauthorized abstractions of irrigation water in many areas. Upstream users are more emboldened to take water beyond their share and *mirabs*, even with the backing of provincial officials, have little recourse to address the situation. In some areas, it has been noted that the traditional water distribution had been more effectively enforced and adhered to under the Taliban than the current situation. The return of authority to local government officials and the rule of law supported through the demilitarization and demobilization of former combatants will be necessary activities to fully restore irrigation management to *mirabs* and the community.

MOVING FORWARD AND ISSUES TO CONSIDER

Moving Forward - Government and Donor Involvement in Irrigation

The Government, through various public and parastatal agencies, played a role in developing and managing irrigation systems over the last 50 years, although the majority of irrigation has always been traditional. When the war started in 1979, irrigation development activities came to a standstill with several projects abandoned. The capacity of the Irrigation Department was significantly diminished during the ensuing civil unrest leaving few qualified engineers or

[10] In some cases *mirabs* may have record books, while in other cases it appears that the allocations are known through memory.

other staff. Limited resources rendered the Irrigation Department a moribund agency with no field activities taking place and provincial offices falling into dysfunction. In the post Taliban period, the Irrigation Department moved to the newly created Ministry of Irrigation, Water Resources, and Environment (MIWRE). In December 2004 after the presidential election of Hamid Karzai, the ministries were reshuffled and consolidated, and the Irrigation Department (including water resources management responsibility) moved to the MEW.[11] As of January 2005, discussion over the final location for the Irrigation Department was still taking place with consideration of the moving it to the Ministry of Agriculture and Animal Husbandry and Food (MAAHF). Regardless of the final organizational arrangements, the task of rebuilding and developing irrigation and strengthening water resources management is enormous.

Securing Afghanistan's Future, which was released in March 2004, lays out a 12 year plan for the redevelopment of Afghanistan. The plan is not only for rehabilitation but for developing Afghanistan's economy to the point of sustainability relying an average 9% growth rate of the non-drug economy. In preparing the document, $645 million of immediate water resources needs were identified including emergency rehabilitation and improvement of small, medium and large traditional irrigation schemes; capacity development and institutional strengthening for irrigation and water resources management; and redevelopment of a national hydrological and meteorological network. Over $1.8 billion worth of long-term investments for irrigation and water resources projects, including dams, were also identified (ADB, 2003). The report estimated the following: 240,000 ha of irrigation that had gone out of production could be rehabilitated and made productive; 1,310,000 ha of currently irrigated land could be more intensively irrigated through rehabilitation; 953,000 ha of land intermittently irrigated could be brought under intensive irrigation through additional storage; and 1,035,000 ha of new area could be brought under irrigation (Government of Afghanistan, 2004c).

Due to the critical role that irrigation and water resources must play in Afghanistan's development, substantial donor assistance is being provided to :rehabilitate irrigation systems; re-establish the Irrigation Department as a competent force in irrigation development; and develop a sound institutional framework for irrigation and water resources. Numerous aid and development agencies are involved including the following: Canadian International Development Agency, United States Agency for International Development, Japanese International Cooperation Agency, Duetsche Gesellschaft fur Technische Zusammenarbeit (GTZ- German aid agency), Government of India, Abu Dhabi Fund, Food and Agriculture Organization of the United Nations, World Bank, European Community, Asian Development Bank, and numerous non-governmental organizations (NGO) among many others. Assistance is being

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[11] MIWRE was dissolved and environment was made an autonomous agency.

provided in the form of grants and soft loans, and approximately $300 to $500 million is programmed for the irrigation and water resources over the next five years, which includes some very large infrastructure projects such as completion and rehabilitation of storage facilities. Donor and NGO supported activities include the following: (i) rehabilitation and completion of irrigation schemes and associated water resource projects including traditional, modern, *karez*, and groundwater schemes; (ii) purchase of computers, vehicles, and other needed equipment for an effective irrigation agency; (iii) development of feasibility studies for new irrigation and water resources projects; (iv) introduction of new technologies such as drip irrigation; (v) reestablishment of a new hydrological and meteorological network throughout the country; and (vi) extensive capacity development for the Irrigation Department staff, *mirabs*, and farmers to provide the necessary skills for irrigation management and development as well as for integrated water resources management (IWRM).

Issues to Consider – Developing Policy Framework

The Irrigation Department is the Government focal point for donor activities to develop the capacity for irrigation management and development and for coordinating donor irrigation rehabilitation and development assistance (civil works, etc.). The Irrigation Department also currently serves as the main entity concerned with overall IWRM. Given the existing capacity constraints of the Irrigation Department, donor supplied consultant support is assisting preparation and implementation of civil works as well as assisting management, planning, and policy development for irrigation and IWRM. A vital need is to increase the capacity within the Irrigation Department to fully manage and support the current donor assistance and in the process, to become an effective irrigation agency to support sustainable irrigation management and development after donor assistance tapers off. Current donor assisted activities are providing substantial on the job training as well as more formal capacity development activities to achieve this end. However, a range of issues needs to be addressed for the long-term management and development of irrigation within a sound IWRM framework

Recently developed policy documents such as the Strategic Policy Framework for the Water Sector (adopted by cabinet in 2004), the draft Water Resources Management Policy, and the draft Irrigation Policy developed by MIWRE identify many of the issues that need to be addressed and provide initial policy direction based current international best practice. The draft Irrigation Policy states, "The specific objectives of the irrigation policy is to develop and manage irrigation systems cost-effectively; ensure technical, social, institutional and environmental sustainability; and promote user participation in local water management that can ensure overall increase in production and productivity of agricultural." However, developing the details and implementation arrangement as well as the capacity (both human and technical), especially at the provincial and regional level, to actualize the policies, pose a real long-term challenge. The

Irrigation Department with support of the donor community is undertaking activities to further develop and implement these policies.[12] While the current underdeveloped capacity of the Irrigation Department and inchoate institutional arrangements for irrigation management and development and IWRM present challenges to be overcome, they also present an opportunity to benefit from the lessons of other countries and to use current best practice in developing the institutional arrangements for irrigation and IWRM.

Issues to Consider - Organizational and Institutional Responsibilities

Agriculture and Irrigation: Regardless if the Irrigation Department stays with MEW or moves to MAAHF, a challenge exists to integrate agricultural support services with irrigation rehabilitation and development to ensure that Afghan farmers are able to maximize benefits from improved irrigation service delivery. To date, emergency interventions for irrigation rehabilitation do not explicitly include the integration of agricultural support services, although several projects under preparation will include agricultural support services as well as watershed management activities. In addition, donors and NGOs are supporting and implementing agricultural and rural development programs that address the various needs for farm production and marketing, yet a fully coordinated approach does not yet exist. The problems and difficulties of integrating agriculture and irrigation is not unique to Afghanistan, however, institutionalizing successful approaches to help farmers who have irrigation with inputs (including credit), post harvest activities, and marketing must be a priority to achieve the full potential from irrigation and to support meaningful alternative livelihood opportunities to poppy production. The modalities to achieve this present a difficult challenge since the MAAHF is currently rather weak, especially at the field level, and clear strategies to provide agricultural support services through the public sector, private sector, cooperatives, community-based approaches, or other arrangements are yet to emerge.

Integrated Water Resources Management and Irrigation: Effective IWRM at the national level will become more critical as new storage and other infrastructure projects will be developed and competing sectoral demands will intensify, especially in the face recurrent droughts. To support effective IWRM in the long-term, the draft Water Resources Management Policy calls for development of an independent apex body at the national level, yet a timeline for this is uncertain. Regardless of the final organizational structure for the responsibilities that accompany IWRM such as intersectoral allocation, entitlements, drought management, and overall responsibility for integrity of the resource base will need

[12] Policies will need to be codified in the legal framework and the national water law, which was last revised in 1981, will need to be amended or new legislation introduced.

to be defined and operationalized effectively to sustain Afghanistan's economic development.

Policies produced under MIWRE have consistently shown a commitment to decentralized water resources management primarily through river basin authorities. Currently, development of river basin authorities is being pursued through various donor supported projects although it will be some time before functional capabilities are developed and institutional arrangements finalized. Addressing basin issues is critical for irrigation since a pressing rehabilitation need is to improve irrigation intakes, which require frequent rebuilding in the traditional systems. However, before more permanent and possibly gated structures are developed, agreement needs to be reached over the sharing arrangements among the different canal intakes along rivers.[13] As more multipurpose storage will likely be constructed in Afghanistan, river basin authorities may have a vital role to play with regard to operation of basin infrastructure and flows. As with the IWRM functions at the national level, international best practice would suggest that in the long-term, service delivery such as irrigation and development of infrastructure be decoupled from a basin management authority, which should have a regulatory role. In the mean time, however, due to the current organizational linkages and the fact that irrigation uses 95% of developed water supply, it is likely that irrigation and IWRM will be addressed through the Irrigation Department.

Issues to Consider - Rehabilitation and Development Assistance

Emergency versus Long-term Development: Although an urgent need exists for irrigation system rehabilitation, a long-term approach is required to rebuild capacity and institutions for more sustainable development and to support the Afghans to fully assume irrigation O&M, management, and development activities commensurate with the donor community's eventual diminished presence. Initially, many aid efforts focused on short-term, emergency rehabilitation measures, which may not support long-term development or may contribute to deterioration of community participation by excluding community involvement or giving the impression that communities no longer need to take O&M responsibilities. The Government has recommended cessation of purely emergency works that do not contribute this long-term vision. The long-term development approach has also led to the realization (in some cases reorientation of programs) that capacity development activities (short and long-term) for all stakeholders must be an explicit component of assistance projects.

[13] Although historical allocations exist, changes have taken place since they were created and discussion of permanent off-take structures is very contentious among *mirabs*.

Influx of Donor Assistance: The massive influx of aid resources to Afghanistan to rehabilitate irrigation is needed, and given the large number of agencies providing rehabilitation assistance, many disparate activities are taking place in the field. Coordination of rehabilitation efforts is vital to ensure that resources are not duplicated or working at cross-purposes and are sequenced to achieve maximum development impact. This challenge will increase as more programs move from preparation to implementation. It will require donors to work closely with each other and the Irrigation Department and to fully communicate all activities and ensure a common agenda. To manage the donor rehabilitation efforts, many ad hoc arrangements such as project coordination units have been created with ministry staff and consultant support. These provide a more expedient and efficient means to manage and implement donor assistance and are essential due to limited capacity. However, it will be important to mainstream and transform the ad hoc arrangements and functions into a permanent organization and institutional structure of the Irrigation Department to ensure that the capacity developed and housed in the ad hoc arrangements (including qualified and trained staff) remains with the Irrigation Department once funds diminish and projects end.

Balancing Modern and Traditional Irrigation

Although substantial assistance is needed and will be provided for some time, the Irrigation Department, which will be developed with donor support, must become sustainable in terms of its mandate and financial resources in the long-term. All aspects of the Irrigation Department need additional capacity, yet lessons from previous donor assisted irrigation departments should be observed. In many countries, donor programs are currently supporting reforms for greater decentralization; right sizing of irrigation departments with greater out sourcing of services; and empowering user participation as means to improve responsiveness and accountability. In some cases, it was donor assistance of a generation ago that helped entrench these public agencies with resources and power that is currently being retrenched as a means to improve service delivery.

Traditional irrigation systems comprise and will continue to comprise the vast majority of irrigation in Afghanistan.[14] Although imperfect, these systems have century-old traditions of community management and O&M and have sophisticated means of water allocation with farmers who understand the rules and have an expectation of limited allocation. Development agencies struggle with mixed success around the world to achieve these management objectives, and the recent emphasis on participatory irrigation management and irrigation management transfer underscores these efforts. In Afghanistan, community

[14] Some Government support had been provided over the years for development and repair of larger structures.

management has been the norm for centuries and the only means of system management and O&M during the recent civil unrest.

The traditional irrigation systems are in serious need of rehabilitation and improvement, and especially in the larger systems, support from the Irrigation Department and donor-assisted projects can offer tremendous benefits. One of the greatest challenges facing irrigated agriculture in Afghanistan will be to provide the needed rehabilitation and system upgrading to the traditional irrigation systems and provide the benefits of modern irrigation while at the same time supporting traditional community management, O&M, and allocation. In the long-term, this means achieving the proper balance and clearly defining the institutional arrangements of the *mirabs*, farmers, and Irrigation Department, so that the Irrigation Department provides needed support and serves as a technical resource, yet at the same time does not usurp or debase the communities role in managing the system.

The draft Irrigation Policy as well as the Strategic Policy Framework for the Water Sector acknowledge the importance of community participation through the *mirab* system and commit to maintain it. The Irrigation Department is also currently developing common principles and guidelines for community participation to be used by donors and projects working with traditional irrigation systems. In defining the terms of engagement with community members, the guidelines will also define many of the institutional issues that will need to be addressed regarding the roles and responsibilities among the Irrigation Department, *mirabs*, and irrigators. Development of the guidelines will also raise many of the issues that must be addressed for the long-term sustainability of irrigation such as: cost recovery for O&M and rehabilitation beyond community in-kind labor; irrigation service fees; and ownership of irrigation assets. Discussion has also taken place and the draft Irrigation Policy calls for the introduction and formalization of water user associations for irrigation management based on the *mirab* system. While certain elements of the *mirab* system need strengthening and the *mirabs'* role will undoubtedly evolve with development, care needs to be exercised in altering institutions that have worked effectively for centuries. As the policies and implementation guidelines emerge and are confirmed over time, the legal framework will also need to be developed to support the institutional arrangements for irrigation management within the civil society that is being reestablished in Afghanistan.

Development of New Irrigation

Modern Systems: Over the centuries, traditional irrigation systems have developed the best land with readily accessible water supply in the major river valleys. They have also been developed up to or beyond the point of reliable water supply. Any new irrigation is likely to require some associated storage and will be developed using "modern" methods. The Strategic Framework for Water

Resources calls for expansion of irrigated area and increasing the modern systems from their current 10% to 35% of total irrigated area. Revitalizing existing modern systems and developing new ones raise the fact that new institutional arrangements to manage these systems will also need to be forged. Ideally, lessons from the traditional systems can be used to ensure active participation of the water users in the management and O&M of these systems. These issues are being addressed in the Helmand Valley where the main rehabilitation work on modern systems is taking place, yet the institutional arrangements are still evolving. In addition to the management of irrigation system, development of new systems, dams, and storage reservoirs even with donor assistance raise technical, social, economic and environmental concerns that will require creation of supporting institutional frameworks and much capacity development.

Groundwater Development: Groundwater is a relatively underdeveloped water resource that holds great potential to bring the benefits of irrigation to many new areas as well as to supplement surface water irrigation in the tail reaches of existing systems. Groundwater development also presents and obvious opportunity that is being exploited for rural and urban and water supply. However, a clear strategy for its management and development is yet to fully emerge. The possible dangers of uncontrolled groundwater development are already being seen in some areas with the loss of *karez* flows. Complicating the situation is the fact that in most areas of Afghanistan little knowledge exists regarding the extent of groundwater resources although investigations have started. In addition, institutional responsibility for groundwater development and management is still evolving, especially with change in ministries at the end of 2004. Previously, most responsibility rested with the Ministry of Mines and Industry (MMI) while the Strategic Policy Framework for Water Resources calls for shared responsibility between MMI and MIWRE (now defunct). An important priority for the Government is to clearly define ministerial responsibility, develop an institutional framework for management and development, as well as create the knowledge base and monitoring capability to support effective groundwater management and development. Some of these activities are currently being supported through several donor projects, however, a nationally focused initiative on groundwater has not been fully realized. As in many countries, implementation and enforcement of any groundwater regulation will be difficult after a framework has been developed.

CONCLUSION

The importance of irrigated agriculture and water resources to the future of Afghanistan cannot be overstated, and the Government in cooperation with the donor community is currently providing tremendous resources commensurate with importance of rehabilitating and developing irrigation and water resources. Afghanistan has a rich tradition of community managed irrigation, yet at the same needs to develop an effective and modern irrigation department and new infrastructure to ensure irrigated agriculture realizes its full potential for the economic development of the country. The Government and Irrigation Department have made remarkable progress to address many difficult challenges, yet much work lies ahead. The situation with regard to the management and development of irrigation is still fluid in many respects, however, in charting the long-term course for Afghanistan's irrigation it is important that the valuable resource of community irrigation management provides a foundation for future development. For Afghanistan, a critical challenge will be reconciling traditional irrigation management with development of modern irrigation systems.

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FIELD TESTING OF SACMAN AUTOMATED CANAL CONTROL SYSTEM

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ABSTRACT

Many irrigation districts currently operate their main canals, pumping plants, etc. remotely with Supervisory Control and Data Acquisition (SCADA) software. This is usually manual operation with perhaps a few local automatic control features. SacMan (software for automated canal management) is a software package that adds canal automation logic to commercially-available, windows-based SCADA packages. It allows the user to implement a variety of automatic control features, including complete automatic control, where feasible. It was developed through research at the U.S. Water Conservation Laboratory in Phoenix, AZ. SacMan has several levels of implementation ranging from manual control to full automatic control, including upstream level control, flow rate control, routing of known demand changes, and full (distant) downstream level control. SacMan interfaces with commercial Supervisory Control and Data Acquisition (SCADA) software, currently *iFix* by GE Fanuc (formerly Intellution, Inc.), but potentially applicable to other SCADA packages. SacMan was field tested on the WM lateral canal at the Maricopa Stanfield Irrigation and Drainage District (MSIDD) in central Arizona. In July/August 2004, SacMan successfully operated the WM canal for a period of 30 days, nearly continuously. This paper describes the features of this canal automation software and some results from this long-term testing.

THE SACMAN CANAL AUTOMATION SYSTEM

The SacMan canal automation system includes three main components: hardware at each check structure, a Supervisory Control and Data Acquisition (SCADA) system, and SacMan. The hardware includes the Automata *Mini* that serves as the RTU, spread-spectrum radios, water level sensors, gate position sensors, gate motors, and relays to drive the gate motors. SacMan is currently configured to work with SCADA package *iFix* by GE Fanuc. We expect SacMan to work equally well with other PC-based SCADA packages, but this needs to be

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demonstrated. The *Mini* and *iFix* communicate with the MODBUS communication protocol. SacMan (Software for Automated Canal Management) provides value-added features to standard SCADA systems by allowing users to implement various canal automation features. Further details about this system can be found in Clemmens et al. (2003).

SCADA Software

iFix by GE Fanuc (previously Intellution, Inc.) is the SCADA package currently being used. The canal is set up for supervisory control in a standard manner. The *iFix* communication drivers are used to communicate with the field sites through ModBus protocol over the spread-spectrum radios. Information from field sites is processed through a series of calculation blocks to yield information that is directly useful to the operator – for example, transducer voltage is converted to a depth and then this depth is adjusted for the location of the sensor to yield canal water depth.

iFix monitors canal water levels every minute and stores these values in a database. Standard *iFix* displays are used to graph the current water levels, flow rates, and gate positions for each check structure. In addition, the water level and flow setpoints are added to the display. These displays can be customized to suit the users' needs. The canal operator can always manipulate gates manually, even when various automatic features are active. Database information and control actions taken are automatically archived for future evaluation.

The above functions are generally available with most commercial SCADA packages. However, not all are capable of the interface required for this canal automation system. SacMan and its interface to *iFix* are described next.

SacMan Software

SacMan monitors the canal by reading the *iFix* database through proprietary database calls. Based on this information, it determines whether control actions are needed. If a change in gate position is needed, SacMan writes a command to the *iFix* database. This "write" command prompts *iFix* to take action. *iFix* interprets the information that was written by SacMan and sends a command to one or more gates through the ModBus driver. These actions are archived for future evaluation.

SacMan has three different levels of implementation: Manual control, local upstream water-level control, and centralized control, including downstream water-level control. Currently all control functions are performed at the central computer, except actual gate position changes, even though some of the control functions use local control logic. Centralized operations allow operators to monitor these processes and to provide archived data on control actions, which is useful in diagnosing the cause of problems. If communication is lost or the central computer goes down, gates simply remain in their current positions.

Within these three main categories, there are various features that can be implemented. For standard manual control or upstream level control, no other features are required. Operators can implement various features as they become familiar with SacMan. The first useful feature is the ability to increment or decrement the flow by an operator specified discharge (based on head and site specific gate information). The second is the ability to set and maintain the flow rate at a particular structure, particularly canal headgates.

A series of alarms are available to alert the operator to any unusual circumstances, particularly when the canal is under automatic control. An out-of-bounds controller is available for sensing excessively high or low canal water levels. When such a condition exists, an alarm is given and control reverts to automatic-upstream level control to protect the canal from failure. This mode is available even for manual control.

SacMan Orders provides the operator with the ability to route water orders through the canal system automatically. The operator specifies the location, time, date and flow change (start, stop, or change). SacMan keeps track of the water being delivered throughout the system and computes the timing of check gate flow changes to accommodate the changes in demand. This can either be implemented manually by the operator or automatically by SacMan.

With multiple changes taking place, it is sometimes difficult for operators to keep track of flows within the system. If water orders are entered into the SacMan demand scheduler, SacMan will display the sum of the demands downstream from any check structure. This can then be compared to the actual flow rates. The operator can then get a quick sense of whether or not canal flows are in balance, even when under automatic control.

Pool volume is an important pool property and is used directly in many control schemes. The rate of change of pool volume is related to the mismatch between inflow and outflow, and thus is a measure of flow rate errors. This flow-rate error is computed and displayed so the operator can use it to adjust canal flows.

Our experience through simulation studies, applications, and control engineering literature suggest that automatic control methods can become unstable if started suddenly. To avoid such problems, SacMan has a smooth start-up procedure. It assumes that the initial water levels are the water level setpoints and gradually adjusts them to the real set points. This ability to vary setpoints also allows the operator to schedule in the volume needed to raise canal water levels.

APPLICATION AT MSIDD

The SacMan control system was implemented on the WM canal at the Maricopa Stanfield Irrigation and Drainage District (MSIDD). The WM canal is a lateral canal with a capacity of 90 cfs (2.5 m^3/s). It was originally supplied with motorized gates. Relay boards, built by Automata, were installed in each gate motor. Automata water level sensors were installed in existing stilling wells along the upstream side of the gate frame. Automata's new gate position sensors were also installed.

The feedback control logic used in this application is described by Clemmens and Schuurmans (2003). Application to ASCE test canal 1, which is based on the WM canal, is described in Clemmens and Wahlin (2003). The control logic converts water level errors into flow rate changes at each gate. SacMan determines the gate position change needed to achieve that flow rate change and sends a gate position change to *iFIX*. The feedback portion of the control system determines new flow setpoints for each check structure every 10 minutes. Feedforward changes in the flow setpoint at each check structure, and associated gate position changes, are performed every 2 minutes. If a large number of sites are being controlled, the flow control function may best be accomplished locally, depending on the complexity of the flow calculations.

Field Testing

Field testing of this system has taken place off and on since 1999, with each set of tests suggesting requirements for improving the software and control implementation. The WM canal was operated nearly continuously for a period of 30 days, from July 14, 2004 to August 13, 2004. During this period of time, the MSIDD Watermaster allowed us to have complete control of the canal. Each day we obtained water orders for the day from the watermaster, scheduled them with SacMan order, provided feedback on when deliveries would arrive at the turnout, and actually made the deliveries to the irrigators in the field. During a majority of this time, the canal was under (distant) downstream water-level feedback control, with scheduled deliveries implemented as feedforward commands.

The first few days of testing was a shake-down period where we periodically shut down the automatic control to fix the SacMan software. There were times when these bugs caused control of the canal to be unacceptable, and we would have to take over and run the canal manually. Gradually, all the bugs disappeared. As testing continued, however, we added features to help us run tests which occasionally introduced new bugs.

During this 30-day period there were 60 scheduled delivery changes. Of those 48 were successfully routed through the canal automatically with SacMan. During the first few days of the debugging, nine deliveries were routed through the canal manually. Human errors later in the testing caused the remaining 3 deliveries to be routed manually.

Example Results

To date, we have not fully analyzed all of the data from this 30-day period. Example results are shown for two types of testing: 1) the ability of the control system to handle routine water delivery changes and 2) the ability of the control system to handle significant disturbances.

Routing scheduled flow changes: The first example consists of 3 scheduled flow changes on July 17, 2004. This was three days into the testing period. Requested flow changes consisted of: 1) a turn on for the pump offtake in pool 7 (WM-7PA) at 8:00 (+3.2 cfs); 2) a turn off of the delivery (gravity offtake) at WM-6 (-8 cfs) at 11:00; and 3) a turn off of WM-7PA at 14:00. Total demand for the canal prior to these changes was 35.5 cfs, with 28.2 cfs supplied from the main canal and 7.3 cfs supplied from wells. WM-3-well-1 adds 3.6 cfs to the canal just upstream from check WM-3, and WM-5-well-1 adds 3.7 cfs to the canal just downstream from check WM-4. These wells remained on during this entire day.

During this test, the canal was under automatic downstream level control. A PI^{+}_{-1} controller was used during this test, as defined by Clemmens and Schuurmans (2004). A simple PI controller would change the flow rate (or gate position) of the gate at the upstream end of the pool. With this controller, an error in water level in a given pool results in a change in flow to all upstream gates (+) and a change in flow to the gate immediately downstream (-1). This controller was designed at 80% of capacity, while the inflow was only about 30% of capacity. In addition, because of previous difficulties in controlling the level at pool WM-5, this controller did not include water level errors from this pool and did not adjust the gate at WM-5. Instead, the water level at WM-5 was controlled by the gate at WM-5 with local upstream-level control.

The requested demand changes were scheduled with the SacMan Order software, which passed the schedule of flow changes to the SacMan control program when posted by the operator. The feedforward schedules for these delivery changes caused the flow to be changed at the headgate at 7:05 (55 minute delay to WM-7PA), 10:11 (49 minute delay to WM-6), and 13:03 (57 minute delay to WM-7PA). The change in delay time for the on and off for WM-7PA results from a change in the initial conditions (i.e., less flow in the canal).

Figure 1 shows the inflow rate at the canal head and the water levels in each pool from 6:00 am to 6:00 pm (18:00). **Neither manual control nor operator intervention occurred during this test period. The canal was under complete control by the combination of iFix SCADA and SacMan.** The flow rate shown at the head (WM-0) is not necessarily an accurate flow rate since we do not have an upstream water-level sensor at this site (i.e., it is based only on gate position). The downstream demand was 28.2 cfs, while the graph shows 31.8 cfs, and the actual flow is likely somewhere in-between. Since control deals with flow changes, this is a minor inconvenience.

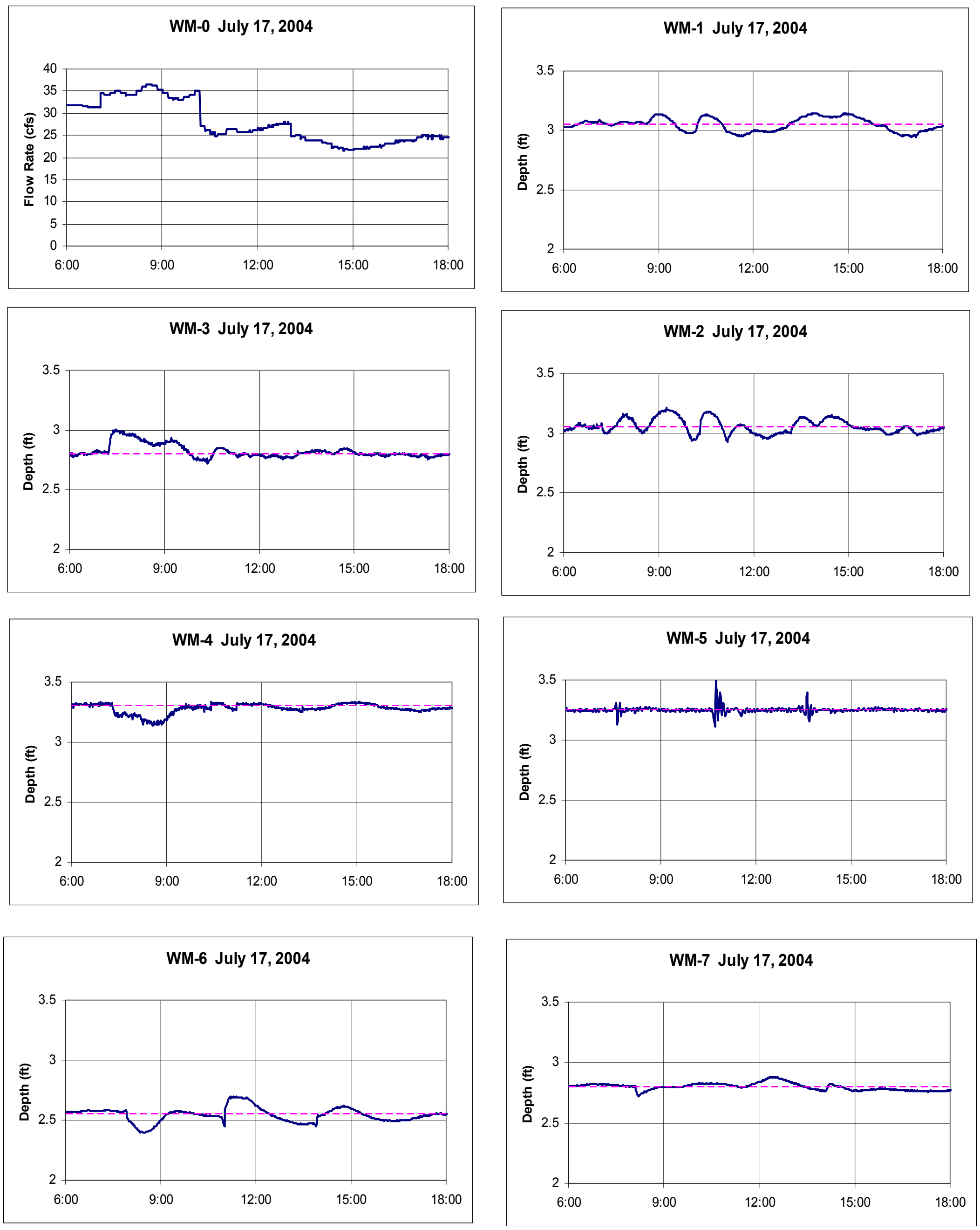

Figure 1. Canal inflow and canal water levels for routine routing or delivery changes on MSIDD's WM canal.

At roughly 7:05, one can see the step increase in inflow corresponding to the 3.2 cfs delivery change. This is followed by 1) some minor oscillations in flow caused by the feedback controller, 2) the step decrease in inflow at 10:11 because offtake WM-6 was to go off at 11:00, 3) additional feedback oscillations, and 4) the step decrease at 13:03. The inflow eventually stabilized at around 18:00.

Water level deviations were on the order of ±0.1 ft. This is acceptable control for this canal. Yet, these results show some interesting feature of automatic canal control. The timing of delivery changes can be seen by the water level deviations that occurred. Because waves disperse as they move down the canal, one cannot obtain perfect control in all pools, without passing oscillating flow changes downstream. For this canal, no spills were allowed, so we could not use this to mitigate the effect of wave dispersion. The timing of the arrival of the wave can be seen by the variations in water levels in pool 7 at 8:00 and 14:00 when the pump was turned on and then off. One can see that the water level quickly returned to the setpoint. At 8:00 the water level was stable, dropped for a short time when the pump came on, then very quickly stabilized, indicating good volume compensation (i.e., we put the right volume into the canal pool, even if the timing of the wave was imperfect). At 14:00, the pool was not stable, but was responding to the shut off in pool 6. The timing there was not as good, as shown by the rise in water level at roughly 11:00 when the turnout was shut. Some of that error in water level resulted in extra water being sent downstream, resulting in a small rise in the water level in pool 7. When the change arrived at 14:00, the water level was dropping, which actually helped to stabilize this pool faster.

As the wave for the flow changes needed in pool 7 passed through pool 6, one sees that the timing was not very good, resulting in deviation in the water level in pool 6. These were not very severe and they stabilized fairly quickly. Some of this deviation is caused solely by wave dispersion and is not entirely due to poor timing.

Pool 5 shows the response of the upstream water level controller. This controller was operated remotely on a two minute time interval. The changes in gate position were determined from a simple PI controller in incremental discrete form

$$\Delta w(k) = 0.668\ \Delta e(k) + 0.198\ e(k-1)$$

where $\Delta w(k)$ is the change in gate position at time step k, $\Delta e(k)$ is the change in water level error between time steps k-1 and k, $e(k$-1) is the previous water level error, and 0.688 and 0.198 are the proportional and integral constants, respectively. While overall control of this water level was reasonably good, there were significant spikes when the flow changes passed through. We discovered that the timing of water level measurement was significantly delayed such that the controller might be working on a measured water level that was a minute old. This actually caused the controller to perform poorly. For later tests, we added filtering to the water level values, upped the scan rate for this site so that we had more recent water level data, changed the control time step to one minute, and retuned the control constants through both simulation and real-time testing (not reported here). This canal pool is a bit extreme in that the pool is extremely short (e.g., backwater extending roughly 100 ft upstream). In this case, we would recommend that such control be implemented at the local site, as opposed to local logic at the central site. For larger canal pools, we did not experience these problems.

On first examination, we were concerned about the large deviation in water level in pool 3. This seemed like more than a timing mismatch. When we examined the data, we discovered that the 3.2 cfs feedforward flow change did not occur at this gate. Thus the flow change was not passed on to pool 4, causing its level to drop, while the level in pool 3 rose. This error was entirely removed with the feedback controller. The problem was caused by operator interaction. Such interaction should not have caused this change to be missed. We have since found the problem in the software and corrected it. This flow setting error also caused the oscillations in pools 1 and 2 as they tried to adjust their flows to compensate through feedback control. We have noted the tendency for pool 2 to oscillate and are working on ways to minimize this. Overall however, the feedback controller did a good job of correcting the problem.

Correcting unknown disturbances: The presence of a well pumping into the canal just upstream from gate WM-3 provided us with a good test scenario for studying the performance of the feedback controllers. Twice during the 30-day test period, this well was turned off by lightning strikes during thunder storms. In both cases, the controller was able to maintain control of water levels, bringing additional water in from the canal headgate to overcome the resulting flow shortage. We found it convenient to simulate this event by just routing a negative flow change down to pool WM-3, and then not implementing any changes there. On July 30 and 31, we performed this routine with two different controllers. Demand from the main canal was 27.0 cfs and no changes in demand occurred during this test period. The first controller was a PI^{+}_{-1}, as described above. The second controller was a fully-centralized controller PIL^{+}_{-}, where water level errors in all pools influence the flow to all gates (a so-called optimal controller). These controllers were designed at 40% of capacity, reasonably close to the test conditions. All pools were under feedback control. There was no demand in pools 7 or 8, so water level data there are meaningless. The results are shown in Figure 2.

The first flow change was routed from the headgate at 20:50, for arrival at 21:04. This flow change caused slight disturbance around 21:00 at WM-1 and WM-2. However, the larger disturbance during the next few hours was caused by the feedback controller trying to bring more water into the canal. As can be seen from the flow at WM-0, the flow had to increase above the steady-state value to provide the extra water needed to make up for the time when the flow was lower.

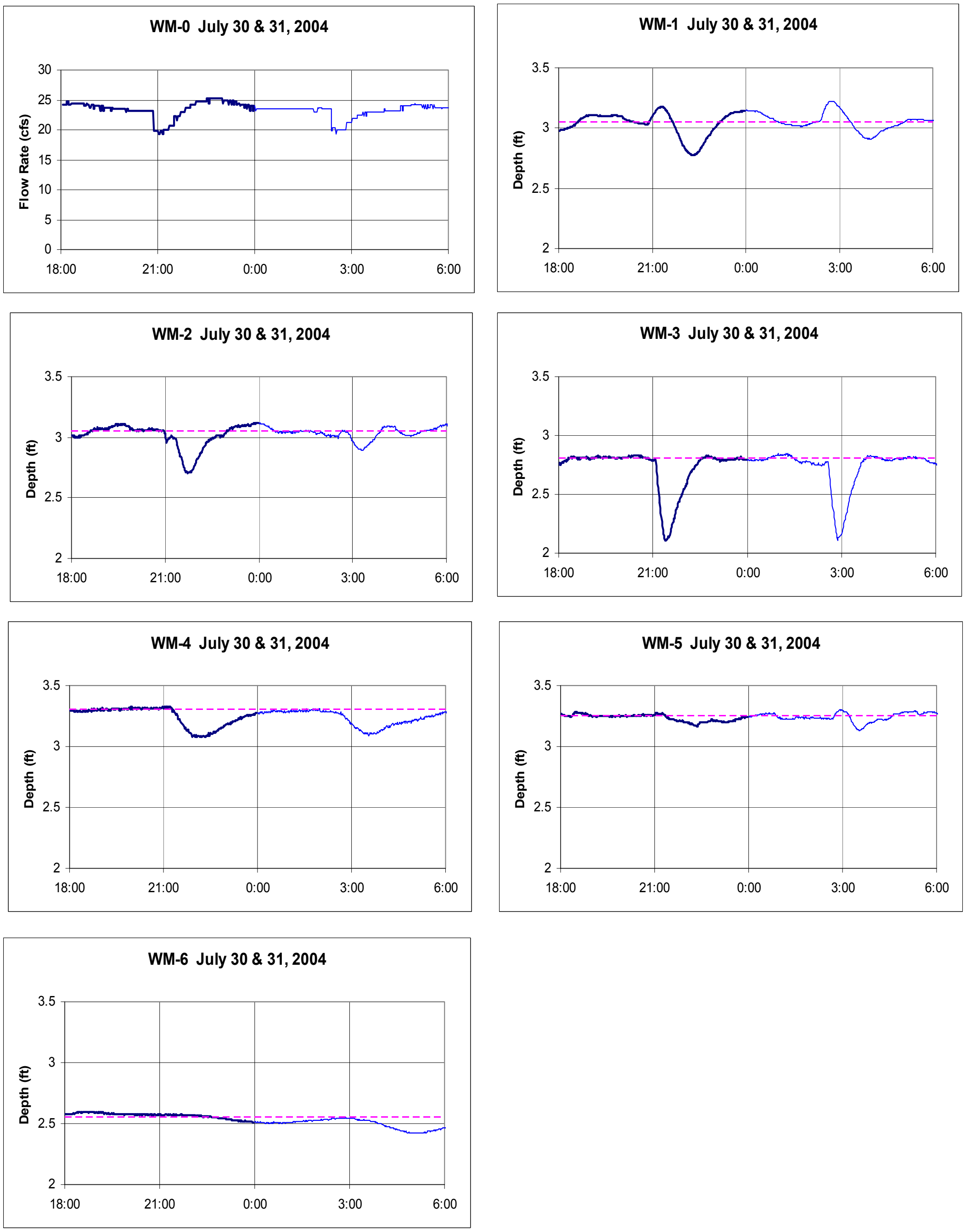

Figure 2. Canal inflow and canal water levels for simulated pump outage on MSIDD's WM canal.

For the first test, the disturbance primarily moved upstream and to the next pool downstream, as one would expect from this PI^{+}_{-1} (deviations influence all gates upstream and one gate downstream). Very little disturbance occurs in pools WM-5 and WM-6 because the flow is held constant at WM-4 by its flow controller.

For the second test, the flow change at the head occurred at 2:20 for arrival at WM-3 at 2:34. This more centralized controller tries to spread the disturbance out since the performance criteria are based on the sum of the squared values of the water level errors. The disturbance in pool WM-3 is slightly less, but is also of less duration. Deviations in pools WM-1 and WM-2 are less and the canal inflow appears to stabilize more quickly. However, more of a disturbance can be seen in the two downstream pools, with WM-6 showing a significant deviation that took a very long time to be removed. These kinds of tests are useful for understanding the performance and strategies of these various controller and should help in selecting the best type of controller for a particular application.

DISCUSSION

We have demonstrated that the SacMan control system is capable of controlling water levels in an irrigation canal. The basic components are working satisfactorily within a commercial SCADA package. The Automata hardware and firmware in the field is also performing as expected. Refinements are needed to make this system more failsafe so that it can run essentially unsupervised.

The SacMan control logic has been developed in a flexible manner so that a variety of control objectives can be attained. More details on the control approach can be found in Clemmens et al. (2002), Clemmens et al. (1997), and Clemmens and Schuurmans (2003).

At MSIDD, only small infrequent spills are tolerated. Under manual control, this also happens, but with manually controlled check gates, some of the error in flow gets distributed to users all along the canal. SacMan currently provides information on flow and volume errors to assist the manual operator in adjusting canal inflow to minimize these problems.

Downstream water-level feedback control eliminates the problem of excesses and shortages. However it is recognized that sloping canal systems cannot automatically respond to large demand changes regardless of the control logic (i.e., open canals cannot perform like closed pipelines). Major flow changes need to be routed through the canal. With SacMan, this can be done manually by the operator or automatically with SacMan Order.

The downstream control logic moves errors in flow to the upstream end of the canal, adjusting the headgate flow to get the canal flows and volumes into balance. However, on many large canals, the headgate flow is not continuously adjustable. Here, what was downstream control logic has to be adjusted to more central control logic, taking this upstream constraint into account. SacMan's flexible approach to control can make this happen. Further, information on flow and volume mismatches provided by SacMan help a manual-control operator in deciding how much water to order from the upstream supplier.

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A MONITORING SYSTEM FOR WATER QUALITY

An Ning[1]

ABSTRACT

A water quality monitoring system using automatic control and network techniques has been built. Hardware and software configuration for the system: measure meters, sensors, client/server configurations, Ethernet networks running TCP/IP, wireless network, Pentium PC-based operator terminals, terminal servers relational database and application software. The telemetry network improves the monitoring system's ability to monitor water quality change. Water quality data collected is more scientific and more representative. The data that can reflect water quality in real time is sent to the computer control center and analyzed. Environmental protection agencies can use the analysis results to manage and supervise the industrial discharges and water quality more easily.

INTRODUCTION

As the industrialization and modernization process evolving water demand is growing continuously□and there are more and more industrial wastewater and life sewage discharged. The surface water of most cities in our country has been and being polluted because of a large amount of non-process wastewater. Water quality and environmental protection are core values to ensure economic development and quality of life for our country. To prevent environmental water degradation, environmental monitoring centers in cities have been set up and are in charge of monitoring surface water quality and industrial discharges in cities. Although water quality monitoring networks have been built in many cities, the pollution source and sewer water quality monitoring is still manual work. It is difficult to reflect completely the continuous change of wastewater discharges using samples collected because of it is not in real time. Therefore, the monitoring results are not as scientific or representative. For upgrading the ability of monitoring water quality, it is necessary to build a monitoring system in real time.

MONITORING SYSTEM DESCRIPTION

Monitoring system structure

The water quality monitoring system is composed of wastewater discharge monitoring substations, a monitoring main station and a management center. The

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system can automatically collect the water quality data and monitor wastewater discharges and main pollution factors in real time. The data collected at desired intervals is sent to the monitoring main station and where it is integrated, synthesized and analyzed. According to the analysis results, environmental protection agencies can manage and supervise the industrial wastewater discharge and life sewage more easily and accurately. Figure 1 illustrates the water quality monitoring system structure.

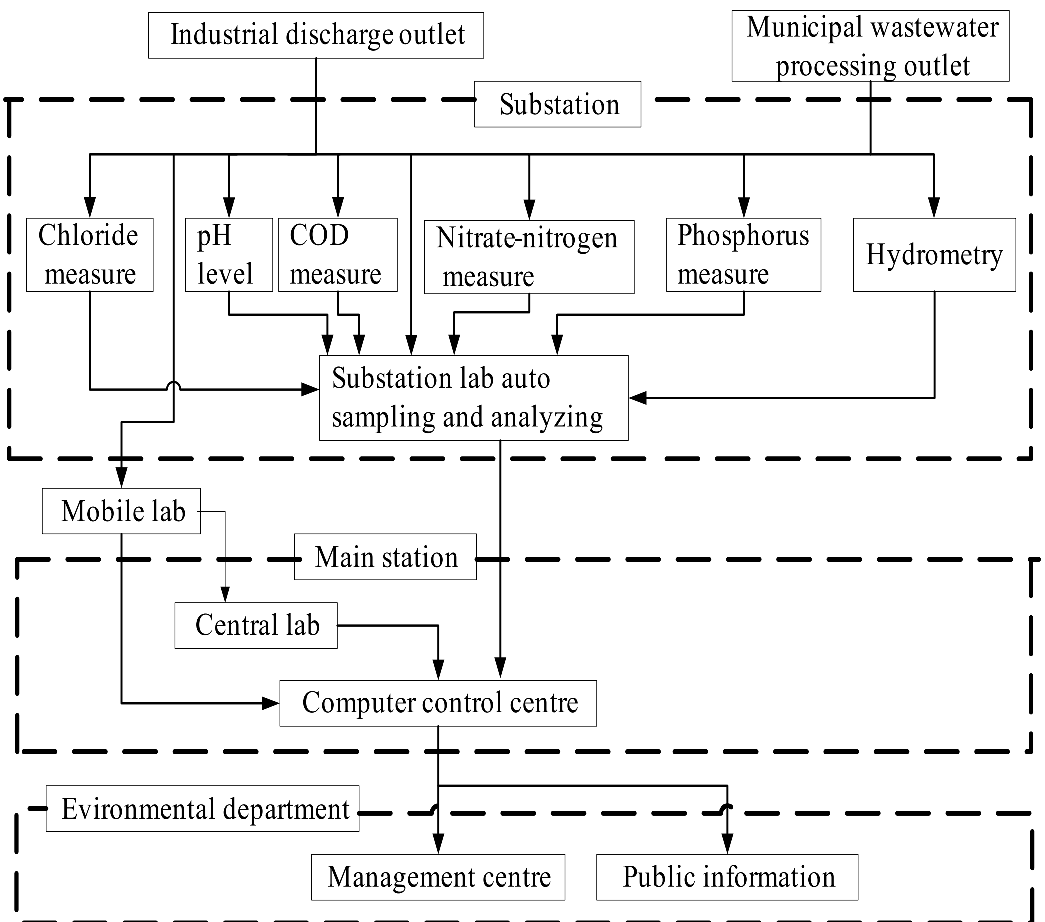

Figure 1. The Monitoring System Structure Illustration

<u>Substations</u>: Substations are set near the factories of which wastewater discharge need to be monitored or municipal wastewater outlets. One of them is set near Dong Lake (the largest lake in city in China). There are transducers and testing equipment that can measure pH level, COD, total phosphorus and so on. The data output from the equipment is processed and sent to the remote main station in real time.

<u>Main station</u> The main station includes a central laboratory, a mobile laboratory built in a vehicle and a computer control center. The mobile lab is useful when water quality somewhere needs to be measured but there is no site supervised.

The data collected is first stored in computers in the mobile lab and dumped to computers in the control center after the mobile lab goes back the main station. The computer control center receives information from substations and other measurement units. All of the collections are processed, analyzed and classified at the main station. Other functions of the main station are monitoring results operation including save, display, print, statistic, report form, etc.

Management center Management center is a department of the municipal environmental agency. It is in charge of management decision-making with the result of monitoring water quality from the main station. There is an information release system with a large image projector. The monitoring results and main pollution sources can be displayed on the screen.

System technical scheme

Hardware and configuration standards for the system: It is a monitoring system that is provided with client/server configurations, Ethernet networks running TCP/IP, Pentium PC-based operator terminals, relational databases, and terminal servers. Hardware is chosen based on industrial standards supporting multiple platforms. It is necessary to build an open system that can interface to all enterprise applications. Taking advantage of the standardization of industrial control products can reduce the cost, risk, and schedule of the project while increasing the functionality delivered, the maintainability and upgradeability of the monitoring system.

Substation on line measuring and testing technical scheme:

1. Monitoring meters. According to the monitoring needs some meters are introduced such as hydrometer, pH meter, meters for COD and nitrate nitrogen measuring, etc.

2. Controller and communications. The controllers adopted in substations are MicroLogix 1000 family produced by Rockwell Automation, Inc. MicroLogix 1000 family's benefits include compact design, simple programming, and several optional communication methods – DF1 protocol for direct connection, DH-485 networking, Ethernet/IP networking and half-duplex slave protocol for SCADA application. The I/O options and electrical configuration make MicroLogix 1000 ideal for our application. We can use different models according to different monitoring sites. MicroLogix 1000 models are as RTUs in the monitoring system.

Main station technical scheme:

1. Data acquisition and communication. Having been used as data acquisition and communication controllers, SLC 5/05 processors can provide high bandwidth networking for the monitoring system. They have all of the features of other SLC 500 processors, and also bring 10Base-T 10-Mbps Ethernet connectivity to the

popular SLC 500 family. Through Ethernet networks, SLC 5/05 processors can communicate plant-floor data in data acquisition, supervisory control, program management, maintenance management, and material tracking applications.

2. Data processing and computer system. Two pentium PC as server are installed in a redundant, automatic failover configuration. There are also two PCs as Historical Data Server (HDS) and MIS server and several PCs as operator terminals. In addition, there are also several PCs that serve as operator terminals in the management center.

Data communication: The communication system is a multiple network system. Local communication uses Ethernet 10Base-T. Fiber communication is adopted between the main station and the management center. The communication method between the main station and any substation is wireless networking or Internet. Wireless equipments selected are products produced by MDS (Microwave Data System), including transceivers, antennas and InSite 6i management software. MDS 2710A data transceivers are used for wireless communication in substations and the main station. The radios are high system performance and data integrity through robust construction and using DSP technology, work in 200-240 MHz frequency range. They can be configured as a master station or remote radio and operate as a half-duplex or simplex radio. The max data throughput is 19.2 kbps. For increasing system reliability, a MDS P20 redundant station incorporated two MDS 2710A is used in the main station.

Instruments of labs in the monitoring system: The central lab has the ability to identify pollutants. It has analysis instruments including general chemistry, microbiology, nutrients, organic analysis and metals. The mobile lab is configured with field-testing kits for portable and quick analysis.

Monitoring system software

Operating system and application software: Servers and client terminals use Windows 2000 Advanced Server and Professional respectively. Data management and analysis uses SQL Server 2000. Other application software includes MS Office products (Word, Excel and Access) and development tools (VC++, VB).

Software based on Rockwell Automation products: Relevant software programs are RSview32, RSSql and RSlinx. RSview32 is an integrated, component-based HMI software package for monitoring and controlling automation machines and processes. Rsview32 provides operators with an extremely flexible, intuitive interface for controlling and monitoring the entire system. RSSql links the monitoring system to the database. Retrieving operational data from the monitoring system and depositing them into the SQL server linked to the MIS in the main station, RSSql integrates the plant floor data with the monitoring system IT. RSlinx is a complete communication server providing plant floor device connectivity for a wide variety of Rockwell Software applications such as

RSlogix, RSview32 and RSSql. It supports multiple software applications simultaneously communicating to a variety of devices on many different networks. All of these applications provide us with an ideal platform on which we integrate and build the solutions run in the monitoring system. Figure 2 illustrates the monitoring system architecture.

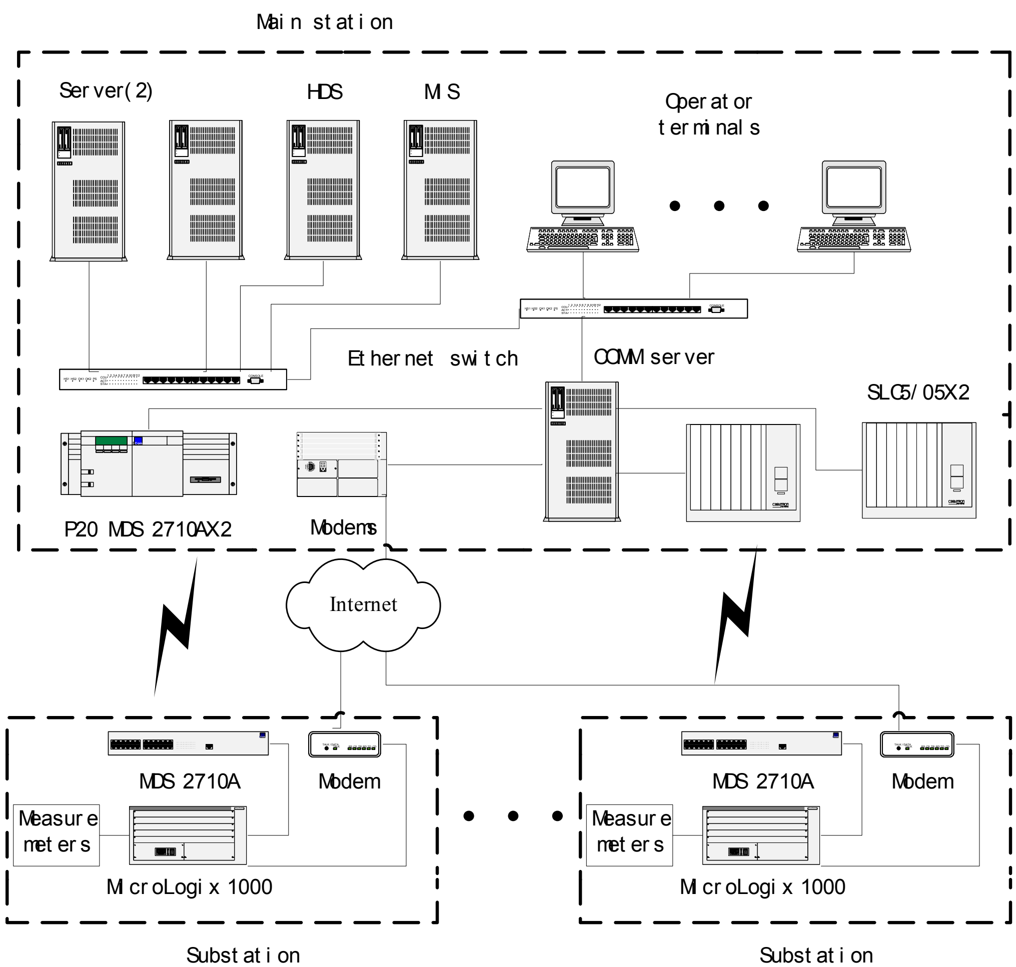

Figure 2. The Monitoring System Architecture

System benefits

We have designed and installed the water quality monitoring system that monitors district's water, industrial discharges and life wastewater. The system excels in:

1. Increased data accuracy.
2. Increased reliability and efficiency.
3. Effective data management.
4. Fully integrated information systems.
5. Redundant servers and communication equipments for increased reliability.

6. Flexibility for system growth.

By using standard product and taking advantage of fine tuned components, we have made the system run efficiently and stably. The monitoring system can now monitor 37 sites via RTUs. If necessary, it can be extended to monitor over 100 sites.

CONCLUSION

Water quality monitoring has become necessary work in environmental protection. Automating monitoring and telemetry is a trend for improving the ability of water quality monitoring system. We have built a water quality monitoring system by using automatic control and network techniques. The monitoring system performs well. It helps us capture more accurate, real time measurement data. The water quality data collected are more scientific and more representative because of the automatic monitoring system. Due to the data is real time, the environmental protection agencies are able to know wastewater discharges immediately and take measure to control pollution source according the information.

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AN INFRASTRUCTURE MANAGEMENT SYSTEM FOR ENHANCED IRRIGATION DISTRICT PLANNING

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Les M. Ryan[2]

ABSTRACT

The common issues of population and economic growth pressures and aging infrastructure, across the province of Alberta, indicated the need for some enhanced level of reinvestment in that infrastructure. The government-sponsored Capital Planning Initiative (CPI) was implemented as an on-going process improving the level and type of information provided to decision-makers, specifically related to a diverse inventory of all infrastructure that had a government-funding component associated with it. As a result of annual capital works funding provided to Alberta's 13 irrigation districts by the Government of Alberta, their works could be eligible for on-going and enhanced CPI funding.

In order to provide appropriate and effective information to the CPI process, an Irrigation District Infrastructure Management System (IDIMS) was developed. It not only provided a means to quantify the cost of aging irrigation infrastructure and its current condition, it also assisted irrigation districts in qualifying and quantifying the state of their works for their continual re-construction planning. A web-based interactive software package known as the *Irrigation District Web-based Infrastructure Management System (I.D.WIMS)* was developed and implemented, now providing a common reference for consistent evaluations on the need for and extent of capital re-investment from one district to another.

INTRODUCTION AND BACKGROUND

Infrastructure and Alberta's Capital Planning Initiative

The entire infrastructure that the Government of Alberta has some form of financial obligation or commitment to totals approximately $95 billion (CDN). This includes "owned" infrastructure such as highways, government offices and water management headworks, as well as "supported" infrastructure (those works owned by other agencies or municipal authorities but for which the Alberta Government does provide on-going capital funding support). The latter includes such facilities as schools, hospitals, rural roadways and irrigation district infrastructure. Recognizing that sustainable infrastructure is critical to Alberta's

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ability to continue its strong economic development, the Government initiated a process to evaluate the condition and use of that infrastructure that it had some responsibility for and to derive a current replacement cost and projected life for those works. Therefore, a system to satisfy those objectives, with respect to irrigation district infrastructure, was developed in a partnership between the Irrigation Branch of Alberta's Department of Agriculture, Food and Rural Development (AAFRD) and the organized irrigation districts within the province.

Irrigation In Alberta

There are 13 organized autonomous irrigation districts in Alberta, collectively supplying water to approximately 1.325 million acres (536,000 ha) of assessed irrigation land in the southern region of the province. In addition, there are approximately 285,000 acres (115,000 ha) of land irrigated across the province through what are referred to as privately licensed and individual water user-developed irrigation projects. Irrigation districts are particularly characterized by their extensive infrastructure and their operation under provincial legislation known as the *Irrigation Districts Act.*

Each of the districts has its own somewhat unique history of development, but, in general, they have been in existence for nearly one hundred years or more. As a result, aging infrastructure has been an issue that has been on the forefront of both irrigation district and government agendas for some time. In the first half of the 20^{th} century, conveyance works were all constructed as unlined open earth channels, many difficult to maintain and much of it plagued with extensive seepage problems. By the beginning of the 21^{st} century, the nearly 7,700 kilometers of water delivery works had been significantly up-graded to a point where nearly 30 percent of that length had been replaced with buried pipelines and an additional 25% rehabilitated as open channels lined for seepage control.

Irrigation Rehabilitation Program. The Alberta Government recognized, many years ago, that the irrigation water management infrastructure in southern Alberta did more than just convey water to irrigation farmers. It not only supported a diversified irrigated agriculture and value-adding industry that promoted regional development, it also conveyed water for municipal purposes to many rural communities, for various industrial uses, for other agricultural purposes (e.g. intensive livestock operations), as well as for recreation and wildlife habitat enhancements.

Therefore, in 1969, the provincial government initiated a capital works funding program that would, on an annual basis, provide cost-shared funds to the irrigation districts to assist them in rehabilitating their respective works in a sustainable fashion. Today, this program, currently known as the Irrigation Rehabilitation Program (IRP), provides a minimum of $19 million (CDN) per year to the 13 districts, to be matched, on a 75:25 cost-shared basis, with $6.33

million (CDN) of irrigation district funding. (Total IRP funding = approximately $19/ac/annum.) It is critical, then, to be able to assess the current state of this infrastructure, qualifying and quantifying the condition of the un-rehabilitated as well as the rehabilitated, particularly after an investment toward the latter of some $700 million (CDN) over the last three decades or so.

INFRASTRUCTURE INVENTORY

In order to adequately develop the required Irrigation District Infrastructure Management System (IDIMS), providing a comprehensive assessment of the current state of the irrigation district works, it was necessary to first develop some system of component identification. Fortunately, a major study to evaluate the opportunities for future irrigation growth in Alberta (Irrigation Water Management Study Committee 2002) was just concluding when this infrastructure evaluation initiative was implemented. As a major component of the water management study, a complete inventory of all irrigation district infrastructure was developed within a GIS application. This was required in support of the detailed water management modeling carried out through the Irrigation Demand Model (IDM) (USCID/EWRI 2002). Now, each year, in consort with the irrigation districts, this spatial and attribute database is up-dated to reflect current configurations and components. This system, referred to as the Irrigation District Infrastructure Information System (IDIIS), contains a wide variety of descriptors concerning three basic groups of infrastructure types, namely:

1) Conveyance works – 7,640 kilometers of open channels and pipelines, made up of more than 10,000 reaches (line segments), delivering irrigation water to more than 13,000 farm turnouts.
2) Drainage works – 282 kilometers of constructed and 3,887 kilometers of natural open channel and pipeline drains, made up of approximately 2,500 reaches (line segments), collecting unused or returned system water from the irrigated areas.
3) Major structures – 163 uniquely identifiable structures such as dams, reservoir headgates, pump lift stations, main canal drop and check structures, and the like.

Some of the principal infrastructure descriptor attributes that are attached to each line segment (reach) are:

- Segment or structure no.
- Land location
- Type of material
- Capacity
- Type of works
- Pipe diameter
- Length
- Purpose of works
- Type of construction

Figure 1 is a graphical representation of the identification and classification of typical works, as stored within the IDIIS GIS shape files, uniquely identifying each canal or pipeline segment, the type of construction, turnout structure locations, etc. A segment is defined as a continuous length of linework that has exactly the same attribute data attached to it.

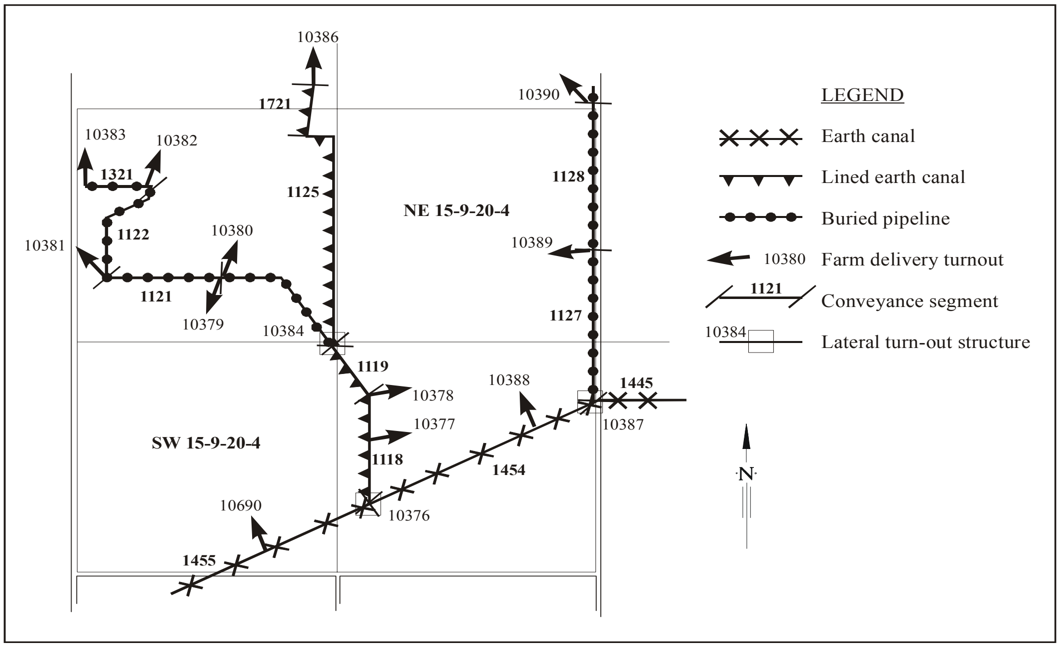

Figure 1. The IDIIS spatial linework and attribute information assignments.

Replacement Cost

In addition to quantifying and qualifying the physical inventory of the existing infrastructure, the other major undertaking required the development of a current replacement cost for each type of works and construction-type identified. This was critical in addressing future capital planning requirements. The technical committee, made up of AAFRD and irrigation district staff that were appointed to develop and implement the IDIMS program, derived current replacement costs that are up-dated each year. Based on numerous works rehabilitation contracts that had been completed in the previous year or two and the experiences of the various irrigation districts, overall average construction costs for all districts, per unit length of works, were agreed upon. These were tabulated by type of construction and by flow capacity. Table 1 summarizes the costs initially applied in the first year of the project (2001). Each year thereafter, these values have been adjusted based upon the annual construction cost index, reflecting inflation through the prior year.

Although, for example, the types of construction of open channel conveyance works were divided into five different groupings, it was agreed that all replacement channels would be assumed to be armored, whether they were

Table 1. Typical unit replacement costs for conveyance works.

CAPACITY of WORKS (cms)	REPLACEMENT COSTS by TYPE OF CONVEYANCE WORKS				
	Earth Canal* ($/m)	**Lined Canal** ($/m)**	**Armored Canal ($/m)**	**Lined & Armored Canal ($/m)**	**Concrete Canal** ($/m)**
55.0 - 100.0	500	800	500	800	n/a
30.0 - 54.99	400	700	400	700	n/a
15.0 - 29.99	300	500	300	500	n/a
6.0 – 14.99	225	380	225	380	380
3.5 - 5.99	175	335	175	335	335
1.5 - 3.49	150	300	150	300	300
< 1.5 ***	$1,000/ac	$1,000/ac	$1,000/ac	$1,000/ac	$1,000/ac

* Replacement costs assume future replacement channels will be armoured.
** Replacement costs assume future replacement lined channels will be armoured.
*** Replacement costs assume future works replacement will all be developed with a variety of pipeline systems.

lined or unlined. It was also assumed, for cost determination purposes, that all existing open channels with a current design capacity of 50 cubic feet per second (1.5 cms) or less, would, at the time of replacement in the future, be replaced with a buried pipeline. On this basis, as illustrated in Table 1, respective replacement costs were assigned.

One of the exceptions to the above concept regarded the costing of pipelines. Due to variable topography conditions, it was recognized that pipeline costs could vary significantly from project to project and from one district to another. Again, after sampling numerous recently constructed pipeline projects, it was generally agreed, the first time that replacement costs were derived, that pipeline costs averaged approximately $1,000 per acre served. Nonetheless, in order to effectively cost out each unique segment of pipeline identified within the IDIIS, there needed to be some correlation of cost with the attribute of the *flow capacity* of the works. Therefore, twenty or so recent pipeline installation projects were assessed for their project costs and as proportionally distributed according to their various flow capacities. This resulted in about 85 different flow rate and cost relationships. Through regressional analysis of these data points, a representative cost equation was derived, as presented as Equation 1.

As a result, for any given segment of pipeline (or future pipeline) of a specified length, the replacement cost value of that pipeline segment could be calculated.

$$C_R = 50 + (240 \times Q) + (80 \times Q^{0.5}) \quad (1)$$

where: C_R = Replacement cost for a pipeline for a given capacity ($/meter);
Q = Rated capacity of the pipeline segment (cubic meters per second).

Similar replacement cost tables and replacement cost equations were derived for constructed and natural drainage works to arrive at a full replacement value of those types of works. For the major structures, an engineering consultant was contracted to derive the current replacement values of each individual structure, applying a consistent costing protocol across all districts.

PHYSICAL STATE OF THE INFRASTRUCTURE

Under the Capital Planning Initiative, all infrastructure was to be evaluated according to three different classification parameters.

1) *Condition* - The overall physical state of a given component of works, relative to its original design and construction, rated as either *"Good", "Fair"* or *"Poor"*.

2) *Functional Adequacy* - Qualifies works as to whether or not a specific segment or component:
   - Has sufficient capacity to meet anticipated demand;
   - Provides an appropriate or realistic level of service to water users;
   - Can be maintained with reasonable access and at reasonable cost;
   - Provides for efficient operations and water use; and
   - Minimizes parcel severance or interference to field farming operations.

   Irrigation works are classified as to their *functional adequacy* by assigning a simple rating of ***Yes*** (adequate) or ***No*** (not adequate).

3) *Utilization* - Quantifies infrastructure as to the extent it is used, relative to its designed purpose. Currently, for irrigation district works, a single overall utilization value for all infrastructure components within an individual district is assigned. It is derived as a ratio of *annual actual irrigated area to assessed irrigation area* for that respective district. This qualifier is now being considered for a more in-depth quantification by deriving more specific utilization values for individual works components.

Condition of Works

For each type of infrastructure, specific criteria were established to rate the physical condition of each component of those works. For open channels, a point rating system was devised that would consider four different physical factors and assign a point value to each given line segment (reach). The better the condition of a channel, the higher the point rating that was assigned. Open channels were evaluated according to the following criteria.

- <u>Bank Condition</u> – Cross-section as affected by erosion, slumpage or livestock damage. (Maximum – 6 pts.)
- <u>Control Structures</u> – Integrity of structure(s) and effectiveness at controlling and regulating flows. (Maximum – 6 pts.)
- <u>Seepage</u> – Impact of water loss. (Maximum – 6 pts.)
- <u>Potential for Failure</u> – Washout potential, scored highest for lowest level of risk. (Maximum – 6 pts.)

Overall points rating:	Good	-	18 to 24 points
	Fair	-	11 to 17 points
	Poor	-	4 to 10 points

Similar rating systems were applied for pipeline conveyance works as well as for both open channel and pipeline drainage works. A more unique set of assessment criteria was developed for those works classed as *major structures*, because of their greater diversity and stand-alone functions.

COLLECTING AND COMPILING THE DATA

In collaboration with the 13 irrigation districts, AAFRD established the common spatial and attribute databases that everyone would work from, while the irrigation districts took care of carrying-out the actual condition evaluations and submission of their findings. It was understood by all parties that the assessments being performed would be carried out in an objective fashion, recognizing the significant investments that the Alberta Government had already committed to in rehabilitating the irrigation works through the past 30 years or more.

A Common Interface for Data Entry and Reporting

AAFRD had a stand-alone software package developed that would allow for easy entry of condition and functional adequacy evaluation data corresponding for each unique reach of conveyance or drainage works, or for each major structure identified within the IDIIS shape files. Further, for easier exchange of required or desired information, the software application was developed as a web-based system, referred to as the *Irrigation District Web-based Infrastructure Management System (I.D. WIMS).*

I.D. WIMS was set-up to have all of the relevant GIS shape file and attribute data hosted on a single common server, accessible to all parties via the Internet. Figure 2 illustrates how all 13 irrigation districts became connected for the compilation of this information. It is important to note that each irrigation district could only access data attributable to their respective works and similarly only input data that were relevant to the database representing their respective district. This applied to both data input and reporting output.

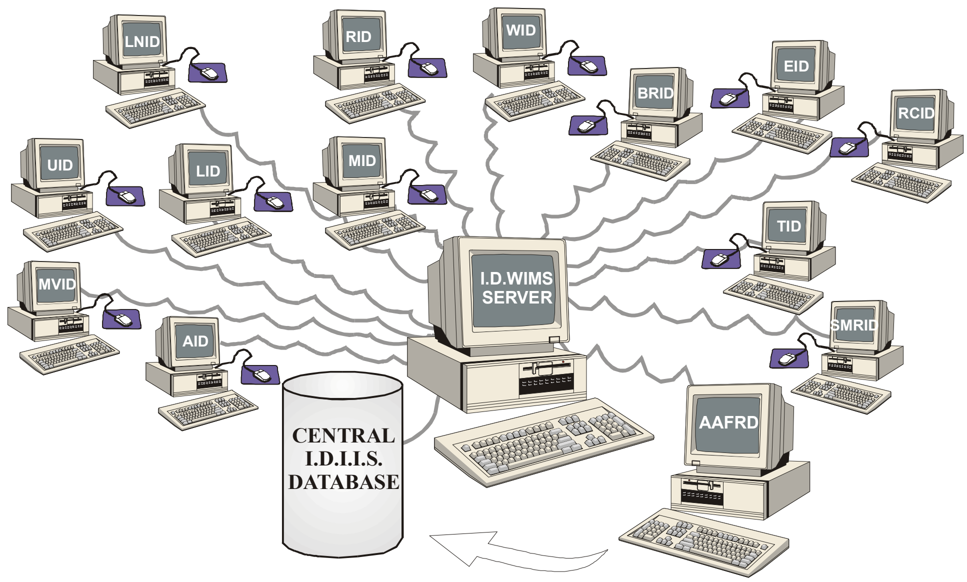

Figure 2. Irrigation district server interface, through *I.D.WIMS* software.

The GIS component of the application was developed using the ESRI MapObjects software components, which provide map-oriented graphical user interface features. Segment and structure data are presented in tabular format for data input and review. The application itself was built as a "desk-top" operating module that only required access to the Internet to download the district-specific server data files and to up-load and synchronize up-dated evaluation information, entered at the local desktop, with the host server database.

<u>Data Entry at the District Level</u>. As the infrastructure component characteristics were already embedded within the attribute databases, districts only needed to (and only authorized to) input condition and functional adequacy assessment data. The structure and security also allowed them to add some optional information such as their own unique works naming conventions and the details of rehabilitation work carried-out themselves, outside of the IRP program. AAFRD staff had "view only" access to the data and therefore could not make any data adjustments unless specifically assigned to do so by a given irrigation district.

<u>Information Reporting at the District Level</u>. Because *I.D.WIMS* was a stand-alone application at the district level, each irrigation district could obtain a variety of district-specific information reports without having to access the web application component, assuming that the data synchronization with the host server was up-to-date. In addition to summarizing the condition of a district's works, these reports would also quantify a number of other details about the local infrastructure, in both tabular fashion or graphically in the form of thematic maps.

Reports express the information relative to both the extent (e.g. length) of works or the projected replacement cost. Table 2 provides an example of a query report for the Bow River Irrigation District (BRID), available at the local district level.

Table 2. Overall summary of BRID conveyance works by construction type.

Construction Type	**Total Length**		**Total Replacement Cost**	
	(km)	**% of Total**	**($M)**	**% of Total**
Open Channel - Earth Only	409.65	39.00%	$81.952	29.22%
Open Channel - Earth & Armored	1.00	0.10%	$ 0.150	0.05%
Open Channel - Concrete Lined	40.18	3.83%	$ 10.495	3.74%
Open Channel - Lined w/ Earth Backfill	164.56	15.67%	$ 46.027	16.41%
Open Channel - Lined w/ Earth Backfill & Armored	210.31	20.02%	$95.445	34.03%
Pipeline - Open or Closed	224.67	21.39%	$46.426	16.55%
Overall Totals	1,050.38	100.00%	$280.496	100.00%

In addition to many other reporting information formats, similar tabulation, as in Table 2, can be obtained and that provide the lengths, replacement costs and proportions of each relative to the *good, fair* and *poor* condition assessments.

Information Reporting at the "Server" Level. A wide variety of "roll-up" reports can be generated at the host server level, particularly ones that provide summaries that include all 13 districts and the cumulative totals thereof. Table 3, as one example, provides a final summary tabulation of the condition of all works for all districts. Figure 3 graphically illustrates the proportional distribution of works condition of all irrigation district conveyance works, according to construction type (EC = Earth Canal; EAC = Earth & Armored Canal; LCEB = Lined Canal w/ Earth Backfill; LCEBA = Lined Canal w/ Earth Backfill & Armored; CLC = Concrete-Lined Canal; P = Pipeline) and as measured relative to replacement cost.

Table 3. Summary of the condition of all works for all districts.

Category of Works	**Replacement Cost ($M) by Condition Rating**			**TOTAL Value ($M)**
	GOOD	**FAIR**	**POOR**	
Conveyance	932.31	790.59	205.65	1,929.55
Drainage	14.07	19.38	9.35	42.79
Major Structures	366.45	202.78	4.26	573.49
TOTAL	**1,312.83**	**1,012.74**	**220.26**	**2,545.83**

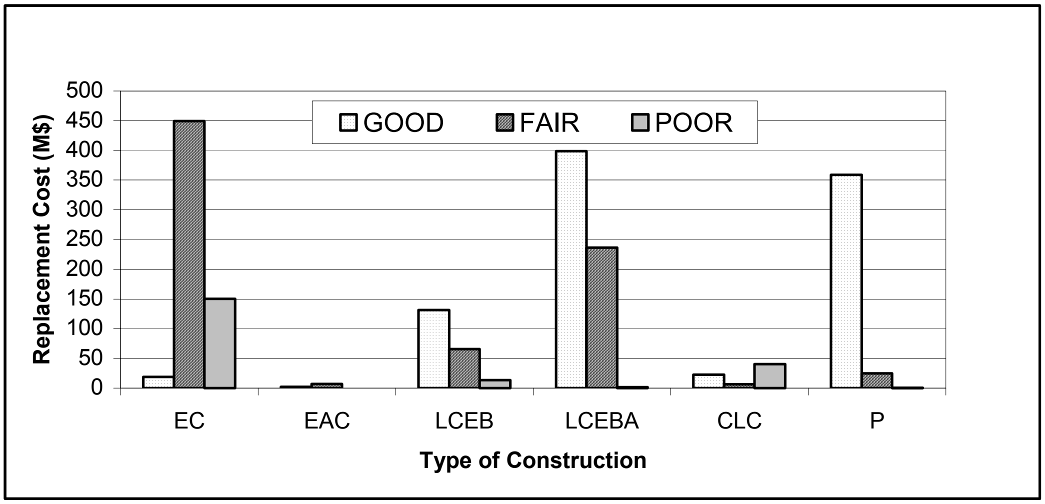

Figure 3. Proportional distribution of all district conveyance works' condition.

CONCLUSION

The IDIMS / I.D.WIMS applications provide an effective means of supporting irrigation infrastructure capital asset management and planning. For example, based on the condition assessment information compiled, it is evident that something in the order of $220 million will need to be invested during the next five to ten years to replace those works currently rated to be in poor condition. Further, during the subsequent 10 to 30 years, reinvestment slightly in excess of $1 billion will be required to rehabilitate those works that are currently rated in fair condition. Similarly, in the 30 to 50-year horizon, a reinvestment of $1.3 billion will be necessary to replace that infrastructure that is currently rated in good condition.

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NCWCD EFFORTS TOWARD IMPROVING ON-FARM WATER MANAGEMENT

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ABSTRACT

The Northern Colorado Water Conservancy District (NCWCD) formally established an IMS (Irrigation Management Service) in 1981 to promote improved on-farm water management. Programs include:

1) Weather Station Network,
2) Field-by-Field Irrigation Scheduling Demonstrations,
3) Surge Valve Loan Program,
4) Agricultural Best Management Practices Field Demonstrations,
5) Cooperative Salinity Program, and
6) Farm Turnout Low-Cost Gate Automation.

Water measurement is a key to improved irrigation management. Needed measurements include flow deliveries to the field, crop water use (calculated from weather station data), local rainfall, tail water runoff, etc. Such measurements allow calculation of on-farm irrigation efficiency. This is a major step beyond just scheduling irrigations. It enables estimation of the volume of water used beneficially.

Increased on-farm irrigation efficiency often requires improved flexibility in water deliveries from the canal to the farm turnout or field. However, this improved delivery flexibility can result in increased spills or waste in canal operations. An appropriate balance must be achieved.

The IMS programs of NCWCD have experienced considerable success. However, institutional and economic barriers continue to inhibit needed improvements in some areas.

BACKGROUND

The NCWCD is comprised of 1.5 million acres in eight counties on the East Slope of the Rocky Mountains in northeastern Colorado. NCWCD has aggressively promoted improved on-farm water management for more than 23 years. Efforts have steadily increased each year and are now supported by nine full-time IMS staff positions.

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From its inception, IMS has been directed toward education, training, and demonstrations. It shares information regarding new technologies, increases public awareness, and enables producer confidence for implementing practical improvements. To date it has not assessed cooperators any fees to participate in the program. All property owners within NCWCD boundaries annually pay a small ad valorem tax assessment to help fund NCWCD operations and activities. The District Board of Directors has consistently supported funding allocations to continue and improve IMS programs. IMS does not focus on policies or politics. With a foundation based on information and technology, it has avoided the controversy and resistance often associated with political mandates and enforcement for regulatory compliance.

WEATHER STATION NETWORK

The NCWCD operates a network of remote, solar powered, automated weather stations throughout its service area for disseminating crop water use information. The Weather Station Network is currently composed of 21 stations. Station sites are carefully selected to ensure readings representative of crop field conditions, always well within a surface-irrigated field of alfalfa hay or over large, well-irrigated areas of urban turf grass. Stations are approximately 25 to 30 miles apart to provide the best practical coverage and are operated year-round. However, station density has increased near metropolitan areas. Each station collects air temperature, relative humidity, wind speed and solar radiation data, which are used to calculate ETR (reference evapotranspiration) on a daily basis using the ASCE standardized Penman-Montieth combination equation for both alfalfa and turf grass. Precipitation, wind direction, and soil temperature are also collected. The weather station data is automatically transmitted at least twice daily to NCWCD headquarters via modem and cellular telephone. Each sensor at each weather station is checked and calibrated annually to ensure data accuracy and to maintain high network reliability.

ETR is factored or adjusted using crop coefficients based on plant growth stages to calculate crop ET or water use for all of the area's major crops. Weather summaries and crop water guides are readily available via the Internet at www.ncwcd.org and also via a telephone voice-messaging system or “Call Center.” The “Call Center” can be accessed using a touch-tone telephone by dialing (970) 593-1605 or (888) 662-6426 (NOCOH2O) toll-free. Voice instruction and menu options allow the user to quickly access information for a selected area.

Accurate and reliable crop ET information supports efficient irrigation scheduling, thereby allowing producers to determine how much water to apply given their specific crop and irrigation practices. Using crop ET information has received wide acceptance and continues to grow. It is a key input utilized in modern, efficient irrigation scheduling methods to maximize water use effectiveness while minimizing required inputs.

FIELD-BY-FIELD IRRIGATION SCHEDULING DEMONSTRATIONS

Since 1981, the NCWCD has provided a Field-by-Field Irrigation Scheduling Demonstration program to growers within its boundaries. This program is an aid in irrigation decision-making to accomplish efficient use of available water. It can provide irrigators with a better understanding of soil moisture management and can often give the grower needed confidence to lengthen the time between irrigations. The program is designed to help growers manage their water throughout the full irrigation season.

The Field-by-Field Irrigation Scheduling Demonstration program utilizes the root zone water balance method, or checkbook method, coupled with soil moisture sensors. Soil moisture holding capacity and an allowable depletion percentage are estimated. Readings from the soil moisture sensors are used to calculate remaining available moisture and are compared to calculated crop ET. The NCWCD's Weather Station Network provides the needed crop ET and is key to the success of the Field-by-Field Irrigation Scheduling Demonstration program.

The program currently targets assistance to 50 area producers, with one to two fields per cooperator each season. Cooperators generally participate in the program for two to three seasons, after which new cooperators replace past participants. Past participants are encouraged to either continue irrigation scheduling activities on their own or to contract with a commercial crop consulting service. By limiting cooperator participation (both quantity of fields and duration), NCWCD has avoided conflicts with commercial crop consulting services and currently enjoys good cooperation and working relationships in this regard.

In the past, tensiometers have been the primary soil moisture device utilized by the program. Instruments were manually read and serviced during a weekly site visit. However, efforts are expanding to include automated soil moisture sensors. Automation allows continuous monitoring and recording of soil moisture at multiple levels within the crop root zone. Several manufacturers now market lower cost electronic soil moisture sensors and data loggers, including telemetry capabilities. Cooperator support for automated monitoring is increasing rapidly.

SURGE VALVE LOAN PROGRAM

Surge valves can be utilized to improve furrow irrigation application efficiency. They are a relatively simple irrigation tool that generally reduces required labor and water. Surge irrigation utilizes gated pipe and an automated butterfly valve that alternates water from one side to the other in timed advance or soak cycles.

NCWCD has provided a Surge Valve Loan Program as a free service to growers within its boundaries since 1993. The program allows growers to evaluate surge irrigation on their own field for a season at no charge. Currently NCWCD maintains an inventory of 30 valves with nearly all valves utilized each season. Valves are loaned to growers, on a first-come first-served basis, with new participants having priority. A NCWCD representative initially meets with the grower and explains the function and basic programming of the surge valve. As surge valves can be installed in many different scenarios, they also discuss installation options and emphasize constraints to ensure successful valve operation. NCWCD then provides 24-hour assistance on the programming and operation of the surge valve.

Most surge valves function in two modes, advance cycles followed by soak cycles. Generally four advance cycles (alternating from left to right) are used to push water down furrows as quickly as possible (without rupturing ditches) to increase irrigation uniformity. After the initial advance cycles, water quickly travels across the already moist soil and continues farther down the field. After the final advance cycle the surge valve begins soak cycles, during which water runs the entire length of the field before switching to the other side. Properly programmed soak cycles have minimal tail water runoff.

In conjunction with the Surge Valve Loan program, NCWCD conducts irrigation efficiency evaluations. Measurements by NCWCD staff (during a single irrigation set) allow surge irrigation to be compared to the grower's traditional practices. Growers can thus better evaluate the effectiveness of surge irrigation. The use of a surge valve generally allows a grower to run more rows on the same amount of water and complete irrigations faster. Tail water runoff is reduced, keeping more water in the field where it is needed. Surge irrigation methods generally improve application efficiency by 10 to 20 percent and often exceed other surface irrigation methods.

AGRICULTURAL BEST MANAGEMENT PRACTICES FIELD DEMONSTRATIONS

NCWCD conducts Agricultural Best Management Practices Field Demonstrations at small acreage educational farms, which it operates and manages. This program effectively promotes improved on-farm water management, including prevention of non-point source pollution. Such efforts have significantly increased NCWCD credibility, raised public awareness, and expanded understanding of improved practices.

In the past, NCWCD has operated farms in conjunction with the Thompson Valley Young Farmers near Johnson's Corner, and with the Valley Young Farmers near Gilcrest. The current demonstration farm is at the northwest corner of Water Avenue and Highway 287 near Berthoud, Colorado. This site is also the new headquarters of NCWCD. It includes crops of small grains and alfalfa hay. Irrigation methods used at this site include surge furrow and linear sprinkler, with installation of sub-surface drip irrigation planned for the near future.

Current or planned field demonstrations include:

1) Surge furrow irrigation vs. conventional furrow irrigation,
2) High efficiency linear sprinkler irrigation,
3) Sub-surface drip irrigation of field crops,
4) Turnout gate automation,
5) Soil additives such as PAM (PolyAcrylaMide) to increase furrow stability and prevent erosion,
6) Grass filter strips and waterways,
7) Turbulent fountain or ‘bubble’ trash screens to prevent clogged sprinkler nozzles,
8) Improved on-farm water measurement, and
9) Soil moisture monitoring for improved irrigation scheduling and management.

COOPERATIVE SALINITY PROGRAM

The quality of applied irrigation water can directly impact crop growth and yield. Crop selection may become limited and/or yields reduced if the salinity of available irrigation water exceeds critical levels.

In cooperation with the U.S. Bureau of Reclamation, NCWCD is completing the fourth year of a multi-year study to assess salinity and its impacts on agricultural crop production in northeastern Colorado and to promote appropriate irrigation management. Monitoring of salinity levels in the surface waters, groundwater, and agricultural soils of the Lower South Platte River Basin is ongoing. This study will build a foundation for development of localized best management practices adapted to preserve productive farm ground in northeastern Colorado. Other institutions, such as Colorado State University, U.S.D.A. Natural Resources Conservation Service, and the West Greeley Soil Conservation District also collect salinity data and collaborate to avoid duplication of efforts.

Beginning in the spring of 2001, NCWCD began monitoring salinity levels in surface waters throughout its delivery area. Coupled with flow data from existing U. S. Geological Survey and State of Colorado stream gauging stations, total salt load and transport is calculated. At present, surface waters of all major tributaries (Boulder Creek, St. Vrain Creek, Little Thompson River, Big Thompson River, and Cache la Poudre River) are monitored.

Continuous, specific conductivity is obtained from 26 newly installed automated salinity monitoring stations. Each station monitors water EC (electrical conductivity) in the range of 0.005 to 7.0 dS/m. Initial EC measurements are temperature corrected to 25C, providing specific conductivity (proportionally related to total dissolved solids). Additional station sensors measure rainfall (tipping bucket rain gauge) and air temperature. Data are sampled at 3-second intervals and averaged (rainfall is totaled) over 15-minute intervals. This continuous monitoring records variability in river/stream or canal EC not obtained by periodic manual sampling. The detection and interpretation of salinity trends and sources is thus facilitated.

InSitu mini-TROLL and Hydrolab Quanta multi-sensor units are used for periodic manual sampling of surface waters at approximately 100 sites (irrigation canals, ditches, reservoirs, and other sources) on a weekly to monthly basis throughout the year. These mobile units contain several sensors, including specific conductance, dissolved oxygen, temperature, and pH. Preferred sampling sites are county road bridges near a stream gauging station.

Groundwater levels are monitored via existing well networks and 20 additional wells newly installed by NCWCD personnel to fill in spatial coverage. A Grundfos Redi-Flo pump draws water from the monitoring wells. An InSitu mini-TROLL or Hydrolab Quanta unit is then used to obtain water quality readings from a representative sample while still at the well site.

Soil salinity is measured and mapped utilizing a Geonics EM38-DD electro-magnetic induction unit mounted on SAM (Salinity Assessment Module, modified diesel powered spray rig, articulated with hydraulic drive wheels). Field sites were selected using a stratified random sampling plan based on a 5-mile grid. Soil sampling procedures closely follow those developed at the U.S. Salinity Laboratory and used by the Lower Colorado Region Salinity Assessment Network. As the EM38-DD can infer salinity distribution with soil depth, valuable insight is obtained regarding the effects of irrigation and drainage within sampled fields.

The raw data from the EM38-DD is analyzed by ESAP software to optimize locations for soil core samples to be obtained. The cores are used to determine soil texture classification and soil moisture, and for laboratory EC analysis. The soil cores are analyzed in 1-foot increments using the Hach Salinity/Sodicity Kit developed by the U.S. Salinity Laboratory. The laboratory analyses are fed back into the ESAP software for the final calibration and spatial mapping of soil salinity.

The severe drought conditions in Colorado during the 2002 and 2003 seasons significantly reduced soil salinity mapping activities. Soil conditions were generally drier and often precluded valid electromagnetic readings using the EM38-DD. Potential field entry for soil salinity mapping is, at best, quite limited. Soil moisture levels must be high enough for valid electro-magnetic readings, yet dry enough to avoid compaction and other damage resulting from equipment passage. Additionally, the crop must also be small enough to avoid destruction by the salinity rig. Frozen soil conditions must also be avoided.

FARM TURNOUT LOW-COST GATE AUTOMATION

The NCWCD began promoting low-cost automation in 2000 under grant funding from the U.S. Bureau of Reclamation. Because on-farm efficiency is largely affected by the operation of local ditch companies, improved canal operations often promote increased irrigation efficiency by the farmer. This program seeks to maintain uniform deliveries and increase flexibility for irrigators. It provides demonstrations of low-cost gate automation on canal structures and/or farm head gates.

Gate automation generally necessitates accurate water level or flow measurement. Long-throated flumes, broad crested weirs, or ramp flumes (Replogle flume) can often provide low-cost flow measurement devices appropriate for many applications with minimum head loss. These are readily designed to meet many site constraints.

Local interest in gate automation has increased rapidly in recent years. Lower purchase costs for equipment, coupled with more flexible operations, are key factors. Additionally, increased urbanization of the NCWCD service area has increased the operational challenges and constraints facing local ditch companies. As productive agricultural lands are sold for development and the associated water rights transferred to cities, irrigation and ditch companies are faced with reduced flow rates, decreased exchange opportunities, and shorter delivery seasons. Improved flow measurement, remote monitoring, and gate automation are increasingly required for successful water delivery operations.

CONCLUSIONS

NCWCD has implemented a wide range of programs to promote improved on-farm water management and conservation. These efforts include a district-wide weather station network, field-by-field irrigation scheduling demonstrations, surge valve loan program, agricultural best management practices field demonstrations, cooperative salinity program, and farm turnout low-cost gate automation.

IMS does not focus on policies or politics. With a foundation based on information and technology, it has avoided the controversy and resistance often associated with political mandates and enforcement for regulatory compliance.

Water measurement is a key to improved irrigation management. Needed measurements include flow deliveries to the field, crop water use (calculated from weather station data), local rainfall, tail water runoff, etc. Such measurements allow calculation of on-farm irrigation efficiency. This is a major step beyond just scheduling irrigations. It enables estimation of the volume of water used beneficially. This in turn supports effective decision making to increase water use effectiveness, reduce production costs, and/or improve the quantity and/or quality of crop yields.

Increased on-farm irrigation efficiency often requires improved flexibility in water deliveries from the canal to the farm turnout or field. However this improved delivery flexibility can result in increased spills or waste in canal operations. An appropriate balance must be achieved.

The IMS programs of NCWCD have experienced considerable success. Formally established in 1981, IMS currently employs nine full-time staff and six temporary field technicians each summer. In many years, area farmers/producers have routinely signed up on waiting lists to participate in several IMS programs. Initially skeptical and reserved, many irrigators quickly learn to accept and rely upon the information obtained through IMS programs. Irrigation effectiveness and efficiency subsequently increase, water resources are conserved, and water quality is preserved. Many cooperating farmers report production cost reductions, primarily in required labor for irrigation. NCWCD and its' IMS have become well recognized for their ongoing efforts to improve on-farm water management.

However, institutional and economic barriers continue to inhibit needed improvements in some areas. These barriers include water right administration, lack of flexibility in water deliveries to field turnouts, reduced canal /ditch flows resulting from water transfers to municipalities, etc. Consequently many area farmers/producers continue historical practices to use irrigation water whenever it is available, rather than just when it is needed, as its future availability is restricted and/or uncertain. In addition, many landowners are reluctant to fund irrigation system improvements needed by tenant farmers. Such investments can significantly reduce or even eliminate their net income from farm ownership. Often the farmer renting such ground cannot justify paying for capital improvements he cannot take with him if his lease is not renewed. Consequently many area irrigators are left to struggle using antiquated and inefficient irrigation methods. In average or wetter growing seasons, irrigation water continues to be a lower cost input to farm production and high irrigation efficiency is simply not required to insure profitability.

A WEB-BASED IRRIGATION WATER USE TRACKING SYSTEM

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ABSTRACT

Across the 13 irrigation districts in the province of Alberta, there is no direct volumetric financial charge attached to water diversions and consumption. Individual water users pay specific and fixed annual rates per unit of irrigation area defined within their respective assessment rolls, regardless of the actual volume of usage. However, as water is becoming a more stressed resource, with increasing competition for limited supplies by a diversity of users, and with greater public call for more accountability on the part of water users, it is becoming increasingly understood that some form of volumetric accountability is warranted.

As virtually none of the 10,000-plus water delivery turnouts have any metering facilities whatsoever, it has been necessary to develop some alternative form of water use tracking to compile reasonable records of individual diversions. Even though these volumes of diversion are not currently tied to water use charges, many of the districts have implemented limits on deliveries to individual land parcels. A *Water Use Module (WUM)* software package has been developed that tracks water use based on the duration of water deliveries to each irrigation system in each field and the respective capacity of each of those systems. This package has recently been up-dated to take advantage of opportunities to interface with the Internet for more real-time, more accurate and more comprehensive irrigation information reporting.

INTRODUCTION AND BACKGROUND

Irrigation In Alberta

There are 13 organized autonomous irrigation districts in Alberta, collectively supplying water to approximately 1.325 million acres (536,000 ha) of assessed irrigation land in the southern region of the province. In addition, there are approximately 285,000 acres (115,000 ha) of land irrigated across the province through what are referred to as privately licensed and individual water user-

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developed irrigation projects. Irrigation districts are particularly characterized by their extensive infrastructure and their operating under provincial legislation known as the *Irrigation Districts Act* and under water License authority through the province's *Water Act.*

Each of the districts has its own somewhat unique history of development, but, in general, they have been in existence for nearly one hundred years or more. Typically, each district, under the authority of its water License(s), has a volumetric limit available to deliver through its respective works to the farm delivery gates of its water users. The latter pay for this supply, to their water user-owned district through annual rates that are levied against each "acre to be irrigated" on the district's assessment roll. Annual water rates have not and are not levied on the basis of the amount of water used. Although, there is a license limit on the amount of water that can theoretically be diverted to each district and subsequently delivered to the farm gate, water users have not, in the past, been subjected to much in the way of restrictions.

However, the irrigated area in Alberta has now matured to the level where double the area is now aggressively being irrigated than was the case 25 to 30 years ago. In addition, the impact of consecutive drought conditions in recent years, combined with the expanded intensive irrigation development, has resulted in situations of limited water supplies and a need, at some times, to impose rationing. In some irrigation districts, where rationing has not been immediately necessary, there has been a recognition that delivery limits needed to be imposed to encourage a greater ethic towards water conservation. As none of the more than 13,000 farm deliveries operated within the 13 irrigation districts have any physical water metering facilities installed, it has been necessary to derive some other "proxy" measurement system to quantify water use at the farm level.

IRRIGATION INFRASTRUCTURE INVENTORY

At the same time as the need to better quantify and control individual irrigator's water use was emerging, a major study to evaluate the opportunities for future irrigation growth in Alberta (Irrigation Water Management Study Committee 2002) was just concluding. This was a significant partnership collaboration between the Irrigation Branch of Alberta's department of Agriculture, Food and Rural Development (AAFRD) and the 13 irrigation districts in the province. As a major component of this water management study, a complete inventory of all irrigation district infrastructure and associated on-farm irrigation operations was developed within a GIS application. This was required in support of the detailed water management modeling carried out through the Irrigation Demand Model (IDM) (USCID/EWRI 2002). Each year, in consort with the irrigation districts, this spatial and attribute database is up-dated to reflect current system configurations, water delivery and application components, as well as field-by-field crop inventories.

Linking Conveyance Networks and Delivery Components

Two different data acquisition and warehousing systems were developed. The system that warehouses all of the district conveyance infrastructure data, including information on each farm delivery turnout, is referred to as the Irrigation District Infrastructure Information System (IDIIS). It contains a wide variety of descriptors concerning irrigation district conveyance and drainage works as well as significant major structures. Further descriptive information and a graphic representation of the IDIIS application are outlined in an associated paper, in these proceedings, discussing an infrastructure management system (Chinn et al 2005).

The second data management application, which captures all of the relevant on-farm information, is referred to as the *District Data Information Tool (DDIT)* and is the mechanism through which district operations staff inventory all on-farm system and crop information each year (AAFRD 2002). Each established on-farm system (e.g. center pivot sprinkler, surface irrigated field, etc.) is inventoried and linked to a specifically identified turnout delivery. Therefore, whether it is for IDM modeling purposes, for example, or for other water use accounting purposes, each on-farm system is "tied" to the conveyance network at some distinct point.

The DDIT application was developed in Microsoft Visual Basic, providing a straightforward user-interface, with Microsoft Access used for backend data storage.

ACCOUNTING FOR WATER USE

Within the DDIT software package, a *Water Use Module(WUM)* was also developed, enabling district operators to track irrigation water deliveries throughout any given district or portion thereof. The premise for this tracking was based on three identified on-farm system parameters, namely:

- Type of on-farm system (e.g. center pivot and side-roll sprinklers, etc.) and the flow rate or turnout delivery rate required for each type of system (e.g. gpm);
- Area irrigated by each system (e.g. acres); and
- Time of water use / water delivery (e.g. hours, days, etc.)

Therefore, to arrive at the amount of water used by a system during a given time period, the following equation is simply applied.

$$V = Q \times T \times 0.0042 \qquad (1)$$

where: V = volume of water diverted through a given turnout (acre-feet)
Q = flow rate through on-farm irrigation system (gallons/minute)
T = time period of water diversion (days)

The accuracy of applying Equation 1 to quantify water use is directly dependent on the accuracy of the system flow rate and the precision of recording actual diversion time. As is the case where any "proxy" system is being used, some assumptions or default information are relied upon. For example, default system flow rates, for southern Alberta conditions, were identified as a standard reference, on a per irrigated unit area, and are listed in Table 1.

Table 1. Default capacities for southern Alberta on-farm irrigation systems.

Type of On-Farm System (HP = High Pressure) (LP = Low Pressure)	**Default Flow Rate* (gpm/ac)**	**Type of On-Farm System**	**Default Flow Rate* (gpm/ac)**
Sprinkler – Solid Set	8.66	Gravity – Undeveloped	9.95
Sprinkler – Hand-Move	8.98	Gravity – Developed	15.35
Sprinkler – Side-Roll	7.15	Gravity – Auto Control	17.25
Sprinkler – Ctr. Pivot (HP)	6.86	Sprinkler – Volume Gun	8.66
Sprinkler – Ctr. Pivot (LP)	6.35	Sprinkler – Traveller	8.66
Sprinkler – C. Piv. Cor. (HP)	7.06	Micro – Spray – Sprinkler	5.45
Sprinkler. – C. Piv. Cor. (LP)	6.48	Micro – Spray – Trickle	4.49
Sprinkler – Linear (HP)	6.86		
Sprinkler – Linear (LP)	6.41		

* These flow rate values are typical for the higher heat unit and longer growing season regions. Default flow rate values for other regions can be moderately reduced.

Because of the prior on-farm system data collected and held within the DDIT database, all that is required to be entered into the WUM to calculate the water use is the date and time of water "turn-on" and the date and time of water "turn-off". All other calculation factors are accessible through the DDIT database. This includes such information and variable particulars as:

- Type of system
- A system I.D. number (established by DDIT)
- Area irrigated by the system
- Default system flow capacity
- Land location of the system
- Name of the system owner / water user
- Turnout number (from IDIIS database) from which deliveries are made
- Type of crop grown under the system
- Water supervisor block

Where it is claimed or determined that the default system capacity is incorrect, a revised value can easily be inserted to overwrite the default value. The updated value will then always be referenced for all future water deliveries.

Water Use Information Reporting

A typical selectable water use report is depicted in Table 2. Pre-designed query reports can provide viewing or printouts of similar format information, based on selections according to the water user name, turnout or conveyance lateral identification, water allocation balance, water supervisor block or water deliveries in progress.

Table 2. A sample water use report for a single system during a single season.

BLOCK Name: Albion Ridge				**Water User Name:** Sun Dried Farms			
Land Location: NW-1-2-3-W4				**System Type:** SPLC		**Area:** 159.30 ac	
Date On	**Time On**	**Date Off**	**Time Off**	**Flow Rate (gpm)**	**Divert Time (Days)**	**Volume Delivered (ac-ft)**	**Water Use (ac-ft/ac)**
Jun-20-03	12:00pm	Jun-23-03	4:15pm	1,010	4.17	18.62	0.11
Jul-2-03	8:30am	Jul-12-03	9:00am	1,010	11.02	49.18	0.31
Jul-17-03	9:45am	Jul-23-03	8:30 am	1,010	6.95	31.01	0.20
Jul-28-03	12:00pm	Aug-2-03	7:00pm	1,010	6.29	28.08	0.18
Sep-15-03	11:15am	Sep-20-03	12:00pm	1,010	5.03	22.45	0.14
TOTAL for System					**33.46**	**149.33**	**0.93**

One of the most useful tools for output reporting that is available to a water supervisor for any given block is a listing of the current water deliveries in progress, indicating the location and flow rate of each of those deliveries. This additional information provides the water manager with a more comprehensive grasp, at any selected time, of how much water is moving through the system. When combined with pending water turn-on and turn-off orders, the block water supervisor can be more efficient and more effective in diverting appropriate volumes of water into various reaches of the conveyance network.

Managing for Rationed Allocations

As indicated previously, one of the main drivers for the use of this system has been the need to limit water delivery volumes at the farm gate, either due to shortages in supply or through conservation initiatives. Under rationing, for example, it may be determined that there is only sufficient water available for a given irrigation season in the amount equivalent to 12 inches per irrigated acre delivered at the farm gate. In order to track water use at each and every turnout, to ensure compliance with the restricted allocation, the DDIT/WUM application will track the number of days that water is diverted to any given system and provide notification as allocations are being fully consumed.

Once again, by the database knowledge of each system's capacity and irrigated area, it can be pre-determined as to the total number of days of delivery it would take to fully divert the rationed allocation volume. This can be derived according to Equation 2.

$$T = 18.857 \times D \times A / Q \tag{2}$$

where: T = allocated time of delivery (days)
D = rationed allocation depth (inches)
A = area being irrigated through the diversion (acres)
Q = *average* rate of flow or system capacity (U.S. gpm)

Therefore, for an irrigation system with an application capacity of 900 gpm and covering 132 acres, it would take 33 days of operation to use the full 12-inch allocation. The WUM provides information reports to list any and all in-field systems that are within a specified balance of the stipulated allocation, thereby notifying the water supervisor as to when and where season cut-offs may be pending.

WATER USE DATA COLLECTION AND COMPILATION

Stand-Alone Computer Assistance

The DDIT application was originally designed to operate on independent computer systems, resident with each local irrigation block water supervisor ("ditch-rider"). Throughout the irrigation season, the water supervisor inventoried all on-farm systems and associated crops, recording the information in whatever form was available and practical at the time. At the end of each day or two, the water supervisor entered the data for his/her block area into the DDIT module installed on his/her home computer system. At the end of the year, summary reports of farm operation details were provided to the irrigation district central office, on a block-by-block basis, and individual block databases merged to provide overall district statistical reporting.

Web-Enabled DDIT

In the evolution of the DDIT and WUM applications, several irrigation districts expressed the desire to have near real-time access to the field information being collected. In particular, the immediacy of on-farm system and associated water use information was expected to be valuable in assisting water operations managers to develop better control of water distribution practices for more efficient water storage and conveyance.

Some water supervisors collected the required information in a manual fashion and then, within a day or two, entered the information into his/her home computer up-dating that block-specific database only. Other supervisors collected and entered the data "on-the-go", carrying laptop computers with them in their work vehicles as they made the daily rounds of their respective irrigation blocks. However, there was still no central district database consolidation until all block databases were merged at season's end.

As a result, a revised application, called Web-DDIT was created. It provided a browser-based tool that allowed access to a centralized database resident on the district's web-server. The DDIT software and WUM application were modified so that all required field data could be collected and made available, via the Internet.

Typically, the inventory of on-farm systems would not change too significantly from one year to the next. However, with the ability to up-date any changes early in the irrigation season and have them up-loaded to the main district server, it became practical then to invoke the water use tracking system in a more rigorous fashion.

With the field information being up-dated more often and routinely on the main district server, the Internet connection also provides an opportunity to allow individual water users to access their water consumption information on a regular basis throughout each irrigation season. This is helpful, for example, where delivery limits are in force, allowing each water user to be completely aware of where his/her operation is at with respect to water allocation used and water allocation remaining.

Evolving to the Cellular Phone Adaptation

As is so often the case, as a new information system becomes more and more accepted, and its application is seen to be more and more useful, the expectations for convenience in its use tend to increase as well. Laptops, were often carried along daily with the water supervisor, were certainly seen to expedite the data acquisition process. Otherwise, written notations of daily collected data were transferred electronically each evening. However, the routine of making nightly up-date submissions over rural communication lines that were very slow, did not enhance the water supervisor's enthusiasm for the process. In addition, these units were not necessarily conducive to the rigors of the heat, dust and light of field duty.

As diverse information-sharing technologies become more and more available, the potential for better and more immediate data sharing becomes possible. Such has been the case with the recent availability of web-enabled cellular communication capabilities. As a result, some irrigation districts have implemented the latest version of the WUM whereby a water supervisor can submit the "turn-on" and "turn-off" dates and times almost instantaneously with the time that the action in the field takes place. Each on-farm system, inventoried within the DDIT database, has a unique identifying system number. At such time as a water delivery is commenced, or terminated, the water supervisor, through a WAP- enabled (Wireless Application Protocol) cellular telephone, simply needs to access the district's web-server and enter the system number of the system being delivered to and selects "turn-on" or "turn-off", depending upon the current operational situation. The delivery rate can also be over-ridden via the cellular connection, if applicable. That is all that is required as the date and time are automatically encoded at the time of data transfer from the cellular unit. This has proved to truly reduce operator workload and provide much better reliability in district management receiving near-real-time information on water operations and how they may affect water management decision-making.

A QUESTION OF ACCURACY

As the WUM application was a proxy measurement system, it was questioned as to how reliable the information was, particularly with regard to its accuracy. Regardless of the sophistication of the data capture and submission techniques, the system was still operating under quantifiers that relied on certain assumptions. Where there was some dispute over the assumed capacity of any given system, that could be verified through direct Doppler or sonic flow measurement devices that most districts had on hand for such situations**.** However, there are several other variables that can, if not correctly quantified, affect the degree of accuracy between the calculated consumption and the actual use. These are:

- System capacity variability;
- Discrepancy between recorded and actually-irrigated area;
- Actual diversion time affected by system shut-downs, etc.; and
- Water supervisor's diligence at recording exact "on: and "off" times.

Any variance from the true values for any of the above could have some degree of effect on the accuracy of the calculated diversion amount. Nonetheless, any loss of accuracy must also be compared to what could be reasonably expected to be achieved with conventional flow measurement equipment.

A Field Test Comparison

In order to determine the relative accuracy of using WUM for tracking water use, a monitoring project was established in the field where actual metered diversions could be compared with the calculated volumes derived through the WUM application.

A conventional conveyance lateral, within the Lethbridge Northern Irrigation District (LNID), was selected for the comparative monitoring evaluation. The

LNID was one of the earliest users of the WUM and are progressing as one of the irrigation districts leading in the adoption of this format of water use tracking. There were 13 different irrigation systems (seven center pivot sprinklers and six side-roll systems) diverting from this supply lateral. Each turnout was equipped with an in-line McCrometer impeller meter, installed at such a location downstream of the turnout and up-stream of the irrigation system so as to satisfy the hydraulic flow guidelines as much as possible. These types of meters had been used by AAFRD on a number of research projects and were found to be quite accurate and reliable. Each meter was also equipped with a datalogger that recorded the date and time of flow as well as the rate of flow and accumulated flow-through. The conventional mechanical meter with a totalizer was installed as well and served as a check against the datalogger readings.

Over the course of three irrigation seasons (2001, 2002, 2003) the actual diverted flows were tracked through the metering equipment. At the same time, the WUM records, as submitted by the local water supervisor for the block, were compiled for later comparative analyses.

Figure 2 illustrates the comparative results from the 2001 irrigation season, one of the highest demand years. The type of system monitored is indicated as well.

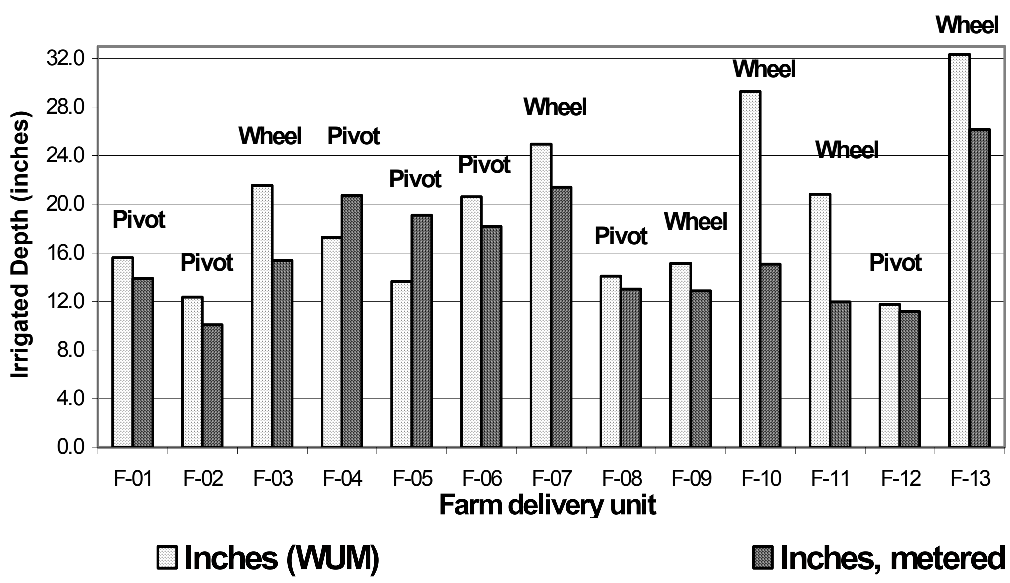

Figure 2. A comparison of metered vs. WUM measurements, by system type

A Discussion of the Results. It was determined that there were some small discrepancies between the assumed system capacity and what was actually confirmed through testing with a more precise sonic meter. It was also found that the actual irrigated area under some systems was slightly different than that which was recorded on the assessment rolls. However, the major factor influencing the variance between the WUM determinations and the metered logs was in the actual time of diversion. The water supervisor tended to not be too specific in his record-keeping as to exactly what time in the day water was actually turned on or off. Similarly, if a system was turned-off during the delivery period, through, for example, an automatic shut-down due to a pivot operational problem, that "water-off" period was not recorded by the water supervisor but was, however, tracked through the meter datalogger. This yielded a trend where the WUM record generally indicated a higher (23.8%) water use than was actually metered.

CONCLUSIONS

The concept of using the WUM application appears to be feasible for southern Alberta irrigation operations. This has been borne out by the successes in its application achieved in critical water rationing years. In comparison to the estimated $20 to $25 million investment that would be required to incorporate physical metering facilities, the WUM is a good first step, at least, in tracking irrigation water use.

On-going follow-up field research, supplemented by simple flow-switch time clocks, has shown that where the time-linked water deliveries are more precisely recorded and on-farm system capacities are better quantified, reasonable measurement accuracies are attainable. With due diligence in acquiring the correct field data, with a convenient and reliable system of data entry, and with timely entry of correct data by local water supervisors, it is expected that the accuracy of the WUM water use determinations can be within ± 10% or less. Relative to conventional metering systems that usually require considerable on-going maintenance, this level of accuracy may be reasonable and practical.

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USING GIS TO MONITOR WATER USE COMPLIANCE

Paul R. Cross, P.E.[1]

ABSTRACT

Irrigation districts are responsible for a wide variety of issues including but not limited to water distribution, water management, regulation of water rights, and collecting assessments. The Lake Chelan Reclamation District irrigation system is owned by the U.S. Bureau of Reclamation and operated by the District. The contract between the District and the USBR limits the application of irrigation water to lands classified as irrigable. The nature of the topography together with the delivery of pressurized water to high value crops has led to both inadvertent and advertent use of irrigation water outside of the classified areas. The high value of the water involved has required the District to use the best technologies available to evaluate the cumulative impact of water use outside of the classified areas.

This paper will describe how GIS is being used as an evaluation tool to quantify and manage the aerial imagery, GPS information, irrigable boundaries, the extent of irrigation and other database properties associated with the land use. One unique aspect of the project is merging and sharing the database information from the District's billing and water management software platforms with GIS so that maintenance of customer information is done only one time in only one location. Automated systems are planned to analyze and evaluate changes in the aerial images over time so that managers can evaluate changes in water use patterns when permanent crops are upgraded and replanted. The results of the analysis will be the basis of a reclassification survey by the USBR to bring the lands back into compliance with the contract provisions.

INTRODUCTION

The Lake Chelan Reclamation District (LCRD) was formed in 1920 as an irrigation district. The system was challenged with years of drought, forest fires, floods and severe winters that threatened the viability of the district. In the early 1970's, the U.S. Bureau of Reclamation (USBR) entered into a contract with the District to construct a modern irrigation system for the district by pumping directly out of Lake Chelan. The District repays the construction obligations and operates the system for the USBR. The contract specifies that the District must supply irrigation water only to lands classified as irrigable or under special contract.

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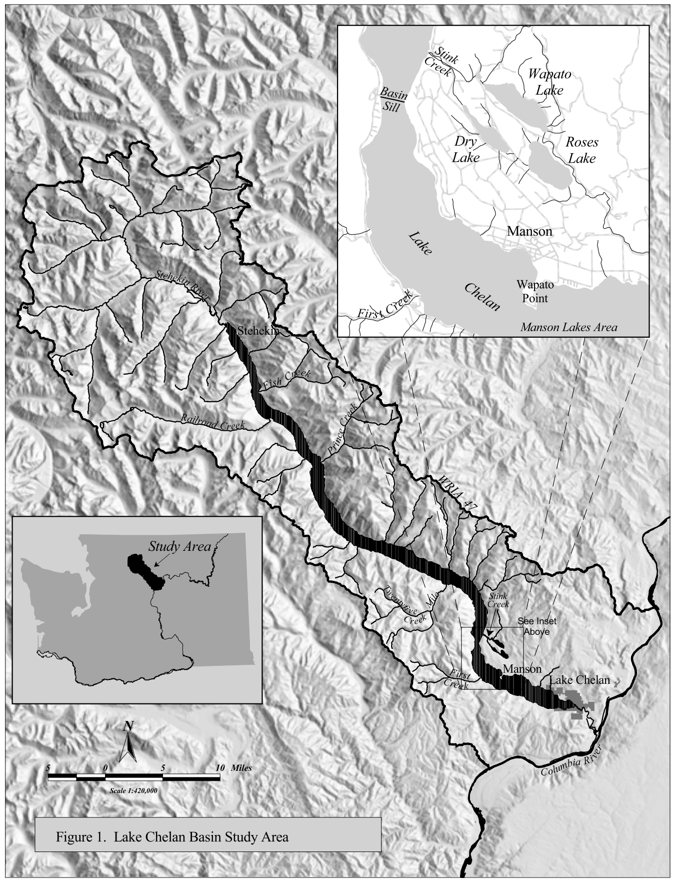


Figure 1. Lake Chelan Basic Study Area

IRRIGATION SYSTEM AND CLASSIFICATION PROCESS

System Design and Layout

The USBR began planning for a new irrigation system for the District back in the late 1950's. The concept of irrigable lands was used to identify agricultural property that had long-term commercial viability within a logical service area.

Topography: The Lake Chelan Reclamation District is in a mountainous region on the east slopes of the Cascade Mountain range. The USBR system identified a service area that extended from 1100 feet mean sea level (MSL) to over 2400 feet MSL that would be served by 12 different pressure zones. The system was designed to provide irrigation water under pressure to all farms with a minimum 30 psi at the high point.

Allotment: The typical crops grown in north central Washington are fruit trees and vines. These crops require an average of 3 acre-feet per acre of supplemental irrigation water to raise a productive crop. The USBR system was designed to provide at least 6.9 gallon per minute per acre to meet daily evapotranspiration requirements of these crops during peak demand.

Delivery: The District operates the system as an on-demand, limited rate system. The farmer may turn their water on and off as needed and is asked only to stay within the maximum instantaneous delivery rate dictated by the system based upon acres assigned to the turnout, overall capacity and demand. The use of flow meters, pressure reducing valves and regulating reservoirs provides the growers with outstanding flexibility of service.

Land Classification

The USBR classifies land in the District as irrigable classes 1, 2 or 3 or as non-irrigable class 6. The lands classified as irrigable have the elevation, slope, soil type and profile to productively grow crops.

Elevation: The USBR system was designed to serve 12 different pressure zones with at least 30 psi at the high point. This criteria was established when overhead impact sprinklers were the most commonly used on-farm irrigation system in local orchards. The high point was established based upon an allowable friction loss in the grower's mainline and instantaneous flows to serve impact sprinklers. The current use of micro and drip sprinklers at low pressures has expanded the grower's potential service area using turnouts based upon the original criteria.

Slope: Irrigable classifications were based upon slopes not exceeding 15%. Classification maps were drawn with topographic information of limited detail and accuracy. The advent and wide-spread popularity of the four-wheel drive orchard tractor made farming slopes steeper than 15% much easier and safer. Land leveling for high value crops also became popular.

Soils: Smaller trees in the orchard setting have proportionally shallow root stock and need less soil depth than in the original criteria. Wet areas that were thought to be non-irrigable have been drained and conditioned making them suitable for cultivation.

Development and Replants

As growers developed the new lands added to the project in the 1970's and 1980's and as old orchards were torn out and replanted, the growers were looking for horticultural situations that were easiest and most profitable to farm. Many land classifications done by the USBR were done without "field truthing" the topography and soil types leaving the grower to plant orchards where the land was truly arable and where the orchards produced the best crop.

MONITORING WATER USE COMPLIANCE

As the proceeding sections briefly describe, the changes that have occurred over time have allowed growers to both advertently and inadvertently use water outside of the lands classified by the USBR as irrigable. The high value crops make land values increase and limited water an increasingly valuable commodity. The modulating topography and odd-shaped properties make visual observation of crop patterns difficult to evaluate and impossible to quantify without a survey. The Lake Chelan Reclamation District is required to regulate the use of irrigation water to stay within the contractual terms of the USBR contract and the state water rights. Geographic information systems allow the Lake Chelan Reclamation District to look at the overall contractual acreage as well as the compliance of the individual grower.

Electronic Mapping and Imagery

AutoCAD® software is used to map parcels, land use and facilities within the Lake Chelan Reclamation District. Orthorectified aerial photos of the lands within the LCRD can be viewed and overlaid with mapped features. Specific features can also be identified by operational personnel with a global positioning system (GPS) and added to the AutoCAD layering system.

Base Maps: Experience has taught the District that electronic mapping and imagery must be done on the proper coordinate system, with very good base information, and to a high degree of accuracy. Assessments and allotments are based upon the number of irrigable acres within each parcel. Every subdivision and boundary line adjustment potentially impacts the assessment of each parcel.

The District began the exercise of mapping parcels into AutoCAD using their actual legal descriptions overlaid on the original USBR plats. The original USBR plats unfortunately contained inaccurate data that was poorly coordinated and constructed. Translating the data to 1983 North American Datum (NAD 83) proved that mistakes were made in the earlier plats. This was verified when the maps were overlaid onto the high quality orthorectified aerial photos. The inaccuracies were not at a consistent offset or scaling factor and rubber sheeting the maps would only distort the metes and bounds descriptions of each parcel.

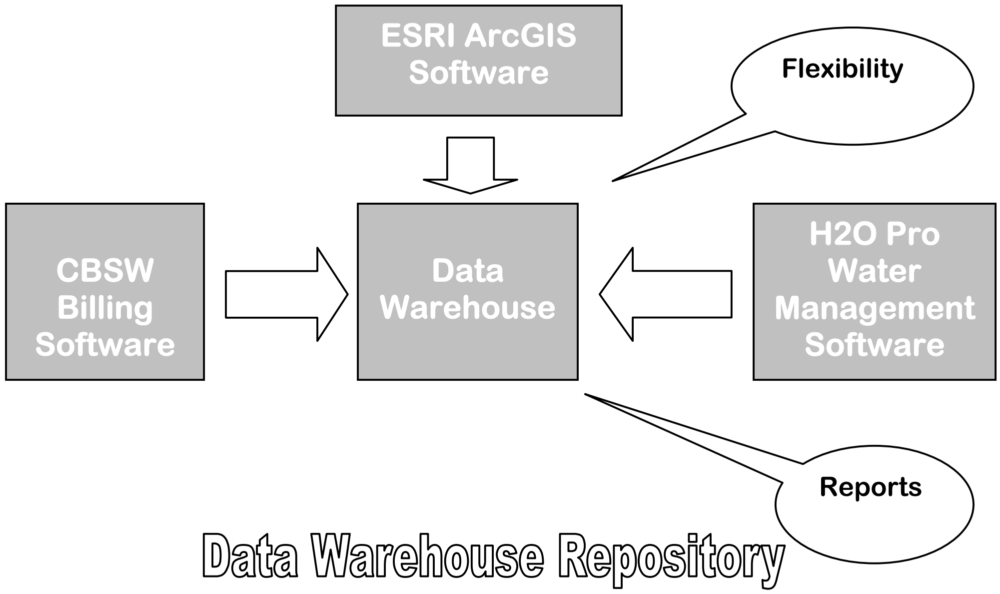
GPS Control Points: The translation of data into NAD 83 required the establishment of known control points as points of reference. District personnel used global positioning systems (GPS) to identify and reference over 4,000 property and plat monuments that could be verified with the high resolution aerial photography. Parcels and plats could then be repositioned and apportioned within NAD 83 to meet accuracy requirements. Physical land use is then digitized within the parcel off of the aerial images. Land classification is digitized off of the USBR classification maps onto specific AutoCAD layers. Other distribution system elements including turnouts and lateral locations were also positioned with GPS.

Integration of Platforms

All AutoCAD drawing layers are being imported into the geographic information system (GIS) used by LCRD. The maps are converted to elements within ArcGIS® by ESRI software. The only attributes imported to GIS at this time are parcel number and irrigation turnout number together with the land use and other physical features represented by closed polylines in the appropriate AutoCAD layer. This process is currently underway in the District and represents the current status of the project.

Electronic Data: The Lake Chelan Reclamation District has worked closely with Easy Reader International through its program H2O Pro® and Continental Utility Solutions through its program Continental Irrigation Billing System for Windows® (CBSW) to develop a new billing and water management software platform. H20 Pro is a robust program designed for irrigation districts that develops a relational database between irrigation water use, crop types and facilities management. CBSW is a relational database that can track multiple services provided by irrigation districts together with several customer information features to meet billing needs. LCRD hired these companies to develop a data warehouse repository for a single common database that works with both programs. The data warehouse program provides periodic exchanges and synchronization of data between H2O Pro and CBSW to coordinate the various functions.

H2O Pro handles all water use issues associated with meters and meter reading functions. This is done by utilizing handheld scanners and bar codes that identify both meter and turnout information in the field. H2O Pro will manage quality control of new meter readings that are entered into the system and allows the operators to read the meters at daily intervals if needed. H2O Pro also provides the internal calculations to determine if water use is within established allotments, or if not, where usage lies within tiered excess rate structures. The program allows for multiple meters that are shared and averaged for one or multiple customers. Water use reports can be generated by customer, crop type, lateral or system for any queried time period. The water use by billing category is then exported to CBSW where bills are generated by service type.



CBSW coordinates customer information, turnout identification and parcel identification together with the same attributes identified in ArcGIS. This customer and facility data is then exported to H2O Pro for its use in developing customer water use reports. The data warehouse is used to coordinate the timing and quality control of the data being synchronized between the three applications.

Populating the GIS Database: Most GIS systems have standalone databases that run independently of other customer information systems. The GIS system must therefore be independently updated and maintained. As described above, CBSW has considerable capabilities to provide customer information. This includes the actual number of acres assessed and allotted to each parcel and customer. The goal in the future is for the data warehouse to allow the database information generated and maintained in the billing software to be exported and populate the GIS database. The cross reference will be the parcel and turnout number that were attributed in the GIS conversion. Queries can then be developed in GIS to compare assessed versus planted acres to be reported both on the District-wide level as well as the ownership or parcel level. The resulting high quality maps can then be used by the USBR as a basis for a reclassification survey. It is anticipated that a reclassification survey will be done soon after the GIS is fully populated with current data and then periodically in small areas thereafter as the need arises.

FUTURE INTEGRATION NEEDS

Within the next year, the Lake Chelan Reclamation District will be integrating the platforms together for an overall compliance report. The compliance report will be a snapshot in time back to when the most current orthorectified aerial photography was done in 2001. Unless aerial photography can be taken every year, none of the land use changes that have occurred since the aerial photography will be reflected in the reports.

Several irrigation districts in Oregon have been using satellite imagery as a cheaper alternative to expensive orthorectified aerial images. The satellite imagery is cheaper to obtain but does not have the resolution or accuracy of the aerial images. It is proposed that the District will obtain satellite imagery on an annual basis to supplement orthorectified photography obtained every 5 to 7 years. ArcGIS can be queried to analyze and identify only changes between the aerial photos and the satellite imagery. If the changes identified in the satellite imagery are a compliance concern, GPS technology can be used to "field truth" the extent and location of the change in land use and make up for the lesser accuracy of the satellite image.

The data warehouse can also be used to synchronize the database between future upgrades of the billing, water management and GIS products described. Subtle changes in the warehouse may be needed to describe where the data is coming from and going to within the upgraded standalone products, but if open architecture remains in vogue, the future of this idea remains positive. The data warehouse is much easier to customize and upgrade than it would be to customize each individual standalone platform.

CONCLUSIONS

Water use compliance is an important issue within irrigation districts in the arid west as more interest groups compete for these limited resources. Water law, endangered species, clean water act provisions, third party impacts and contractual obligations are just a few of the competing factions interested in assuring that present uses of water are efficient and effective. At the Lake Chelan Reclamation District, GIS will be used to advance our understanding of water use and efficiency and document the same. The integration of various software platforms allows the customer information to be updated, queried, compared and maintained within one single database. This makes data management more efficient and useful.

DEVELOPMENT OF A WATER MANAGEMENT SYSTEM TO IMPROVE MANAGEMENT AND SCHEDULING OF WATER ORDERS IN IMPERIAL IRRIGATION DISTRICT

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Bryan Thoreson[2]
Alpha Baro[3]
Carlos Villalón[4]

ABSTRACT

Over the last decade, distribution system operations at Imperial Irrigation District (IID) have evolved, driven by internal water-user needs and external pressures to conserve water. The result is increasing flexibility in deliveries to water users. However, associated distribution system operations have resulted in fluctuating water levels, varying delivery flows, increasing canal over toppings and other issues – leading to the need for fine-tuning of the ordering, tracking, and delivery processes.

IID's goal is to manage water flowing from the Colorado River to the delivery gate in a single, integrated environment. Presently, management of water from the river to the farms is performed by series of processes that are part digital and part paper. While the system works well relative to current needs, system improvement and integration is needed to facilitate higher levels of service and efficiency and to meet increasing requirements for operational flexibility. This improved system is referred to as the Water Management System (WMS).

This paper provides an overview of the functional requirements for the WMS, the anticipated software and hardware architecture, and the process that will be used to ensure IID staff's full ownership of the system.

INTRODUCTION

IID needs a more clearly defined and responsive water operations environment that allows effective management of the water from the river to the farm gate. This will require the ability to integrate water user, lateral operations, main canal operations and river operations within one information management system.

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Water users have also indicated the need for a user-friendly tool that allows on-farm irrigation scheduling and the placing of water orders directly with the IID. Additionally water users want to be able to track the status of their orders, charges to the delivery gate and historic water use with an easy-to-access and operate interface. This improved system is referred to as the Water Management System (WMS).

The WMS must be able to allow IID staff to efficiently receive orders from farmers, schedule deliveries based upon orders, crop types, water supplies and delivery capacity, and compute appropriate delivery charges based upon field data obtained by Zanjeros[5].

In addition, the plans are for the WMS to eventually allow farmers the flexibility to directly place orders over the Internet, rather than call or walk-in orders to IID Division offices.

The WMS will be implemented in four distinct phases, one of which will be developed immediately:

1. Water Order Entry Migration[6]

As operations and needs become more defined during implementation and initial operations of the first phase, three other phases will subsequently be implemented:

2. System Management Integration
3. Water Conservation Issues
4. Customer Service Improvements

To understand the needs of the WMS, an initial effort was initiated to define functional requirements for Phase 1 and to define the supporting software and hardware needs.

USE-CASE SPECIFICATIONS

The following section provides an overview of the intended functional requirements to be created during Phase 1 of the WMS implementation. The sampling of "use cases" listed in Table 1 include the functional task and the "actor", or intended user of the system. Thirty use-cases were defined for

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[5] A Zanjero is an IID employee tasked with opening and closing gates to deliver ordered quantities of water to IID customers.
[6] As of the writing of this conference paper, IID is initiating contracts for the first implementation phase. Completion is expected in mid 2005.

implementation during Phase 1. Use-cases are the core building blocks of the WMS, and will be built upon during the latter implementation phases.

Table 1. Sampling of Use-Cases to be Implemented

Category/Ref. No.	Task	Actor(s)
Water Order Scheduling and Recording		
C001	Create/Change/Display Customer Water Order	Division Coordinator
C002	Schedule (line up) Water Order with Pre/Final Allotments	Division Coordinator
C009	Submit to WCC Estimated Orders for Master Order	Division Coordinator
C010	Enter yesterday's tailwater measurements	Zanjero/Hydrographer
Main Canal Operations (Water Control Center)		
M003	Develop/Adjust Main Canal Scheduling Plan	Dispatcher
M005	Create Hydrographer Lateral Heading Run Sheet	Dispatcher/Hydrographer
M007	Reports from Daily Water Record (DWR)	Dispatcher
Lateral Operations (Division)		
L001	Set/Change canal reach capacity limits (provide warnings)	Division Coordinator
General Administrative Functions		
G001	Display Tenant and Owner Information	All
G002	Create/Change/Display Crop Master List	Delivery Analyst
G004	QA/QC and Migrate Record to Water Information System (WIS)	System
G005	Create regular crop reports	Delivery Analyst
G008	Information Queries and Reports	All
G011	Canal Cut Out Notification	Dispatcher/Division Coordinator

Use-cases capture requirements as they are first identified and are used to update requirements as they change. Each of the 29 use-cases has been detailed using a combination of text and graphics to articulate its functional requirements. These details allow the intended actor to check that the appropriate functionality is being addressed, and act as instructions for use by programmers when writing the actual software code. Details developed for each use-case primarily included:

1. A listing of preconditions – the state of the system that must be present prior to a use case being performed, i.e. the Water User placing an order must not have a delinquent account, and necessary details for a water order must have been provided
2. A brief description – an overview of the use-case that can be quickly reviewed to understand the intended functionality
3. Detailed description – explicit details indicating the steps of the use-case and the associated data. Graphic "process flow" and "data flow" diagrams were also created. These diagrams schematically depict the functional process for a use-case and the accompanying vital data (see Figure 1 for a sample process flow diagram).

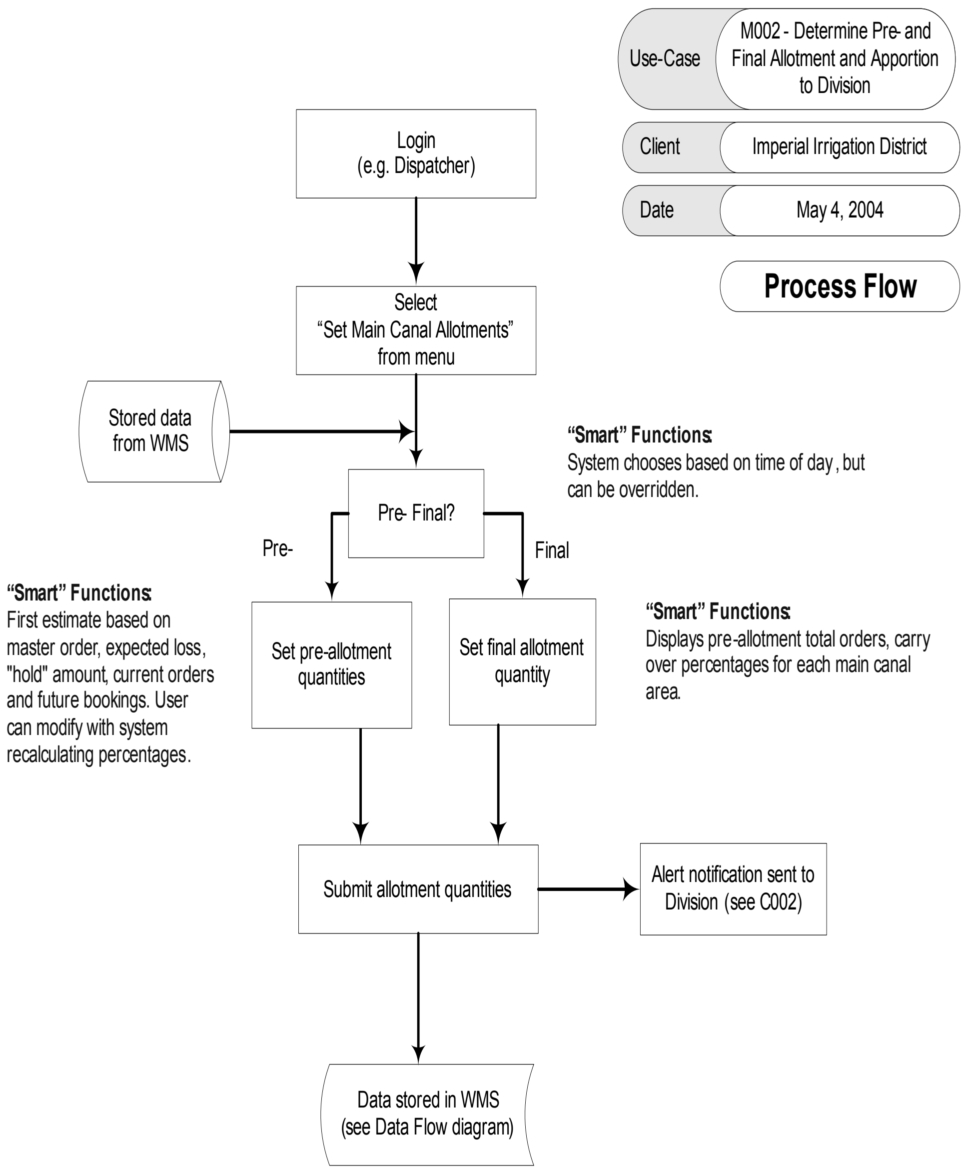

Figure 1. Sample Use-Case Process Flow Diagram

PROPOSED TECHNICAL SOLUTION

IID currently operates a custom water order entry program within its SAP[7] enterprise solution, along with many spreadsheets and hand-recorded paper tables. The main objective of the project is to migrate the current Water Order Entry functionality running on SAP to the WMS, adding certain enhancements identified by the Water Department and automating paper dispatching. The target solution will also host other functional requirements that will be implemented during Phase 2-4.

The WMS will be a fully web-based application; IID staff – and in the future, IID customers – will access it using their browsers. In parallel they will be able to access other IID applications (SAP, etc) using those current interfaces. One of the major constraints and a requirement of the project is to keep the billing functionalities on SAP; hence the proposed technical solution for WMS is based on a scenario requiring the integration of WMS with SAP R/3.

Overview of the solution

Figure 2 describes the two main components of the solutions:

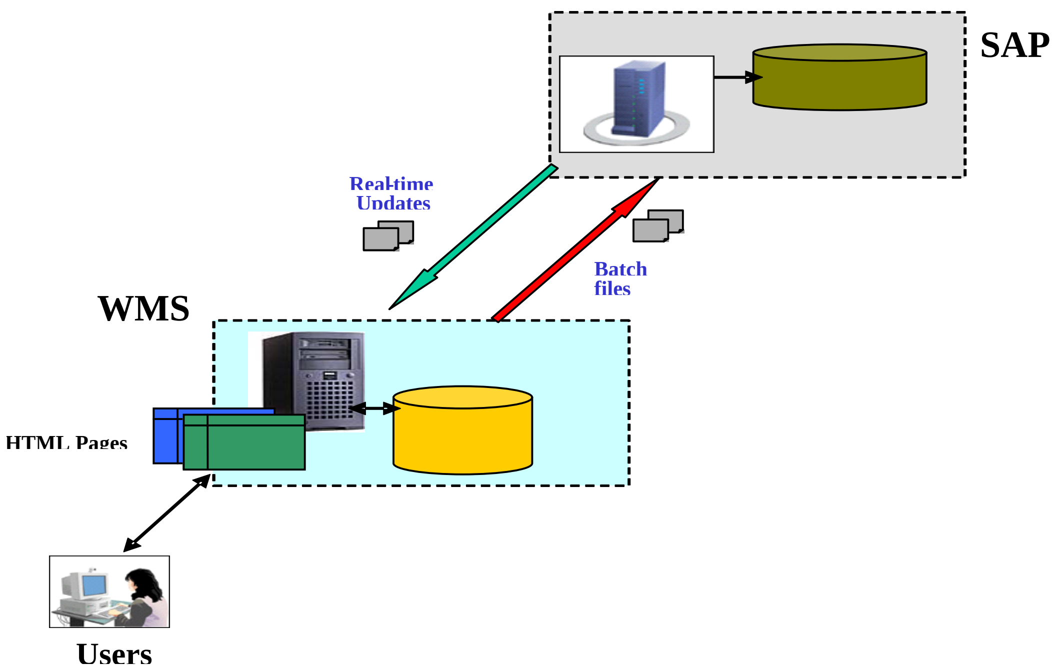

Figure 2. Primary Components of the WMS Information Architecture

[7] SAP AG (NYSE: SAP) is a leading provider of inter-enterprise solutions. IID's financial and other business functions are built within the SAP solutions.

WMS will allow water users to perform all the operations specified in the use-cases included in Table 1. The WMS will store data in its own repository, which will need to contain all the data required to perform the necessary water operations. For the WMS to perform the water operations, however, real-time data is required from SAP. This data transfer from SAP to the WMS is mandatory to allow creation of an order within the WMS that can subsequently be submitted back to the SAP system to perform billing, invoicing, and payments services.

Interfacing from SAP to WMS: SAP will remain the referential database for the data shown in Table 2. This data is required in real-time on the WMS repository to allow water operations. At the end of each SAP update-transaction, a file containing the updates will be generated. This file will be transmitted to WMS (via ftp); the reception of these files on WMS will trigger a Java program that will update the data on the WMS data repository.

Optimized versions of this transmission mechanism will be defined during the development phase. These will allow the transmission of several concurrent updates and also define the procedure in case of SAP or WMS downtime.

Table 2. High-level data transfer requirements from SAP to WMS

Data Type	Data	Transactions	Transmission
Master data	Tenant & Owner Contract accounts Plots	Create / Change / Retirement / Delete	Real-time
Notifications	Maintenance Notifications	Create / Change / Delete	Real-time
Delinquency	Delinquency status Blocked orders	Change	Real-time
Other ….			

Interfacing from WMS to SAP: The primary water operations functions (see Table 1) will be performed on the WMS. However, specific data (Table 3) generated by the WMS application is required by SAP in order to perform billing, invoicing and payment operations. This data is shown in Table 3.

SAP billing is a batch activity (completed once a month), so the need for data is not real-time. Based on discussions with IID staff, transferring this data once a day is recommended. During the development phase, this recommendation will be reviewed and revised if necessary or if a different frequency is found to be optimal (to reduce the buffering of changes and thus, limit the impact of downtime data handling on SAP). The updates will be transmitted from WMS to SAP in a batch file that will be mapped to the appropriate SAP elements to directly update the data on SAP.

Optimized versions of this transmission mechanism will de defined during development phase to potentially handle the transmission of several updates and also to accommodate potential SAP downtime.

Table 3. High-level data transfer requirements from WMS to SAP

Data type	Data	Transactions	Transmission
Orders	Water Orders Periodic Contracts Credit debit memo Prorated orders	Create / Change / Delete / Confirm	Daily batch file from WMS
Deliveries	Deliveries Zanjero charges Carry Over Good Issues	Change / Charge / Confirmation / Delete / Cancel	Daily batch file from WMS
Crop Maintenance	Crop allocation	Changes	Daily batch file from WMS
Other ……			

IID STAFF ACCEPTANCE

The successful implementation of the WMS is fully dependent on the acceptance of the application by those that must use it on a daily basis. To this end, the development of the use-cases and the proposed software and hardware solution have been grounded in a user-intensive, iterative approach referred to as the *Rational Unified Process* (RUP). The RUP has a "bottoms-up" orientation that focuses on the perspectives and tasks of each WMS user.

This approach ensures that every solution is designed to meet the needs of IID's users, rather than forcing IID's functions into pre-packaged solutions and applications. The RUP affectively forces the development of an application to undergo iterations – thus recognizing that a solution cannot be fully defined at the beginning of a project and must undergo refinement throughout the process. Figure 3 depicts the general structure of the RUP.

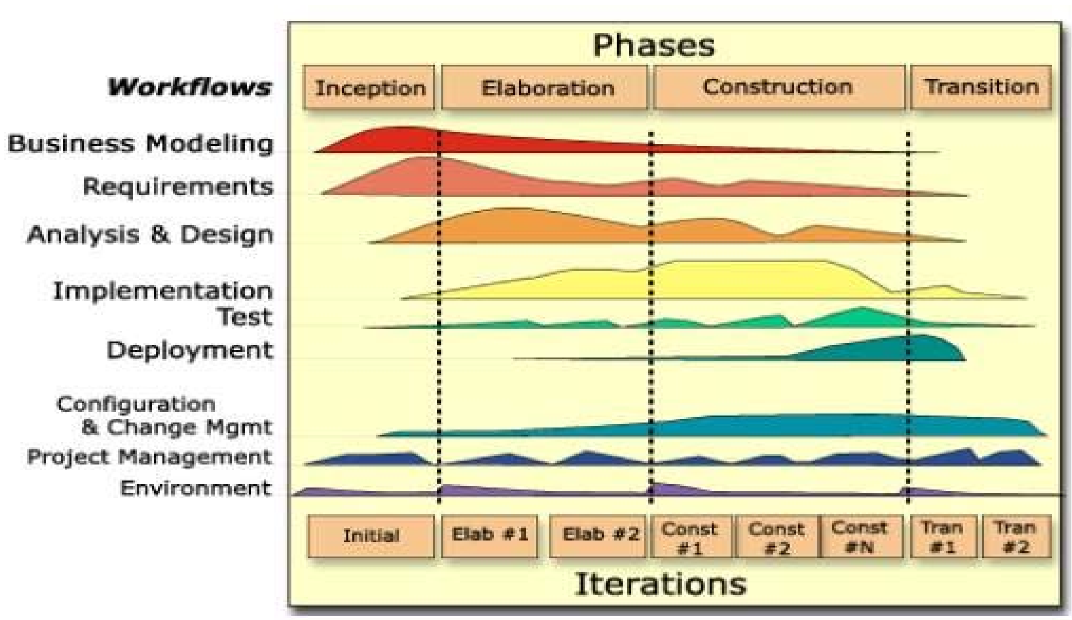

Figure 3. Graphic Representation of the Rational Unified Process

Several user committees will be formed by IID to interact with the WMS development team as required by the RUP. For the Phase 1 implementation, focused committees will be formed for:

1. Growers
2. Zanjeros
3. Water Division Coordinators
4. Assistant Superintendents for Water Operations
5. Water Control Center Dispatchers
6. Management

The cornerstone to successfully achieving ownership by the staff at IID will be the combination of face-to-face user committee meetings and a project web site to test user interfaces.

CONCLUSION

Once implemented, the WMS will improve IID's ability to meet the changing needs of its delivery system and its customers while increasing the efficiency of data management. The key to the successful WMS implementation is ultimately the acceptance of the IID staff who will use the system to perform their everyday tasks more efficiency and effectively. For the WMS to successfully enhance the performance of IID staff, their involvement and acceptance of the application is critical. The development team sincerely believes that listening to the experiences of IID staff and involving them in the development of the interfaces and routines that they will be using will result in an improved long-term return on investment. Achieving the efficiencies desired will require IID staff to abandon the paper parts of their system and move to a fully integrated digital system. This in turn requires that the IID staff have complete confidence in the digital system to perform the required functions quickly and accurately.

This underscores the importance of the RUP process implemented through the user committees to (1) develop the user committee trust in the development team and the application, and (2) to employ these committee members as the application "sales persons" throughout IID.

All too often these projects fail due to the lack of confidence in the application by the staff that will use the application. IID is to be commended for the foresight to embrace a development team and process that involves the IID staff in the interface development.

RADAR WATER-LEVEL MEASUREMENT FOR OPEN CHANNELS

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ABSTRACT

The U.S. Geological Survey is investigating the performance of radars used for water-level measurement. This paper presents data collected using the Design Analysis Associates H-360 radar sensor in the laboratory and in the field. (The use of firm, trade, and brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.) Radar water-level measurements at field sites were compared either to pressure sensor or float measurements by using simple statistical comparisons and frequency analysis with Fourier transforms of the data. Laboratory testing checked the performance of the radar sensor over the operating temperature range. Field data comparison and laboratory temperature testing indicate that the unit has an accuracy of about 0.03 feet except for windy conditions, when errors of -0.30 feet can occur.

INTRODUCTION

Water-level (or stage) measurements are used to compute discharge by the U.S. Geological Survey (USGS) at over 7,000 streamgaging stations throughout the United States (Hirsch and Costa, 2004). The discharges are computed from relations between stage and discharge that are used by managers to issue flood warnings and manage water supply. The accuracy and performance of stage instrumentation at these stations directly affect the quality of the discharge computed. Because of the importance of water-level measurements, the USGS has an accuracy requirement of 0.02 feet (ft) or 0.2% of reading (whichever is largest) for water-level measurements (Office of Surface Water, Technical Memo 93.07).

Several standard types of water-level instrumentation are used at USGS gaging stations: (1) a float with shaft encoder in a stilling well (float-well), and (2) two types of pressure systems– nonsubmersible pressure-transducer bubbler systems and submersible pressure transducer systems. A newer method, radar, has recently been installed at a few stations.

Radar level instruments have maintenance and installation advantages over the standard instrumentation. No stilling wells or orifice lines need to be constructed for radar. Moreover, because radar is a "non-contact" measurement method, it is

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not susceptible to being obstructed by sediment or debris. Bubbler and stilling well (float with shaft encoder in stilling well) installations have orifice lines that can be obstructed and require more effort to install than a radar. Unlike acoustic water-level sensors, the accuracy of the radar measurement is not significantly affected by air temperature or by moderate rainfall (Serafin, 1990).

Little information is available comparing the performance of radar water-level instrumentation with the older, standard instrumentation. The older instrumentation has been rigorously tested for compliance with USGS accuracy requirements. Laboratory temperature testing and comparisons between field data collected by a Design Analysis Associates H-360 radar sensor and older instrumentation at two field sites are presented, herein. Differences in instrument frequency response and simple statistics also are presented.

WATER-LEVEL RADAR SENSOR

The Design Analysis Associates (DAA) H-360 (figure 1) is a continuous-wave frequency-modulated radar equipped with SDI-12 communications that operates in the X-band frequency (10 Ghz). The H-360 measures water level by propagating electromagnetic energy with an antenna. Objects in the propagation path reradiate the microwave energy back to the radar. The time it takes for the energy to return to the radar (travel time) is used to determine the distance to the object (or water level). Radar energy propagation reflects and scatters similarly to light. Unlike sound energy, the speed of radar energy is not significantly affected by air temperature. Digital signal processing software is used to process the received microwave energy into distance. The sensor used by the H-360 was designed for liquid level sensing in a tank and has been modified to use SDI-12 communications. Specifications for the H-360 are provided in table 1 (Design Analysis Associates, 2003).

LABORATORY TEMPERATURE TESTING

The DAA H-360 was temperature tested in a walk-in environmental test chamber for temperatures ranging from -40 to +20 ^{o}C. Several units were placed in the chamber and pointed horizontally at a stationary, metal target (chamber wall). The stage readings were set to give an arbitrary 10-ft reading at room temperature for the stationary target.

Initial testing done in October 2003 found that the units did not transmit data reliably to the data logger when temperatures were below 0 ^{o}C. The manufacturer addressed the communication problem and sent replacement chips for the test units, which solved the problem. However, the radar units continued to sporadically report either a very high level (>30 ft) reading or a reading of -99 when temperatures dropped below -20 ^{o}C. Some of the scatter in the data may be due to electromagnetic noise from the chiller unit in the chamber and other

Figure 1. Design Analysis Associates H-360 radar water-level sensor.

Table 1. DAA H-360 Specifications

Feature	**Specification**
Housing	cast aluminum
Housing dimensions	5.5 x 6 x 7.5 in. 16 in. waveguide
Weight	8 lbs
Power external	10.5 to 16.0 VDC
Power consumption Standby Measuring	 200 μA typical 240 mA typcial
Communication	SDI-12, RS-232
Radar Sensor	
Range	115 ft
Accuracy	+/-0.026 ft
Repeatability	+/-0.026 ft
Frequency	9.5 to 10.5 GHz
Antenna horn diameter beam angle	 4 in. 18^o
RF output power	1 to 3 mW
Operating Temperature	-40 to 60 ^{o} C

equipment in the laboratory. Efforts were made to determine if noise was a problem by cooling the chamber to -40 ^{o}C, turning the chamber off and letting the temperature rise back to "room" temperature in the laboratory. Some scatter was still present in those data. The manufacturer is currently working to address this problem.

Figure 2 shows data collected for one unit in the walk-in chamber. The differences in figure 2 are between the reading of the radar and the arbitrary 10 ft. Temperatures above -30 ^{o}C were collected when the chiller was off. The data show more scatter at the lower temperatures and an obvious linear trend with temperature. The range in the trend is about 0.03 ft over the tested temperature range of -40 to +20 ^{o}C. The temperature trend is possibly due to temperature sensitivity of the oscillator in the radar unit. Some of the scatter in the data is due to noise and some is suspected to be due to the instrument.

FIELD DATA COMPARISON

Two gaging stations, maintained by the USGS Mississippi District Office, were used for field comparisons: the Wolf River near Landon, Mississippi (02481510), and the Pearl River near Jackson, Mississippi (02486000). The Wolf River station

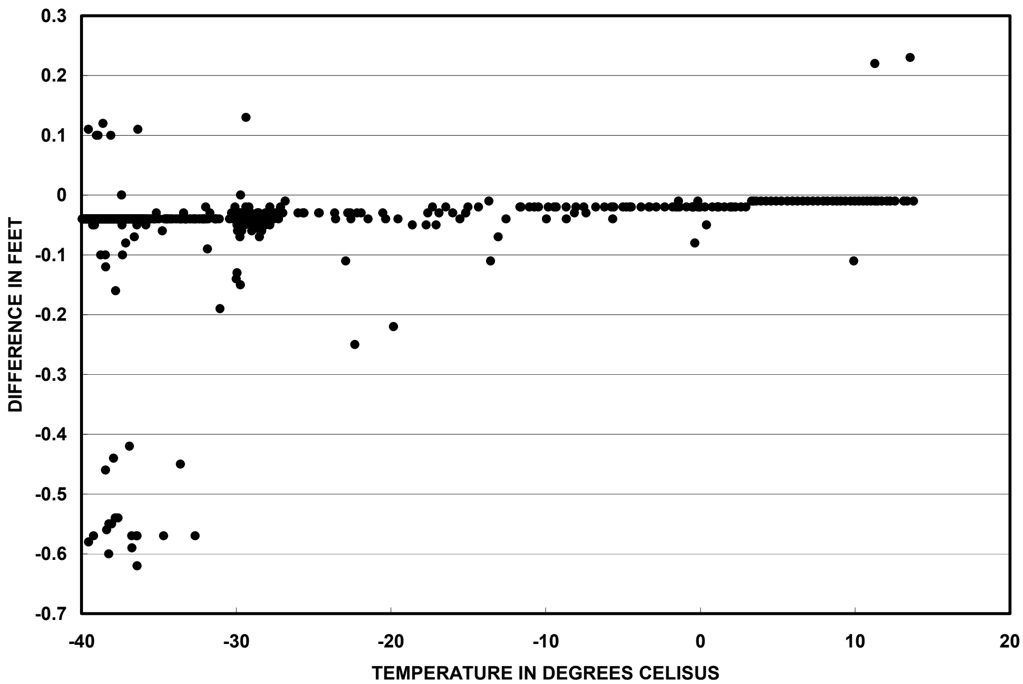

Figure 2. Difference between radar reading and initialized reading of 10 ft for the stationary target over a range of temperatures.

has a drainage area of 308 square miles (mi^2), which is about one tenth of the drainage area of the Pearl River stations (3,171 mi^2). Mean daily flows are 628 cubic feet per second (ft^3/s) for the Wolf River station and 4,476 ft^3/s for the Pearl River station (Morris and others, 2004). Both sites have other instrumentation in addition to the radar sensor. The Wolf River site has a stilling well equipped with a float and a shaft encoder. The Pearl River site has a Sutron Accubar bubbler system. Data collected by the radar units and the other water-level instrumentation were compared by using statistics and frequency analysis.

Data sets analyzed for the Wolf River and for the Pearl River are not for the same dates or duration. Data were collected for the Wolf River over approximately 21 days during the summer of 2003 and for the Pearl River over approximately 85 days during the fall of 2002. Data were sampled at a 15-minute interval, which is typical for USGS gaging stations. This sampling rate is used because of the need to conserve battery power at remote sites and the slow rate of water-level changes at most gaging stations. The 15-minute sampling rate can under sample the water-level data because wind driven waves can have periods that are 5 minutes or less (Kinsman, 1965). For a given discharge and 15-minute sampling interval, the measured water levels affected by wind waves will be periodically high or low compared with the same water level that was unaffected by wind driven waves.

Field Data Statistics

The average water level for the data collected by each instrument was removed from the data. The resulting data are shown plotted for the Wolf River in figure 3 and for the Pearl River in figure 4. Both stations have more than one flow peak in the record studied. The plotted data for the Wolf River show that the radar periodically measured stage about -0.3 ft lower than the float well. The lower stage is likely due to the wave troughs focusing the radar energy back at the antenna and the crests dispersing the energy away from the antenna. Because the radar antenna receives more energy from the troughs, an erroneously lower water surface may be measured during windy conditions.

Summary statistics for both stations and instruments are listed in table 2. The stage data statistics show that the radar instrument has a larger range between the maximum and minimum values, from 0.16 ft (Wolf River) to 0.39 ft (Pearl River) larger than the two older instrument types. Lower minimum stages are measured by the radar at both of the stations. The minimum radar stages are lower than the older instrumentation by 0.16 ft (Wolf River) to 0.19 ft (Pearl River).

Frequency Analysis

Frequency analysis was used to help find the differences in response between the instruments. The field data for both stations were transformed into frequency data using a fast Fourier transform (Bracewell, 2000). The 15-minute sampling

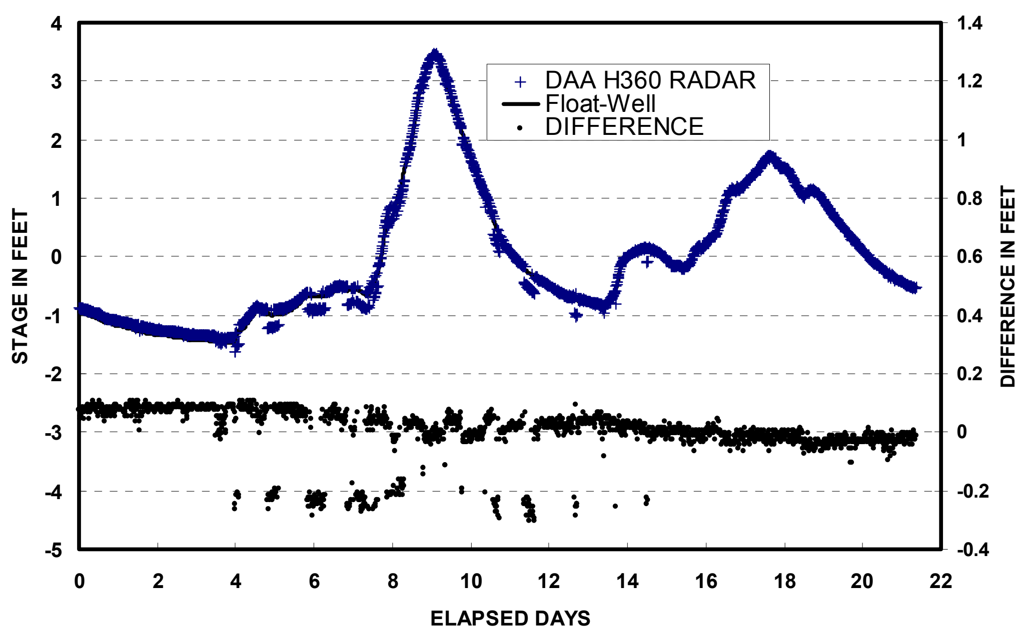

Figure 3. Wolf River water-level data for DAA H360 radar and the float encoder during the summer of 2003.

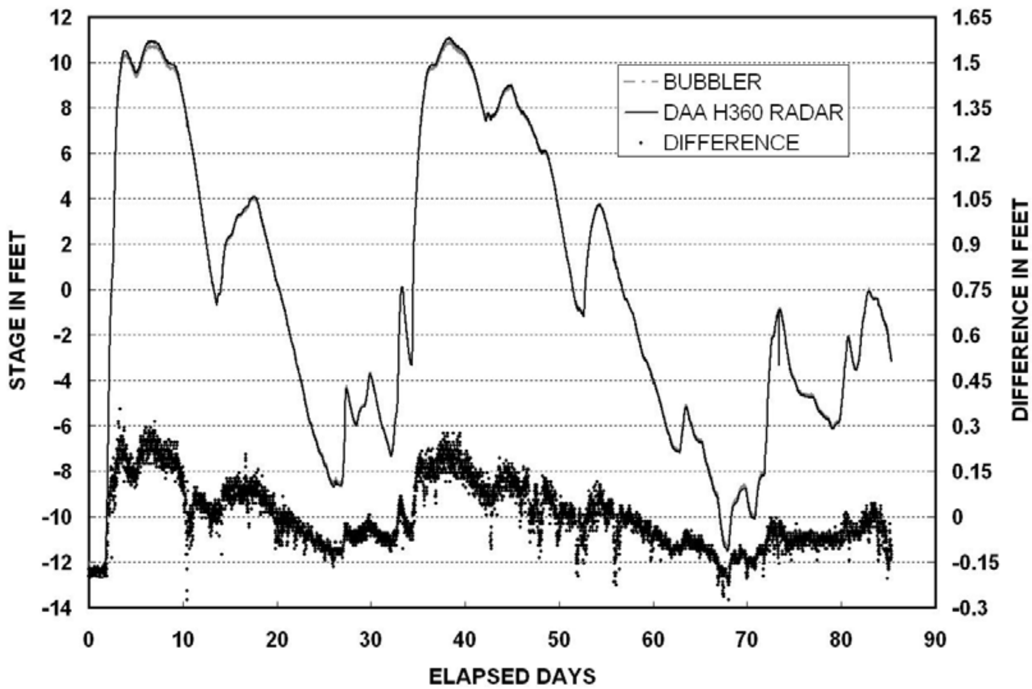

Figure 4. Pearl River water-level data for DAA H360 radar and pressure sensor (bubbler) during the fall of 2002.

interval used at USGS stations restricts the highest water wave frequencies that can be measured to 0.00055 hertz (the cutoff frequency) or a period of 30 minutes. Only the magnitude of the transform data is presented in figures 5 and 6. The magnitude is plotted as a function of period in minutes. Period, the inverse of frequency, is the time it takes for a complete wave to pass by a fixed point and is proportional to wavelength. The magnitude indicates how much energy is present for a water wave of a particular period. For river systems, most of the energy is at the larger wavelengths with periods of several hours because the response of streams to rainfall events ranges from several hours to days. However, wind-driven waves typically have periods of 5 minutes or less.

Table 2. Summary statistics for radar and older instrumentation data measured at the Wolf River station and the Pearl River station. The mean value was removed from the data.

	Wolf River Station		Pearl River Station	
	Radar	Float-well	Radar	Bubbler
Median (ft)	-0.31	-0.26	-0.78	-0.73
Standard deviation (ft)	1.15	1.17	6.63	6.53
Maximum (ft)	3.48	3.48	11.11	10.91
Minimum (ft)	-1.63	-1.47	-12.70	-12.51
Sample size	2048	2048	8192	8192

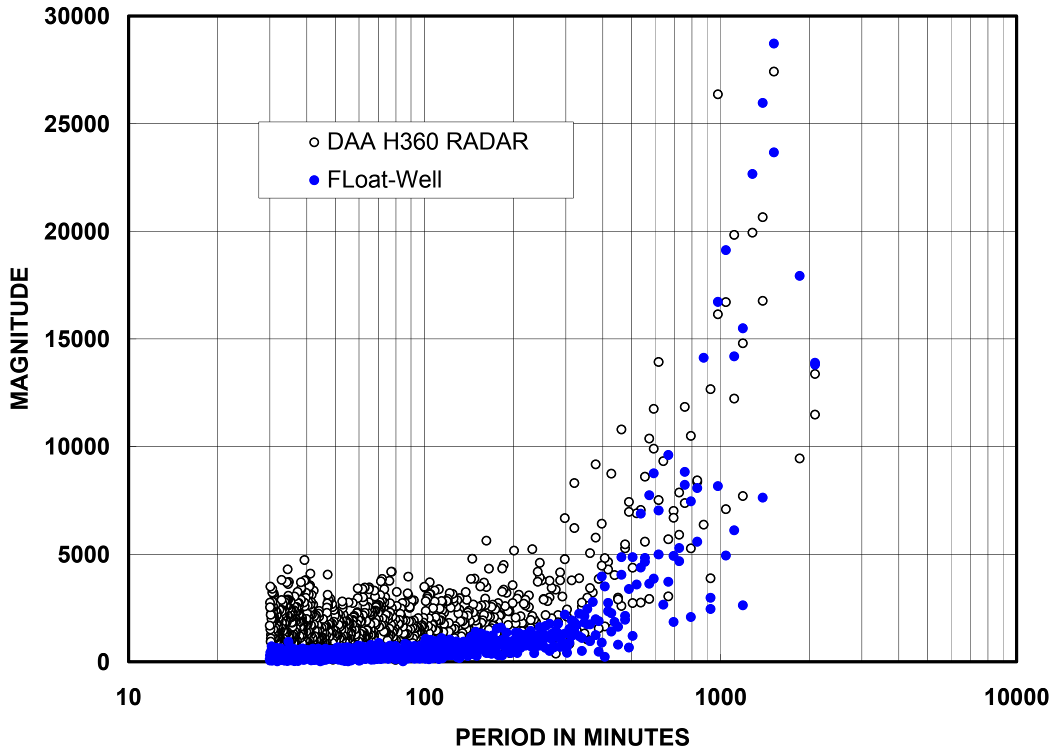

Figure 5. Wolf River water-level data for radar and float encoder instruments transformed into frequencies.

The frequency data for the float-well instrument (Wolf River) had considerably smaller magnitudes (about 1/3 less) than the radar for periods shorter than about 200 minutes (0.005 hertz). Because a stilling well acts as a low-pass filter, it damps out the shorter period (or higher frequency), small surface waves that are produced by wind or other small flow disturbances. The resulting water level is closer to the local (in time) average water level. The bubbler instrument (Pearl River) was slightly less variable and had slightly lower magnitudes than the radar for periods shorter than 150 minutes (0.0067 hertz frequency). The column of air in the bubbler line, similar to a stilling well, damps out some of the smallest surface waves.

Low-pass filtering (removing the higher frequencies from the data) also was tried in an attempt to reduce the differences between the radar data and the float-well data. However, after low-pass filtering, the radar data had larger magnitudes for the higher frequencies than the float-well because the 15-minute sampling interval "aliased" the data collected. Aliasing of data results when water levels are sampled at a rate that is slower than the frequency of periodic water-level changes. Waves occur in the collected data that do not exist in the actual water levels and result in the large magnitudes at the higher frequencies, even after low-pass filtering. Similar to the radar, the bubbler system also had large magnitudes

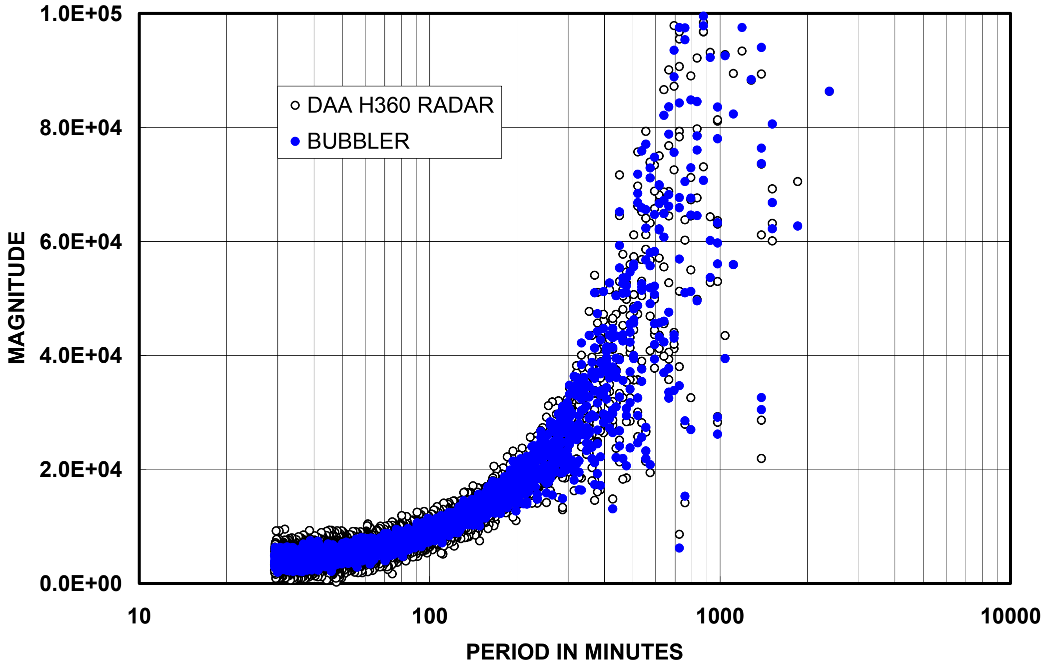

Figure 6. Pearl River water-level data for radar and bubbler instruments (pressure sensor) transformed into frequencies.

at the higher frequencies when compared to the float well. Because the radar and the bubbler sample at a 15-minute interval, the instruments may collect data that are influenced by wind-driven waves, resulting in a value that is either too high or too low.

SUMMARY

Radar instruments are a promising new tool for measuring water levels. Radar water-level sensors require less construction to install than traditional contact water-level sensors. However, radar accuracy may be affected by oscillator sensitivity to temperature changes. Units tested in the laboratory were found to vary 0.03 ft over -40 to +20 ^{o}C temperature changes. Additionally, field data indicate that currently available radars may have negative bias when surface waves are present. Wave troughs act to focus energy back at the radar and wave crests act to scatter energy away from the radar, biasing the stage reading low. Frequency analysis of the field data with Fourier transforms found some aliasing in the data collected at 15-minute intervals for the radar and bubbler systems.

Changes in sampling rates and appropriate filtering of the data may enhance the accuracy of radar water-level measurements and may enable radar water-level sensors to approach the accuracy of well-float systems. The noncontact methodology used by radar water-level sensors makes the unit tested useful for sites at which sensor fouling is a problem for traditional contact type sensors and where an accuracy of 0.03 ft is adequate.

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USE OF GEOGRAPHICAL INFORMATION SYSTEMS (GIS) IN DEFINING MUNICIPAL WATER SUPPLY NETWORKS

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Guy Fipps[1]

ABSTRACT

Geographical Information Systems (GIS) have been helping the Irrigation District Team (IDEA) of the Irrigation Technology Center to provide services and assistance to the agricultural communities and irrigation districts in the Lower Rio Grande Valley of Texas. During the summer and fall of 2003, we took advantage of the GIS program started in 1997 that included mapping of the irrigation districts and assembling basic attribute data on the water distribution networks. In cooperation with the 14 irrigation districts in Hidalgo and Cameron Counties, we conducted a study to identify the extent of the municipal water supply networks (MSN) defined as those portions of the water distribution networks and control structures of irrigation districts that transport raw water to municipal treatment plants.

This study was a time and labor intensive process and involved frequent visits to the irrigation districts for the collection and review of field data and analysis. This paper presents the procedures and methods used to produce the first initial estimates of the MSN. The characteristics of the MSN include the static volume (or capacity), evaporation and seepage losses from reservoirs, resacas (oxbow lake) and canals, and leakage from pipelines. Also discussed are alternate operating scenarios and future recommendations to improve estimates for seepage losses and leaks and to take a regional approach to planning distribution network improvements.

BACKGROUND

In the early 20th century, the newly established land development companies started carving-out irrigation canals to serve the million plus acres of agricultural lands in the Lower Rio Grande Valley of Texas. The farmers and the growing towns depended on water from the irrigation distribution networks for their daily consumption. Today 14 of the 28 irrigation districts continue to pump water from the Rio Grande River to one or more of the 39 municipal water treatment facilities through the gravity-flow canals and underground pipelines.

Generally, the amount of municipal water in the distribution networks at any one

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time is small compared to the amount of agricultural water (90% of water rights held by agriculture). In essence, the agricultural water fills the distribution networks and the municipal water is "piggy-backed on top" of it. Thus, in the absence of agricultural water, municipal water deliveries can become problematic.

During the late 1990s, the irrigation districts were plagued by regional and local droughts, causing water supply shortages and several districts to run out of all available water allotted for irrigation purposes. Those districts that served the municipalities could no longer charge (fill-up) the distribution networks necessary to transport the raw water to the takeout points without tremendous pumping costs and accruing negative balances charged against the districts' agricultural water accounts.

The municipal water supply network (MSN) is defined as those portions of the irrigation distribution networks, which also carry municipal water. The extent of the MSN is based on the locations of existing control structures that can be closed to isolate the MSN from downstream portions of the irrigation districts. During the summer and fall of 2003, the Irrigation District Team (IDEA) of the Irrigation Technology Center conducted a study of the extent, capacities and loss of water of the MSN. This study can be used as a step to help start addressing future problems that may hinder irrigation and municipal water supplies deliveries alike.

INTRODUCTION

In 1997, we began a GIS program that included mapping irrigation districts in the Lower Rio Grande Valley and assembling basic attribute data on the water distribution networks. The development of this GIS resource has played a key role in the planning and completion of this study.

The study was done in the following steps:

- identification and verification of the districts with municipal water deliveries;
- production of review maps for each of the 14 districts;
- initial meeting with irrigation districts to:
  A. review maps,
  B. identify on the maps the locations of municipal takeout points and downstream control structures, and
  C. collect available data on sizes, dimensions and capacities of MSN components;
- with district staff, conduct field reconnaissance and measurements as needed;
- mapping and computing the surface areas of reservoirs and resacas using aerial photographs and GIS mapping tools;
- determining the lengths of MSN components from GIS-based maps;
- processing data, completing analysis, and production of tables and maps for districts to review;
- meetings with district personnel to review data and analysis;

- follow-up field measurements and other efforts as needed to develop complete data sets and analysis;
- finalizing MSN estimates under normal operational conditions, including:
  A. static volume,
  B. evaporation, and
  C. seepage losses;
- feasibility assessment of analyzing MSN requirements assuming no agricultural water deliveries; and
- formation of recommendations for further analysis.

IDENTIFICATION OF THE MUNICIPAL SUPPLY NETWORK

We first obtained a GPS survey from the Rio Grande Water Master office, which contained the latitudes and longitudes of municipal water treatment facilities in Hidalgo and Cameron Counties, and each of the irrigation districts that supplied raw water to the division points. Next, we imported this data into *ArcGIS*, and produced GIS maps of each district showing the district boundaries and water distribution networks in relation to the plant locations. The municipal supply systems that carry water from the district takeout point to the plant were unavailable.

For the next several weeks meetings were scheduled with district personnel to verify, on the maps, the exact location of the takeout points for each treatment plant, and also to identify the nearest control structures needed for isolating the MSN from the remainder of the distribution network. From the meetings, we learned that the districts had limited knowledge of what systems could be eliminated to obtain the most direct path to the takeout points.

EXTENT, CAPACITIES AND SURFACE AREAS

Our GIS-based maps and databases include canal type (lined, unlined) and top widths for most canal segments in the region (for more information on these maps, see http://idea.tamu.edu). However, we have not assembled other attribute data such as canal shape, slide slopes, bottom width, and the actual water span widths and depths at different operating levels. All of this information was needed for this study, but few of the districts had this information readily available. Out of the 14 districts, only one district had all needed information, and only two of the remaining districts had a significant amount of the necessary information.

With limited district personnel, we took measurements of canal water-span widths and depths during normal operation conditions of most canal segments within the MSN. The segments were selected and measured according to size variations and in relation to the control structure locations, which isolate the MSN components. Figure 1 shows portions of four (4) districts and segments for which field measurements were taken. Segment lengths were calculated using GIS mapping tools.

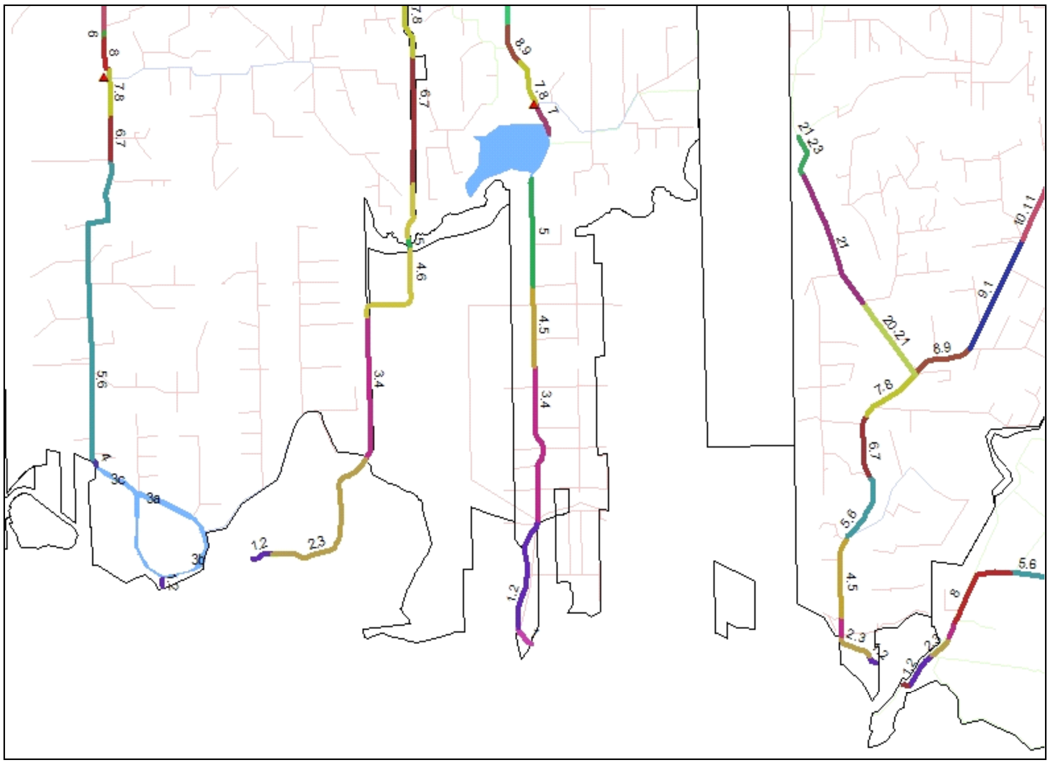

Figure 1. Shows portions of four (4) irrigation districts with MSN segments and segment reference numbers for which depth and width measurements were taken.

The next step was to combine canal width and depth measurements with canal shape information to determine the capacities of each segment. However, only three of the 14 districts had information available on canal shapes. Thus, we had to assume canal shapes to complete this portion of the analysis. We used the following two shapes:

- a parabolic shape to produce a low volume estimate
- a rectangular shape to produce a high volume estimate

Most lined canals have a trapezoidal shape that will have a volume that is greater than a parabolic but less than a rectangle. Very large, unlined canals tend to be rectangular, while smaller unlined canals develop a more parabolic shape.

Next, using aerial photographs, we mapped the boundaries of all reservoirs and resacas, and for districts without capacity data, took depth measurements and calculated surface areas and total storage volumes.

Table 1 summarizes the characteristics of the MSN. <u>*Static volume*</u> is defined here as the volume of water needed to fill the MSN to normal operating levels for agricultural water deliveries. <u>*Static*</u> means that water is not flowing in the system (an analogy is the filling a bath tub with water). Usually, water is not static in distribution networks, but continuously moves. This *transient* capacity will be somewhat higher than the static estimates provided here.

Table 1. Summary of the municipal water supply network characteristics.

component	**width/ diameters**	**total length (miles)**	**surface area (acre-feet)**	**static volume (acre-feet)**
lined canals	4 - 80 ft	92	229	721 - 866
unlined canals	10 - 150 ft	168	1,137	4,382 – 6,527
pipelines	14 - 72 in	25		27
resacas			377	2,484
reservoirs			3,845	8,216
TOTALS		**285**	**5,588**	**15,830 - 18,120**

Figure 2 shows the irrigation district service area boundaries, locations of the water treatment plants and takeout points, and the extent of the MSN.

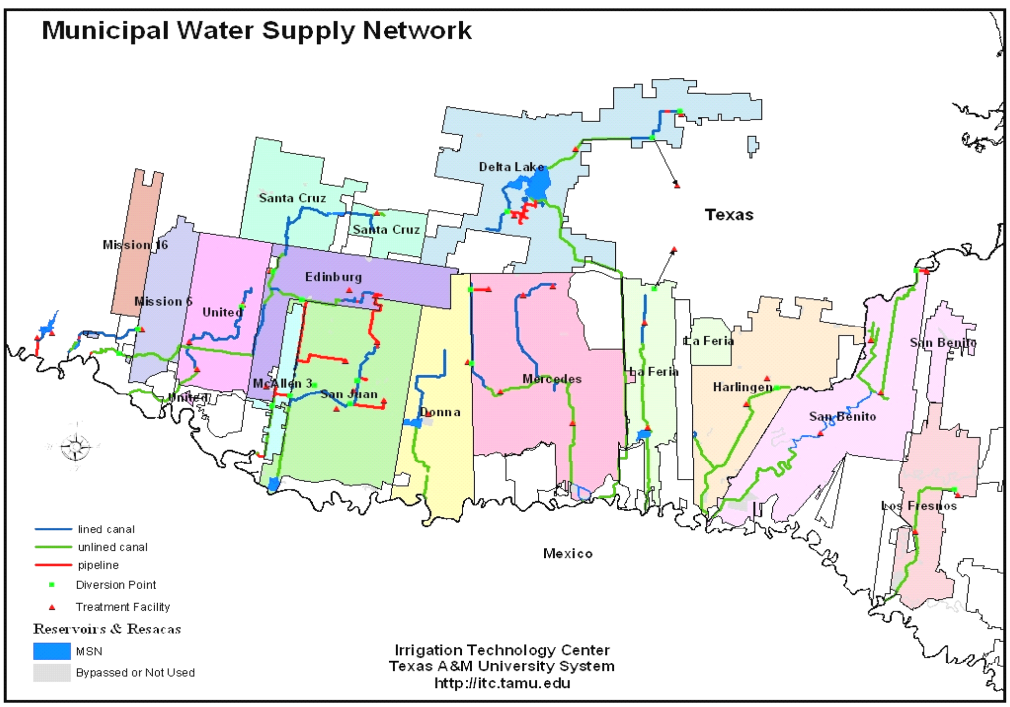

Figure 2. The Municipal Water Supply Network

ADDITIONAL ESTIMATIONS AND OPERATING SCENARIOS

The estimates assume that the MSN is operating at normal levels used for agricultural water deliveries. We have good confidence in the volume and evaporation estimates. More work is needed to improve seepage loss estimates and narrow the range shown below.

We did not attempt an analysis of the MSN for the case of only municipal water deliveries (i.e., in the absence of agricultural water). The data to complete such an analysis is not currently available, and collecting this data and performing the analysis would be a time and labor intensive effort. To evaluate the value of such an analysis, we recommend that a pilot study be done on one to two districts to determine if further analysis is warranted.

Evaporation

To estimate evaporation from canals and resacas, we used the following equation:

Evaporation = 0.8 x (peak Class A pan evaporation) x (surface area)

From National Weather Service data, the peak Class A pan evaporation rate occurs in July and is equal to about 0.25 in/day.

For determining evaporation from reservoirs, we used the following equation:

Evaporation = (peak lake evaporation rate) x (surface area)

From the Texas Water Development Board website, we selected an average peak lake evaporation rate of 0.33 in/day for these calculations.

Table 2 gives the estimated evaporation rates for the MSN. Delta Lake accounts for 62% (65 ac-ft/day) of the total evaporation from the reservoirs.

Table 2. Maximum daily evaporative losses of the municipal water supply network.

component	**surface area (acres)**	**evaporation (ac-ft/day)**
canals, resacas	1743	0 - 29
reservoirs	3845	0 - 106
TOTAL	**5588**	**0 - 135**

Seepage Losses and Leaks

Most of the 14 districts in the MSN charge for water losses based on a percentage, ranging from 15 - 30%. One district has a higher charge for municipal deliveries when there is no agricultural water, and two districts use rates based on the gallons delivered. A percentage is not useful for calculating seepage losses. Instead, we need a rate such as gal/ft^2/day, which is the most common measurement of seepage loss rate.

Since 1998, we have conduced 52 ponding tests to determine the seepage and total losses of irrigation canals in the Lower Rio Grande River Basin. Table 3 provides a summary of test results. The results labeled *high with leaks* were in canals that, in addition to seepage losses, had leaks caused by cracks and holes in the canal embankment, and/or leaking valves and gates within the test segment.

Table 3. Expected seepage and total losses (gal/ft^2/day) from MSN canals, reservoirs and resacas based on ponding tests conducted in the Lower Rio Grande Valley

component	**low**	**High**	**high with leaks**
unlined canals	0.15	3.14	4.71
lined canals	0.25	4.62	6.93
reservoirs/resacas	0.15		

While only a few of our ponding tests were conducted on canals within the MSN (Figure 2), we expect that losses in the MSN will be similar to test results. To determine MSN seepage and loss rates, we combined the rates given in Table 3 with the actual dimensions of MSN components.

Table 4 gives MSN losses for three cases: *low*, *high* and *high with leaks*. The low case assumes the "low" loss rates from Table 3 and an assumed parabolic shape for canals with an unknown shape. Likewise, the high case assumes the "high" loss rates from Table 3 and an assumed rectangular shape for canals with unknown shapes. However, we do not expect many of the segments within the MSN to have leaks, thus seepage is more likely to be within the range of 42 to 826 ac-ft/day.

Table 4. Estimated seepage losses and leaks of the municipal water supply network (ac-ft/day).

component	low	High	high with leaks
unlined canals	27	556	834
lined canals	9	171	257
reservoirs/resacas	5	81	81
pipelines	1	18	18
TOTALS	**42**	**826**	**1190**

We have tested only one (1) pipeline for leaks. Leakage from pipelines depends on such factors as the type of materials, joints (if used), and pressures (or how full pipe flows). Older, concrete pipes with no rubber seals are likely to have high loss rates, while newer PVC pipelines will have very little. The pipeline leakage in Table 4 is a first estimate only. More work is needed to confirm this estimate.

The No Agricultural Water Case

In the absence of agricultural water, the operational levels may be lower when supplying just municipal water. In such situations, the static volumes and losses may be lower than given in Tables 2, 3 and 4. This is because seepage loss rates are usually lower at shallower depths and the wetted perimeter and associated areas decrease very rapidly as the water level is reduced.

However, there will still be a minimum operational level. Many of the municipal takeouts depend on gravity flow from canals, which requires a relatively high operating water level. Similarly, for pump takeouts, a minimum water depth must be maintained above the pump for proper operation.

Of the 14 districts, only four (4) had such data readily available. As a result, most of the operational requirements would need to be determined in the field or obtained from the water utilities.

In addition, the *transient volumes* within the MSN at these lower operating levels would need to be considered. These volumes include the flow and depth of water needed to overcome resistance to flow caused by friction losses in canals and pipelines, and restrictions and friction losses caused by water control structures. The information needed for this analysis includes the types, elevations, and operation requirements of control structures (gates, siphons and culverts), and slopes and elevations of the MSN canals and pipelines. Such data is not currently available and would take a considerable effort to obtain (note: for the static volumes reported in Table 3, since depths were measured at normal operating levels, "transient" volumes are considered).

SUMMARY AND RECOMMENDATIONS

An initial analysis of the municipal water supply network (MSN) in the Lower Rio Grande Valley was completed. The extent of the MSN was based on the locations of existing control structures that can be closed to isolate the MSN from the remaining portions of the irrigation water distribution networks. Volume and loss calculations were completed for normal operating levels used for agricultural water deliveries.

There are 39 municipal treatment plants that take water from the water distribution networks of 14 districts in Hidalgo and Cameron Counties. As of November 2003, the MSN consisted of approximately:

- 92 miles of lined canals
- 168 miles of unlined canals
- 25 miles of pipelines
- 377 acres of resacas
- 3845 acres of reservoirs

We also produced the following estimates:
- the static volume (or capacity) is between 15,830 and 18,120 ac-ft
- evaporation from reservoirs, canals and resacas of the MSN ranges from 0 to 135 ac-ft per day
- Delta Lake accounts for 62% of the peak reservoir evaporation, or 65 ac-ft/day
- seepage losses range from 41 to 1190 ac-ft/day
- leakage from pipelines ranges from 0.25 to 18 ac-ft/day

Recommendations

- Improve the seepage loss and leakage estimates of pipelines and canals
- Conduct a pilot study on the *no agricultural water scenario* (i.e., only municipal water delivery) to determine if this analysis is warranted. Initially select one or two districts for this intensive data collection and analysis effort
- Take a regional approach in planning and implementing programs and projects to change the distribution networks to reduce water losses in the MSN and improve the dependability of water supplies.

NON-STANDARD STRUCTURE FLOW MEASUREMENT EVALUATION USING THE FLOW RATE INDEXING PROCEDURE — QIP

Stuart Styles[1]

ABSTRACT

This paper summarizes the results of a performance evaluation using advanced hydroacoustic rating techniques in irrigation canal systems. Standardized field-tested procedures and technical specifications for index velocity ratings have been developed for rating measurement locations using hydroacoustic flow meters. Water managers and users of advanced electronic flow measuring devices can improve the cost effectiveness, accuracy, and quality control of discharge records, even at sites with complex flow conditions, by observing these recommended guidelines.

Keywords: flow measurement, non-standard structure, hydroacoustic flow meter, index velocity rating

BACKGROUND

Irrigation districts, farmers, and other agricultural and environmental water users need to accurately measure the rate and volume of flows at key points in their water distribution and delivery systems. A key device that has traditionally been used is a Replogle Flume. This is a standard measurement device recommended by the Water Measurement Manual of the USBR (3rd Edition 2001). Some locations are not suited for a Replogle Flume due to headloss constraints. At these sites where headloss is a constraint, another option has been to use simple rating tables based on the depth of the water in the canal.

However, traditional techniques used to develop a rating curve at non-standard locations are time consuming and there are a limited number of sites with good measurement capabilities. The rating of a non-standard structure in the field requires a tedious and laborious procedure. Flow data must be collected manually using a hand held current meter to determine the discharge at a specific water level (stage). Using a current meter to determine the discharge is a repetitive task and requires readings and calculations at multiple points to find the total flow.

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As a result, there is an opportunity to apply the flow rate indexing procedure (termed "QIP") to rate a large number of existing non-standard structures. Flow rate indexing with hydroacoustic meters greatly reduces the time required to rate a structure, and the measurement accuracy is improved because of the large number of data points that can be collected by autonomous installations over a wide range of flow conditions.

RESEARCH OBJECTIVES

The Irrigation Training and Research Center (ITRC), California Polytechnic State University, San Luis Obispo performed this technical study on behalf of the U.S. Bureau of Reclamation, Mid-Pacific Region. Thirteen water agencies participated. This study evaluated the performance of advanced electronic flow measurement devices and technologies in field applications at water agencies throughout California. A key objective of this project was to prepare and evaluate standardized, step-by-step instructions for developing accurate and reliable discharge ratings. The procedures follow the approach used by Morlock (2002) with the USGS. The USGS approach is primarily used in streams and rivers. The ITRC approach is designed for irrigation canals. The ITRC investigated the feasibility of using these hydroacoustic technologies for developing rating curves by deploying equipment and conducting field data collection at nine demonstration sites. The devices were deployed in different configurations at places identified as key measurement points by the cooperating water agencies.

PROCEDURE

Acoustic Doppler Profilers and Velocity Meters

The ITRC has worked with manufacturers and users of high-precision acoustic Doppler flow meters for several years to improve their performance by incorporating important design and software features that make them more user-friendly and robust. The instruments used in this study have been deployed successfully in many irrigation applications and represent industry standard specifications. The sensors at the demonstration sites were calibrated prior to deployment at the flow measurement facilities located at ITRC's Water Delivery Facility.

For this study, ITRC utilized the leading Acoustic Doppler Profiler (ADP) discharge measurement systems designed for hydrological applications – the SonTek/YSI RiverSurveyor and the RD Instruments StreamPro. Both units are shown in Figure 1. These boat-mounted profilers collected discharge records concurrently with the SonTek/YSI Argonaut Side-Looking (SL) and Shallow Water (SW) units. Water velocities and depths were measured at different flow rates. The discharge measurements obtained from the RiverSurveyor and StreamPro were analyzed and used in the computation of index velocity ratings at each site.

Figure 1. Boat-mounted Acoustic Doppler Profilers collecting flow rate and cross-sectional measurements in irrigation canals

Technical Approach and Project Components

The procedure for collecting velocity and stage datasets and performing regression analysis is straightforward and the necessary fieldwork can be completed in several hours per site. The large internal memory of modern datalogger and sensor systems means the devices can be set up and left in the field for several months to collect data at user specified intervals, which is then analyzed using ordinary office programs such as Excel.

The use of hydroacoustic flow meters dramatically reduces the time required to generate a rating curve for a site by the ability to record many more data points for stage and discharge measurements in an autonomous installation. To take advantage of this feature of hydroacoustic technology, temporary demonstration units were deployed at existing non-standard structures in irrigation canal systems. Data was downloaded in the field and checked for gaps and out of range values.

The *QIP*developed by ITRC consists of data analysis in addition to deploying field equipment and recording site parameters. The mathematical process describing the rating for a site is given a brief explanation here to illustrate the basic technique that is used with the new hydroacoustic technologies. Figure 2 shows a typical calibration curve using current meter readings.

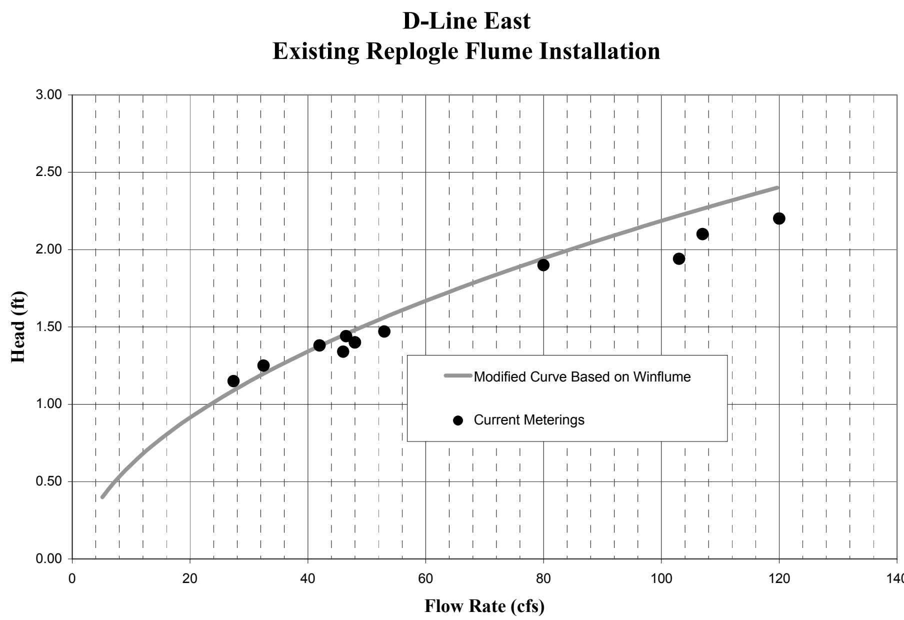

Figure 2. Plot of current metering data and head-discharge curve

The recommended calibration procedure for a non-standard site is as follows:

- A wide range in the measured flow rate is required. At least a 2:1 ratio in the flow rates should be used to create the dataset.
- A minimum of 10 values should be measured across the entire flow rate range.
- Data should be evaluated using the trendline function to evaluate the equation. The equation is in the form of a power curve. This type of graphing function is a standard option in programs such as Excel®.

The data should evaluated to determine the coefficient and exponent in the power equation listed below. The exponent should be between 0.3 and 0.7. A program such as Excel can be used to determine the equation and the regression coefficient. The equation should be of the form:

$$H = KQ^x$$

where "x" is a value between 0.3 and 0.7

The regression coefficient (r^2) must be better than **0.96** to assure confidence in the results. This has been determined to provide the required +/-5% flow measurement accuracy of a rated site. If the data is less than 0.96, additional data points must be obtained.

Recommended Site Conditions for Hydroacoustic Devices

The physical setting of hydroacoustic devices and the flow conditions at the site have a major impact on the potential accuracy of discharge records. This deserves special consideration in indexing applications when hydroacoustic flow meters are being used to rate a structure. Before deployment of a device such as the Argonaut SL or SW, the site must be evaluated according to manufacturers' recommendations.

The following guidelines outline the required characteristics of a site for the hydroacoustic devices such as the Argonaut SL. The sensor must be:

1. At least ten widths of the canal away from bends or turbulences.
2. At a concrete-lined section of the canal that is well surveyed.
3. Installed on a secure, movable arm for easy removal of the sensors for maintenance.
4. A trash deflector must be installed around the device.
5. A calibration procedure, such as the Flow Rate Indexing Procedure (QIP), must be completed.

Flow Rate Indexing Procedure

Hydroacoustic flow meters are high-precision instruments that very accurately measure the velocity of water in the section of flow being sampled. The water velocity measured by hydroacoustic flow meters represents a sampled portion of the canal that can be used as an "index" for the actual mean channel velocity. Hydroacoustic flow meters are appropriate in many situations where, for example, the flow conditions are too complex for traditional devices. The flow rate is computed by devices such as the Argonaut SL flow meter internally by the firmware using a programmed stage-area rating and the index water velocity ($Q = V \times A$). The user can input an indexing equation into the unit with the deployment software based on the results of the QIP process.

In QIP applications, the measured velocity is sampled and recorded in programmed time intervals concurrently by both the device being calibrated (e.g., an Argonaut SL at the head of a lateral canal), and a second profiling device that produces an accurate discharge measurement such as the RiverSurveyor. Mean channel velocities can also be obtained from current metering as long as the time periods are the same.

The data for multiple pairs of mean velocity and index velocity collected over a range of flow are analyzed using regression techniques, with and without multi-parameter ratings to account for the effect of stage. The resulting equation of the index velocity rating is necessary for using the internal flow computational feature on hydroacoustic flow meters or for post-processing data from temporary deployments.

Major Steps in the Flow Rate Indexing Procedure - QIP

During an indexing session, the technician follows a set of standard procedures to collect data from the different sensors for a specified time period. Following the recommended guidelines for deployment of hydroacoustic flow meters is essential. The dataset for each measurement period is comprised of:

- Mean velocity in the standard cross-section using a standard device such as a boat dopplers described previously.
- Average measured velocity from the hydroacoustic flow meter
- Average stage

The following major steps outline the procedure for developing an index velocity rating:

1. A hydroacoustic flow meter is installed in the canal with the appropriate deployment settings and mounting bracket. Site selection is an important consideration and the diagnostic guidelines provided in the manufacturer's technical documentation should be carefully observed.
2. The channel is accurately surveyed and a stage-area rating is developed. The same standard cross-section is used every time indexing data is collected. Elevations for the cross-section points are in terms of stage referenced to the station datum.
3. The average stage during the discharge-measurement period is recorded. A secondary water level monitoring device may be utilized to provide quality assurance data (as was done in this study).
4. Discharge measurements are made near the hydroacoustic flow meter site while the instrument is sampling and recording velocity and stage.
5. Mean channel velocity is derived for each individual discharge measurement by dividing the measured discharge by the channel area computed from the stage-area rating.
6. For each measurement period, the index velocities are averaged.
7. Each measurement yields a computed mean channel velocity and an average index velocity.
8. A regression analysis is performed to determine the equation of a plotted line using single or multi-parameter analysis to account for the effects of stage. The relation between the mean velocity and the index velocity is the "index velocity rating".
9. Discharge is computed from the standard equation $Q = VA$. (V) velocity is computed from the application of the index velocity rating to the measured velocity. The (A) area is computed from the stage-area rating of the canal and the measured stage.

10. The index velocity rating procedure recommended by ITRC requires a wide spread in the measured discharge (a 2:1 ratio), usually at least 10 measurement values over the entire range of flows. The regression coefficient (r^2) must be better than 0.96 to assure confidence in the results.

11. The validity of the index velocity rating depends on maintaining stable channel and hydraulic characteristics at the measurement site. Changes in channel conditions due to sedimentation or weed growth can invalidate an index velocity rating. Accurate discharge measurements from hydroacoustic instruments depend on regular assessments of the index equation using ADP or current metering data.

The index velocity rating is developed by first validating that a linear relationship exists between the mean velocity and average of the sensor-measured velocity data collected during the same time period. This is done by creating a scatterplot with mean velocity as the y-axis and index velocity as the x-axis (Figure 3).

Linear regression produces a straight line that is the best fit for all the data points. The equation of this line is an index velocity rating with the single parameter (independent variable) of sensor-measured velocity. For some sites, the inclusion of stage as an additional regression parameter can improve the accuracy of the index velocity rating. The product of the index velocity and stage is the second independent variable in the multiple regression. Stage may have a significant impact depending on channel geometry, channel roughness, the set points of downstream structures, stability of the velocity profile etc.

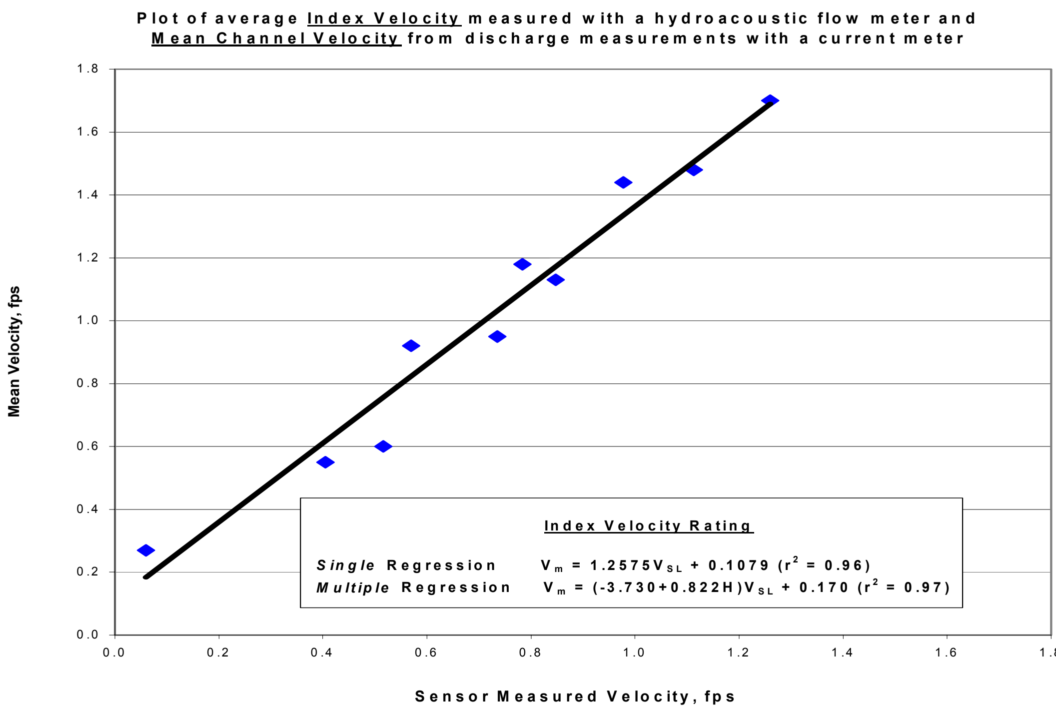

Figure 3. Example scatterplot of an index velocity rating for single and multiple linear regression ($r^2 \geq 0.96$)

Index Velocity Ratings

Table 1 summarizes the deployment of equipment and field data collection used for index velocity ratings at the cooperating water agencies.

Table 1. Summary of field data collection, index velocity ratings, and discharge rating development at study locations

Water Agency	SonTek/YSI Argonaut SL	SonTek/YSI Argonaut SW	Telog Water Level Monitoring System	Index Velocity Rating Procedure	Rating Development for Discharge Records
Alta Irrigation District		√	√	√	√
Contra Costa Water District	√		√	√	
Dunnigan Water District			√		√
Klammath Irrigation District	√			√	
Madera Irrigation District		√	√	√	
Merced Irrigation District			√√		√
Patterson Irrigation District	√		√√	√	√
Sutter-Mutual Water Company					
Tulare Irrigation District	√√	√	√√√√√		√√
Colorado River Indian Tribes	√			√	
Lower Colorado River Authority	√			√	
Paradise Valley Irrigation District	√			√	
Yuma Co. Water Users Assoc.	√			√	

Summary Error Analysis

The index velocity ratings developed at each one of the demonstration sites were used to compute the discharge and compare to the mean discharge collected with the RiverSurveyor and RD Instruments Stream Pro. The average percent error of discharge records collected at sites before the QIP index velocity rating was applied was 12.7% with average errors ranging from 25% to –25%. The results from the QIP evaluation at the demonstration sites improved the average error at all the demonstrations to at most 0.5%.

The percent error in discharge was calculated using the following relationship:

Before QIP (sensor measured discharge)

$$\text{Percent Error} = \frac{\text{Sensor Measured Discharge - Mean Discharge}}{\text{Mean Discharge}} \times 100$$

With QIP

$$\text{Percent Error} = \frac{\text{Computed Discharge w/ Index Velocity Rating - Mean Discharge}}{\text{Mean Discharge}} \times 100$$

SUMMARY

The ITRC's QIP technique has been successfully used to rate non-standard structures by indexing flow rates with hydroacoustic meters. This method greatly reduces the time required to rate a structure, and improves the measurement accuracy by collecting a large amount of data by autonomous installations over a wide range of flow conditions. Standardized, step-by-step instructions have been prepared for developing accurate and reliable discharge ratings.

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DECISION SUPPORT FOR THE RED RIVER BASIN, USA — SHARING DATA AND TOOLS

Mark R. Deutschman[1]

ABSTRACT

The Red River Basin Decision Information Network (RRBDIN) is an internet site (http://www.rrbdin.org/) developed for the purpose of supporting the information needs of residents and organizations throughout the Red River Basin of the North, USA. The Red River Basin is an international watershed with a network of state, federal and international governmental jurisdictions, local units of government and non-governmental organizations. The RRBDIN is a central data source or portal, for locating geo-spatial information, people, communications and water management decision-making. The RRBDIN maintains a distribution list of interested parties or members, broadcasts news updates and coordinates on-line meetings. Regular and special virtual meetings are held each month.

Two internet tools are especially important for decision-making. The first is an interactive web-mapping tool coined the BasinViewer, which uses the open-source MapServer programming language and the Open GIS Consortium Web Mapping Service protocol. BasinViewer accesses data from the host server and distributed data from the Minnesota Department of Natural Resources Data Deli and the U.S. Geological Survey EROS Data Center. BasinViewer can overlay critical geo-spatial data on the fly, and is a mapping interface to an array of on-line databases pertaining to water quality, culvert and bridge characteristics, land use, biological monitoring, topography, and water resources. The DataViewer tool provides a one-stop shopping portal to on-line data for the basin, hosted by the U.S. Geological Survey, the U.S. Army Corps of Engineers, the National Weather Services, the Province of Manitoba and other organizations. DataViewer allows access to data for multiple locations and sources without leaving the host server.

The RRBDIN began as a Global Disaster Information Network initiative of the United States Government. The International Joint Commission (IJC) Red River Basin Task Force also supported a portion of the initial RRBDIN development. The site is currently maintained and funded by the U.S. Army Corps of Engineers.

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PHYSICAL SETTING

The Red River originates at the confluence of the Bois de Sioux River and the Otter Tail River, forming the boundary between North Dakota and Minnesota. It enters Canada at Emerson, Manitoba and continues northward to Lake Winnipeg and thence to Hudson's Bay.

The Red River basin covers 116,500 km^2, of which 103,600 km^2 are in the United States. The remaining 13,000 km^2 are in Canada. A major western tributary, the Assiniboine River, enters the Red River at Winnipeg. It is a large basin, producing relatively little runoff, and is not included in this study area. The basin generally does not have the conventional dendritic pattern of small tributaries leading to larger ones and hence to the river. Instead relatively short tributaries flow directly to the main stem of the river. The opportunities for in-channel storage and construction of reservoirs are limited.

The central portion of the Red River basin, known locally as the "Red River Valley", is very flat as it originated as the bed of glacial Lake Agassiz. The River drops only 71 m over a river length of 870 km. The slope varies from 250 mm/km in the headwaters to 40 mm/km at the International Boundary. The River channel can hold roughly the mean annual flood peak so during major floods the river leaves its banks and flows north constrained by natural topography and infrastructure such as road and rail networks. In 1997, the Red River spread to a width of up to 40 km in Manitoba.

The Red River basin has a subhumid to humid continental climate with moderately warm summers, cold winters, and rapid changes in daily weather patterns. Monthly mean temperatures range from -15 to +20^{o} C. About three-quarters of the basin's approximately 500 mm of annual precipitation occurs from April through September, with almost two-thirds of that falling during the spring. The winter months are driest having only about 10 to 15 mm of precipitation each month.

The total basin population is about 1.4 million, almost half of them living in the Manitoba capital, Winnipeg. The Red River basin is a highly productive agricultural region. As such, it has been profoundly altered by human activity. These changes relate not only to drainage and crop development but also to construction of major transportation corridors. Land use and land use change is therefore a major issue throughout the basin.

FLOOD OF THE CENTURY

In 1997 the Red River basin experienced the “Flood of the Century”. The 1997 flood arose from a number of factors: a wet autumn, record or near-record snowfalls during the winter, heavy early-spring precipitation, and coincidence of tributary peaks with main stem peaks. Overland flooding was significant and

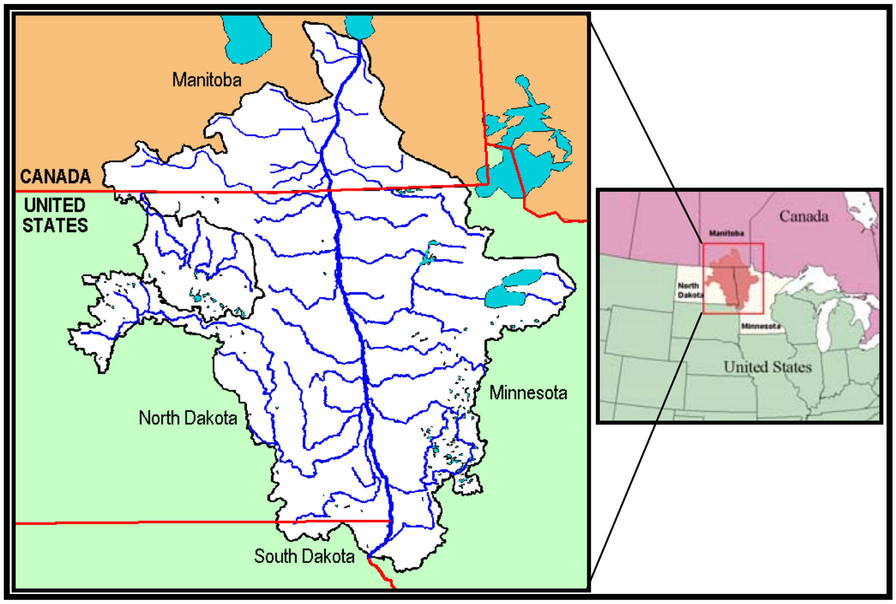

Figure 1. Red River of the North Basin as defined for International Joint Commission Study.

unpredictable even though forecasts of river elevations were, for the most part, accurate.

The emergency dikes in Grand Forks, North Dakota and Ste Agathe, Manitoba failed causing widespread damage. At least 103,000 people, 75,000 in the USA and 28,000 in Canada, were evacuated. There were no lives lost but flood damages exceeded $3.5 billion in the USA and $300 million in Canada. The flood had a frequency of roughly 1:100 but some tributaries experienced much rarer events.

Rare floods such as the 1997 flood are not the only flooding problem, however. The basin also experiences smaller floods in the spring and summer that affect rural areas and agricultural lands. Land-use issues such as drainage and road construction, are seen by many as contributing to the flooding problems. Dealing with the broad range of flooding and other water problems in the Red River basin therefore requires considerable coordinated effort. That effort is complicated by the fact that the basin comprises two countries, three states, one province and countless local governments. In addition, there is a broad range of governmental and non-governmental water institutions operating at a basin-wide or subbasin level. Nearly 1000 relevant organizations have been identified that have some role or interest in floodplain management in the Red River Basin.

In the aftermath of the flood, the governments of the US and Canada asked the International Joint Commission (IJC) to analyze the cause and effects of the Red River flood of 1997 and to recommend ways to reduce the impact of future floods. These efforts were directed by the IJC appointed Red River Basin Task

Force. The wide range of issues, interest groups, and multiple jurisdictions at play in the basin were clarified during the IJC study. One area where there was clear consensus concerning needed improvement related to data and information sharing: a need existed for major improvements in data availability, improved data dissemination to the public; more efficient data exchange between agencies involved in floodplain management; and greater database integration for the whole basin. Improved coordination, collaboration, and resource sharing were clearly needed.

INITIAL ACCOMPLISHMENTS

Several steps toward meeting the goal of shared data were accomplished by the Task Force including conducting a data/information needs assessment, basin-wide data inventories, and creation of a metadata clearinghouse. A Data Focus Group was formed which identified and debated numerous data sharing issues including vertical datum variances at the US/Canadian border and the use of local datums, Canadian Policy restricting free sharing of some spatial data sets, data quality, and data standards. Most of the problems identified remain unresolved.

In addition the Task Force, in partnership with the Global Disaster Information Network (GDIN) initiative, initiated development of a prototype Internet-based system to provide users with a means to obtain and share relevant data and information. The Red River Basin Decision Information Network (RRBDIN) (http://www.rrbdin.org) was formed to provide for an interactive and iterative process of building basin-wide information resources and to improve communications and enhance cooperation.

The RRBDIN also provided a mechanism for improved collaboration and information sharing through a "Virtual Forum". The concept provided for Live Discussion Rooms where round table meetings, presentations on specific topics, or mutual help sessions were held via the Internet.

CURRENT EFFORTS AND OPPORTUNITIES

When the IJC Task Force concluded its work in April 2000 formal coordinated efforts and joint funding between the US and Canada for the prototype RRBDIN ended, yet interest in the Network and efforts initiated during the study continued to evolve. The Water Resource Branch of Manitoba Conservation expanded upon the Virtual Database developed under the IJC Study and added additional decision support tools both for internal use and eventually for access by the general public in the basin. In the United States the U.S. Army Corps of Engineers provided funding to enhance the prototype RRBDIN to a point where it could more easily be handed over to one or more local sponsors for continued operation and support into the future.

The RRBDIN currently consists of a community of "Members" (individuals and organizations) that use, test, and direct the content of the RRBDIN Internet Web Portal (http://www.rrbdin.org). The portal currently includes communication tools, searchable lists of organizations and points of contact, documents library, policies and procedures, web-mapping tool, and other "Information Resources."

Most existing information systems in the Red River Basin have been designed by separate agencies to address their individual problems and requirements. Stand-alone systems result in 'Islands of Automation'. Advances in information technologies allow improved means of sharing and processing vital information. A decision support system (DSS) can connect these "islands" and enable automated floodplain management queries and analyses to be performed by the community of stakeholders. The DSS can be a tool that brings together the virtual database, models, and other disparate information, and provides an integrated environment where decisions can be made about floodplain management and flood preparedness.

RRBDIN

The RRBDIN provides the framework from which the DSS is developed. The DSS was formed in several stages. The early concept for the RRBDIN included the identification and development of several complex applications or "tools", which utilized seamless geo-spatial data, to aid in emergency response planning and flood management. However, many of the early ideas were not technically feasible. For example, an early concept consisted of fully automated execution of hydrologic and hydraulic models across the internet, with the automated generation of input models from the geo-spatial data. Model results were to be returned to the users screen and graphically displayed using available geo-spatial data sets. Upon further evaluation, it became obvious that not only was automating this process a significant technical challenge, but an even more preliminary gap existed for a mechanism to locate, assess, and share geo-spatial data. In many cases, the basic geo-spatial data required were not even available.

The present, refocused phase of the RRBDIN continues the early efforts to share information, but takes a more basic, practical approach building upon the lessons learned. Several use cases, developed by the community of stakeholders, have been considered for implementation. These use cases identify the need for continued information about activities, organizations, news and references being developed within the basin; i.e., a basic information-sharing component. However, the use cases also identify important new tools that have been completed.

These primary tools consist of: 1) geo-spatial data applications; and 2) a real-time data display for hydrologic, hydraulic, climate, weather and water quality data. The concept is that decisions about floodplain management, disaster relief and mitigation, and basic water management issues can be enhanced by properly organizing and making available this information within a web environment.

The geo-spatial data applications consist of several tools. These tools include an internet-based MapServer application for the display of basin geo-spatial data by the client, map generation of multiple layers and the printing of maps for local use. The RRBDIN is intended to provide seamless, authoritative GIS data for the Red River Basin. Several organizations continue to cooperate with this aspect of the project. Much of this data has come from a joint US/Canadian project sponsored by the Federal Geographic Data Committee and the GeoConnections Secratariet. Plans are to enhance this tool to allow the upload/download of geo-spatial data.

A second geo-spatial data application is developing and making available basic geo-spatial data used by flood managers on a routine basis. These data may be necessary for the development of parameters used by hydrologic or hydraulic models, be needed for understanding the movement of water within the basin, or be useful for other reasons. Examples include land use data necessary for the development of curve numbers when modeling runoff and a culvert/bridge database that can be used to determine water movement and refine hydrologic boundaries. These applications were built with the cooperation of other state agencies using existing data sets.

Ultimately, the RRBDIN is expected to become the primary portal for geo-spatial data within the Red River Basin. The first step in this process has been the creation of a metadata node specific to the basin. Ultimately, the intent is to provide a geo-spatial search and retrieval tool allowing the user to download the data locally.

Development of the real-time data display has also been completed. The application provides real-time or near real-time data from multiple sources including the U.S. Geological Survey, the U.S. Army Corps of Engineers, the National Weather Service, the Minnesota Department of Natural Resources, North Dakota State Water Commission, and the Province of Manitoba.

A basic philosophy of RRBDIN development is to maximize the use of data generated or made available by others: i.e., to avoid duplication to the extent possible. This presents a significant technical challenge because of the need for many agencies to protect these data behind security systems. Expectations are that some of these issues will be overcome by porting data to a server external to the agencies system.

Joint US/Canada Framework Project for the Red River Basin

A basic challenge, which became all too apparent early during the development of the RRBDIN, is access to good, acceptable, authoritative geo-spatial data for the Basin. A private sector/public sector partnership (the "Partnership") consisting of

US and Canadian entities received a cooperative agreement from the Federal Geographic Data Committee (FGDC) and the GeoConnections Secratariet during the summer of 2001.

The concept for the effort consisted of using "model" watersheds to address some of the basic geo-spatial data issues within the Red River Basin across the US-Canadian international border. Addressing these issues for these model watersheds increased the likelihood of success for the entire Red River Basin. The Partnership selected two basins with straddle the US and Canadian border for the project. The Pembina River Basin straddles the US – Manitoba Border and has a history of complex flood management issues. The Roseau River Basin, an area that recently formed one the first cooperative US-Canadian Board consisting of local government representatives, was initiating a water management planning process.

The project consisted of developing a framework in the sense of the FGDC, for geo-spatial data within the Red River Basin. The technical challenge consisted in part of combining geo-spatial data of varying scales, accuracy and provenance. Responsibility for creating and making available seamless framework datasets rested with the U.S. Geological Survey (EROS) and the Canadian Centre for Remote Sensing. Seven data themes comprise the framework datasets: geodetic control, orthoimagery, elevation, transportation, hydrography, governmental units, and cadastral information. Transportation, elevation and hydrography were selected by the Partnership as example framework datasets for resolving geo-spatial issues between the US and Canada. Select non-framework geo-spatial data were also created, primarily subwatershed boundaries.

Other Related Efforts

There are several related efforts either specific to or affecting the Red River Basin, many of which are significant by themselves. The Information Technology Division within the State of North Dakota has enhanced their existing Geographic Information Clearinghouse. The intent is to provide access to basic geo-spatial data for North Dakota.

The Manitoba Conservation Department Water Branch in cooperation with the Prairie Farm Rehabilitation Services completed an important flood management and planning tool. The tool uses recently completed high resolution topographic data in the form of a DEM and hydraulic simulation results to show the predicted extent of flooding. Development includes tools to estimate resources needs for flood fighting.

A significant and important effort within the basin was the International Flood Mitigation Initiative (IFMI). IFMI was launched in December 1998 bringing together 30 top present and former officials from provincial, state, local, and federal governments, private sector, and non-profit organizations together to address flood damage mitigation concerns in the Red River Basin. The IFMI vision became one of addressing flooding through mitigation that achieves significant flood damage reduction goals while enhancing economic, social and ecological opportunities by the year 2010. The IFMI effort lead to many existing initiatives for data sharing in the basin, the most prominent being the Red River Basin Institute for Research, Mapping and Watershed Education. The Red River Basin Institute is presently evaluating how to best enhance the sharing of geo-spatial data within the Red River Basin. Their involvement may include either funding support or actual development of additional technologies. A companion effort is the development of a public educational web site by Prairie Public Television.

LONG-TERM VIABILITY

A concern among the stakeholder community is the long-term viability of the internet-based system being developed to support decision-making. This system includes the RRBDIN, sites developed during the Joint US/Canada Framework Project, state efforts, efforts resulting from IFMI, and the efforts of the Manitoba Water Resources Branch and the Red River Basin Institute.

One goal is to provide a common access point to each of these information sources through the RRBDIN. To further this effort, two important information items have been developed. These included the development of a business model for sharing geo-spatial data as a part of the Joint US/Canada Framework Project for the Red River Basin. A second document identifying routine operation and maintenance costs for the RRBDIN has distributed to the stakeholder community. This information is intended to provide the basic information necessary to make decisions about future financial support.

A major goal of the RRBDIN is to involve the broadest range of interested individuals in an exchange of data, information, knowledge, and ideas through the free sharing of relevant databases and participation in various networking opportunities. It is also hoped that ultimately this system will provide the framework for the development of decision-making tools for floodplain management, disaster relief and mitigation. The vision is for the RRBDIN to become a trusted and dependable resource for informed decision-making built upon and maintained by a strong network of cooperating individuals, organizations, and agencies.

A GIS-BASED IRRIGATION EVALUATION STRATEGY FOR A RICE PRODUCTION REGION

Zongyao Sha[1]
Fuling Bian[2]

ABSTRACT

Water shortage has become an international problem and this is especially true in China. This paper will detail the process of constructing a GIS-based information system to complete large-scale evaluation for water irrigation efficiency in a rice production region in China. A GIS-based system is built to integrate evaluation models and manage irrigation region actively and present the evaluation result in this paper. The research region is divided into several sub-regions and each sub-region is irrigated differently. After comparison of the results of different irritation methods, the suitable way of irrigation for a certain region can be selected. In this study, each rice production farm field located in sub-regions will be regarded as a basic unit and is digitalized to form spatial database. We monitor all growing stage of paddy rice and record water irrigation and rice yield. The goal is to find region-fit irrigation strategy and thus to enhance the profitability of irrigation water.

INTRODUCTION

Lack of available water resources in most countries is increasingly becoming a serious problem. Development of industries and agriculture thus have been severely limited by the shortage of available water and will be even more serious in the near future if no effective measures are taken. As the world population is still increasing, food security is challenged by large food demand and threatened by declining water availability. Take Asia as an example, to keep up with population growth and demand for food (Pingali, 1997), it is estimated that rice production has to be increased by 56% over the next 30 years (IRRI, 1997). At the same time, waste of water resources in agricultural irrigation is still serious, however, agricultural irrigation in rice production has the potential to be improved. In Asia again, irrigated rice accounts for about 50% of the total volume of water diverted for irrigation (Guerra, 1998). In many Asian countries, per capita availability declined by 40±6.0% between 1955 and 1990, and is expected to decline further by 15±5.4% over the next 35 years (Gleick, 1993). This situation is further aggravated by dramatically increasing costs for irrigation development over the past decades. Because of the combined increasing demand for food with the increasing shortage

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of water, rice producers face three major challenges (Belder, 2004). Research and development of a water-saving agriculture in paddy rice is an important way today to make agriculture and industries sustainable in terms of water consumption. The traditional irrigation system of rice production is transplanting in a field that is kept continuously flooded throughout the growing season. This is called flooded irrigation. Land preparation consists of soaking, ploughing and puddling (i.e. harrowing until a soft muddy layer of 100±15mm is formed in saturated conditions). The water requirement for land preparation is theoretically150±20mm, but can be 5 times higher when its duration is long (De Datta, 1981; Bhuiyan, 1995). Evaporation, transpiration, and Seepage and Percolation (SP) are the main outflows of water from a rice field. SP rates depend on the hydraulic properties of the soil, water pressure heads, and the length and state of the bunds (Wopereis, 1994). It has been estimated that SP accounts for 50±8.0% of the total water input to the field, and most field-level water-saving strategies concentrate on the reduction of SP flows (Tabbal, 2002). In support of water-saving efforts, Different farm-level technologies to save water were experimented to increase water productivity. Since the term “water-saving irrigation techniques” been introduced (Guerra, 1998), many irrigation systems in rice production have taken aim at reducing SP rates by reducing the depth of flooded water, keeping the soil just saturated or alternate wetting/drying, i.e. allowing the soil to dry out to a certain extent before re-applying irrigation water.

GIS technology has come a long way in the past decade and continues to evolve, with the basic function being spatial data management. New application areas have been found, including agriculture, forestry, hydrology, resource management, and coastal resource management. Those areas benefit much from the development of GIS. In addition, new products have appeared in the marketplace. What is more, dramatic improvements continue in the capability of hardware and software operating platforms; and many large data sets have become available. GIS technology has grown rapidly to become a valuable tool in the analysis and management of spatial ecological problems. It is not new for GIS to be used in agriculture. Since the Canada Geographic Information System or CGIS, generally acknowledged as the first GIS system, GIS has been applied by resource planners and decision-makers with a set of tools to analyze spatial data effectively. Agricultural resource planning, and land assessment are also among the areas that GIS can provide benefits. These areas can be classified as macro applications since large areas are usually covered. A more popular application of GIS in agriculture, which may be classified as a micro application nowadays is precision agriculture, tailoring soil and crop management to fit the specific conditions found within a field with the aim to improve production efficiency and/or environmental stewardship.

After a literature review and analysis, this study focused on comparison of different water-saving irrigation techniques at the field-level. The main objective is to find a suitable irrigation method and thus to formulate a suitable irrigation system for our research region with the aid of GIS.

METHODOLOGY

Research Region

The central theme of this paper is investigating farm-level water irrigation with different strategies, i.e. water-saving strategy and flooded irrigation. We select an agriculture production base in Jingmen city as the experiment base. Located in the Hubei Province, China, with 112.11 east longitude and 30.52 north latitude at an altitude of 100 m, Jingmen City has a total land area of nearly 800 km^2. Most of the area for agriculture production covers the suburb region of the city. The semitropical climate of the city meets required living conditions of paddy rice. The experimental site was surrounded by lowland rice fields in the 160,000 ha irrigation system. The soil texture was silty clay loam.

Experiment design

Agriculture production is a spatial ecological system that shows uncertain, fuzzy characters in management. To get maximal benefit and minimal side effect, it is necessary to test management method on different agriculture farm field to get the most suitable irrigation system. There are two kinds of agriculture field model: regular grid field in precision agriculture and irregular field grid typical in rugged regions. Precision agriculture usually regularly partitions a large area into groups of small cells (Figure. 1 (a)). In practice, however, it is almost impossible to get regular farm field due to scatted farm location and rugged land (as in mountainous region). Figure 1 (b) shows decision-making grid for large-scale farm-level fields. Those fields are irregular, scatted and ill shaped. Because of this fact, it is much more complicated for farm-level agricultural field management than that for digital agriculture because the diversity of living conditions for crop should be considered when decision on field management is made. So we select a relative flat study region and design two water-saving irrigation systems to investigate the effect of saving-water irrigation strategy compared with the traditional flooded irrigation system.

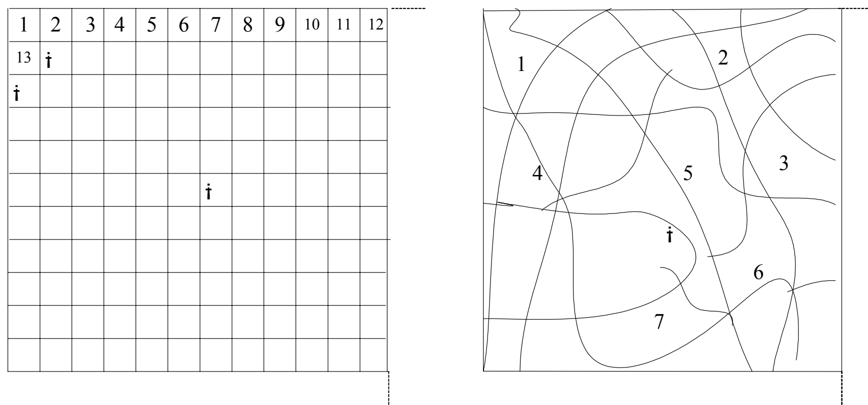
The designed irrigation systems adopted in this study include the traditional irrigation and two types of water-saving irrigation as shown in Figure 2. The whole stage of rice growth can be divided as vegetative, reproductive and ripening periods. Table 1 gives the cropping calendar for the experiments. Irrigation treatment in different stage is varied for all the irrigation strategies. For the traditional irrigation (signed as TM2), much of the time during the growing period rice is covered by irrigation water. This way is also called flooded irrigation. Compared with this traditional way, water-saving strategies is much different. The TM1 and TM3 in Figure 2 represent two types of water-saving irrigation. It can be seen that alternative irrigation is conducted for the whole growing stage with TM1. Alternative irrigation is conducted for the first part of growing period and shallow saturated irrigation is conducted in the following period with TM3. Figure 3 is the outline map of the experiment base. The whole research region is divided into 3 sub-regions and each sub-region is composed of numerous farm fields. Three types, i.e. TM1, TM2 and TM3, of irrigation strategy are conducted in different fields randomly, belonged to the three sub-regions respectively. Soil property of each farm field is similar so the factors that affect yield can be neglected. And the rice plants are specifically prepared before transplanting to ensure the least difference for each treatment. Monthly rainfall, temperature and radiation are recorded as shown in Table 2. The shape of each field is digitalized by GIS software and GIS can easily calculate the area. We monitor all growing stages and record the rice yield and water consumption for each field and compare the difference of irrigation treatments. The average yield and water input per hectare is calculated to evaluate the effect of different irrigation methods with evaluation models of water efficiency organized in different ways.

Table 1. Cropping calendar for the experiments

Experiment	Sowing	Transplanting	Panicle initiation	Flowering	Harvest
Date	18 April	20 May	6 July	8–12 August	6–11 September

Table 2. Monthly rainfall (mm), mean maximum temperature (˚C), mean minimum temperature (˚C), and mean daily radiation ($MJm^{-2}\ d^{-1}$)

Month	Rainfall	Tmax	Tmin	Radiation
May	162	27.4	15.3	18.5
June	153	27.9	21.6	17.4
July	94	30.5	23.7	19.2
August	52	30.8	23.4	19.9
September	50	29.5	20.9	17.1



(a) Regular grid in digital agriculture (b Irregular farm-level field distribution

Figure 1. Comparison between two kinds of agriculture field model

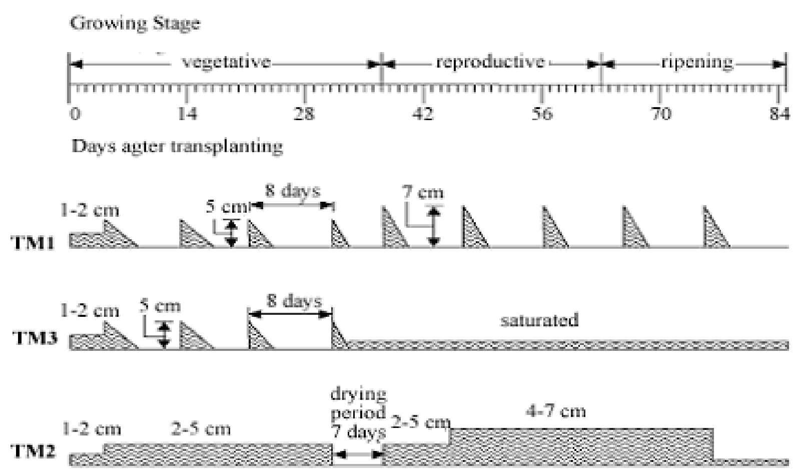


Figure 2. Irrigation design: water-saving treatment (TM1 & TM3) and flooded irrigation (TM2)

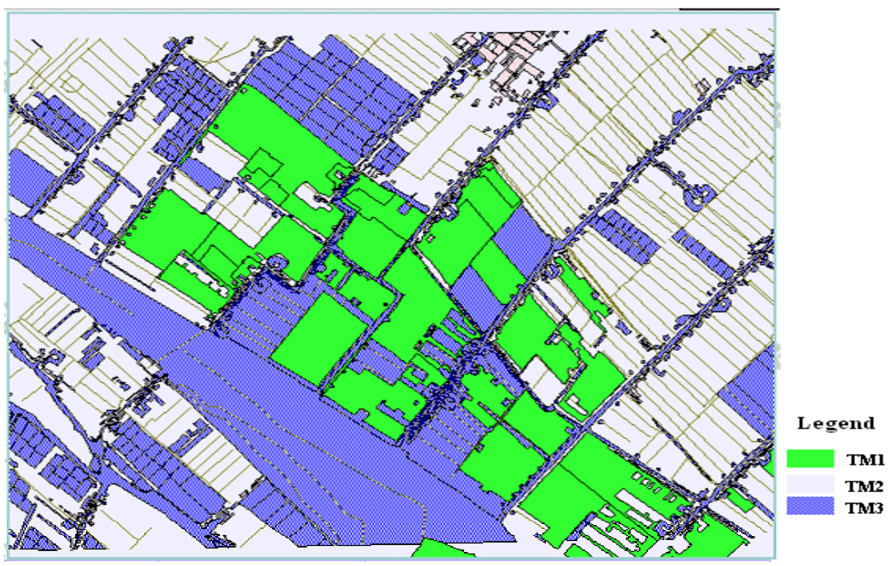


Figure 3. Experiment design: water-saving irrigation & traditional flooded irrigation

Basic software and evaluation process

To actively manage the experiment site, we design a GIS-based software named Irrigation-GIS to monitor the whole region. It is actually a web-based rice production experts to assist the farmer in irrigation, fertilization and other management issues. Three layers, viz. data layer, application layer and browser layer, logically composes Irrigation-GIS framework (Figure 4). This multi-layer structure makes the system maintenance easier and the service range wider.
The first layer, also called presentation layer, is used to communicate with users by various web interface elements known as graphic user interface or GUI. Anyone who can connect to the Internet can be authorized to use the system and aid management of the farm fields in any place at anytime through GUI of the system. So it is easy to input or get data remotely. GUI is built in dynamic Java Service Page or Jsp, so that it can be used over the Internet (or any other large network) without other additional requirements for the client computer but general website browser software, such as Internet Explorer or Netscape. This is the browser layer.
The second layer is the key component that supports the whole function of Irrigation-GIS, including problem interpretation, operation control, knowledge reasoning, model realization and their integration in problem solving. This layer forms the web pages that will forward to browser layer dynamically or statically. These web pages either accept data from the browser or forward analysis result to the browser. The accepted data then will serve as parameters of analysis models, conditions for irrigation affecting evaluation process or basic information for GIS. The evaluation model syntax/implication interpretation module will be triggered and interprets the input parameter value to choose and forms a suitable model or

models the complete numerical calculation. Similarly the evaluation model formalization/resolution constructor will interpret some input data to form conditions for model parameter input. As for GIS functions, the input data also includes spatial information as farm field ID, soil type relating to the field, etc., so GIS will locate and produce a map-based analysis result to users with the help of model analysis and GIS spatial analysis modules. In order to get map-based analysis result, Esri's ArcIMS 4.0 is used as WebGIS engine. ArcIMS supports java connector that passes request of java-program to the spatial server and thus generates the result expressed in map. All these processes are universally controlled by the controller component. The controller component is also responsible for interaction with system data through data access interface Jdbc. The bottom layer is system data. Here the system data represents evaluation models, knowledge and spatial database as well. Spatial data are those data that are geo-referenced and can be accessed by SDE API offered by Esri's ArcSDE 8.1 while non-spatial data are accessed by Java DataBase Connectivity (JDBC). Evaluation models are represented in Objected-oriented frame and can be constructed dynamically at system run time. All parameters and syntax/implication interpretation used in models as well as spatial information are stored and retrieved by the database. Figure 5 demonstrates the three layers and shows the logical design of irrigation-GIS. Users interact with the key components (including application server and database server) through mobile devices or browsers using Extensible Markup Language (or XML) protocol.

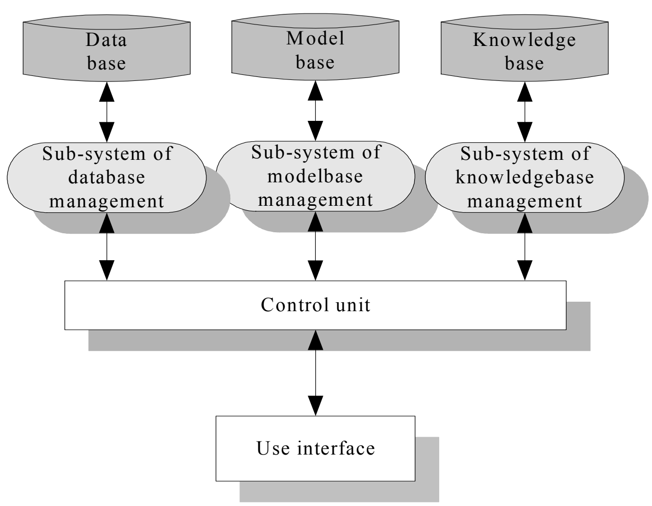


Figure 4. Key components of Irrigation-GIS

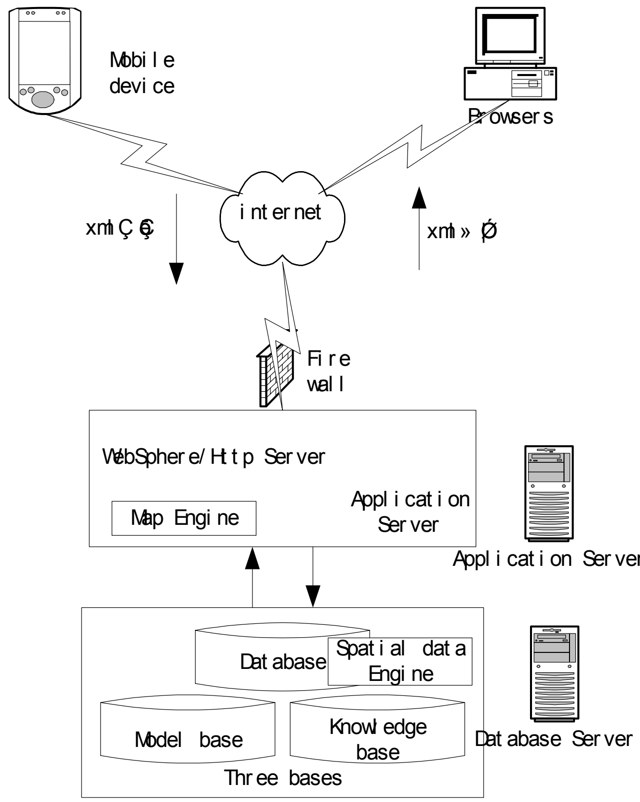


Figure 5. Logical design of Irrigation-GIS

ANALYSIS OF RESULTS

GIS is used as a tool to manage spatial data. GIS gives a clear and active map as water input or grain yield distribution that can help to find valuable rule of different irrigation systems. The area of each experiment field can be calculated easily be GIS and the data of all farm fields experimented can be managed by GIS and displayed in the form of map. What we care most is all water input and the ultimate grain yield for different farm fields. And the average water input and grain yield of different irrigation strategy are summarized. Though all stage of rice growth was monitored and the dried bio-mass was weighed, as for this study, we just want to compare the efficiency of water use in irrigation. Table 4 shows the total average irrigation water input. The water input in TM1 averaged 392 cubic meters per hectare. This is also the traditional irrigation method (TM2). Obviously this irrigation strategy wastes water. Contrary to TM2, TM3 has the least water input, averaging only 326 tons per hectare. Compared with TM2 and TM3, alternative irrigation (TM1) stands on the middle in terms of water input. Then we compare the average grain yield of different irrigations (Table 5). It can be seen that alternative irrigation (TM1) ranks at the top with a grain yield of 8.4 tons per hectare. Flooded irrigation, with the average yield of 8.1 t/ha, follows TM1. Alternative-saturated or TM3, though with the least of water input, has the least grain yield. So we can conclude that least water input of irrigation treatment may not be the case with least grain yield and the largest water input of irrigation treatment may not be the case with largest grain yield either. There may exist a balance for grain yield and water input.

The grain yield for water input can also be analyzed here. It can be found that traditional irrigation has an average of 20.1 grain per kg water. Similarly TM1, i.e. alternative irrigation strategy, has an average of 25.1 grain per kg water and TM3 is 23.6. As for water use efficiency, it is obvious that alternative one (TM1) has the top value and is our recommended irrigation strategy for this region.

Table 4. Average irrigation water inputs ($\times 10^3$ kg ha−1) in the experiment

Experiment	Flooded irrigation (TM2)	Alternative (TM1)	Alternative-saturated (TM3)
Water input	392 ± 62	334 ± 94	326± 20

Table 5. Average grain yield ($\times 10^3$ kg ha−1) for the experiments

Experiment	Flooded irrigation (TM2)	Alternative (TM1)	Alternative-saturated (TM3)
Grain yield	8.1 ± 1.2	8.4± 2.1	7.7± 0.9

CONCLUSION AND DISCUSSION

Water shortage has become an international problem. Scientists are trying to find effective ways to improve water use efficiency. Agriculture irrigation takes a great part of water use and waste of water in irrigation is easy to see. So, finding and evaluating an irrigation system for a certain region is important. GIS originally is developed to store, retrieve and display spatial data and domain models are combined with GIS to simulate some complex phenomena later. The use of domain models in GIS greatly expands its application domain and improves its application level. Applications such as environmental pollution simulation, shortest route selection and material distribution plan, flood submersion prediction, etc are benefited a lot from GIS and domain models. Some special spatial tasks are beyond either GIS itself and can be solved by domain models. This put GIS use in wide applications. The integration of GIS and evaluation model of irrigation effect is our research consideration. The advantage of GIS and evaluation model integration is its power to support people in decision-making with reliable and comprehensible map-based format. The critical factors in this integration include evaluation model construction, model organization, the integration of GIS models and spatial data, and the proper use of model and spatial data.

The fact is that the topologic features and uneven surface of agricultural land in most regions makes farm fields small in area, irregular in shape, and scatted in distribution. The overpopulation makes this even worse since a large farm field usually has to be divided into bits and pieces to meet all farmers need for sharing. This is particularly true in China and many overpopulated countries. The mode of digital agriculture that a large land evenly partitioned into regular grid is inapplicable in those regions. Moreover models are the main component that calculates fertilizer, water and pesticide application for different grids while expert knowledge is usually fixed in models. Knowledge lacks flexibility in maintenance. This also limits the extension of GIS use. The approach discussed here for using farm fields (grids) variability information and expert knowledge for enhancement of yields and reduction of risk in farm field management should be applicable over much of those regions. To offer an application system accessible to location-distributed users, a web-based spatial decision system with the integration of GIS models (irrigation effect evaluation) and spatial data (the farm field distribution), Irrigation-GIS is developed. Farm fields associated with paddy rice are digitalized and evaluation models for irrigation effect are constructed that can serve as the basic data to evaluate and compare agriculture water profit. It will lead to appropriate field management in irrigation to any farm field and guide us to better the use of water in irrigation. The novelty of Irrigation-GIS is its integrated evaluation models of irrigation that contains information on most of agronomic knowledge. With the system run, it is possible to tap the complex spatial decision-making and gain an insight into the variety of options of management practices of water irrigation suitable for each piece of farm fields. This paper presents water irrigation for rice field with the aid of GIS and a Web-based software Irrigation-GIS is built to support the process.

Acknowledgement: The data for this paper was actually gathered in 1999. I have to acknowledge Dr. T.P. Tuong, Prof. Lu Guoan and Prof. Li Yuanhua with whom the experiment was done in Jingmen city.

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TOTAL CHANNEL CONTROL™
AN IMPORTANT ROLE IN IDENTIFYING LOSSES

Tony Oakes[1]

ABSTRACT

Total Channel Control™ (TCC™), a system of automated structures and advanced control and modeling software, has been operating for the last two irrigation seasons in South Eastern Australia. Two large systems have been implemented involving more than 500 gates. It is now established that the system can provide better control, more responsive customer service and effectively eliminate system outfalls. The system has also shown considerable potential to identify areas of high system losses primarily attributed to leakage and seepage. The extent and benefit of the water savings realised has been the subject of some debate both in a policy and technical sense. The policy debate revolves around the merit of environmental benefits associated with uncontrolled outfalls from channels that may accrue a downstream benefit. The technical debate centres around the comparison of the before and after positions and necessarily focuses on the accuracy and timing of flow measurement under both regimes. The paper provides a high level overview of TCC™ and a detailed analysis of components of the overall water balance.

INTRODUCTION

Total Channel Control™ (TCC™) has been developed by Rubicon Systems Australia Pty Ltd (Rubicon) and involves a number of integrated technologies centred around major breakthroughs in system modelling and control theory. The improved monitoring and control associated with TCC™ accrues benefits in the following areas

- **Improved customer service**
  - Close to "on-demand" supply to customers
  - Supply of flows as ordered.
  - Automated opening and closing of outlet.
  - Orders are confirmed at the time lodgement.
  - Ability to interface to on farm automation equipment

- **Water Savings**
  - Channel system outfalls are effectively eliminated whilst delivering significantly improved customer service except in shutdown events.

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  - The "on demand" service combined with assured flow rates onto farm facilitate on-farm savings and improvements

- **Productivity Savings**
  - The TCC™ system operates automatically without a traditional field operator
  - The Planner's role changes from routine scheduling to supervision, exception handling and emergency response.

- **Occupational Health and Safety**
  - The TCC™ system eliminates the manual lifting of drop bars and meter outlet doors.
  - The TCC™ system eliminates the OH&S risks associated with lifting of the Dethridge Outlet door and the rotating wheel.

Key theoretical and practical aspects of this work have been published in refereed journals and conference papers locally and internationally. For further information on the control and modelling aspect of TCC™ refer to Oii 2001 and Mareels 2003. Luscombe 2002 and Luscombe and Oakes 2003 detail expectations and preliminary outcomes for the TCC™ pilot on the No. 2 channel in the Central Goulburn Irrigation Area. Goulburn-Murray Water (2004) provides a comprehensive report on the outcomes of the pilot and G-MW have recently taken a decision to significantly expand TCC™ in the Central Goulburn Irrigation Area during the 2005 calendar year.

The primary focus of this paper is on the water savings aspects of TCC™ and more particularly an analysis of unaccounted water and how previous understanding may be extended.

BACKGROUND

There are many definitions of irrigation efficiency but in the context of irrigation distribution systems this is generally regarded as the ratio of water delivered to customers versus the volume of water taken into the system. Sinclair Knight Merz (SKM 2000) undertook a major study of the efficiency of the Northern Victorian Irrigation systems. This report showed that the average weighted distribution efficiency for the 10 years from 1989/90 to 1998/99 was 71% for the gravity irrigation areas. The report also indicated that the 10 year average diversion volume was or the order of 3380 GL, deliveries approximately 2400 GL with losses of the order of 980 GL. The 980 GL loss component was reported as shown in Table 1.

Table 1. GMID 10 year average unaccounted for water – 1989/90 to 1998/99 (SKM2000)

Mechanism	Volume (GL)	Percentage	Volume (GL) without unaccounted component
Outfalls	298	30	387
Meter Error	110	11	143
Evaporation	101	10	131
Leakage	85	9	110
System Filling	64	7	83
Seepage	55	6	71
Unmetered D&S Supplies	38	4	49
Theft	5.5	0.6	7
Unaccounted	225	23	0
Total	981.5	100.6	981

A significant conclusion from this work was that 225 GL could not be assigned with confidence to any of the eight physical components shown in the table. Clearly 225 GL is a very substantial quantity of water and the fourth column of the table simply apportions this volume to the other categories.

Luscombe and Oakes (2003) reported the following 5 year average annual statistics for the Central Goulburn No 2 Channel (CG2) prior to the commencement of the CG2 pilot in 2002/2003 as:

Table 2. CG2 efficiencies - 5 years 1996-2001

Inflows	13,100 ML
Deliveries	10,800 ML
Outfalls	1,500 ML
Efficiency	82 %

The data reported in Table 2 and substantial amounts of the data reported in Table 1 are based on once a day measurement, typically taken at 8:00am.

An analysis of the continuous flow measurements acquired from the TCC™ system on the CG2 channel for the 2003/2004 season shows the following quantities:

Table 3. CG2 efficiency - 2003/2004

Inflows	14011 ML
Deliveries	11064 ML
Outfalls	10 ML
Efficiency	79 %

Despite outfalls effectively being eliminated and a slight increase in the volume of water delivered the comparison of the data from Table 2Table 3 and Table 3 shows the overall efficiency has declined by the order of 3%. This is a non intuitive outcome. However, G-MW continue to collect once a day measurements of the inflow to the CG2 system and the sum of these figures for the same period represents a total volume of 11,263 ML which equates to an overall efficiency of 98%. On the basis of these data a reasonable conclusion would be that the historic methods of data recording significantly under estimate system inflows. Experience with the introduction of continuous measurement within other authorities, particularly on outfalls has shown substantial variation with traditional manual measurement and in an extreme case last season this was under recording by 500% i.e. manual measurements showed 1/5th of the volume recorded by continuous measurement.

SEASON ANALYSIS

Necessary prerequisites to delivering the control outcomes associated with TCC™ are

- Accurate and continuous water level measurements
- Accurate Flow Measurement
- Accurate and timely representation of demand
- An accurate network model
- Control and actuation equipment capable of supporting a high duty cycle

Accurate and continuous flow measurements together with the network model also enable real time water balances to be undertaken on a pool by pool basis. Furthermore the ability of the TCC™ system to maintain constant flows on to farm ensures that the ordered flow rate (demand) equates very closely to metered usage.

Figure 1 shows a plot of the inflow to the CG2 system less the demand, using average daily quantities. Given that demand is an excellent indicator of metered usage this is effectively a plot of system loss computed on a daily basis, although these daily values are underpinned by continuous records. Apart from one small order on 18 September 2003 the system was not completely filled until the first significant demand that occurred on 28 September 2003. The volume of water taken into the system from the filling start date of 10 Sept. until 28 Sept. was 292 ML and as a percentage of the total inflow for the year (from Table 3) this represents a value of approximately 2%. This is substantially smaller figure than that quoted by SKM as shown in Table 1, although it is reasonable to expect this for a small channel when comparing to system wide data.

Note that the loss was highest for the initial filling period, when there was no demand and fluctuated between 0 and 20 ML/day with an average of 9.1 ML/day over the period of the season when orders were being delivered.

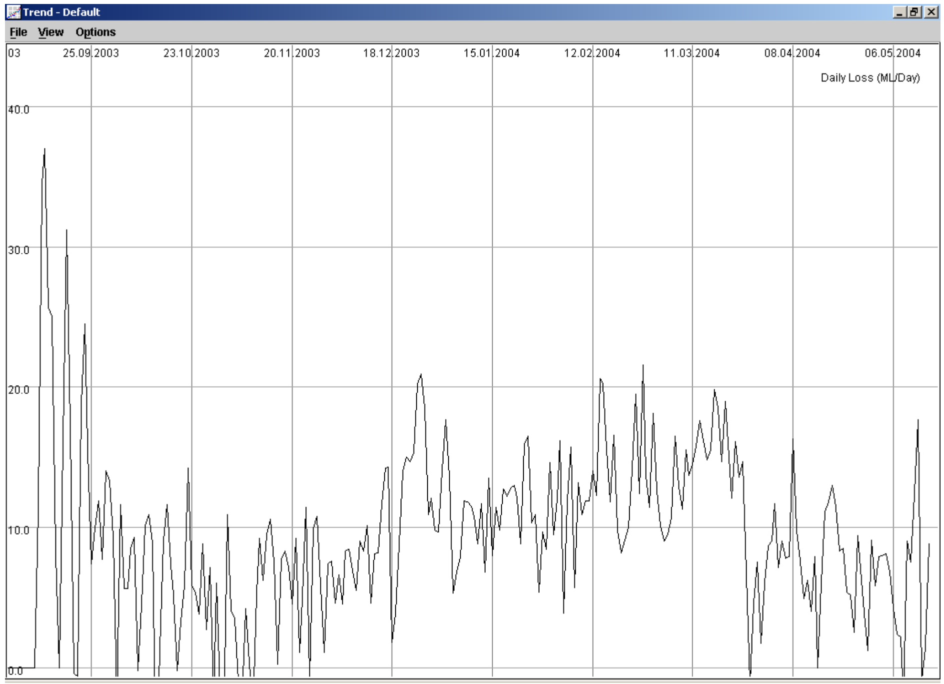

Figure 1. Plot of Inflow - Demand (loss) - CG2 System 2003/2004 Season.

Figure 2 shows the demand (represented as a step function plot) and inflow (represented as a continuous line generally above the demand) during a major shutdown event.

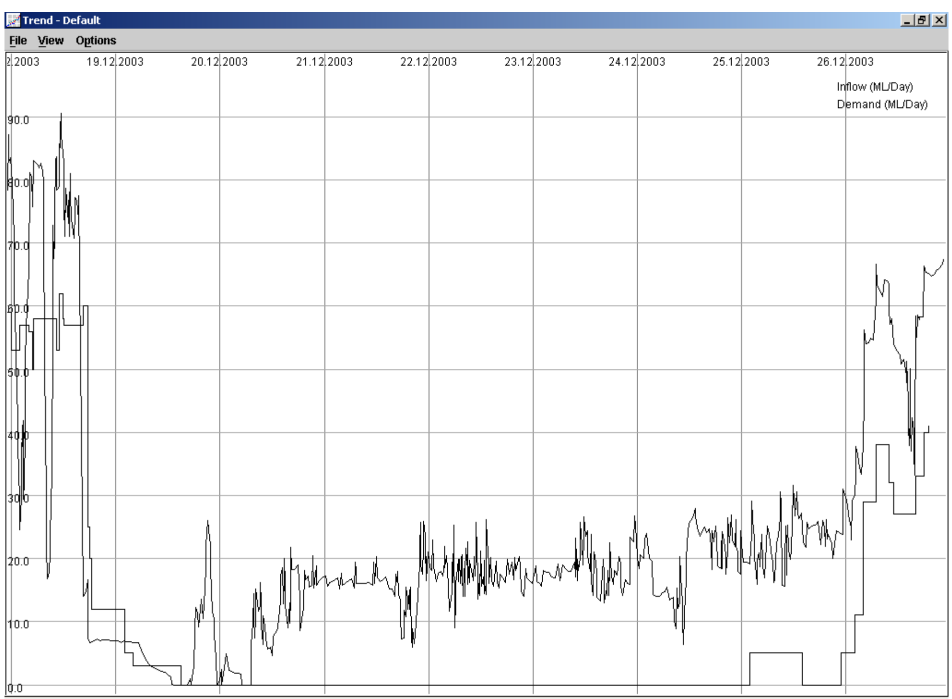

Figure 2. Plot of Inflow and demand – December Shutdown.

This shutdown occurred after a major rainfall event (of the order of 125 mm) on 18 December 2003. There was no demand from midway through 19 December until Boxing Day but significant inflows were required to maintain the channel system at supply level. Clearly this water was consumed by the mechanisms shown in Table 1 and a total volume of 86 ML was brought into the system over this six day period, which represents an average value of 14.3 ML/day. This event was the catalyst for increased scrutiny of losses and subsequent to this period a number of significant channel leaks were identified and repaired. The fact that the average daily loss of 9.1 ML/day for the entire season was less than this figure would imply a reduction in the leakage from the system. Of course since leakage is not directly measured we cannot assert with 100% confidence that this reduction is due entirely to leakage.

Given that TCC™ had effectively eliminated outfalls (Table 3) but system efficiency had marginally decreased, the estimates of loss shown in Table 1 must not be representative of the loss distribution for CG2. There is a strong argument that TCC™ has reduced meter error and Evaporation was one of the components that SKM had most confidence in estimating. On this basis it is concluded that Leakage, Seepage or Theft must represent a much larger proportion of the loss than reported by SKM.

END OF SEASON MEASUREMENT

In light of the mid season shutdown event and the insight gained throughout the balance of the season it was decided to continue to operate the system after the season concluded. The last order finished at 10:00 am on 16 May 2004 and the system continued to operate in TCC™ mode (i.e. system maintained water levels at set point) until 10:00 am on 28 May 2004. The system was then allowed to “drain” for 1 week before being turned on again at 10:00 am on 4 June to fill before being finally turned off on 7 June 2004.

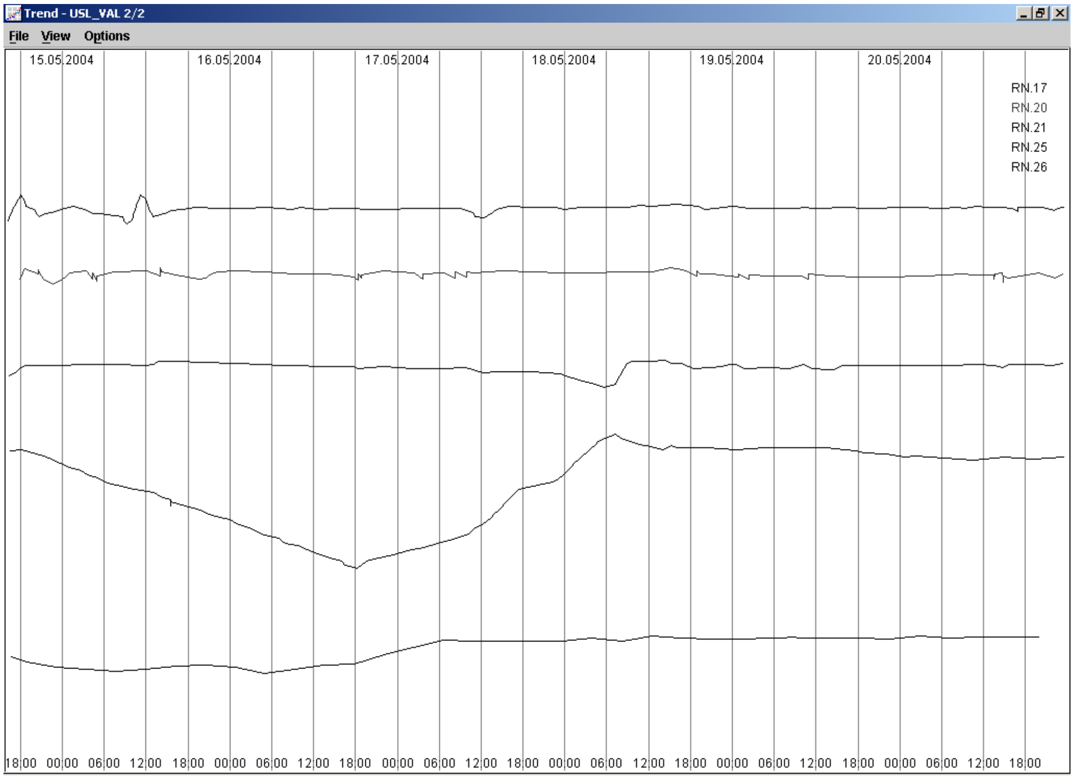

Figure 3. Water level reduction with no demand.

It was expected that the inflow to the system would reduce after the conclusion of the last order however the converse situation was observed. Figure 3 shows the rapid reduction in the water level in one pool and given that no leaks or channels breaks were reported it is concluded that some unauthorised access took place at the season end and due to the configuration of the control system at time this time it took nearly two days to replenish. The average inflow to the system over this 10 day period was 8.2 ML/day although this reduced to 7.5 ML/day over the last week.

A quantity of 37 ML was required to replenish the system after the 1 week drain period which equates to an average daily loss rate for the week of 5.3 ML/Day.

POOL LOSS ANALYSIS

At the conclusion of the irrigation season an audit of the water level and gate position instrumentation was undertaken on the “in-line” FlumeGate™ devices to verify measurement accuracy. For the period from 17 May 2004 to 28 May 2004 an analysis of the pool by pool losses showed that 49% of the losses from the entire system were contributed by four of the 38 pools in the system. 81% of the losses were contributed by 11 of the pools. If these statistics are representative of the entire system then targeted leakage recovery is an attractive water savings option.

OUTFALLS AND SAVINGS

There are two key issues to be addressed when considering the benefits of reduced outfalls

- What is the magnitude of the saving
- What is the value

Both questions have stimulated considerable discussion within the industry in recent times. In the case of the CG2 system after two seasons of operation there seems to be little debate that outfalls can be effectively eliminated. The key issue is just how accurate was the before estimate and how representative is this amount for other systems. Anecdotal evidence from Southern Rural Water in the Gippsland region of Victoria, Australia is that continuous measurement on 6 outfalls has shown previous estimates to be in error by 100%. In targeting systems for water savings manual once a day measurement can at best be used as only a guide and that ongoing continuous measurement is necessary to verify and audit the quantity of savings.

There are policy makers that consider if an outfall can be reduced and the source of water retained in storage then this is a legitimate water saving. However, some advocate that uncontrolled outfalls are consumed further down river and therefore there is no value to be gained by their reduction. Clearly this is not a black and white issue and available capacity and timing are key factors is determining the value of the overall reduction. Clearly those advocating the maintenance of outfalls are at odds with the general water saving principles and advertisements used in the major urban locations.

CONCLUSIONS

Whilst the initial drivers for the development of TCC™ were based primarily on the benefits accruing from improved control, accurate and continuous measurements of flow on an intense basis have shed new light on the distribution of losses within open channel systems. Outfalls from the CG2 channel system were effectively eliminated for the 2003/2004 irrigation season and yet the computed efficiency was marginally lower than that previously reported. It is the author's view that point source leakage is a more significant component of water loss than previously thought and this should become more apparent as more focus is placed on water recovery.

ACKNOWLEDGMENT

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COMMENCING THE MODERNIZATION PROJECT ON THE GILA GRAVITY MAIN CANAL

Wade Noble[1]

ABSTRACT

The Gila Gravity Main Canal diverts approximately 700,000 acre-feet annually from the Colorado River at Imperial Dam. The canal serves five irrigation and drainage districts, as well as a number of other contractors and domestic areas. It is federally owned and its administrative board is made up of representatives from each irrigation district. The canal currently faces three problems: sedimentation, imprecise flow measurement, and a lack of real-time monitoring capabilities. Planned responses to these problems include dredging, the installation of a Replogle flume, remote monitoring and canal automation systems, and the application of a clay sealant. This project will be funded by a grant from the Border Environment Cooperation Commission (BECC) and a challenge grant through the US Bureau of Reclamation.

THE GILA PROJECT

The Gila Project was first authorized by 48Stat.195 in 1933. The Project was reauthorized under 61Stat.628 in 1947.

The 20-mile Gila Gravity Main Canal was completed in 1943. The Canal serves Wellton-Mohawk Irrigation and Drainage District (63,000 acres), Yuma Mesa Irrigation and Drainage District (authorized to irrigate up to 20,000 acres), Yuma Irrigation District (authorized to irrigate up to 11,600 acres), North Gila Valley Irrigation and Drainage District (authorized to irrigate up to 6,587 acres), and Unit B Irrigation and Drainage District. In addition, the Canal provides water for a number of other contractors including domestic water for the City of Yuma, Far West Water Company, (a private water company) and the Marine Corps Air Station - Yuma. 2004 diversions from the Colorado River were more than 700,000 acre-feet.

The Districts

Wellton-Mohawk Irrigation and Drainage District (WMIDD): Wellton-Mohawk Irrigation and Drainage District (WMIDD) irrigates approximately 63,000 acres and provides domestic water of up to 12,000 acre-feet with an annual consumptive use of 278,000 acre-feet. WMIDD is located east of Yuma and extends west from the Dome Narrows to the Mohawk Pass along the Gila River.

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The Gila River is an ephemeral stream. Water from the Gila Gravity Main Canal is supplied to the District by means of three pumping plants. The District is authorized to provide 12,000 acre-feet of domestic water. The principal domestic water user supplied at this time is the Town of Wellton. (The Town of Wellton was named from being a “well town” for steam-powered railroad engines.) Major projects in the area involving water are a proposed gas-fired power plant – the Wellton-Mohawk Generating Facility and an oil refinery proposed by Arizona Clean Fuels.

WMIDD’s contract with the Secretary of Interior, for a permanent water supply of 278,000 acre-feet, includes credits for returns flows to the Colorado River. Most of the return flows from the District come from a drainage well system of over 90 wells. The drainage is conveyed from the District in the Main Outlet Drain (MOD) to the Yuma Desalt Plant. The drainage bypasses the Yuma Desalt Plant into the Main Outlet Drain extension (MODE) and is conveyed to the Cienega de Santa Clara, a marsh below Mexicali, Mexico. Public Law 93-320 authorized the construction of the Yuma Desalt Plant to treat Wellton-Mohawk drainage. There is substantial controversy over the operation of the Yuma Desalt Plant. If operated, flows to the Santa Clara Slough would be reduced.

WMIDD is also the Wellton-Mohawk Division of the Gila Project. The other Division is the Yuma Mesa Division. WMIDD plays a major role in winter produce for the nation, including lettuce, broccoli and other similar vegetables.

Yuma Mesa Irrigation and Drainage District (YMIDD): Yuma Mesa Irrigation and Drainage District (YMIDD) is the largest of three irrigation districts of the Yuma Mesa Division of the Gila Project. YMIDD is authorized to irrigate up to 20,000 acres under its contract with the Secretary of Interior. The District is located on the Yuma Mesa where the soils are sandy. Water is lifted to the District from the Gila Gravity Main Canal through the Yuma Mesa Pumping Plant. The primary crops grown are alfalfa and some citrus. The sandy soils are not conducive to growing the produce that is otherwise successful in the area.

The District shares an undivided 250,000 acre-feet consumptive use entitlement with the Yuma Irrigation District and North Gila Valley Irrigation and Drainage District.

Yuma Irrigation District (YID): Yuma Irrigation District (YID) is farmed using wells along the Gila River. When the Gila Gravity Main Canal was built, Yuma Irrigation District became the South Gila unit of the Yuma Project.

YID is technically advanced. Fields are laser leveled, ditches are lined and turnouts are metered. YID provides water for a substantial portion of the Yuma area winter produce crop. A groundwater mound under the Yuma mesa projects into YID. The groundwater mound requires drainage pumping in order to maintain groundwater levels low enough to permit farming.

North Gila Valley Irrigation and Drainage District (NGIDD): North Gila Valley Irrigation and Drainage District (NGIDD) is one of the earliest diverters of Colorado River water. It has some Present Perfected Rights (PPR) under the decree in *Arizona vs. California*. It is the smallest of the irrigation districts in the Gila Project with authority to irrigate up to 6,587 acres on a consumptive use contract with some 4,000 acres of Present Perfected Rights. North Gila is perhaps the converse of the Yuma Irrigation District. Because of its proximity to the Colorado River and only minor problems with groundwater, the District does not have lined canals. Drainage from the District does not include drainage wells.

The Administrative Board

The Administrative Board is comprised of representatives from each of the irrigation districts. The Gila Gravity Main Canal is the property of the Federal Government.

The Canal

The diversion point of the Canal is Imperial Dam on the Colorado River between the states of Arizona and California. On the west side of the river the diversion is for the Yuma Project, comprised of the Yuma County Water Users' Association, the Bard Irrigation District, and the Imperial Irrigation District.

The Gila Project annually diverts approximately 700,000 acre-feet. The Canal is unlined and 20.5 miles long. More than half of the water diverted is delivered to WMIDD.

PROBLEMS

Since 1943, sediment load from the Colorado River has deposited between three and five feet of sediment on the bottom of the Canal. With an average designed depth of 13.5 feet and an average designed width of 22 feet, the impact on canal operations of the sediment deposit is substantial. The first step in modernizing the Canal is sediment removal.

A second problem addressed by the modernization project is the lack of precise water flow measurement. Improved water flow measurement is a priority for conservation. Improved water flow measurement through construction of a water measurement structure will assist not only in conserving water but in managing and operating the Canal.
A third problem is the lack of real-time capability to monitor the operations of the Canal. The Administrative Board plans to install remote monitoring equipment in order to more efficiently operate and manage the Canal.

One of the near future goals of the Administrative Board is automated canal operation. The remote monitoring equipment will assist in eventually establishing a system for automated operation of the Canal. Additional equipment will be installed for automated operation.

A final problem on the Canal is seepage. There are certain areas in the Canal where seepage occurs. A clay lining of the Canal has been proposed to alleviate this problem.

Solutions to the Problems

1. Sediment removal is planned to be accomplished by dredging.
2. The water measurement structure proposed is a Replogle Flume.
3. Remote monitoring and canal automation systems are proposed in a thick book, as usual, from the Cal Poly Irrigation Training and Research Center, detailing the equipment and systems necessary to bring the plans to fruition.
4. The Canal sealing will be with the use of a Bentonite-like clay.

FINANCING THE CANAL MODERNIZATION PROJECT

The initial cost estimate of the Project was over $1.7 million. The Border Environment Cooperation Commission (BECC) was offering, at the time, grant funds in the amount of $40 million to the United States side of the Mexican border for irrigation and other water projects. The total amount available for projects along the Mexican border was $80 million. The $40 million going to the Mexican side of the border did not require matching funds. The $40 million going to the U.S. side of the border required 50 percent matching funds.

An application to BECC was submitted identifying the five components of the Project:

1. Canal Sediment Removal,
2. Canal Efficiency Enhancement,
3. Water Measurement Improvement,
4. Remote Control and
5. Canal Sealing.

The estimated cost for the Project was $1,756,255.

A Steering Committee and Technical Work Group were formed and required public meetings held. An Environmental Assessment for NEPA compliance was prepared. A Categorical Exclusion was issued. Correspondence from water districts was submitted in support of the Project. Upon submittal of the requested documentation and public participation meetings, a Comprehensive Final Public

Participation Report was sent to BECC.

The Project was approved by BECC for $827,500. North American Development Bank (NADBank) is preparing the grant contract.

Western Water Initiative Challenge Grant Program

The Department of the Interior, Bureau of Reclamation Challenge Grant Program (Challenge Grant) provided an opportunity for funding which could be used as part of the Board's 50 percent matching funds obligation.

The Board applied for and received a Challenge Grant in the amount of $227,250.

Component Costs and Work Schedules

The following tables show the anticipated costs for the Project Components and the expected timelines for completion. Work on the water measurement structure has commenced. The "dirt work" is completed and concrete work will begin shortly.

Table 1. Budget

	Canal Sealing	Canal Efficiency Enhancem't	Water Measurem't Improvem't	Remote Control	Canal Sediment Removal	Total
SUMMARY BUDGET						
Project Budgeted Costs	147,000	815,000*	312,500	included	850,000	2,124,500
Design Costs Admin	8,000	46,500*	5,000	included	75,255	134,755
TOTAL	*155,000*	*861,500*	*317,500*		*925,255*	*2,259,255*
DETAIL BUDGET						
Equipment costs	15,000	315,000	60,000	included	317,037	707,037
Other Equipment & Operating costs					155,664	155,664
Maintenance & Repairs					55,000	55,000
Fuel & Supplies					65,800	65,800
Engineering & Design					49,854	49,854
USBR Design		46,500*	5,000	included		51,500
Labor Costs	65,000	110,000	155,000	32,500	222,075	584,575
Contract Admin & Supervision		23,000	35,000	7,500	59,825	125,325
USBR Construction	15,000	155,000	62,500			232,500
Indirect Costs	60,000	172,000*		included		232,000
TOTAL	*155,000*	*821,500*	*317,500*	*40,000*	*925,255*	*2,259,255*

Table 1. Budget (cont.)

FUNDING	Canal Sealing	Canal Efficiency Enhancem't	Water Measurem't Improvem't	Remote Control	Canal Sediment Removal	Total
NAD Bank Funds	97,500	149,500	214,713	32,500	317,037	827,500
Water 2025 Challenge Grant	15,000	155,000*	62,500	included		232,500
GGMCAB Funds	15,000	23,000	40,287	7,500	120,800	214,187
GGMCAB In Kind	27,500	494,000			487,418	487,418
TOTAL FUNDING	*155,00 0*	*821,500*	*317,500*	*40,000*	*925,255*	*2,259,255*

Table 2. Sediment Removal Costs

Operating Costs	65,800
Repairs	55,000
Labor Costs	222,075
Additional Equipment	155,664
Total	*498,539*
Engineering	49,854
Supervision	59,825
Total with Engineering and Supervision	*608,218*
Dredge Cost	317,037
Total with Dredge	***925,255***

OBTAINING GAINS IN EFFICIENCY WHEN WATER IS FREE

Ross E. Hagan[1]
Jochen Regner[2]

ABSTRACT

Improvements in on-farm water use efficiencies in the Jordan Valley have been demonstrated by a USAID project. A GTZ project is establishing water users' organizations in the Jordan Valley that demonstrate increased water distribution equity. With improved distribution equity, the demonstrated gains in efficiency should increase. Water delivery service fees or a "water price" played no role in the average 20% reduction in water use and average 5% increase in production or yield. Also, in Jordan at the time of the project neither the responsible water distribution agency nor the Ministry of Agriculture Extension Service offered assistance to farmers in on-farm water management. The key for unlocking the potential for water conservation was knowledge transfer to the farmer. On a few selected farms the benefits to be gained from improved management were demonstrated, extension information on irrigation system management was provided to farmers, and a resource of trained irrigation specialists from the Jordan Valley Authority was available to farmers.

INTRODUCTION

Jordan is one of the most water-scarce countries in the world, with a projected water deficit of 260 MCM/year in the year 2005. According to the Ministry of Water & Irrigation Wastewater Policy, "*Wastewater is a perennial water source and shall form an integral part of renewable water resources and the national water budget*." As urban and industrial uses increase, water used for agriculture will continue to transition to the lower quality wastewater, bringing changes in cropping patterns. Municipal and industrial demand consumes about 30% of the water with agriculture taking the remainder. The Highlands and the Jordan Rift Valley are the two areas of irrigated agriculture in Jordan. About 84,000 acres (33,000 hectares) or 40% of Jordan's irrigated area is in the Jordan Rift Valley.

Long before any government was involved, farmers developed traditional systems for sharing water sources, which are still in place in areas of the Jordan Rift Valley – including the West Bank. In large part these systems became redundant as the government took over management of irrigation in Jordan's East Bank in the 1950s and 1960s. The Jordan Valley Authority (JVA) of the Ministry of

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Water and Irrigation emerged from preceding organizations in 1977 with a mandate for all socio-economic development in the Valley.

Today JVA is responsible for distributing all water on the East Bank. The water storage, conveyance and distribution system is technically sound with an overall efficiency of about 80%. In normal years farms receive water two to three times a week at times specified by JVA. Officially, farmers have no control over the time or amount of water received. Nevertheless, some farmers influence JVA staff to their benefit. Farmers have a right of water usage but do not own rights to water. Water is allocated seasonally based on the area planted to crop categories. The allocation of irrigation water is attributed to the agricultural area; it is transferred with the land and cannot be separated.

US delegations visiting the Middle East often state that problems of low water use efficiencies and shortages of funds for operation and maintenance of water delivery services can be remedied with a higher "price for water", an inappropriate choice of words that often causes irritation and difficulties in moving the discussion forward. Nevertheless, encouraging efficient water use practices without increasing low fees for delivery is a difficult problem for water managers.

With low delivery service fees, improvements in the equity of water allocation and technical assistance in on-farm water management can among others be effective tools for encouraging efficient management of water resources. With equitable water allocation, managers can promote water conservation and increase economic returns from each cubic meter of the water resource. Users' active participation is essential to improve water distribution equity and for water allocation procedures to succeed. To obtain support from government decision makers, it is often necessary to raise their awareness of the economic value of water resources. Also, it is sometimes required to educate governmental leaders and employees that users are capable of managing water resources. Prerequisites for active users' participation include a legal framework permitting users participation in decision making, two-way information flow between irrigation management professionals and users, and amicable relations between all parties.

USERS ORGANIZATIONS

With government takeover of water distribution and allocation, farmers learned they needed to cooperate with government authorities. The JVA took from the traditional groups all the responsibility and trouble of water distribution. If a farmer obtained bad service, he could approach the Authority for improvements much easier than starting quarrels with neighbors. Farmers no longer need to cooperate with each other and subsequently exert efforts to get more water, sometimes using illegal methods. They see their neighbor as a competing rival who appropriates more than his official share of water using political connections, money, and transgressions. Law enforcement has problems with influential farmer clans who have the political clout to lobby for a disproportionate share of water. It is equally difficult if transgressions become every farmer's daily routine. These actions occur at the expense of the community at large, as a commonly shared resource is unevenly exploited.

The JVA provides water without prior consultation with farmers, and with no consideration of on-farm demand. This results in conflicts among farmers and between farmers and JVA leading to waste, corruption, and physical destruction of distribution lines and equipment. Years of constant growth in irrigated land, coupled with a series of dry years, have pushed the system to the limit. The support and active involvement of farmers is needed to ensure sustainable changes and improvement in irrigation management in the Jordan Valley.

Key water distribution challenges facing farmers can be summarized as: (1) unreliable water supply, both in quantity and quality; (2) pressure to adopt drip without receiving extension support, and without an on-demand water supply; (3) poor JVA management and lack of JVA interest in farmers' needs; (4) lack of trust and confidence between JVA and farmers; (5) illegal transactions to secure scarce supply that erodes trust among the farmers; and (6) the growing gap between water demand and availability due to (i) sequence of dry years (ii) raised domestic and industrial demand (iii) intensified cropping practices

A sustainable improvement of water distribution services is only possible through an active farmers' role. Indeed, Farmers are convinced they have to actively participate for a more efficient water supply. Only farmers can protect the system from transgressions by using social pressure to monitor and reduce theft and corruption. Their cooperation in the final distributaries utilizes local know-how and decreases water distribution costs and improves service. Communities of farmers must be organized on common interest and preferably as legal bodies. A valuable source of organizational experience lies with the traditional systems of water rights and irrigation management that were practiced in the Jordan Valley.

The Process for Establishing Water User Organizations

The Water Resource Management in Irrigated Agriculture project (WMIA) was established by GTZ to organize farmers as a service organization. The length of time required to organize farmers as a user group varies considerably. The process must be allowed sufficient time and it has taken as little as one month and as long one year. Any new idea will be resisted at the beginning, especially by those who stand to lose from improved equity and transparency in water distribution. Even those who expect improvement fear change – any form of social change in a small, close-knit community can be difficult. Farmers need to overcome a history of bad experience with individuals misusing systems for their individual profit. The JVA had to learn that they can only improve delivery efficiency by sharing responsibility for operation and maintenance with farmers. The approach taken requires time, patience, and the ability to listen closely to farmer and JVA needs, fears, and wishes for the future.

Support was provided for improving irrigation services at the local level. A series of formal workshops for farmers and JVA provided an opportunity to disseminate information about established Jordan Valley water user groups, discuss their applicability to new areas, and increase rapport and understanding. Training workshops for staff and JVA focused on communication and participatory community development skills. Farmers and JVA were directly involved in participatory planning workshops for Phase II, which helped to improve their communication and management skills. Addressing farmers fear for the sustainability of the organizations and the inherent legal issues for formalization of water user participation was necessary.

Beyond support for developing water user associations, a range of broader activities focused on improving communication and understanding between farmers, the JVA, and WMIA. Since local governors have authority to communicate both officially and unofficially with all those involved in Jordan Valley activities they were brought into the process. These events reinforced participant skills in communication and planning, and their understanding of the opportunities and constraints in Jordan Valley irrigated agriculture. They also reinforced relationships and strengthened communication among farmers themselves and between the farmers and JVA staff at all levels.

The WMIA focused on establishing water user groups. As a part of this activity, WMIA also formulated operating rules and procedures with agreements formalizing the rights and duties of the water user organization and issuance of decrees from the JVA Secretary General to the relevant Directorates for each new active group, listing group members and foci of group-JVA cooperation.

The nine water user groups established to date have taken three organizational forms: Committees (6), Water Councils (2), and Cooperative (1). Cooperatives are the only fully legally recognized form of farmer organization, having legal affiliation with the Jordan Cooperative Corporation (JCC). Water Councils and Committees are as yet not legally recognized, although they do have an official letter of recognition from the JVA Secretary General.

Most **Committees** are established in the Southern Ghors. Committees are based on traditional forms of farmer management that existed before the JVA, and still exist in other parts of Jordan. They are formed by representatives chosen by the farmers in a general assembly after several informal meetings. Farmers are hesitant to pass on power to a small number of delegates, and in many areas prefer this informal system before committing themselves to anything more formal such as a cooperative. Farmers monitor representatives carefully. If they find an underperforming representative, they appoint another farmer in his place.

The committee meets as a group approximately twice a month with the Director of the relevant JVA Directorate, and coordinates water deliveries on a daily basis with their local JVA counterpart and one or several WMIA Project Advisors. During their meetings with the Director, minutes are taken which outline any agreements made. Initially, the WMIA representatives take minutes, but as farmers gain experience, a farmer representative takes on this and other management tasks.

The committee is the weakest of the organizations, but it does serve as a basis for more formal structures. Farmers are able to test the commitment of their fellow farmers, and of the JVA, and to experiment with working together. In several areas, committees have opened discussions with WMIA on their desire to form Cooperatives or another legally recognized form of organization.

Water Councils were established in the direst situation in terms of distribution management, infrastructure breakdown, and transgressions. The desperation of farmers in these areas provided an opportunity for successful implementation. Water Councils are more formal than committees, with the concept also based on a traditionally utilized mechanism for conflict solving. Each Council has 15 farmer members chosen through informal appointment by the concerned farmers – not through a formal election process. The Water Council is presided over by a *Mutasarif* (sub-governor). He represents the Ministry of Interior, i.e. police force, at the Sub-Governorates level, the lowest administrative division.

Each council is divided into two groups, one focusing on operation and the other on maintenance. The Council, on their behalf of its members, helps JVA define and resolve problems in water distribution and convenes on penalties for cases of transgressions. The Mutasarif provides executive power through his legal authority to hold transgressors accountable for their actions – both for illegal water use from JVA irrigation lines, and for illegal wells. Relevant high ranking JVA staff attend meetings and offer assistance and advice when necessary. The Water Council is not involved in payments or discussions of water rights.

As mentioned**, Cooperatives** are the only legally recognized form of farmers' organization. The statutes of the cooperative detail the objectives and rules chosen by the members. Frequent meetings between the cooperative and JVA and a rigorous daily control of regular water distribution helped improve water management in the area. Illegal water use has greatly reduced. Indicators of success include the self-operation of farm units, monitoring of water distribution, and a reduction in illegal water use to less than 10% of the former level.

Continual monitoring, evaluation and re-evaluation are the keys to project success. If farmers lose interest, a reassessment is conducted. In some cases, the reassessment brings to light issues that can be immediately tackled. In others, it is considered best to temporarily suspend activities and wait for the farmers themselves to request further assistance.

Results/Lessons Learned

Farmers and JVA are particularly receptive to forming organized groups for irrigation management in areas having high levels of illegal water use.

Farmers and JVA officials working together can improve delivery efficiency and reduce transgressions to below 10% in most areas. Overcoming technical flaws in the water distribution network and adapting the water allocation cycle to actual farm water demands can reliably delivers water at stable high pressures to the farm gate. Farmers will not have to maximize soil store of water out of fear they may miss the next water delivery. Soil storage usually results in over irrigation causing damage to the crop and decreasing yields. With improved service, farmers use the available water to intensify cultivation and increase farm incomes.

By November 2003, nine water user groups covered 25% of the irrigated area in the Jordan Valley. These groups represent 2,530 farmers, about 27% of all farmers in the Valley. An additional eight water user groups were well under way in other areas, which will bring the total irrigable area in the Valley covered by water user groups to 36%, serving 34% of all Jordan Valley farmers.

Farmers have found that speaking as a group rather than as individuals is a useful tool for providing demand oriented water distribution services and ensure transparency, and equity. JVA staff realize that working with a group representative spares them from dealing with individual farmers, each with their own agenda. This streamlined communication makes JVA staff more effective in operation and maintenance of the water distribution system.

In all organizational forms, farmers have taken on greater management responsibilities as they get used to working together. In areas with established groups, the farmers themselves initiate meetings, set agendas, keep meeting minutes, provide reports, and manage communication with JVA.

Until recently, there were complaints from farmers about weak communication with JVA. This was solved with an innovation that improves communication and gives farmers a stronger feeling of project "ownership". The JVA agreed to allow water user groups to choose JVA staff members with whom to work. This gives the group an opportunity to choose someone who is supportive of the concept of farmer participation. If they are not content with the official, they can discuss issues with the WMIA project staff and JVA and chose a new JVA counterpart.

JVA has seen: farmer participation improving its organizational efficiency, farmer organizations helping to reduce needed personnel (for activities such as operating farm gates and reporting technical or operational flaws), reductions in illegal water use that reduce the need for emergency plans to supply farmers who did not receive water; and reductions in repair and maintenance and thereby an increased satisfaction with JVA services. Farmers who receive reliably water see less need for transgressions. They survey together with JVA the regular water distribution and provide a physical protection of the infrastructure. The dramatically reduced number of transgressions removes the need for intensive intervention by JVA. Although specific data has not been gathered, there appears to be higher efficiency of water distribution measurable by an improved, constantly pressurized water system, implying no transgressions/losses. JVA also has had a significant decrease in penalties charged for transgressions

IRRIGATION ADVISORY SERVICE PROGRAM

When construction of the King Abdullah Canal (KAC) began in the 1960's one unit of the development organization was dedicated to assisting farmers make best use of the water being provided. Services included assistance in all aspects of irrigation water use and in crop selection and production. As the pace of development in the Valley accelerated in the 1970's, this unit was disbanded and members transferred to construction-oriented divisions. In subsequent years the Jordan Valley Authority (JVA) offered no assistance to farmers and operated as if its responsibility stopped at the farm gate turnout. The Ministry of Agriculture had no water specialists and claimed it too has no responsibility for on-farm water use. In retrospect, JVA's dissolution of the unit was a mistake that has proven costly to Valley agriculture.

The Jordan Valley has been in recent years in perpetual drought, irrigation water supplies are insufficient to meet all agricultural demands. In its effort to increase irrigation efficiencies, the JVA has converted the delivery system off the KAC to pressurized pipelines and promoted the use of modern irrigation technology in the farm unit. Each farm unit has a single point delivery with a gate valve, flow restrictor, flow meter, and pressure regulator. In 1993 about 40% of the 24,400 acres (9,600 hectares) of the central Jordan Valley Directorate office was irrigated using micro irrigation; this percentage had increased to 52% by 1996 and 100% by 2003. JVA personnel report that all land under irrigation in the Jordan Valley and Southern Ghors now use micro irrigation.

In the 1993-94 crop season, just before the start of a new program on water management in the central Jordan Valley, a baseline survey was conducted. The baseline survey found the annual average management efficiencies for high technology trickle irrigation systems were lower than those for low technology surface irrigation systems, 64% and 76%, respectively. The most sophisticated production systems, plastic houses using trickle irrigation under plastic mulch, had the lowest efficiency numbers, 44%. In 1998 farmers that participated in the survey were revisited. Efficiency levels had fallen in the intervening years to an average of 42% for plastic houses and 46% for open field trickle systems. A study of on-farm irrigation efficiencies in the Highlands gave similar results.

The low value for management efficiency in plastic houses was investigated in more depth. It was concluded that water losses in plastic houses were due to a lack of knowledge. Farmers knew neither how much water to apply nor the crop water requirement. Farmers did not realize that irrigation requirements under plastic houses are about 35% less than those under open field conditions. Field observations and site visits to growers using plastic houses showed that the soil moisture content was always near saturation. In many cases, runoff was observed at the end of the plastic houses and in some cases algae growth was observed.

Studies concluded that poor design of on-farm drip irrigation networks, improper maintenance and use of screen and media filters, no control of algae and organic slimes, and poor operation and maintenance practices contribute to low efficiency. About 75% of all farms experienced significant emitter plugging beginning with the second year of lateral line use. The data clearly showed irrigated agriculture in the Jordan Valley was far from reaping the water conservation benefits possible with a pressurized pipeline delivery system and drip irrigation application.

Although a high percentage of all micro irrigation equipment used in Jordan is manufactured locally, most of the components are manufactured according to dimensions used in other countries. Basic micro irrigation system designs also are imported from countries where fields are significantly larger than is typical - in Jordan. Consequently, many components installed in local systems are oversized for the short row lengths typical to the Jordan Valley. Though more costly to install, an oversized system is more forgiving of mistakes and will function efficiently even with some major installation flaws. A study of water application uniformity for newly installed trickle irrigation systems in the Jordan Valley found the systems "good" with EU values above 85%, some were in the "excellent" range. With proper management, water-use efficiencies can be high.

Farmers in the Jordan Valley can be classified into three groups: 20% have full technical knowledge and experience with irrigation and agriculture, 30% have some knowledge and experience with irrigation and agriculture, and 50% have none; but all want to learn more but don't where to go to get the right information. About eighty percent of Jordan's farmers need assistance.

Pilot Implementation

To promote the goal of higher efficiencies in water use, in 1997 with support from USAID the JVA created (one could say recreated) a pilot Irrigation Advisory Service (IAS) division with three field staff to assist farmers in these activities. In working with farmers IAS staff learned the value of being flexible to best serve the client. Some farmers change water applications by reducing the duration of irrigation, others change irrigation frequencies but the duration of applications is fixed and still others accept changes in both frequency and duration of water applications. To promote improved management practices the IAS team spoke to meetings of MOA Extension Agents, farmer organizations, and gatherings of farmers on crop water demands and irrigation scheduling.

Results from demonstration farms under the IAS program in the Jordan Valley have shown that water consumption at the farm level can be reduced by an average of 20% with an average increase in production of 5%. The most striking case was a farmer growing eggplant that reduced his water use by 47% and increased production by 22%. It is apparent that farmers were over-irrigating to the extent they were saturating the soil, in effect drowning their plants. Farms that received water reliably obtained higher production increases and greater water savings than did their neighbors with greater variability in water deliveries.

There are empirical measures of IAS program success. Farmers request that they not be delivered water on their normal rotation. The IAS has requests for assistance exceeding their capacity to fulfill. Farms whereon demonstrations are conducted quickly adopt the demonstration irrigation program. Neighbor farmers adopt the new schedules. These practices made it impossible to collect data for a statistically valid analysis of results; in no case was a "check" site carried through the season. This is why average values are used to report success.

At the end of its pilot period in 2000 the IAS ended. The concepts, extension literature, and training materials developed are being used by JVA in a new Modern Farms program, which is expanding in the Jordan Valley and the Highlands. Farmers who participated in the pilot program continue to use the knowledge gained and the improved practices are slowly spreading in the Valley.

Lessons Learned

At the farm level, a decrease in water consumption reduces the farmer’s costs. This has larger implications in the uplands where farmers incur higher costs for pumped water than farmers in the Jordan Valley. Upland farmers pay \$0.09 to \$0.21 /m^3, while in the Jordan Valley farmers pay an average fee of \$0.03 /m^3, a price that has changed little over the last decade. Water is one of several inputs needed for crop production and its use is evaluated on its cost versus the perceived benefit received. Currently, water delivery fees offer no economic incentive for farmers to conserve water. In the Jordan Valley water delivery fees are 0.5% to 2% of total input costs. Studies in Egypt show that for the cost of water to be a driver in water conservation, delivery fees would have to equal about 25% of net farm income in order to achieve a 15% decrease in water use.

In Jordan the two key levels of focus for irrigation water conservation are on-farm water distribution system management and maintenance practices and off-farm operation and management of the delivery system. On-farm offers the most significant savings in water use. However, it is also the place where it will be most difficult to achieve best use of water. The delivery of water to the farm offers less direct water savings but potentially large indirect savings. Most savings will come from changes in operation and management (software), which enables customers to optimize their use of water resources (indirect savings), and few from changes in physical infrastructure (direct savings).

From the time of the studies and pilot IAS program to the present, Jordanian small farmers, the 80% who want to know more, have been hampered by a lack of extension literature and assistance in the proper operation and maintenance of micro irrigation, fertigation practices, crop water requirements, and most other aspects of on-farm water management. Farmers also need an irrigation water delivery schedule compatible with the on-farm micro irrigation system, a change from the current rigid delivery schedule to a flexible delivery schedule, perhaps a limited rate demand schedule. Cleaning the water in the delivery system of physical contaminants could allow farmers to do away with pools, currently used to store water between deliveries and to settle out contaminants, and use the pressure in the JVA delivery pipeline.

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[3] WQIC = Water Quality Improvement and Conservation

A QUALITATIVE APPROACH TO STUDY WATER MARKETS IN PAKISTAN

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ABSTRACT

The government of Pakistan has recently introduced reforms to reduce the financial deficit of the country's irrigation sector. Reforms are expected to grant autonomy to irrigation agencies and transfer part of the management responsibilities to water users. Water markets are already functioning in the country, but are limited to tube-well or sub-surface water in two provinces only. Although the development of water markets is described as being efficient, little is known regarding the potential feasibility for and impact of such markets on small landholders. The government's public investment in large irrigation projects has already widened the gap between large and small landholders in terms of revenues and financial assets. It is feared that reforms will further allow for arrival of powerful landholders and businessmen from other regions that will steadily displace the small local agricultural producers.

Several studies have been conducted from a quantitative perspective, but no qualitative study has been conducted that may provide insight into the equity issues in regard to water markets. Therefore, a qualitative study is proposed to investigate the affects of water markets on small landholders in Pakistan and the markets' role in the distribution of the benefits of water resources among landholders across all categories.

INTRODUCTION

Governments of Pakistan's proposed reforms are mainly aimed at reducing the financial deficit of the country's irrigation sector. Reforms are further expected to grant greater autonomy to irrigation agencies and transfer part of the management responsibilities to water users by establishing water users associations (WUAs) and Water Area Boards (WABs).

Pakistan's neo-liberal economic reforms introduced during the early 1990's sought change in the water sector by establishing a privatized water rights system, i.e., a water market. In other parts of the world water markets are characterized as efficient and successful. Gazmuri (1992) claims that the water policy applied in Chile, resulting from the adoption of the neo-liberal economic model during the early 1980, has fostered efficient agricultural use of water mostly because of

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adequate pricing and uncoupled transferability of water and land. Nevertheless, studies like Gazmuri's have focused merely on its efficiency, while they have neglected the issues such as equity in water distribution.

Informal water markets are already functioning in Pakistan, but are limited. Farmers adapt their weekly roster of canal water turns, exchange partial and full turns, and sometimes sell or purchase their turns informally. However, there is no formal mechanism to facilitate such activities. Farmers also participate actively in tube-well water transactions. These transactions allow farmers to more closely match the water supply to crop water requirements and to improve water use efficiency.

Under specific conditions of canal water supply with a high degree of variability, high seepage losses, and poor quality groundwater, farmers participate actively in the sale and purchase of canal water; which is of course informal and some times considered as illegal. In some cases, all farmers of a given watercourse command area may sell or purchase canal water turns for a certain period of time (week or ten days) or even for a season. Tube-well water markets are common in Sindh and Punjab provinces, whereas in two other provinces tube-well markets are not well established because of the poor quality and quantity of the ground water.

The aim of the proposed study is to conduct a qualitative enquiry into the effects of water markets on small landholders in Pakistan and the markets' role in distribution of benefits of water resources among landholders across all categories. To understand the impact of water markets on small landholders, the study shall make use of qualitative methods. Expected results will contribute to formulizing government policies on water resources and agricultural development, and guidelines and recommendations to decision-makers for improving public policy on irrigation water systems[2], especially water policy that is sensitive to the needs of small landholders. Key activities include archival research, in-depth interviews and application of questionnaires, and dissemination of results.

Problem

In the given socio-political situation and absence of strong public institutions in Pakistan, specific changes in the management of irrigation systems, i.e. a water market *per se* is viewed with a suspicious eye. Many fear that reforms will allow

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[2] The modern irrigated agriculture system is understood here as an array of instruments, e.g., water markets, water pricing, public investment in irrigation infrastructure (reservoirs and the water distribution system), direct subsidies to farmers to build farm-level infrastructure and purchase of irrigation technology, technology transfer schemes, water rights tenure, as well as the physical network of dams and canals.

powerful businessmen from other regions to steadily displace the small and medium-sized local agricultural producers. Despite the existence of public policies and State subsidies to improve production conditions of existing agricultural stakeholders, differential access to these resources is observed and large-scale producers largely capture benefits. Consequently, small and medium-sized producers are removed from agriculture.

The State has traditionally supported the distribution of these resources, but most of the benefit is reaped by those who can invest in the subsurface waters. Because of the high costs associated to drilling and well construction, most of the local small landholders are marginalized and their access to the resource has been potentially limited. The proposed modern irrigated agriculture system that pertains to water markets and water pricing might further preclude the smallholder sector of the rural dwellers from enjoying the benefits of long-term public investments in the water sector.

Gazmuri et al. (1994) reported that some of the research considers water markets efficient as they allocate the resources to higher value activities[3]. According to them there is an undeniable economic improvement measurable through the increase of agricultural annual revenues, private investment, and manual labor demand. Nonetheless, efficient water markets and decreasing poverty indexes do not match in the (Chilean) region as there are significant proportions of rural dwellers in the area that have not yet been able to benefit from the market-oriented economy and their access to water is restricted and unclear. Hence, the existence of a water market, while assuring higher economic efficiencies in producing agricultural products, does not address the issue of poverty alleviation (ECLAC 1995, Dourojeanni and Jouravlev, 2001).

Though little literature on this subject is available on Pakistan on which an argument maybe based, it is assumed that imperfections in water markets and the government's subsidy programs will cause further deterioration of the rural livelihoods[4]. In Pakistan, although water management system is largely State owned and funded, and a water market does not exist to trade surface water legally, the major benefits of public investment are directed to the most powerful

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[3] Studies have largely focused on productivity factor, but have failed to address the impact of irrigation system and its implications on social and economic relationship structuring in irrigated zone of arid regions. Researchers have extensively written on the subject in the context of South and Central America.

[4] The governments of Pakistan's previous record-investment of multi-million dollars on dams and other water systems have not contributed to the reduction of rural poverty due to inequitable distribution of the resources and the benefits.

and large producers, while the local rural population is excluded from these benefits.

Significance

Although water markets have been described as efficient under diverse socio-economic and hydrological conditions in other countries such as the United-States, Chile, India, and Australia, little is known regarding the potential feasibility and impact of such markets on small landholders in any of these situations. In Pakistan several studies along technical, institutional, economic and environmental impacts have been conducted. But, most of these studies are quantitative in nature and there is no information available that may give us insight into the equity issues in regard to water markets.

Generally, qualitative research can be characterized as an attempt to obtain an in-depth understanding of the meanings and 'definitions of the situation' presented by informants, rather than the production of a quantitative measurement of their characteristics or behavior. For qualitative researchers the subjective beliefs of the people being studied have explanatory primacy over the theoretical knowledge of the researcher. According to Jorgensen (1989) the researcher may have a theoretical interest in being there, but concepts and their relevance to the subject of study are important. Therefore, concepts used in qualitative study should remain open and subject to refinement and definition based on what the researcher is able to uncover and observe.

Moreover, proposed qualitative study on the subject is preferred as it will answer why, what and how questions better than any quantitative study. The following section states some of the questions that drive the research on water markets. It is not intended to down play the importance of quantitative study where solid data is available, but rather to approach the question by an in-depth study of the issues involved in water markets and their impact on resource poor farmers.

Questions

From the above discussion it is evident that government's water policies do not automatically yield benefits to all farmers. On the contrary, the actions might displace farmers. Proposed water markets may create new problems, for example by disrupting existing local institutions for operation and maintenance of the irrigation infrastructure. The benefits of reforms may be small and may be misdirected to some groups who already are well off. The history of large scale irrigation projects has shown that results are often far below what was expected. In Pakistan construction of three big dams has helped the economy, but has created wide disparity in incomes. Based on personal experience and an extensive review of the literature, research will focus on the following main questions:

- How will water markets impact small landholders?

Sub Questions

- How will water markets distribute water resources among small, medium and large landholders?
- How do farmers perceive the change in water policy and its impact on agriculture and related livelihoods?

The questions tend to emphasize the need to ask whether, government's proposed course of action shall actually help farmers. This may help us to learn how to best make use of scarce resources and find alternate solutions to solve problems.

Audience

For any kind of research, quantitative or qualitative, it is advisable to identify the entities that in the end will utilize the research. Following are some of the major stakeholders in water resources management of Pakistan. It is anticipated that they will read, critique, provide feedback and utilize the findings of the proposed research.

The Water and Power Development Authority (WAPDA): WAPDA, created in 1958 as a semi-autonomous body is responsible for planning and execution of schemes pertaining to:

- Generation, transmission and distribution of power;
- Irrigation, water supply and drainage;
- Prevention of water-logging and reclamation of waterlogged and saline lands;
- Flood control;
- Inland navigation.

Provincial Irrigation and Drainage Authorities (PIDAs): The main responsibility of the PIDAs relates to the operation and maintenance of the irrigation, drainage and flood-control systems. Under the provision of the Irrigation and Drainage Act, the PID is responsible for on-farm use; however, in practice, their activities stop at the end of the watercourse (mogha) or tertiary level of water distribution.
The Provincial Agriculture Departments: The Provincial Agriculture Departments (PADs) are mainly responsible for organizing input distribution, the extension service to farmers and - farm management. The PADs are responsible for the implementation of the government's on-farm water management programs. Farmers are responsible for operation and maintenance of watercourses and field canals.

The Indus River System Authority (IRSA): The Indus River System Authority (IRSA) provides continuing interaction and a resolution of any disputes among the four provinces on matters relating to sharing the Indus waters

Farmers: Farmers manage their operation and take care of their watercourses. Farmers often participate extensively in the management of large-scale systems. Provincial Irrigation and Drainage Authority is responsible for maintenance of infrastructure, though; few researchers noted that the farmers are actually interfering with the operation. Examples include enlarging outlets, taking water out of turn, or adjusting of the levels of gates and even channel beds (Chambers, 1989).

Paradigm

For a qualitative study it is important to be grounded in a certain paradigm to seek direction and guidance while interpreting the data. Therefore, the post-positivist paradigm will be used , which states that-reality can be approximated but can never be fully apprehended. Post-positivists use disciplined research techniques such as "constant comparison" to make sure that empirical data not their impressions drives their findings (Hatch, 2002). This paradigm suits this kind of qualitative enquiry, since, the researcher will be constantly comparing farmers' responses across the categories (small, medium, and large landholders) and shall cross check them with the official responses.

Researchers using post-positivist paradigm are -interested in capturing participant perspectives but in a rigorously disciplined way (Hatch, 2002). The outcome or product is analytical generalization, description, patterns and grounded theory. When patterns are discovered, the researcher uses deductive processes to verify the strength of those patterns in overall data to arrive at some conclusion.

RESEARCH DESIGN

Sampling, Data Collection, And Data Analysis

Sampling: Qualitative research is generally based on non-probability and purposive sampling rather than probability or random approaches. Sampling decisions are made for the explicit purpose of obtaining the richest possible source of information to answer the research questions. Purposive sampling decisions influence not only the selection of participants but also settings, incidents, events, and activities for data collection.

The researcher needs to use purposive sampling for site selection. Choosing an appropriate site to study, and forging a relationship with its participant members, is a key issue for all qualitative studies. Site selection has consequences for validity and generalizability, and both can be maximized either by selecting a 'typical' site or else conducting a multi-site study. In this study, it is proposed to choose water courses that have all categories of farmers (small, medium, and large landholders). It will be appropriate to choose from the well known sites/watercourses to maximize the information collection, validity and generalizability of the study. Three watercourses that have common characteristics i.e. reasonable number of landholders from all three categories will be selected.

Farmers will be selected by stratified sampling choosing farmers from varied categories. However, a very small sample may be obviously unrepresentative. The claim to "objectivity" is more or less achieved if the target farmers are selected on the basis of reasonable and clearly stated criteria (categories). - Fifteen farmers will be selected across all three categories i.e. 9 small landholders as they are the main focus of the study, and 3 each from medium and large landholders' categories.

Data Collection Techniques: Data collection techniques that are commonly used in qualitative research are questionnaire survey and in-depth interviews. However, researchers should consider other (secondary) data sources such as journals, newspapers, books, video tapes (if available) and any other research material on the subject that may assist researchers with the current situation. Secondar sources will also be helpful historical analysis of water policies.

There will also be a structured questionnaire survey for farmers (sample-size of 15 farmers across all three categories). Each questionnaire should take no more than 40 minutes.

Nine in-depth interviews will be conducted with officials including federal minister for agriculture and rural development, chairman WAPDA, chairman IRSA, Director General PIDA, and other key officials. Researchers may conduct maximum nine in-depth interviews. Each interview should take less than one hour.

Data Analysis: Qualitative data analysis, unlike quantitative is not concerned with statistical analysis, but with analysis of themes and patterns in the data. Increasingly, qualitative researchers use computer software programs to assist with analysis of data. Qualitative research may produce a rich, thick description of the phenomenon being studied or a theory about the phenomenon. Qualitative research reports often contain direct quotes from participants that provide rich illustrations of the study themes. Qualitative research, unlike its quantitative counterpart, does not lend itself to empirical inference to a population as a whole; rather it allows the researcher to generalize to a theoretical understanding of the phenomenon being examined.

For this study purposes typological data analysis seems suitable. Typological data analysis helps divide the dataset into categories based on predetermined typologies and patterns. Typologies are generated by a theory, common sense, and/or research objectives (Hatch, 2002). Researcher will follow three steps in developing typologies 1) assess the collected materials and then seek out mutually exclusive categories, then. 2) make sure that all of the elements being classified have been accounted for, and 3) examine the categories and their contents and make theoretical meaningful appraisal.

Trustworthiness

Trustworthiness is about being honest, telling the truth, keeping promises, and being loyal so that people can trust researchers. Researchers have moral obligation to do the right thing and they should demonstrate integrity and the moral courage to report what they discover and not twist the facts in order to serve their ends or please the government officials. There are several ways including triangulation, referential materials, peer debriefing, and member checks that can help researchers maintain the trustworthiness.

Reliability And Generalizability

Reliability: The researcher may also make sure that instrument of investigation is fully tested and applied and during analysis outliers and extreme cases are discussed and are accounted for.

Generalization: Sample size employed in quantitative research is often small, thus it is not free from criticism when it comes to generalization of findings. In case of agriculture and irrigation research it is even more complex as research findings and its use may affect hundreds of thousands farmers and families. Therefore issue of generalization needs to be handled with care.

Generalization depends on rigor of analysis method and interpretation. In many respects, the way in which generalization is conceptualized in quantitative studies is alien to qualitative research. For the social researcher what matters most is gaining an in-depth understanding of the attitudes, beliefs and behavior of the people s/he studies; the assumption is that this worldview will be context specific, and that generalization to others will therefore be extremely limited. Similarly, social research starts from the assumption that society is in a constant state of flux, that the social world and our understanding of it are constantly changing, again limiting the value of generalization

Although qualitative research may question positivist or post-positivist assumptions about generalizability, both approaches aim to produce findings that have relevance beyond the immediate context of the study. Whilst the production of laws of behavior is eschewed, there remains an often almost hidden claim that the behavior found in the study will shed some light on the behavior of others, even if this explanatory range is limited in time and space. As Janet Ward-Schofield (1993) has suggested this claim entails a re-conceptualization of generalizability in terms appropriate to qualitative research. She prefers the terms 'fittingness', 'comparability', or 'translatability', reflecting the process of detailed description of the content and context of a study, so that it can be generalized to examples that match it closely.

The use of 'thick description' to boost the generalizability of a qualitative study is important, but generalizability depends not just upon detailed description of a phenomenon, but on revealing the social relations that underpin it.

Ethical Issues

There are two groups of respondents i.e. farmers and the key officials. From an ethical stand point the researcher is answerable to both. Before administering questionnaire survey to farmers s/he shall discuss with them objectives of the study. If possible researcher may hand out a hard copy stating the objectives of research to all farmers that maybe part of study. But the problem is literacy among farmers, especially small landholders is extremely low. However, the idea is to make it discuss the objectives of research upfront and eliminate any unfounded expectations that they might attach with the study – s/he shall make clear that this study is not going to save them (farmers) from displacement, heavy water charges or any other kind of taxes that government plans to impose upon them. However, research findings shall be presented to government and rest depends upon government to act or not to act.

With key officials -- one technique to cope with ethical issues is to circulate and discus draft report before finalization and publication. This has the effect of involving agency staff in the analysis itself. This may sometimes lead to some findings not being reported formally, or being rephrased in more diplomatic language. However if agency attention is drawn to important problems and ideas generated about possible solutions then the more fundamental applied goals may be achieved. Similarly some sensitive issues may only be discussed verbally, especially if they are beyond the official scope of the research. However as an applied research process this still functions to improve agency action. Such a participatory approach is likely to be much more productive than simply presenting a final report, which is easily ignored.

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INTEGRATED WATER MANAGEMENT CHALLENGES IN EGYPT

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ABSTRACT

Many countries face severe stress on their water resources due to growing populations and increasing demands coupled with ineffective management. Integrated water resources management (IWRM) is one recognized approach to balance demands on the water resource with available supplies. However, a transition will be slow until a country accepts and understands the terminology embedded in the IWRM concept. The United States Agency for International Development (USAID) and other donors have used infrastructure rehabilitation as a carrot to begin a change in engineering dominated decision making and to widen discussion of the change process. *Interdisciplinary* field teams, water users' *participation* and integrated water management were new concepts. To obtain users' participation *policy adjustments* were required. Only after several years in the policy adjustment process was the terminology *policy reform* accepted. Even today it is not acceptable to talk about *water pricing*, though *cost recovery* is gaining acceptance, and *cost sharing* is accepted. This paper discusses Egypt's move toward IWRM by looking at the country's progress in accepting changes in water management. Through a process of subtle word changes, the -terminology has changed and brought acceptance of real change.

INTRODUCTION

During the end of the last century many countries started to face water scarcity and others will face water shortage in the coming years. According to World Bank documents about 72 countries will suffer water shortage by the year 2025. Egypt is one of these countries. Egypt relies on the Nile River for 97% of her water, a source shared by nine other countries; all of which are upstream riparians with growing populations and increasing demands for water.

Integrated water resources management is one recognized approach to balance demands on the water resource with available supplies. IWRM is a complex

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process, with engineering, social, economic, and political aspects to integrating management of all water resources. It is less difficult to integrate management when the focus is on supplies of different water sources and demand management is ignored. Demand management is difficult because it requires consideration of user behavior, and has social and political dimensions. IWRM, where both supply and demand are components and water users participate in decision-making, requires changes in policies written to support top-down decision-making for supply management. Egypt's top-down water managers found the concept of IWRM difficult to accept and to adopt.

WATER MANAGEMENT IN EGYPT BEFORE 1961

Water management in Egypt before 1960 focused on meeting water demands. Land was owned by large holders, limiting the number of water users. There was approximately 6.0 million acres of cultivated land and demand was determined by direct contact between water managers and farmers. Egypt's share of water from the Nile was sufficient to meet the demands of all users The government utilized the old Aswan Dam, completed in 1902, to control - discharges to the irrigated lands and other -users.

Water delivery infrastructure was managed by civil engineers and mechanical and electrical engineers operated and maintained the few pump stations. The Cairo headquarters provided central management for all decisions regarding river diversions. Irrigation directorates, which more or less coincided with the administrative boundaries of governorates, were divided into irrigation districts. An irrigation district was a hydrologically bound area of about 20,000 to 40,000 acres managed by one engineer who was the point of contact between the Ministry and the water user. The district office had responsibility for managing all water resources: surface water from canals, the drainage system, groundwater wells, and any pump stations.

WATER MANAGEMENT IN EGYPT 1961 - 1972

In 1961 Egypt, the socialist government limited land ownership to 100 acres per family and redistributing land in excess of 100 acres to poor farmers. This expanded the number of water users and significantly increased the work load on the small district staff. The government controlled the crop pattern, specifying crops and requiring farmers to sell the harvest to the government at low prices. The government sold the cash crops, such as cotton, rice, and wheat, on the international market for higher prices with the difference flowing into the government treasury. The pre-determined crop pattern was good for water managers and distribution efficiency was high.

Employment was controlled by the government and all university and secondary school graduates were assured government employment. This practice resulted in multiple employees for each position and forced an associated reduction in salaries. With the economy in recession the buying power of salaries became very low and most government employees had a second job, which reduced their performance for the irrigation agencies. There were no standards or incentives for employee promotion and there was no budget for training. This corrupted the relation between staff members because ability and training was not required for promotion. Water management suffered. Operation and maintenance of the irrigation and drainage system was inadequate and channels and control structures deteriorated.

Increases in demand from a growing population and horizontal expansion of agricultural land began taxing Egypt's fixed water share from the River Nile. The water manager-engineers attempted to resolve the issue with new infrastructure to increase water supplies, e.g., the new High Aswan Dam.

WATER MANAGEMENT IN EGYPT 1972 - 1986

In 1972 Egypt abandoned socialism, embraced capitalism and opened communications with the West. A free market economy was adopted removing government control from many sectors of the economy. The Israel-Egypt Middle East Peace process brought donor assistance, advanced technologies, and improvements to educational institutes; many Egyptians benefited from training abroad. These changes were to have a long-term positive impact on the water sector though the initial impacts were negative.

Freeing the cropping pattern, removing government restrictions on specific crops, had strong impact on the agriculture water sector. Because of its high water demand, restrictions do remain on the planting of rice. However, the government cannot enforce the limits on rice area because farmers' representatives in the Peoples Assembly cancel penalties on farmers who cultivate rice illegally.

Subsequent to the peace between Egypt and Israel, the number of Egyptians looking abroad for high paying job opportunities increased. The effects of this trend had two major impacts on agriculture and the associated water management. With money from abroad, families and returning workers build houses on the agricultural land in their villages, removing large areas of fertile lands from production. The water conveyance system became the repository of solid wastes and untreated wastewater from the growing villages. The farmers that worked abroad left the management of their land to their wives and children with help from inexperienced labor. On-farm water use management and efficiency suffered and contributed to the many challenges faced by the water sector.

The Ministry of Water Resources and Irrigation[4] (MWRI) was faced with many questions requiring answers. How could an increase in demand be met with the limited water supply? What were the options for increasing the low water use efficiency? How could the delivery systems be protected from pollution? How could the water delivery system be efficiently managed under a free cropping pattern and no information on farmers' water needs?

Water shortage was the big challenge because of Egypt's fixed share of water from the Nile River. During the later years of this period the country also suffered from a drought on the Ethiopian watershed supplying most of Egypt's water. Mixing drainage water with canal water, re-use, was initiated. Pump stations were established in the Nile Delta (North of Cairo and the tail of the delivery system) to lift water from large drains to canals—mixing the two waters—to compensate for water shortage in some canals. Over time, increasing levels of pollution in the drains led to shut-down of many of these pump stations.

To better face the challenges of water shortage and water quality the Ministry structure was reorganized. The new divisions, e.g., one each for management of the drainage system, mechanical and electrical for pump station management, and groundwater management, were separated from the irrigation division. Top down management continued and the organization remained vertical with each division reporting up and down within the division and with very few lateral links. The fragmentation of offices increased the number of employees, raised the cost of operation, and reduced efficiency. Water users had to visit many offices to resolve water issue, and often received no resolution. Water conflicts increased and violations became the accepted way for users to resolve their problems. The civil engineer water managers assumed improving or replacing the infrastructure could increase control of the system and consequently increase water efficiency.

After 1976, donors offered assistance to Egypt. The MWRI received support from many donors. The United States Agency for International Development (USAID), the World Bank, and other donors used the infrastructure rehabilitation carrot to begin changing engineering dominated decision making. New concepts of *multi-disciplinary teams*, *water users' participation*, *cost recovery,* and the *economic dimension of water* were introduced to the MWRI.

- Multi-disciplinary Teams: This was a concept difficult to introduce to water manager-engineers. They had to be convinced that for proper water management a team with a spread of skills was necessary. Multi-disciplinary field teams comprised of engineers, agronomists, sociologists and economists were formed.

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[4] The Ministry of Water Resources and Irrigation is the current name, it has changed over time.

- Water Users' Participation: The introduction of water users' participation grew out of a concern for sustainability of the rehabilitated system. Users' participation in decision making and water management was not accepted by the civil engineer water managers. Establishment of water users associations (WUA) at the mesqa (tertiary) level of the irrigation system was initially also resisted by politicians, even though the tertiary system is farmer-owned. The MWRI allowed USAID to form a few pilot WUAs to study the concept. With positive results from the pilots—increased production, more efficient water use, and improved maintenance of the mesqa system—government officials were convinced of the benefits to farmers. Training and study tours for ministry staff aided the acceptance of the concept.

- Cost recovery: In Egypt water is free and not allocated to individuals. Everyone can pump from the water system with no restriction on quantity and water is delivered to the customer without charge. The government pays the cost of water system operation and maintenance from the State treasury. Some donors tried to introduce the concept of water pricing, which was rejected by government officials, politicians, and users. It is common belief among Egyptians that water is a gift from God and it is not a commodity for trading with others. With a change in terminology, cost recovery for operation and maintenance services was well received.

- Economic Dimension: The engineering perspective for water management focused on meeting demands. Since they paid nothing for water, users were not concerned with efficient and economical use of water. Donors introduced the economic value of production per unit of water to farmers by promoting the transition to high value cash crops from traditional low value crops.

- Capacity Building: Donors provided opportunities to build the capacity of MWRI staff through training abroad and locally. Modern equipment and computers were supplied to the ministry to allow staff to fully use their newly acquired skills.

WATER MANAGEMENT IN EGYPT AFTER 1986

1987 began a period of transition from emphasis on water supply, hardware, and infrastructure to emphasis on software, policy, and strategy. The term *water policy* was not accepted and was replaced in donor proposals by *water strategy, policy adjustments,* and *participatory irrigation management* entered the vocabulary.

- Participatory Irrigation Management: This terminology was introduced to the MWRI by the World Bank. Though the term has not received much use in Egypt it did stimulate study of the roles and responsibilities of water users.

Study results did influence policies that resulted in later changes to water management practice. A 1994 law allowed establishing WUAs on mesqas. There are over 6,000 WUAs in Egypt today.

- Communication and Public Awareness: As users became involved in water management the need for getting information to them became apparent. A public awareness strategy and program was developed to reach water users with water messages. In 1997 a Water Communication Unit was established within the MWRI.

In 1997 Dr. Mahmoud Abu Zeid became the Minister of Water Resources and Irrigation and accelerated the change process in Egypt. *Decentralization, policy reform,* and *private sector participation* in water resources decision-making became parts of the vocabulary and were soon followed by *integrated water resources management (IWRM)*, which drove changes to Egyptian water management policy. Egypt, with assistance from USAID, is implementing integrated water resources management at the district level in an area of about one million acres (12% of the cultivated area). Policy reforms were followed by *institutional reform* and policy implementation. Recently the MWRI is beginning to grapple with the concept of *Management Transfer/Privatization*. Along with changes in vocabulary and practices has come greater awareness of water quality, environment, and water allocation concerns. These issues are elements of any proposed change in water management practices.

- Decentralization: accustomed to top-down management, the MWRI has found it is difficult to accept decentralization of authority because of the implied significant changes to the status quo. The concept is being implemented at the district level with public awareness for staff and customers and staff capacity building as key elements.

- Private Sector Participation: Water users' associations are being established on branch canals to offer users a unified voice in presenting concerns to the MWRI. A branch canal is government owned infrastructure that delivers water to farmer owned mesqas. Branch Canal Water Users' Associations (BCWUA) include representatives from all residents within the command area: farmers, village residents, and local civil administration.

- Integrated Water Resources Management: Egypt is implementing IWRM through integration of five components at the District level: consolidation of water management administration, integration of all water resources, users' participation in operations and maintenance, stakeholders' participation in decision making, and integration of information. Yet to be addressed are modes for interministerial cooperation and resolution of overlapping jurisdictions and responsibilities in the water sector. An example of the complexities is the finding from a recent study, there are 27 agencies in seven ministries responsible for monitoring water quality.

- Institutional Reform: MWRI senior staff recognizes that implementing IWRM requires changes in the institution. Restructuring ministry administration, privatization of some services, delegation of authority to water users, and cost sharing mechanism are under investigation by the Institutional Reform Unit established by the Ministry and funded by the German GTZ and the Netherlands Embassy.

- Management Transfer/Privatization: This concept is still new and MWRI staff is not confident that the private sector can manage and maintain the water distribution system. However, proposed amendments to the Law on Irrigation and Drainage will permit the contractual delegation of authority for water system management to private sector entities. Questions for irrigation management transfer under study include: at which levels of the system, how and what management will be transferred, monitoring of private sector performance, impacts on MWRI permanent staff, and delivery fee setting, collection, and distribution. It is planned that the first contracts will be between the MWRI and the BCWUAs for operation and maintenance of the branch canals.

- Water Quality and Environmental Considerations: Problems with water quality have come with increased reuse of drainage water (salinity) and growing populations in unsewered areas (biological contaminants) without operating solid waste collection systems. Canals and drains are available and used for waste disposal. Rural residents and the MWRI recognize that improving water quality is top priority and pollution of the irrigation and drainage systems must be reduced. With the assistance of donors, studies are being made and implementations of pilot efforts are planned and underway.

- Water Allocation: When water is in the canal, Egyptian farmers have no limits on the amount of water they can take. Taking a realistic look at the future the MWRI knows this cannot continue for much longer and allocation by volume is beginning to be discussed. Water allocation criteria, system capabilities, allocation procedures and political/social issues are considerations to be addressed and studied.

It is worth mentioning that the driving force behind most of these changes is the MWRI. Two other papers presented at this conference offer more detail on the changes occurring in Egypt. "Implementing District Level Integrated Water Management with Stakeholder Participation" presents a look what is ongoing with district level decentralization and formation of BCWUAs. "Organizing for

Integrated Water Resources Management" begins the discussion on future changes in the organization of water management in Egypt.

SUMMARY AND CONCLUSIONS

During the era of water abundance, careful water management was not needed. With increasing demands on a fixed water supply, water management became more complex. New terminology and concepts were introduced: multi-disciplinary teams, users' participation, cost recovery, policy reform, water allocation, institutional reform, environmental impacts, private sector participation, management transfer and privatization, decentralization, integrated water resources management, and economic value of water. Training opportunities and off-shore study tours offered a chance for water managers to understand, accept, and adopt these terms and concepts.

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LOCAL GROUNDWATER MANAGEMENT DISTRICTS AND KANSAS STATE AGENCIES SHARE AUTHORITY AND RESPONSIBILITY FOR TRANSITION TO LONG TERM MANAGEMENT OF THE HIGH PLAINS AQUIFER

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ABSTRACT

Kansas faces complex challenges in managing the Ogallala-High Plains aquifer for the future. This aquifer, one of the largest in the world, is critical to a sustainable economy for Kansas and the other seven states that rely on it. Kansas withdraws between 3 and 4.5 million acre feet annually from this source for irrigation of corn, sorghum, and alfalfa that supports some of the largest livestock feeding and meat packing industries in the world. Overall declines of the aquifer, which occurred in about one generation of family farmers, threatens an economy that is projected to no longer be possible in 50 to 100 years in many areas and less than 25 years in some areas[2].

Established rates of withdrawal exceed natural recharge by such large amounts that very large decreases in use must be considered to achieve any measurable decrease in depletion. An urgent need to begin a transition to a less water intensive economy has motivated organizations representing local water users and state agencies to cooperate in a proactive management strategy. Under this strategy, three local ground water management districts have been given the responsibility for developing a protocol for more intensive management. The protocol includes defining hydrologic sub-units, determining priority sub-areas to focus implementation activities, and setting goals for extending the life of the aquifer to protect the economy. Local Groundwater Management Districts and state agencies are working cooperatively to ensure that regulatory authorities of the Division of Water Resources and the policies of the state support local efforts through the State Water Plan developed by the Kansas Water Office.

KANSAS FACES COMPLEX MANAGEMENT CHALLENGES

A Declining Aquifer

The Ogallala-High Plains aquifer, one of the largest in the world, is critical to a sustainable economy for Kansas and the other seven states that rely on it. Kansas withdraws between 3 and 4.5 million acre feet annually from this source for irrigation of corn, sorghum, and alfalfa that supports some of the largest livestock

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[2] Schloss, 2000 and McGuire, 2003

feeding and meat packing industries in the world. Typical overall declines of the aquifer vary from 30 to 60 percent of the original saturated thickness which threatens an economy that is projected to no longer be possible in 50 to 100 years in many areas and less than 25 years in some areas. Concerns for the future of this region are compounded by the fact these declines have occurred in about one generation of family farmers[3].

Groundwater Management Districts and State Agencies Share Water Management Responsibility

Kansas has a well established organizational and administrative structure for water management. It includes responsibilities for local Groundwater Management Districts, state water management, and state planning agencies defined by statute (see Table 1).

Three Groundwater Management Districts cover the Ogallala-High Plains aquifer in western Kansas as shown in Figure 2. The boundaries are set by the users within the District, subject to approval by the Chief Engineer. Each district has an elected board of directors that represents the water users within the boundary of the district. The board of directors establishes water management policies for the district that will provide the most economic benefits from water use and protect the water supply. A manager directs the daily operations of the district, which provides technical assistance to water users, represents the users on issues before the state, and implements the policies of the board of directors. The districts have the authority to assess fees upon the water users for operational expenses and state law sets the limits. The district board of directors has the authority to recommend rules and regulations to the state's Chief Engineer, and enforce rules and regulations adopted by the Chief Engineer for the district. Policies of the board must not conflict with state law[4].

The Kansas Department of Agriculture, Division of Water Resources, is the water management agency for the state. Responsibilities authorized by state law include appropriation of water, which includes permits for all beneficial uses except household and farmstead domestic uses, water use reporting, and compliance enforcement. The Chief Engineer, who is the director of the Division of Water Resources, has the authority to adopt rules and regulations needed to administer the water laws in the state. The Chief Engineer also adopts rules and regulations recommended by the Groundwater Management Districts unless they conflict with state law or state rules and regulations[5].

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[3] Schloss, 2000 and McGuire, 2003
[4] Kansas Statutes Annotated, K.S.A. 82a-1020 et. seq.
[5] Kansas Statutes Annotated, K.S.A. 82a-701 et. seq.

Table 1. Structure and Functions of Water Management Organizations in Kansas

Western Kansas Groundwater Management District No. 1 Southwest Kansas Groundwater Management District No. 3 Northwest Kansas Groundwater District No. 4 A local entity authorized by state statute to manage ground water resources within its defined boundaries in Kansas. It is directed by a Board of Directors and a District Manager hired by the board. The board is elected by the water users within the district (one vote per user). It has authority to assess fees on irrigated land and water, recommend rules and regulations to the state's Chief Engineer, and enforce rules and regulations adopted by the Chief Engineer for the district.
Kansas Department of Agriculture, Division of Water Resources A division of a state agency directed by statute to administer the Kansas Water Appropriation Act. This division is under the direction of the Chief Engineer with statutory authority to issue permits to put water to beneficial use, quantify and certify water rights, and enforce compliance with the terms, conditions, and limitations of water rights.
Kansas Water Office A state office with statutory authority to prepare and maintain a state water plan, to coordinate with state agencies and local organizations in the water planning process, and to acquire and market reservoir storage. The office is under a Director appointed by the Governor and serves as the executive to the Kansas Water Authority. The Director manages the water plan funds generated by water protection fees collected for water planning and management projects approved by the Kansas Water Authority.
State Conservation Commission A state office with authority to administer cost share programs for water management and structural projects that support improved conservation practices in the state. Administers the distribution of cost share funds for the Federal Environmental Quality Incentives Program (EQIP), flood and other water control structures, and state water conservation programs. Administers the activities of the county conservation districts throughout the state.
Kansas Water Authority An appointed board of representatives of all water interests in the state including appointments by the leadership of the state Legislature. Recommends water planning and management initiatives and policies to the Governor and the Legislature. Heads of state water agencies are non-voting members of the Authority. The Governor appoints the Chairman of the Authority.

Water planning is the responsibility of the Kansas Water Office under the direction of the Kansas Water Authority. The Kansas Water Office coordinates with Groundwater Management Districts, state water agencies, and local organizations to prepare and maintain the state water plan. The plan, once approved by the Kansas Water Authority, is submitted to the Governor and Legislature as a recommendation for water policy in the state. Members of the Water Authority represent all water interests in the state, including members appointed by the State Legislature, major water users, Groundwater Management Districts, and heads of state agencies. The Governor appoints the chairman of the Authority and also the Director of the Water Office[6]. Other state agencies also share responsibilities for water resources as listed in Table 1.

MEETING THE CHALLENGES OF MANAGING THE OGALLALA-HIGH PLAINS AQUIFER

Planning for the future

An Advisory Committee was convened by the Director of the Kansas Water Office to prepare recommendations for addressing the depletion of the Ogallala Aquifer. The Committee members were all water users or representatives of water users and all from areas within the Ogallala-High Plains Aquifer boundaries. The chairman of the Committee was an irrigation farmer and former President of the Board of Directors of Southwest Kansas Groundwater Management District No. 3. The Committee was provided two support staff that were not members, one from the Kansas Water Office and the other from the Division of Water Resources. Key recommendations and principles from the report prepared by the Committee were:

1. Management strategies should be focused on decreasing the depletion of and extending the life of the aquifer, not a commitment to lower the levels of water use required to stop the depletion.
2. The strategy should be an incentive based approach that would encourage water conservation and less intensive water uses and impose specific water management options through state regulation when incentives are not successful.
3. Retain and exercise all the existing regulatory authorities of the Chief Engineer to enforce compliance with the existing annual diversion limits on each water right or permit.
4. Economic impacts of water management options must be considered.
5. The variability of the saturated thickness and other aquifer characteristics must be reflected in the management strategy through determination of hydrologic subunits.
6. Each Groundwater Management District was required to prepare a Water Management Protocol to address the depletion and extend the life of the aquifer within their boundaries. The Division of Water Resources was

[6] Kansas Statutes Annotated, K.S.A. 74-2601 et. seq.

required to prepare a protocol for those fringe areas of the Ogallala-High Plains aquifer outside the Groundwater Management District boundaries.

The Advisory Committee report was submitted to the Kansas Water Authority that approved it as part of the Kansas Water Plan[7].

Enhanced water management protocols

Protocols prepared by the Groundwater Management Districts include general methods for defining aquifer subunits that reflect the variability in aquifer characteristics and a commitment to setting priorities of high, medium or low for each subunit. Enhanced water management would not be immediately necessary in the low priority areas. Enhanced water management goals will be set by each district for each high priority and some medium priority subunits. Protocols are included in the District Management Program by the District Boards, and are submitted to the Chief Engineer for review to ensure that it does not conflict with state law and rules and regulations. A public hearing is held before approval by the Board.

A fundamental factual concept used in defining subunits and setting priorities is the projected usable lifetime of the aquifer. The Kansas Geological Survey published an initial analysis of projected usable lifetime that computed the time required for a projection of the past rate of decline in the water table to deplete the current saturated thickness down to a threshold considered to be a minimum required to support marginal irrigation practices. The geographic distribution of these computations reflects the variability in aquifer characteristics combined with the variability in current decline rates[8]. Expressing the results in time periods describes the future impacts of current pumping in terms understood by all water users and it gives a relative sense of urgency in defining priority subunits. Water level data used in the analysis was primarily annual mid-winter measurements made on hundreds of wells over the past thirty years. Analysis of the data was done at approximately square mile resolution with results provided at about the township level (every 36 square miles). The results were refined to use a threshold well yield or pumping rate rather than a threshold saturated thickness so the value is more directly related to the practical limits for traditional large-scale irrigation in the area. The Kansas Geological Survey established the relationship between well yield and saturated thickness for various values of aquifer hydraulic conductivity and well density found in the aquifer[9].

A map of the projected usable lifetime of the aquifer in Southwest Kansas Groundwater Management District No. 3 with a threshold of 400 gallons per

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[7] Ogallala Aquifer Management Advisory Committee, 2001
[8] Schloss, 2000
[9] Hecox, 2002

minute is shown in Figure 3. The 400 gallons a minute threshold is one considered to be a minimum well yield adequate for large scale irrigation of corn using the most common irrigation technology which is center pivots. The map shows some areas with a useful lifetime of more than 100 years and others less than 25 years. However, there are some areas where the aquifer has never been adequate for large-scale irrigation so there are a few wells even though the projected lifetimes are relatively short. It would not be appropriate to define these marginal subunits of the aquifer as high priority even though they have short projected lifetimes. Final decisions made by the Groundwater Management District will consider subunit boundaries based on the areas defined by the contours on the map.

GOALS AND SOLUTIONS

The goals and solutions for the priority subunits follow the Advisory Committee recommendations in the water plan. Administrative processes to address the water management challenges in the recommendations must be available to Groundwater Management Districts and the State.

Challenges in the Application of Prior Appropriation

Kansas's water law applies the prior appropriation doctrine to ground and surface water[10]. Since 1978, the law requires a permit approved by the Chief Engineer for any beneficial use except household and farmstead domestic use. Permit approval was based on an allowable depletion rate or safe yield set by the Groundwater Management Districts or the State outside of District boundaries. Safe yield is defined as authorized annual withdrawals equal to average annual natural recharge. Water development exceeded safe yield in many areas of the Ogallala-High Plains Aquifer before 1978 and continued thereafter under allowable depletion criteria for a number of years. Therefore many areas are over appropriated to the extent that annual quantity authorized for diversion far exceeds safe yield. A substantial decrease in annual water use is needed in many areas to make any noticeable decrease in the water level declines.

Stream base flow is fed by outflows from the regional aquifer in the fringe areas near the boundary. Gradients in the water table of the Ogallala-High Plains Aquifer determine the amount of base flow directly to the stream and to the alluvium. Pumping near the boundary decreases the gradient, decreasing or curtailing flows depending on the pumping water levels. Kansas water law acknowledges that groundwater rights are protected when pumpage from junior water rights decrease base flows beyond a reasonable limit. New groundwater permits have been denied in some instances where the additional pumping is expected to impair existing surface water rights on streams fed by the aquifer.

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[10] Kansas Statutes Annotated, K.S.A. 82a-701 et. seq.

Ensure this is accurate, extensive edits: The Hoxie area in Sheridan County of northwest Kansas is an example of the extent of over appropriation in some areas that have a short usable lifetime (see Figure 3). This area near Hoxie has about 30 irrigation wells within a circle of 2 miles in radius around a well that has reported substantial yield declines that dip below 400 gallons per minute. The reported water use in this area exceeds the estimated annual natural recharge by about 30 times[11]. Most of the irrigated crop production is corn that is sold to a beef cattle feeding operation within the 2-mile radius circle. A computation of the projected usable lifetime for this area to reach a threshold of 400 gallons a minute is less than 25 years at current pumping rates and some wells have already reached this threshold. It is apparent that a substantial decrease in pumping must occur in order to decrease the declines and extend the life of the aquifer.

Kansas's law is based on prior appropriation and would require the wells with the most junior rights to cease pumping until the most senior rights can be protected from depletion. If safe yield were a goal for this aquifer subunit, the reported use for the two wells with the most senior rights would exceed the estimated safe yield. There are about 12 wells with water rights senior to those supplying the feedlot, which is the primary market for crops produced. Even though some water users have expressed their concerns, no senior water right owner has filed a formal impairment complaint at this time.

Intensive Groundwater Use Control Areas

Kansas state law gives Groundwater Management Districts the authority to recommend to the Chief Engineer that an intensive groundwater use control area be designated[12]. Under this authority the state may impose such regulatory provisions as necessary to protect the public interest in the water supply where groundwater levels have declined excessively. These provisions allow the Chief Engineer to depart from the prior appropriation doctrine as may be necessary in these specially designated areas. A decision to use this authority has not been made by any Groundwater Management District included in the Hoxie area.

Incentive Programs

The primary incentive programs are some form of financial compensation for decreasing irrigated acres or some other means of decreasing water use. In each case the decision to participate is the water user's choice.

The Environmental Quality Incentives Program (EQIP) is a voluntary federal conservation program that promotes agricultural production and environmental quality. Farmers may receive financial and technical assistance to install or

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[11] Huntzinger, 2003
[12] Kansas Statutes Annotated, K.S.A. 82a-1020 et. seq.

implement structural and management conservation practices on eligible agricultural land. Local and state entities develop an evaluation process for defining high priority applicants to meet local and national objectives. Groundwater Management Districts participate in the evaluation process to ensure that applications are approved that will significantly decrease water use. The Natural Resources Conservation Service administers the federal program. Groundwater Management Districts and the State priorities are directed to using this federal program in assisting farmers in the transition from irrigation to dryland agriculture.

Another federal program is the Conservation Reserve program, which provides annual per acre payments to landowners for taking land out of crop production by planting it to a natural vegetation cover. The federal program is administered by the U.S. Department of Agriculture, Farm Services Agency. Participating farmers enroll in the program for 10 to 15 years. Farmers that would typically use the EQIP program, but are irrigating land that is not suitable for dryland farming, would be encouraged to use this program.

Groundwater Management Districts and state agencies have been working with the state's congressional representatives to get provisions included in the Farm Security and Rural Investment Act that would encourage water conservation. Payments and other benefits related to the current federal law provide loans and price support payments to farmers that are based on crop acreage and crop yields which tend to encourage large applications of irrigation water to increase yields. Discussions with legislators are directed at new provisions that would base program payments and other benefits on the costs of transition from irrigation to dryland, not on crop yields in the Ogallala-High Plains where the aquifer is depleting.

Kansas state law has provisions for the state to acquire water rights from owners to conserve water. Regulations are being written at this time to set criteria for the amount of compensation to be paid to a water right owner. Water right owners would be required to permanently retire their water rights upon receipt of payment under this state program. State funding for the program to date has been small.

A local foundation has been created in northwest Kansas to raise funds for buying water rights that would be permanently retired to conserve water. Northwest Kansas Groundwater Management District No. 4 is administering the foundation.

Kansas's water law requires that water be put to beneficial use under all water rights. Those rights that have not had water use for more than 5 consecutive years without justifiable cause are abandoned and dismissed. Kansas's rules and regulations provide specific due and sufficient causes for non-use that will not result in abandonment[13]. All programs that result in curtailment of water use for a specified period of time must be considered by the state and determined to be due and sufficient cause for non-use to avoid abandonment under state law. Water users may protect a water right from abandonment by enrolling it in the state Water Resources Conservation Program if it is located in an area that is fully appropriated (exceeds safe yield) or has been closed to further appropriation by law or regulation.

Laws that apply to the management of groundwater vary among states that share this multi-state aquifer. The U.S. Geological Survey has compiled water level and water use information from each state and frequently publishes reports on the decline of the aquifer. There has been limited coordination among states agencies that share this multi-state aquifer. Some federal legislation has been introduced by congressional representatives from New Mexico that would provide federal funding to the state geological surveys in each state and the U.S. Geological Survey for coordinated data collection and analysis.

CONCLUSIONS

Groundwater Management Districts are sharing the responsibility for planning and water management with the state in addressing challenges of a depleting water supply. Local organizations and water interests in the Ogallala-High Plains Aquifer area prepared recommendations that were included in the Kansas State Water Plan. Protocols for defining high priority areas for enhanced water management are included in the Groundwater Management District Management Programs. The Groundwater Management Districts and state agencies are working together to establish realistic goals, define incentive programs, and identify regulatory options that will extend the life of the depleting aquifer and protect a water supply for the future.

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Figure 1. Location of the Ogallala-High Plains Aquifer, Central United States

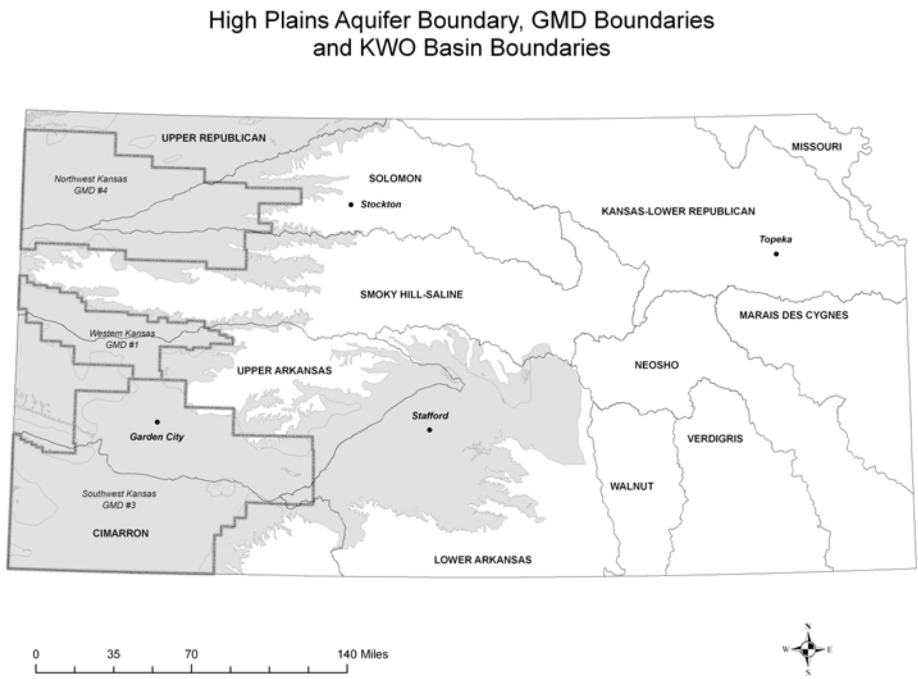

Figure 2. Groundwater Management Districts in Kansas

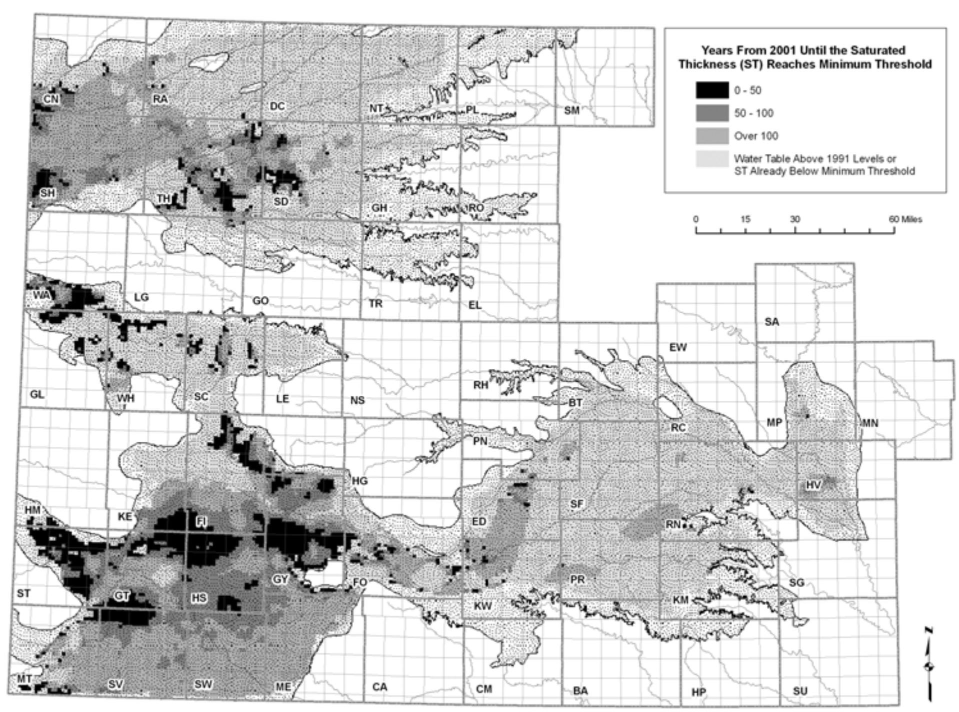

Figure 3. Estimated Usable Lifetime for the High Plains Aquifer in Kansas (Based on groundwater trends from 1991 to 2001 and the minimum saturated thickness required to support well yields at 400 gpm under a scenario of 90 days of pumping with wells on ¼ section.)

WATER USER MANAGEMENT AND FINANCING OF IRRIGATION FACILITIES THROUGH USE OF IMPROVEMENT DISTRICTS

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Todd Troglin[2]
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ABSTRACT

The Turlock Irrigation District (TID), California's first irrigation district, was established in 1887. The TID owns only the main canals and laterals, which bring irrigation water to large geographical portions of the TID. Improvement districts are organized by local landowners to convey the irrigation water to individual parcels. These local organizations provide essential irrigation service including water conveyance, drainage, and supplemental water from wells and pumps. The cost for these services is paid by assessments levied against the member properties.

BACKGROUND AND HISTORY

The Irrigation System

The Turlock Irrigation District was established as California's first irrigation district on June 6, 1887, under provisions of the Wright Act, a law enacted in the state of California providing for the establishment of irrigation districts. After building the diversion and distribution facilities, the TID made its first delivery of irrigation water from the canal system on March 9, 1900. Today the TID irrigates 150,000 acres of land that consist of 7,500 parcels of property and approximately 5,000 individual irrigators. A location map showing the District is shown in Figure 1. The District extends from the foothills of the Sierra Nevada on the east to the San Joaquin River on the west. The Tuolumne River forms the TID's northern boundary, while the Merced River forms the southern boundary. The TID canal system stretches from La Grange in the foothills of the Sierra Nevada Mountains where water is diverted from the Tuolumne River, to Lateral 8 which ends 2 miles from the confluence of the Merced and San Joaquin Rivers.

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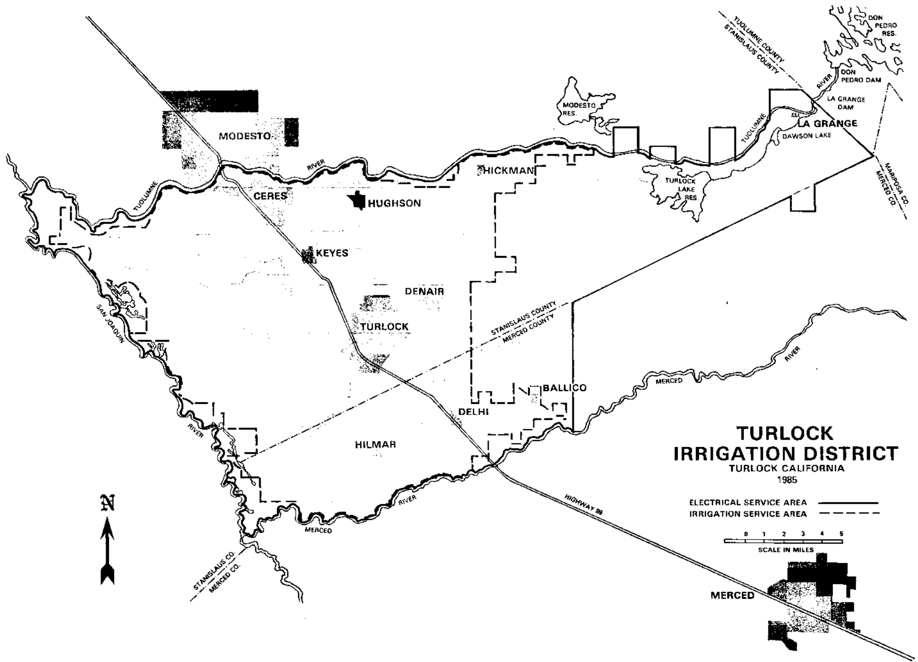

Figure 1. Map of TID

As the TID developed its irrigation system, it also developed a philosophy of determining what facilities would be owned, operated and maintained by the TID, and what facilities would be owned operated and maintained by the users of those facilities. The TID owns and operates the canal system, which consists of 250 miles of concrete-lined and unlined canals and laterals that provide irrigation water to large geographical areas of the TID. The TID also owns, operates and maintains spills from the canal system and provides drainage facilities in the western portion of the TID. District water charges and revenue streams pay the cost for these TID facilities.

The TID established that delivery of water to individual fields is the responsibility of the property owner. Such deliveries are accomplished through improvement district pipelines or ditches, or privately owned pipelines or ditches.

The concept of organizing improvement districts to own local water delivery facilities was developed to provide a mechanism for orderly construction and operation of local irrigation facilities. These districts also apportion the costs of constructing and maintaining these facilities to the users of the facility. Figure 2 shows the layout of a typical improvement district with a pipeline irrigation facility.

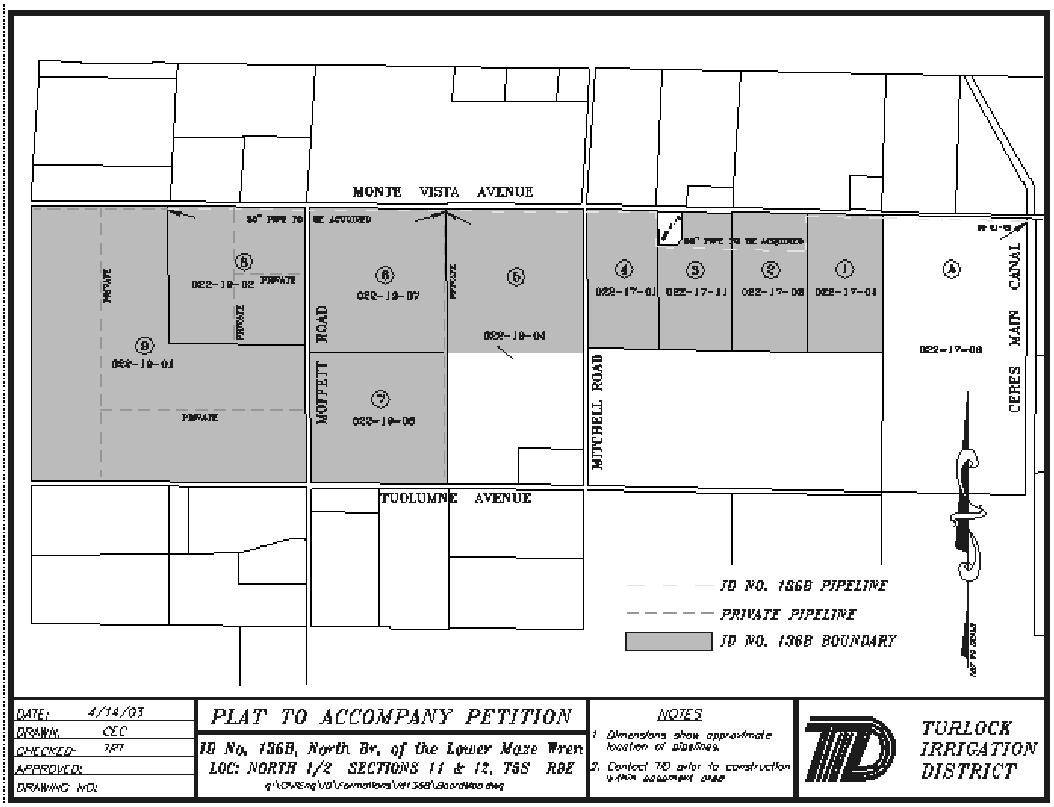

Figure 2. Map of Typical Improvement District

Types of Improvement Districts within the Turlock Irrigation District

Improvement districts (ID's) are special governmental organizations organized under provisions of the California Water Code and consist of the particular properties that utilize a specific irrigation facility. They are organized to own and operate various irrigation facilities apart from those owned by the Turlock Irrigation District. The property within the improvement district pays the costs of constructing and maintaining the irrigation facility. The Turlock Irrigation District Board of Directors governs the Turlock Irrigation District and is trustee for the improvement district. As such, the Board holds title to the assets of the improvement district for the benefit of the property within the improvement district. The five members of the Board are elected from geographic divisions of the District for staggered four-year terms.

The California Water Code provides that improvement districts may be formed for various purposes related to constructing and maintaining irrigation and drainage facilities. Table 1 details the types of improvement districts organized with the Turlock Irrigation District, the number of each type of ID and the total acreage of those improvement districts. A photograph of a typical improvement district facility is included for each type of ID.

Table 1. Improvement District Facilities

Type of Facility: Irrigation Ditch
No. of ID's: 28
Total Acres: 13,824

Type of Facility: Irrigation Pipeline
No. of ID's: 751
Total Acres: 114,607

Type of Facility: Irrigation Pump
No. of ID's: 238
Total Acres: 89,911

Type of Facility: Drainage Pump
No. of ID's: 23
Total Acres: 5,829

Type of Facility: Surface Drain
No. of ID's: 28
Total Acres: 18,338

Type of Facility: Urban Storm Drain
No. of ID's: 1
Total Acres: 10

Type of Facility: Pump and Micro Irrigation System
No. of ID's: 1
Total Acres: 56

IMPROVEMENT DISTRICTS WITHIN THE TURLOCK IRRIGATION DISTRICT

Formation of Improvement Districts

Improvement districts are formed under provisions of California Water Code Sections 23600 to 24103 and conforming rules adopted by the Turlock Irrigation District. Landowners interested in forming an improvement district discuss their plans with TID staff assigned to administer improvement districts. Details of formation procedures, costs, and timeframes are explained upfront with the interested parties. In general, formations of improvement districts follow the following steps:

- TID staff prepares a legal document called a petition for the interested parties.
- The interested parties sign the petition and return the document to the TID
- The TID Board of Directors receives the petition and requests that TID staff prepare a map and preliminary study of the proposed improvement district formation.
- The preliminary study and map of the proposed improvement district is presented to the TID Board of Directors. The Board then requests TID staff to prepare a detailed feasibility study that includes the following
    - Plans and Specifications for the facilities of the proposed improvement district
    - Estimate of construction costs for the facilities of the proposed improvement district
    - Estimate of the annual costs to maintain the facilities of the improvement district.
- The feasibility study is presented to the TID Board of Directors who then schedules a formal hearing to consider the proposal to form the improvement district. The proposed improvement district members are notified of the hearing, and notices of the hearing are posted in the local newspaper and physically posted in the neighborhood of the proposed improvement district.
- The Board of Directors conducts the hearing and listens to any problems or objections of the proposed landowners or neighbors of the proposed improvement district. If the Board finds that formation of the improvement district is in the best interests of the proposed improvement district and the Turlock Irrigation District, the improvement district is formed. Legal notice is filed in the county recorder's office so that the ID membership condition will appear on the property's chain of title.

The California Water Code provides a mechanism that has been implemented by the Turlock Irrigation District for property to include into an existing improvement district. For example, a property owner may acquire a neighboring parcel and change the source of irrigation water from one improvement district to another. TID procedures follow the outline of the Water Code sections to allow the new parcel to join the other ID. Inclusion of property into an improvement district follows a similar sequence of events as forming a new ID. The including parcel is required to “buy” into the new ID by paying an amount based on the original construction costs of the ID facility.

Owners of property that no longer requires the services of the improvement district facilities may request the TID Board to allow the property to “abandon” the ID. Such abandonments are allowed in limited circumstances, such as when property develops from agricultural to urban uses. In these cases, all assessments the property owes the improvement district must be paid, and the developer may be required to improve the irrigation facility to urban development standards. This work to improve the facility is required so that the remaining landowners in the improvement district are not adversely affected by the property leaving the improvement district.

Operational Considerations

Turlock Irrigation District rules establish the TID Board of Directors as the governing board of the improvement district. In order to establish common operating procedures, the TID Board has adopted rules and regulations pertaining to all improvement districts. The rules provide that each improvement district may appoint a committee of landowners within the ID to handle day to day operation of the improvement district. For example, the committee may request repair work to be done on an improvement district pipeline, or establish operating procedures for an improvement district pump. All procedures followed by improvement district members must conform to TID rules for irrigation of property, and the general rules for the operation of improvement districts.

Maintenance Considerations

Maintenance of the irrigation facilities of the ID is one of the primary functions of improvement districts. Members of the committee of the ID are charged with keeping the facilities in good operating condition. When maintenance is required, the committee follows procedures set up by the TID to schedule appropriate TID maintenance staff to attend to the needs of the ID facilities. In order to foster accountability and openness in ID procedures, two members of the ID committee must approve the work being planned.

The ID committee members may also request that private contractors perform the maintenance activities, subject to TID contracting rules and procedures. The TID may also recommend that private contractors provide the maintenance service, if TID forces are backlogged or that specialized work is required.

Capital Construction Considerations

Financing the construction of capital improvements is another of the primary functions of improvement districts within the Turlock Irrigation District. Typical capital projects include replacing a dirt or concrete lined ditch with a concrete pipeline, or constructing a well and pump for supplemental irrigation water. When the need or desire arises for these capital improvements to irrigation facilities separate from the canals owned by the Turlock Irrigation District, the proponents discuss the plans with staff members of the TID who develop the necessary preliminary engineering and cost estimates. This information is used during the formation process, which was previously illustrated. Final construction costs are paid by assessments against the ID property for ten years. The assessments include principal and interest at the current interest rate.

Financial Considerations

Improvement districts are financed by assessments against the property that are calculated and billed on a yearly basis by the Turlock Irrigation District. The assessments are calculated on a per acre basis, with the total costs of the improvement district divided by the number of assessed acres within the improvement district. The assessed acreage of a parcel is normally the parcel's gross acreage. The assessment bills are mailed to property owners in November of each year, with half of the assessment due in the month of December, and the remaining half due in June of the following year. Unpaid assessments can become a lien against the property and therefore have a high priority against other liabilities of the property owner. In addition to any improvement district assessments, property that receives irrigation water must pay a yearly charge for irrigation water service.

Operation and Maintenance (O&M) costs of the improvement district are accumulated from September of the previous year through August of the year the assessment is calculated.

Capital costs are accumulated during the construction period and summed to provide a construction assessment for the following ten years. Construction assessments commence when the work is completed and the facilities are in operation. In addition to this principal, an interest payment is added. The current interest rate charged improvement districts is 6-1/2%.

During the calendar year of 2003, improvement districts paid $939,255 in O&M assessments to operate and maintain their irrigation facilities. During that same year, improvement districts with recently constructed irrigation facilities paid $365,312 in construction assessments to pay off the construction cost of the ID facilities.

ID Member Considerations

As a result of their direct financial stake in the ID facility, the users of those facilities generally operate them in a prudent manner. As a result of operating their ID facility, the users can have a great influence on the cost of O&M for those facilities. The user's expectations of service levels and maintenance services are tempered by their direct financial participation in those activities.

TID Considerations

One benefit of forming improvement districts is the TID is able to direct the costs of constructing and maintaining user irrigation facilities to the owners of the particular facility. Another major benefit of the formation of improvement districts is that it provides a governance structure to the users of the improvement district facility. This structure consists of a committee of users that can be consulted and can provide coordination services between the TID and members of the ID.

The TID provides administrative and engineering services to the improvement districts. These services include design of the facilities, construction management, operation and maintenance consultation and accounting services. These service levels are not inconsistent with the service levels that would be needed if the TID directly owned, operated and maintained the irrigation facility. In addition, fees and overhead recovery charges paid by the improvement districts offset the costs for TID to provide these services.

CONCLUSIONS

General TID revenues pay for irrigation facilities that serve the District as a whole thus ensuring that TID irrigation rates remain competitive. The innovative use of improvement districts within the Turlock Irrigation District assures that customers receiving irrigation water from the TID have the opportunity to construct and maintain irrigation facilities appropriate for their needs. Through improvement district assessments, the users of those facilities pay the costs for those facilities serving individual irrigated properties.

MULTIPLE MANAGERS CASE STUDY: DEVELOPMENT AND IMPLEMENTATION OF THE SAN JOAQUIN RIVER AGREEMENT

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Lowell Ploss[2]

ABSTRACT

In 1995 the California State Water Resources Control Board (SWRCB) adopted a Water Quality Control Plan (WQCP) for the Sacramento and San Joaquin Rivers Bay-Delta which included water quality and flow objectives for the San Joaquin River Basin. San Joaquin River stakeholders felt that they were not properly represented during the negotiations that established the WQCP objectives and that the objectives lacked scientific support and took legal action against the SWRCB challenging the objectives. In an effort to settle out of court the San Joaquin River stakeholders collaborated with environmental and governmental interests to identify feasible voluntary actions to protect the San Joaquin River's fishery resources and implement the flow objectives of the WQCP. During this discussion and negotiation stage a group of San Joaquin River basin water agencies formed a joint powers authority known as the San Joaquin River Group Authority (SJRGA). As a result of these negotiations the San Joaquin River Agreement (SJRA) was developed and ultimately adopted by the SWRCB. The SJRA, a landmark agreement between environmental, governmental and water user agencies, includes a study program called the Vernalis Adaptive Management Plan (VAMP) with the purpose of gathering the best scientific information on the impacts of river flows and State and Federal Delta exports on out-migrating salmon smolt survival in the lower San Joaquin River and Delta. This paper will discuss the formation of the SJRGA and the development and implementation of the San Joaquin River Agreement.

BACKGROUND

The San Francisco Bay/Sacramento – San Joaquin Delta Estuary (Bay-Delta Estuary) is the largest estuary on the west coast of the United States and is a major crossroad between migrating fisheries, environmental restoration, and water supply for the majority of Californians. The Sacramento River from the north and the San Joaquin River from the south are the two largest river systems draining into the Bay-Delta Estuary. In May 1995 the California State Water Resources Control Board (SWRCB), the agency responsible for the regulation of water quality and water rights in the state of California, produced and adopted the Water

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Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (1995 WQCP), which established water quality and flow objectives for the Sacramento and San Joaquin River basins. The water quality objectives include maximum allowable chloride and maximum allowable salinity at various locations throughout the basins and estuary. The flow objectives define minimum fish and wildlife flow requirements at various locations in the basins and estuary. The 1995 WQCP superseded both the Water Quality Control Plan for the Sacramento-San Joaquin Delta and Suisun March, adopted August 1978, and the Water Quality Control Plan for Salinity for the San Francisco Bay/ Sacramento-San Joaquin Delta, adopted in 1991.

Figure 1. Location Map (Source: California Department of Water Resources)

An association of San Joaquin River basin water agencies known as the San Joaquin Tributaries Association (SJTA) filed suit against the SWRCB challenging the flow objectives in the 1995 WQCP, claiming that scientific support in regards to the relationship of flow to salmon survival was lacking and that the San Joaquin River stakeholders were not represented in the exporter/agency negotiations that established the objectives. The agencies represented by the SJTA were the Merced Irrigation District (MeID), the Modesto Irrigation District (MID), the Turlock Irrigation District (TID), the Oakdale Irrigation District (OID) and the South San Joaquin Irrigation District (SSJID).

A desire to settle this issue without going to court led to a unique collaboration of San Joaquin River basin water users, environmental interests and governmental agencies. The goal of this collaboration was to identify feasible voluntary actions that would protect the San Joaquin River's fishery resources and implement the objectives of the 1995 WQCP. In 1996 this collaboration resulted in an agreement known as the Letter of Intent to Resolve the San Joaquin River Issues.

THE SAN JOAQUIN RIVER AGREEMENT

In an effort to develop the scientific support that was lacking in the WQCP, a plan of study was outlined by fishery biologists from State and Federal agencies and other stakeholders which would collect the best available data on the relationship between lower San Joaquin River flows, Delta exports and salmon smolt survival. This study plan is known as the Vernalis Adaptive Management Plan (VAMP).

The VAMP calls for a steady 31-day pulse flow, which is an increase in the flow that would exist without the VAMP, in the San Joaquin River at the Vernalis gage (see Figure 2) in April and May and a corresponding reduction in State and Federal exports from the Delta to the California Aqueduct and the Delta-Mendota Canal. An additional and equally important element to the VAMP is the closing off of the Old River channel where it bifurcates from the lower San Joaquin River near the mid-point between Vernalis and the City of Stockton with a temporary barrier. Out-migrating salmon smolts that head down the Old River channel would have a high probability of ending up entrapped by the Delta export pumps. The temporary closure allows for nearly the entire San Joaquin River flow along with the majority of out-migrating salmon smolts to remain in the San Joaquin River, thereby increasing their prospects of survival.

During the pulse flow salmon smolt survival studies would be conducted, with the hope that if this study is carried out for a number of years enough data could be collected to develop a relationship between flow and salmon survival from which a scientifically supportable flow objective could be derived.

The implementation of the VAMP study would require supplemental water to achieve the pulse flow and funding to carry out the salmon survival studies, along with a significant level of cooperation and coordination between many public and private water agencies in the San Joaquin River basin and Southern California. To this end a diverse group of State and Federal agencies, Delta export interests, environmental community representatives and San Joaquin River water users collaborated in the development of the San Joaquin River Agreement (SJRA).

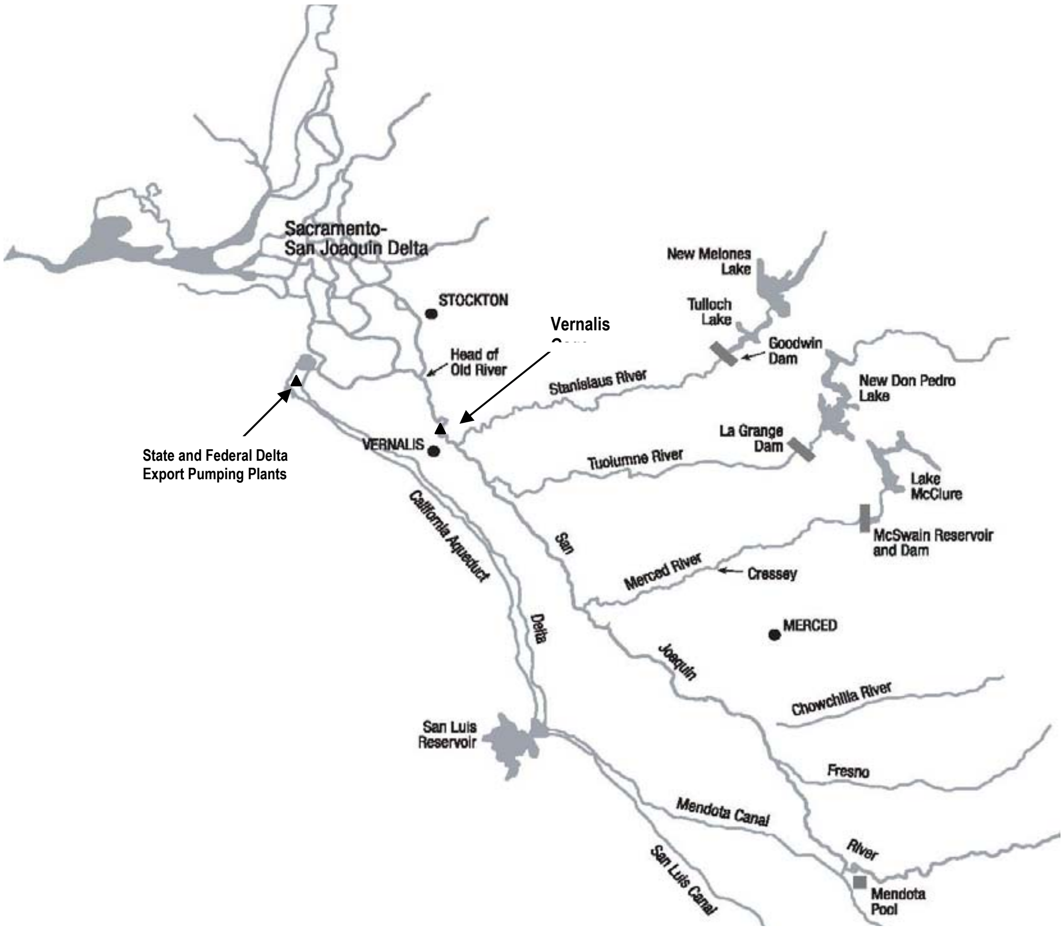

Figure 2. San Joaquin River Location Map

To represent their legal, financial and operational interests during the development of the SJRA, water users in the San Joaquin River basin formed the San Joaquin River Group Authority (SJRGA) in 1996, a joint powers authority consisting of Merced Irrigation District, Modesto Irrigation District, Turlock Irrigation District, South San Joaquin Irrigation District, Oakdale Irrigation District, San Joaquin River Exchange Contractors Water Authority and the Friant Water Users Authority. The City and County of San Francisco joined the SJRGA the following year. The SJRA was completed and signed with an effective data of March 1, 1999. The following is a complete list of the signatories to the SJRA.

- California Department of Water Resources (CDWR)
- California Department of Fish and Game (CDFG)
- United States Bureau of Reclamation (USBR)
- United States Fish and Wildlife Service (UFWS)
- San Joaquin River Group Authority (SJRGA)
- Modesto Irrigation District (MID)

- Turlock Irrigation District (TID)
- Merced Irrigation District (MeID)
- South San Joaquin Irrigation District (SSJID)
- Oakdale Irrigation District (OID)
- San Joaquin River Exchange Contractors Water Authority (SJRECWA)
- Central California Irrigation District
- Firebaugh Canal Water District
- Columbia Canal Company
- San Luis Canal Company
- Friant Water Users Authority (FWUA)
- Metropolitan Water District of Southern California (MWD)
- Natural Heritage Institute (NHI)

The SJRA is a twelve year agreement in which the United States Bureau of Reclamation (USBR) and California Department of Water Resources (CDWR) will pay a fee to the SJRGA to provide the supplemental water necessary to achieve the VAMP pulse flow, up to a maximum volume of 110,000 acre-feet. If more than 110,000 acre-feet of supplemental water is needed to meet the VAMP pulse flow target, then the USBR will attempt to acquire the necessary additional water through purchases from SJRGA and other willing sellers.

In January 1999 a Final Environmental Impact Statement and Environmental Impact Report for Meeting Flow Objectives for the San Joaquin River Agreement 1999-2010 was issued, satisfying the regulatory requirements under the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA).

The SWRCB incorporated the SJRA into their water rights Decision 1641 (D-1641) which was initially adopted in December 1999. Several petitions for reconsideration were filed in response D-1641. The SWRCB held a hearing in response to the petitions and as a result adopted several minor changes and issued a revised D-1641 in March 2000. A subsequent environmental document for the purchase of additional water was finalized in March 2001.

With the regulatory hurdles cleared the VAMP was officially implemented for the first time in the spring of 2000.

VAMP IMPLEMENTATION

The SJRA created a Management Committee among the signatories to oversee the program and the San Joaquin River Technical Committee (SJRTC), a group of State, Federal, and stakeholder technical specialists tasked with implementing the VAMP and undertaking any other technical activities necessary to meet the goals of the SJRA. Two subgroups were formed within the SJRTC: 1) the Hydrology

Group, which is tasked with performing the flow related activities of the SJRA, including determining the flow target and supplemental water volume and planning and coordinating the flow operations necessary to achieve the flow target; and 2) the Biology Group, which is tasked with designing, performing and analyzing the results of salmon smolt survival studies.

The VAMP pulse flow, which is measured in the San Joaquin River near Vernalis, is achieved through the provision of supplemental water from the following SJRGA agencies: MeID, MID, TID, SSJID, OID and SJRECWA. . A Division Agreement between the SJRGA agencies defines the quantity and priority of supplemental water for which each of the agencies is responsible. The MeID supplemental water is made available on the Merced River, the MID and TID supplemental water is made available on the Tuolumne River, and the OID and SSJID supplemental water is made available on the Stanislaus River. The SJRECWA supplemental water can be made available through releases from district irrigation ditches, but for the last two years has been provided by MeID through an agreement between MeID and SJRECWA.

An important role of the SJRTC is the coordination of the VAMP pulse flow with fishery studies on the three major tributaries that feed the San Joaquin River (the Merced River, Tuolumne River and Stanislaus River). The fishery studies on the individual tributaries generally have desired flow patterns associated with them. A great deal of coordination and cooperation is required of the SJRTC and its member agencies to schedule and implement the real-time flow operations on the tributaries such that both the goals of the VAMP and the individual tributary studies are achieved. This operation is especially challenging since the points of control for the supplemental water releases range from 59 to 107 miles from the VAMP target flow location of Vernalis, with flow travel times in the two to three day range. Figure 3, which shows the observed flows from the 2004 VAMP operation, provides an illustration of the coordination required for the VAMP operation.

As noted previously, the year 2000 was the first official year of VAMP implementation. This year, 2004, marks the completion of five years of VAMP implementation. A summary of the VAMP period mean target and observed flows for the five years of VAMP implementation is provided in Table 1. A summary of the supplemental water contributions that have been made by the SJRGA to achieve the VAMP pulse flows over the five years of implementation is provided in Table 2.

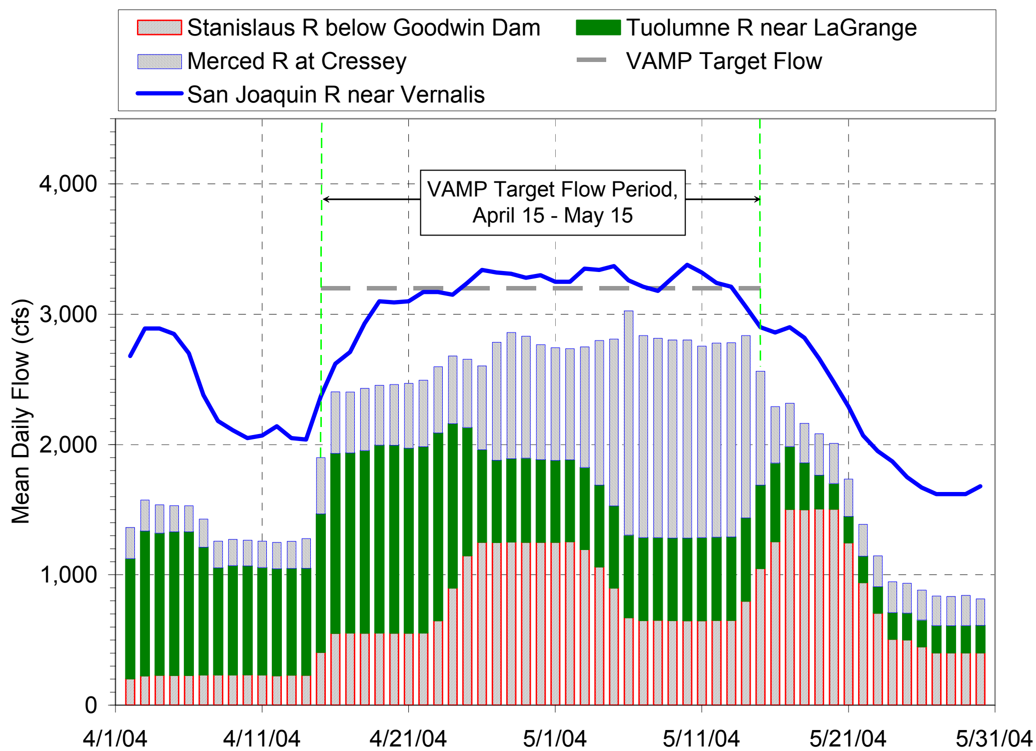

Figure 3. 2004 VAMP Operation River Flows

Table 1. VAMP Period Mean Target and Observed Flows, 2000 - 2004

Year	Existing Flow (cfs)	VAMP Target Flow (cfs)	Observed VAMP Flow (cfs)	VAMP Supplemental Water (acre-feet)	Delta Export Target (cfs)	Observed Delta Export (cfs)
2000	4,800	5,700	5,896	77,680	2,250	2,155
2001	2,909	4,450	4,224	78,650	1,500	1,420
2002	2,757	3,200	3,301	33,430	1,500	1,430
2003	2,290	3,200	3,235	58,065	1,500	1,446
2004	2,088	3,200	3,155	65,591	1,500	1,331

Table 2. VAMP Supplemental Water Contributions, 2000 – 2004
(all values in acre-feet)

Year	Total	MeID	OID	SSJID	SJREC WA	MID	TID
2000	77,680	42,770	7,300 [a]	7,300 [b]	8,280	6,015	6,015
2001	78,650	42,120	7,365	7,365	7,740	7,030	7,030
2002	33,430	25,840	3,795	3,795	0	0	0
2003	58,065	33,257	5,039	5,039	5,000 [c]	4,864.5	4,864.5
2004	65,591	37,680	5,880	5,880	5,000 [c]	5,575.5	5,575.5

[a] Provided by MID
[b] Provided by MeID, MID and TID
[c] Provided by MeID

Over the first five years of the VAMP the number of coded-wire tagged juvenile salmon smolt consisted of 325,000 (2000), 350,000 (2001), 400,000 (2002), 300,000 (2003) and 200,000 (2004) released at upstream and downstream location for testing purposes. Thus far the salmon smolt survival studies have shown mixed results in the relationship between smolt survival and flow and export rates. Prior to 2003 the relationship did show a statistically significant relationship, however the unexplained poor recovery of test fish in 2003 and 2004 has resulted in overall results showing no statistical significant relationship at this time. It is hoped that with the additional seven years of data to be collected as a result of the SJRA that these relationships will become clearer.

CONCLUSION

The SJRA and VAMP serves as a benchmark for flow related environmental restoration programs. As a result of the SJRA, agencies and stakeholders throughout the San Joaquin River and Sacramento River watersheds are seeking similar programs for flow related restoration programs. Over the first five years of the SJRA and VAMP a number of intermediate conclusions have been reached, with recommendations being followed for the improvement of the program. Uncontrollable factors of hydrology, climate, and ocean conditions all influence the survival of salmon populations making the VAMP a new challenge each year, yet stakeholders and agencies support the continuation of the program.

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LINKING IRRIGATION PRACTICES TO THE QUALITY OF DRAINAGE WATERS

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ABSTRACT

Water quality has always been a challenge for irrigators in arid and semi arid regions either with respect to finding water of suitable quality to apply to crops or finding means of disposing of saline drainage water. With the intensification of agriculture and the addition of fertilizers, pesticides, and other chemicals to enhance crop growth, a greater range of pollutants are found in irrigation and drainage waters, resulting in growing concerns about the quality of water in and around irrigation-drainage systems. Combined with increasing competition for scarce water resources for urban and environmental uses, the quality of water used in agriculture is coming under ever-closer scrutiny. For example, assessment of total maximum daily loads (TMDLs) are underway in the USA and elsewhere to specify the maximum amount of salts and other pollutants allowed in drainage waters of agricultural watersheds.

To assist growers in complying with TMDLs, an improved irrigation practice was developed in Imperial Valley, California, to minimize or eliminate surface runoff from fields with clay soils. Minimizing or eliminating surface runoff has numerous benefits including reducing the amount of water applied (thereby lowering irrigation costs and increasing the availability of water for more productive uses elsewhere) and improving the quality of drainage waters (thereby lowering costs by avoiding the need for disposal and meeting quality standards). The improved practice was initially applied to fields on a research station, and, after it was found to be viable, the practice was successfully applied to a commercial field. In both situations, application of the improved irrigation practice and reduction of surface runoff resulted in crop yields being maintained

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and salinity in the crop root zone being within acceptable concentrations. The improved irrigation practice increased irrigation efficiency and reduced sediment loads in drainage waters. In addition to the reduction in sediment loads, the irrigation practice reduced the load of soluble phosphorous in surface runoff water.

INTRODUCTION

Irrigation in arid and semi-arid regions has always had two challenges with water quality: finding water of suitable quality to apply to crops and disposing of poor quality drainage water resulting from the need to remove undesirable salts from the crop root zone. Historically, the main requirement was to leach salts brought in by the applied irrigation water and left behind after crop evapotranspiration. The residual salts comprised mainly of minerals and other elements dissolved in the applied water, but also included naturally occurring salts leached out of the soil profile. With the intensification of agriculture and the addition of fertilizers, pesticides, and other chemicals to enhance crop growth, a greater range of pollutants are found in irrigation and drainage waters, resulting in growing concerns about the quality of water in and around irrigation-drainage systems. Combined with increasing competition for scarce water resources for urban and environmental uses, the quality of water used in agriculture is coming under ever-closer scrutiny.

In order to ensure the quality of water for other uses, governments are setting water quality objectives for the reasonable protection of beneficial uses of water or the prevention of nuisance within specified areas, by establishing limits or levels of water quality constituents or characteristics for drainage waters from agricultural watersheds.

In California and elsewhere, how much of a salt or other pollutants a waterbody can tolerate on a daily basis is determined by setting a Total Maximum Daily Load (TMDL). A TMDL for agricultural drainage is defined as the load allocations for non-point source of pollution and natural background pollution, plus a margin of safety such that the capacity of the waterbody to assimilate pollutant loadings without violating water quality standards is not exceeded. A TMDL can be expressed in terms of either mass per time, toxicity, concentration, a specific chemical or other appropriate measures.

To comply with TMDLs and mitigate the impacts of agriculture drainage waters on other uses, irrigators and farm managers have to be more attentive to the quality of the water applied and the quality of drainage waters leaving their fields, as they must adjust their irrigation practices to ensure compliance with the regulatory standards.

In this paper, we discuss how an improved irrigation practice (Grismer and Tod, 1994 and Bali et al., 2001) was developed in Imperial Valley, California to assist growers in complying with TMDLs for sediment and phosphorous loads by significantly reducing surface runoff from fields with clay soils. Minimizing or eliminating surface runoff has additional numerous benefits including reducing the amount of water applied (thereby lowering irrigation costs and increasing the availability of good-quality water for more productive uses elsewhere) and reducing the volume of drainage water (thereby reducing disposal costs).

LOCATION OF THE STUDY

The Imperial Valley is located 120 miles (195 km) east of San Diego, California in the North-western Sonoran Desert. Rainfall is about 3 inches (75 mm) per year and agricultural production is completely dependent on irrigation water diverted from the Colorado River through the All American Canal and delivered by the largest irrigation system in Southern California. About 2.8 million acre-feet (3.45 billion cubic meter) of Colorado River water are diverted annually to irrigate more than 500,00 acres (202,342 ha). Field crops including alfalfa, wheat, and Sudan grass are grown on 80% of irrigated land. Agricultural production from Imperial Valley contributes about one billion dollars in gross income to the California economy (Imperial County 2003).

Alfalfa is the principal crop in the Valley. As much as 1.1 million acre-ft (1.36 billion cubic meter) of water are used every year to irrigate 170,000 acres (68,850 ha) of the alfalfa crop. The alfalfa crop is irrigated approximately 16 times during the year, commonly with two irrigations between each cutting. During an irrigation event, the flow is usually cut off when the wetting front has reached about 80% along the length of the field. Approximately 15-20% of the applied water ends up as surface runoff (Meister, et al. 2004).

Approximately one-third of applied irrigation water leaves fields as surface runoff and subsurface drainage waters that eventually flow into Salton Sea. The Sea has been serving as a drainage sink for the Imperial Valley since the early 1900's. Drainage flows from Imperial Valley account for about 85% of the total annual inflows to the Sea, the Sea continues to exist primarily because there is no outlet and the annual inflows are almost equal to the 6 ft (2 m) annual evaporation from the Sea.

The Salton Sea is the largest inland body of water in California and provides significant habitat for fish and wildlife. Rising concentrations of salts, sediments, nutrients, and pesticides threaten these habitats. For example, the deterioration in water quality caused by high nutrient loads (mainly phosphorous and nitrogen) and sediments originating from agricultural drains have resulted eutrophic conditions that damage fish populations.

TMDLs are being developed by the state government to improve the water quality of the Salton Sea through a participatory process involving the main stakeholders. Currently the two TMDLs of concern to Valley growers are the Salton Sea Nutrient TMDL and the silt/sediments TMDLs for drains and rivers in the Valley. Silt/sedimentation standards have been developed for the rivers and drains in the region (CEPA 2003), and discussions are proceeding on the TMDL for phosphorous (P-TMDL). Tentatively, the Technical Advisory Committee for the Salton Sea P-TMDL have proposed a 25-50% reduction in external phosphorous load to the Salton Sea. A significant reduction in the phosphorous loading of drainage waters can be achieved by altering irrigation and fertigation (applying nutrients through irrigation water) practices to reduce the concentration of phosphorous in surface runoff water.

IRRIGATION AND PHOSPHOROUS MANAGEMENT PRACTICES

Surface irrigation, by mainly of furrows or border checks, is the primary method for irrigation in the Valley, and is used on more than 90% of the cropped area. Drip irrigation is used on less than 5% of the cropped area and mostly on vegetable crops. Sprinkler irrigation is mostly used to germinate some crops, but growers switch to surface methods once the crop is established.

Approximately 22 million lb (10 million kg) of phosphorous (in the form of P_2O_5) is used annually to fertilize the alfalfa crop (Meister et al., 2004), and this amount accounts for almost 50% of the total phosphorous applied to crops in the Valley. Phosphorous is applied once or twice per year as water-run phosphorous during the growing season with subsequent yearly applications in the springtime, or applied at a higher rate prior to planting to meet alfalfa demand for the entire growing season (approximately 3 years). The estimated phosphorous load in surface runoff waters is approximately 10-15% of total applied phosphorous. In addition, phosphorous may move directly to surface waters via sediments carried in the surface runoff, and via cracks in the soil to subsurface drains.

The field trials discussed in this paper focused on reducing the phosphorous loading of drainage waters by applying an improved irrigation method to eliminate or greatly reduce surface runoff. The improved irrigation practice that was initially applied to fields at the University of California Desert Research and Extension Center (UCDREC) in Holtville, Imperial Valley, and, after the practice was shown to be viable (Bali, et al., 2001 and Grismer and Bali, 2001) the practice was applied to a commercial field in the Valley.

IMPROVED IRRIGATION METHOD

The improved irrigation method (Bali et al., 2001 and Grismer and Tod, 1994) reduces surface runoff to less than 5% of applied water for clay soils. The method is based on determining the cut-off time necessary to minimize runoff and to improve water use efficiency, and is a combination of the volume balance model and the two-point measurement method (Elliot and Walker 1982). The cut-off time or cut-off distance is calculated for a given border check layout on the basis that the total volume of water applied equals that volume stored on the surface plus the volume stored in the soil (subsurface storage). For clay soils, the volume of water stored in the soil is roughly equivalent to the volume of the cracks, as the advance of the wetting front is linear (Grismer and Tod, 1994).

During an irrigation event, the volume of applied water is estimated from measuring the inflow rate and the time since irrigation began. The surface storage is calculated from the product of the average depth of water and the area covered by water. The volume of the subsurface storage is the difference between the applied water and the surface storage. The total volume of applied water required is then determined by calculating the subsurface storage for the whole field.

METHODOLOGY

The field trials were designed to assess the effectiveness of the improved irrigation method in reducing the load of soluble phosphorous and sediment in surface runoff water. The trials were conducted on an 80-acre (32 ha) commercial alfalfa field. Alfalfa was planted on 102 ft (31 m) wide and 1250 ft (380 m) long border checks in October 2000 and a single application of 500 lb/acre (560 kg/ha) of P_2O_5 (11-52-0) was applied to the whole field prior to planting with no subsequent P applications during the growing season. The northern 40 acres (16 ha, North field) were cultivated following common commercial methods that included the normal 15-20% tailwater discharge (surface runoff). The other 40 acres (16 ha, South field) were cultivated using the improved irrigation method to reduce tailwater discharge to about 5% of applied water. Irrigation practices on both fields followed common practices between the time of planting in October 2000 and the first cutting in February 2001, but thereafter the improved irrigation method was used on the South field. Other than altering the duration of irrigation events and the volume of water applied, all other agricultural practices were identical on both fields. Both fields were harvested between February 2001 and August 2003. Alfalfa yields were determined from sample cuttings in 48 locations (two 0.25 m^2 quadrants along each border check at 91 and 274 m from the irrigation turnouts) in each field. Also, immediately after baling, we counted hay bales on each border, weighted selected bales one bale from each border, and recorded bale moisture from bales in each border. From bale data, we also estimated hay yields.

Both fields were irrigated sequentially at a rate of approximately two irrigations per cutting. The quality and the rate and amount of Colorado River water delivered and the rate, amount and quality of surface runoff were determined for each irrigation event and flow rates were measured using trapezoidal and long-throated flumes, for applied water and surface runoff respectively (see Table 1 for details). Irrigation and surface runoff water quality parameters (N, P, turbidity, and salinity) were determined using standard analytical methods, as shown in Table 1. The sediment load in surface runoff water was determined from the runoff rate and duration and the corresponding turbidity measurements. Pesticide residue loads in surface runoff water were determined for irrigation events that followed any pesticide application.

Table 1. Analytical instruments and flow rate measurement methods and quality assurance objectives.

Parameter	Method	Units	Detection limit	Sensitivity	Precision	Accuracy
Water delivered	Trapezoidal flume	Cfs	0 to 25	0.5 cfs	±4%	±10%
Runoff water	Long-throated flume	cfs	0 to 9	0.2 cfs	±5%	±10
PO_4	US-EPA 365.2 (Acid Persulfate Digestion)	mg/L	0-3.5	0.01	±5%	±5%
Salinity	EC (Tanji, 1990)	dS/m	0-3.0	0.05	±2%	±5%
NO_3	Spectrum™ (Cadmium Reduction Method)	mg/L	0-30.00	0.01	±5%	±10
Turbidity	US-EPA 180.1	NTU	<0.02	0.01	±10	±10

RESULTS AND DISCUSSION

Alfalfa yields obtained from both the North and South fields were similar for almost all of the 22 cuttings (see Figure 1). The average whole-field yield from the South field was lower than that of the North field by less than 2%. However there were no significant (P=0.05) yield differences between both fields. Despite the significant reduction in surface runoff, alfalfa yields for the South field were not significantly impacted by the improved irrigation practice. We used 123 ac-ft less water on the South field as compared to the water use on the North field. Water use efficiency (WUE) may be defined as the amount of dry matter produced per unit of water applied. On the South side of the field WUE, as Mg of hay per ac-ft of water was 1.51; WUE on the North side of the field was 1.23. The improved irrigation method increased WUE by 22.7%.

Using the turbidity values for the South and North fields and the tail water runoff estimates for both fields, we estimated the sediment load in runoff water. The average silt load per irrigation on the south end of the field was approximately 0.14 Mg/irrigation while the average load was 0.51 Mg/irrigation on the North field (Table 2.). The improved irrigation method reduced sediment load in surface waster by more than 50%. Tailwater PO_4 concentration was 2.11 mg/L for the South field and 2.12 mg/L for the North field. However, because of the volume of runoff water was substantially less for the South field as compared to the North field, the load of P in runoff water was greatly reduced. The load of P was reduced by almost 70% on the South field as compared to the North field.

Table 2. Average water quality and yield parameters of irrigation water and surface runoff waters.

Parameter	Runoff water- Improved irrigation practice	Runoff water-Normal irrigation practice
Runoff rate % (runoff water/applied water)	5.89	17.36
Total sediment load in runoff water Mg/irrigation	0.14	0.51
Total PO_4 load kg/irrigation	2.04	7.48
Total water, 38 irrigations, ac-ft	509.48	632.49

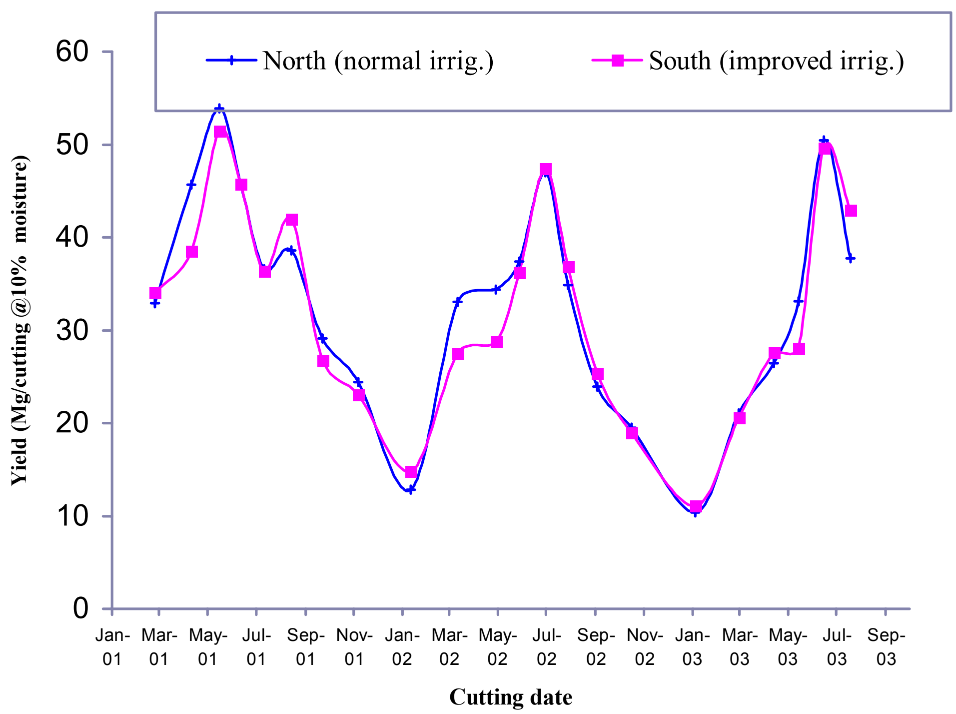

Figure 1. Alfalfa yields distribution.

CONCLUSIONS

Application of the improved irrigation method resulted in significant reduction in the amount of phosphorous and sediments leaving the fields. The reduced-runoff irrigation method did not have any significant impact on yield in this study. By reducing surface runoff growers may be able to reduce the amount of these pollutants draining to water bodies to meet the current and the expected TMDL standards. With increasing interest in water quality, agriculture practices may have to be adjusted to minimise the impact of drainage water on other beneficial uses.

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A PROACTIVE APPROACH TO WATER QUALITY IN THE YAKIMA RIVER BASIN

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ABSTRACT

Coupled with three consecutive drought years (1992-1994), water right adjudications, more stringent safety regulations, new listings of species under the Endangered Species Act, and enforcement of the Clean Water Act, the mid 1990's represented a tough period for Yakima Valley farmers. It was a time when the agricultural community was scrutinized by environmental groups and the legislature. To make matters worse, the two most productive irrigation districts in the valley, the Roza and Sunnyside Valley Irrigation Districts, were in a court battle over the payment structure of their jointly maintained drains.

The prominent farmers of the Roza and Sunnyside irrigation districts realized this was a period when the agricultural community needed most to work together rather than against each other. With that in mind, the Roza-Sunnyside Board of Joint Control (RSBOJC) was formed in 1996.

The original goal of the RSBOJC was to create an entity with a stronger political voice and greater financial strength with the ultimate objective of improving the reliability of water supply through water conservation, water transfers and increased storage. However, shortly after the formation of the RSBOJC, the Washington State Department of Ecology (WADOE) established a Total Maximum Daily Load (TMDL) for DDT and sediment for the Yakima River.

The focus of the RSBOJC quickly shifted to water quality. The board decided an aggressive and proactive approach of voluntarily trying to improve the water quality in the Yakima River Basin was the best strategy. A joint policy was implemented between the two districts with the intent of meeting the TMDL 2002 target date goals established by the WADOE.

The RSBOJC water quality policy proved to be not only successful but influential as well. The RSBOJC water quality policies now serve as the model for other irrigation districts to follow. In 1998 Washington State Governor Gary Locke recognized the RSBOJC with the Environmental Excellence Award.

This paper presents an overview of the RSBOJC and its proactive approach to improving water quality in the Yakima River Basin as well as the lessons learned from this experience and the benefits gained.

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INTRODUCTION

The Yakima Valley is located in South Central Washington, along the eastern slopes of the Cascades Mountains in the lower Yakima River Basin. According to the Yakima Basin River Alliance, Yakima Basin agriculture generates over $1.3 billion annually and employs over 50,000 people. The 450,000 irrigated acres within the Yakima Valley produce an abundance of crops such as hops, apples, stone fruits, mint, asparagus, and wine grapes.

Water is supplied to the basin from the Yakima and Naches Rivers and five storage reservoirs with a combined capacity of 1 million acre-feet. Utilizing the reservoirs, the United States Bureau of Reclamation (USBR) manages the water and the diversions to the six divisions which makeup the USBR Yakima Project. Of the six divisions, the Roza Irrigation District (Roza) and the Sunnyside Division (Sunnyside) are the two most productive and influential divisions in the valley.

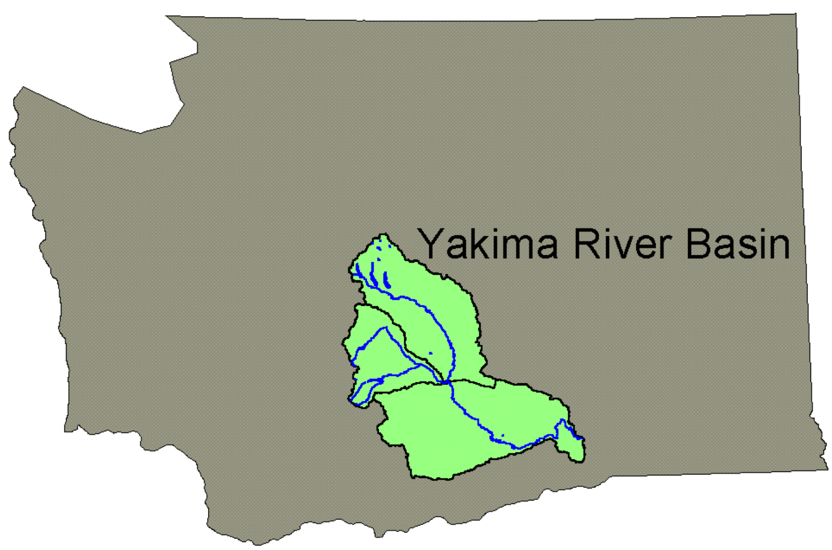

Figure 1. The location of the Yakima Valley River Basin relative to Washington State.

The Roza Main canal is 94.8 miles long, serving 72,000 acres along the northern rim of the lower Yakima Basin. The District delivers water to 45,000 acres below the main canal by gravity and 27,000 acres above the main canal via 18 pumping plants. Irrigation water is diverted from the Yakima River in the Ellensburg Canyon at the Roza diversion dam. The Roza Irrigation District has 375,000 acre-feet of junior or proratable water rights.

The Sunnyside main canal parallels the Roza canal above and the Yakima River below. The Division is approximately 70 miles long and 12 miles wide. Irrigation water is diverted from the Yakima River just below the City of Yakima at the Sunnyside diversion dam. The Sunnyside Division delivers water to 99,244 irrigable acres. Approximately two thirds of its entitlement is senior or non-proratable and one third is junior or proratable.

Prior to the formation of the Roza-Sunnyside Board of Joint Control (RSBOJC, often pronounced as Bo-Jack) the relationship between the Roza and Sunnyside irrigation districts could be characterized as antagonistic competitors.

ROZA-SUNNYSIDE BOARD OF JOINT CONTROL

Mark Twain has said, "Whiskey is for drinking, water is for fighting." That sums up the mood of Yakima Valley Farmers in the year of 1995. After three consecutive drought years, the Endangered Species Act listing of Steelhead and Bull trout as a "threatened" species in the Yakima River basin and increased pressure from the Washington State Department of Ecology (WADOE), farmers were feeling stressed. To make matters worse, the Roza and Sunnyside irrigation districts were in a court battle over the operation and maintenance costs of approximately 80 miles of joint drains common to both Roza and Sunnyside. As a method to address increasing state regulatory pressures, federal legislative mandates, competing supply needs, and internal conflicts, Roza and Sunnyside formed the Roza-Sunnyside Board of Joint Control composed of board members from each district.

With the creation of RSBOJC, the districts had greater financial strength and a stronger political voice to tackle the issues affecting its landowners. In addition, it enabled both entities to work cooperatively to develop joint projects and goals.

Initially, the primary goal was to increase the water supply through water conservation projects, water transfers and additional storage. However, with the WADOE's evaluation of the Yakima River and subsequent establishment of a Total Maximum Daily Load (TMDL) for return flows to the Yakima River, RSBOJC redirected its focus to water quality.

WATER QUALITY POLICY

In 1997 WADOE established a TMDL that set a 90th percentile (90% of measurements taken) Nephelometric Turbidity Unit (NTU) target of 25 NTU by the year 2002 for all return flows to the lower Yakima River. To meet the TMDL goal, RSBOJC decided upon an aggressive and proactive approach to meet these goals.

With the help of advisory workgroups composed of land owners, irrigators, state and federal entities and other interested parties, RSBOJC adopted a comprehensive water quality policy. The goal of the policy was to have the mouth of all drains and tributaries comply with the 90th percentile turbidity target of 25 NTU by the end of the year 2002. To achieve this goal, RSBOJC established a monitoring program, set water quality goals and standards for irrigation runoff, improved infrastructure through special projects, and developed a loan program.

The first step towards meeting its water quality goals was to establish base line data. This was accomplished by developing an in-house water quality lab accredited by the WADOE. Procedures were developed for measuring flow and analyzing data. The lab was responsible for collecting and measuring turbidity and sediment loading data from the four major drains entering the lower Yakima River. In addition, laboratory analyses are conducted from samples taken from discharges leaving parcels that, by visual observation, appear to be in violation of RSBOJC policy. A huge factor in the success of the RSBOJC water quality policy was the credibility of the lab. Both the WADOE and the United States Geological Society recognized the lab for producing sound data.

The next step involved attacking the water quality problem at its source, on-farm runoff. The on-farm runoff was attributed to rill or furrow irrigated land.

Figure 2. Furrow irrigation often results in sediment loaded runoff.

Furrow irrigation involves applying water to a ditch or furrow at the top of a field and then collecting the water in a tail ditch at the bottom of the field. Typically, the water from the tail ditch will flow to a drain that will ultimately end up in one of the major drains addressed in the WADOE TMDL. As shown in Figure 2, unfortunately, the runoff collects sediment along the way and is the primary source of sediment loading in the drains.

1997 RSBOJC policy stated that, "all irrigation runoff discharged to project waterways either directly or indirectly from lands within RSBOJC boundaries must comply with the water quality goals established by the RSBOJC." As a method to achieving those goals, RSBOJC established the following target goal for 1997:

- When the sum of the NTU reading exceeds 2000 from three or less consecutive samples taken no more than weekly from a parcel, the discharger/operator will be in violation of RSBOJC policy.

Once a discharger is deemed in violation of RSBOJC policy they must do the following:

1. Develop and submit a short-term plan to the appropriate district, and implement the corrective action specified within the plan, within 10 days of the violation or prior to the next irrigation, whichever is shorter. A short-term plan typically includes at least one of the following: application of PAM (Polyacrylamide), reducing furrow flow rate, border strips, piping the tail ditch, sediment basin.
2. Develop and submit to the appropriate district a long-term plan by the start of the next irrigation season. The plan will include a time schedule to implement proposed practices and projects to achieve target goals.

If a short-term plan is not submitted, or after submittal the sum of three or less samples exceed the applicable target goal, the appropriate district will reduce the discharger's delivery rate to 0.37 cfs (166 gpm) per 40 acres (4.2 gpm/acre). If, after this rate reduction, the discharger continues to be in violation of RSBOJC water quality policies, the water delivery rate is further reduced to 0.25 cfs (112 gpm) per 40 acres (2.8 gpm/acre).

Water will not be delivered the following water year to a parcel in violation until a long-term plan has been submitted and approved. If the discharger continues to be in violation of RSBOJC policy, the rate reduction procedure outlined above is implemented.

To meet the 2002 goal of the TMDL, the runoff NTU target goals have become increasingly more stringent each successive year of the RSBOJC water quality policy as shown in Table 1 and Figure 3.

A third component of the RSBOJC comprehensive water quality plan was infrastructure improvement through special projects such as large sediment basins. However, the largest project was a constructed wetland.

Table 1. RSBOJC Turbidity Target Goals

Year	Turbidity Target Goal (NTU)
1997	2000
1998	1000
1999	1000
2000	500
2001	500
2002	400
2003	400
2004	400

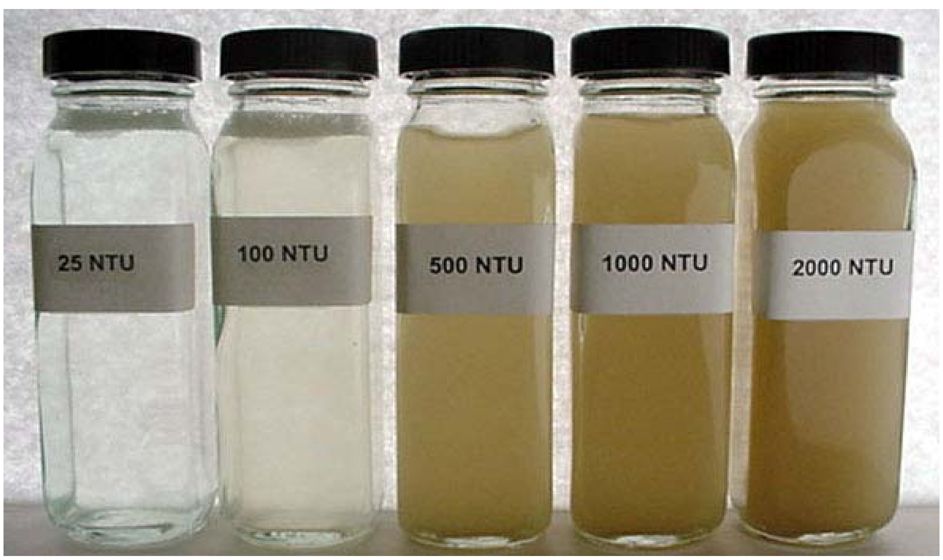

Figure 3. Physical depiction of sediment at various NTU levels showing progressively more stringent target goals for on-farm runoff.

By the year 2000, the RSBOJC water quality policy was already deemed successful by the entity that mattered, the WADOE. With that success, RSBOJC gained notoriety and funding opportunities. In 2000, the Washington State legislature awarded RSBOJC a $250,000 grant to implement a water quality project. RSBOJC decided to construct a wetland as a demonstration project to show how a wetland can act as a filter in removing total suspended solids, fecal coliform, nutrients, and reduce turbidity.

The last major component of the RSBOJC water quality policy was a loan program. Again, with success comes funding. RSBOJC applied for and was awarded a $10,000,000 loan to be used for RSBOJC landowner projects, which improve water quality such as conversions from furrow irrigation to sprinkler or drip irrigation and tail water return systems.

MEASURE OF SUCCESS

In 1998 Governor Gary Locke awarded RSBOJC the Environmental Excellence Award based on the success of its water quality policies. A dramatic example of that success is shown in Figure 4. Taken during the same time of year, the picture highlights the reduction in sediment loading at the mouth of Sulphur Creek between 1997 and 2000. As shown in Figures 5 and 6, for three out of four targeted drains, the 2002 TMDL goal of 25 NTU was not only met but surpassed. Meeting the goal of 25 NTU in the Granger drain continues to be elusive. However, the water quality in the Granger drain has substantially improved. A huge measure of success is the reduction in sediment loading at the mouth of the Granger and Sulphur drains from 100 tons/day to 12.6 tons/day and 150 tons/day to 16.8 tons/day, respectively.

Figure 4. As can be seen above, sediment loading has substantially decreased at the mouth of the Sulphur Creek drain, also known as Sulphur Creek Wasteway.

By examining the data, it is obvious the RSBOJC comprehensive water quality policy was a success, but why?

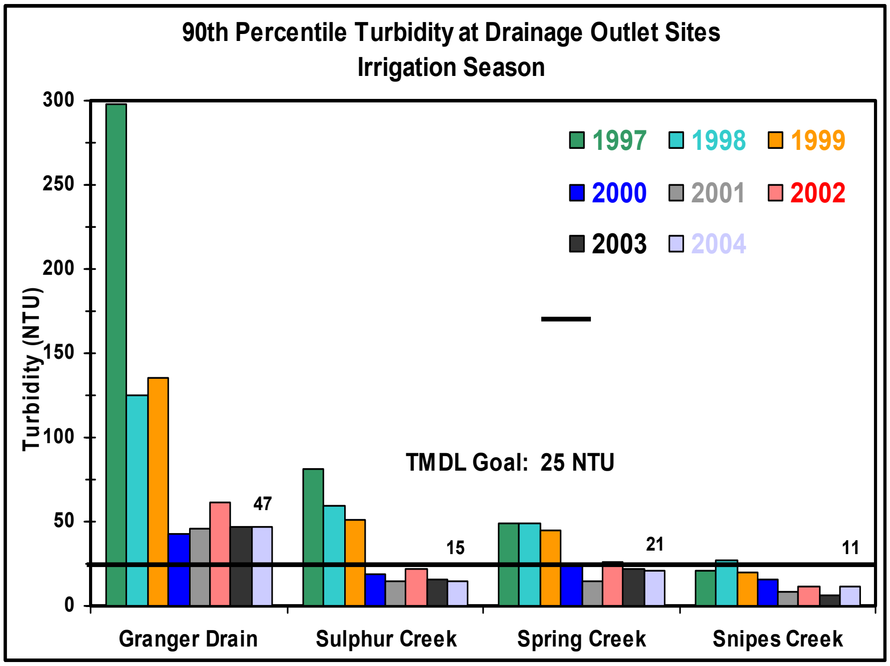

Figure 5. As of 2004, three out of the four targeted drains have met the 25 NTU goal established by the WADOE.

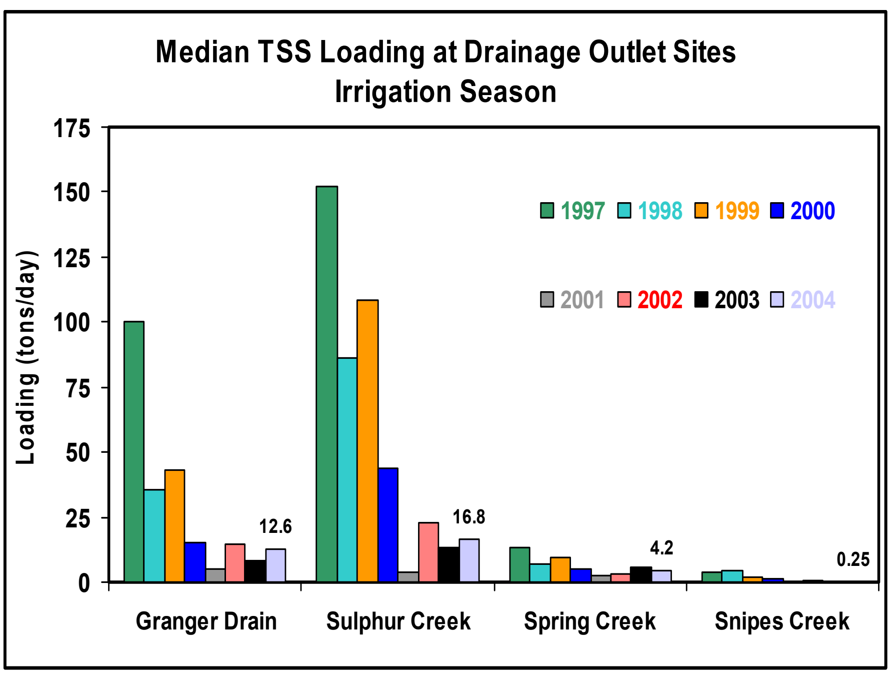

Figure 6. Although the turbidity target goal has not been met on Granger Drain, as with all four drains, the sediment loading has been greatly reduced.

The answer starts with the individual Board members of the Roza and Sunnyside irrigation districts. When subjected to an unfunded state mandate, rather than being passive and doing nothing, which likely would have forced the state or federal governments to implement punitive actions, which likely would have led to a costly and expensive court battle, the Board decided to be proactive. But the Board was not only proactive, it was aggressive. It directed policy right at the source, on-farm irrigation practices. The Board members, being farmers themselves, knew they needed a hammer for the policies to be effective and they knew no farmer could ignore a reduction in flow rate. Flow rate reduction is not a trivial matter. In the Yakima Valley we are talking about high value crops such as grapes and cherries.

The typical reaction to RSBOJC's water quality policy from farmers outside the Yakima Valley starts with, "what gives you the right…" But therein lays the biggest reason the RSBOJC policies were successful, the Yakima Valley farmers bought into it.

For the most part, the farmers approved of the RSBOJC water quality policy. They believed that if they were not proactive, and at the least, appeared to be addressing the water quality problem in the Yakima River, the Federal government would indeed step in and mandate much harsher policies than the WADOE. The farmers believed the RSBOJC was acting in the long-term interests of its constituents. In addition, through the forum of RSBOJC workshops, the farmers were intricately involved in developing and approving policy. The few farmers that were unhappy were encouraged to attend workshops and debate policy. In this way the farmers were taking ownership in the policy.

SUMMARY

By being aggressive and proactive, the RSBOJC developed and implemented a water quality policy that has become the model of success for irrigation districts. Many of the components that make up the policy have been adopted by other districts. For example, several other districts in Washington State, such as the Columbia Basin Irrigation District, now have loan programs to help farmers fund water quality and water conservation projects.

Many lessons have been learned since the RSBOJC water quality polices were implemented in 1997:

- Proactive policies encourage unlikely partnerships. For example, Roza and Sunnyside irrigation districts typically did not see "eye to eye" with the WADOE, whose job it is to enforce the Clean Water Act. The RSBOJC water quality policies made not only RSBOJC look good, but the WADOE as well. With improved water quality in the Yakima River there is recognition of the WADOE for successfully administering the mandates of the Clean Water Act. Mutual success has led to mutual respect, which has led to additional partnerships such as the $10,000,000 loan program.

- To be effective, policies should aggressively attack the source, such as on-farm irrigation, rather than passively attacking the problem with only high profile, but low yield projects, such as sediment basins.

- Policies need a hammer. As good as the intentions are of farmers, the RSBOJC policies would have likely been ineffective without the authority and the gumption to reduce the on-farm flow rate of violators.

- With success comes political clout. Environmental groups generally do not look favorably at irrigation districts. Yet when you are receiving awards for environmental excellence, you may also be receiving insulation from your adversaries.

By successfully implementing its water quality policy goals, RSBOJC has been awarded several of its original charter goals, that is, greater financial strength and a larger political voice with which to protect its farmers.

In conclusion, if more farmers would buy into the idea that the best defense against unfunded mandates is an aggressive and proactive approach to solving the water conservation and water quality problems in the West, then they too could reap the rewards that come with success stories, for it really can be a win-win situation.

NUTRIENT MANAGEMENT REGULATIONS IN DELAWARE AND MARYLAND

William F. Ritter [1]

ABSTRACT

Delaware and Maryland have developed nutrient management regulations. The nutrient management regulations came about because agriculture is the largest source of nonpoint source nitrogen and phosphorus loads in the Chesapeake Bay watershed and Delaware's Inland Bays watershed. Maryland's nutrient management regulations are regulated by the Maryland Department of Agriculture, while in Delaware the Nutrient Management Commission consisting of 19 appointed officials representing different interests oversee the nutrient management regulations. The Delmarva Peninsula has intensive broiler production. In counties with intensive boiler production over 75% of the soils test high in phosphorus. Both Delaware and Maryland regulations are based upon phosphorus to determine application rates.

INTRODUCTION

The Delmarva Peninsula produces about 600 million broilers a year. The intensive broiler production is located in the Chesapeake Bay watershed (Figure 1). There have been a number of reports since the 1970s that have documented the water quality impacts of the poultry industry. In Sussex County, Delaware over 75% of soils test high or very high for phosphorus. Poultry producing counties of Maryland also have 75% or more of the soils that test high for phosphorus. In a comprehensive groundwater study in the early 1980s Ritter (1982) found 32% of the wells had nitrate concentrations above 10 mg/L. Since agriculture is the largest nonpoint source of nitrogen and phosphorus in the Chesapeake Bay watershed and Delaware's Inland Bays, both Delaware and Maryland have passed nutrient management regulations.

MARYLAND REGULATIONS

In 1998 the Maryland legislature enacted the Water Quality Improvement Act (WQIA) (MDA,2004) which mandated sweeping changes for Maryland agriculture. The WQIA required

- nitrogen and phosphorus based nutrient management plans.
- reduction of the phosphorus in manure via feeding regimes.

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- provisions for transporting animal manure from fields showing excessive phosphorus to fields needing additional nutrients.
- inspection of records.

The WQIA requires anybody with 8 animal units or more or more than $2500 in gross animal income to have a nutrient management plan. Initially nutrient management plans were based upon nitrogen requirements, but in 2004 all plans are to be based upon phosphorus as the limiting nutrient. In addition, commercial lawn care companies, landscapers and certain non-agriculture fertilizers applicators are required by law to follow Maryland Cooperative Extension guidelines when applying nutrients to lawns and fields. The non-agricultural applicators include golf course managers, public grounds keepers and athletic field directors.

The Maryland Department of Agriculture's (MDA) Nutrient Management Program is responsible for carrying out the requirements of the WQIA. It is responsible for overseeing calibration and licensing of nutrient management consultants as well as continuing education and applicator training programs for consultants and farmers.

The WQIA requires nutrient management plans to be developed by certified consultants who must pass an exam by the end of 2003. There were 982 certified nutrient management consultants at the end of 2003. The figure includes 147 farmers who are certified and 320 individuals who are actively uniting plans. Consultants have to file an annual report with MDA.

The certification training for farmers who want to write their own nutrient management plans, is a two-day session. On the first day the participants learn the fundamentals of nutrient management and work through a model plan. On the second day they take a certification exam and work with Maryland Extension staff to develop a nutrient management plan for their own operation. Farmers who are non-certified and apply nutrients to 10 or more acres of cropland are required by the WQIA to attend an applicator training course every three years.

Under the WQIA two incentive programs were developed. The Maryland Agricultural Water Quality Cost-Share Program provides financial assistance to farmers who hire private contractors to prepare nutrient management plans for their operation and for updating their plans every three years. The reimbursement rate is 85.5% of the cost of the plan, up to $3500 per operation. The second incentive program is the manure transport program. The program helps poultry, diary, beef and other livestock producers cover the costs of transporting excess manure identified by their nutrient management plans off their farms. Any animal producer with high soil phosphorus levels or too little land to apply their manure can receive cost-share assistance of up to $18 per ton to transport excess manure to other farms or alternative use facilities that can use the product safely.

Maryland's goal is transporting 20% of the poultry litter produced on the Lower Eastern Shore to other areas. A manure matching service supports the transportation program by linking farmers who have excess manure with others who can use the manure as a fertilizer in an environmental safe way to the WQIA.

Maryland also has a nutrient management plan implementation review process. Operators are selected randomly by MDA for a plan implementation review. The basis of the plan implementation review is to evaluate the operator's documented records of actual nutrient applications against records of planned nutrient applications contained in the current nutrient management plan. In certain situations MDA may also verify the compliance of a P-Site Index related best management practice if required.

MARYLAND'S RESEARCH AND EDUCATION PROGRAM

The University of Maryland's College of Agriculture and Natural Resources (AGNR) has expanded its nutrient management research and education efforts in agriculture and urban communities in response to the nutrient management regulations. They have programs throughout the College on nutrient management in livestock production, nursery and greenhouse industries, home landscapes and parklands, and vegetable and field crops. The College plays a vital role in the state's nutrient management education programs. It co-sponsors continuing education programs with MDA for certified consultants to meet their continuing education requirements. In 2003, a total of 965 people attended workshops.

Research has focused on reducing nutrients in manure by reducing the amount of nitrogen and phosphorus fed to animals while maintaining a given level of production. Several of the research projects in this area includes:

- determining the best use of phytase in broiler diets such that phosphorus excretion is minimized.
- feeding of beneficial microorganisms to improve nutrient utilization in broilers and to decrease nitrogen and phosphorus in the litter.
- investigation of the impact of soil phosphorus levels on grain phosphorus content and types of phosphorus and availability of it to broilers.
- investigation of urea-nitrogen in the milk to fine tune dairy cow diets and decrease the potential for under feeding or overfeeding proteins.
- investigate the relationship of dietary phosphorus to dairy herd health and reproduction.

DELAWARE'S NUTRIENT MANAGEMENT REGULATIONS

Delaware's Nutrient Management Act established in 1999 has a 19-member commission that is charged to develop, review, approve and enforce regulations governing the certification of individuals. The Commission representatives are appointed from a broad cross-section of businesses and organizations so that all nutrient management interests in the state are represented on the Commission (DNMC, 2003).

The Commission's responsibilities include:

1. Consider establishing critical acres for voluntary and regulatory programs;
2. Establish best management practices to reduce nutrients in the environment;
3. Develop educational and awareness programs;
4. Consider incentive programs to redistribute nutrients;
5. Establish the elements and general direction of the state nutrient management program;
6. Develop nutrient management regulations

Nutrient management plan development started in 2003 and will be completed by 2007. The people will be randomly selected in 20% increments. Any business operation that applies nutrients to10 acres or more or manages 8000 pounds of animals or poultry needs a plan. Besides having a nutrient management plan, the operators must

1. Maintain nutrient handling records.
2. Submit one page annual reports.
3. Become certified by attending classes by January 2004.

Plans are developed by certified private consultants or by nutrient consultants of the Sussex and Kent conservation districts.

Nutrient management training under the regulations is done by the University of Delaware Cooperative Extension. In 2002, the University conducted 166 certification classes. Along with training, Cooperative Extension has also implemented demonstration projects on 28 Delaware farms. They include:

1. Starter fertilization on corn
2. Poultry litter application rates
3. Pre-side-dress soil nitrate test
4. Field evaluations of amended poultry litter to reduce phosphorus concentrations.
5. Use of diagnostic tools to improve nutrient management

The Commission also has a nutrient management relocation program under the Act. The Commission provides cost assistance for poultry litter cleanout, loading and transport to alternate use projects or farms. The farmer has the option of moving the litter themselves and being reimbursed by the Commission.

CONCLUSIONS

Delaware and Maryland have developed nutrient management regulations because of the environmental impacts of agriculture on the Chesapeake Bay and Delaware Inland Bays. In both states, nutrient applications rates are based upon phosphorus. In the counties on the Delmarva Peninsula with concentrated poultry production, over 75% of the soils test high or very high in phosphorus. In some areas there is a surplus of poultry manure. The poultry industry has started to develop alternative uses for the excess poultry manure.

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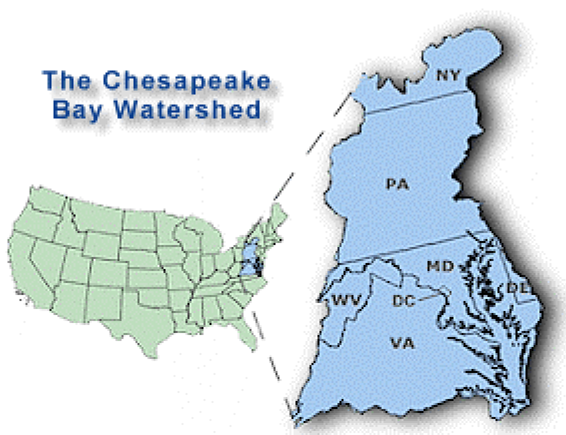

Figure 1. Chesapeake Bay Watershed

IRRIGATION MANAGEMENT TRANSFER TO WATER USER ORGANIZATIONS IN TURKEY

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Hasan Özlü[2]

ABSTRACT

Supplying irrigation water is very important in dry or semi dry areas like Turkey in order to produce sufficient agricultural production for the country. The main task is to manage irrigation system developed by government properly. Like in many countries, irrigation projects have been developed and managed by government organization in past several decades. In 1990s, government changed the policy concerning the management of irrigations and participatory approach has been adopted in the country

Up to present, Turkey developed slightly more than half of its total potential irrigable area (8.5 million ha). Taking part in the management responsibility of irrigation schemes, users organized as Water Users Organization (WUO) and took the responsibility of the management from the central government. The logic behind the transfer is to enable efficiency in terms of cost of Operation and Maintenance and higher quality of service in irrigation water distribution. This was to be achieved by the participation of water users. After a decade from the transfer we may conclude that Water User Organizations are managing the system quite well and their performance is highly satisfied.

INTRODUCTION

The purpose of this paper is to clarify the irrigation management reform conducted in Turkey during last decade. The role of central government in the management of irrigation schemes developed by the State has changed and redefined. Users took the new roles in irrigation management. They are not only service receiver anymore but also provider. It is important to answer why users participation is required for irrigation management in state developed and managed irrigation projects. Irrigation Management Transfer (IMT) is an outcome of the government policy that it has been implemented by the State Hydraulic Works (DSI), one of the major government organizations, responsible for developing water resources in the Country. Government has changed policy in irrigation water management from central to local (users).

Turkey's uneven rainfall regime necessitates irrigated agriculture. Up to present, Turkey developed slightly more than half of its total potential irrigable area. Most of the irrigation projects have been developed and

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managed by the government. In 1993, State Hydraulic Works (DSI) initiated accelerated transfer of Operation and Maintenance (O&M) services of irrigation schemes to Water User Organizations (WUOs). Irrigation Management Transfer (IMT) program has become very successful and 93% of DSI built irrigation projects (2.3 million ha) were transferred to WUOs up to present. WUOs performance in O&M of their systems has been considerably satisfied. Sustainability of WUOs have been the main concern of the government. Necessary steps are being taken to overcome program shortfalls.

LAND AND WATER RESOURCES

General

Turkey has settled on a large peninsula between 35-42 north latitudes and has been surrounded by the Black Sea in the north, the Mediterranean Sea in the south and the Aegean Sea in the west. Turkey has a total area of 78 million hectares (mha), of which 76.5 mha is land and the remaining 1.5 mha is water surface. The population of Turkey is about 70 million with annual growth rate of 1.5%. The share of agricultural production in GNP is estimated as about 15% of the total whereas 40% of the total population is dealing with agriculture.
The average annual precipitation (643 mm), ranges from 250 mm at the central Anatolia to over 2 500 mm at the eastern Black Sea coast in Rize province. Meteorological data show that over 96 percent of the country gets inadequate moisture during plants' growing periods. Therefore application of irrigation water is necessary over the whole country to secure agricultural production.

Land Resources

Almost one third of total area 28.0 million hectares can be clarified as cultivable land, and according to the recent available comprehensive studies an estimated 8.5 million ha is economically irrigable under the available technology. The total area under irrigation is about 4.36 million hectares (net area), which includes private and public irrigation schemes (DSI and GDRS projects).

Water Resources

Turkey's hydrology is divided into 26 drainage basins. The rivers have generally irregular regimes and natural flows cannot be taken directly as usable resources. Average annual precipitation (643 mm), evaporation and surface runoff geographically vary greatly. The average annual runoff of the country is about 186.0 km^3, and the total safe yield of groundwater resources was determined to be 13.7 km^3 by means of comprehensive hydro-geological investigations carried out in Turkey. It is estimated that 95.0 km^3 of surface runoff and 10.9 km^3 of groundwater could be technically developed for consumptive purposes.

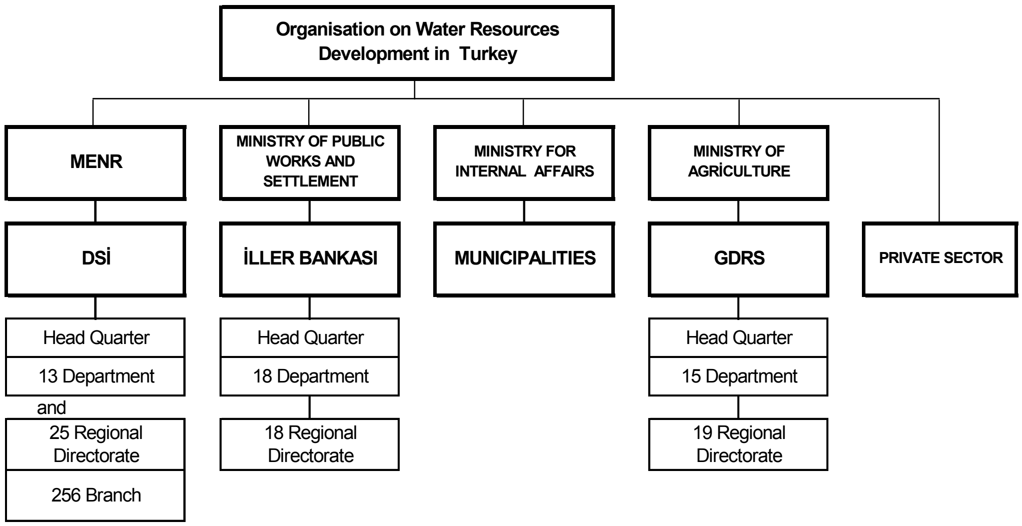
Presently, the actual consumption from surface waters is 40 km^3 per year. This shows that only 37.0 percent of the surface water potential has been consumed. Actual annual consumption of groundwater is 6.6 km^3. Agricultural sector is the major consumer (74%) of water where as domestic use (15%) and industrial use (11%) follow it with smaller portions.

IRRIGATION DEVELOPMENT

Institutions Responsible for Irrigation Development and Management

Irrigation development in Turkey is carried out by both the public sector, represented by DSI (State Hydraulic Works) and GDRS (General Directorate of Rural Services), and the private sector (farmers and group of farmers). DSI under the Ministry of Energy and Natural Resources (MENR), is a governmental organization, which has been established in 1954 by law coded 6200. This and the subsequent laws authorized DSI almost all aspects of water resources development of Turkey. DSI is responsible for the execution of the following activities; to investigate, search and develop surface and groundwater resources, to construct protective structures against floods and torrents, to construct irrigation and surface drainage systems, to construct big dams and hydroelectric power generation plants, to operate and maintain dams, irrigation and drainage systems, to supply water for drinking, domestic and industrial purposes for the cities with population over 100 000.

By the end of 2004 DSI completed the construction of 212 large dams and 346 low dams and developed 2 393 862 hectares of irrigation schemes. Proportion of agricultural sector in the investment budget of DSI is about 42%, which constitutes about 550 million USD in 2004. This share of total investment budget has changed from 30 to 55 percent in years passed.
The responsibility for on-farm development and minor irrigation works (with a discharge capacity of less than 500 l/s) belongs to the General Directorate of Rural Services (GDRS). GDRS deals with land leveling, land consolidation, sub-surface drainage works and irrigation network of minor irrigation projects. GDRS is also simultaneously working together with DSI in the large surface water irrigation projects and in the small size projects of groundwater irrigation cooperatives.



Development of Irrigation in Turkey

Irrigation demands cover 74 % of the overall water consumption. The growing period for most of the crops covers the summer months June, July and August of which have almost no rain and lowest base flows on the rivers, water storage, therefore, is indispensable. Currently, 558 storage facilities (212 large dams and 346 low dams) developed by State Hydraulic Works (DSI) are in operation. About 70 % of the irrigation projects use the water supplied by reservoirs and regulated natural lakes.

Table 1. Development achieved so far, as of end of 2004 is as follows:

Potential for Irrigation Projects	8 500 000 ha
Projects in Operation	4 395 862 ha (net)
DSI	2 393 862 ha
GDRS	1 002 000 ha
Farmers	1 000 000 ha
Projects under Construction	753 000 ha

On public schemes, the national average of the irrigation ratio (the part of the equipped area actually irrigated) varies between 60 and 70 % with wide regional fluctuations. Of the total area developed by the public sector (DSI and GDRS) for full and partial supply of irrigation water is from groundwater. DSI and GDRS have jointly developed about 393 000 ha that use groundwater. DSI drill the wells, install the pumps and set the power transmission lines while GDRS constructs the irrigation canals or pipes.

PARTICIPATORY IRRIGATION MANAGEMENT (PIM)

Irrigation Management Transfer (IMT) and Participatory Irrigation Management (PIM) are used interchangeably in this paper.

Background of Transfer of Irrigation Schemes in Turkey

Since 1954, Turkey has had a legal framework allowing the transfer of management responsibility for public constructed irrigation schemes to local control irrigation management by the Government. At the early sixties some small-scale irrigation schemes, which were isolated and far from the administrative units of DSI, had initially transferred to users with different approach from the Participatory Irrigation Management (PIM) concept we perceived today.

Before the accelerated transfer program was commenced, water user groups (WUGs) had been working at DSI managed irrigation schemes, which was accounted for 40 % of command area. Before 1993, DSI’s policy focused on transferring only small and isolated schemes, the management of which was difficult and uneconomical. Until 1993, small schemes total area of which was about 72 000 ha were gradually transferred to users. DSI's policy shifted from transferring only small and isolated schemes to an accelerated approach of transferring large schemes as well as small and isolated schemes.

In 1993, pilot transfer program was implemented effectively for transferring the irrigation schemes in the regions that WUGs had already been existed and worked efficiently, Antalya, Adana, Konya and Izmir regions, where DSI officials had shown a higher level of preparation and dedication and farmers were more receptive, considerable internal training, including seminars and workshops significantly contributed to the process. The main underlying reason for accelerating transfer program has been the operation and maintenance financial burden for DSI and the Government, which was getting unsustainable. The operation and maintenance cost recovery (rate of collection of water fees), has been unsatisfactory (about 40%). The present Government's general policy of promoting privatization was also a contributing factor.

Present Status of Irrigation Management Transfer

At present, O&M responsibility of about 1.85 million hectares have been transferred to water users organizations established in several different forms. Transfer is not restricted to a single type of user organization. Based on the user's preference and size of the related schemes, irrigation systems have been transferred to WUOs such as Water Users Associations (WUA), municipalities, village authorities and cooperatives.

Table 2. Organizational Distribution of Transferred Irrigation Schemes

ORGANIZATIONS	**No's**	**Rate (%)**	**Area (ha)**	**Rate (%)**
Village authority	227	29.1	37 351	2.0
Municipality	144	18.5	58 424	3.2
WUA	329	42.2	1 678 174	90.6
Cooperatives	74	9.5	76 533	4.1
Others	5	0.6	1 744	0.1
T O T A L	**779**	**100**	**1 852 226**	**100**

Rationale of PIM and Benefits of Transfer

Participation of Users and Self Management: Economic and technical efficiency of irrigation systems can be attained by developing a concept which can be formulized as "sense of ownership". A successful transfer should encourage water users to operate and maintain their systems through assigning them as stakeholders and through making these services without free of charge. This approach will in turn provide water security and sustainability. Water users constitute the major portion of the agricultural population (40%) in Turkey. In the past, because of the social pressure, their responsibility to join the irrigation management in the schemes developed by DSI was negligible. Turnover process has provided beneficiaries to take part in the governance such as electing their own board members and the management, determining the water charges to be collected, DSI has transferred the responsibility of O&M not only the tertiary and secondary canal level but also main canal of the irrigation schemes in order to strengthen user responsibility. IMT created a self-control both adequacy and quality of services supplied by WUA and control of budget with respect to revenue and expenditures.

The picture is quite different after the PIM, same farmer now does not dare to ask or demand water out of his schedule and feels like using water more efficiently to avoid paying high electricity cost in pumped irrigation.
One more example about the past can be given for gravity irrigation; damages to irrigation structures could not be recovered due to failure of finding the offender. Now with the PIM all the users feel obliged to safeguard the facilities and easily catch the offender. The person who causes damage pays normal cost of that damage before he is asked. Otherwise he pays fine which accounts for about 4 to 10 times more than that of the cost.

Good Governance: By transfer, WUO management consisted of chairman and WUO board become accountable for WUO assembly convenes at least twice a year where quality of irrigation scheme performance with respect to equitable water distribution, water use efficiency and upkeep of project facilities as well as budgetary control are discussed. Satisfactory performance of the WUO management and transparency are prerequisites for the next board election. This constitutes true self-control of WUOs at a democratic level. Water users are now well organized. They establish their own organization by and manage it themselves. Instead of individual demand of user WUO managers make their requests from government institutions on behalf of WUO. This make easier to meet the demand for both government and users. Farmers, accounted for 40 percent of the employment in the country, have had the right and responsibility to join the irrigation management such as choosing the manager, water charges to be implemented, making a decision on system management with the participatory irrigation management.

In transferred pump irrigations, users are very sensitive in running the pumps and using the water for irrigation.

Financial Sustainability**:** WUOs self-financing and budgetary control provides flexibility in finding optimum solutions to maintenance and further improvement of the system.

Decreasing O&M Cost and Increasing Collection Rate: Operation and maintenance cost of government decreased naturally with transfer and saved allocation is subject to be used in new investment of irrigation project or other ways by government. The number of operation and maintenance Staff of DSI decreased about 60%. Labor cost of DSI is considerably higher than that of WUOs because of strong Labor Union at DSI whereas WUOs pay minimum wage and employ seasonal labor when needed. This lower labor cost results in lower operation cost. Efficiency of seasonal labor employed by WUOs has been highly satisfied. WUO collection ratio of water charges has doubled.

PROBLEMS FACED BEFORE AND AFTER TRANSFER

There were experiences in transferring small scale and individual irrigation projects which are isolated and far from management unit of DSI. Besides this these projects were serving to only one village or small town. But in this case large irrigation schemes are subject to transfer to users. It was a big challenge that government has transferred management of irrigation projects without considering how large they are. How can they manage these large irrigation areas without having any help from government? There was a great suspicion on loosing jobs for DSI's staff after the transfer. Some old projects needed rehabilitation may not be easy to operate for users. WUOs were newly established and they needed training, technical guidance and capacity building on the management of the irrigation system.

Technical guidance and training needs of WUOs have been met by DSI and will be met in the future. However those trained technical staff of WUOs are not to be sustainable because of lower wage and not having of work guarantee. This makes

WUOs employ new technical staff for managing the irrigation system. Nobody lost his job because of transfer of irrigation management. DSI is such a large organization that staff have been moved to another departments such as planning, design and construction or retired voluntarily.

Aging problem for O&M Department because of not recruiting new staff for O&M services seems to be one of serious problems. By the time DSI may lose its O&M experience and be weaken. Although policy for the rehabilitation has been defined as participatory approach, Government sould develop an action plan for the long run. Role of the O&M Department is to be modified for sustaining O&M services in the long run and necessary measurements have to be taken.

In order to mainly meet the needs of machinery and equipment of WUOs, a project named Participatory Privatization of Irrigation Management and Investment Project (PPIMIP) was commenced by DSI with support of World Bank in 1998.

A Project Implemented (1998-2004) to Sustain IMT

Participatory Privatization of Irrigation Management and Investment Project (PPIMIP -Loan 4235):

DSI wanted to help meeting the urgent equipment needs of WUOs, which have been recently and rapidly established and took over the operation and maintenance (O&M) responsibilities from DSI, starting from 1993, for uninterrupted and successful O&M activities. At the same time, GDRS wanted to initiate changing its traditional investment policies that fully subsidized by the Government, as well as to help modernization of classical irrigation systems, operated by WUOs. Therefore, both state agencies DSI and GDRS, which are responsible for irrigation investments in Turkey, decided to implement this project, financed by the World Bank and executed by DSI, GDRS and WUOs (Water User Organizations = Water User Associations, Irrigation Cooperatives etc.).

Out of those, 308 WUOs, commanding an irrigated area of 1.59 million ha, have actually benefited from this component through the purchase of 567 pieces of heavy equipment (graders, excavators, loaders, tractors, etc.), and 3,204 pieces of small equipment (pumps, computers, motorcycles, etc.) at a total cost of about USD 36,5 million. The beneficiaries contributed more than 63 percent of that total cost, the remaining part being financed under the Project.

Under Pilot Rehabilitation Program component introduced with the amendment dated June 2001, investment activities have been implemented under contracts to be financed on a 50 percent basis by the loan and 50 percent contributions by the participating WUOs. Sixteen WUAs have participated in the pilot with rehabilitation contracts of about USD 3,800,000. These are the first examples in the country that have done substantial rehabilitation with large financial contributions from the members. These experiences have increased the interest among members of the WUOs and improved the trust between WUO management and members.

PERFORMANCE EVALUATION OF WUOs FOR 2003

Monitoring and Evaluation (M&E) studies have been carried out by O&M Department of DSI. WUOs have generally demonstrated the ability to operate and maintain the system satisfactorily, specifically setting up balance and equity in water distribution. Some findings from M&E study as average for 2003 are given below:

1. Irrigation ratio in transferred irrigation schemes and DSI managed were 66 % and 34 % respectively.

2. Irrigation efficiency was 41% when irrigation schemes was being managed by DSİ, after transferring this ratio increased to 44%.

3. Power consumption of pump irrigation schemes decreased after transfer. Average consumption was 1 323 kWh/ha in surface water pump irrigation schemes. However this figure decreased to 910 kWh/ha that accounts for 31% electricity saving provided by transfer.

4. By transfer, the number of DSI's O&M staff declined about 60 % and it will continue to go down until it reaches a certain number.

5. Collection rates of water charges are recorded about 39 % and 80% for DSI and WUOs, respectively.

6. Total budget of WUOs amounted 108 Million YTL (80 million USD) in 2003.

7. In 2003, expenditures of WUOs are 58% for operation, 28 % for maintenance-repair and 14% for others.

8.Technical managers of WUOs are usually agricultural engineers (70%).

Those performance indicators given above show that WUOs have performed quite well comparing to the government managed ones. Since 1994, DSI have organized several training programs in order to increase capacity building of WUOs. A total number of 1 068 staff of WUOs has been trained. 474 engineer, 408 accountants, 186 pump operators participated those programs organized in different times and years in local or national level. In addition to these, in the year 2000 and 2003 a three-day seminar was organized for the Chairmen of WUAs and Cooperatives to discuss over all issues. A follow up seminar was organized at national level for the Chairmen of WUAs and Cooperatives in May 2004.

WHAT IS NEXT FOR SUSTAINING OF WUA?

The following measurements should be taken to sustain IMT:

1. Flexibility should be given to WUOs in order to achieve their required and needed structural changes.

2. Given training, technical assistance and guidance by DSI to WUOs should continue until they get adequate experience in irrigation management.

3. In a transferred irrigation area, modernization and rehabilitation of irrigation system or network on cost sharing basis, should be given priority by the government. It was implemented with Pilot Rehabilitation Program (PRP) that is a sub component of PPIMIP.

4. As a matter of fact, a huge portion of the budget only covers the electricity cost. In order to provide sustainability of transferred pump irrigations, water charges should be determined realistically, irrigation ratio should be increased and irrigation methods should be replaced with efficient ones by WUOs. Price of electricity used in pump irrigation should be kept modest. Otherwise it may not be possible to compete with surface irrigation.

5. To change stakeholders' (users, politicians, technicians, farmers) mentality expecting full support from government is highly difficult handicap to be exceeded. So providing a close collaboration, information exchange among stakeholders and organizing training programs to train them are needed.

6. WUOs should set their fees (tariff) in order to balance with their expenditures of operation, maintenance, energy and equipment purchase.

7. If a large irrigation project is required to transfer to a number of WUOs, command areas of each one should be kept larger as much as possible.

8. DSI is monitoring and controlling the activities of WUOs but has not enough power of sanction for WUOs to fulfill operation and maintenance deficiencies in proper time with enough budget.

9. Shortcomings of WUO O&M services should be accountable for DSI. This topic can be surmounted by legislation proceeded.

10. Agricultural extension services have to be intensified in order to shift farmer's customary habits, to tell the latest development in the sector and agricultural policy and outdated farming practices, which hinder improvement of irrigated agriculture and reduce efficiency of the project.

11. Encourage users in participation of WUA management in order to create competitive environment.

12. Close contact of O&M staff with WUAs should be kept alive to inspect O&M activities.

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LIST OF ABBREVIATIONS

Bank	World Bank
DSI	State Hydraulic Works
GDRS	General Directorate of Rural Affairs
MENR	Ministry of Energy and Natural Resources
WUAs	Water User Associations
WUGs	Water User Groups
WUOs	Water User Organizations
IMT	Irrigation Management Transfer
PIM	Participatory Irrigation Management
PRP	Pilot Rehabilitation Program
PCU	Project Coordination Unit

Note: Unless stated otherwise, the area figures show net area.

ORGANIZING FOR INTEGRATED WATER RESOURCES MANAGEMENT[1]

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Stefan Sennewald[3]

ABSTRACT

The Ministry of Water Resources and Irrigation in Egypt recognizes that better water management is essential for maintaining a viable agriculture while facing increasing demands from other sectors of the economy and society. Beyond just recognition, the ministry has committed to implementing integrated water resources management (IWRM). This commitment is requiring the ministry to reassess its organizational structure. The authors have found the literature on IWRM to be strong on the principles and practices but weak on how a country should organizationally implement IWRM. This paper reports how Egypt is moving organizationally to implement IWRM. This is a work in progress and changes are to be expected as more experience is gained.

INTRODUCTION

Integrated water resources management (IWRM), which includes water demand management, is recognized as the only way nations will be able to successfully cope with increasing demands on limited supplies of fresh water. However, most, if not all, water management agencies, ministries, or institutions in the world are not organized to efficiently or effectively implement IWRM. "*When a large government agency with limited resources is the provider of the water delivery service, all the water users are effectively tail-enders and the first remedy is to divest the agency of its operational and management burden, including the responsibility for funding O&M expenditures*." (Skogerboe, Merkley, and Rifenburg, 2003)

The Ministry of Water Resources and Irrigation (MWRI) of Egypt has recognized the need for reform of the institution. To be able to monitor progress in reform it is important that the reasons for institutional reform be precisely articulated. In Egypt there are two primary *reform drivers*: a continuing rapid increase in the demand for fresh water while the supply is fixed and the high cost of continuing

[1] Some organization names were chosen by the writers for convenience. The contents of this paper are not intended to imply MWRI, USAID, or GTZ endorsement but reflect the thinking of the authors at the time of preparation.

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to subsidize the delivery of water to users. There are four primary *reform objectives*: increase water use efficiency, improve water distribution equity, improve water quality, and increase the participation of customers in water resources management decision-making. In Egypt, increased participation of customers is a key component of decentralized water resources management decision-making. "*The best operated irrigation systems in the world are managed by farmers, not government agencies*." (Skogerboe and Merkley, 1996)

Key donors in Egypt came together in 2001 to establish the Institutional Reform Unit (IRU) within the Ministry of Water Resources and Irrigation. However, the reform process began earlier. One could say it started in the early 1980's with the formation of the first mesqa—a small canal from which the farmer takes water—Water Users Association (WUA), a private organization. Since that time the reform process has moved slowly up the system with private Branch Canal Water Boards and Branch Canal Water Users' Associations (BCWUA) becoming involved in the management of branch canals. More recently, Integrated Water Management Districts (IWMD) are being formed within the MWRI organization. Most recently the Netherlands Embassy launched a program to establish a pilot District Water Board.

Reform and development are evolutionary processes with pilot implementation followed by reflection, evaluation, and process revision. While efforts are in piloting or testing stages a certain degree of un-clarity is acceptable. However, when pilots begin moving into the mainstream, as some are now beginning to do, organizational linkages, purpose/role, responsibility/function, and authorities must be clearly defined and disseminated. This paper will present some reflection on these concerns for organizational reform.

HUMAN RESOURCES MANAGEMENT

Organizational reform is more than redrawing organogramme boxes and moving people; this is easy. The hard parts are to determine the new mandates, roles, responsibilities, authorities, qualifications, reporting lines, and career paths for staff filling each organogramme box. When one realizes how hard it is to do this for each institutional office, repeating the work for each organogramme box can appear daunting. But it must be done. To further complicate the process, the strong interaction and dependency between the institution and each employee requires that institutional reform be a simultaneous iterative and multi-level effort.

Reform inherently involves changes in work processes and procedures, which creates a demand to teach people how to do things in a new and improved way. Unfortunately, employees often are expected to change habits built up over years with only a few hours or days of training. Or, employees are taught technical skills but not the social skills or attitudes needed to make the new arrangement work. When the new orientation is more customer service focused, attitude training is often as important as skills training. Successful decentralization of the MWRI and turnover of operation and maintenance of parts of the delivery system to users requires that MWRI employees interacting with farmer managers have a more customer service orientation. To ensure successful organizational change/reform, training must be continuous, provided in the right subjects, at the right times, and in sufficient quantities. Employees need training to start a new task but follow-up training is needed to help the employee solve problems encountered on the job. An organization in transition needs a full time human resources and training management team.

Under the ongoing implementation program a local consultant met with Directorate, IWMD, and Non-IWMD staff to identify reporting lines, tasks, qualifications, authorities, and responsibilities for all IWMD staff. In addition to the above, an output of the study was descriptions of training needs. Some of the required training has been completed and modules are being prepared for additional training. We have planned for reinforcement training and are developing continuous training programs to ensure staffs are competent and confident in doing their jobs. Yet to be settled are career paths. This aspect is perhaps the most difficult because the IWMD is a flat organizational structure and the MWRI has a vertical organizational structure. As reform moves up the MWRI organization career paths should become better defined.

MULTI-STAKEHOLDER PARTNERSHIPS

As mentioned in the first section of this paper, increased participation of customers is a key component of decentralized water resources management decision-making program of the MWRI. In essence multi-stakeholder partnerships are being formed. A key consideration for the formation of an effective partnership is that the organizations involved must have compatible motives for collaboration, a *common vision*. Key institutional requirements for development of sustainable partnerships are identified as the adoption of natural watershed boundaries (canals and drains), collective and cooperative approaches, participation of local constituents, and inclusive, transparent and accountable decision making at the local level.

There are requirements for the successful operation of a partnership. There should be a fair *balance* of representation and power among the participants. This is particularly important where issues cut across numerous government jurisdictions—water quality—and require consideration of different perspectives and sectoral interests. It must be flexible in order to respond sensitively to different circumstances and needs, *adaptive capacity*. Lateral rather than hierarchical decision-making structures can provide a greater degree of flexibility and are an important feature of many adaptive organizations. Collaboration does require additional resources and whilst the provision of *adequate human and financial resources* does not guarantee the success of a partnership, an absence of these elements is likely to seriously damage performance. *Independence* is a crucial factor for effective decision-making. A partnership must have a clearly defined function that does not duplicate the roles of existing organizations.

Compatible motives and sound procedures are important elements of a successful partnership to address water-related problems, but the actual impacts of the initiative are probably the most crucial indicators of performance. Without demonstrated impacts, the commitment of stakeholders in terms of both political and financial support is unlikely to be maintained. Nevertheless, the *outputs and outcomes* from a partnership can indicate progress towards long-term goals. Outputs are the products or services delivered whilst outcomes are a measure of the extent to which overall goals and objectives are being achieved. The importance of monitoring and reporting progress is recognized.

The paper presented in this conference entitled "Implementing District Level Integrated Water Management with Stakeholder Participation" offers more detail on how these aspects of multi-stakeholder partnerships are being addressed in the Egypt program.

ORGANIZATIONS — NEAR-TERM PERSPECTIVE

This section will offer preliminary descriptions of the organizational linkages, purpose/role, responsibility/function, and authorities of each level of the water management organizational structure in the near term proposed by the writers. Figure 1 shows how each organization links to the others during this transition phase.

Ministry of Water Resources and Irrigation (MWRI) The purpose/role of the Ministry is to ensure Egypt's limited water resources are used for maximum benefit to all citizens of Egypt. Functions could include: Repository of data, information, and knowledge concerning Egypt's water resources; Responsible authority for international water policy issues; National Legal, policy, and regulatory issues: water quality and water quantity; Water allocation to Governorates based on agreed allocation determination process and National Water Resources Plan; Management of Lake Nasser and River Nile; Supervision of Directorates (*DIR*); Licensing of Directorate Water Boards (*DirWB*); Post contract monitoring regarding Ministry assets (some delegated to DIRs).

Directorate (DIR) The DIR is the MWRI office fully responsible for water distribution in the governorate. Ensures the physical infrastructure is maintained and water delivery services are undertaken as per contractual agreements and delegated authorities. Some authorities may be delegated to the IWMDs and DirWB. Functions could include: Supervision, Monitoring, Licensing: DirWBs, BCWUA, WUA; industrial water use and disposal; Compliance with legal, regulatory, and contractual arrangements between DirWBs, BCWUA, WUA;

Industrial water use and disposal; Water allocation to IWMDs; Right to unscheduled inspections and sampling; Enforcement and assessment of penalties for violations; Data, information, and knowledge supplied to MWRI.

Directorate Water Board (DirWB) **[NEW]** There are certain functions that can only be done efficiently at the directorate level. The DirWB would have an umbrella function and serve as the interaction point between stakeholders, all water users, and the DIR as regards water allocation needs. In the near-term the Board would be responsible for reviewing data and information from the IWMDs: directorate water allocation needs, regulatory compliance information, etc. This organization would operate within a framework of regulations put in place by the central and governorate level of Government of Egypt authorities as well as their own constitution authorized by MWRI. The Board would be a private non-profit organization comprised of representatives elected by all stakeholder groups and representatives from key Government of Egypt institutions. Functions would include: Authority for fee assessment, collection, and management (under regulatory control); Stakeholder input – representative body, complaint receiving and resolution center, water allocation to IWMDs and BCWUAs; Political relations – issues advocacy; Water focused stakeholder awareness and training programs; Coordinate participatory pollution prevention and mitigation efforts; Agreements with other DirWBs on inter-boundary issues—canals and drains that cross boundaries; Data, information, and knowledge supplied to the DIR.

Integrated Water Management District (IWMD) The IWMD would be the lowest level of MWRI authority and in the near term responsible for technical aspects of integrated water resources management. The IWMD would be responsible for aggregating data and information from the BCWUAs that would be passed to the DIR and the DirWB. IWMDs should be established and functioning before the DirWB is established. By the time the DirWB is formed, it is expected that the IWMD organizational structure and staffing levels have been right-sized. Functions could include: Supervision, Monitoring, Licensing: industrial water users, BCWUA, WUA (as delegated by the Directorate); Compliance with legal, regulatory, and contractual arrangements: industrial water users, BCWUA, WUA (as delegated by the Directorates); Physical infrastructure operation and maintenance; Water quality and quantity monitoring; Water allocation and delivery to BCWUAs; Data collection, aggregation, and analysis (information formation); supplied to Directorate and DirWB.

Branch Canal Water Users' Association (BCWUA) The organization will take over full responsibility for branch canal maintenance and operation, including assessment and collection of fees to fulfill these functions. Decisions on spending these fees should be made by the paying users as represented by the BCWUA. In the near-term the BCWUA would monitor and serve as an independent check on the performance of the IWMD and DirWB. The BCWUA should merge with the equivalent drainage organization in its command area, if any. Inter-organizational

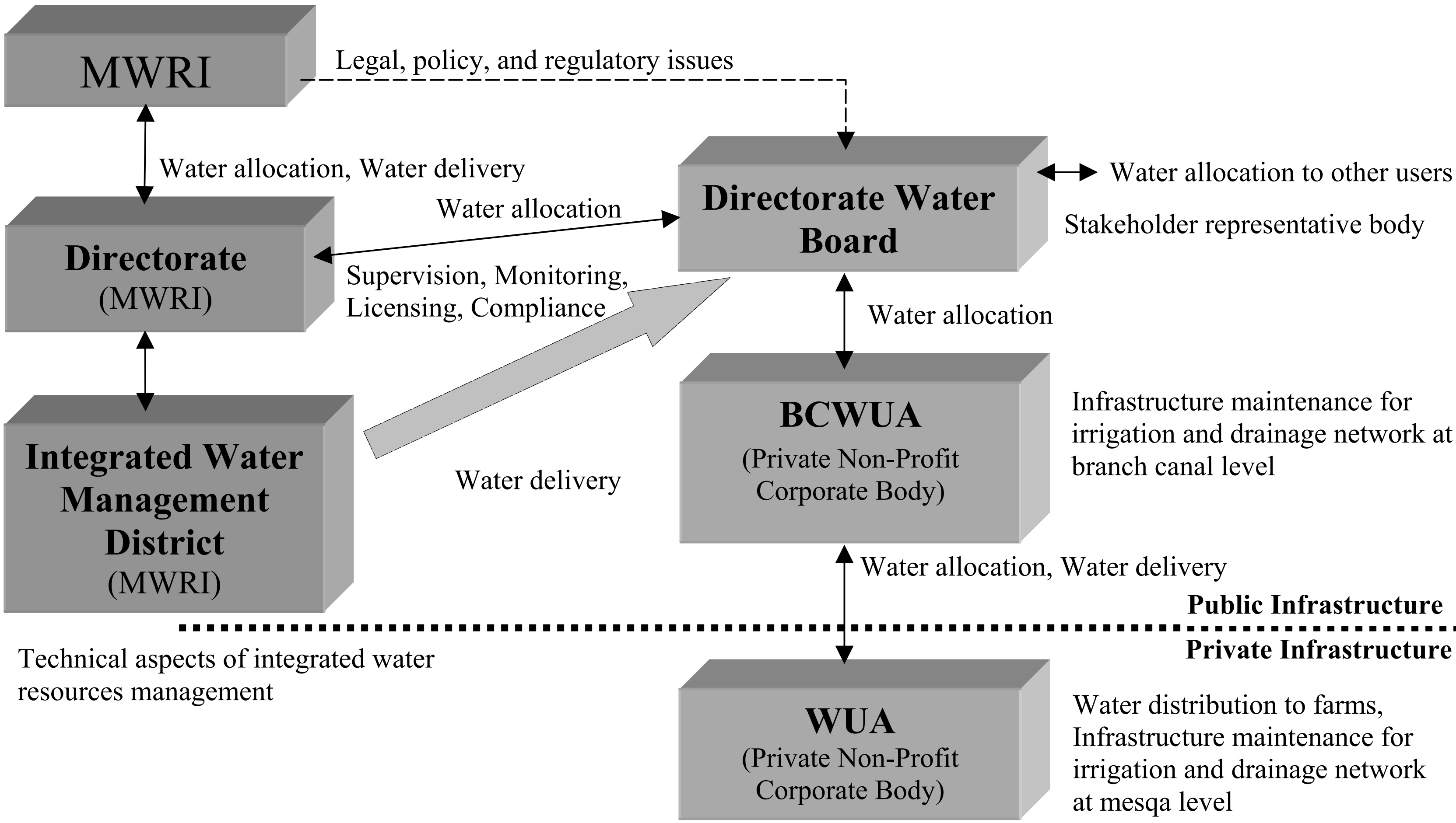

Figure 1. Functions and Relations of Water Resources Management Organizations (Near-Term, transition phase)

infrastructure can be managed by protocols and agreements between responsible organizations. Members elect officers by secret balloting and functions could include: Water distribution to WUAs (Mesqa level); Irrigation and drainage infrastructure maintenance at branch canal level; Data collection and transmittal to IWMD; Fee assessment and collection, management: Financial oversight—are members receiving value for fees paid (records transparency); and an Avenue for stakeholder input/feedback to IWMD and DirWB: performance monitoring.

Mesqa Water Users' Association (WUA) Responsibilities include: Distribution of water to farmers; Maintenance of infrastructure; Data collection: cropping pattern, changes in farm ownership/tenancy; and an Avenue for stakeholder input/feedback.

ORGANIZATIONS — MID- AND LONG-TERM PERSPECTIVE

The IWMDs are absorbed by the DirWBs, see Figure 2, and become the field arm of the DirWBs, which will be responsible for O&M of the irrigation and drainage system in the Directorate above branch canal level. The MWRI would delivery water directly to the DirWBs, from there to the BCWUAs and other users and finally to the WUAs. Where feasible, WUAs and/or BCWUAs would combine with drainage associations. This would reduce the number of organizations with which farmers must interact and better integrate management of the two water resources. The DirWBs will solve the current problem regarding representation for water users who are within the command area of a BCWUA but take water from the Main Canal and therefore are not members of the BCWUA.

Amendments to Law 12/1984 on Irrigation and Drainage are approved and BCWUAs become fully responsible for branch canal maintenance, improvement, and operation. Key amendments to Law 12 give the associations the legal right to open bank accounts, assess and collect fees from members, and to enter into legally binding contracts.

Legal authority for Supervision and Monitoring of DirWBs, Licensing, Compliance, and legal enforcement responsibilities would reside in the Directorate, which may have respective regional offices to assist in monitoring of compliance, supervision, monitoring of BCWUAs and WUAs and would focus on pollution control and prevention and water quality monitoring. Formation of a Compliance Board to offer a venue for stakeholder appeal of regulatory and compliance rulings. The Board would have three members: one each from the DirWB, Directorate, and a third member from the judiciary. Figure 2 shows how each organization links to the others during this operation phase.

In the long-term, responsibilities for potable water supply and collection and treatment of wastewater would come under the authority of the DirWB. The

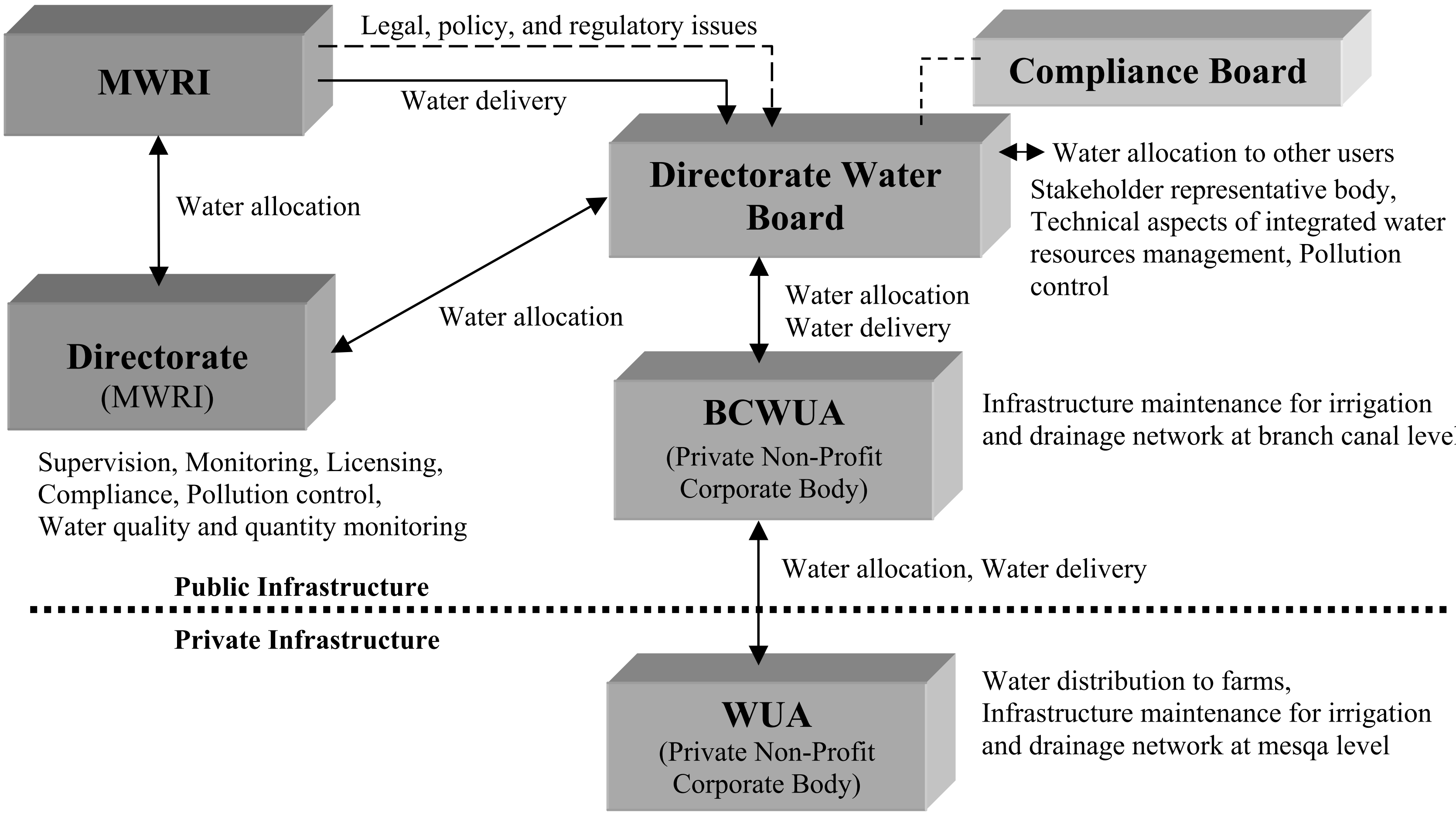

Figure 2. Functions and Relations of Water Resources Management Organizations (Mid-Term, operation phase)

Directorate ensures the DirWB, and in some cases local civil government, complies with applicable laws and regulations regarding management and treatment of urban, municipal, and rural water supplies. DirWB stakeholders have an interest in the proper treatment of wastewater and therefore would be a logical responsible authority.

IMPLEMENTATION ENVIRONMENT & PROGRESS

There are conditions that must be met for this approach, as well as any other, to work and be sustainable: Legal authorization, regulatory framework, and monitoring and enforcement systems must be in place before or soon after organization formation; Authority to act must be delegated by MWRI to the Directorate and IWMD, who in turn will delegate certain; functions and responsibilities to the DirWB and BCWUA, respectively; Protocols, contracts, and etc. must clearly define the roles, responsibilities, and authorities of all parties; Human resources/manpower concerns must be addressed early in the change process: training and capacity building must be provided sufficient funds and supported by decision makers; Public awareness of the process must cover all stakeholders and be continuous and ongoing throughout the transition; During the transition stage IWMDs and BCWUAs are essential to DirWB operation and success; Financial sustainability of established water user organizations must be addressed early and sustainability proven.

From December of 2003 to September of 2004 the MWRI, with USAID assistance, established 96 new BCWUAs to cover the command areas of the first four IWMDs. During this activity a conscious effort was made to develop sets of modular training materials and to maintain a complete documentation of the process. Subsequent to this effort a survey of integrated and non-integrated districts, directorates, and customers was conducted to identify aspects of the implementation program that could be improved. To broaden understanding of the IWMD and BCWUA concepts within the MWRI a videotape/video CD was prepared discussing the concepts, process, expected results, and impact on MWRI staff from the changes.

A new USAID funded effort, which started September 2004, will assist in the establishment of about 1,000 additional BCWUAs to fully cover 23 new IWMDs. Upon completion of this effort four Directorates will be fully served by the new organization structure, about 20% of Egypt's irrigated area. As an indication of MWRI commitment to the process, the MWRI has completed redrawing district boundaries and appointing Directors for the new IWMDs, about 6 months ahead of schedule. The MWRI is evaluating the feasibility of expanding the program to additional Directorates using primarily internally generated funds with limited donor assistance. The MWRI minister recently formed a committee to assess the impacts of IWMDs, BCWUAs, and the Netherlands Embassy supported District Water Board pilot on the roles and responsibilities of the Directorate.

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THE UPPER ARKANSAS WATER CONSERVANCY DISTRICT GENERAL PLAN OF AUGMENTATION UNDER THE WATER RIGHTS DETERMINATION AND ADMINISTRATION ACT OF 1969

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ABSTRACT

In 1969 Colorado enacted legislation that resolved the conflict over the use of surface and tributary ground waters. This legislation was crafted to determine priorities of use and right between surface diverters and tributary ground water users and to efficiently maximize the utilization of water resources. The means to achieve efficiency and flexibility of use would become known as augmentation plans.

Although irrigation wells were not replacing all depletions from their out-of-priority diversions in the Arkansas basin the State's water administrators continued with administration policies that only partially embraced the 1969 Water Rights Determination and Administration Act. The unintended results of ignoring the inequities caused by this administration reached a crescendo in the Upper Arkansas Valley in 1978 encouraging the creation of the Upper Arkansas Water Conservancy District in 1979. Created under the water conservancy statutes developed during the reclamation period of the early 20th century, this District has as its primary mission the protection of the historic use of water and the protection of water rights from out-of-priority depletions (especially caused by well use).

In 1992, the Upper Arkansas Water Conservancy District applied for a "first of its kind" blanket augmentation plan to provide a mechanism through which out-of-priority depletions caused by well water use could be replaced to the effected tributaries. The plan was approved by the water court in 1994, in time to meet the large demand for augmentation caused by the fallout from the Kansas v. Colorado law suit and the subsequent adoption of the Arkansas Basin's "Amended Rules and Regulations Governing the Diversion and Use of Tributary Ground Water in the Arkansas River Basin in Colorado". In Colorado, water entities are utilizing this blanket plan to develop solutions for replacement of depletions caused by out-of-priority well pumping. Since 1994, the Upper Arkansas Water Conservancy District has developed a network of small storage facilities and a network of court approved augmentation plans to provide water for commercial, domestic and agricultural water use as well as pond evaporation replacement.

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INTRODUCTION

In 1969 the Colorado Assembly overhauled the "Colorado Doctrine of Appropriation" which was adopted by immigrant miners and irrigators who settled in and around the snow capped peaks of Colorado. Diverting native water from the many streams that originate from Colorado's mountains gave rise to mining and irrigation practices that represent the history of most of the state. The courts and the legislature responded from time to time to tune the process, but not until passage of The Water Rights Determination and Administration Act of 1969 (the 1969 Act) did the lawmakers make major comprehensive revisions to Colorado "Water Law".

The new legislation ushered Colorado on to the stage of the 21st century to address determination and administration of water rights to Colorado's natural streams and ground water tributary thereto. Most of the changes were procedural to meet the needs of a growing state in need of a means for recognizing, securing and administering water rights, including non-tributary ground water not subject to the doctrine of prior appropriation[3], and including instream flows not previously appropriable.

The 1969 Act authorizes enforcement authority in the state engineer and grants the engineer to adopt rules for the administration of water rights within each of seven water divisions to meet the needs of such division and downstream delivery obligations to nine other states pursuant to interstate compacts. It was the litigation between the State of Kansas and the State of Colorado[4] that created special emphasis for the need of a lawful right of domestic and irrigation water users to augment out-of-priority water uses without injuring the rights of senior

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[3] In Colorado the doctrine of prior appropriation is founded on the basis of statutory and case law. Generally there are four major elements: (1) water in its natural course is the property of the public and is not subject to appropriation (except for preservation of the environment as a decreed in-stream flow right which may be held solely by the Colorado Water Conservation Board), (2) a vested right to use the water may be acquired by appropriation for a beneficial use, (3) the first person in time to use the water is the first in right, and (4) beneficial use is the basis, the measure, and the limit of the right. Further the measure of the beneficial use is often expressed as the amount of historic depletion. Water rights can be acquired through appropriations from surface or ground water sources. Both surface and tributary ground water are subject to the priority doctrine.

[4] In December 1985, the State of Kansas filed a motion with the United States Supreme Court for leave to file a complaint against the State of Colorado alleging, among other things, that post-compact well development along the Arkansas River in Colorado had materially depleted usable Stateline flows in violation of the Arkansas River Compact.

appropriators and remain in compliance with the 1948 interstate compact between the State of Kansas and the State of Colorado.

The 1969 Act authorized the innovation of augmentation plans approved by the state engineer and sanctioned by water court decree to enable out-of-priority tributary water use through the provision of replacement water from storage to compensate for consumptive use depletions.[5]

WATER USE FLEXIBILITY

Formation of the Water District

The Upper Arkansas Water Conservancy District (UAWCD), located on Colorado's Southeastern front- range[6] was born in response to the effects of the drought of 1977 and 1978 and in response to the need to provide water services and protection for the upper valley water rights. A fundamental doctrine of Colorado water law is to recognize the rights of senior appropriators and under federal law to protect water rights of neighboring states. The genius of the 1969 Act was to provide legal vehicles that could operate within these fundamental principles and allow property owners to utilize locally available supplies of tributary surface water and tributary ground water without injuring the stream. This would be accomplished with state and division supervision.

As a consequence of the settlement between Kansas and Colorado the state engineer promulgated "Amended Rules and Regulations for Administration of Water Rights in the Arkansas River."[7] Following months of public hearings and committee meetings, the amended rules and regulations were presented to the water court for final approval. After several weeks of evidence and testimony, the court issued a decree, which brought all tributary water, except in-house use, under the strict rule of priority. Commercial water well users, many of which had operated for years with domestic well permits, were required to comply with the new rules and regulations or cease pumping. Virtually every well user other than

[5] Use of surface or tributary ground water may occur without a decreed right through means of a plan for augmentation. The depletions occurring through this use must be replaced by time, amount and location as set forth in a decreed augmentation plan. An augmentation plan may also be used with a decreed water right (surface or ground water) when that water right is not in priority. This is referred to as out-of-priority use. In this instance the out-of-priority depletions associated with the out-of-priority use are replaced through the means of a decreed plan of augmentation.

[6] The Upper Arkansas Water Conservancy District includes the Colorado Counties of Chaffee, Western Fremont and Custer County. (See Maps in Appendix)

[7] Case number 95CW211

the private domestic household was faced with compliance. New commercial users would meet the same requirements.

Blanket Augmentation

In 1992 UAWCD under a wholly owned Water Activity Enterprise filed with the water court a first impression general plan for augmentation covering the majority of the District's territory on the main stem of the Arkansas River and on the South Arkansas River using transmountain water supplies and the yield of some native water as the primary base of stored consumptive use water to replace stream depletions created by out- of-priority water use. With consultation and guidance from the Division No. 2 Engineer and the State Engineer, boundaries for operation of the plan were drawn to provide general coverage on streams served by reservoirs managed by the District, and limited coverage in drainages without reservoirs and on which exchange decrees had not been granted by the water court. The primary source of trans-mountain water under the original filing is Twin Lakes Reservoir and Canal Company shares. This water originates on the western slope of the Colorado Mountains and is diverted by tunnel to the front-range for storage in Twin Lakes Reservoirs. The water is totally consumable, and with approved engineering municipal use can be recaptured and reused to extinction. The District plan of augmentation allows for adding Twin Lakes Water incrementally as it acquires available shares. The water is extremely versatile because each share includes storage rights in Twin Lakes, and can be stored in other vessels from the upper valley to Pueblo Reservoir. Unused annual supplies can be carried over and traded to other reservoirs if mandatory spills are required to accommodate new storage in Twin Lakes. An integrated augmentation system was created when the District developed other plans for Arkansas River tributaries not able to be served by the original blanket plan. In addition to some native water owned by the District trans-mountain water supplies have been integrated into these adjunctive augmentation plans.

A secondary trans-mountain water source is the Frying Pan-Arkansas Project managed by the Southeastern Colorado Water Conservancy District (SECWCD) and operated by the Bureau of Reclamation (the Bureau) under federal law. This water, like Twin Lakes water originates from the Colorado River basin. The water is stored in Turquoise Reservoir and in Pueblo Reservoir. Its primary limitation for the District is the requirement that it must be used within the territorial boundaries of the SECWCD. In the upper basin, this includes municipalities, but narrowly follows the Arkansas River. Project water, however, can be stored outside the SECWCD boundaries and can be used to replace reservoir evaporation. One of its chief utilities is Bureau imposed price, which is about $8.00 per acre-foot per year. At this price the District can operate irrigation plans under its plan of augmentation if the irrigated property lies within the SECWCD boundaries. Project water is allocated annually by that district and the water can be stored in Pueblo Reservoir, Turquoise Reservoir and in other District reservoirs. As with Twin Lakes Water, Project water can be traded from Turquoise and Twin to Pueblo Reservoir, and visa versa, by administrative trades.

Operation of the Plan

Prior to the advent of the Upper Arkansas Water Conservancy District "blanket" plan of augmentation, augmentation plans covering one well and its historic use required an applicant to find and purchase credentialed water with storage, retain legal and engineering services and adjudicate the plan in water court. Not only expensive and difficult, the adjudication process typically requires two years. The District's plan simplified this process. It consists of an administrative process with application for augmentation and a time period of 60 to 90 days for completion. This new concept of a "blanket" plan for multiple uses covering a large geographic area necessitated the development of a business administration plan as well as an integrated water management plan by the District. Water management requires acquisition of water, storage and exchange rights strategically located throughout the various tributaries of the District to meet water demands in each of the geographic regions.

UAWCD operates its plan of augmentation by selling a license for annual use of fractional shares of water and water storage rights in its storage system. Location of the reservoir releasing replacement water is determined by the Division Engineer. The District sells an "Augmentation Certificate" that coordinates well location on the same grid system used by the State Engineer for well permits. The primary unit of water on each certificate is 0.10 acre-feet. Approximated 1/3rd is designated for in-house use and the balance for outside irrigation. This accommodates the normal domestic use and allows for a minimal lawn or other outside use. The primary unit can be supplemented by additional units of consumptive use water based upon user needs or based on an engineering analysis, with approval of the Division Engineer. The current basic cost of a unit is $2500 one time, with annual reservoir maintenance fee of $125 per unit. The cost of the units encourages "xerophytic landscaping", and also permits the user to substitute lawn or shrubbery for domestic livestock. Subject to Division Engineer and State Engineer approval, the plan's flexibility can meet almost any reasonable need.

Administration of the Plan

Since this was the advent of blanket style augmentation, a wholly new method had to be devised to manage the plan. The location, timing and amount of water replacement required a unique form of management and administration. The Enterprise, created to administer the plan, developed an automated approach based on electronic accounting. This approach was essential, since as the number of plan participants increased the accounting tasks rose exponentially.

Customized point of sale type software was developed to process applications as the transaction occurred. Entries into the database record a participant's biographic information, location, amount and type of water use. Information is included that identify the area of depletion impact, source of replacement water, and the amount of transit loss. Transit loss is calculated from the source of the replacement to the point of depletion impact for each well in the system. The transit loss calculation is based on a standard transit loss factor used in the Arkansas Basin of .07 percent per mile. The distance is calculated using Universal Transverse Mercator (UTM) coordinates to locate the source of replacement and the point of use (well location). The UTM information is automatically gathered from the State's Well Database for each location of use. In addition each database record includes information on annual meter readings and is used as a financial accounting database for billing and payment recording.

Reporting to Colorado Division Water Engineer is required on an annual basis. The database allows generation of this annual report. Other reports can be generated based upon an infinite number of desired results. This allows the Enterprise Manager to calculate the amounts, and source of replacements that need to occur on a monthly basis.

During the first years the amounts of replacement were very small, therefore the Division Engineer allowed slug releases to be used for depletion replacements. As the plan developed and the monthly depletions became more significant, the Division developed a model for replacements based on the location and type (i.e. domestic, irrigation or commercial use) of depletion. This model has been adopted by the Enterprise and now replacements follow the model on a monthly basis.

BLANKET PLAN BECOMES A WATER PROJECT

Typically water projects are storage reservoirs, pipelines or some type of infrastructure used to deliver water. In the case of the blanket augmentation plan, it is a series of decrees administered by the use of native water rights, exchange rights, trans-mountain water and small storage facilities located at the headwaters of major tributaries to the Main-stem Arkansas River operated in conjunction with a "large bucket", Pueblo Reservoir in the Lower Arkansas Valley. Collectively the "plan" forms a project that continues to develop as new areas are added by decree. Integrated with the new decreed areas are new water rights and facilities. In the case of trans-mountain water rights these are added on as needed and/or as available basis. The flexibility of this project became apparent after several years of operation and demand for augmentation, due to growth of new developments spurred by the desire of retirees to locate in the Colorado Mountains, required the addition of new areas, more water rights and storage facilities to meet the demand.

Compared to large metropolitan areas the quantities of water are very small in this blanket augmentation plan. The area served, which includes small municipalities with independent water systems, has a total population base of approximately 18,000 people. Beginning in 1994, the plan served fewer than 100 units (10 acre feet of water) and today the plan serves nearly 1400 units. Combined with the irrigated uses this project now replaces 300 acre-feet of water to the river system annually. Based on the plan's standard depletion factor the amount of water appropriated is approximately 1200 acre feet annually or about 390 million gallons.

Initially the District adopted the blanket augmentation plan concept in response to a need for augmentation of existing wells impacted by the Arkansas Basin's adoption of well regulations in the wake of the Kansas v. Colorado case. But inherent in the plan was the general mission and goals of the District to provide a means to retain water rights in its basin. The plan provided a vehicle through which water could be purchased and retained for both present and future uses in the Upper Arkansas Valley. Since the District holds more than sufficient water resources to serve its present needs it has recently embarked on a joint-use venture with other entities to provide minimum flows for fish habitat and other riparian values.

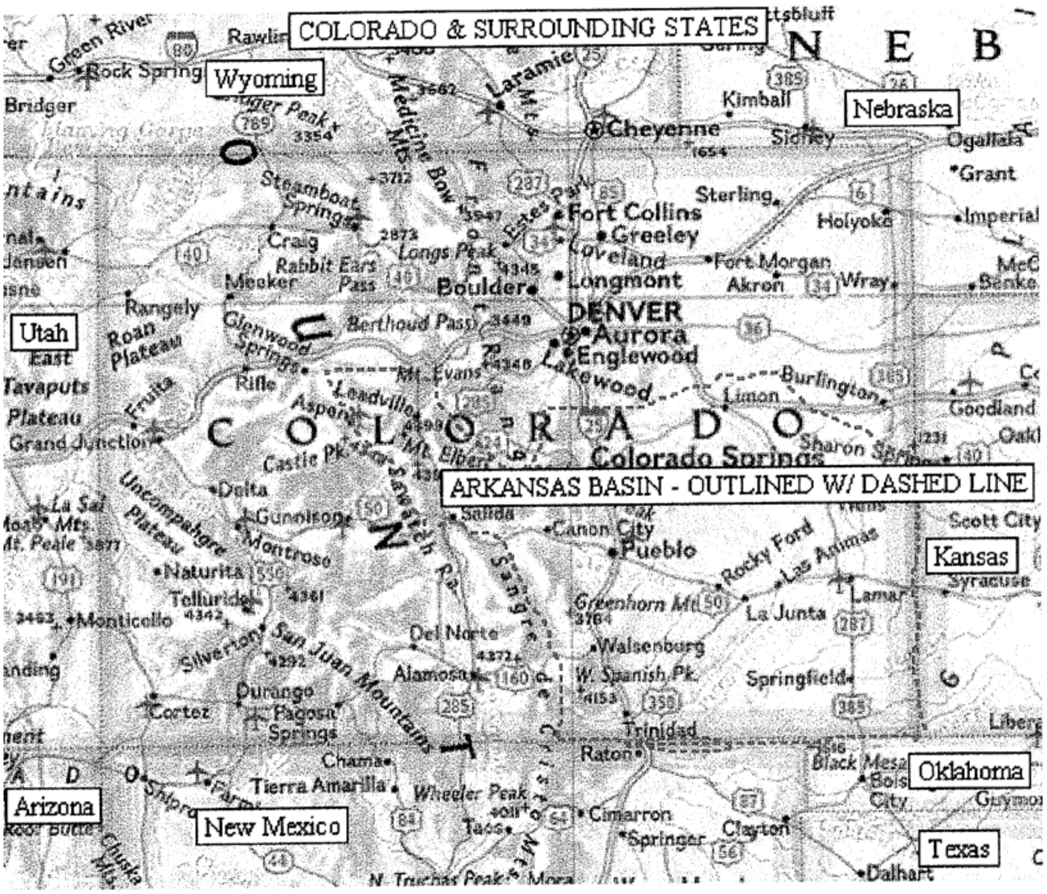
Working in conjunction with other entities water is supplied from District reservoirs to be used by these other entities for environmental protection in exchange for native water rights that require development and storage space. At the same time this allows the District's augmentation areas to expand and provide much need water service via augmentation and potentially direct delivery of water for domestic, irrigation and commercial uses.

This project, the blanket plan of augmentation, is just beginning to create synergistic opportunities that will propel the Upper Arkansas Water Conservancy District beyond a simple augmentation plan. Provision of water service by replacement of depletions to direct water service using augmentation and enhancement of environmental, cultural and recreational uses are all being combined under this project.

MAP APPENDIX

Colorado & Surrounding States

Arkansas Basin Outlined
With Dashed Line



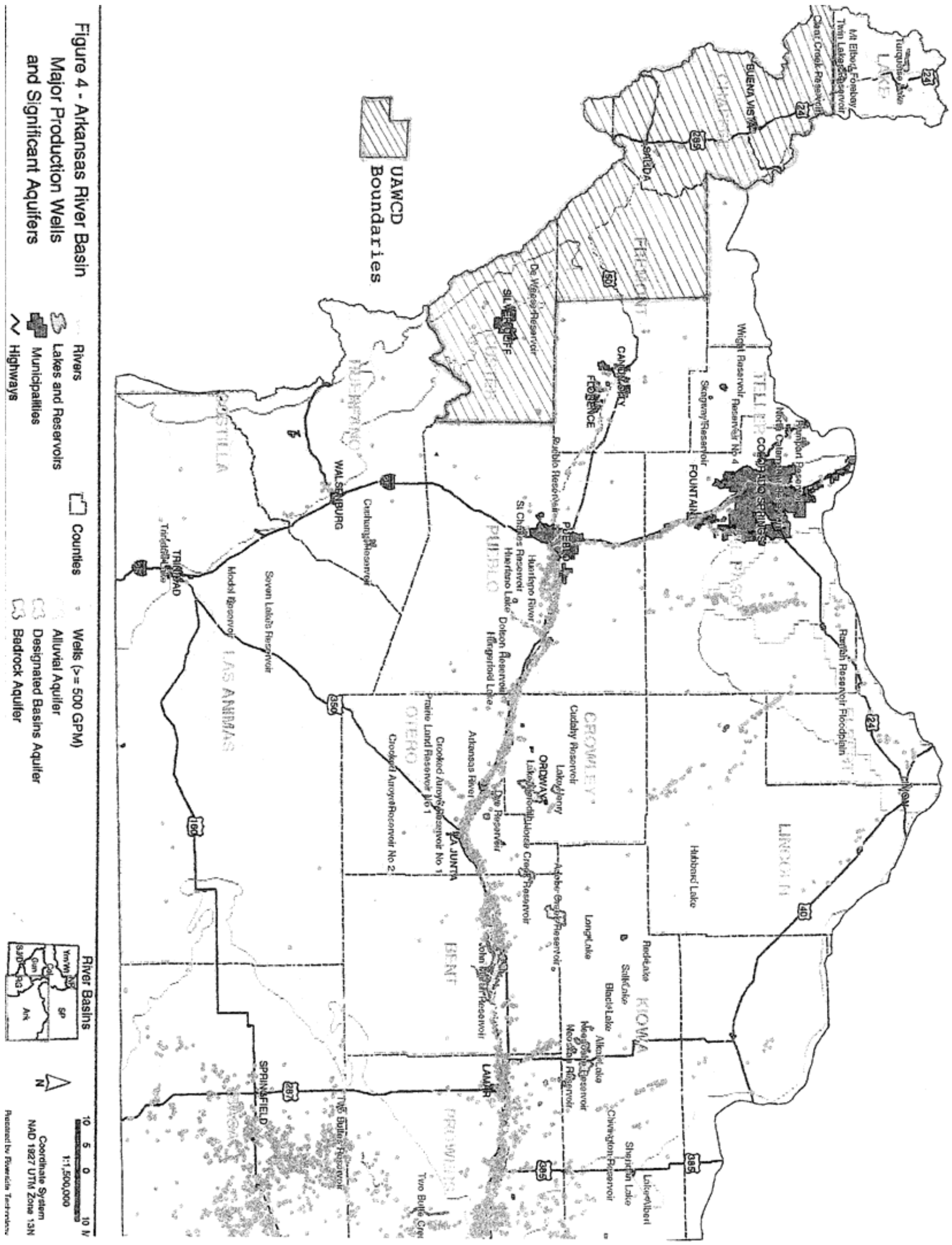


Figure 4 - Arkansas River Basin Major Production Wells and Significant Aquifers

MANAGING CHANGING WATER DEMANDS IN THE CENTRAL OREGON IRRIGATION DISTRICT

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Steven C. Johnson[2]

ABSTRACT

This paper examines evolving management issues facing the Central Oregon Irrigation District (COID), one of seven irrigation districts in the Deschutes Basin. Two related issues facing managers of COID are urbanization and the changing patron base. The paper discusses several aspects of urbanization, including the encroachment of urban boundaries into the irrigated service area, increasing demand for water by cities whose only option is to purchase water rights from irrigators and decreasing size of irrigated parcels. A changing client base, in the form of newcomers and their changing agricultural activities, constitute an important management challenge. In order to deal with these issues COID has developed a strategy which encompasses dialogue with agencies, municipalities and patrons; adoption of labor saving technologies; water conservation; and diversification of business interests. A critical component of this strategy is the need to cover operation, maintenance and overhead costs despite a shrinking service area. COID, which serves in a trustee relationship with water right holders, plans to allow landowners to sell their water rights providing that overhead costs, through an exit fee or other means, are met. Strategies to lower overhead costs include consolidation of management services among districts and adoption of technology, such as remotely sensed gauges.

BACKGROUND

The Deschutes Basin, the second largest basin in Oregon, collects snowmelt and rainfall from the eastern side of the Cascade Mountains along a 170 mile corridor in central Oregon, draining into the Columbia River. Irrigation, which is necessary in this high desert climate, is the highest consumptive user of water in the basin. While water rights established over one hundred years ago fully appropriated the flow of the Deschutes River, alternative demands, including municipal use and maintenance of in-stream flows for environmental purposes, now compete for this limited resource.

This paper describes how the Central Oregon Irrigation District (COID), one of seven major irrigation districts in the Deschutes Basin, is responding to changing demands of its 3,882 account holders, changing water requirements in its service area of over 45,000 acres and changing demands for water use in the basin. The

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original role of COID and many other privately developed irrigation districts in the West was defined under the Desert Reclamation Legislative Acts in the 1880s. The irrigation district was the developer of the canal system and the acquirer of the diversion rights under federal and state authority. The district established contractual relationships with the individuals who then developed farmland with the delivered water and subsequently received ownership of the land and rights to the delivered water. Without the irrigation district there was no water or system to deliver water, and without the settler there was no "beneficial use" of water on the developed land. Today the irrigation district maintains this "trustee" relationship with the patrons and an essential interest in the rights to water.

The COID irrigation delivery system consists of two main canals, the Pilot Butte Canal, which runs north from the diversion point on the Deschutes River in Bend through Redmond and Terrebonne; and the Central Oregon Canal, which runs east through the diversion point south of Bend through Alfalfa and Powell Butte (See Figure 1). COID owns and maintains more than 395 miles of canals, laterals, sub-laterals and waste ditches which provide agricultural and industrial water to Terrebonne, Redmond, Bend, Alfalfa and Powell Butte areas. COID also transports water to the Lone Pine Irrigation District and provides water to the city of Redmond and numerous subdivisions in the Bend area. COID is the manager and operator of the Crane Prairie Reservoir dam in the Upper Deschutes Basin. Additionally, COID owns and operates a 5.5 megawatt FERC licensed hydroelectric facility on the Deschutes River within the city limits of Bend which has been operational since 1989 and now contributes positive cash flow to the District.

COID is a municipal corporation chartered under Oregon statute in 1918. COID is governed by a five member board of directors who are elected for three year terms from geographical divisions within the District. Board members serve staggered terms so that continuity is maintained on the Board. The Board, which meets monthly, hires the general manager and sets policy and regulations. COID has the power of eminent domain, has federal easement authority and has the power to lien and foreclose on property. The District conducts audits which are presented annually to the Board.

Surface and Ground Water in the Basin

The Deschutes River was fully appropriated by the end of the 19th century, when agricultural interests established claims to all of the surface water. As the towns of Central Oregon grew they could no longer rely on surface rights they held, but have had to develop water supplies from groundwater sources.

During the 1990s a United States Geological Survey study (Gannett, et al. 2001) established a hydraulic connection between groundwater aquifers in the Upper and Middle Deschutes basin and surface water of the lower Deschutes River. As

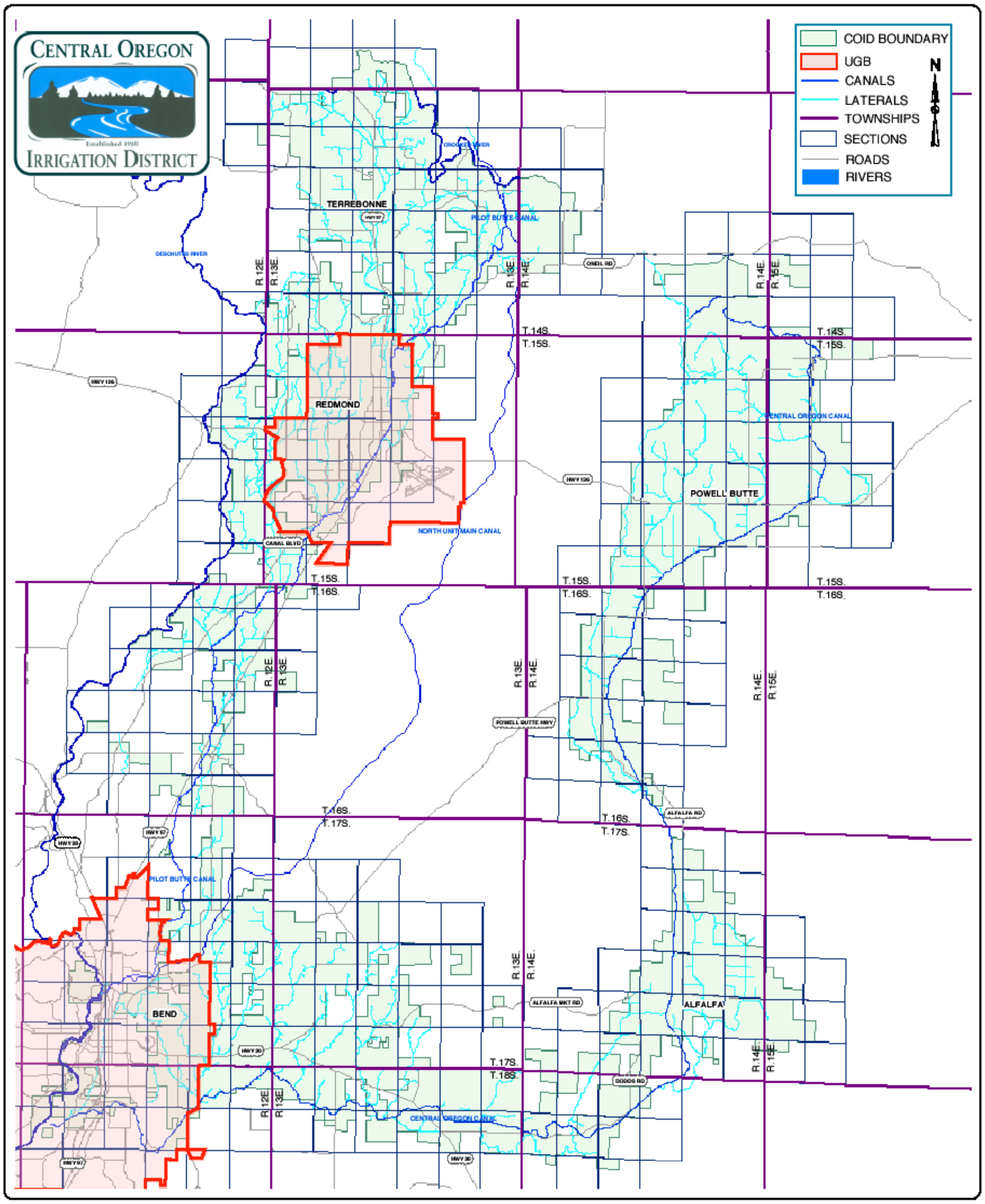

Figure 1. Central Oregon Irrigation District Boundary Map

a result the State placed a moratorium on pending groundwater applications until new rules were established. With the mitigation rules now in place, in order to be issued a groundwater extraction permit an applicant must mitigate (or replace) the amount of water they wish to extract from the aquifer with an equal volume of surface water. The most likely available water rights to mitigate are from surface water rights owned by irrigators. While the opportunity exists for conserving water from canal seepage due to the high seepage rates of the unlined canals of COID and other irrigation districts in the area, there will likely be increasing pressure for irrigation patrons to sell their water rights to other users.

Urbanization and the Changing Patron Base

Population growth in the upper and middle Deschutes watershed continues unabated. In Deschutes County, where 90% of the COID service area is located, the population is now 115,367, an increase of 54% between 1990 and 2000, maintaining a 20 year trend of the highest population growth in the state. Bend and Redmond, which were established with lands donated from COID's predecessor organizations, have populations which are expected to double between 2000 and 2020, while the rural areas of the county are expected to grow by 55% during this period. Crook and Jefferson counties which account for the remaining 10% of the COID service area, are in the central and eastern Deschutes watershed, each with populations of roughly 19,000 and have also experienced higher levels of growth than other areas in the state.

Despite Oregon's land use planning laws which were intended to restrict subdivision of land outside designated urban growth boundaries, population growth has hit rural Central Oregon. One factor contributing to growth in these areas is that many land divisions were created before the 1973 land use laws were passed. Traditional agriculture on large parcels of land has been greatly reduced, particularly in the COID service area and the two other irrigation districts which also border the Urban Growth Boundary of Bend.

Associated with the increasing population is a decrease in parcel size. At the time of original settlement of the irrigated area, settlers were allocated 160 acre parcels, only two of which are left intact in the COID service area. The average parcel size is now 11.6 acres, with the median at 4.9 acres.

As the economic value from the sale of land for development exceeds the economic value from agriculture there is an increasing turnover and fragmenting of holdings and the emergence of a new style of irrigation patron. Figure 2 shows changes in Deschutes County over the past 15 years in five parameters as reported by the Department of Agriculture (USDA 1987, 1992, 1997, 2002). According to the USDA farms are defined as producing more than $1000 of products per year. In 2002, of the county's 1632 farmers, 48% of the operators reported farming as their primary occupation. The absolute number of operators who consider farming their full time occupation continues to increase in line with the number of farms, which have increased 85% in 15 years. Hay and alfalfa production is by far the most important crop produced and sold. Acreage in hay and alfalfa has increased in line with irrigated acreage, which has increased 47% over the past 15 years. Similarly, the percentage of pasture land has remained relatively constant while increasing in real terms along with the acreage of irrigated land. A significant trend is that the number of horses in the county increased by 95% while cattle population decreased by 15 per cent over the same period.

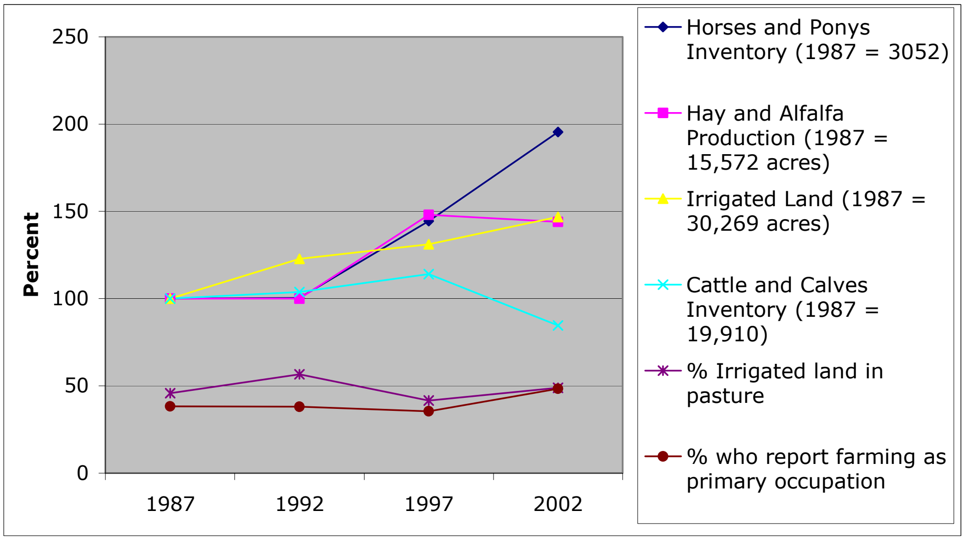

Figure 2. Changing Characteristics of Agriculture in Deschutes County, Oregon

It is surprising that the percentage of respondents reporting farming as their primary occupation is relatively constant, one would expect this number to have declined. One explanation, as described in the census documentation, is that a growing number of individuals who report themselves as full time farmers are actually retirees, another explanation is that many of the COID patrons may not be considered as "farms" in the USDA definition.

The split of irrigated land between hay production and pasture is not surprising since there are very limited crop opportunities in the high desert region with its short growing season. The decline in cattle production is also not surprising due to adverse beef prices, at least until recently. The significant trend of increased number of horses in the county and the decreasing parcel size of COID patrons provides an emerging picture of greater numbers of horse operations with hay and or pasture to support them, although cattle production is still significant, particularly on the larger holdings.

Although more economic data would be useful to further analyze the changing characteristics of COID patrons, there appears to be a substantial division among COID patrons – those farmers who continue to face economic difficulties in producing traditional crops and a new group of farmers, perhaps with income from other sources, who are less concerned about farm economics and more concerned about the quality of life offered by the rural landscape.

MANAGEMENT RESPONSE TO CHANGE

There are a variety of forces at play in the dynamic water allocation situation in Central Oregon: the changing nature of irrigation patrons and their agricultural activities, decline in "traditional" agricultural activities, increasing pressure to sell water rights, and pressures such as those to lease water rights for environmental purposes as documented elsewhere (Blank, et al., 2004). In response to these changing conditions and pressures, COID has undertaken a number of activities in order to plan for and respond to change. The following sections discuss representative activities to modernize not only the irrigation system but to modernize the way the district relates to water management issues in the region.

Exit Fee Concept

One problem facing COID is an increasing desire for patrons to sell their water rights to parties outside the district. Such sales must have approval of the district. Any decrease in the number of irrigated acres financially impacts the irrigation district since the overhead costs remain relatively constant. The continued loss of the assessment base from urbanization with no replacement of assessed lands increases the overhead costs to the remaining patrons to a financial crisis point where the expense of paying for water exceeds the capability of the remaining patrons to support the irrigation district. Recognition of this problem by stakeholders in the basin is needed in order to successfully plan for future water allocations.

Figure 3 shows water charges for a typical 10 acre parcel over the past ten years. COID water charges are comprised of two parts, a base charge per patron per season, currently set at $275 and a charge per irrigated acre, presently at $23. The delivered amount of water varies but the maximum is set at 5.51 acre-feet per acre (Oregon State University, 2004). Water charges were not increased from the period 1996 through 2001 since funds from the hydro-electric facility were used to defray operational costs. Subsequently, the Board has decided to allocate proceeds from hydropower generation to a capital account.

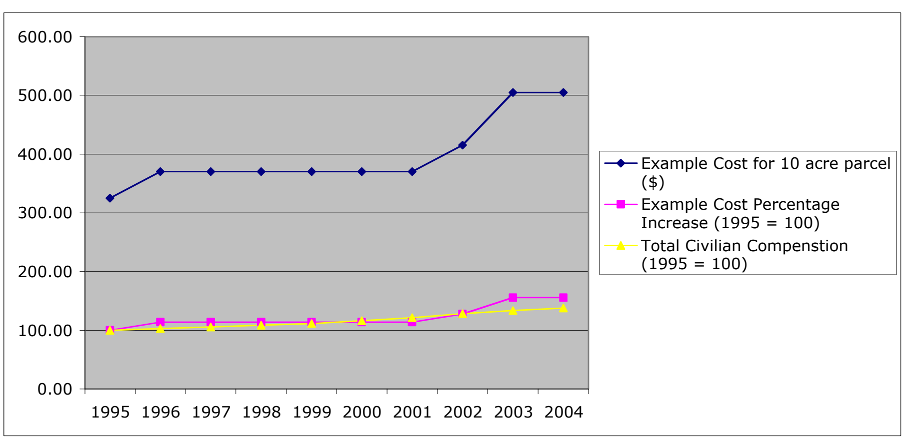

Figure 3. Water Charges Central Oregon Irrigation District

The Deschutes Basin faces pressure of allocating water away from irrigation uses. Developers of destination resorts and the growing urban areas, for example, are willing to pay substantial sums for water rights. One of the areas worth exploring is how to make an irrigation district financially “whole” during this period of change. Both the cities of Bend and Redmond have declared it is in their interest to continue to pay COID its annual assessments with any water rights acquired within the district’s boundaries. Other entities that may acquire mitigation credits are under no such obligation. The danger is that the loss of enough assessed acres will create a loss of financial critical mass, with the district unable to support the cost of a system to deliver water.

One alternative is an exit fee for those water right holders who wish to sell their water rights into the mitigation program. The fundamental rationale for the exit fee is that it offsets the responsibility a water right holder has to the fellow patrons. The exit fee would serve to amortize the loss of annual revenue from the lost acreage. Because of the limited number of patrons, a water market of this sort will only support a certain number of exit transactions so the number of patrons exiting will need to be limited.

Dialogue and Participation with Agencies, Municipalities, Other Districts and Patrons

Managers of COID have participated in a number of forums such as the Upper Deschutes Watershed Council and the Deschutes Coordinating Group which have goals to restore and improve riparian and aquatic habitat in the basin. COID has conducted continuing discussions with Deschutes Resources Conservancy (DRC) on the structure of a water bank, addressing issues of insuring institutional guarantees of consent with COID water rights and potential assessment scenarios. Further, COID has participated in discussions with the cities of Bend and Redmond on their requirements to meet water supply needs over the next 25 years. While the municipalities’ objectives are to assure water supplies, COID and other irrigation districts generally want to financially sustain their districts and upgrade service, for example, in providing piped service to patrons.

COID initiated a strategic project analyzing areas of the District for inefficiencies in water deliveries by lateral, pump replacement capabilities, and on-farm conservation. Implementation of the plan involves coordinating with Deschutes & Crook Counties Soil and Water Conservation Districts and the National Resources Conservation Service (NRCS). Under State law, a portion of this conserved water is returned to the river, while the irrigation district and more junior right holders allocate the remainder.

COID along with partners Swalley Irrigation District, the cities of Bend and Redmond, the DRC, and the Confederated Tribes of Warm Springs formed the Deschutes Water Alliance. The DWA is a collaborative group to generate baseline data and information on water management issues within the Middle Deschutes and Lower Crooked River basins. The DWA applied for and received a

Bureau of Reclamation Water 2025 challenge grant which will finance studies on a pilot water bank and of supply and demand scenarios for the basin with various optimization and conservation strategies. The seven irrigation districts of Central Oregon also jointly created the Deschutes Basin Board of Control under state law ORS 190 to coordinate and manage common challenges and solutions to the variety of management issues facing the districts. The DBBC organizes and shares resources related to common problems, to create standard policies and to share mutual costs.

COID maintains dialogue with its patrons through a number of means. These include a website, a monthly newsletter, e-mail and post cards. Board members are elected by division and maintain close contact with their constituents. Ditch riders travel their routes daily during the season and often meet users face to face and are in telephone contact with water users and the office. With this variety of alternatives, information can be easily passed and questions and problems from patrons can be readily resolved.

Adoption of Labor Saving Technologies

Delivering water for irrigation purposes to over 3800 account holders covering 45,000 acres is a personnel intensive service. Eighty one per cent of the annual operations and maintenance budget is costs related to personnel. It has been quite common for standard employee benefits to experience double digit cost increases per annum although overall water charges have kept pace with national personnel cost indices (See Fig. 3).

The District saves significant amounts of personnel time by utilizing the automated water measuring telemetry stations for daily operations. It is no longer necessary for individual field employees to manually measure these locations and each employee’s service area can be expanded eliminating the need to hire additional employees.

The District is also evaluating the upgrading of its existing computer systems and network to utilize wireless communications for its field staff and management personnel. This will enable the District to eliminate a considerable amount of manual data entry and create a more efficient field staff.

Water Conservation

COID has steadily reduced its total seasonal water diversion over the past 40 years due to a number of projects and programs aimed at water conservation and conservation activities by farmers (COID, 2002). On-farm water conservation has a high potential for water savings. COID estimates that only 35 percent of irrigated acreage is irrigated by sprinklers with the remaining using surface methods including furrow, corrugation, border and flood. Overall seasonal on-farm irrigation efficiencies are estimated at 25 to 50 percent for surface irrigation methods versus 50 to 85 percent for sprinklers (COID, 2002). Potential water savings from shifting to sprinklers are high, however investment in equipment and pumping costs hold many farmers back from adopting this technology. Various programs from the NRCS and elsewhere are available to reduce farmers' costs by providing matching funds. COID participates in these programs to encourage adoption of more water efficient on-farm systems. In some cases COID has installed pressurized laterals with adequate head to operate sprinklers. This is an attractive alternative in that pumping costs to users are eliminated while water conservation goals are achieved.

In 1999, COID embarked on a project in conjunction with the Bureau of Reclamation to begin tracking water loss in its system. This was accomplished by placing gauging stations at strategic locations throughout the district and continuously monitoring the canal system. Using radio telemetry each station is equipped to transmit canal data to a central computer where it is analyzed and archived. Factors such as turbidity, water temperature, air temperature, and water elevation are tracked. Additionally, alarms were added to alert COID personnel of abrupt changes in the level of canals or other problems at the stations. Currently, COID operates six stations and new stations will be added to better enable the district to monitor and manage water.

As with other irrigation systems in Central Oregon, significant transmission losses occur in the COID distribution system. Although losses have been reduced by replacing approximately 15 miles of canal sections with pipes, seasonal total losses are still estimated at 30%. Due to the fractured lava through which many of the canals traverse, sudden openings can occur with sudden increases in losses. COID has identified priority canal sections for piping with a goal to further reduce distribution and delivery losses to a level of between 15 and 20 percent over the next 30 years. Improved flow measurement and control in main canals, upgrading of siphons and flumes, and reduction in seepage from canals and laterals are among the specific conservation activities of the District. The District feels replacement of delivery canals with piping is the best option, despite the high cost. Lining of the canals presents serious maintenance problems, particularly due to the requirement for winter water deliveries for livestock.

Piping provides an opportunity for making use of the significant elevation drop in the system. The elevation drop in the 14 mile distance between Bend and Redmond is 700 feet which could generate 12 megawatts of power. COID has prepared plans for two small hydro-electric plants and is working to streamline the implementation process, which generally includes a two to four year licensing process for hydropower facilities. Financing of the project could involve a number of partners including municipalities and developers who could utilize a portion of the conserved water.

Diversification of Business Interests

COID is currently evaluating options for integration of COID and the City of Redmond Public Works Department facilities. Facility, staff, and operational requirements are very similar and economies of scale of a joint facility may prove to be cost effective as both organizations need to expand and their current locations are unsatisfactory.

Providing technical and water rights services to patrons is a good example of new COID activities. There are a number of cases of new clients desiring irrigation water who are within the service area but not served by the pressurized gravity system. COID can provide the service of transferring water rights among patrons within the system and even transferring surface rights to groundwater rights for patrons desiring pressurized water. This service to clients meets the needs of a flexible, automated delivery schedule while keeping water rights within the district and maintaining the assessment base.

As mentioned earlier, COID installed a 5.5 megawatt hydropower facility in the 1980s and has plans for another two smaller units. Patrons of a neighboring district have recently approved plans for a small hydropower plant in connection with plans to convert a section of canal to a piped system. This type of diversification of business interests has the potential to provide additional cash flow and thus contribute to the sustainability of the irrigation district. Although additional technical and managerial staff may be required, the positive returns make this an attractive business opportunity.

CONCLUSIONS

COID is an example of an organization which is adapting to new realities in water management. The district is faced with competing demands from urban, environmental, and recreation interests as well as legal uncertainty and the declining economic profitability of traditionally grown crops. COID is addressing those issues while providing a high level of service to its customers and maintaining its financial viability through a multi-faceted approach which includes technical improvements, diversification of business interests and forward looking policies.

A number of reasons can be cited to account for the success of COID. Some of these may be obvious from the US perspective, but may not be so obvious in an international context. First, COID is a financially viable organization which is responsible to its clients through an elected Board of Directors and is governed by clearly established rules. COID patrons have the ability to pay for the services provided which enable the District to be financially self-standing. COID has the necessary powers to enforce its regulations, including the power of lien and foreclosure, though these are rarely used. Further, COID employees have a service mentality: they do their best to provide good service to the patrons, which includes keeping the system well maintained in order to deliver water to users when needed and in the needed amounts. COID sees itself in the larger context of the region. It realizes it is the trustee of a scarce resource and that its patrons are the largest consumers of water in the region. In this sense it works as an advocate of these users and strives to find solutions to improve efficiency of water use and to meet increasing demands by other users.

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SALT RIVER PROJECT EXPERIENCE IN CONVERSION FROM AGRICULTURE TO URBAN WATER USE

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ABSTRACT

Salt River Project (SRP) was established in 1903 to deliver water to farms on approximately 250,000 acres located in south-central Arizona. Today, only about 13% of that land is still in agriculture. Urbanization of the vast majority of water service area has caused SRP to rethink and adjust every aspect of its business, from daily operation and maintenance to the overarching issues of liability and public involvement. Some of the issues being addressed and lessons learned are addressed in this paper.

BACKGROUND

The Salt River Project (SRP) is an organization consisting of the Salt River Valley Water Users Association and the Salt River Agricultural Improvement and Power District. SRP delivers water to about 250,000 acres (100,000 hectares), and power to about 2900 square miles (750,000 hectares) in and around the metropolitan Phoenix area in south central Arizona.

SRP was established in 1903 as the nation's first multipurpose reclamation project authorized under the National Reclamation Act. Six reservoirs with a total storage capacity of more than 2.3 million acre-feet (2800 million cubic meters) gather water from the 13,000 square mile (3.4 million hectare) watershed of the Salt and Verde Rivers north and east of the service area. Water released from these reservoirs is then routed through 1300 miles (2000 km) of canals and laterals to the water users. Other sources of water include 250 groundwater wells and an interconnection with the Central Arizona Project, which brings water from the Colorado River to farms and cities throughout central and southern Arizona.

At the time SRP was established, water was used almost exclusively for agricultural purposes. Fifty years ago, the service area was still predominantly agricultural with less than 20% of the land urbanized. Today, 87% of the service area is urbanized, and SRP delivers most of its water to municipal water treatment plants.

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From water delivery to facility maintenance to public involvement, nearly every aspect of SRP's operations is affected as a result of this urbanization.

WATER QUALITY

When SRP was strictly an agricultural water supplier, water quality was a very minor issue. That is no longer the case now that 80% of the water delivered by SRP serves urban uses. Agricultural and urban irrigation, industrial processes, and domestic needs all have different water quality needs and water quality has become a major issue.

Water delivered by SRP is a mix of Salt and Verde River water, water from the Central Arizona Project canal, groundwater, urban runoff and agricultural return flows. SRP takes a variety of steps to protect and monitor these water resources.

Urban-related surface water quality issues primarily have to do with turbidity, taste and odor, arsenic, salinity and disinfection byproducts such as trihalomethane (THM). Groundwater quality issues include management of nitrate, boron, arsenic, salinity and trichloroethylene (TCE).

Both surface water and groundwater are regularly monitored by SRP for these as well as other organic chemicals, heavy metals, and selected pesticides. Also, SRP has partnered with the Arizona Department of Environmental Quality to address known pollution problems and work on projects such as groundwater well remediation. Other partnerships for monitoring and protecting water quality have been developed with various cities in the metropolitan Phoenix area. Environmental Compliance also routinely reviews proposed wastewater discharge permits of non-SRP facilities to ensure that the water resources managed by SRP are protected.

SRP has developed a steady-state, mass-balance water quality model to estimate concentrations of conservative constituents[3] in the canal that come from the watershed and from the groundwater. The model is currently being enhanced to operate in a GIS environment. The model results are used as a guide for operations personnel for operating wells along the canal, especially upstream of water treatment plants.

FLOW CAPACITY

In addition to quality issues, there are water quantity issues. Because water rights are such that the water belongs to the land, the canal and lateral system was designed and built to deliver water uniformly throughout the water service area.

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[3] Conservative constituents are those that do not lose or gain mass as they travel through the system.

As farms were replaced by houses, businesses and industry, the water has been delivered to these new users through municipal water treatment plants. As a result more and more water has been delivered to the water treatment plants at points along the canals far away from the land with the water right, and less water has been delivered through the lateral system to farms.

As an area develops, irrigation laterals are often in the way and need to be moved. Since demand on these systems is decreasing because of development, it seems that some irrigation facilities (laterals and associated structures) could be downsized or eliminated. However, according to SRP bylaws, SRP cannot abandon those deliveries. The law requires that SRP be able to deliver water to the high quarter corner in each section of land within the water users' service area. Even if this land is developed with the densest of commercial development, SRP still must have a way to get water to that land, which means that there must be a conduit able to carry the proper amount of water to a delivery structure that is able to deliver the water at the proper location. Cities, with SRP's agreement, are allowed to remove these facilities if they commit in a legal document to replace them if the land ever returns to agriculture. SRP has struck many such agreements with the cities in the area, and, as would be expected, none of those lands has returned to agriculture.

Another potentially bigger problem is in portions of the canal system where demand is actually increasing, which are canals and laterals delivering water to water treatment plants. The capacity in these reaches may not be sufficient to handle the increased demand at water treatment plants. To get an idea of the magnitude of this problem, SRP developed projections for what may be required for canal capacity based on land use and water demand forecasts and compared them to the carrying capacity of the canals. These projections revealed that there were a few sections of the canal system where the carrying capacity could become insufficient. Recently, one of the cities in the service area developed plans to build a new water treatment plant at the end of one of SRP's canals that does not have enough available capacity to meet that plant's demands. The capacity projections developed by SRP are currently being used to work with the City on design enhancements to that canal so that they will be able to get a sufficient supply of water.

A third major concern is that many wells originally drilled throughout the service area to serve primarily agriculture are becoming underutilized because the lands whose water came from these wells had developed, and their water right was being delivered through a water treatment plant located upstream of the well. As a result, when the operations plan calls for a heavy reliance on groundwater, such as in periods of drought, the water is not available where it is needed. To address this problem, SRP has engaged in, and will continue to engage in, well exchange programs with cities and landowners in the area, has drilled some new wells, and has piped others to canals upstream of water treatment plants.

SYSTEM OPERATION

Urbanization significantly impacts access to irrigation facilities and scheduling. Many of the delivery points are in highly urbanized areas. When a zanjero[4] needs to change a gate, he must often travel through heavy traffic and road construction (including occasional road closures), and may sometimes have his access blocked and be required to park further away from his gate change. Zanjero schedules and service areas are reviewed annually and adjusted, if necessary, to account not only for shifting demands, but for shifting traffic patterns. When designing or redesigning delivery points, SRP has found it necessary to include a place for a zanjero to park his vehicle, and to design it in such a way as to discourage others from using it.

Schedulers for SRP no longer schedule multiple changes at once, but include in their schedules travel time appropriate for the traffic to be expected in the part of town and at the time of day when the change is to occur.

DEVELOPMENT WITHIN SRP RIGHT-OF-WAY

Canals

Probably the biggest challenge SRP faces is the multiple use of the main canal rights-of-way. SRP has worked with cities and developers to establish the best use for this land while maintaining the ability to operate and maintain the canals. Uses vary widely, and SRP has adapted and allowed construction and events to be held within its right-of-way that would not even have been considered a few decades ago.

Along the Canals: The SRP irrigation system is designated as a federal multi-purpose water resources project and as such is available for outdoor recreation. Canal maintenance roads are commonly used as jogging, hiking, bicycling and equestrian trails. The Sun Circle Trail, an officially designated federal equestrian trail, includes paths along about half of SRP's canals. Several cities have designated trails along canals within their boundaries and have improved the trails to include upgraded surfaces, landscaping, park benches, pedestrian/equestrian crossings and signage. Currently, there are about eleven miles of developed recreational trails with paved surfaces, landscaping and lighting. Another sixteen miles are under design and should be developed within the next five years.

The most common commercial development within SRP canal right-of-way has been for parking and landscaping. Urban canal banks are coveted by developers as waterfront features that could enhance the attractiveness of their development.

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[4] Spanish name for a ditch rider (one who operates the delivery gates) commonly used in the Southwestern United States.

Proposals have been made for commercial development within the right-of-way of the SRP canal system for open-air cafes, portable vendor stands and boat marinas.

Over and Under the Canals: There are over 100 bridges crossing SRP canals, and several hundred utilities crossing the canals either underneath or attached to bridges. A three-mile stretch of one of the main canals in the system has been piped and a major freeway was constructed over it. A commuter train terminal is currently being designed that will be constructed over an SRP canal, with access to and from the terminal via escalator and stairs to street level.

In the Canals: Fishing is allowed in all canals, although it is illegal to catch and keep the weed-eating carp that have been introduced for weed control. The State's Fish & Game Department is undertaking a program to formalize an urban canal fishing program that would require a special license. Proposals have been made for boat tours in SRP canals similar to those at the San Antonio River Walk.

Events: SRP has an average of five "special events" on the canal banks each month. These events are non-SRP events and require a special use license. Most of these events are marathons, scout hikes and functions, private running club events and commemorative events. In the past, events have included "duck races" where 75,000 toy rubber ducks are dumped into a canal and "race" downstream to benefit a local charity. A "floating rocks" display in SRP canals was held by the local arts community, which also sponsored a competition where artists used trash cleaned out of canals as material for "canal art".

Distribution System Facilities

Laterals: Much of SRP's lateral ditch system (smaller open channels that deliver water from the main canals to the delivery gates) lies in the path of development and is continually being replaced with underground pipe to free up the land for other amenities. SRP has a full-time staff dedicated to redesigning these laterals and their associated control structures. SRP crews also construct many of these laterals, and all of the control structures. SRP is reimbursed by the cities and developers for the cost of this construction. There are typically 100 to 200 of these jobs in some phase of development at any one time.

Public Safety and the potential for vandalism are much more important issues in the design of lateral systems in an urban environment. SRP designs requirements include safety grates at the entrance to long stretches of piped lateral, locked metal covers for turnout structures and manholes, locked steel boxes for sensitive equipment, graffiti-resistant surface treatments, beautification, and more.

Wells: Well sites in areas that are urbanizing are often subject to redesign and beautification, and in some cases, are required to relocate. The issues with wells are not only that they are located in the path of development, but that people living and working nearby may object to the noise they produce. An "aesthetics fund" has been set up by SRP for cities to use to pay for enhancement of well sites, which usually involves constructing attractive walls around the site. These funds can also be used by cities for work in other parts of the SRP system, both for irrigation and power facilities. In cases where wells need to be moved, the developer or agency requiring the move pays the cost of relocation.

Land Rights

Right-of-Way Infringement: A common problem SRP deals with on a daily basis is the illegal use of its right-of-way by others. Vehicular access on SRP right-of-way is prohibited, yet people drive the canal roads regularly for purposes ranging from taking shortcuts to accessing property bordering the canals. There are several properties along the canals where the only access is via canal roads. These cases are usually difficult to solve because they can lead to legal battles over responsibility and alternative access.

SRP has a field permit process in place which allows limited access to SRP right-of-way and covers minimum safety and liability requirements. However, these permits are normally limited to project-related access, such as for hauling material to a construction site.

Licenses: The SRP irrigation system is built primarily on land owned by the US Government, and SRP is charged with the stewardship of that land. SRP has processes in place that allow cities and developers to use SRP right-of-way as long as they meet some basic requirements that allow SRP to continue to operate and maintain the canals. These include keeping access roads open and construction out of the cross section of the canal. But even these requirements are occasionally waived if SRP can come up with new ways to operate and maintain the system.

SRP cannot grant property easements because it is not the landowner. However, SRP does have the authority to act as a representative of the USA when permitting others to use the right-of-way for purposes other than the irrigation system through licensing processes. These licenses require the licensee to indemnify SRP, to pay incremental costs of operation and maintenance, and to maintain public access to the land. An average of 125 sets of plans is received each month for review, and there are 300 to 500 requests monthly for installation record drawings of SRP facilities. About twenty licenses per month are issued for work done on SRP right-of-way.

The field permit process mentioned earlier is also used for some preconstruction or temporary construction activities that may or may not be related to fully licensed projects.

Archeological/Historical Clearances: The SRP system is located in an area that is rich with history, and formal processes are in place to preserve as much as practical. From about 200-1450 A.D., the Phoenix area was home to a large population of Native Americans now called the Hohokam. In addition to the buried remains of their many towns and villages, the Hohokam had an extensive network of irrigation canals, a network that served as the inspiration and base of the SRP historic irrigation system. The SRP irrigation system itself is an historical project being the first multipurpose reclamation project authorized under the National Reclamation Act of 1902. There are several locations within the system that are specifically designated as historical sites.

The cultural clearance process has been delegated to SRP by the US Bureau of Reclamation for all but the most sensitive sites. For most of the canal system, construction activities are not a problem. Projects can be quickly given a clearance after staff consults local archeological databases. For the more sensitive sites, archeological and historical surveys are done, and artifacts are uncovered and preserved before any construction can take place. There are a few sites where no construction activities are allowed.

Easements: Occasionally SRP will require the use of land other than what the USA owns. In these cases, SRP will either purchase the land, or obtain an easement. SRP manages these lands in the same way as it does USA land. Because of SRP's position in the area as the holder of prior rights to most of its property, this can cause confusion for cities and developers and continually needs to be addressed in projects occurring with SRP right-of-way.

NEARBY DEVELOPMENT INFLUENCING THE SRP SYSTEM

SRP's canals run through all kinds of development, *e.g.* heavy industrial, high rise commercial, blighted urban neighborhoods, expensive residential, and semi-rural mixed use. SRP works closely with cities, agencies and developers to blend SRP irrigation facilities into the surrounding areas. Cities plan around the canal system and often times require development to include or enhance the facilities as part of the development. The City of Phoenix, for example, has a city ordinance that requires the developer of any new development adjacent to canals to work with SRP for installation of public improvements.

The Tempe Town Lake is a recently developed 220 acre urban lake located within the Salt River bed near the center of the metropolitan Phoenix area. SRP has a contract with the City of Tempe to operate and maintain the lake. Lake make-up water is provided via the SRP canal system.

Several large flood control projects parallel portions of the canal system, including the Arizona Canal Diversion Channel, the Bethany Home Outfall Channel, the STP Conveyance Channel, the old Crosscut Canal, and the Laveen

Area Conveyance Channel. These are designed to collect storm water that would normally flood areas on the upstream side of the canal embankments and carry it to downstream rivers. Maintenance personnel for these channels share canal roads with SRP.

PUBLIC INVOLVEMENT

SRP has recognized the importance of public involvement in an urban environment. As a primary raw water provider for nearly two million people in the metropolitan Phoenix area, SRP has a high profile and important influence in the community. On the other side, there is much more political pressure and people demand more information.

Customer Service has become very important to maintain SRP's image as a highly regarded irrigation district and power utility. SRP has worked hard to raise the level of customer service and has done very well. Although SRP's customers are landowners in the service area that have the rights to the water, SRP management also emphasizes that those we work with, cities, agencies, developers, are also considered customers and their satisfaction is monitored and scored as well.

In a desert environment that is currently in drought conditions, water conservation is taking on more importance. The prevalence of urban irrigation and the apparent abundant supply of water in the past have detracted residents from being as aware of the desert environment as they should. To bring the general awareness level up, SRP is working with the cities on programs such as "Water – Use It Wisely", a conservation information campaign, and "Desert Wise Homes", a demonstration of water efficient applications in a residence. SRP has worked with local hardware stores to promote water-saving equipment, has worked with local universities to develop low-water use turf and xeriscape landscaping, and has worked with cities on their campaigns to raise drought awareness.

Public safety is an important part of SRP's public involvement. Urbanization has enveloped our facilities, which are largely not fenced. Roadways and traffic have encroached on SRP right-of-way and public use of the right-of-way increases as the population around it increases, which increases exposure to liability for public safety. To help counteract this exposure, SRP participates in safety campaigns having to do with watching children around water and staying out of and a safe distance away from canals and laterals. SRP specifications and guidelines also always specify that contractors must work in safe ways and construct safe products, and SRP works with cities, agencies and developers to adjust these requirements when needed for safety reasons.

SRP also actively encourages its employees to be active as volunteers, to participate in community activities and to contribute to charitable organizations.

Last year, approximately 770,000 hours were contributed by employees to charitable organizations. This is all seen as SRP being an active part of the community.

THE FUTURE

Forecasts indicate that the SRP water service area will be almost completely urbanized in another ten to fifteen years. Issues anticipated to be on the forefront include:

- Water quality monitoring and reporting will likely increase as drinking water regulations tighten and alternative sources of water, such as reclaimed water, are given consideration.

- Groundwater deliveries will become less effective as farms go out of existence. Mitigation options may include new exchange agreements, rerouting delivery points to different locations, drilling new wells and rehabilitating or redrilling old wells to improve pump rate and water quality.

- Pressure for alternative uses of irrigation facilities will continue to increase.

- Liability issues will continue to evolve.

- There will be pressure to change SRP governance. Currently, the Board of Directors for SRP is elected by individual land owners. Non-individuals, *e.g.* businesses and cities, may not vote. As agriculture disappears, there may be pressure to change the rules concerning Board representation.

- There will be pressure to change delivery agreements with the cities to give them more authority and flexibility in using, transporting and accounting for water.

- Water rights issues will continue to be challenged.

SUMMARY

SRP is much further along the urbanization path than most other irrigation districts in the U.S. and the world. Experiences gained by SRP indicate that a district facing urbanization should plan for fully-developed conditions, seek to be flexible, and be prepared to change their entire way of thinking. Urbanization changes everything.

For more information, see SRP’s web site at www.srpnet.com.

BAYVIEW IRRIGATION DISTRICT IS BALANCING CONSERVATION, DEVELOPMENT, AND WILDLIFE NEEDS FOR THE FUTURE

Gordon R. Hill, Sr.[1]

ABSTRACT

Realizing that Irrigation Districts will be limited in their water supply as they were between 1992 and 2002, they are beginning to look at major water conservation efforts and water management tools. The manmade water shortages during these years has not been resolved between the United States and Mexico and water conservation is the Districts' only option to survive into the future. Conservation plans developed by the Districts create unique challenges. Development or growth patterns of municipalities in addition to rural growth will produce an extreme challenge to the Districts do to the fact that millions of dollars are needed for rehabilitation on delivery systems. It will be important that a District look at current and future developments to make decisions on what rehabilitation should be done in their District.

The other challenge will be wildlife vs. water conservation (water management). These needs consist of water in drain ditches plus water needs of native brush that is established along drainage canals used by wildlife. The Rio Grande Valley is home to an abundant bird population and endangered species and a conservation plan would need to review the impact on wildlife preservation. Bayview Irrigation District # 11 has worked on these challenges in its conservation plans and water management to meet the future needs.

INTRODUCTION

Sustainable management of water resources views water as a critically important natural, social, and economic resource. As population, urbanization, industrialization, and incomes continue to grow, and water becomes more scarce, sustainable management becomes an urgent task. Worldwide, regional problems of inadequate supply and quality, inefficient investment and use, and misallocation of resources have beset water management policies. These trends are forcing planners, researchers, and stakeholders to reevaluate the efficacy and flexibility of existing laws and institutions managing water and to involve local populations in planning and implementing solutions that take into account the specific conditions of each region and enhance its potential for sustainable development. Semi-arid regions often suffer from periodic droughts. For them, sustainable water management means proactive drought management.

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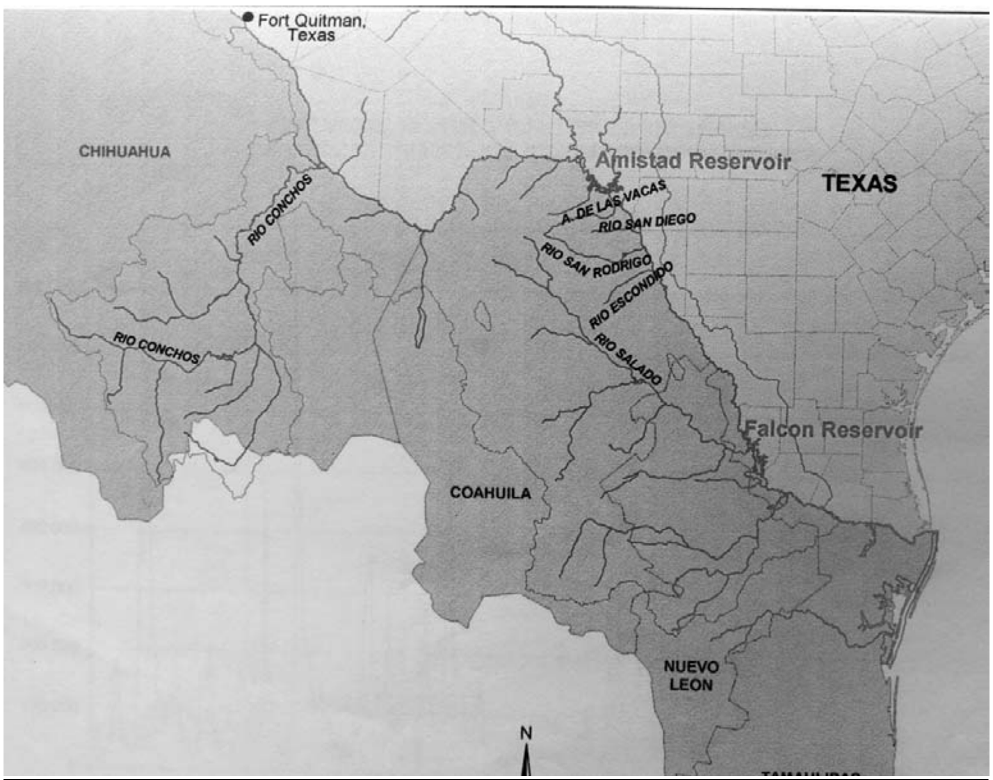
The Lower Rio Grande Basin (LRGB) is drought prone, shared between Mexico and the United States, and, in it's most easterly part, experiencing rapid growth. This defines a difficult task for water managers. In this paper I examine how the LRGB may deal with water scarcity and growing demand. The water management system of the Lower Rio Grande is complex, incorporating international, state, and local components.



Map of the Lower Rio Grande Basin

International: The river is shared between two sovereign countries. The international Boundary and Water commission (IBWC) is responsible for implementing the 1944 treaty between Mexico and the United States on how water will be shared in a mutually beneficial way. The principal responsibility of the IBWC, in the Lower Rio Grande Valley, has been the construction and management of Amistad and Falcon International Reservoirs and the monitoring of each nation's water accounts. The IBWC releases water from the two reservoirs to users in Mexico and Texas.

State of Texas: The Rio Grande Watermaster is responsible for allocating water received from the IBWC to individual water districts and cities. The office of Watermaster has been in existence for twenty-five years.

Irrigation Districts: Twenty-nine irrigation districts serve as intermediaries between the Watermaster and end users. The districts request water from the

Watermaster and distribute it to farmers and other users. Only a few of the districts have upgraded their distribution systems, and thus increased their efficiency in using water.

City Water Offices: Cities receive water directly through irrigation districts. Because of rapid growth, cities will need an increasing share of Rio Grande waters, and some water transfers from agriculture to urban use are already occurring.

Wildlife: This transboundary area suffers mounting ecological stress from rapid economic and population growth. The area has eleven distinct habitats ranging from arid thorny woodlands to the last remaining tropical Sabal palm grove in the United States. There are feeding and nesting grounds for native birds and resting places for migrating birds throughout the region. The Lower Rio Grande/Rio Bravo ranks with the tip of Florida as the nation's most ecologically complex biotic province. There are more endangered species along the U.S. – Mexican border than anywhere else in the United States. Four of the ten most endangered species in the U.S. maintain habitats in the borderlands.

BAYVIEW IRRIGATION DISTRICT CONSERVATION PLAN

Bayview Irrigation District #11: The Bayview Irrigation District encompasses 8,012 irrigated acres of land and is located roughly halfway between South Padre Island and the city of Harlingen in Cameron County. While this irrigation district surrounds the tiny town of Bayview, population 261, it does not supply water to the municipality. The district oversees the provision of services to 34 farmers. The small size of this organization has helped to foster cooperation and a family-like atmosphere among the irrigators and the district. The district is technically a secondary water supplier in that it does not pump it's own water out of the Rio Grande. Rather, it pays the Los Fresnos Irrigation district in the neighboring town of Los Fresnos to pump and deliver water to the Bayview district.

In 1991, the Board of Directors of the Bayview Irrigation District #11 became concerned about the falling water levels in the reservoirs. This concern provided the impetus for establishing a pilot project to determine how the district could reduce it's water usage. Consequently, the board adopted a five-year water conservation plan with the goal of reducing the district's water usage by 15 percent. Through initial studies, the board and the manager discovered that they could not conserve water in a cost-effective manner within their system's infrastructure of canals. Studies showed that the district's canals had been lined naturally over time with sediment such that water cannot seep into the ground. Therefore, expending the funds to line the canals with concrete would not result in significant water savings. Instead, they decided that the best way to reduce water usage would be to implement on-farm conservation techniques.

Pilot Project: The most effective study was to save water on individual farms; the Bayview Irrigation District began its pilot project in 1991 on a 500-acre farm within the district. On this piece of land, 200 acres of sugar cane, a very water-intensive crop, and 300 acres of row crops were grown and closely monitored with water meters. The project spanned two years and involved studying the effects of irrigation with both the traditional open-ditch system and a more innovative system utilizing polypipe. Polypipe is plastic piping that measures 8 to 21 inches in diameter and is punctured at the head of each furrow to distribute water evenly to the crops (see photos below).

The main advantage of polypipe over open ditches is that in the latter irrigation method, water is allowed to evaporate or seep into the ground as it stands in the farm's ditch system whereas water in a polypipe system is completely enclosed by plastic (see photos below).

Polypipe replaces earthen canals in watering citrus. No water is allowed to evaporate or seep into the ground; all water goes right to the tree or row.

This polypipe line runs 1.3 miles from pump station to sugar cane field. In this District, polypipe has replaced the old earthen canals used to transport water.

Due to the Valley's semiarid climate, water seepage into the ground and evaporation into the air can account for significant water losses.

After the initial stage of the pilot project, the Bayview district discovered just how much water and money they and their customers could save by simply installing polypipe on individual farms. For example, the district found that supplying an adequate amount of water to 200 acres of sugar cane via an open canal system required 672 hours of irrigation per year. However adequately watering the same amount of sugar cane via polypipe required only 252 hours of irrigation per year. As a result of this initial phase of the project, the district realized that by using polypipe on the 500 acre farm, it saved 420 hours, or 63 percent, in salaries for farm irrigation workers which translates to a per acre savings of $11.97 per year. This reduction in labor cost was a direct result of the fact that polypipe delivers water to crops more efficiently. Thus, fields require fewer hours of irrigation and laborers do not have to spend as many hours monitoring the irrigation process. The monetary savings illustrated by the project are important because they provide individual farmers with greater incentive to conserve water and the District reduced water usage on this test project by 20%.

<u>The Second Phase: Convert to Polypipe</u>: This phase of the project involved the district helping its farmers install polypipe on individual farms. In order to

encourage farmers to participate in the project and accomplish a near 100 percent coverage of polypipe throughout the district, Bayview implemented a plan in which the farmers themselves would pay for all materials and the district's employees would install the materials on the individual farms. In all, the district spent $100,000 in labor costs for the project. Since 1992, when this phase of the project was begun, the district has seen startling results. The decrease in water use was 3,876 acre-feet of water since the project began. This water conservation is directly the result of the use of polypipe, which reduces evaporation and seepage losses. Water conservation also resulted from the improved knowledge of irrigation timing (how long certain crops need to be irrigated to prevent waste from over-watering). Today, over 90 percent of the irrigated land within the district has been converted to the poly pipe system.

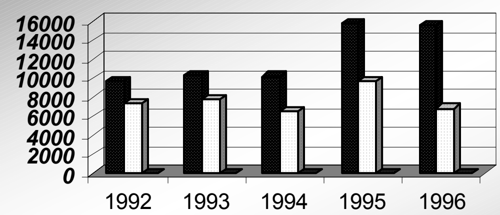
Phase Three: Another innovative solution, which Bayview recently implemented, is the use of on-farm water metering. In January 1995, the district purchased and installed meters on each farm's main water pump, the pump that transfers water from the district's distribution infrastructure to an individual's land and field turnouts, if not on a main pump line. These meters allow irrigators to be more aware of the water amount that they are using. The meters also allow the district to charge its customers according to the amount of water that they take from the system. Metering resulted in a total savings of 4,737 acre-feet of water since the project began. While commonplace in urban homes, metering is not widely used in irrigation districts. While all districts must meter the amount of water they divert from the river or pump from other sources, only three irrigation districts in the Valley currently employ on-farm metering.

The success of Bayview's program has been recognized by many of the irrigation interests in the Valley. In March 1996, the Bureau of Reclamation issued a report describing possibilities for water conservation in LRGV irrigation districts. This report also included a statement of the Bureau's belief that Bayview's program can be used as a model for other districts such that "[s]imilar water conservation results appear possible at other districts within the LRGV area."

The District has also seen dramatic financial savings from these projects. For example, the district saved $38,758.72 in pumping charges paid to the Los Fresnos Irrigation District and $38,586.24 in electricity for pumping within the district and to individual farms. In total, the district saved $77,344.96 between 1992 and 1996 because of its water use reduction efforts. While individual irrigators are using less water and thus paying fewer fees to the district, the district has not suffered from revenue losses because it is in turn paying the Los Fresnos district less money in pumping fees and less in electricity expenses. The number of inches of water applied to each acre by farmers decreased by 43 percent in four years, falling from 9.1 inches per acre in 1992 to 5.1 inches per acre in 1996 and saved a total of 8,613 acre-feet of water since the projects began.

The overall results of Bayview's water conservation efforts over a four-year period are illustrated in Table 1.

Table 1



	Jan-92	Jan-93	Jan-94	Jan-95	Jan-96
Acres Watered	*9686.19*	*10339.57*	*10179.47*	*15701.19*	*15603.36*
AC/Ft Through Bayview Meter	*7344.29*	*7820.96*	*6480.28*	*9673.57*	*6853*
Inches Applied Per. Acre	*9.1*	*9.1*	*7.7*	*7.4*	*5.1*

Although the amount of irrigations in the district has increased since 1992, the total amount of water used by the district's farmers has decreased substantially.

<u>Current Issues:</u> If Bayview's board of directors had not taken the initiative to begin their pilot project back in 1991, the district would have run out of water during the drought of 1996. Luckily, the results of the district's water conservation efforts have completely altered the way the entity conducts its business. The district's board and I continue to be committed to finding even more innovative methods to reduce our farmers' water usage. For instance, the pilot project proved to the board of director's that certain crops, such as sugar cane, are much more water-intensive than other crops, such as cotton and grain. They therefore concluded that they needed a more equitable way of distributing the district's water since some farmers grow sugar cane and others grow less water-intensive crops. As a result, the board decided that water should be sold to farmers on a per acre-foot basis, in other words volumetrically, rather than on a per acre basis, which is the traditional method employed by many irrigation districts in the Valley.

Each individual farmer within the Bayview Irrigation District realized financial savings along with water savings because of the district's conservation efforts. Aside from enlightening irrigators about precise amount of water they were actually using on their crops, grain and cotton farmers found that they saved enough water to sell the remainder of their allotment to their sugar cane citrus growing neighbors or they were able to transfer allotments to sugar cane and citrus from their row crops. Farmers are also enjoying the fact that they do not have to employ as many farm workers to spend as many hours irrigating their land as before the polypipe was installed. This is in addition to the fact that irrigators are now only paying for the true amount of water they use as opposed to the water usage that was pre-determined according to their acreage. The improved pricing system is especially beneficial for cotton and grain growers who use comparatively less water. Moreover, the district has been able to lower the rates it charges its customers by 28 percent over the past four years because it no longer requires as much water from the Los Fresnos Irrigation District and therefore does not have to pay as much in pumping fees. All of these financial savings to the farmers provide additional incentive for them to conserve water.

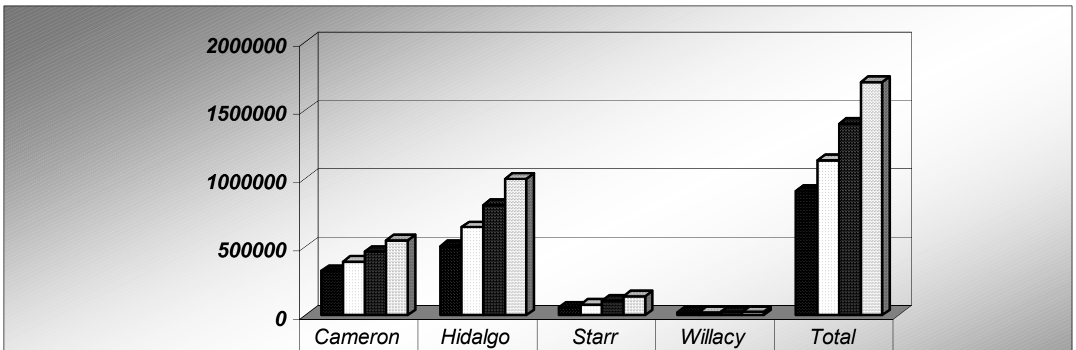
Wildlife Issues: Bayview is located on the southernmost portion of the Texas coastal region, the Lower Rio Grande Valley. The Valley lies in one of the most ecologically complex and biodiverse regions in all of North America. As more people become aware of the ecological treasures that exist there, ecotourism in the Valley has developed into a rapidly growing sector of the regional economy. Tourism is the 3rd largest industry in Texas, and ecotourism makes up a significant share of total tourism in the state. Texas is the number one bird-watching state/province in North America, and the Valley is often considered the number two bird-watching destination in North America. The four counties of the Valley – Hidalgo, Starr, Willacy, and Cameron - together have recorded almost 500 bird species.

Ironically, while ecotourism is growing, the Valley's fragile ecosystem is facing unprecedented pressure from other economic activities. As agricultural production, industry, and a rapidly growing urban population use all but a trickle of the Rio Grande (the region's only major source of fresh water), the water needs of the ecosystem are rarely considered and this fragile natural asset is deteriorating. An important obstacle to more widespread recognition of the ecosystem's water needs is that the economic value of using water to sustain the Valley's ecosystem has never been quantified. Without "economic representation" of this value, it is difficulty for water managers, planners, and users to consider the ecosystem, along with agriculture, industry, and municipalities, when making water use decisions.

Bayview's Pilot project revealed that conversion to polypipe did not change the amount of tail-water (water entering into a drainage canal). We found that tail-water losses were 100% accountable to the employees watering each field and his ability in managing water. Much of these losses occurred between 10 p.m. and 7 a.m. After metering began we discovered that losses dropped dramatically, farmers no longer drained water from the fields but made small borders at the end of each field to turn tail-water back into the unwatered rows. Farmers didn't like paying for their employee's poor water management skills.

Selling water by the acre-feet to farmers had a negative effect on wildlife and native plants living along drainage canals in the District. In an attempt to correct these issues Bayview Irrigation met with farmers and landowners and after long discussions and compromises we arrived at a settlement that would insure that drainage canals would receive sufficient water to maintain wildlife and native plants in between storm events. Farmers and landowners agreed to place one drain per field to allow for water to be released into the drainage canals.

<u>Development:</u> The Lower Rio Grande Valley, and its counterpart in Mexico, is home to two million people, inhabiting the area downstream from Falcon Reservoir to the Gulf of Mexico. Population has doubled over the last three decades and is continuing it's rapid growth. Between 1980 and 2000 population grew by 3.9 percent per year in the United States and even faster on the Mexican side.



	Cameron	Hidalgo	Starr	Willacy	Total
Dec-00	324137	505404	57402	20137	907080
Dec-10	391874	643056	78482	22001	1135413
Dec-20	465354	806704	105685	23377	1400120
Dec-30	546289	997206	139730	23984	1707209

Population in the Valley is growing at a rate exceeding both Texas and the United States' growth rates. This rapid growth pattern dictates an increased future demand for infrastructure of delivery systems and water supply.

Each district will need to involve local municipal users, individual landowners and farmers to insure cooperation on future developments before upgrading the district's water delivery system.

Bayview Irrigation can no longer look at the past decade to justify demand uses on its system, due to the fact that land usage is changing rapidly and so is the ownership. Irrigated land that was in row crops two years ago is now a 20-acre pasture with a home on it. The District cannot afford misallocation of grant funds. To upgrade a system that historicity deliver 30 acre-feet of water per day will cost of $374,664. This same canal with the changes in land usage and ownership and a demand change of about 10 acre-feet of water per day will save $162,000 in cost to upgrade to underground pipeline. The District will save over 312 acre-feet of water per year by upgrading the earthen canal to pipeline.

The increasing population in the district and in the border region will require careful planning and innovative practices between municipalities, agricultural users, and water distributors to deliver water more efficiently to all end users and the best use of financial assistance.

CONCLUSION

Lower Rio Grande Valley residents recognize the need for growth in balance with available natural resources. Improvement in irrigation technology, conveyance systems, and on-farm innovations, are widely recognized as the best source of new supplies for growing urban areas and to minimize the impact of future droughts on agricultural users.

Currently most farmers resist the idea that it is their responsibility to undertake conservation for the sake of cities. It is equally difficult to convince cities of their responsibilities to the farmers, because the water rights system favors municipal over irrigation uses.

Farmers contribute much to the economy in the Valley. If crops fail jobs are lost. Without the farming sector, city budgets will be affected. According to a commonly cited scenario, a 10 percent reduction in water used for irrigation equals the total amount used by municipalities in the Valley right now. One must be careful not to place responsibility for conservation solely on the farming sector.

Valley stakeholders ultimately include everyone living, working, or seeking a better life in the region. More precisely, stakeholders include not just those who own water rights, but everyone who uses water in the valley. Water management in the Valley is one of the main ingredients of the sustainable future; a future where people can continue to farm, open and run a business, and raise children. Only after understanding that everyone owns a stake in this complex system of water rights, institutions, and diverse interests, can we look to the future of the Valley and begin to address the management of water to insure the balance of growth, wildlife, and agricultural needs of this natural resource.

A SUBDIVISION POLICY FOR AN URBANIZING IRRIGATION DISTRICT

Steven R. Knell, P.E.[1]
Kevin L. King[2]

ABSTRACT

An ever increasing challenge for rural irrigation districts in the agriculturally rich San Joaquin Valley of California is adjusting to urbanization while maintaining an effective irrigation water delivery system. The Oakdale Irrigation District (OID) is currently facing this challenge and has developed a Subdivision/Parcel Map Development Policy that attempts to bring balance to that concern. This paper will present OID's Subdivision Policy and discuss the reasoning for the conditions and requirements within the policy. It is the intent of this paper to provide other irrigation districts, facing similar urbanization pressures, a foundation for development of similar policies in the hopes of preserving and protecting the water delivery systems so vital to our agricultural community.

INTRODUCTION

Oakdale Irrigation District

Oakdale Irrigation District (OID) is located in the northeastern portion of Stanislaus County and is considered the northern boundary of the fertile San Joaquin Valley. OID provides irrigation and domestic water within a service area of 72,345 acres of which approximately 55,000 acres are irrigated farmland. The OID holds a senior water right to the Stanislaus River in addition to managing 27 deep wells and 43 reclamation pumps that provide water to its agricultural customers. Principle crops in the area are irrigated pasture, almonds, walnuts, corn and rice.

Situated an hour and a half east of the San Francisco Bay Area, the Oakdale area is considered within the ideal commute range for a growing number of metropolitan workers. The Oakdale area offers much of what the urban dweller lacks within their own region; that being open space, relatively affordable housing, less crime, increased recreational opportunities and a country atmosphere. All together these amenities amount to an increasing urban inflow and a new set of challenges for an irrigation district. Primary amongst these challenges is how to continue the delivery of irrigation water while wrestling with

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the demands of facility impacts from a patchwork quilt of sprawling developments.

OID has developed a Subdivision/Parcel Map Development Policy (hereafter referred as Policy) that attempts at one end; to control development which has a negative impact on OID water delivery and drainage facilities and on the other end is pliable enough for developers to work with, such that planned changes may enhance the expanding community areas.

What follows first is a presentation of the Policy itself. The presentation is then followed by a general discussion of certain sections of the Policy for purposes of clarifying the intent of the OID Board of Directors in making such requirements.

SUBDIVISION/PARCEL MAP DEVELOPMENT POLICY

In accordance with the Subdivision Map Act (California Government Code Section 66410 et seq.), a Parcel Map is distinguished from a Subdivision Map by the number of parcels created and its designation when submitted by the appropriate lead agency for review. A Parcel Map can create up to 4 new parcels plus a remainder. A Parcel Map can create more than 4 parcels, and a remainder, if the parcels are 40 acres or greater in size or has a zoning designation of Commercial or Industrial. A Subdivision Map creates 5 or more parcels.

Pursuant to California Law, a parcel map is required when:

1. The land before division contains less than five (5) acres, each parcel created by the division abuts upon a maintained public street or highway and no dedication or improvements are required, or

2. Each parcel created by the division has a gross area of twenty (20) acres or more and has an approved access to a maintained public street or highway, or

3. The land consists of a parcel or parcels of land having approved access to a public street or highway which comprises part of a tract of land zoned for industrial or commercial development, and which has been approved as to street alignments and widths, or

4. Each parcel created by the division has a gross area of not less than forty (40) acres or is not less than a quarter of a quarter-section.

The following are the requirements, recommendations and considerations from the Oakdale Irrigation District (District) regarding development of subdivisions and parcel maps within the District's water service area in accord with and pursuant to the Subdivision Map Act.

Requirements-General

1. The District requires written, recorded easements for all of its facilities within the development area with the recorded instrument number noted on Parcel and Final (Subdivision) Maps.

2. The District requires that its irrigation and drainage easements be clearly identified on recorded Parcel and Final (Subdivision) Maps. Any proposed easements due to relocation requests shall also be identified.

3. The District requires that existing irrigation pipelines, canals, ditches, structures, turnouts and drains on the created parcels (both District and Private) be shown on the Parcel and Tentative Subdivision Maps for review purposes.

4. The District requires full, unencumbered access, as determined solely by the District, to both sides of its facilities and will rehabilitate, at its cost, those facilities within its control that do not meet that standard. This work shall be performed by the District after receipt of recorded easements and prior to signing the Final Map.

5. Relocation of District facilities to the benefit of the development must be coordinated and approved by the District. All costs associated with design, approval and analysis of relocations, including reasonable attorney and consultant fees, shall be at the Developer's expense.

6. The District shall require a Developer Agreement before any work can be done on District Facilities. Developer Agreements require a retainer for staff preparation time and additional related costs reasonably incurred by the District.

7. All irrigation facilities to the benefit of the development shall be built outside the District's easements and rights of way.

8. The District shall not provide water to ponds except as approved by the Board of Directors.

Requirements-Irrigation

1. The historical water delivery point for the developed property will continue to be the point of diversion for the development. No additional irrigation delivery connections will be provided as a result of development unless approved by the Board of Directors.

2. The historical water delivery volume for the developed property will not increase as a result of development. Totalizing flow meters shall be installed, at the developer's expense, to all District approved water delivery points within the development as a condition of project approval. All testing associated with verifying the flow volume shall be performed by the District at the Developer's expense.

3. The historical water delivery point and flow volumes will be determined by the District. The District may, at its sole discretion, reduce the number of historical delivery points on any development.

4. Parcels within the proposed development that will continue to irrigate shall be required to have independent water delivery systems. The independent delivery systems will be served by a cluster well or sump provided at the historical point of delivery by the developer. The District has standard plans available for this purpose.

5. The District will not serve irrigation water to created parcels that are less than 10 acres in size unless approved by the Board of Directors.

6. If parcels created by a Parcel Map or Subdivision Map choose not to irrigate, the Developer may apply to the District for a Surface Water Irrigation Service Abandonment and Quitclaim Agreement. Any Irrigation Service Abandonment Agreement is subject to approval by the District Board of Directors.

7. California Water Code requirements will be enforced on each irrigated parcel to ensure the reasonable and beneficial uses of water. Parcels or lots within developments, which have not shown a reasonable standard of care in the preparation for the receipt of irrigation water, as determined by the District, will not be permitted to irrigate or receive water.

Requirements-Drainage

1. No drainage from residential and rural subdivisions, industrial developments and commercial developments shall be allowed into District facilities. All costs incurred by the District to mitigate or resolve drainage issues shall be at the cost of the Developer, including consultant and/or attorney fees.

Requirements-Easements and Encroachments

1. Revocable License Agreements are required for any existing encroachments or proposed improvements within the current or requested District easement.

2. The District requires that its easements, rights-of-way, and fee title property be fenced to District Standards. This cost shall be borne by the Developer. Fencing shall be completed prior to approval of the Final Map. No gates nor cross fencing shall be installed or permitted within these areas without prior written authorization from the District.

3. Existing District facilities within a public road right-of-way shall be relocated into a right-of-way or easement dedicated to the District.

4. Standard Easement widths for District facilities shall be:

Main Canals	100 foot centered on canal
Canals/Drains	60 foot centered on canal/drain
Pipelines	30 foot centered on pipeline
Pipelines adjacent to roadways	20 foot
Pipelines adjacent to PUE	15 foot

Easement widths for joint projects shall meet the above minimum easement widths plus any additional easement width that may be required based on the specific project uses or as approved by the Board of Directors.

5. If an existing District facility is not centered on the property boundary between two properties, the District may require an easement width based on the distance to the centerline of the District facility.

Recommendations and Considerations

1. The developer should provide private irrigation easements for said properties to insure that existing downstream users can have access to irrigation water and can irrigate or continue to irrigate.

2. The developer should provide private drainage easements for the benefit of upstream parcels that have historically drained across newly created parcels.

3. If, upon review, the District determines that parcels created in a Parcel Map or Subdivision cannot irrigate efficiently, based on poor grading and planning, irrigation water will not be delivered until the situation is corrected to the sole satisfaction of the District.

4. "Improvement District" formation should be considered as a mechanism to ensure the responsible long-term operation and maintenance of private irrigation systems and as a means of irrigating parcels or lots developed under the ten-acre minimum.

5. The District would consider financially participating in conjunctive use reservoirs constructed to serve the irrigation needs of the development.

BASIS FOR POLICY REQUIREMENTS

The following section provides some insight and background on the basis for many of the aforementioned policy requirements. Each segment will be addressed in the order it appeared in the Policy.

Requirements-General

During the early development of irrigation districts in California, many of the canals and drains were constructed under verbal agreements with underlying landowners who were more than cooperative to have irrigation water delivered to their lands. After so many years, the districts acquired prescriptive rights to the canal or drainage facility, but still no written easement. In today's "modern" society, while the importance of irrigation water to the urban dweller has mostly diminished, their desire to challenge the land holdings of the irrigation district has escalated.

Therefore, OID has made it a condition of development that the developer shall provide deeded and recorded easements for all OID facilities within the developed area. In addition, these facilities (whether ditch, pipe, turnout, check, etc.) will be clearly identified and marked on the Tentative Maps.

The loss of facility access is one of the biggest impediments caused by urban development that OID is facing. To ensure no further loss of access occurs, OID intends to go in and reconstruct its facility within developing areas to re-establish its footprint. By so doing, with proper markers, fences, etc., not only does it become more difficult to encroach upon OID facilities, it makes illegal encroachments more visible. Further enhancing OID's ability to be proactive in the early detection and removal of such illegal encroachments.

The desire to have a pond by small ranchette owners who purchase rural acreages is problematic for OID. Most believe this is a right associated with land ownership and they share little sympathy or understanding with the reasonable and beneficial use standards for water use in California. Early denial, while still in the planning process, is viewed as an effective tool to curb this practice.

Requirements-Irrigation

Much of this section of the Policy is fairly self explanatory, but the largest premise here is; OID will not accept additional new turnouts as a result of development. A 40-acre parcel broken into eight 5-acre parcels adds a net seven (7) customers to what previously was one. The increased labor demand on an irrigation district can be substantial and it is not an expense OID wishes to pass on to its customers.

Likewise, on issues related to billings and non-payments, shut-off events are more easily controlled and performed if each resident has their own individual shut-off valve located at a cluster well accessible by the irrigation district. This is why the OID reserves the right to dictate the location of the point of water delivery for each development.

The 10-acre limitation for receipt of water delivery is an attempt to differentiate between true agricultural usage and non-agricultural usage (i.e. ranchette water) for purposes of billing structure in the future. It is also an attempt to further limit the 1 and 2 acre parcels that seem to be appearing in the countryside from 40 acre parcel owners wishing to cash in on high land values.

As always, the OID wishes to further influence the need for good water management practices even on small acreages. As OID's own policy dictates, if the land is not prepared for the receipt of irrigation water, it may not be delivered. This standard applies to all landowners equally.

Requirements-Drainage

Changes in the laws concerning agricultural drainage in California are putting an ever increasing demand on drainage water containment. Current policy in OID requires the agricultural discharger to have a drainage agreement from the OID before runoff water will be accepted into OID facilities.

Approximately 10 percent of OID is in San Joaquin County. The storm containment policy of that county is the 50-year storm event. The remaining 90 percent of OID within Stanislaus County has a storm containment requirement for the 25-year event. Any exceedences of these events are considered "acts of God" and beyond the control of OID should these waters enter an OID facility.

Requirements-Easements and Encroachments

The Policy intent is not to permit the permanent installation of any encroachment not integral to the delivery of irrigation water. That being said, OID's use of a Revocable License Agreement ensures this legal control.

The ability to fence an easement in California is precluded by law unless that right is waived by the underlying landowner. OID, as a condition of development, requires that the developer give up that right and give an easement to OID waiving their rights. This requirement ensures that OID's facility footprint is established prior to the creation of multiple parcels.

Recommendations and Considerations

Beyond the easement and rights of way boundaries of the OID, OID is precluded from placing conditions or requirements on land not within its control. However, it does not preclude the OID from making recommendations or considerations to developers during the development process. This section of the Policy is an attempt to deal ahead of time with many of the post-development issues OID encounters resulting from poor planning of subdivisions and/or parcel splits. After development, unsuspecting urbanites, with preconceived premises of country living, come to the OID seeking assistance in obtaining water. Often, their premises and OID policy requirements are at odds.

The OID irrigation system was laid out to provide water to the quarter section (160 acre parcel). Upon OID meeting that requirement, all systems emanating from that point are considered private systems and the responsibility of the benefiting landowners. When new property owners come to OID seeking water, OID informs them of the nearest point of delivery and their obligation to get the water to their lands. Often this requires crossing another parcel or parcels to accomplish that effort. This is the most common issue OID faces with new small parcel owners. As such, OID recommends that the ability to bring water to a new parcel be addressed by providing legally dedicated irrigation easements for that purpose.

As enthusiastically as the above easements are sought for irrigation, dedicated drainage easements are equally suggested. For any seasoned veteran in agriculture, the need for drainage pathways seems intuitively obvious. For the urbanite however, this is not the case. Their past world has dealt with water flowing to the front of the lot, into the street, down the gutter and into a storm drain system. In the county however, the storm drain system is above ground, and if one purchases low-land properties, one ends up seeing quite a bit of that flow across their property. This issue consumes more field staff time than any other issue faced at OID. Having defined drainage easements attached to property titles goes a long way in quelling complaints.

To address both the above issues, OID encourages the formation of “Improvement Districts” as a means to operate and maintain common irrigation and/or drainage facilities within developments. These organizations, outlined in California’s Water Code (§ 23600), provide a sense of certainty for small parcel owners that their irrigation and drainage needs will be met financially for years to come.

Landowners within rural subdivisions or small parcel owners in the country, if not retired and not farming for a living, have another job. If they are a daily commuter, they travel long distances consuming a good portion of each and every day of the week. Their need to take care of their properties then is usually relegated to weekends, including the need to irrigate.

In its intent to adjust to a changing customer base, OID is open to the development of multi-functional reservoirs within developments. OID offers to each development the opportunity to build reservoirs that serve both a function to the development and also OID. This offering is predicated on the idea that a reservoir could be constructed within the development, sufficient in size to accommodate the weekend water needs of the development. In short, irrigation water would be available Saturday and Sunday within the development.

During the Monday through Friday time period, when not in use or needed, OID could use the reservoir as an intermittent storage or delivery facility to meet its agricultural demands. However, always leaving the reservoir full come midnight on Friday. Costs for this division of use are left to be negotiated on a case by case basis.

SUMMARY

Portions of OID's Subdivision/Parcel Map Development Policy have been in effect for a number of years. However, the recent surge in developments, subdivisions and the parceling out of Oakdale's rural countryside has prompted OID to take a more proactive roll in protecting its' irrigation and drainage interests.

It would be futile to attempt to change the course of the community's growth. However, Oakdale is still a heavy agricultural area producing a way of life and a national product (food) that needs to be protected. The end result OID strives for is balance. A balance in the protection of an irrigation district's ability to provide efficient operation and maintenance of its water delivery and drainage facilities with the needs of professional well planned developments that strive to meet the quality of life needs of a growing community.

FARM SIZE, IRRIGATION PRACTICES, & ON-FARM IRRIGATION EFFICIENCY IN NEW MEXICO'S ELEPHANT BUTTE IRRIGATION DISTRICT

Rhonda Skaggs[1]
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ABSTRACT

Relationships between farm size, irrigation practices, and on-farm irrigation efficiency in the Elephant Butte Irrigation District, New Mexico, U.S.A. are explored using water delivery data supplied by the District. The study area is experiencing rapid population growth, development, and competition for existing water supplies. Analysis of pecan and alfalfa water delivery data, fieldwork, and interviews with irrigators found extremely long irrigation durations, inefficient irrigation practices, inadequate on-farm infrastructure, and little interest in making improvements to the current irrigation system or methods on the smallest farms. These findings are attributed to the nature of residential, lifestyle, or retirement agriculture. Irrigation practices on large farms are notably different from small farms: irrigation durations are shorter, less water is applied, producers are commercially oriented, and have high levels of on-farm efficiency. Many small producers appear to view irrigation as a consumptive, recreational, social, or lifestyle activity, rather than an income generating pursuit. Small farm operators are likely to show limited interest in improving on-farm irrigation infrastructure, adopting management intensive irrigation technologies or practices, or making significant irrigation investments. Easement and common property disputes over ditch maintenance between owners of small parcels also create disincentives for infrastructure improvements.

INTRODUCTION

New Mexico's Lower Rio Grande Valley is experiencing rapid population growth, development of the rural countryside, and decreasing municipal groundwater supplies. Plans are underway to transfer some of the surface water from agriculture to municipal and industrial use in Doña Ana County, where most of the Elephant Butte Irrigation District (EBID) is located. Lifestyle agriculture is widespread in the county, where the total number of irrigated farms increased by 70% between 1974 and 1997 (U.S. Dept. of Commerce, 1981; U.S. Dept. of Agriculture, 1999). EBID irrigated acreage has been stable over that period of time (~75,000 acres), while numbers of farms in the smallest acreage categories

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grew dramatically as a result of land splits. For instance, there were 150 farms between one and nine acres in 1974 and 691 of these farms in 1997.

EBID currently delivers water to almost 8,300 parcels of land. Thirty-eight percent of the irrigated parcels are less than two acres in size, while another 28% are between two and five acres, with both these parcel categories accounting for 12% of the District's irrigated lands. In comparison, irrigated parcels of more than 100 acres comprise less than 2% of irrigated parcels, but account for almost 28% of irrigated land. Larger, commercially-oriented farms often operate on numerous non-contiguous parcels. Alfalfa, pecans, cotton, chile peppers, and onions are the primary crops produced in the District.

EBID conveyance efficiency (e.g., diversion / farm delivery) is estimated to be 54%, while district-wide on-farm irrigation efficiency (e.g., consumptive irrigation requirement / farm delivery) is estimated to be 83% (Magallanez and Samani, 2001). Although most of the District is irrigated by traditional basin or basin-furrow methods (with no runoff from the end of the field), on-farm efficiency is high as a result of deficit irrigation practices on much of the crop acreage.[3] The efficiency studies that support EBID's aggregate assessments have been conducted on a small number of relatively large, commercial farming operations; thus while they represent a large percentage of irrigated lands, they reflect the irrigation practices of a small percentage of total irrigators and farms.

The objective of the research reported here was to examine irrigation practices and efficiency across a broad cross-section of farms. Water delivery data for 864 EBID accounts were analyzed using Excel™ and SAS™, with the objective of identifying patterns in on-farm irrigation efficiencies and water use in pecans and alfalfa. The data presented in this report are for the 2001 irrigation season. Field visits were conducted in 2002 and 2003 in order to ground-truth findings of the data analysis, observe actual irrigations, and meet the irrigators.

FINDINGS

Total Irrigation Water Applied

Descriptive statistics and quantile analysis for acre-feet/acre of water applied for the 340 pecan farms are presented in table 1. Analysis of variance confirmed that the water applied means were not significantly different by farm size; however, the range of water applied does vary greatly by farm size. The range of water

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[3] Samani and Al-Katheeri (2001) used on-site flow measurement and chloride tracing and found basin and basin-furrow irrigation efficiency to be as high as 95% for pecans. Deras (1999) found efficiencies ranging from 88% to 98% in alfalfa, 88% to 97% in cotton, 79% to 94% in pecans, and 83% to 94% in chile peppers (Salameh Al-Jamal et al., 1997).

applied across all quantiles is 5.30 acre-feet/acre for the smallest farm size, which is more than three times larger than the second highest range (≥ 20 acres). The irrigation district data included no information about supplemental groundwater, and parcels which received surface water less than five times during the irrigation season were not included in the analysis in an effort to eliminate farms which apply primarily groundwater. Nevertheless, it is curious to see the low levels of surface water applications in the 25% of the pecan farms using the least amount of water in each farm size category. It may thus be more appropriate to compare the ranges of water applied to pecans for the highest 25% of water users in each farm size category, to reduce the likelihood of supplemental groundwater use. Examination of the ranges of water applied for the highest 25% of water users again shows the largest range of acre-feet/acre in the smallest farm size group.

Table 1. Quantile analysis and descriptive statistics for pecan water applied (acre-feet/acre) relative to farm size (2001, n = 340).

		Farm Size Category			
		2 ≤ acres< 5	*5 ≤ acres < 10*	*10 ≤ acres < 20*	*≥ 20 acres*
Quantiles					
0%	Minimum ac-ft/ac water applied	1.85	2.18	2.47	2.27
25%		3.04	3.11	3.37	3.28
50%	Median ac-ft/ac water applied	3.78	3.67	4.01	4.49
75%		4.53	4.37	4.95	4.98
80%		4.72	4.51	5.35	5.09
85%		4.97	4.61	5.61	5.20
90%		5.44	5.09	5.63	5.79
95%		6.09	5.59	5.64	5.95
99%		6.45	5.99	5.70	6.23
100%	Maximum ac-ft/ac water applied	7.15	5.99	5.70	6.23
Descriptive Information					
	Number of farms	223	65	24	28
	Percent farms	65.6	19.1	7.1	8.2
	Mean ac-ft/ac[1]	3.91	3.79	4.12	4.23
	Grand mean – all farm size groups	3.93 acre-feet/acre (47.16 inches/acre)			
	Standard deviation (ac-ft/ac)	1.05	0.94	0.99	1.09
	Range (all quantiles) (ac-ft/ac)	5.30	1.26	1.58	1.70
	Range (75% - 100%) (ac-ft/ac)	2.62	1.62	0.75	1.25
	Number of acres	648	396	303	1,368
	Percent acres	23.9	14.6	11.2	50.4
	Total water applied (ac-ft)	2,567	1,483	1,224	5,748
	Percent total water applied	23.4	13.4	11.1	52.2

[1] Means were not significantly different.

Acre-feet/acre of water applied to alfalfa parcels relative to farm size is presented in table 2. Analysis of variance found significant differences in means of water applied for alfalfa. Specifically, the mean acre-feet/acre for the smallest farm size was significantly lower than the means for farms in the 10 ≤ acres < 20 and ≥ 20 acres groups. As presented in table 3, differences in the ranges of water applied for the highest 25% of water users are very large, with an almost 10-fold difference between the smallest and largest farm size groups. Examination of differences in mean water applied by farm size indicates that larger parcels have a higher average level of water applied. However, the data for ranges of water applied complicate that conclusion, and show that even when the highest 1% of extreme observations is excluded, the range of water applied is greatest for the smallest farm size.

Table 2. Quantile analysis and descriptive statistics for alfalfa water applied (acre-feet/acre) relative to farm size (2001, n = 524).

		Farm Size Category			
		2 ≤ acres< 5	*5 ≤ acres < 10*	*10 ≤ acres < 20*	*≥ 20 acres*
Quantiles					
0%	Minimum ac-ft/ac water applied	2.00	2.19	2.29	2.21
25%		3.03	3.39	3.76	3.90
50%	Median ac-ft/ac water applied	3.86	4.17	4.45	4.62
75%		4.75	4.98	5.37	5.14
80%		5.08	5.17	5.50	5.75
85%		5.34	5.31	5.76	6.00
90%		5.61	5.59	5.99	6.13
95%		6.13	6.59	6.59	6.54
99%		8.55	7.19	7.25	6.59
100%	Maximum ac-ft/ac water applied	19.18	10.91	7.25	6.59
Descriptive Information					
	Number of farms	290	116	73	45
	Percent farms	55.3	22.1	13.9	8.6
	Mean ac-ft/ac[1]	4.06[ab]	4.29	4.52[a]	4.60[b]
	Number of acres	884	727	946	1,479
	Grand mean – all farm size groups	4.22 acre-feet/acre (50.64 inches/acre)			
	Standard deviation (ac-ft/ac)	1.53	1.24	1.11	1.11
	Range (all quantiles) (ac-ft/ac)	17.18	8.72	4.96	4.38
	Range (75% - 100%) (ac-ft/ac)	14.43	5.93	1.88	1.45
	Number of acres	884	727	946	1,479
	Percent acres	21.9	18.0	23.4	36.7
	Total water applied (ac-ft)	3,605	3,117	4,363	6,734
	Percent total water applied	20.2	17.5	24.5	37.8

[1] Means with the same letter are significantly different at $p < 0.05$.

Pecan consumptive use is ~5.0 acre-feet/acre for mature trees. Based on analysis of the District's 2001 records, approximately 18% of the pecan farms analyzed applied water in excess of the consumptive use requirement. By comparison, 70% of the 524 alfalfa farms analyzed were applying water in excess of consumptive use (i.e., ~3.5 acre-feet/acre).

Irrigation Duration

The District's 2001 accounting of water delivered does not reflect actual measurements. The water delivery data analyzed are based on engineering estimates of canal deliveries, and the similarities in tables 1 and 2 between percent total acreage and percent total water applied by farm size group illustrate this situation. During examination of the 2001 water delivery data provided by EBID, differences in irrigation durations between farms became very obvious. The data included start and stop times for water deliveries, and spreadsheet functions were used to estimate total irrigation durations and irrigation durations per acre. Field measurements conducted for this research showed that for alfalfa irrigators EBID's accounting is about 30-35% lower than actual applied water. For pecans, actual water applied was found to be more consistent with EBID's records for the farms where field measurements were taken. Given these field observations, the irrigation duration data were analyzed extensively. Irrigation duration (i.e., hours/acre/irrigation) is an indicator of field level irrigation efficiency, and is particularly useful when measurements of actual water applied are unreliable.

Descriptive statistics and quantile analysis for irrigation durations are presented in tables 3 and 4 for the two crops.

Table 3. Quantile analysis and descriptive statistics for pecan irrigation durations (hours/acre/irrigation) relative to farm size (2001, n = 340).

		Farm Size Category			
		2 ≤ acres< 5	*5 ≤ acres < 10*	*10 ≤ acres < 20*	*≥ 20 acres*
Quantiles					
0%	Min. hours/acre/irrigation	0.35	0.46	0.28	0.91
25%		0.98	0.70	0.52	0.28
50%	Median hours/acre/irrigation	1.25	0.82	0.65	0.38
75%		1.71	1.17	0.92	0.46
80%		1.80	1.24	0.97	0.53
85%		1.95	1.48	1.01	0.53
90%		2.14	1.65	1.40	0.81
95%		2.73	1.74	1.44	0.83
99%		7.54	2.05	2.01	1.09
100%	Max. hours/acre/irrigation	25.6	2.05	2.01	1.09
Descriptive Information					
	Number of farms	223	65	24	28
	Mean hours/acre/irrigation[1]	1.57[abc]	0.97[a]	0.76[b]	0.42[c]
	Grand mean – all size groups		1.30 hours/acre/irrigation		
	Standard deviation (hours/acre/irrigation)	1.93	0.40	0.40	0.21
	Range (all quantiles) (hours/acre/irrigation)	25.25	1.59	1.73	0.90
	Range (75% - 100%) (hours/acre/irrigation)	23.89	0.71	0.64	0.63
	Total irrigation hours	10,288	4,165	1,473	2,004
	Percent total irrigation hours	57.4	23.2	8.2	11.2

[1] Means with the same letter are significantly different at $p < 0.05$.

Table 4. Quantile analysis and descriptive statistics for alfalfa irrigation durations (hours/acre/irrigation) relative to farm size (2001, n = 524).

		Farm Size Category			
		2 ≤ acres< 5	*5 ≤ acres < 10*	*10 ≤ acres < 20*	*≥ 20 acres*
Quantiles					
0%	Min. hours/acre/irrigation	0.59	0.44	0.33	0.24
25%		1.10	0.72	0.56	0.46
50%	Median hours/acre/irrigation	1.38	1.00	0.74	0.55
75%		1.86	1.33	1.12	0.67
80%		2.06	1.39	1.19	0.70
85%		2.29	1.52	1.29	0.74
90%		2.73	1.76	1.50	0.90
95%		3.92	2.25	2.27	0.99
99%		7.20	2.55	2.83	1.09
100%	Max. hours/acre/irrigation	9.90	2.76	2.83	1.09
Descriptive Information					
	Number of farms	290	116	73	45
	Mean hours/acre/irrigation[1]	1.73[abc]	1.10[ad]	0.92[be]	0.57[cde]
	Grand mean – all size groups		1.38 hours/acre/irrigation		
	Standard deviation (hours/acre/irrigation)	1.19	0.50	0.53	0.20
	Range (all quantiles) (hours/acre/irrigation)	9.31	2.32	2.50	0.85
	Range (75% - 100%) (hours/acre/irrigation)	8.04	1.43	1.71	1.02
	Total irrigation hours	11,836	6,870	8,077	8,070
	Percent irrigation hours	33.9	19.7	23.2	23.2

[1] Means with the same letter are significantly different at $p < 0.05$,

Prior field work and recent observations throughout the district by the authors have resulted in the empirical guideline of 0.5 hours/acre/irrigation. Regardless of soil type (e.g., sand, loam, clay), it has been found that irrigations on large, commercially-oriented farms typically require about 30 minutes of water flow per acre through the farm turnout onto the field. This guideline reflects typical lengths of run for the water in the fields, normal water flows at the farm turnouts, and adequately-sized on-farm turnouts. On heavy, clay soils, 0.2 hrs/ac/irrigation has been observed. Very long irrigations usually indicate that on-farm irrigation efficiency will be reduced due to deep percolation losses at the front of the field.

Differences in irrigation durations and ranges between the $2 \leq$ acres < 5 group and all other farm size groups are very striking. There is a clear distinction in irrigation duration on parcels of less than 5 acres relative to all other parcel sizes. The pecan and alfalfa data sets also were each divided into four equal quartiles by hours/acre/irrigation, and chi-square tests of differences in proportions were conducted. The chi-square analyses found that for both crops, there were significantly more small farms with the longest irrigation durations, and significantly more large farms with the shortest irrigation durations.

Several fields with long irrigation durations were visited during the 2002 and 2003 irrigation seasons to gain a better understanding of the conditions which led to the lengthy irrigation periods and confirm whether the extreme observations found in the EBID data were accurate representations of on-farm conditions. These fields were visited while irrigations were underway. Fields with average and below average irrigation durations were also visited while irrigations were occurring in order to compare those conditions with long duration conditions.

Common reasons identified for long durations were the condition of the farm delivery ditches and the size of the on-farm turnouts. In several cases, the water was moving so slowly through the farm delivery ditches toward the on-farm turnouts that flow measurements could not be taken with a digital propeller meter. The water was released from the district's larger canal via partially open 24-inch gates into the farm delivery ditch, and then through very small on-farm turnouts onto the fields. These small turnouts were usually round four-inch pipes. In other cases, the on-farm turnouts were not really structures; instead, they were more like controlled breaks in the farm delivery ditch. When asked about the length of time spent irrigating their fields, several individuals complained about the bad condition of the on-farm delivery ditch from which they take their water. The irrigation district has no responsibility or authority for maintaining these ditches, and the irrigators noted that weeds, trash, rodents, and breaks were factors that resulted in long irrigation durations. In the case of one of the long-duration fields, a fallow lot approximately 100 feet wide and 100 feet long was being used as a channel through which the water flowed uncontrolled before it reached the small pecan orchard actually being irrigated. Complaints about neighbors' unwillingness to grant easements for improving irrigation water delivery, or allow modifications to easements for the purpose of increasing the size of the on-farm delivery infrastructure were often heard. Conversations with the irrigators conducted during the field visits revealed some common themes. One theme can be summarized by one older man's comment regarding the fact that it took him almost two days to irrigate his ~3 acre pecan orchard. He said, "I'm retired, what else have I got to do?" Other comments revolved around the view that irrigation was a family tradition, that irrigating often meant the involvement of members of extended families, that irrigation was a social undertaking, that irrigation was a peaceful, meditative, enjoyable task.

Overall, the levels of irrigation technology and water management found on field visits to small farms were extremely low, and often a consequence of inadequate irrigation design. The principal design problem found was narrow diameter farm turnouts which cannot physically deliver to the field the minimum flow necessary to rapidly push the water across the field, thus reducing both the time spent irrigating and infiltration losses during the irrigation process. The level of involvement by other small-scale water users in the practice of irrigation also appeared to be quite low, and a relatively high degree of resentment toward other users of the same farm delivery ditches was noted among some interviewees (e.g., "Nobody else does anything to maintain the ditch, why should I?"). Many of the long-duration irrigators complained about their neighbors' unwillingness to improve the mutual on-farm delivery ditch (i.e., that part of the delivery system not maintained by the district).

The EBID water delivery data were collected for the objective of billing irrigators; and were not the result of actual measurements of on-farm deliveries. Results of the field measurements have been intriguing, and usually at odds with the district's water delivery data, which record six acre-inch deliveries for most irrigation events. Field analysis on selected farms consistently found that the amount of water applied to a field is strongly and positively related to irrigation duration per acre. Irrigation depths per event ranging from 2.2 acre-inches to 14.7 acre-inches were measured in fields. Furthermore, the excessively high water applications (including the 14.7 acre-inch case cited above) are an *average* across the entire parcel, and do not account for what may be 20+ acre-inch applications at the top of the fields. These high top-end applications occur during the process of the irrigation water's extremely slow advance.

Results of field measurements taken in 2002 and 2003 indicated a large range of actual water deliveries to farms, and some patterns have emerged. Results tend to show underdelivery (i.e., less than six acre-inches) and subsequent overcharges to larger fields, while smaller fields (i.e., less than 10 acres) tend to receive more than six acre-inches per irrigation. Smaller farms are thus undercharged for their irrigation water. Overdelivery of water is related to the excessively long irrigation durations discussed above, with reasons for overdelivery including long fields (i.e., irrigation runs >1,200 feet), rough field surfaces, low flows, and small turnouts to the farm. During field work many water deliveries ranging from 8-12 acre-inches were measured. The fields receiving the water were generally smaller, although not exclusively so. Many deliveries in the range of two to four acre-inches on larger fields were also measured. These fields tended to be intensively managed (evidenced by surface smoothness and absence of weeds), and were part of large, commercial farms. These fields also tended to be located near the larger delivery canals, irrigated through large turnouts, and received high flows of water during the observed irrigation events. The water rapidly moved over the fields, and due to the common practice of shutting off the water when it reaches the end of the field, underdelivery occurred.

Monthly Irrigations and Evapotranspiration

Both field work and examination of the irrigation district's data also lead to the conclusion that there is little relationship between seasonal water demand and applied water for the fields studied. Traditional irrigation timing practices (i.e., every 7-14 days throughout the irrigation season) contribute to overwatering at the beginning and end of the irrigation season, plant stress at peak crop water use periods, and can result in reductions in both crop yields and quality. Figures 1 and 2 show average water applied by month for each farm size group on the left vertical axes and maximum monthly evapotranspiration on the right vertical axes.

The pattern of water application to pecans and alfalfa is similar across the different farm size groups. Average acre-feet/acre/month applied to pecans is very stable throughout the irrigation season, while alfalfa generally shows decreasing applications from the beginning to the end of the irrigation season. Both figures 1 and 2 illustrate over irrigation at the beginning of the season, and less than optimal applications during the peak growing months of June and July. For the two smallest size pecan farm groups and all the alfalfa farm sizes, irrigation at the end of the season is higher than maximum evapotranspiration.

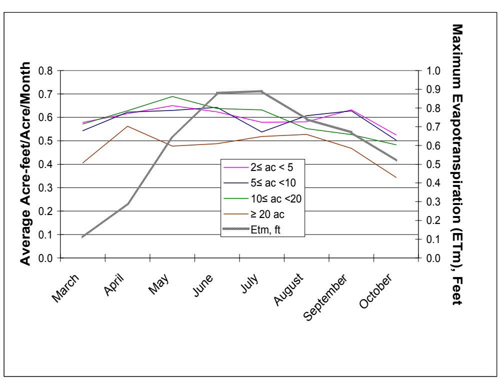

Figure 1. Pecan average acre-feet/acre/month water applied by farm size (by month, 2001, n = 340) and maximum Et.

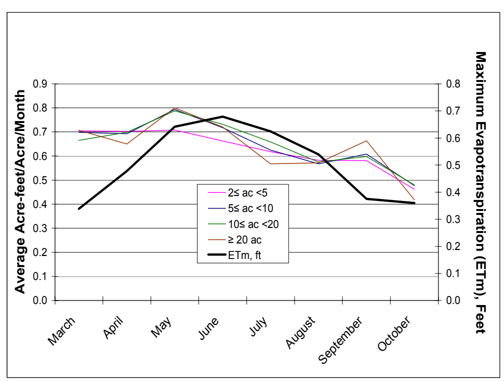

Figure 2. Alfalfa average acre-feet/acre/month water applied by farm size (by month, 2001, n = 524) and maximum Et.

Differences in farm size should be considered a proxy for other characteristics of the irrigator population (for which data are currently unavailable), and it should be clear that the irrigator population is not homogeneous. As discussed above, irrigation duration may be a better indicator of actual water deliveries than the district-recorded data. And, interviews with irrigators leads to the conclusion that a portion of the irrigator population does not view long durations as problematic, and that dealing with the "problem" of long irrigation durations is very complicated (i.e., common property issues, easement disputes, etc). Potential water savings from increased on-farm efficiency and irrigation infrastructure investments, or responses to incentives created by water marketing thus will vary by farm and throughout the irrigator population.

The loss of 46% of EBID's diverted water before deliveries to the farm turnouts is often cited by critics as an example of extreme inefficiency. However, the research described here has led to skepticism about the 54% diversion-to-delivery efficiency estimates. It is likely that at least part of the loss claimed to occur from diversion into EBID canals to delivery on farms is water actually applied to fields and not accounted for at the farm level. The district's water accounting procedures do not document this. It is also likely that carriage water requirements are larger for the smaller water deliveries to the smaller fields. Irrigation infrastructure on the smaller fields limits the rate at which water can be diverted to farms, resulting in deep percolation, runoff, and excess carriage water losses. Many necessary infrastructure improvements are unlikely to occur as a result of limited financial resources, easement disputes, disagreements between local irrigators, and lack of urgency or interest on the part of many irrigators.

It is commonly assumed by many observers and critics of EBID that the irrigation practices of the large, commercial farms must be improved in order to release water for other uses. However, the results of this and earlier research, the prevalence of deficit irrigation practices and other techniques or technologies currently used on large farms to increase the physical efficiency of irrigation water indicate that marginal increases in efficiencies on many large farms are likely to be small and come at a high cost. And the price at which many small farm operators will be inclined to change their irrigation practices may be extremely high, because for them, irrigation is a recreational, social, or lifestyle activity, and not an income generating pursuit. The common property nature of those segments of the water delivery system not owned by EBID also creates a disincentive for investment and improvements by individual water users.

We currently hypothesize that many smaller EBID water users have minimization of the costs or risks of operating their small farms (regardless of the impacts on irrigation water productivity, yields, or total production) as their primary objective. Some smaller water users seem to have maximizing their utility or satisfaction from the small farm generally (and irrigation activities in particular) as a key objective. Again, these objective functions do not seem very compatible with the notion that water users generally will be interested in increasing irrigation efficiency through changes in technology, increases in management intensity, and responding to financial incentives to release surface water from agriculture for other competing uses.

The number of irrigated farms in the EBID has increased over the last several decades, due to splitting larger farms into smaller parcels. The ramifications of this for on-farm irrigation, delivery efficiencies, irrigation infrastructure, and irrigation system management are serious and underappreciated. One final conclusion of this research concerns the relationships between engineering and socio-economics. The conclusion is that the irrigation structures (e.g., ditches, gates, turnouts, etc.) designed for the agricultural structure (i.e., numbers and distribution of farms by size) which characterized the EBID in the early 20th century are currently a source of significant inefficiencies. The degree of reinvestment or disinvestments necessary to make irrigation structure compatible with current agricultural structure is surely very large. Furthermore, agricultural structure in Doña Ana County will continue to evolve with urbanization, population growth, and economic development. As a result, compatibility between irrigation infrastructure and agricultural structure is not a static target, given the dynamic nature of urban fringe agriculture in Doña Ana County.

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IRRIGATION MANAGEMENT TRANSFER AND WATER TRANSFERS: CHALLENGES FACING WATER USER ASSOCIATIONS IN THE LERMA-CHAPALA BASIN, MEXICO

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ABSTRACT

In the Lerma-Chapala Basin surface water depletion exceeds supply in most years, causing Lake Chapala, the water body into which the Lerma River flows, to dry up. To increase lake levels, Mexico's National Water Commission transferred water from upstream irrigation districts to the lake in 1999, 2001 and 2003. The legality of these water transfers was strongly contested by Water User Associations (WUAs) of the irrigation districts in the Basin, as the 1991 surface water allocation treaty does not outline procedures for such transfers, and transfer impacts on lake levels were minor. WUAs have responded by organizing themselves at basin level, to gain a more significant input into the design of a new water allocation model. Created in the 1990s under the Mexican Irrigation Management Transfer program, the WUAs have been effective in improving the provision of irrigation services and recovering costs from users. However, the water transfers have placed great strain on the WUAs, and their efforts to reach a negotiated agreement on surface water allocations have been unsuccessful. Instead, water allocations at basin level remain highly politicized and the design of water transfers procedures from agriculture to other uses has stalled.

INTRODUCTION

In 1989, a program of transferring the management of publicly owned irrigation systems in Mexico to Water Users Associations (WUAs) commenced. The process of transfer has been well documented (Trava, 1994; Gorriz et al, 1995; Kloezen et al, 1997; Rap et al, 2004), showing that WUAs have done relatively well in executing irrigation management tasks formerly carried out by government agencies.

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While initially the focus of the newly transferred WUAs was on the establishment and running of their Associations, many of these Associations are now faced with the challenge of negotiating and securing their rights and access to surface water. This is particularly the case in the Lerma-Chapala Basin, located in central Mexico. From a water perspective this basin is in serious trouble. While average annual rainfall from 1993 to 2003 (at 675 mm) was only 5% below the historical average of 711 mm, and efforts were made by the government to reduce water use in irrigation through water saving programs, the total amount of surface and groundwater used in the basin exceeded supply by 9% on average during this period (Wester *et al.*, 2001). Groundwater is being mined, and surface water depletion exceeds supply in nearly all years, causing Lake Chapala to dry up.

As Mexico's largest natural lake, Lake Chapala generates significant tourism and real estate revenues, while also providing Guadalajara, Mexico's second largest city, with 190 Million Cubic Meters (MCM) of water annually. The lake is highly valued by the inhabitants of Jalisco State, where it is situated, as well as some 30,000 retirees living on the lakeshores. Despite efforts by the federal government to increase lake levels through water transfers from upstream irrigation districts to the Lake, by June 2002 the lake had dropped to 14% of its capacity, the second lowest level recorded since systematic data collection began in 1934. The water transfers have increased conflicts between states and water users in the Basin, not least because their impact on lake levels were minor and farmers in the irrigation districts were not compensated for the reduction in water allocations for irrigation.

This paper analyzes the challenges facing WUAs in the Lerma-Chapala Basin due to increasing inter-sectoral competition for water, and how they have responded to the water transfers. It shows that farmers have had little time to develop their associations, while having to focus on the river basin level to secure and retain an adequate share of water.

THE LERMA-CHAPALA RIVER BASIN

The Lerma-Chapala Basin, covering some 54,300 km^2, lies between Mexico City and Guadalajara and crosses five states: Querétaro, Guanajuato, Michoacán, Mexico and Jalisco. The basin accounts for 9% of Mexico's Gross National Product, and is home to over 11 million people. It is also the source of water for a further 4 million people in Guadalajara and Mexico City. The irrigated area of some 794,000 ha represents 13% of the irrigated area in Mexico.

The Lerma River rises in the east of the basin at an elevation of 2600 m.a.s.l. (meters above sea level) to discharge into Lake Chapala in the west at an elevation of 1,500 m.a.s.l. (see Figure 1). Lake Chapala, with a length of 77 km and a maximum width of 23 km, stores 8,125 MCM and covers 111,000 ha when full. The shallow depth of the lake (average 7.2 m) results in a lake evaporation of some 1,440 MCM (25% of the average annual runoff in the basin) each year (de

Anda *et al.*, 1998). During periods of high water levels Lake Chapala discharges into the Santiago River, which flows for a further 524 km before discharging into the Pacific Ocean.

Irrigation is the main water user in the basin, good for 68% of current water use. Evaporation from water bodies accounts for 23% of water consumed (Wester *et al.*, 2001). Nine canal irrigation districts cover 284,000 ha, while some 16,000 irrigation units or private irrigation systems cover 510,000 ha. Twenty-seven large reservoirs provide 235,000 ha in the irrigation districts with surface water while around 1,500 smaller reservoirs serve 180,000 ha in the irrigation units. An estimated 26,000 wells provide around 380,000 ha in the basin with groundwater, of which 47,000 ha lies in the irrigation districts (CNA/MW, 1999).

Figure 1. Location and Topography of the Lerma-Chapala Basin

Since the mid 1980s, surface water in the Basin has been over-committed. The average annual runoff in the basin from 1940 to 1995 was 5,757 MCM. Figures on groundwater recharge are inconclusive, with best guesstimates placing it at 3,980 MCM (CNA, 1999a), giving a total of 9,737 MCM annual renewable water. Informed estimates place total consumptive water use at 10,637 MCM, yielding an annual deficit of 900 MCM (CNA, 1999a). This deficit is covered by the over-extraction of groundwater and the drying up of lakes in the basin.

Concern about water quantity and quality issues in the Basin prompted institutional changes from the mid-1980s onwards. Inspired by the French model of river basin management, the federal water agency sought to decentralize water management in the Lerma-Chapala Basin (Mestre, 1997). The prospects for institutional reform improved further after 1988, with the newly elected president for Mexico, Carlos Salinas, giving high priority to water issues and decentralization (Rap *et al.*, 2004). This resulted in far-reaching water reforms, such as the creation of the *Comisión Nacional del Agua* (CNA, National Water Commission) in 1989, the transfer of government irrigation districts to users (1991–present), the establishment of technical committees for groundwater (1995-onward), the creation of state water commissions (1991-onward), and the promulgation of a new water law in 1992 (Wester *et al.*, 2003).

An important step towards improved collaboration in the Lerma-Chapala Basin was taken in April 1989 when the Mexican president and governors of the five states falling in the basin signed an agreement to strengthen mechanisms for water allocation, to improve water quality, to increase the efficiency of water use and to conserve the basin's ecosystems. Crucially, the signatories recognized that the agreement could not be implemented without the support of a broad range of stakeholders. In September 1989, a Consultative Council (CC) was created consisting of federal and state government representatives as well as stakeholder representatives to implement the agreement. Further, the CC established a Technical Working Group (TWG) of 60 government and user representatives to translate the agreement into action. Achievements of the CC include the formulation of a river basin master plan in 1993, a wastewater treatment program initiated in 1991, a surface water allocation treaty signed in 1991 and annual meetings to determine surface water allocations (Mestre, 1997).

The initial success of the CC led to the inclusion of an article in the water law of 1992 on River Basin Councils (RBCs), defined as coordinating and consensus-building bodies between the CNA, federal, state and municipal governments, and water user representatives (CNA, 1999b). While responsibility for water management was retained by CNA, the RBCs were conceived as important mechanisms for negotiation and conflict resolution (CNA, 1999b). The Lerma-Chapala Consultative Council became a RBC in January 1993. Presently, it consists of a Governing Board made up of the CNA director, the five state governors and a representative for each of six water use sectors (agriculture, fisheries, services, industry, livestock and urban). In addition, the RBC includes a Monitoring and Evaluation Group (MEG), the successor of the TWG, an Assembly of User Representatives and a number of Specialized Working Groups. The decision-making body of the RBC is the MEG, which is a carbon-copy of the Governing Board except that state governors send representatives in their stead, while CNA is represented by the head of its regional office. The MEG meets on a regular basis and is charged with preparing and convening Council meetings and applying the 1991 surface water treaty. Ensuring effective representation of water users has been a challenge for the Lerma-Chapala RBC from the start. Formally, the representatives of water users on the Council are elected but links with their constituencies are often weak (Wester *et al.*, 2003).

IRRIGATION MANAGEMENT TRANSFER IN THE LERMA-CHAPALA BASIN

The irrigation management transfer (IMT) program in Mexico is often held up as a model for others to follow. The main objective of the transfer program was to reduce public expenditure while increasing farmer participation in the management of the irrigation systems. The IMT program was introduced as part of a series of constitutional, economic and institutional reforms aimed at modernizing and revitalizing the agriculture and irrigation sectors. A major reform was the amendment of Article 27 of the Constitution which effectively ended the land reform program formulated following the Mexican revolution of 1910. The reform legalized the privatization of the *ejidos* (land reform communities). In 1992 a new national water act was promulgated which formalized the roles and responsibilities of the various actors in the IMT process. Two important features of the water law were the establishment of tradable water concessions, and the granting of permits to users to use government owned irrigation and drainage infrastructure.

The transfer program created a more complex organizational framework, with six main actors involved: the users, the WUAs, the Hydraulic Committee, the Limited Responsibility Society and the CNA. The WUAs have the responsibility for management, operation and maintenance within the "module", comprising the secondary canal command area. In the initial phase of IMT CNA ran the primary canal system, headworks and reservoirs, but over time responsibility for main system management has been taken over by farmer-run Limited Responsibility Societies (LRS) in several larger irrigation systems, mainly in northern Mexico. The Hydraulic Committee (HC) comprises representatives of the WUAs, CNA and the state government, and has the responsibility for planning water distribution within the irrigation districts (this was solely the responsibility of the CNA prior to transfer). CNA is now responsible for the management, operation and maintenance of the headworks and the reservoirs, for which it receives a fee from the WUAs.

The philosophy of the transfer program is strongly service-based, with each actor receiving payment for services provided. The WUAs collect irrigation service fees directly from the water users, who have to pay "up-front" for each irrigation turn. A proportion of the fee recovered from the water users is transferred to the CNA by the WUAs, based on the proportional amount of the main infrastructure serving a module. In those districts with a LRS, its expenses are also covered by the WUAs, who pay a percentage of their income from water fees to the LRS. This percentage has to be approved by the CNA district office.

The performance of the IMT program and individual WUAs has been impressive, with: a functioning new Water Law; measurable improvements in matching expenditure and farmers' perceived needs; significantly improved financial self-sufficiency; increased levels of managerial accountability; and significantly improved levels of expenditure on maintenance (Kloezen et al, 1997). Concerns are the lack of control by WUAs over the level of groundwater abstractions; a failure to increment the irrigation service fee in line with inflation; lack of clear mechanisms under the Water Law for allocation of water amongst different users, or during times of water scarcity; a failure of WUAs to build up contingency funds; and reducing competence of WUA staff due to high staff turnover levels and low levels of training. A final point is that there has been no discernible evidence that the transfer program had any impact on agricultural and economic productivity, fluctuations that have been observed are as likely to arise from other developments as from IMT.

WUA RESPONSES TO WATER TRANSFERS

The sections above have outlined two parallel developments, river basin closure and irrigation management transfer. While the two are separate processes, their interaction effects change in each. Where IMT is introduced into less developed, water abundant river basins the WUA can focus on internal management processes. In well developed, water scarce river basins the WUA must focus on both internal and external management processes. Internally to make the most productive use of available water, and externally to ensure that an adequate share of the water is obtained and retained over time against competing uses.

There are considerable strengths within the farmer-managed Mexican irrigation districts. Farmers are active within the WUAs, and are increasingly active in external affairs. A good initial step in developing the external focus of the WUAs has been their participation on the Hydraulic Committee. A second step has been the formation of Local Responsibility Societies (LRS) to take over and manage main canal systems. The major threat to the irrigation districts comes from the increasing pressure from other sectors on the available water supplies.

The Mexican Constitution defines surface water as national property placed in the trust of the federal government. Through the CNA, the federal government can grant water use concessions to users for periods ranging from 5 to 50 years (CNA, 1999b). The concession titles set out the maximum volumes concession holders are entitled to, although CNA may adjust the quantity each receives annually based on water availability, with priority given to domestic water use (CNA, 1999b).[4] In the Lerma-Chapala Basin surface water is allocated annually based on the surface water allocation treaty signed by the governors of the five states in the basin and the federal government in August 1991 (CCCLC, 1991). An important

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[4] Thus, for allocating surface water, Mexico follows the proportional appropriation doctrine and, in theory, all concession holders share proportionally in any shortages or surpluses of water. This contrasts with the prior appropriation system, where first rights have seniority.

objective of the treaty was to maintain adequate water levels in Lake Chapala and to ensure Guadalajara's domestic water supply. To preserve Lake Chapala, the treaty set out three allocation policies, namely *critical*, *average* and *abundant*. For each allocation policy, formulas have been drawn up to calculate water allocations to the irrigation systems in the basin, based on the surface runoff generated in each of the five states in the previous year. Based on extensive modelling of these formulas, it was concluded that the resulting water allocation would not impinge on the 1,440 MCM needed by Lake Chapala for evaporation.

Since 1991, the MEG of the Council has met each year to apply the water allocation rules set out in the 1991 treaty. According to CNA's data the WUAs in the irrigation districts never used more water than allocated to them under the treaty. Nonetheless, Lake Chapala's volume more than halved between 1994 and 2002 (cf. Wester *et al.*, 2001). This has led to intense debates in the RBC, with environmentalists and the Jalisco State government blaming the upstream irrigation districts in Guanajuato for using too much water. However, CNA's weak control over surface water use in the irrigation units, direct pumping from the river and lake, ten years of lower than average rainfall and reduced river base flows due to groundwater overexploitation are also plausible reasons for the reduced inflows from the Lerma River to the Lake. In addition, the 1991 treaty itself is partly at fault, as it overestimated annual water availability[5] and underestimated Lake Chapala's evaporation.

Because of critically low lake levels, the CNA decided to transfer 200 MCM from the Solis dam, the main water source of the Alto Río Lerma irrigation district, the largest district in the basin, to Lake Chapala in November 1999. This was the first time that surface water was physically transferred from the agricultural sector to the urban and environmental sector under the 1991 treaty. A second transfer of 270 MCM followed in November 2001, as lake levels continued to deteriorate.[6] These water transfers met with staunch resistance from farmers, mostly from the middle of the basin, and undermined the legitimacy of the Council as a body for conflict resolution. Farmers felt that their water was being "stolen", as they received no compensation, and because the 1991 treaty does not outline procedures for water transfers. On the other hand, environmentalists and the Jalisco State government argued that much more water had to be transferred to save the Lake, as 10 MCM are needed to raise the Lake level by 1 cm. This led many in Jalisco to refer to the water transfers as "aspirins" for the Lake's headaches, with the media calling for much stronger medicine to cure the Lake's ills.

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[5]The treaty was based on hydrological data from 1950 to 1979, which in later analyses turned out to be a relatively wet period.
[6]As a rule of thumb, 1 MCM is sufficient to irrigate 100 ha, thus with each transfer 20,000 to 27,000 ha could not be irrigated.

The transfer of 1999 led to reduced allocations to the Alto Río Lerma irrigation district and resulted in some 20,000 ha out of 77,000 ha not being irrigated with surface water in the winter season of 1999/2000. For many of the wealthier farmers who could switch to groundwater, this was not too problematic, but for poorer farmers who mainly rely on surface water, the consequences were serious. Scott et al. (2001) estimated that the benefit foregone by farmers due to the November 1999 water transfer was some US$ 14 million. In addition, many poor farmers who traditionally pumped return flows from the Lerma River were hard hit as the use of this precarious source of water was prohibited and enforced through army patrols along the river.

In the summer of 2001 Lake Chapala had dropped to its lowest levels in 50 years, which triggered environmental NGOs and the Jalisco representative on the RBC to demand a transfer of 500 MCM to the Lake in 2001. Through intense negotiations between the governments of Jalisco and Guanajuato, and political dealings at the federal level this amount was reduced to 270 MCM. The RBC approved this decision, although the agricultural water user representative strongly opposed it, thus further weakening its legitimacy in the eyes of many farmers.

Before 1999 none of the WUA leaders in the Alto Rio Lerma irrigation district (see Kloezen, 2002) were actively involved in the RBC. However, the water transfers galvanized WUA leaders to act. In May 2000, the presidents of WUAs from Jalisco, Guanajuato, and Michoacán met each other for the first time to discuss ways to strengthen their representation in the RBC and to influence the water allocation process. Until then, WUAs of a particular irrigation district only dealt with the CNA, and there were no horizontal linkages between WUAs from different irrigation districts. In 2001, WUAs from Querétaro and Mexico joined the discussions, and the WUAs established a new working group in the RBC, under the leadership of the representative for agricultural water use on the RBC.

From mid 2000 until the end of 2002 this *Grupo de Trabajo Especializado en Planeación Agrícola Integral* (GTEPAI, Specialized Working Group on Integral Agricultural Planning) attempted to strengthen the negotiating position of irrigators in the RBC. Its aim was to improve the participation of farmers in the RBC by developing links between the representative for agricultural water use and farmers throughout the basin, and to reach negotiated agreements concerning surface water allocations that took into account the needs of farmers. A central element of the GTEPAI's strategy was to show that the irrigated agriculture sector was serious about saving water and hence a credible negotiating partner. To identify more profitable crops that use less water, GTEPAI brought together farmers, government agencies, agro-industries, and research institutes to elaborate a Crop and Marketing Catalogue. This Catalogue sets out which crops can feasibly be grown under each of the three water allocation policies of the 1991 surface water treaty, and links these with contracts from agro-industries.

The cooperation of government agencies, agro-industries and producers under the GTEPAI initiative in 2000 and 2001 resulted in a change of cropping patterns for the winter season of 2001/2002. Throughout the basin, GTEPAI facilitated the conversion from wheat (4 irrigation turns) to barley (3 irrigation turns) on 47,000 ha. This resulted in a record production of barley, reduced imports for the involved industries (mainly breweries), and claimed water savings of 60 MCM. While GTEPAI considerably improved farmer representation and participation in the RBC, the efforts by GTEPAI to save water went unrecognized by most of the other members of the RBC. Environmental NGOs and the Jalisco State government continued to blame irrigated agriculture for the decline of Lake Chapala, and in the course of 2002 the representative of agricultural water use on the RBC came under increasing attacks in the media.

While the farmer representatives took the lead, grass roots tensions and the threat of civil disobedience by farmers decreased, but remained dormant. However, when the CNA decided in November 2002 that another water transfer of 280 MCM was to take place during the summer of 2003, tensions increased and farmers warned that they would occupy the Solis dam so that it could not be opened. Simultaneously, the representative of agricultural water use on the RBC and the leader of the GTEPAI initiative was pressured to resign from the RBC during the MEG meeting in November 2002. The disappointment of farmer representatives and others involved with GTEPAI was such that they decided to dissolve the GTEPAI and to revert to interest group politics.

During the summer of 2003, unexpectedly heavy rains coincided with the third water transfer, causing floods in many parts of the basin. Instead of being accused of stealing irrigation water from farmers, the CNA was blamed for aggravating flooding through the water transfer. During the transfer, farmers from Guanajuato occupied the CNA office and diverted water in transit from Solis dam to Lake Chapala to Lake Yuriria to express their fury. Although the exceptionally good rains of 2003 led to a spectacular recovery of Lake Chapala, with stored volumes jumping from 1,330 MCM in June 2003 to 4,250 MCM in January 2004, this did not cool down tempers. In November 2003, the Jalisco representative on the RBC again demanded the transfer of water from upstream dams to Lake Chapala, fuelling the anger of farmer representatives and further straining the relationship with Guanajuato.

How the current standoff develops will be essential for the future of agriculture and the environment in the basin. The collapse of active stakeholder participation and representation in the RBC through the dissolution of the GTEPAI and the strained relationship between Jalisco and Guanajuato highlights the challenges the Council faces in reaching consensual water management decisions in the basin. Despite the good rains in 2003, it is clear that the conflicts surrounding surface water have not been resolved and that negotiated agreement is far from sight.

CONCLUSIONS

The paper has described the challenges facing locally managed irrigation in a closed river basin. The Lerma-Chapala river basin is at the limits of its capacity, with all available water resources developed and with over-exploitation leading to unsustainable water use. Linked into this basin is a 15 year old irrigation management transfer program which has brought together formerly communally owned and private land owners into user associations managing often large scale irrigation systems.

The WUAs have had relatively little time to come to terms with establishing and running user associations based at secondary canal level and below before being forced by circumstance to become involved in external activities including Hydraulic Committees and the River Basin Council. There are significant strengths in the manner in which locally managed irrigation is functioning at present, but there are also threats looming which will need to build on these strengths if they are to be dealt with. Attention needs to be given to preparing a strategy that brings the level of water resource depletion into balance with renewable supply. This strategy will need to include measures to control the mining of groundwater, reduce and control levels of pollution, and release water from irrigated agriculture for use in other sectors. WUA leaders and representatives will need to be part of the solution, and will need to work with other water users in formulating fair and feasible measures which may range from programs to improve the efficiency and productivity of water within irrigation systems to more drastic action such as compensation for water transferred out of agriculture and for taking irrigated land out of production.

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THE ITRC RAPID APPRAISAL PROCESS (RAP) FOR IRRIGATION DISTRICTS

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ABSTRACT

The ITRC Rapid Appraisal Process (RAP) for irrigation projects was created in 1989 as a tool to quickly provide valuable insight into many aspects of irrigation performance including project design, engineering, operations and management. The RAP is a 2-week process of collection and analysis of data both in the office and in the field. The process examines external inputs such as water supplies, and outputs such as water destinations, and provides a systematic examination of the hardware and processes used to convey and distribute water internally to all levels within the project (from the source to the fields). The organization and content of the RAP provides a systematic project review that enables an evaluator to provide pragmatic recommendations related to hardware and management for the improvement of water delivery service.

INTRODUCTION

The Irrigation Training and Research Center (ITRC), California Polytechnic State University, San Luis Obispo, is actively involved with finding solutions to improve irrigation performance. ITRC has a history of over 20 years of working with irrigation districts and agricultural water users to develop, implement and monitor strategies for improving irrigation performance.

Since 1989, ITRC has pioneered work on the Rapid Appraisal Process (RAP) for distribution systems for irrigation projects. In general, the RAP is a quick and focused examination of irrigation systems and projects that can give a reasonably accurate and pragmatic description of the status of irrigation performance, and provide a basis for making specific recommendations related to hardware and management practices.

An RAP is designed to:

- Identify specific and immediate actions that could be easily taken, with a minimum of investment, to improve operation and water management

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- Quickly critique options that have been proposed for major future investment
- Provide a fresh look at the whole system, with the goal of being able to provide suggestions for new ways to improve the overall irrigation distribution system

This paper will focus on the RAP approach applied to irrigation districts, and will discuss how and why the RAP was created, what the necessary components are for a successful appraisal, and why the ITRC RAP is unique in its thoroughness and effectiveness.

HISTORY OF THE RAP

The RAP was initially developed as a set of recommendation-orientated irrigation system evaluation procedures for different on-farm irrigation methods. In 1983, ITRC began to develop standardized procedures for evaluating on-farm irrigation systems with support from the Water Conservation Office, California Department of Water Resources (WCO/DWR). The result was the Cal Poly ITRC on-farm irrigation system manual and software package that has become the standard for field evaluations in the Western U.S. (Burt et al. 1995).

The Rapid Appraisal Process was designed in 1989 out of the techniques used for the irrigation evaluations. ITRC has successfully used variations of the RAP approach as a diagnostic and research tool in a wide variety of situations both in the U.S. and internationally (Burt et al. 1996, Burt and Styles 1999, Burt and Styles 2000).

The use of a systematic RAP for irrigation projects was introduced in a joint FAO/IPTRID/World Bank publication entitled *Water Reports 19 (FAO) – Modern Water Control and Management Practices in Irrigation – Impact on Performance* (Burt and Styles 1999). That publication provides an explanation of the RAP approach and gives the results from RAPs the authors conducted at 16 international irrigation projects. Refer to Water Reports 19 for further background to the RAP approach, available directly from FAO (http://www.fao.org/icatalog/inter-e.htm).

OBJECTIVES

The first step in evaluating irrigation performance, whether at the farm level or an entire irrigation district, is to perform a rapid appraisal of the system as it is being operated. In typical project evaluations, a common error is that there is no daily operational strategy for moving water around in the system that relates to the detailed engineering recommendations.

It is essential that hardware or automation recommendations be linked to such an operation plan and strategy if the investment is to provide maximum benefits. When this is not done properly (as in many cases), it is almost inevitable that the wrong types and sizes of structures are installed, and key regulation and operation structures are overlooked. Further, it is critical that recommendations to irrigation districts keep in mind the economic reality of irrigated crop production. Expensive structures and computerized automation systems may look nice but may have little or no impact on the level of water delivery service provided to farmers.

The RAP approach allows ITRC to assist irrigation districts and agricultural water users in quickly identifying and prioritizing the specific changes in their water management practices that will provide cost-effective improvements in the performance of their distribution systems. Many times irrigation districts are aware of the potential to improve their operations, but they lack the knowledge or experience with current water control and measurement technologies. An irrigation district will have distinct hydrologic, engineering, operational and agronomic conditions, in addition to a history based on local agricultural practices, which will affect its ability to meet specific performance objectives. Moreover, some districts may not even be aware of the appropriate ways of thinking about performance in terms of service to farmers and water conservation.

A key component of the successful application of the RAP approach is the knowledge and experience of qualified technical experts that can make proper design and modernization decisions. It is critical that RAPs be conducted by irrigation professionals with an extensive understanding of the issues related to irrigation water control. In addition to making proper recommendations for modernization, evaluators using the RAP approach must have the ability to synthesize the technical details of a project with the concepts of water delivery service into a functional design that is easy to use and efficient.

PROCEDURE

As a center of irrigation excellence with state-of-the-art facilities, ITRC is able to work with irrigation districts in assessing the potential for improvement in their operations and then provide support and training for personnel through technical assistance programs. The RAP is the first step in accomplishing these goals.

The RAP can generally be completed with two weeks or less of field and office work. The process involves a pre-site visit survey sent to the district, followed by 1-2 days of field time by key ITRC personnel to visit the irrigation district to meet with district personnel, collect available data, and visit major structures in the system. Additional time, usually 2-3 days, is required to develop specific engineering recommendations for items such as Supervisory Control and Data Acquisition Systems (SCADA), flow measurement or canal gate automation techniques, design of water control structures, etc.

Survey Questions

A key to evaluating the distribution system for an irrigation district is to target the key factors that influence the performance of the structures and operational procedures used to convey and distribute irrigation water. One begins the RAP with a prior request for information from the irrigation district. Information such as crop types, irrigated acreages, flow rates into the system, weather data, budgets, staffing levels, existing water conservation programs, and pumping records can be assembled beforehand and then reviewed by the evaluator and project managers during a site visit to the project.

ITRC has been involved with water conservation projects and modernization programs at dozens of irrigation districts in the Western U.S. A library of information about each district is maintained and updated to reflect ongoing technical assistance programs.

The following is a general outline of the issues that need to be addressed before a set of recommendations can be made:

General Irrigation District Characteristics
- General Project Conditions
- Reservoirs
- Drainage
- Groundwater
- Crops
- Water Supply
- Water Use

Irrigation District Operations
- Water Delivery System Characteristics (Main and Lateral Canals)
- Flexibility- Frequency
- Flexibility- Flow Rate
- Flexibility- Duration
- Flexibility from Water Suppliers
- Flow Measurement at Farm Turnouts
- Facilities and Upgrades

Irrigation District and Farm Economics
- District-Level Economics
- Water Billing
- Farm Economics

Status and Needs of Modernization Programs
- Water Delivery Service

- On-Farm Improvements
- Canal Improvements
- Water Conservation Programs
- SCADA
- Training and Education

Site Visit

Upon arriving at the project, the data gathered through the survey is organized and project managers are interviewed regarding missing information and their stated perceptions of how the project functions. The evaluator then travels down and through the canal network, talking to operators and farmers, and observing and recording the actual methods of operation and hardware that are used for water control. Through this systematic diagnosis of the project, many aspects of engineering and operation become very apparent.

Interpretation of RAP Results

The RAP, by itself, is only a diagnostic tool. It allows a qualified evaluator to systematically examine the irrigation project. Through FAO and World Bank funding, the authors have developed a set of EXCEL spreadsheets with two characteristics:

1. Several hundred questions are provided that evaluators must answer in a standardized format. Questions cover topics such as water supply, personnel management, canal structures, level of water delivery service throughout the project, and numerous related topics.

2. The values of a large set of external and internal indicators are automatically computed. The automatic computations provide rapid results and also eliminate computation errors.

> External indicators are expressions of various forms of efficiency, whether the efficiency is related to budgets, water, or crops yields. They only require knowledge of inputs and outputs to the project – but by themselves they do not provide any insight into what must be done to improve performance. Traditional irrigation project investment decisions are based on these indicators. Internal indicators examine the hardware and processes that are used to actually move, sell, and schedule water throughout the project on an hourly, daily, and seasonal basis. (Burt and Styles 2003)

The interpretation of the results requires one or more irrigation specialists who clearly understand the options for modernization. Without a thorough knowledge of these options, the recommendations can be ineffective or damaging.

For example, a very common mistake in modernization plans is the elimination of first-time losses with the belief that this will improve project irrigation efficiencies—even though those first time losses may already be recirculated within the project. If this is the case, there may not be any true water conservation.

In general, the process of interpretation involves the examination and review of the following six components:

1. Field irrigation efficiencies

2. Project irrigation efficiencies

3. Conveyance efficiencies (compared against field irrigation efficiencies)

4. The attributes of water delivery service

5. The appropriateness of hardware and operator instruction

6. The existence of recirculation systems

The process of implementation is as follows:

1. A first step is to eliminate any discrepancy between "actual" and "stated" service. Some project managers do not fully understand that there even is a discrepancy.

2. Frequently, the instructions that are given to operators need modification. Sometimes, these modifications are simple and result in significantly improved operations.

3. The next steps, more or less in order of sequence, are to improve the following areas:

    a. Understanding of what actually happens in the system. An expert can quickly evaluate a project and because of his or her background, almost immediately understand cause/effect relationships and the probable level of service.

    b. Communications at all levels. This starts with human-human communications – often with radios or cell phones.

    c. Mobility of staff. In general, a small yet mobile staff is much more efficient than a large, immobile staff.

d. Flow rate control and measurement at key bifurcation (canal split) points. Note that "measurement" and "control" are not the same. Both are needed.

e. Construction of recirculation points or buffer reservoirs in the main canal system.

f. Improved water level control throughout the project. The flow rate control and measurement (item "d") only pertain to the heads of canals, laterals, and pipelines. Downstream of the heads, it is important to easily maintain fairly constant water levels so that turnout flow rates do not change with time, and so that the canal banks are not damaged. With the proper types of structures, this is easy to do without much human effort.

g. Re-organization of procedures for ordering and dispersing water. In most modern projects, one group is responsible for operating the main canal; another is responsible for the second level, and so on. The complete procedure for receiving real-time information from the field and responding quickly to requests must typically be revamped for most projects.

h. Remote monitoring of strategic locations. Such locations are typically buffer reservoirs, drains, and tail ends of canals.

i. Remote manual control of flow rates at strategic locations. These are the heads of the main canal, and heads of major off takes (turnouts) from the main canal.

j. Provision for spill, and the recapture of that spill, from the ends of all small canals.

What may seem surprising to some is the complete lack of discussion of canal lining and maintenance equipment. There is no doubt that maintenance equipment must be adequate. Canal lining can reduce maintenance and seepage. But these topics have been discussed for many decades, and the billions of dollars that have been spent on canal lining have generally not brought about modernization. Concrete canal replacement has also been proven not to be a viable solution for most projects. This is because modernization is not just a single action. The items "a-j" above represent a departure from traditional thinking of "concrete civil engineers" and focus on operations.

ITRC also does not employ GIS imaging in its results because GIS maps and charts, although visually appealing, generally reveal only superficial issues. At best, these graphics display where symptoms of problems exist without dealing with their more subtle, underlying causes. Mapping and surface studies alone do not take into account management issues, communications, procedural analysis, remote control and automation failures, or overall structural or organizational problems. The ITRC approach focuses on the interpretation and evaluation of findings, not the findings themselves.

SUMMARY

The ITRC RAP deals with a broad spectrum of analyses on several different levels. When properly executed by trained evaluators, the RAP approach can quickly provide valuable insight into many aspects of irrigation performance including project design, engineering, operations and management. Furthermore, the organization and content of the RAP provides a systematic project review that enables an evaluator to provide pragmatic recommendations related to hardware and management for the improvement of water delivery service. The ITRC approach has been refined by over two decades of experience and application, and has stood the test of time as a proven, internationally recognized method of irrigation system evaluation.

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RELATIONSHIPS BETWEEN SEEPAGE LOSS RATES AND CANAL CONDITION PARAMETERS FOR THE RAPID ASSESSMENT TOOL (RAT)

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ABSTRACT

A rapid assessment tool (RAT) is being developed for evaluating irrigation network performance. As part of that development, the relationship between condition rating factors and seepage loss measurements was examined. The statistical analysis was based on 32 ponding test sites in the Lower Rio Grande Valley (LGRV). The results indicate that seepage losses from the lined canal segments can be modeled as a function of a rating factor describing the spacing of large cracks in the lower part of the canal cross-section. Cross-section appears to be a moderating variable in relating seepage loss to canal condition. Separate ratings are proposed for overall canal condition and seepage loss condition for lined canals. There was no statistical relationship between seepage loss and condition rating factors for unlined canals. The overall condition of the lined canal was correlated with the rating of canal bank condition. Presently the RAT is the only reported rating scheme that utilizes Geographic Information System (GIS) to display the rated conditions.

INTRODUCTION

A challenge to improving water resource management in irrigated regions is ageing and/or under performing irrigation infrastructure. Many of these systems suffer from both high seepage and operational losses. These losses reduce supplies and cause water logging and soil salinization problems. Irrigation districts are therefore being forced to examine management, maintenance, rehabilitation and modernization (MMRM) strategies with the goal of improving performance. Rehabilitation or modernization needs of irrigation systems are related to the structural condition, hydraulic performance, seepage loss rate and the level of obsolescence of the infrastructure. A critical aspect of MMRM strategies is the application of innovative methodologies to quickly and inexpensively relate the condition of the assets to the technical performance of the scheme. These methodologies enable scheme planners and managers to then prioritize investment options based on the condition of different scheme and scheme components.

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The Texas A&M University is currently developing a Rapid Assessment Tool (RAT), to analyze the status of irrigation water distribution networks. The RAT is a combination of infrastructure condition rating, seepage loss tests along with both mapping and analyses using Geographic Information Systems (GIS), (Fipps and Leigh, 2000). During phase 1 of the RAT development, Fipps and Leigh (2000) proposed an initial condition rating system for lined and unlined canals. This paper outlines the continued development of the rating methodology including relationships between the canal condition and seepage losses. The objectives of this work are to:

(i) Further develop a condition rating system for irrigation canals and hydraulic structures.
(ii) Determine relationships if any, between the condition rating factors and measured seepage loss rates in lined and unlined canals.

The goal is to develop a modeling system to quickly and inexpensively evaluate irrigation network improvement needs in irrigation districts.

CONDITION RATING SCHEMES FOR HYDRAULIC ENGINEERING INFRASTRUCTURE

The US Army Corps of Engineers (USACE) under their repair, evaluation, maintenance and rehabilitation project (REMR) has developed within the last 15 years, several rating procedures to evaluate the condition civil engineering infrastructure. These include indexing systems for embankment dams (Andersen and Torrey III, 1995), navigation structures (Mckay et al., 1999). Burton et al. (2003) used a simplified procedure for rating the condition, performance and importance of irrigation infrastructure. The method was applied to several irrigation schemes in Albania. The authors reported that initial asset management procedures had to be simplified given the lack of local resources including maps, database software and personnel with suitable experience. Cornish and Skutsch (1997) proposed a detailed procedure to evaluate components and prioritize maintenance and rehabilitation of irrigation networks. The method outlines the development of a priority index based on an assessment of the structural and hydraulic condition, importance and area served by the respective component.

Fipps and Leigh (2000) also developed rating procedures for both irrigation network condition and performance, as part of a Rapid Assessment Tool (RAT), being developed at Texas A&M University. The RAT is the only reported condition rating methodology that utilizes GIS. The methodology is being applied to irrigation networks in the Rio Grande Valley, Texas. Phase 1 of the RAT development involved seepage loss tests, mapping of the existing infrastructure in the LGRV, along with performance rating of canal discharge, head and physical condition. Canal riders in the LGRV irrigation district completed the head condition surveys, while extension personnel evaluated the condition of the irrigation infrastructure. To date, the Biological and Engineering Department has completed seepage tests (ponding method) on 44 canal sections in the LGRV.17 of those tests were conducted on unlined canal sections and 27 on lined sections. A total of 22 of the lined canal sites and 10 of the unlined sites were rated.

RECENT DEVELOPMENT WORK ON THE RAT

The development team reviewed the RAT development phase I results and agreed on the following issues for further work under phase 2:

(i) In lined canals, the seepage losses appeared to be greater for canals rated with higher frequency of large cracks i.e. canals with larger cracks tended to show higher seepage loss rates. Additionally, most of the horizontal cracks occurred below the normal operating level, suggesting that these could contribute to the seepage losses. Thus the contribution to the seepage losses by both crack frequency and distribution over the wetted perimeter was examined.

(ii) In unlined canals, there did not appear to be any clear relationship between the seepage losses, and the rating factors considered. It is possible therefore that the team did not account fully for all the variables that contribute to losses. Silt levels along with maintenance operations were some of the previously excluded factors that were considered in this phase.

(iii) Indicators of possible structural failure of canal elements were not previously considered. These indicators include the extent of canal bank erosion as well as observed seepage levels through the embankment of canals and structures.

(iv) Several natural indicators of seepage losses would also be considered further, including aquatic weed growth along the canal bank as well as in adjacent fields and drains.

(v) Some analytical tools were required to develop useful relationships between seepage losses and the parameters being evaluated. Statistical tools including regression analysis and correlation were therefore used to explain the variability of seepage loss rates.

The team then agreed that the following objectives were critical to the further development of the RAT:

1. Relate canal condition to seepage losses
2. Assess parameters that contribute to the overall condition of the canal.
3. Examine those rating factors the indicate chance of canal bank failure

Some factors relate to more than one objective. For example, visible signs of seepage losses through the canal banks are related to both objectives 1 and 2.

NEW APPROACH TO CONDITION RATING

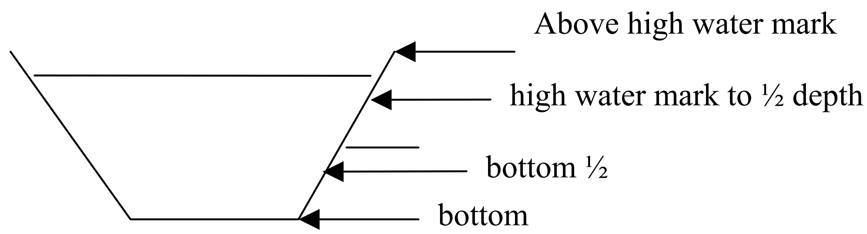

Figure 1: Segments of the lined and unlined canal to be rated.

Based on the experience from the original rating methodology, a new approach was proposed. Instead of rating the overall canal section, cross-section was divided into 4 sub-sections and each rated separately (fig 1). The sub-sections are above high water mark, high water mark to half depth, half depth to canal bottom and canal bottom. The ratings form also expanded to examine several factors including:

(i) High water marks to estimate the maximum operating depth
(ii) The presence of aquatic weeds in the irrigation canals and adjoining fields.
(iii) The level of erosion of the canal embankment.
(iv) The level of non-aquatic weeds in the irrigation and drainage canals as well as on the embankment.
(v) An overall rating of the maintenance needs of the canal section as well as the condition of concrete joints.

Table 1: Concrete crack size and frequency rating for lined canals

Crack type	**Size range (in)**	**Size rating**	**Crack Frequency**	**Frequency rating**
Hairline	0<=1/16	0	none	0
Crack	1/16<1/4	1	sparse	1
Pencil	¼<1/2	2	>10 ft apart	2
Finger	½<3/4	3	5 – 10 ft apart	3
Break	>3/4	4	3 – 5 ft apart	4
			less than 3 ft apart	5

All field data collected during the survey, were coded in the statistical package SPSS 11.5. The evaluated seepage loss rates were reported in in/day and (gal/ft^2/day). To develop statistical relationships, the seepage results were plotted against several rating factors including the size and frequency of cracks at different sections of the canal cross-section. The statistical package was then used to develop regression relationships as well as correlation between the measured variables. The Pearson ranked correlation, was used to check for the significant correlations between the parameters.

RESULTS

Table 2: Correlation between different parameters for lined canal

Param.	Test	Bottom Finger	Bottom Break	Lower Finger	Lower Break	Aquat. veg	Seep. (in/day)	Seep. per unit area (gal/ft^2/d)
Bottom finger	Pearson Correlation					.845(**)		
	Sig. (2-tailed)					.008		
Bottom Break	Pearson Correlation				1.00(**)		.967(**)	.897(**)
	Sig. (2-tailed)				.		.000	.002
Lower finger	Pearson Correlation				.666(**)	.761(**)		
	Sig. (2-tailed)				.009	.004		
	N				14	12		
Lower Break	Pearson Correlation		1.000(**)	.666(**)			.967(**)	.897(**)
	Sig. (2-tailed)		.	.009			.000	.002
Aquatic veg.	Pearson Correlation	.845(**)		.761(**)				
	Sig. (2-tailed)	.008		.004				

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

The most promising relationships appeared to be between the seepage compared with large cracks in the lower part of the cross-section and bottom of the canal. These are shown in Figures 2 and 3 below.

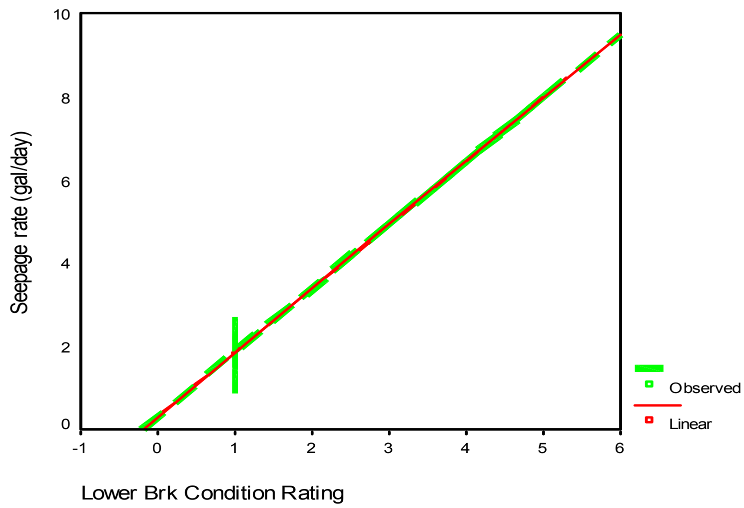

Figure 2. Actual and predicted seepage loss rates (in/day)

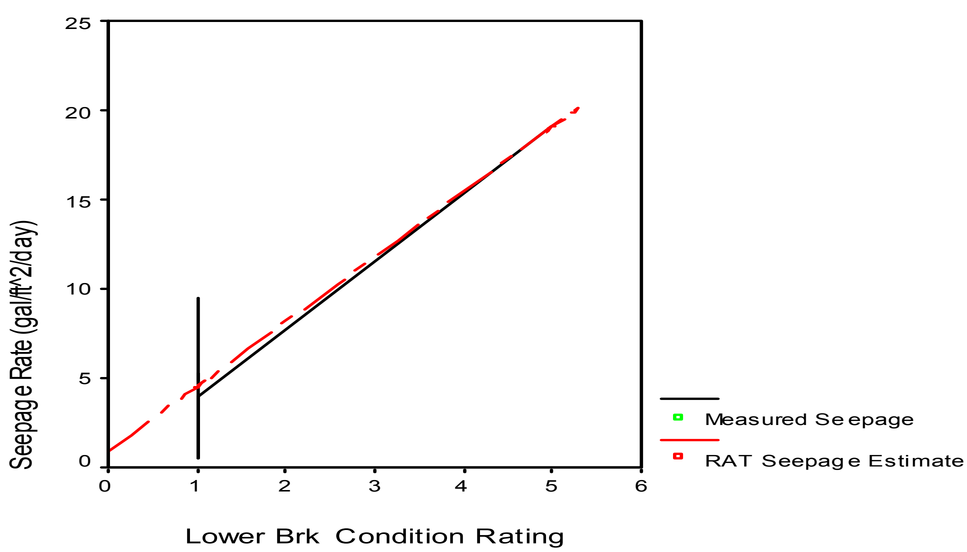

Figure 3. Actual and predicted seepage loss rates (gal/ft^2/day)

The best-fit linear regression model for the data is given by equations 1 and 2 below.

$S1 = 0.32 + 1.530 l_{br}$ adjusted $r^2 = .93$, SE = .61 (1)

Where S1 = seepage loss rate (in/day)

l_{br} = rating for the frequency cracks > ¾” in the lower half of the canal cross-section.

$S2 = .889 + 3.634\ b_{br}$ adjusted $r^2 = .77$, SE = 2.72 (2)

Where S2 = seepage loss rate (gal/ft^2/day)
lb_{br} = rating for the frequency cracks > ¾" in the lower half of the canal cross-section.

The relationship in equations (1) and (2) indicate that the seepage rates in the lined canals are explained by the frequency of large cracks in the lower cross-sections of the canals. This model is consistent with the sensitivity analysis reported by Rastogi and Prasad (1992) who noted that canal supply depth strongly influences seepage. Therefore, frequent large cracks in the lower section and bottom of the canal should have a greater effect on seepage compared to those at the top of the cross-section. Recent work by Rahimi and Bahootkoob (2002), canal lining failure is caused by a net unbalanced stress due by non-uniform soil swelling pressures. These stresses tend to cause lining failure in the lower third of the side panels.

Generally, canals in the LRGV are raised above ground level and constructed on compacted soil. As a result, neither properties of the surrounding soil nor

Table 3: Pearson correlation of overall rating and other parameters

Parameter	Pearson correlation
Pencil cracks above ½ depth	.470(*)
Break in top of canal	.752(**)
Finger cracks in top of canal	.694(**)
Overall repair rating	.616(**)
Joint condition rating	.744(**)

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

As shown in table 3, the overall rating is correlated with the large cracks in the upper section of the canal (0.75), the condition of the joint (0.74) as well as the overall repair rating (0.66). The condition of the joint as well as break-sized cracks at the top of the canal cross-section explained most of the variance in the overall canal rating. However the overall rating did not correlate with the condition rating in the lower section of the canal. Conversely, the seepage loss correlated well with cracks in the lower portion of the canal cross section. Separate overall condition and seepage loss conditions should therefore prove beneficial. The overall condition rating may reflect better the repair requirements of the canal to enhance hydraulic performance and reduce the risk of failure. Alternatively, the seepage loss rating could be considered a subset of the overall rating, to estimate the chance of seepage, largely based on the frequency and size of cracks in the lower portion of the canal cross-section.

DISCUSSION

The results of the statistical modeling indicate that for lined canals, the seepage loss rate depends on the frequency of large cracks in the lower segment of the canal cross-section. While this relationship is supported by the scientific literature, further field assessment and validation would prove useful. In using the RAT to estimate seepage losses from irrigation canals in the LGRV, some care should be exercised in rating the large cracks in the bottom half of the canal. Groundwater levels should also be noted when conducting seepage loss ratings as these levels moderate seepage losses. A minimum depth of 3 meters below the canal bottom is recommended. The overall condition of the lined canal is explained largely by the condition of the expansion joints as well as the size and frequency of cracks in the top half of the canal. A useful approach therefore is to have separate rating for both the overall maintenance needs and the level of seepage loss expected.

There was no statistical relationship between seepage loss rates and unlined canal parameters. This could be due to the high variability in the parameters along with the relatively small number of samples. The most recent publications on seepage losses in unlined irrigation canals suggest that losses may be related to large holes in the embankment caused by rodent, insects and rotting roots. This may be moderated by both silt build-up and level of maintenance.

Currently the RAT is the only rating scheme that uses GIS to display results. As the canal network is geo-referenced, the modeled seepage loss relationship can be displayed throughout the network once the rating is completed. This will allow district personnel to view spatially the estimated seepage rates for lined canals and therefore develop suitable plans. Such plans may include a combination of repairs and replacement of canal sections. In case of limited funds, the model suggests that sealing the large cracks (including joints) in the lower sections of the canals should have the maximum impact on seepage reductions in lined canals.

CONCLUSIONS

Development work on the Rapid Assessment Tool (RAT) indicates that seepage loss from lined canals is best explained by the size and frequency of large cracks in the lower sections of the canal. However there was no relationship between the rating factors and seepage losses in the unlined canals. Separate rating for the overall canal conditions and maintenance condition is recommended.

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ZARAFSHAN WATER DISTRICT IMPROVEMENT PROJECT IN UZBEKISTAN

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ABSTRACT

Irrigation plays an important role in the economy of Uzbekistan with almost ninety percent of the cropland irrigated. Fifty percent of the irrigated area in Uzbekistan is already affected by water logging and/or salinization. Zarafshan and other Soviet-built irrigation schemes are in disrepair and not functioning efficiently. Crop losses and high operating costs ensue. Water flow information and communications systems are unreliable, forcing scheme administrators to make management and operational decisions based on insufficient information.

The Zarafshan Water Districts Improvements project is design to be a model program that will guide the rehabilitation of other irrigation districts in Central Asia. This paper describes this program and what lessons have been learned to date.

Key Words: irrigation scheme, rehabilitation, modernization, Uzbekistan, Central Asia, Aral Sea basin

INTRODUCTION

Since the break-up of the Soviet Union, the effectiveness of water control and allocation in the Aral Sea basin has been reduced, largely due to a deterioration of regulating structures and the lost of experienced personnel. Irrigation schemes are in need of improved and automated flow measurement, gate control, and SCADA systems. Improvement in flow measurement and control is needed throughout Uzbekistan to ensure the stability of agricultural production and to reduce the potential for conflict over water allocations.

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One area with particularly critical need is the Zarafshan River Basin in Uzbekistan, where the livelihood of 5.5 million persons depends heavily on irrigated agriculture. The Zarafshan River Basin has an irrigated area of 560,000 hectares. It extends into the four Oblasts (administrative regions) of Jizzak, Samarkand, Navoi and Kashkadarya near the Tajik-Uzbek border and runs along about 350 km of river (Fig. 1). Water management in the basin is under the responsibility of Zarafshan Basin Irrigation Systems Authority (BISA), which is under the Ministry of Agriculture and Water Resources (MAWR) of the Republic of Uzbekistan.

Funding for the Zarafshan Water Districts Improvement Project has been provided by the United States Agency for International Development (USAID through the Natural Resource Management Project (NRMP), which started on September 1, 2000. A related project, entitled the Special Initiatives Water Project (SIWP) for Uzbekistan and Tajikistan, Task Order 812, began on May 1, 2002. The objective of the SIWP is to increase the ability of CAR (Central Asian Republics) water managers to measure, control and allocate water resources in critical areas of the Zarafshan river basin.

Initial meetings were held with water managers responsible for allocating and controlling water supply to determine priorities for improving equipment and procedures. Equipment that showed the greatest potential for improving operations was made available to Zarafshan BISA. During this time, field visits were made to identify areas with potential for making operational improvements through enhanced measurements or automated controls. Elements of the project plan included acquisition of heavy construction equipment for system maintenance of communications and automation equipment, and additional funding for civil works needed to install the automation and communications equipment systems.

The President of Uzbekistan issued decrees in March and July 2003 that replaced the existing territory-based water resources administration with a basin-based management approach. New Basin Irrigation System Authorities (BISA) were introduced within the water management sector to ensure and promote:

- common policies in regulation and use of water resources
- the rational use of water resources on the basis of market economy principles
- technical reliability of water management structures
- accurate calculation of water consumption.

New Main Canals Authorities and Irrigation Systems Authorities became the structural sub-units of the BISA. World experience shows the basin-based water management as the most efficient and flexible. This new organizational structure will help assure equitable water distribution by avoiding undesired interference and pressure of local authorities in the water distribution process. It is expected that this organizational reform will significantly increase operational efficiency of the water management sector in Uzbekistan.

PROJECT DETAILS

Eleven sub-tasks formed the core of the improvement program as initially developed.

Heavy equipment

Zarafshan BISA has requested the NRMP to assist in provision of vehicles and heavy construction equipment for irrigation system repairs, maintenance, and improvements. Heavy equipment and light vehicles for canal inspections and maintenance operations were identified as a top priority by national and local counterparts. Since their own heavy construction equipment was in bad condition and the number of units in operation was declining, Zarafshan BISA was not properly maintaining their canal systems and cleaning hydro-structures from the sediments brought by the river. Canal capacities were reduced by sedimentation, resulting in reduced and unreliable deliveries to users. In total, thirty-seven pieces of equipment were supplied to the Zarafshan BISA by September 2003. The equipment has been in nearly constant use since that time, and has been of major benefit to system maintenance and operations.

Construction and improvements to selected water control facilities

There are many offices and operational stations (dispatch centers) throughout the Zarafshan River Basin. Most of the office and operations facilities were in good condition, and required only minor renovation work. After a discussion with the management of BISA, 20 key locations including the dispatch center in headquarter building were selected for preparation for communications and data management systems improvements. Responsibility for rehabilitation of existing offices at these key control points was imposed on the management of BISA. Instead, NRMP was asked to renovate a dorm facility for training participants at the central warehouse of BISA.

Communication systems

The highest priority communications project is the installation of a MPT 1327 trunk radio system in the Zarafshan region. This project has large visibility within NRMP, USAID, and the counterpart organizations due to its size, importance, and schedule ramifications.

Preliminary design work and specifications for a new radio communications system was completed during late 2002 and early 2003. It was determined by detailed investigations that a trunk radio system operating in the 400 MHz range was most suitable for the required application. Field surveys and additional consultations with counterparts were undertaken to develop and refine a list of sites throughout the region for the installation of communications stations. Based on the findings and following discussions with the Ministry of Agriculture and Water (MAWR) and Viol Company, who assisted in the site surveys, NRMP concluded that a trunk radio system with three base stations for Zarafshan region would be sufficient.

Automation of irrigation structures

Funding was insufficient to complete all planned automation projects. Thus, the MAWR recommended undertaking one project that would demonstrate how modern equipment collect, process, and store up-to-date water flow information needed to ensure optimal and equitable water distribution.

The Ak-karadarya Barrage was chosen for this automation project. It is the second water control structure in the Zarafshan River, and is located 425 m downstream from the river and next to the Tashkent–Samarkand railroad bridge. The barrage was constructed during 1968-1973 and has a total capacity of 888 $м^3$/c (31359.3 cfs) It supplies water to the main canals of Kurbanabad and Central Miankal, to the secondary ("interfarm") canals of Kalandar and Sulakhly, and distributes water to Karadraya and Akdarya rivers. The total command area is 114,100 ha. The facility consists of a series of 16 gates used for flow diversion into the main and interfarm canals, and into the rivers. An upstream head monitoring station is located next to the headwork structure of Akdarya river. Downstream monitoring stations are located approximately 25-100 meters downstream of the each of the canals and rivers.

The work consists of mechanical refurbishment of the gate hoist mechanisms, installation of a new electrical motor (including the refurbishment or replacement of faulty motors), and gate automation system. The work was broken into five phases:

1. Design
2. Mechanical refurbishment
3. Installation of New Electrical System
4. Installation of Automation System
5. Training and Final Documentation

All works related to the barrage automation was completed by March and includes a SCADA (Supervisory Control and Data Acquisition) system. The barrage is now automatically operated by dispatchers through special computer software. All water related data is processed in real time and can be transmitted to the head organization through a modem connection.

Local area network and mini-telephone station in HQ building

To further improve data exchange and efficiency of management, a new local area network and mini-telephone station was installed. Computers were networked together, so that data entered in the dispatch center could be observed by management and used to make timely decisions. The old telephone system that used over 30 separate telephone lines, was replaced with a new mini-telephone station capable of serving more personnel with only 8 telephone lines.

Office equipment

Advanced data collection and transmission required additional computer and other equipment for the management organization. Under this component it is planned to provide key locations in the HQ building with necessary equipment.

Establishment of the system maintenance group

A system maintenance group was needed to maintain newly provided equipment and communication systems. The maintenance group was provided with a vehicle and tools, and was staffed with trained specialists to conduct various maintenance tasks in the field and the HQ building.

Computerized Water Database

An additional important component of the project was the development of a computer database program. The original concept was to develop a computer program to correlate projected crop demands with system supplies as provided by automatic flow measurement stations throughout the irrigation system. With the removal of the automated flow measurement stations from the work plan, it was decided that a computer database for storing, managing, and analyzing system data was more useful and appropriate at this stage. This plan was executed with the development of a customized database with geographical information system (GIS) interface.

The database/GIS system allows the irrigation department staff and management to manage and analyze information much more efficiently. When the communications system is operational, the program will allow data to be input from remote locations throughout the irrigation system via radio modem (and telephone modem from some locations). Data collection, analysis, reporting and archiving will be greatly improved.

It was decided to develop a Centralized Water-Management Data Storage and Processing System (CWMDSPS) of BISA. The system provides data entering and data transferring capabilities between different BISA subdivisions, dispatch centers and MAWR. Furthermore, the system provides several tools for data analysis, preparation of graphs, reports and output forms.

The CWMDSPS consists of independent software components, including:

- Relational water-management database
- Data entering software component
- Data exchange software for synchronization of BISA and MAWR databases
- Analytical component (AC) which provides some basic capabilities for water-management data processing as well as reports and graphs preparation
- Geographic Information System (GIS) Interface providing map-based access to all water-management and technical information in CWMDSPS

MS Access was chosen as a Database management system (DBMS) for CWMDSPS because it can be easily managed and maintained by BISA specialists. Data entering software was developed to enter water-management information to CWMDSPS database. The final version of software was provided to end-users as a distributive installation package, and was developed in the Visual Studio.NET programming environment.

All software components were installed and tested in dispatch centers of the BISA and Main Irrigation System Authority. All system capabilities were demonstrated to the BISA management during a presentation organized in Samarkand in July 2004.

Currently, all the required water-management data is being transferred from Zarafshan BISA dispatch center to MAWR using CWMDSPS. All CWMDSPS software was developed as a flexible set of components, which allows future adaptation for additional requirements by BISA staff. Such flexibility is very important for long-term and sustainable system operating. The CWMDSPS was also successfully adopted by the Amu-Surchon BISA.

Establishment of training facilities and programs

Both MAWR and Zarafshan BISA asked NRMP for assistance in establishing a training center and programs for water specialists from the bordering oblasts, with the goal of reducing costs by conducting training activities on-site rather that in

Tashkent. Taking this into account, several rooms were renovated and equipped with needed equipment. On a regular basis, the BISA staff attended training programs on advanced computer skills, database and spreadsheet development. Meanwhile, the facility has been used for trainings and seminars for water specialists from Jizzak, Navoi, and Kashkadarya oblasts. The facility is becoming an integral part of the effort to improve water resources management and economic life in the Zarafshan River basin.

The data communications system and irrigation database use IBM-compatible personal computers and software. Training of system managers and operations staff in the use of computers and various software applications was essential to allow the use of these powerful tools and to derive the anticipated benefits. In January 2003 a plan was developed to set up a permanent training facility in the central office of the counterpart's headquarters building in Samakand. From March 2003 through July 2004 training sessions were conducted at the Samarkand training facility. Each group consisted of 14 participants and the aim of the training was to teach how to maintain and upgrade the computers and database system after the completion the NRMP Task. Trainings were held in basic and advanced computer literacy, database, Geographic Information Systems (GIS) and related computer mapping. A total number of 200 dispatchers and operators of the systems were given training in basic and advanced personal computer training, computer service and maintenance, GIS, and the use of the NRMP-developed Centralized Water-Management Data Storage and Processing System (CWMDSPS) of the BISA.

The trainings were very well received by the participants and felt to be very successful overall. The computer skill level of the participants was clearly and significantly improved, and, combined with the provision of computers by the NRMP, the participants found the trainings to be of great practical value in their work activities.

Public Awareness Activities

The dissemination of knowledge related to water as a limited resource is seen as a mandate of the NRMP. Public awareness and input to the NRMP program is desirable to help assure sustainability of the improvements. Many very successful public awareness events were conducted during the course of the Task, and many other products and services for the dissemination of information were developed

All components above were seen to compliment and reinforce each other, providing a synergistic effect and improving the total expected benefits of the program.

CONCLUSIONS AND RECOMMENDATIONS

Most of the work initiated under this project has been successfully completed and is providing significant benefit to the counterpart agency and the Zarafshan basin as a whole. This work includes:

1. Provision of 38 units of heavy equipment and vehicles for canal maintenance and SMG.

2. Establishment of a Training Center in HQ building and renovation of a Dorm Facility at the Central Warehouse of the BISA.

3. Improvements to voice and data communications including new telephone exchange, telephones, trunk radio-communication.

4. Provision of 52 computers, 39 printers, large format plotter, copy machine, custom database for irrigation system management, and computer training for over 335 irrigation system staff.

5. A successful public awareness campaign promoting careful use of water as a scarce resource, public participation, and project sustainability.

The following recommendations can be made to continue the support to BISA:

1. Improvement the flow monitoring system within the BIS by establishing automatic flow monitoring stations, which will link with trunk radio communication system into the existing database

2. More training

TECHNOLOGICAL MODERNIZATION IN IRRIGATED AGRICULTURE: FACTORS FOR SUSTAINABILITY IN DEVELOPING COUNTRIES

L. Humberto Yap-Salinas[1]

ABSTRACT

Technology has much to offer to irrigated agriculture in developing countries. Many technological advances have been introduced into practice in these countries. National governments have often played an important role in this process by investing in modern equipment needed by their irrigation districts. Computers, meteorological monitoring stations, and GIS, to mention just a few examples, are used in transferred irrigation districts ranging from large to small, in different climatological and hydrological settings, and by users of varying degrees of education. At first glance, all this would appear to signal success, particularly at the end of a project. In some countries, such as Chile and Mexico, modernization efforts have helped the agricultural sector become more competitive in the global market. However, in other countries, modernization efforts and investments have failed to achieve their goals of improving agricultural production at a competitive level. Thus, there have been considerable successes, but there have also been gaps in this transfer of technology.

This paper examines this troubling situation from first-hand experience, and it looks at lessons learned from experience gained in introducing technology along with water users organization in developing countries. Factors that help ensure sustainability of technological modernization in irrigated agriculture in developing countries are discussed, and suggestions are given to make investments in this modernization process more effective in the long term.

INTRODUCTION

As the twenty-first century begins, technology is the buzzword; technology is what makes the world go 'round. In business, implementation of new technology is often viewed as the way to make any enterprise more competitive. Similarly, technology transfer is often considered the answer to many problems in irrigated agriculture in developing countries. However, while many developing countries have made significant investments in irrigated agricultural technology, not all of these countries have experienced the same success. At the same time, with globalization and the lowering of trade barriers, the need has become urgent for

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developing countries to be ready to compete globally with their agricultural products (Yap-Salinas 2004).

In many developing countries, water users associations (WUAs) have become the heirs of irrigation system management. Because the irrigated agricultural sector contributes the largest percentage to a country's agricultural production in many of these countries, WUAs bear an increasing responsibility. Nevertheless, introducing technology to WUAs is a complex endeavor that is not always successful. How can WUAs in the irrigated agricultural sector become technologically savvy and use modern technology in an effective, sustainable way to become competitive in today's markets?

BUILDING COMPETITIVENESS IN WATER USERS ASSOCIATIONS

Ingredients in Successful Agricultural Enterprises

Some developing countries have become very competitive in international markets with their agricultural products, but others have been far less successful despite significant modernization efforts. A look at two common factors in the successful cases is warranted.

1. Private Sector Investment: In many countries where agricultural production has become successful in the global market, outside, or foreign, investment, with outside, or foreign, technological implementation, is responsible. Often, this investment takes place where there are good natural resources, good human resources, and security of property rights; and where a stable local economy and good governance provides security for the investor. Often this investment is by private investors; indeed, success tends to be more likely when investment is by the private sector than when investment is by the local government (USU 2001, Yap-Salinas 1994b). Thus a look at characteristics of the private sector may be helpful in determining how to help WUAs become successful and competitive.

2. Continuity: Another factor that often can be observed in these countries with successful agricultural competitiveness is a national government policy committed to success in the agricultural sector and supportive of private sector investment and exportation. This can even be seen in some parts of the irrigated agricultural sector in societies that do not always have a stable economy, because the government apparently recognizes that the success of a given agricultural enterprise benefits the country economically as a whole. Thus providing continuity, protection, and stability to WUAs may similarly help WUAs become successful and competitive (Yap-Salinas 1994b, USU 1997-2001).

Water Users Associations

These two observations in countries with successful agricultural exportation and global competitiveness can provide answers to making WUAs competitive. First of all, WUAs should be considered as analogous to private sectors. Into the collective enterprise of WUAs, water users invest of themselves through their own effort and time, as well as through their land and their financial resources; this last is accomplished by equitable water tariffs agreed upon through a collective, participatory process. Furthermore, if WUAs are organized well, they can act as legal cooperatives for water users in the marketplace, much as Ocean Spray does for cranberry producers in the U.S. To be effective, however, WUAs must incorporate some of the characteristics that make private sector investors effective, and they must have continuity, protection, and stability to flourish. Without these conditions, technological modernization programs will not have their maximum intended effect. Secondly, continuity and uninterrupted programs are essential for WUAs.

KEY STEPS IN PROMOTING EFFECTIVE TECHNOLOGICAL MODERNIZATION IN WUAS

At least six main steps are necessary to make technological modernization effective and sustainable in the irrigated agricultural subsector in developing countries. Once again, these efforts focus on strengthening WUAs so that they can absorb and use new technology effectively.

1. Develop Human Resources

The first key to making technological modernization effective in the irrigated agricultural subsector of developing countries is to develop the human resources of WUAs. Technology cannot just be "dumped" on water users. Water users must be prepared to receive it. Again, the characteristics that contribute to the success of private sector in business provide guidelines. Some such characteristics include:

- order and discipline
- entrepreneurial capabilities and experience
- decision-making capabilities
- responsibility
- financial resources

In lessons learned in transfer projects with WUA formation and building, the International Irrigation Center of Utah State University (IIC/USU) has found that institutional innovation provides the "red carpet" for technological modernization (USU 2001, Yap-Salinas 2003b). In other words, developing the managerial and entrepreneurial abilities of water users and providing training in representative self-governance and decision-making have been key in making water users and their associations strong and sustainable. In USU projects it has been observed that as water users gain confidence in the representation and fair management of their WUAs, their commitment to the growth and strength of their WUAs grows, and they are more interested in learning new technologies that can save water and produce more agricultural yield (Yap-Salinas 1994b, USU 2001).

Thus, it is necessary to build strong WUAs with equitable, participatory self-governance in order for technological modernization to be effective and sustainable. In fact, USU's eight-year On-Farm Water Management Project (PROMAF) in the Dominican Republic, concluded in 1993, produced strong WUAs open to technological modernization (Yap-Salinas 1994a); these served as models for irrigation system management transfer throughout the country. Later, because of their orderly participatory self-governance, their understanding of their community water needs, and earlier experiences with technology in PROMAF, these WUAs were able to absorb more advanced technology such as GIS mapping and computer scheduling in follow-up projects.[2] This shows the clear advantages of training WUAs in self-governance and management and of using a stepwise approach to technological modernization. Similarly, projects and training in the Dominican Republic, El Salvador, and Ecuador have focused on building water user capabilities in managing their own WUAs effectively as part of the prerequisite for sustainable modernization (Yap-Salinas 1996, 2003a, 2003b).

However, one size does not fit all. In developing the skills and capabilities of water users, the characteristics and culture of water users in each individual WUA must be respected and considered. In any given developing country there exists a great range of water users: some educated, some with minimal education, some illiterate; some already with extensive entrepreneurial experience, others with minimal or none; some with experience in irrigation, others with little or none; some with traditional indigenous agricultural and societal customs, others with more national customs; and some with already functioning, representative WUAs, others just beginning. The amount and type of training in the various areas of institutional innovation and managerial skills accordingly varies with the characteristics of water users in each WUA. The IIC's Technical Assistance Project in Ecuador involved seven different WUAs in different geographical and climatological regions, with the whole continuum of capabilities represented. Nevertheless, effective WUAs were built in each of these (USU 2001).

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[2] PROMASIR and PROMATREC, USU follow-up projects to the USU On-Farm Water Management Project, have been operating in the Dominican Republic since 2001.

2. <u>Make Technology Functional, Friendly, and Affordable</u>

Any introduction of change, including technology, must take into account the receiver. Just as in training in institutional innovation and technical skills, the characteristics and culture of water users in each WUA must be respected and taken into account when introducing technology. Water users who have higher education, entrepreneurial experience, and financial resources are more mentally and financially receptive to technological modernization. In contrast, water users who have limited educational and entrepreneurial background and financial resources require a more stepwise approach. New technology must be demonstrated to provide real advantages, and it must be introduced in a simpler, more "friendly," way.

An example of this took place in the introduction of greenhouses in the Andean WUAs. One WUA already used sophisticated greenhouses in rose production. At a higher elevation, in WUAs with limited educational and financial resources, simple rustic greenhouses of eucalyptus poles and inexpensive plastic covers were built and produced a dramatic increase in agricultural production, including production of tomatoes, which normally could not be grown there. The success won over many water users, as well as non-project farmers in the area, and rustic greenhouses started sprouting all over. As production and income increased, water users were able to upgrade the technology of their greenhouses, switching from surface irrigation to pressurized systems and improving their crop production techniques, thus increasing their use of technology in a stepwise, affordable way (USU 1997-2001).

The age of water users is also an important consideration. Many water users in developing countries are older because of the difficulty of rural, agricultural life; their children often leave the countryside for the cities. Thus introduction of technology must be more gradual and demonstrative, taking into account the fact that older farmers are often more inflexible and "set in their ways."

3. <u>Provide Continuity</u>

Continuity is necessary in three areas. One form of continuity involves the water users themselves; a second involves the government; and a third involves government assistance projects and programs.. Continuity is essential to the life of WUAs, and to their technological modernization. Interrupting or cutting short the process to prepare WUAs to receive new technology is analogous to taking a cake out of the oven early; the results are not optimal.

<u>Continuity in the WUAs</u>: As already mentioned, there are fewer young people to be found among water users; many flee to the cities seeking a better

life; a few find it, but the growth of urban slums in many developing countries attests to the failure of many such dreams (Yap-Salinas 1996). Poverty, in turn, leads to social unrest, and the objective of keeping the farmer on the land is a valid one. Young people, furthermore, are often more open to technology and can provide new life to the WUAs. One solution is to provide programs that encourage young people to become involved in agriculture and in WUAs to provide continuity to the agricultural enterprise.

Continuity in Government: Continuity also means government commitment to the irrigation system management transfer process and to WUA formation and strengthening. This commitment, or political will, must be at the national level, and it must also be at the district level as well (Yap-Salinas 2003a). When the national government makes this a national policy, dictated from above, tolerating no obstruction from district level officials, WUAs receive government support and their progress can continue (Carrasco 2004). When officials at the national level are not committed and district officials do not cooperate for fear of change, progress is more halting and limited (USU 2001).

Thus political will is necessary at all levels of government, and a state commitment to WUAs is essential. While much easier said than done, demonstration of success and effectiveness of WUAs can often achieve national government commitment, as it did, with time, in the Dominican Republic with the IIC's On-Farm Water Management Project and follow-up IIC projects.[3]

If there is government commitment to continuity, with political will, red tape can be minimized for importation of technology; programs for technological modernization will be supported, and funding will sought.

Continuity in Projects and Programs: Providing continuity in projects and programs aimed at strengthening WUAs and implementing technological modernization is essential. This continuity can be interrupted by various events:

- change of governing party or group
- social unrest
- lag time between projects or programs
- politicization of WUA leadership

Change of governing party or group. Because in many developing countries, a change of political party as a result of an election or a coup often results in a change of administrative and technical personnel at all levels of governments, assuring continuity in government assistance projects and programs is often a serious problem (Yap-Salinas 1994b, USU 1997-2001). Following a "clean

[3] PROMASIR and PROMATREC, mentioned earlier.

sweep," new personnel, often political appointees, come in, and there is often a time lag of even months as these new personnel become acquainted with ongoing projects and programs. In addition, these new personnel frequently lack political will and interest, and the latter must be cultivated all over again; this situation results in further delay in progress in any program benefiting WUAs, including those supporting technological modernization.

A further problem of change of governing party in many developing countries is that, unlike the situation in developed nations, the new party in power often feels no obligation to continue projects and programs started by the previous administration. These projects and programs may simply be cut (Yap-Salinas 1994a, USU 2001).

Social unrest. Social unrest can also result in halts and serious delays in project progress. Roads may be blocked, and transit may be dangerous for technical personnel traveling to agricultural areas (USU 2001).

Lag time between projects or programs. Another problem in continuity occurs at the end of a project or program. Even if a project or program supporting WUA growth and technological modernization has not been slowed by the above factors, often its objective is just part of the progress needed to give optimal strength to the WUAs. There may be a follow-up project planned, but that project may not start for months or years later, or because of political or other problems, it may never start. Water users may have been given new technology and started to use it, but they may run into problems with it, or they may need more technology to support it as their WUAs grow, and the necessary project and government support may not be there.

In view of this latter problem, the IIC built, toward the end of its technical assistance project in Ecuador, a cadre of young engineers at the government district level that could serve as resource help to WUAs during a lag period between projects. However, this type of solution is not permanent; if the lag period is too long, elections and other factors that cause change of personnel can intervene to diminish the government help available to WUAs.

Politicization of WUA leadership. In addition to the above situations affecting project and program continuity, a further problem arises when political parties attempt to gain control of WUA leadership and divert WUA goals for political gain. We call this process politicization. This is most often a danger around election time, but can occur at any time; for example, populist parties often promise water users certain benefits if those parties win elections. Politicization is especially serious if it takes place at the start of WUA formation, but whenever it takes place, it can derail the whole concept of water users' self-governance through their WUAs (USU 2001). As WUAs gain strength through national confederation of WUAs, they are even more vulnerable to attack by those who wish to use them as political instruments.

4. **Provide Legal Protection and Stability**

Once again, political will at all levels of government, and a state commitment to WUAs is essential. When water users have legal property rights, when WUAs have legal jurisdiction for action, and when water laws are modernized and effective, WUAs have legal protection and the stability necessary for growth, including technological growth. In contrast, when protection and stability are lacking, WUAs, just like the private sector, hesitate to invest in technological modernization.

5. **Provide Market Stability and Increased Financial Resources**

As in the private sector, financial resources and financial stability are necessary for WUAs to be able to invest in technological modernization. “Closed” market systems, i.e., where markets are assured for agricultural production, reduce farmer risk and assure farmer income. Accordingly, marketing assistance should be provided in programs to WUAs as a complement to increasing agricultural production. In addition, WUAs need to be motivated to plan for the future in generating aggregated value; this helps provide sustainability, particularly in monocrop areas.

6. **Provide Opportunities for Professional Continuing Education**

In many developing countries, irrigation engineers and other irrigation professionals receive no continuing training past their university graduation. There are very few conferences or journals that are available or affordable in-country, and most do not have the means to travel abroad or subscribe to foreign journals. Thus, for lack of “refreshing” by continuing education, their concepts and understanding essentially “fossilize” at graduation. They are often unaware of new technology and may be afraid to use it. As a result, when a project or program is proposed or contracted for WUA technological modernization, there may be resistance or even fear of losing face. This resistance, in turn, can translate into a lack of political will and cause delays and obstruction of the technological modernization process of WUAs.

There is, therefore, a need to provide some means of “updating” professionals’ technical knowledge so that they can be optimal resources for WUAs, guiding them in managing new technology. Education for the professionals, particularly government personnel at district level, who work with WUAs should be incorporated as part of any WUA technological modernization program. National professional organizations should also be encouraged and assisted in providing continuing education programs.

CONCLUSION

Water users associations are quite analogous to the private sector in their required conditions for growth and stability. Growth means technological modernization in today's world in order to be competitive. Stability means sustainability, and it requires continuity. For developing countries that depend on agricultural exportation, strengthening WUAs in the irrigated agricultural subsector is necessary in the areas of self-governance and institutional innovation, which in turn enable effective technological modernization. However, technology must be introduced carefully, with respect, taking into account the unique characteristics of each WUA, and efforts need to be made to provide supporting external conditions, conditions outside the WUA, that promote the introduction and effective use of technology.

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RELIABILITY CRITERIA FOR RE-ENGINEERING OF LARGE-SCALE PRESSURIZED IRRIGATION SYSTEMS

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ABSTRACT

A study was conducted in a pressurized irrigation district in southern Italy to analyze current delivery performance and determine improvements needed to meet current and future delivery needs. Such an analysis is required due to changes that have occurred, since the system was first put into service, in cropping patterns, farming practices and irrigation techniques. The **C**ombined **O**ptimization and **P**erformance **A**nalysis **M**odel (COPAM) was used to evaluate the irrigation system present performance under different operating conditions, to identify the areas within the irrigation district where rehabilitation and modernization are more urgently needed, and to suggest the most effective engineering and operational improvements. Post-intervention operating scenarios were simulated and analyzed to refine and validate the re-engineering process. Results show the usefulness of simulation models when analyzing modernization alternatives for irrigation schemes.

INTRODUCTION

In the arid and semi-arid regions of the Mediterranean, most of the economically viable water resources development has already been implemented. Population growth and cyclic droughts have put pressure on available water resources. These conditions create a structural imbalance between increasing water demand and limited water supply (Hamdy and Lacirignola, 1999). Moreover, many large-scale irrigated areas have recently experienced an increase in water demand for municipal and industrial use, and a reduction in the amount of water available for agriculture. Therefore, irrigation agencies and farmers' associations have been asked to improve the efficiency of their irrigation networks and delivery systems by means of more rational use of limited water resources (D'urso, 2001). New methods are needed to assess irrigation system performance and to support decision-making in regional water management. Reliable information is needed with regard to spatial and temporal patterns of farmers' water demands, farming

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and irrigation practices and physical and operational features of large-scale irrigation systems. Future projections and simulation of alternative management scenarios need to be conducted to understand how irrigation systems respond to changes in operating conditions. Simulations of feasible management scenarios are helpful for identifying the most promising directions with the greatest impacts on irrigation system performance (Prajamwong et al., 1997). Simulation models can enable managers and planners to predict the effects of various management strategies under different climatic and operational conditions. They can be used as analytical tools by researchers and practitioners responsible for investigating water management alternatives.

OBJECTIVES, METHODOLOGY AND APPROACH

Our goal is to provide a methodology for performing diagnostic analyses on large-scale pressurized irrigation systems. These analyses are required to address the main issues in rehabilitation processes and to support decision-making in re-engineering and in water management for irrigated agriculture.

A large-scale irrigation system located in Southern Italy and managed by a local Water Users Association (WUA) was investigated. This irrigation scheme was originally designed to operate by rotation delivery schedule. Nevertheless, changes in cropping patterns occurred and progresses in irrigation were achieved. As a result, the actual operating conditions and farmers' irrigation demands are now different from those foreseen during the design stage. As a result, the system performance has greatly decreased with time. Rehabilitation and modernization are required to improve the system performance and the level of farmers' satisfaction. To achieve this, potential and actual failures of the system and their related causes were first identified. Changes in the actual operation, capable to positively affect performance, were envisaged. Physical and operational rehabilitation measures were pointed out. Several analyses were carried out in order to evaluate the hydraulic response of the system under different operating conditions. The Combined Optimization and Performance Analysis Model (Lamaddalena and Sagardoy, 2000) was utilized for these analyses. COPAM software includes the ICARE and AKLA simulation models.

DESCRIPTION OF THE STUDY AREA

The analysis was conducted on District 7 of the large-scale irrigation scheme "Sinistra Bradano" located in southern Italy (Apulia Region) and managed by the "Stornara e Tara" Water Users Association. The district covers a net irrigated area of 392 ha. Its spatial extent has coordinates 2669919 E, 4493641 N and 26900994 E, 4472609 N (UT 1983, Zone 33 N). The elevation ranges from 3.0 to 45.0 m above the sea level. Water is conveyed from a regional reservoir located in a neighboring region by means of a main conveyance canal. From the canal, water is then diverted into district distribution networks, which consist of pressurized underground pipelines. Water is finally delivered to farms by means of multi-user hydrants, designed to provide a nominal flow rate of 10 l s^{-1} or 20 l s^{-1}. The WUA performs the rotation at two different levels: a) the district level, by opening the sectors in certain days of the week and for pre-fixed durations; b) the sector level, rotating the farm stream among the different farms composing the sector. The existing cropped areas and the cropping patterns considered at the designed stage for the future agricultural development of the district are shown in Table 1.

Table 1. Cropped area for the irrigation district 7

Actual cropped areas and cropping pattern foreseen at the design stage		
Crops	**Actual area (ha)**	**Foreseen area (ha)**
Table gapes	158.0	80.0
Citrus	155.0	80.0
Olive trees	40.0	36.0
Vegetables	20.0	116.0
Wheat	19.0	-
Row crops	-	40.0
Fodder crops	-	40.0
TOTAL	**392.0**	**392.0**

As illustrated in Table 1, variations in cropping patterns mostly concerned grapes, olive and citrus. Availability of good quality water and favorable weather and soil conditions pushed farmers to grow these crops to obtain profitable yields; but citrus and grapes have high water requirements. During the peak periods the system is often unable to fulfill the overall district water needs. Organizing irrigation rotations to satisfy the ever-increasing water demands has became troublesome for the technical staff of the local WUA. Improving the system operation according to the actual needs has therefore become of a high priority.

RESULTS AND DISCUSSION

The set of analyses was carried out by using the ICARE model (CTGREF, 1979) and the AKLA model **(**Ait Kadi and Lamaddalena, 1991; CHIEAM internal note not published). These two models are stand-alone components of the COPAM software package. Their use enabled to simulate change of the system's operation, from rotation to on-demand delivery schedule and determine the overall system performance (Zaccaria, 1998). Results obtained from the analyses showed that shifting the system operation from rotation to on-demand delivery schedule would enable a higher flexibility in water distribution and a simplified water management for the WUA. The overall performance and the quality of irrigation service would greatly improve. The models also enabled simulation of the post-rehabilitation operation to evaluate the system performance in the new operational scenario. In order to accomplish the operational change, some rehabilitation and modernization works are required. Application of the above simulation models allowed the identification of critical areas within the irrigation district, where rehabilitation and modernization measures are more urgently needed. Results of the study were then validated by means of field analyses and through interviews with irrigation users as well as to the managers of the local WUA.

In order to apply the ICARE and AKLA models, several input files were prepared. These files contain all the information concerning design assumptions, physical features of the network and its scheduled operating conditions. Node elevations, diameters, lengths, locations of hydrants and their features (such as flow meters and pressure regulators) were identified and reported in the input file. Two different sets of analysis were conducted: 1) verification of the network operation under the actual conditions; 2) hypothesis of rehabilitation and analysis of the system under improved operating conditions.

In the first set of analyses, the system's hydraulic behavior was investigated under actual operating conditions. Current delivery conditions are quite different from those the system was originally designed for. Current deliveries occur on a 10-day basis and have a typical standard rotation lasting 10 days and cycling for the whole irrigation season, except under particular conditions (failures, rain, emergency irrigation, temporary stops). On the basis of this schedule, daily length was subdivided into four six-hour intervals. Within each of these intervals, the sectors simultaneously in operation were set according to the real schedule. Knowing the characteristics of the flow limiters located at the upstream end of sectors, the discharge flowing into the network for each six-hour interval was computed. The AKLA model was run for each six-hour interval, considering the existing piezometric elevation at the upstream end of the network $Z_o = 45.50$ m above sea level and the total discharges (Q_o) as computed for every single interval. The current delivery requirements (flow rate of 5 l s^{-1} with minimum pressure head $h_{min} = 20$ m) were considered. The most representative outputs of the analysis are presented in Figure 1 to 4. Some severe deficit problems may occur for any tested flow rates. For several hydrants (located within sectors 32, 33, 38, 39, 40) the relative pressure deficit sometimes reaches $\Delta H < -1$, which means negative pressure at the hydrants and, consequently, a risk of air entering the pipes. For some other (located within irrigation sectors 42, 43, 44 and 45) the available pressure heads are much higher than 20 m. Such outputs show that there is poor pressure uniformity among the different zones of the district. This reduces the performance of the network, not allowing for a proper operation of on-farm irrigation systems for several areas. In these areas, farmers need to use booster pumps. These results show that the hydraulic performance of the system is rather poor. Consequently, adjustments of operation to meet actual delivery requirements, also considering the physical capability of the network, are strongly required.

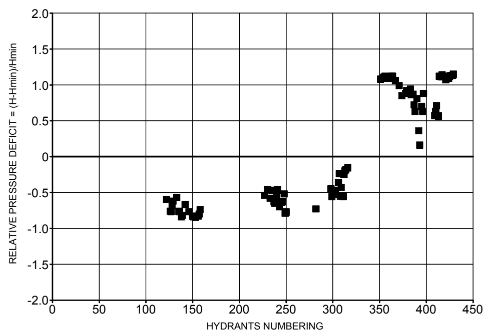

Figure 1 – Relative pressure deficit at each hydrant according to the rotation adopted by the WUA. Interval 12 am – 6 pm of the 1st day of the standard rotation. $d = 5\ l\ s^{-1}$ and $h_{min} = 20$ m

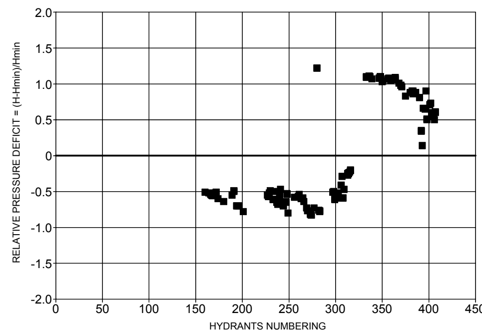

Figure 2. – Relative pressure deficit at each hydrant according the rotation adopted by the WUA. Interval 12 am – 6 pm of the 5th day of the standard rotation. $d = 5\ l\ s^{-1}$ and hmin = 20 m

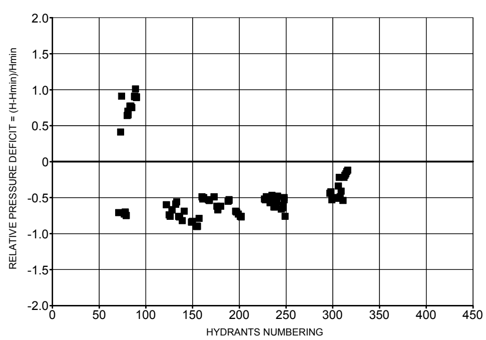

Figure 3. - Relative pressure deficit at each hydrant according the rotation adopted by the WUA. Interval 12 am – 6 pm of the 10th day of the standard rotation. $d = 5\ l\ s^{-1}$ and $h_{min} = 20$ m

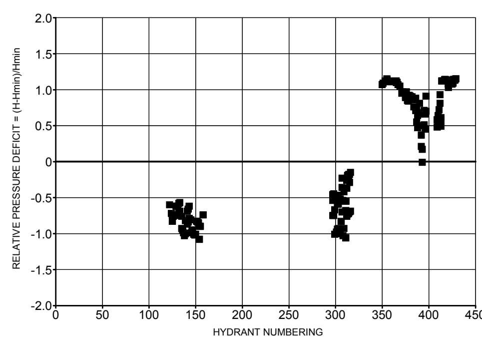

Figure 4. – Relative pressure deficit at each hydrant according the rotation adopted by the WUA. Interval 6 am – 12 am of the 1st day of the standard rotation. $d = 5\ l\ s^{-1}$ and $h_{min} = 20$ m

In the first set of analyses, the hypothesis of operating the system on-demand under the actual conditions was also tested. The change was simulated to determine whether it could lead to an overall improvement of the system operation. Understanding whether the network might be operated on-demand and identifying the consequences resulting from these changes in operation are the main purpose of the analyses.

The range of discharges flowing into the network during the peak period (July) was determined. The range was $40\ l\ s^{-1}$ to $150\ l\ s^{-1}$. The flow rate continuously available at the upstream end of the network was referred by the WUA to be $200\ l\ s^{-1}$. The ICARE model was run for different discharge values, ranging from $40\ l\ s^{-1}$ to $200\ l\ s^{-1}$. For each of the discharge values, 500 different configurations of hydrants operating simultaneously were randomly generated. Results of the analyses are reported in Figure 5.

For the piezometric elevation of 45.50 m a.s.l. more than 70 % of the simulated configurations are satisfied when the discharge flowing into the network is lower than 100 l s^{-1}. As the flowing discharge increases, the system can satisfy a decreasing percentage of the simulated configurations. For Q_o = 150 l s^{-1}, the system satisfies a percentage ranging from 50 % to 60 % of the configurations. For the maximum continuously available discharge Q_o = 200 l s^{-1}, 30 % to 40 % of configurations can be satisfied. Based on information obtained, one can infer that the system ensures a high performance when on-demand delivery is applied for hydrants discharging 5 l s^{-1} with a pressure head h_{min} = 2 m. A shift from rotation to on-demand delivery does not negatively affect the actual hydraulic performance of the system. Operating the system on-demand is technically feasible and would benefit the WUA and irrigation users. Under actual conditions, however, the system cannot fulfill the farmers' needs even if operated on-demand. At present, the system can deliver an adequate discharge (d = 5 l s^{-1}) at each point of the network, with a pressure head that in nearly all cases is not sufficient for adequately operating the on-farm irrigation systems.

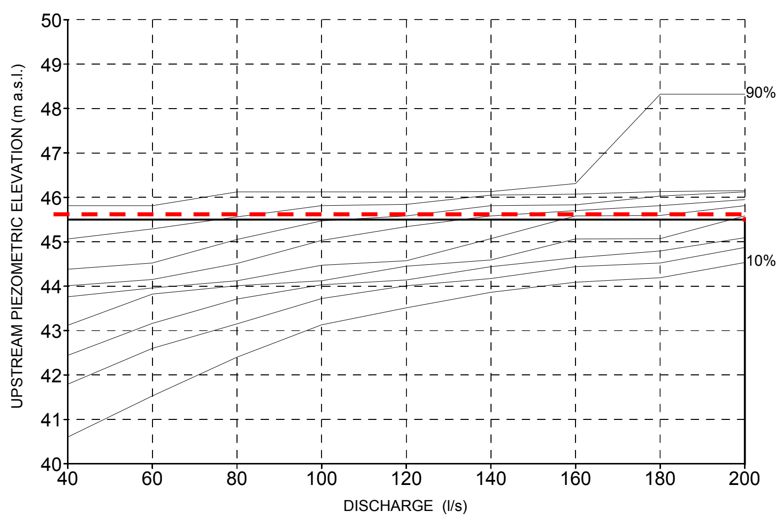

Figure 5. Percentage of satisfied configurations for the distribution network for Zo = 45.50 m a.s.l. And h_{min} = 2 m

For assessing rehabilitation needs, the hydraulic performance of the distribution network under the hypothesis of hydrant discharging d = 5 l s^{-1} and minimum pressure head h_{min} = 20 m was tested. These water delivery conditions correspond to the actual farmers' requirements. The maximum upstream discharge flowing into the network was computed by using the Clément probabilistic model (Clément, 1966). The continuous specific discharge resulted q_{sc} = 0.48 $ls^{-1}ha^{-1}$. This value of q_{sc} was utilized for the determination of the upstream discharge Q_{up} (l s^{-1}) flowing into the network. Based on the continuous specific discharge, the total flow rate Q_{up} = 340 l s^{-1} was obtained. This value of flow rate was used in the ICARE and AKLA models. Twelve different flow rate values, ranging from

50 l s^{-1} to 600 l s^{-1} were analyzed using the ICARE model. For each value, 500 different configurations were generated. A minimum pressure head h_{min} = 25 m and a nominal flow rate of d = 5 l s^{-1} were imposed at the hydrant level. Some representative results are in Figure 6 and 7.

For an upstream elevation Z_o = 45.50 m a.s.l., none of the generated configurations are satisfied, for any value of discharge tested. Even for very low flow rates, the system cannot adequately fulfill the on-farm needs. In order to get an acceptable performance (at least 50 % of the generated configurations satisfied) for the value of Clément's discharge Q_{cl} = 340 l s^{-1}, the system requires at least a piezometric elevation Z_o = 70 m a.s.l. If the discharge flowing into the network is higher than 340 l s^{-1}, a piezometric elevation at the upstream end Z_o = 70 m enables the system to satisfy a decreasing percentage of the generated configurations. Analyzing the performance of the irrigation network for flow rates higher than 340 l s^{-1} corresponds to simulating different cropping pattern scenarios. If the total irrigated area of the district 7 would be fully converted to citrus, the Q^{1}_{cl} would rise up to 355 l s^{-1}. At this flow rate, the system could satisfy a percentage ranging from 30 % to 40 % of the generated configurations. If the total area of the district 7 was planted with summer vegetables, the discharge would rise to Q^{II}_{cl} = 570 l s^{-1}. With this discharge flowing into the network, not even 10 % of the configurations would be satisfied with Z_o = 70 m a.s.l. A further lift of the piezometric elevation to Z_o = 75 m, would enable a percentage of configurations ranging from 10 % to 20 % to be satisfied. For the actual cropping pattern and for Z_o = 75 m a.s.l., the system performs very well even when Q_o is higher than Q_{cl} = 340 l s^{-1}. In order to obtain more accurate information about the satisfaction of the requirements for every single hydrant within each investigated configuration, a further analysis by running the AKLA model was conducted to overcome ICARE's shortcomings. The AKLA model was run for Z_o = 70 m a.s.l. and flow rates Q_o ranging from 200 l s^{-1} and 600 l s^{-1}. The relative pressure deficit for every hydrant within each configuration was determined, identifying the unsatisfied hydrants. No deficit problem occurs when the discharge Q_o is lower than the Clement's discharge Q_{cl} = 340 l s^{-1}. Starting from the flow rate Q_o = 400 l s^{-1} in sectors 32, 33, 38, 40, pressure heads lower than 25 m were observed. In these areas, the relative pressure deficit is higher than ΔH = - 0.2 corresponding to a residual pressure head h_{min} = 20 m. As the flow increases, the situation in these areas becomes worse, but never critical. In particular, for Q_o = 550 l s^{-1} in the sectors 40 and 41 a maximum pressure deficit ΔH = - 0.3 can be observed. This value corresponds to a pressure head at hydrants h_{min} = 17.5 m, which still provides enough pressure to operate trickle irrigation systems. For Q_o = 600 l s^{-1}, a general pressure deficit is noted for the central portion of the network. By considering the 90 % envelope curve, a pressure deficit at most equal to ΔH = -0.6 corresponding to a pressure head h_{min} = 10 m, is observed. This pressure head does not allow for appropriate trickle irrigation methods.

Figures 8 and 9 provide the identification of unsatisfied hydrants through the curve of Percentage of Unsatisfied Hydrants (PUH). From the results, areas where deficit problems occur correspond to few unsatisfied hydrants which, being within different configurations, result in indexed curves shifted up. ICARE considers all hydrants in one configuration together, while AKLA identifies conditions prevailing at each hydrant. The AKLA model allows more complete analyses with the identification of the zones where important pressure deficits occur.

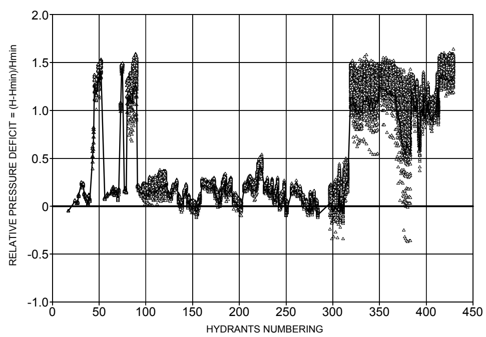

Figure 6 - Relative pressure deficit at each hydrants. Discharge Qo = 400 l s^{-1} , upstream piezometric elevation Zo = 70 m a.s.l. and h_{min} = 25 m.

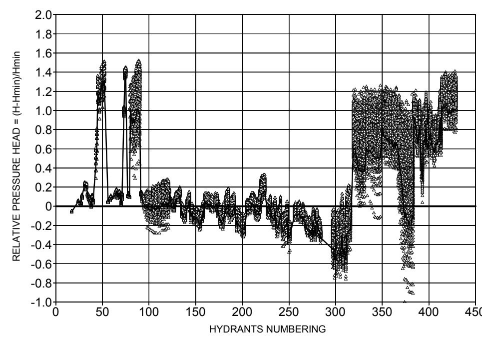

Figure 7 - Relative pressure deficit at each hydrants. Discharge Qo = 600 l s^{-1} , upstream piezometric elevation Zo = 70 m a.s.l. and h_{min} = 25 m.

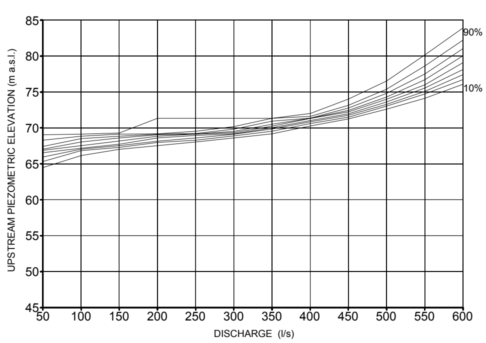

Figure 8 - Percentage of satisfied configurations for the network of the district 7 for Zo = 45.50 m a.s.l. , d = 5 l s^{-1} and h_{min} = 25 m.

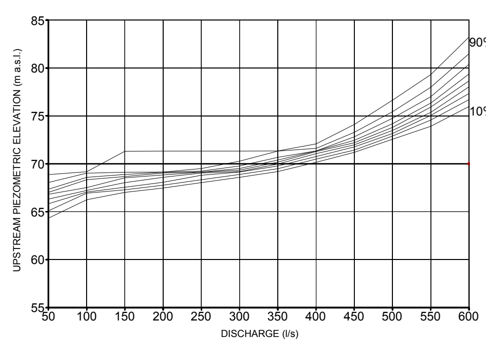

Figure 9 - Percentage of satisfied configurations for the network of the district 7 for Zo = 70.00 m a.s.l. , d = 5 l s^{-1} and h_{min} = 25 m

CONCLUSIONS AND RECOMMENDATIONS

The importance of performance analyses for re-engineering of existing irrigation systems was described. The usefulness of advanced models for monitoring and simulating different physical processes involved in an irrigation system was illustrated. Both models are very helpful to get a better understanding of distribution network behavior, both from usual operation and from rehabilitation perspectives.

For our case study, results show that the system under consideration is not capable of fully satisfying farmers' needs in terms of pressure head at hydrants. Improving system performance is a priority task and should be carried out through technically and economically feasible rehabilitation measures.

In order to obtain acceptable performance levels, for the discharge equal to the maximum design discharge Q_{cl} = 340 l s^{-1}, lifting the upstream piezometric elevation from 45.50 m up to Z_{up} = 70 m a.s.l. is required.

Some operational measures positively affecting system performance are advisable. An effective shift from rotation to on-demand delivery should be implemented to improve the flexibility in water distribution. Since, for operation on demand, the maximum withdrawals may occur during the morning hours, a farm control can be achieved by installing in the critical sectors delivery equipment allowing withdrawals only within pre-determined set-times (Nerilli, 1996). These equipments could also enable to adjust the flow hydrograph to the actual system capabilities. The WUA could restrict, within the critical areas, the withdrawals to certain daily hours in order to modify the flow hydrograph, without necessarily modifying the operation from the full demand to the restricted frequency demand for the whole system. The system management could be improved without seriously penalizing the on-demand delivery schedule.

Establishment of adequate water tariffs according to classes of volumes consumed could contribute to adjusting the flow hydrograph to the system capacity and prevent failures.

The following re-engineering options should also be considered. Within each hydrant flow, limiters should be replaced with others delivering a maximum nominal discharge of 5 l s^{-1}. A storage and compensation reservoir should be built at the upstream end of the district network for ensuring the regular operation of the system during the peak periods, and to reduce the water losses when the system is not operating. The district network should be equipped with a pumping station to lift the piezometric elevation at the upstream end of the network up to 70 m a.s.l. Equipping the lifting plant with variable speed pumps could ensure optimal power management. Finally, a flow recorder installed at the upstream end of the network would allow monitoring daily flow hydrographs and therefore would enable a better understanding of how to adjust operation of the irrigation system to its maximum capacity.

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A WATER QUALITY STUDY OF DDT IN THE MANSON LAKES

Paul R. Cross, P.E.[1]

ABSTRACT

Irrigation districts are responsible for a wide variety of issues including but not limited to water distribution, water management, regulation of water rights, collecting assessments, managing return flows and interfacing with environmental needs related to endangered species and water quality issues including total maximum daily loads. Some irrigation districts also provide additional services including domestic water, sewage collection or power generation and distribution. The Manson Lakes are a series of three small lakes in an agricultural area in north central Washington state where one of the lakes, Roses Lake, is on the 303(d) list for exceeding total DDT levels in fish tissue. The Lake Chelan Reclamation District received a grant to study the location, extent and levels of DDT in the water and soil within the subbasin together with the nutrient phosphorus. The Manson Lakes drain to Lake Chelan, a near-pristine lake of state-wide importance. Lake Chelan is also on the 303(d) list for DDT in fish and has a preventative TMDL for phosphorus to protect its ultraoligatrophic status. This study concentrated on the sources of DDT for fish in the Manson Lakes together with the function and impact of the Manson Lakes as a source or sink to Lake Chelan for both DDT and phosphorus.

The agricultural lands around the Manson Lakes have been used for the production of apples for over 80 years. DDT was used from the 1940's to the early 1970's to control coddling moths in apples. Although DDT hasn't been used in over 30 years, it is very persistent in the environment and biomagnifies in the food chain. Our 2-½ year study identified several unique issues associated with the transport and concentration of DDT together with the fate and transport of phosphorus throughout the three lake system. The results of the study will be incorporated in a TMDL for DDT in both Roses Lake and Lake Chelan being prepared by the Washington State Department of Ecology.

INTRODUCTION

In Washington state, the state agency with jurisdiction on Clean Water Act implementation is the Washington State Department of Ecology (DOE). As early as 1995, Roses Lake (within the Manson subbasin and the boundary of the Lake Chelan Reclamation District) has been listed on the 303(d) list for exceeding the Clean Water Act standards for DDT in fish tissues. The 303(d) listing is based

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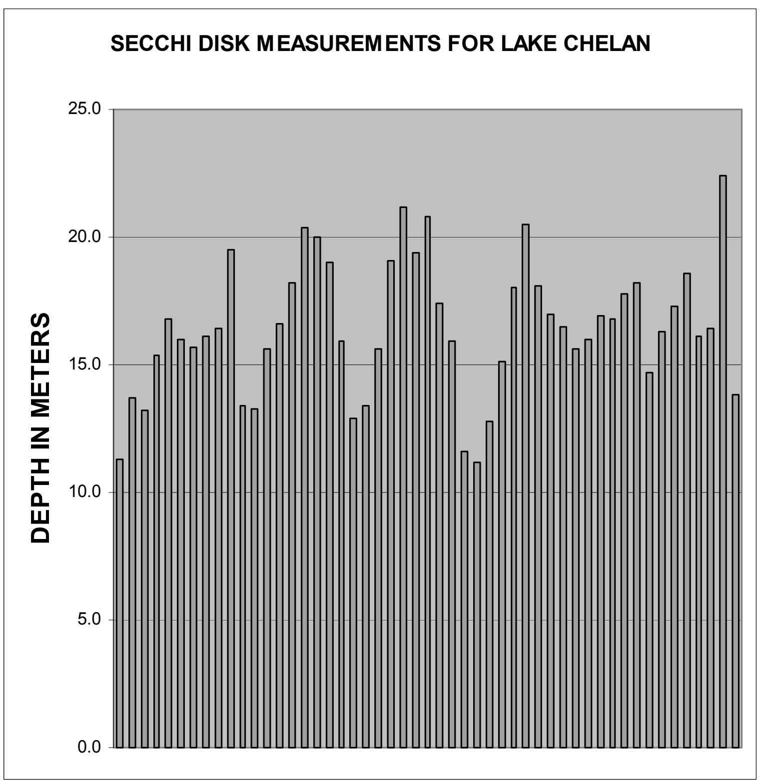
upon a very limited amount of data making the development of a clean-up plan and load allocation analysis very difficult.

The Lake Chelan Reclamation District (LCRD) took it upon itself to become involved in a water quality assessment of the subbasin to help support the total maximum daily load (TMDL) and clean-up plan required of the DOE. As the major representative of agriculture in the basin, the LCRD viewed its involvement as a proactive step towards addressing a residual problem from a legacy agricultural chemical.

The Manson Lakes subbasin drains into Lake Chelan, an ultraoligatrophic lake of statewide significance. Lake Chelan is over 460 meters deep and is the third deepest lake in North America with a clarity of up to 20 meters. A significant component of the water quality assessment would be to evaluate if the Manson Lakes are a sink or source of nutrients and DDT to Lake Chelan.



WATER QUALITY STUDY PLAN

The listing of Roses Lake fish was based upon only a limited number of fish and very limited information about sources of DDT. Little was known about the sources of DDT for the fish except that high concentrations of DDT had been found in a few lake sediment samples and that several agricultural drains outfall into the Manson Lakes subbasin. It was unknown if DDT was continuing to enter into the lake systems or if DDT was simply resident in the lake sediments.

Goals and Objectives

The water quality study revolved around four major goals. The study was to evaluate the level and extent of DDT in lake sediments in all three of the Manson Lakes. DDT would also be measured in water samples of all the major inlets to the lakes, both creeks and agricultural drains, to determine if they are a continual source of DDT. It was hoped that analysis of the data would determine if sources of DDT were associated with land use, farming or irrigation practices and thereby remediated by best management practices. Finally, the study hoped to determine if the Manson Lakes are a sink or a source of nutrients and DDT to Lake Chelan.

Quality Assurance Project Plan: The study began by developing standard operating procedures for collecting samples, performing field measurements, transporting samples, chain of custody and meeting statistical assurances with field duplicates and blanks. The plan needed to establish laboratory test standards adequate to measure the expected concentrations and to identify field equipment and supplies needed to make field measurements and to keep the equipment properly cleaned, maintained and calibrated. A state certified laboratory was selected that could perform the test standards and had the proper quality control methods to assure reliable testing.

Sampling Strategy: Sediment samples were taken at three locations in all three lakes and a repeat sample was taken in Roses Lake the following year. Sediment samples were also taken in three orchards adjoining one of the agricultural drains in the second year of the study to characterize DDT concentrations and depth. Water samples were taken once per month during months when the lakes and inlets were ice free.

Related Parameters: In soils, total DDT and its metabolites were measured together with total organic carbon, pH, total phosphorus, particle size and total solids. In water, flow, pH, dissolved oxygen, temperature, secchi depth, total phosphorus, soluble reactive phosphorus, alkalinity, nitrate/nitrite, chlorophyll a, turbidity, total soluble solids and DDT and its metabolites were measured.

DESCRIPTION OF SUBBASIN

The Manson Lakes subbasin is comprised of three small lakes, Wapato Lake, Roses Lake and Dry Lake. Wapato Lake is fed by one surface stream and has an artificial outfall that ultimately flows into Stink Creek. Roses Lake has no surface inlets and drains through a small, unnamed channel into Dry Lake. Dry Lake also has no surface inlets and drains directly into Stink Creek. Stink Creek drains into

Lake Chelan. Five agricultural drains and one spring represent the balance of the point source inflows to the three lakes. The agricultural drains are subsurface drains designed to lower perched groundwater from surrounding agricultural lands through perforated drainage pipe buried four to eight feet in depth in gravel envelopes. Water sampling occurred at all seven inlets, all three outlets and one combined outlet location along Stink Creek for a total of 11 sites.

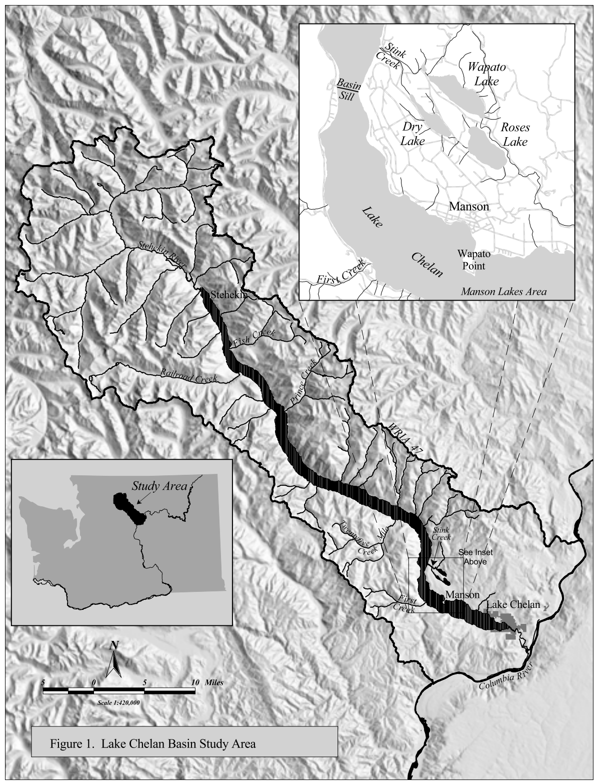


Figure 1. Lake Chelan Basin Study Area

There are approximately 100 homes in the subbasin with the majority being associated with agricultural farmsteads and a rising minority associated with recreational homesites around the three lakes. Homes in the subbasin are served by on-site septic tank and drainfield systems.

Farming in the subbasin is primarily orchards and a few vineyards. Irrigation water is served under pressure to the growers and the predominant method of on-farm irrigation is micro sprinklers and under tree impact sprinklers. Orchards have cover crops between the rows but a lot of vineyards are clean cultivated.

RESULTS

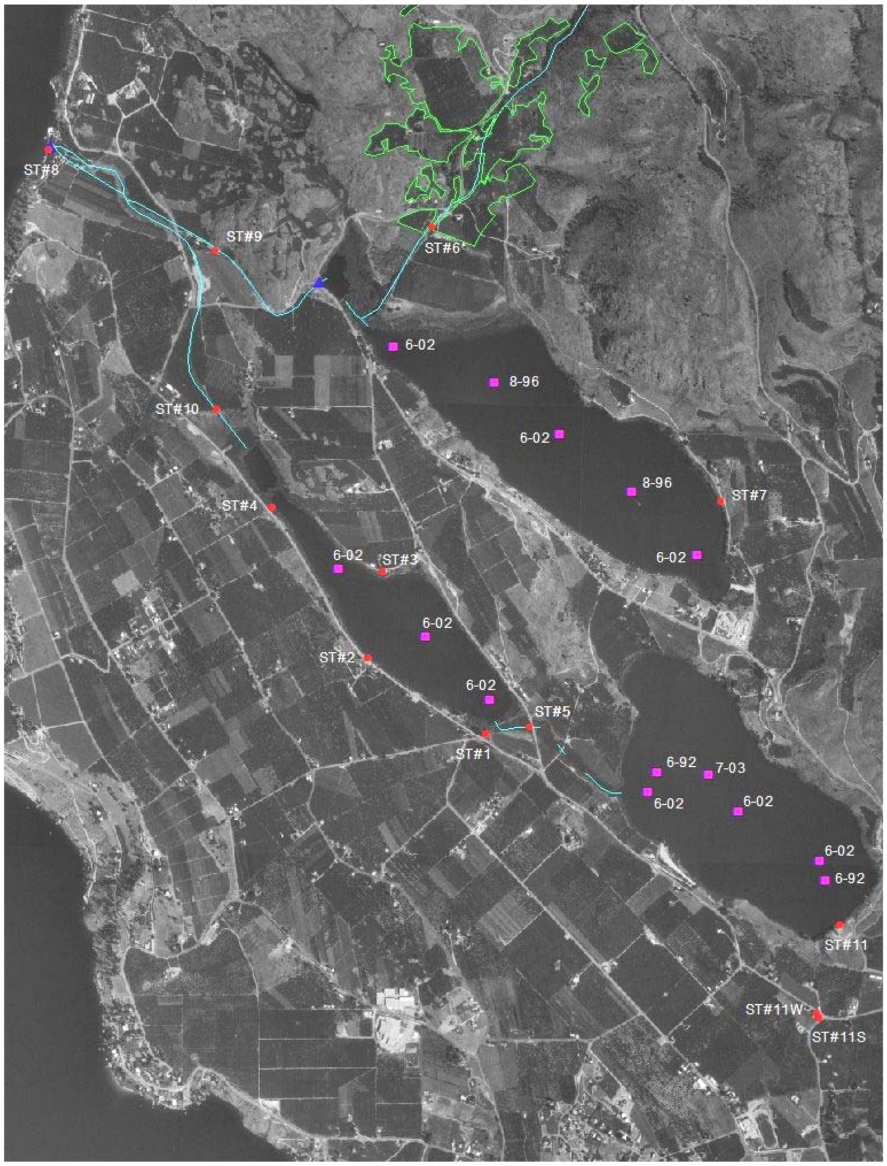
The purpose of this paper is to present general information, discussion and conclusions and does not present scientific results or conclusions. A technical report titled “Manson Lakes Water Quality Assessment” (July 2004) was prepared by Water Quality Engineering in Wenatchee, WA for the Washington State

Department of Ecology and provides a comprehensive technical analysis of the data.

DDT in Surface Waters: Average DDT concentrations in 9 of the 11 water sampling sites exceeded the chronic toxicity level of 1 part per trillion (ppt). Note that the chronic toxicity level is very close to the minimum detection limits of 0.38 ppt making detection near the toxicity level statistically problematic. None of the average DDT concentrations were more than 3% of the acute toxic limit of 1.1 parts per billion (ppb). The concentrations of DDT remained relatively constant throughout the sampling season, with the highest levels occurring in the winter months.

Turbidity and TSS in Surface Waters: Average turbidities in the agricultural drains were all under 1 NTU. Several of the same drains had average total suspended solids below the 0.5 mg/L detection limit. The subsurface drains with gravel envelopes did a good job of maintaining filter criteria and appear to avoid migration of the surrounding soils into the drainage pipes. The creeks and springs all averaged under 10 NTU and 30 mg/L TSS. Of all the water sampling sites, station 11 was the station with the highest average DDT concentration of 23 ppt. Station 11 also had one of the lowest average turbidities 0.5 NTU and one of the lowest average TSS of less than the detection limit of 0.5 mg/L.

DDT in Lake Sediments: Average total DDT in lake sediments are often times listed on a total organic carbon (TOC) basis. Samples were taken at three locations in each of the three lakes near the quarter points. All three lakes were under 100 ug/kg in total DDT and under 800 ug/kg of DDT on a TOC basis. This compares to the Ontario Provincial Guidelines severe effects level of 12,000 ug/kg of DDT on a total organic carbon basis. These also compare to total DDT in Roses Lake in 1994 as high as 88,000 ug/kg of DDT on a TOC basis and total DDT in Wapato Lake in 1997 as high as 8,900 ug/kg of DDT on a TOC basis.



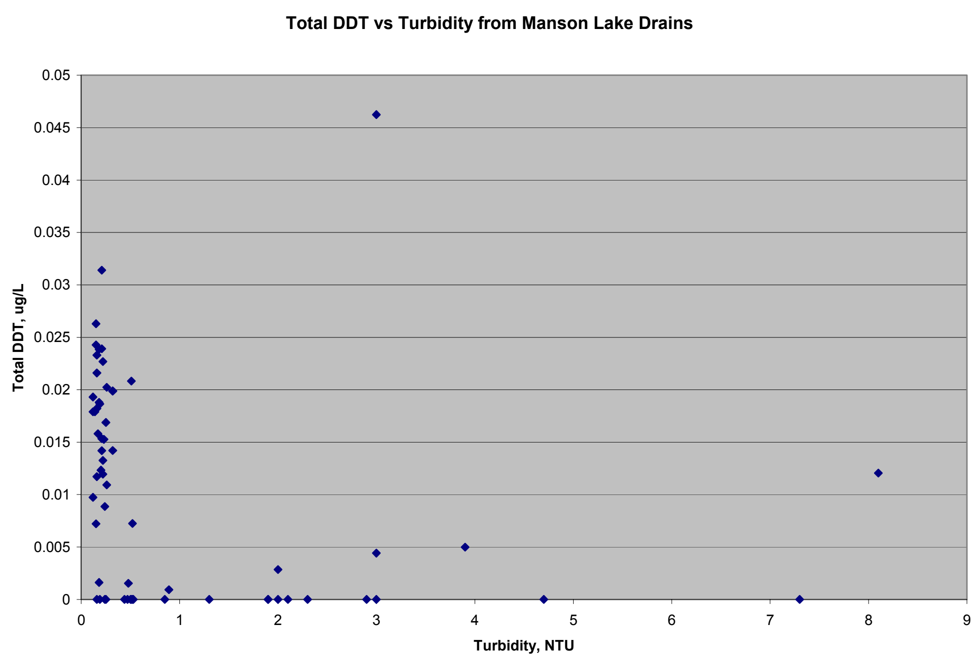
<u>DDT in Orchard Sediments:</u> Average total DDT in orchard sediments in the station 11 subbasin were 1 or 2 orders of magnitude greater than total DDT concentrations in lake sediments. This attests to the persistence of DDT in the environment. The DDT was also found to be fairly evenly dispersed between the upper layers of the soil profile and the lower layers near the subsurface drain. This contrasts with many studies where DDT was found to stay in the upper 12" of the soil column.

<u>Movement of DDT into Lake Chelan:</u> During 2002 about 57% of the DDT load was stored in the Manson Lakes as compared to 79% of the DDT load being stored in 2003. It appears that the Manson Lakes are an effective sink for DDT that protects Lake Chelan from additional loads. About 85% of the DDT load

entering Lake Chelan from the Manson Lakes occurs during the winter and early spring. The strong seasonal influence may be due to lake mixing from winds when the lakes exhibit homogenous temperatures in the water column. Thermal stratification during the rest of the year limits lake mixing and may enhance storage of DDT.

DISCUSSION AND CONCLUSIONS

DDT in Water: Most of the literature reviews and studies in the northwest show a near linear relationship between sediments in water (TSS and turbidity) and increased levels of DDT. In the Manson Lakes, the highest levels of DDT in water were found in some of the waters with the lowest levels of TSS and turbidity. This implies that the DDT may be moving through the drains and surface water systems attached to organic or mineral colloidal material. The overall low suspended solids suggest that DDT may be difficult to remove with available treatment technologies.



DDT levels in water were highest in the winter months when precipitation and snow melt are the largest source of water movement. The consistent movement of DDT the rest of the year implies that irrigation practices have little accelerative impact on DDT movement. The Lake Chelan Reclamation District has a progressive irrigation water management program with the growers in the District that is aimed at reducing runoff and deep percolation. The existing management practices are likely performing well towards minimizing the man-induced impacts on DDT loads.

DDT in Lake Sediments: Lake sediment surface samples were well below the severe effects levels and an order of magnitude lower than sediment samples taken only 10 years ago. These lowered concentrations imply that DDT in lake sediments may have been buried by deposits of organic plant materials and may gradually be removed from the food chain by natural processes.

DEVELOPING THE TMDL

This study of the Manson subbasin is just the first step towards developing a cleanup plan for DDT in the Chelan Basin. DDT loads from other subbasins and other sources are needed to perform a mass balance for the Lake Chelan basin. The study conclusions show different solutions emerging in the cleanup plan than was stereo-typically recommended at the onset. Most agencies consider runoff from farms to be the most significant source of DDT into lake and river systems. The Manson Lakes study puts the obvious conclusions in serious doubt. The study also illustrates why irrigation districts should be progressive in water quality projects to offer perspective and technical assistance in the science. The irrigation district can also be an effective and trusted communication link between the regulatory authorities and the farmers. This adds credibility to the conclusions and implementation strategies developed as part of any cleanup plan.

UPGRADING EXISTING DATABASES: RECOMMENDATIONS FOR IRRIGATION DISTRICTS

David Flahive
Guy Fipps[1]

ABSTRACT

All of the district in the Lower Rio Grande Valley currently store all of their accounting and water delivery records in computer databases. It has been known for several years that these database systems in the Lower Rio Grande Valley are in need of replacement. The current database systems are not compatible with modern software, including GIS and management software. Due to this lack of software compatibility the districts are unable to directly access the historic watering records in their databases. Without access to these records the districts are losing out on a valuable management and decision making tool. To determine the best upgrade option available, we considered the current database requirements of the district, as well as any foreseeable future requirements. We compared the costs and benefits of several free and commercially available database systems, taking into consideration software compatibility, ease of management, operating system requirements, and future software support. Based on our findings we are recommending upgrading to a Windows server running a SQL Server database. This configuration will give the districts the ability to fully utilize there existing datasets, while giving them the ability to be compatible with GIS and other management software.

SUMMARY

With only a few exceptions, irrigation districts in the Texas border region have old, outdated database systems that need to be replaced. These old databases are costly to maintain, make accessing and analyzing data difficult, and limit a district's ability to implement certain important new technologies and software into district operations. Upgrading out-of-date databases should be a part of any program to renovate and modernize district facilities and to improve the operational efficiency of a district.

Modern databases allow easy integration with GIS and other software packages, facilitating the use of data in making management and operational decisions, and in the design of new facilities. Commercially available databases are also relatively easy to use, thereby reducing the need for external software consultants.

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In this report, we discuss important issues and questions that should be considered when upgrading databases, and provide database and operating system recommendations. Estimated costs of the required software and hardware are also provided.

We recommend that districts move to one of the following two database systems:

Option 1: *Microsoft SQL Server 2000* running on *Microsoft Windows*; or

Option 2: *MySQL database* running on *Red Hat Linux*

We also recommend that districts team together in database upgrades so that the costs of reprogramming the client software can be shared.

TERMS AND DEFINITIONS

In order to make this report easier to understand, we first need to define several terms.

<u>Database</u>
A *database* is collection of data arranged in a structured format (think of a table with columns and rows). However, unlike a simple table, the information (or data) in a database is indexed and organized in a way that allows very fast data searching and retrieval.

<u>Data</u>
Data is factual information. As far as this report is concerned, the term *data* refers to account and water ordering information, order history, maintenance records and all other information contained within the database system.

<u>Server and Database Software</u>
The term *server* can mean two different things; it can refer to the physical hardware of the computer, or it can refer to the software on the computer which "servers out" information over a network. In this report, we use the term *databases* or *database software* to refer to the software and *server* to refer to the hardware (i.e., computer) that the software runs on. However, keep in mind that many computer and database experts use the term *"database server"* to refer to the database software running on the computer.

<u>Client</u>
Interfacing with the server and database is another software package referred to as the *client*. The *client* is a software package that reads the information that the server is sharing over the network. In most of the districts, office personnel use a *client* to input water ordering and other account information, as well as to produce reports. The *client* allows persons with no database

knowledge to enter and retrieve information from the database.

PROBLEMS WITH EXISTING DATABASES

With only a few exceptions, the database software being used by most districts is long past needing replacement. The majority of these databases are "flat-file" type database systems (or single-user systems) which are limited in the multi-user networked environment that most of us work in today. In other words, these tend to be on a single computer that only one person at a time can access and use.

Many irrigation districts have proprietary (non-standard) database software for which only certain individuals can work on. Likewise, the associated client software can only be programmed and changed by the same person, resulting in added costs and potential delays when changes are needed or different reports are needed.

Upgrading to modern databases will allow districts to take full advantage of the extensive data records they already have. These data records can be analyzed with various software packages, thereby aiding in management decisions, project design and future planning. Modern databases also facilitate the integration of modern GIS mapping systems into day-to-day operations of the districts.

DATABASE UPGRADE CONSIDERATIONS

Irrigation districts have data needs that differ from many other organizations. Important database considerations include the following:

<u>What capabilities must the database have</u>?
The new database must be able handle all of the district's accounting data and needs, and be able to accommodate as many simultaneous connections as needed by the district without faltering. The database must be capable of handling in-house water ordering, end-of-day and end of the season reporting, and have the capability of meeting future needs such as on-line, web-based water ordering and account access.

<u>Who will update the client software</u>?
Each district has a slightly different client (the program that handles the water ordering and reporting). Client software compatibility is the only significant problem when moving to a new database, as the only database that is compatible with current client is the existing database system, which should be replaced. The current client software will need to be reprogrammed in order to use with the new database.

<u>How easy is the database software to manage</u>?
This was a major consideration we used in developing our recommendations.

With a little "familiarity" training with the database, a district employee should be able to take over general management of the database system. This should reduce the need for external software consultants.

How easy and expensive will it be to upgrade the system to keep it up-to-date? This is an important consideration over the long term. Both the database and the operating system should be easy and cost effective to upgrade in order to stay up with new technologies. The new database should also have excellent compatibility with other commercially available software in order to avoid becoming obsolete.

What operating system should the database run on? Currently, districts are using three different computer operating systems: *UNIX*, *Novell*, and *Windows*. In addition, there is a relatively new operating system available named *Linux*. Each operating system has its advantages and disadvantages as follows:

$ *UNIX* is known for it stability and robustness. However, for a district with a small office staff, it has two major limitations.
  (1) *UNIX* is a complex operating system which makes it difficult to manage without special *UNIX* training, thereby requiring the hiring of consultant.
  (2) *UNIX* system hardware and software is very expensive.

$ *Novell* has good stability. However, since it is designed to be used only in server applications, it does not have good software compatibility and requires specific training for management.

$ *Windows Server* is the server version of the *Windows* desktop operating system that most people have on their personal computer. *Windows Server* has a good reputation as an easy to manage operating system with great software compatibility. *Windows Server* does have several shortcomings in stability and performance when compared to *UNIX* and *Linux*; however it makes up for those shortcomings in ease of use.

$ *Linux* is a relative newcomer to the operating system market. With its low cost, rock solid stability and excellent performance, *Linux* is great choice for replacing a system using *UNIX*. However, it requires advanced *UNIX* system administration training.

DATABASE UPGRADE RECOMMENDATIONS

Based on the requirements discussed above, we have two recommendations for replacement existing database systems.

Option 1: *Microsoft SQL Server 2000* running on *Microsoft Windows*.

Microsoft SQL Server is a robust, high-performance database capable of handling the needs of irrigation districts with ease. *SQL Server* offers several advantages over other databases, and is a vast improvement over the existing database systems in most districts.

$ *SQL Server* is a solid database easily capable of handling all of a district's needs.

$ *SQL Server* is fully compatible with almost all commercial software packages that run on *Windows*.

$ With its graphical user interface, very complete management packages for database tables and information, and *Windows*-like user friendliness, *SQL Server* is probably one of the easiest databases to manage.

$ *Microsoft* provides excellent product support, and the software is easy to upgrade. The upgrade can often be done by persons with little technical expertise, making it easy for districts to keep their systems up to date.

Option 2: *MySQL* database running on *Red Hat Linux*.

MySQL is also a robust, proven, open-source database system that may well be the fastest database system available. *MySQL /Linux* offers several advantages over the *Microsoft* option discussed above.

$ *MySQL* and *Red Hat Linux* paired together offer an extremely reliable, robust, and fast database solution. Also, both *MySQL* and *Red Hat* are "open source" software and are available free of charge. Being free does not undermine the value of the software; in fact open source software represent the world's best cutting edge software development.

$ *MySQL* is fully ODBC complaint ("Open Database Connectivity:" allowing for integration with all windows software) and offers excellent software and technical support through the web.

$ Several graphical management interfaces are available for *MySQL*, offering an extremely easy way to manage the databases, tables and information within.

$ *Red Hat* provides excellent product support, and has an easily automated support system that downloads and installs all necessary product patches and upgrades. System upgrades are also relatively easy using the *Red Hat* installer.

Other major commercially available database systems were considered, including *Oracle* and *IBM's DB2*. Both *Oracle* and *DB2* are powerful database systems; however, they were not selected because they offer features beyond the requirements of the irrigation districts and are very expensive.

Hardware Requirements and Costs

A dedicated server is the best option for a complete database upgrade. One dedicated *Intel*-based server costing about $5000 will meet the needs of most districts. Some of the district offices that are currently running *Windows* or *Novell* may be able to avoid this cost if the existing server is less than three years old.

Software Requirements and Costs

Microsoft software and licenses must be purchased while the *Linux* software is free. The price of the Microsoft option varies depending on server configuration, but a rough estimate is $2500 for both *Microsoft Windows Server* and *Microsoft SQL Server*. This should be a one time charge; however *Microsoft* is continually restructuring its licensing policies so it is difficult to say what the ownership costs will be in the future.

There also will be the cost of reprogramming the existing client software (the program that currently handles the water ordering and reporting) to make it compatible with the new database system. The cost to reprogram the client will vary from district to district depending on the costs of the districts' consultant. We suggest that districts team together, thereby sharing the costs of programming the new client.

IMPACT OF AGRICULTURAL PRACTICES ON SOIL EROSION AT THE FIELD-SCALE IN THE SALTON SEA WATERSHED

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K. M. Bali[3]
W. W. Wallender[4]

ABSTRACT

Soil particles moving as suspended sediment degrade the quality of drainage waters in arid basins. In the Salton Sea basin of southern California, soil particles traveling as suspended sediment impair water bodies by blocking light transmission, smothering benthic habitat, and releasing adsorbed pollutants. Although California Regional Water Quality Control Board, Colorado River Basin Region (CRWQCB 7) has implemented two silt/sedimentation TMDL regulations for the Alamo and New rivers, these regulations are based on monthly sampling and mean annual statistics, which fail to represent the complex physical process of sediment transport at the field scale. This three-month study conducted in two field-scale drain channels aimed to quantify 5-minute and daily variations of sediment load (Q_s) and discharge (Q) due to the variations of main agricultural and management practices mainly including land use (i.e. bare soil vs. cropped lands), irrigation methods (i.e. surface vs. sprinkler irrigations), land cover (i.e. vegetable vs. pasture crops), soil texture (i.e. sandy soil vs. clay soils). Averaged daily Q_s and Q showed that soil erosion in the early stage of the crop season was more intensive than in the late stage. Averaged hourly time series of Q_s and Q selected during two irrigation events revealed that surface irrigation produced higher Q_s than sprinkler irrigation. Daily Q_s and Q for one month and particle size analysis of soils in six fields connected to one field-scale drain channel indicated that pasture crops produced less Q_s than sugar beets and that sandy soil produced much higher Q_s than clay soils.

INTRODUCTION

Sediment transport and deposition induced by soil erosion on irrigated farmlands are major economic and environmental problems in agricultural regions. In the

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Salton Sea basin of southern California, excessive sediment has impaired water quality and degraded aquatic habitats of the major water bodies. Sediment in this basin mainly originates from irrigated fields and transports through agricultural drain channels into Alamo and New rivers ending at the Salton Sea. The California Regional Water Quality Control Board, Colorado River Basin Region (CRWQCB 7) has developed silt/sedimentation TMDLs for the two rivers in the region (CRWQCB 7, 2001, 2002). While those rules are based on monthly sampling and mean annual statistics, effective abatement of sediment requires a process-based understanding of how farm management practices impact soil erosion and sediment transport. The management practices primarily include land use, irrigation methods, land cover, and soil texture. The objective of this study was to compare and contrast the sediment loads in the field-scale drain channels for two different types of these practices.

STUDY AREA AND MAJOR AGRICULTURAL PRACTICES

The study area is within the Imperial Valley, which contains major agricultural drains within the Salton Sea watershed and more than 200,000 hectare of farmlands irrigated every year with 3.5 billion cubic meter of Colorado River

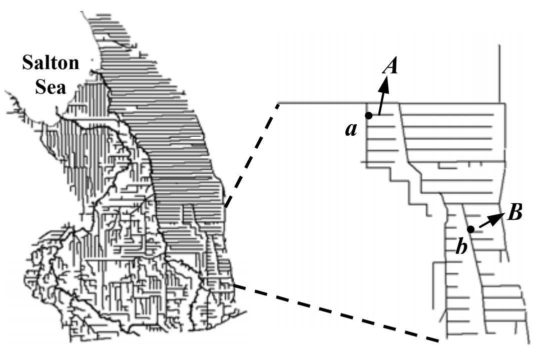

Figure 1. The Salton Sea watershed and the two selected FSD channels

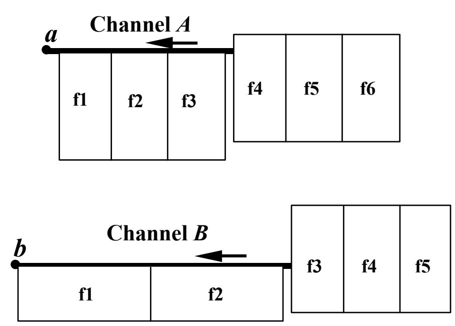

Figure 2. Two selected FSD channels and their contributing fields

water (Fig. 1). Approximately 35% of the delivered irrigation water in the Valley becomes drainage water (surface & subsurface). Drainage water enters the drain channels directly connected to the agricultural fields, herein defined as field-scale drain channels (FSD channels). Since soil particles eroded from the fields travel as suspended sediment load Q_s (kg/s or t/day) in the FSD channels, the impact of agricultural practices on soil erosion is also reflected in the changes of Q_s in the FSD channels. Therefore, in this study, we selected two FSD channels (labeled A and B) located in the eastern side of the drainage system and their associated fields (Figs. 1 and 2). Channels A and B were 1.18 and 0.82 km long and were linked to 6 and 5 32-ha farm fields, respectively (Fig. 2).

The high temperature and extremely dry environment allow year-round agricultural activities in the Salton Sea basin. Crops are grown on a wide range of soil types including fine and coarse textured soils. Agricultural and management practices change during a crop season and mainly depend on land use, irrigation method, land cover, and soil texture.

Land Use

In one crop season, land use can be categorized as three stages: land preparation, stand establishment, and growing season. In early stage (i.e. land preparation), lands are prepared by chopping crop residues, improving drainage, and flattening and furrowing the soil. In middle stage (i.e. stand establishment), lands experience sowing and germinating, and crops grow up. In late stage (i.e. growing season), crops are mature but not harvested. These three stages occur for vegetable fields in November, December, and January, respectively.

Irrigation systems

Drip, sprinkler, and surface irrigation systems are used to irrigate farm fields in the region. If properly designed, both drip and sprinkler irrigation systems should not generate surface runoff. However, in reality, sprinkler irrigation often results in runoff. Therefore, both surface and sprinkler irrigations generate runoff that may cause soil erosion. Surface irrigation may be further divided into border (i.e. flat field) and furrow irrigation. Border irrigation is commonly used to irrigate alfalfa, bermuda grass, sudangrass, wheat, and other field crops. Furrow irrigation, is mostly used in vegetable fields but is also used on field crops such as alfalfa, cotton, and sugar beets. In this study, border irrigation was used on field crops while furrow irrigation was used on vegetable crops. Thus, differences between border and furrow irrigations may be represented by differences in land covers. Therefore, changes in irrigation methods are reflected by two types of irrigation: sprinkler and surface irrigation.

Land cover

During the growing stage of a crop season, the area of soil covered by crops varies with crop type and irrigation methods (border vs. furrow). Specifically, pasture crops such as alfalfa, bermuda grass, and sudangrass grow on flat lands and thus cover almost the entire soil surface, while sugar beets and cotton grow on furrows and hence only cover a proportion of the soil surface. Therefore, differences of land cover were manifested by crops in the fields associated with FSD channels.

Soil texture

Soils in the study area belong to Imperial-Holtville-Glenbar soil Association and Meloland-Vint-Indo Soil Association, which contain fine sand, silt, and clay. For a given field, soil texture is represented by the median soil-particle size D_{50} (μm) of a representative soil sample.

METHODS

High variability in sediment loads caused by differences in land use and irrigation method requires high-frequency measurement of suspended sediment concentration *C* (mg/L) and *Q* to discern sediment dynamics. To obtain these data, 5-minute averages of turbidity and stage were measured at the outlet of channel *B* (Fig. 2, point *b*). These data were collected using an OBS-3 turbidity meter (D&A Instrument Company) and a CS420-L pressure transducer (Druck) attached to a CR510 data logger (Campbell Scientific, Inc) installed on the bank

Figure 3. The high-frequency monitoring station in channel *B*

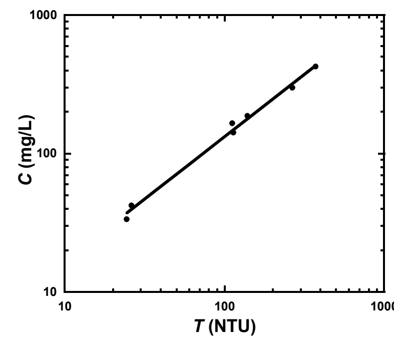

Figure 4. The *C*-*T* calibration for 5-minute data

of channel *B* (Fig. 3). The turbidity *T* (NTU) values were subsequently converted to *C* using a *T*-*C* calibration established with intermittent water samples collected independently and measured for *T* and *C* in the laboratory using a Hack 2100 p turbidity meter and the conventional gravimetric method, respectively (Fig. 4). Because suspended sediment particle sizes were not uniformly distributed, the *T*-*C* calibration was nonlinear. The good fit of the *T*-*C* relationship ensured that values of *C* obtained from *T* measurements were reliable. In channel *B*, *Q* was measured at cross section *b* using the velocity-area method wherein depth and velocity were measured incrementally across the channel using a staff gage and USGS-type Price AA current meter, respectively. A stage-*Q* relationship was developed by linking the measured *Q* to the associated stage for channel B (Fig. 5). Averaged *Q* values were then calculated using the stage-*Q* relationship. Using derived *C* and *Q*, Q_s was computed as $Q_s = CQ$. Because different land uses corresponded to different months, the 5-minute data for channel *B* were averaged to daily data for smoothing the

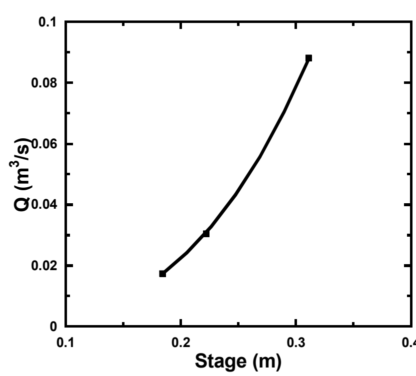

Figure 5. The stage-*Q* relation for channel *B*

unnecessary variations. The variability of Q_s as a function of land use was then investigated by (1) qualitatively describing Q_s and Q time series and calculating mean Q and Q_s and total Q_s for the three months, and (2) running statistical tests to determine whether Q and Q_s were unique for November, December, and January in which the null hypothesis was that the mean monthly Q (and Q_s) obtained from daily average data was statistically indistinguishable for the different cropping stages. To evaluate the event-based differences in sediment load between surface and sprinkler irrigation methods, the 5-minute data were averaged to hourly data to better describe changes of Q and Q_s during individual irrigation events. Two individual hydrographs related to surface and sprinkler irrigations were isolated by matching the visually observed periods of single-field irrigations with the same periods in the data. The difference of Q_s between the two selected irrigations was investigated by comparing their maximum Q and Q_s, average Q, and total sediment load.

Since land cover and soil texture do not change in one hour, their effects on Q_s do not require high-frequency data. At the outlet of channel *A* (Fig. 2, point *b*), water stage was measured and a grab sample was collected once a day for one month. *T* was measured in the laboratory with the Hack 2100 p turbidity meter. *T*-*C* and stage-*Q* relationships for daily data were previously calibrated and validated employing two independent data sets of 127 samples and 10 measurements (Fig.

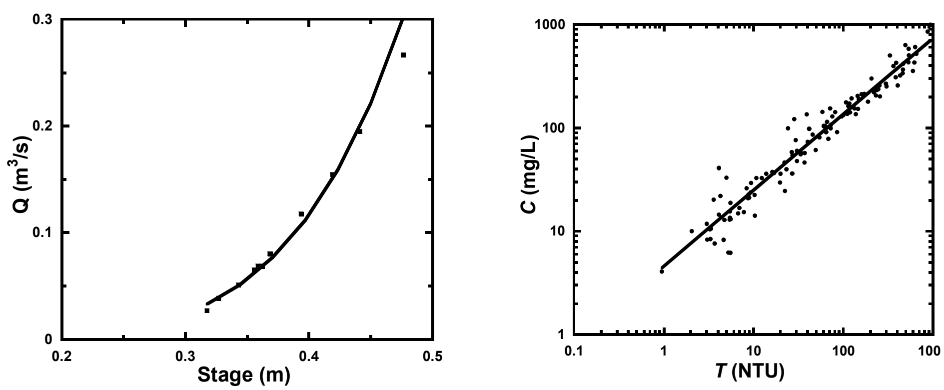

Figure 6. The Stage-*Q* and *T*-*C* relations for channel *A*

6). These relationships were then adopted to convert *T* and stage to *C* and *Q*, respectively. When irrigation occurred in one field connected to channel *A*, several pairs of grab samples and stages at the outlets of the irrigated field and channel *A* were taken to compare Q_s at the two locations. The effect of different land covers on Q_s was examined by comparison of Q_s induced by several irrigation events in two fields with different land covers, and by comparison of Q_s at the outlets of one field and channel *A*. A representative soil sample was taken at the outlet of each field connected to channel *A*, as various types of soil in a given field would be ultimately entrained to and mixed at the field outlet by runoff. The analysis for particle size distribution was conducted using a laser diffraction instrument (Beckman-Coulter LS-230 with a 750 nm laser beam) located at University of California, Davis. To evaluate the effect of soil texture on Q_s, Q_s values corresponding to irrigated fields with different soil textures were compared.

RESULTS AND DISCUSSION

Effect of land use on Q_s

Time series of Q_s and Q spanning the three months show that Q_s in November (i.e. during the land preparation) was considerably greater than that in January (i.e. during the growing season), while Q was marginally larger than that in January (Fig. 7). This was because during land preparation, agricultural fields were essentially covered by bare soil, which was readily eroded by irrigation runoff, whereas during the growing season, the potential for soil erosion decreased due to crop coverage and soil surface hardening. In early December, values of Q_s had the similar magnitude to those in land preparation while In late December they were close to those in growing season. This indicated that the period of stand establishment served as a transition to distinguish the intensive-erosion period (i.e. land preparation) from the light- erosion period (i.e. growing season).

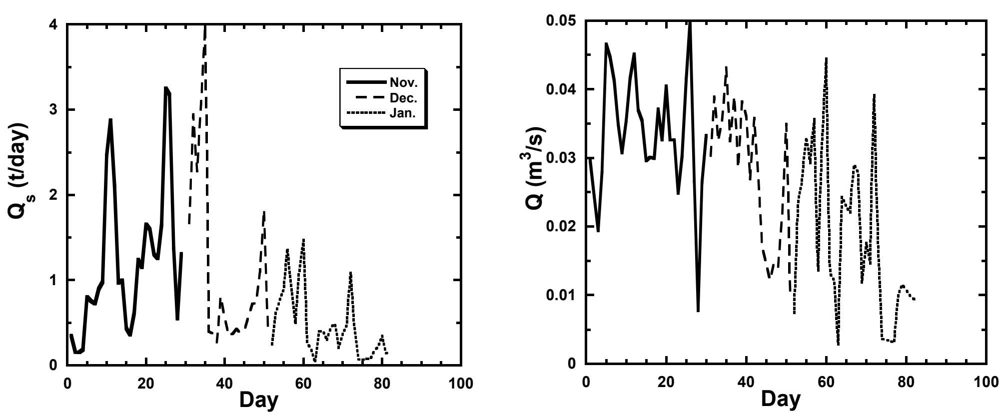

Figure 7. Time series of Q_s and Q in three consecutive months

Since Q_s and Q were not normally distributed, the nonparametric statistics should be used (Pasternack and Brush, 1998). The Mann-Whitney test was adopted to assess the null hypothesis for Q_s and Q in three months. The p-values for pairs of Q_s and Q in the three months (Table 1) indicated that Q_s and Q in November and December were independent with only 70% and 90% confidences, while they were different between December and January with 95% and 96% confidences, and between November and January with more than 99% confidences.

Table 1. The p-values for pairs of Q_s and Q in the three months

	Q_s			Q		
	November	December	January	November	December	January
November	x	0.301	< 0.001	x	0.096	< 0.001
December	0.301	x	0.005	0.096	x	0.0042
January	< 0.001	0.005	x	< 0.001	0.004	x

The average Q_s and Q in three months (Table 2) showed that Q_s in November was almost three times higher than that in January, while Q in November was only two times higher than that in January. Therefore, though Q in November was generally higher than that in January, the higher degree of soil erosion in November than in January was primarily caused by the lack of crop coverage in November. This suggested that for a given Q, Q_s in the period of land preparation was higher than that in the period of growing season. In other words, the difference in land use in agricultural fields constitutes an important source of the scatter in the Q_s and Q relationship at the field scale.

Table 2. Sediment data in three months at channel *B*

	Mean Q (m^3/s)	Mean Q_s (kg/s)	Total monthly Q_s (t)
November	0.03234	49.72	35.8
December	0.02681	43.03	30.98
January	0.01846	19.48	14.03

Effect of irrigation systems on Q_s

Temporal variations in Q_s and Q induced by single surface and sprinkler irrigation events were shown in Figure 8, respectively. Surface irrigation generated Hortonian overland flow, which resulted in the hydrograph with high-peak Q_s and

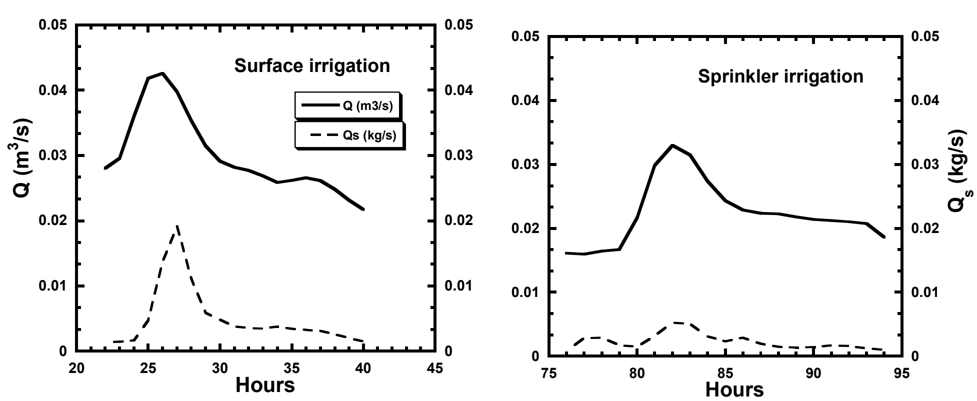

Figure 8. Time series of Q and Q_s for two individual irrigation events

Table 3. Properties of individual surface and sprinkle irrigations

	Q_{max} (m^3/s)	Q_{ave} (m^3/s)	Q_{smax} (kg/s)	Total sediment load (t)
Surface	0.04257	0.02974	0.01915	0.351
Sprinkler	0.03297	0.02238	0.00527	0.157

Q and steep rising and falling limbs. Sprinkler irrigation produced saturation overland flow, which gave rise to the hydrograph with lower-peak Q_s and Q and gradually changed rising and falling limbs. Although peak discharge in the hydrograph generated by the surface irrigation was 30 percent higher than that by the sprinkler irrigation, the averaged discharge Q_{ave}, defined as Q averaged in the period of irrigation (18 hours), was similar (Table 3). However, total sediment load and peak Q_s were much higher in surface irrigation than those in sprinkler irrigation. As shown in table 3, the maximum Q_s and total sediment load during 18 hours in surface irrigation were more than three and two times higher than those in sprinkler irrigation, respectively. Therefore, for the same amount of discharged water (drainage water), surface irrigation produced more sediment than sprinkler irrigation.

Effect of land cover on Q_s

The six fields contributing to channel *A* had three different crops (Table 4). Fields 5 and 6 were drip irrigated, while field 3 was fallow. Accordingly, these fields did not contribute surface runoff to channel *A*. Time series of Q_s and Q showed that channel *A* experienced seven complete surface irrigation events (Fig.

Table 4. Land cover in the fields connected to channel *A*

field 1	field 2	field 3	field 4	field 5	field 6
Sugar beets	Alfalfa	Bare soil	Melon	Melon	Melon

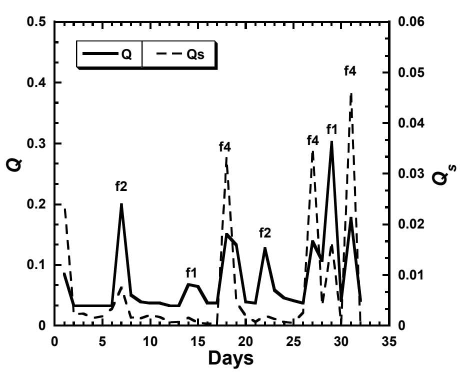

Figure 9. Time series of Q and Q_s at two fields

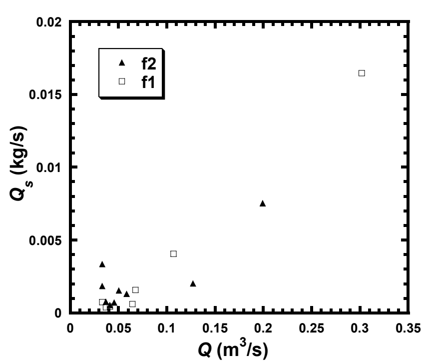

Figure 10. Q_s vs. Q for data during irrigations in the channel A

9). Among these surface irrigations, two were applied in field 1 (sugar beets) and two in field 2 (alfalfa). To compare Q_s produced from sugar beets with that from alfalfa, Q_s for the data collected during irrigations in the two fields was plotted against corresponding Q in Figure 10. For higher Q (i.e. $Q > 0.068$ m^3/s), the two fields produced similar Q_s as the data could be well described by a single function. For lower Q, however, the alfalfa field generated more sediment than the sugar beets field. This was further supported by the values of averaged Q_s in field 1 and 2, which were 0.19 and 0.30 t/day, respectively. Apparently, the degree of soil erosion in the alfalfa field is higher than that in the sugar beets field.

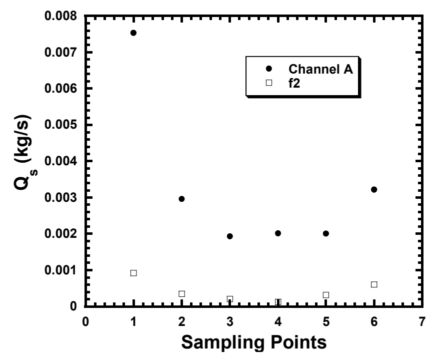

Figure 11. Q_s sampled at the outlets of Field 2 and channel A

However, field observation indicated that the alfalfa field generally produces much less sediment than other types of fields. The contradiction arose from the fact that Q_s, which was obtained at the outlet of channel *A*, was not the real Q_s only from field 2. Data obtained simultaneously at the outlets of field 2 and channel *A* suggested that on average, Q_s directly from field 2 was only one third of the channel *A* (Fig. 11). As water drained out of field 2, it must pass about one third of the channel length before arriving at the channel outlet (see Fig. 3). Because flow coming out of field 2 had very low sediment concentration, it was able to erode the channel bed and gain additional sediment before it arrived at the outlet of channel A. Therefore the actual average Q_s for alfalfa field (i.e. field 2) was about 0.1 t/day, which was only half of that for field 1. In other words, soil erosion generated from the sugar beets field was approximately two times more than that from the alfalfa field.

Effect of soil texture on Q_s

The three irrigation events for field 4 had higher Q_s peaks than those for fields 1 and 2 (Fig. 9). The high Q_s peaks were not due to channel bed erosion as the concurrent values of Q_s collected at the outlets of both field 4 and channel *A* showed that Q_s from field 4 was higher than that at the channel outlet, suggesting that some sediment was deposited in channel *A*. The high Q_s peak was not likely due to the land cover difference between fields 4 and 1, as both melon and sugar beets fields were furrow irrigated, which suggested that field 4 and 1 had similar land cover. It was

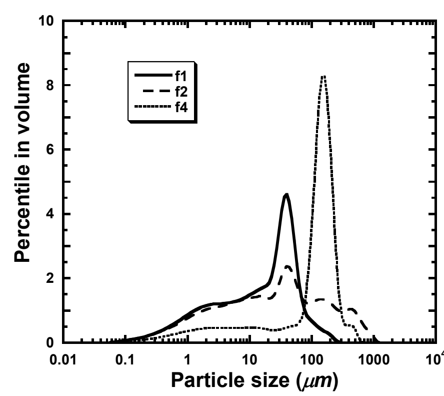

Figure 12. Particle size analysis at the Three fields

hypothesized that the difference was related to field-scale soil texture. This hypothesis may be tested by the results of the particle size analysis for soils in the three fields, which showed (1) that D_{50} in field 4 was 141.7 µm, while D_{50} was 20.2 and 26.93 µm in fields 1 and 2, respectively (Fig. 12), and (2) that the percentage of clay in the soil samples in fields 1, 2, and 4 were 38.9, 36.1, and 15, respectively. These results signified that soils in field 4 were mainly fine sand, but in fields 1 and 2 were predominately clay and silty clay. Because sand is non-cohesive, while clay is cohesive, sandy soil is more easily eroded than clay soil, though the former is coarser than the latter. As a result, soil erosion in sandy soils (i.e. field 4) is greater than in silty and clay soils (i.e. fields 1 and 2).

CONCLUSION

The effect of four types of agricultural and management practices on soil erosion at the field scale was investigated using 5-minute averaged and daily data containing Q and Q_s, collected from two field-scale drain channels in the Imperial Valley of southern California. More soil erosion occurs during the land preparation stage than in the growing season stage mainly because bare soils are more eroded than those with crops. Soil erosion rates were typically higher in surface irrigation systems as compared to sprinkle irrigation systems due to the flashy hydrographs generated by surface irrigations. Sediment loads generated from fields planted with vegetable crops were generally higher than those with field crops. Erosion rates were much higher in the fields with sandy soil than in those with clay and silt soils.

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GROUNDWATER USE IN IRRIGATED AGRICULTURE IN AMUDARYA RIVER BASIN IN SOCIO-ECONOMIC DIMENSIONS

These research results a part of INTAS 1014/1003 Project

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ABSTRACT

The paper analyses groundwater resources use in socio-economic context in Amudarya River Basin. The paper discusses present extent of groundwater resources use and special focus is on agriculture, livestock use and small farmers in their homegardens. Institutional and social pattern of groundwater resources use, allocation, monitoring and distribution are other aspects that reviewed. After the collapse of former Soviet Union with its old water resources management mechanism and infrastructure, new underdeveloped systems are being practiced over Amudarya River Basin. Many assessment reports haven't considered Afghanistan in their analysis for water allocation. In Afghanistan, after the end of civil war, irrigated lands are being expanded and the share of groundwater use is increasing too according to the recent reports and assessment projects by international institutions and local scholars.

Local farmers use water from boreholes and wells for their water supply systems in order to range livestock and grow crops for sustaining their livelihoods. For example, in Afghanistan karezes (traditional groundwater extraction structure) are widely documented as main extraction methods. Many farmers and settlements use different water extraction mechanisms for withdrawing water. Some drill new boreholes and some renovate old wells. Majority of locals does not have access to machinery pumps and do not have funds for purchasing or renting such pumps for practicing irrigated agriculture.

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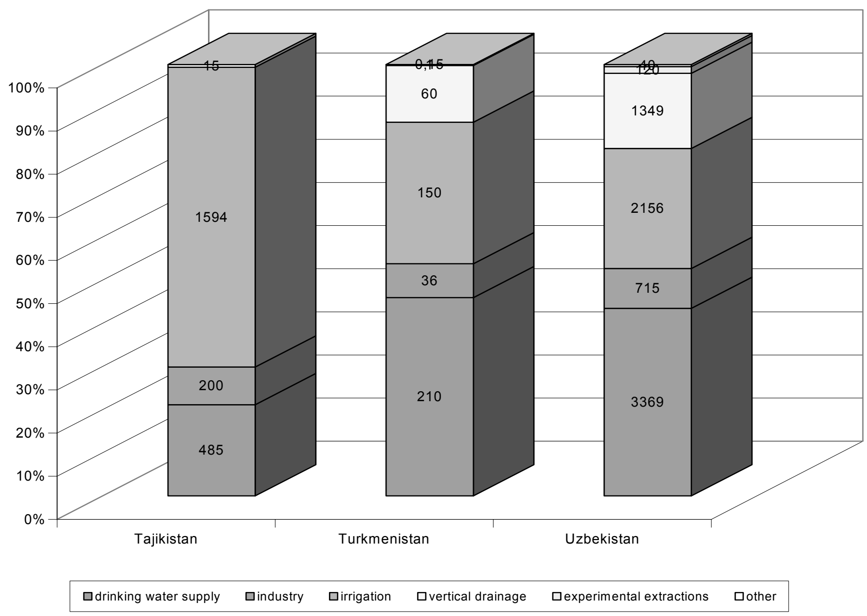
Economic aspects are discussed in broader sense and results are taken from farmers' interviews, personal communication with national hydrogeologists. In general, may farmers claim that it is worth to invest in finding groundwater for producing agricultural products and rearing livestock.

Groundwater resources becoming alternative source of supply for irrigated agriculture, livestock ranching worldwide. Amudarya River basin (Tajikistan, Afghanistan, Uzbekistan, and Turkmenistan) countries due to its climatic characteristics, economic development strategies and geopolitical situation have been experiencing everlasting competition over water resources. Mostly arid, agrarian countries pursue their own development and integration into global community through expanding irrigated lands, growing cash crops such as cotton, rice and wheat for meeting their domestic food security.

BACKGROUND

Groundwater resources have become a reliable and guaranteed water supply for practicing agriculture. For example, drought hit all basin countries and farmers turned for extensively using groundwater resources. Groundwater is site-specific, easy to locate and use for water supply. For example Government of Uzbekistan has issued a special program for providing boreholes and drilling wells in Khorezm province and Karakalpakistan Autonomous Republic for having access to safe and reliable groundwater resources supply for population domestic needs after those regions were hit by severe droughts. There are few farmers that have powerful pumps who efficiently practice agriculture.Groundwater resources were not widely used for irrigated agriculture in post Soviet Central Asian Republics (Tajikistan, Uzbekistan, and Turkmenistan). But the groundwater resources were used primarily for livestock sector and very site-specific purposes for example drinking water supply. There are numerous research and assessment studies on “regional operational groundwater reserves” that deal with assessment of those resources. The foremost purpose of those studies was to use groundwater for meeting drinking water supply needs of local population, in particular domestic water supply and livestock sectors. During the Soviet period, groundwater was not widely used in irrigated agriculture due to sufficient surface water with reliable water supply delivered to the farmers. Water allocation and irrigation system infrastructure were well maintained and operated with massive funding from central government.On the other hand, traditionally, Afghanistan has relied on surface water and groundwater springs and karezes for agricultural irrigation. During recent drought years, the use of deeper groundwater, abstracted via pumped dug wells and boreholes has increased rapidly. Private farmers have drilled many of these new wells and boreholes, there is concern that, in some areas, groundwater abstraction rates are already exceeding, or will soon exceed, sustainable groundwater resources (David Banks, 2002).

Figure 1. Groundwater Use for Different Purposes



Groundwater as a main source for irrigation

Groundwater overdraws is not the case in Amudarya river basin but the water drought experienced in 2000-2001 in downstream part of the River have brought to people the idea of "why not to use groundwater for irrigation". Many farmers (who could afford) started the pumping of groundwater from the irrigation fields to sustain the production during low flow periods and maintain the salinity issues. The main goal of the project is to document and understand the new realities of the groundwater use in agriculture by small holders and private farms and draw the policy makers' attention to this very important resource as potential in reducing the poverty. Groundwater is a reliable source of water and farmers and locals who distant from source of surface water can obtain it. One can just rent a land of several hectares and plant quick cash crops. Then finds a driller and drills well with engine and pumps. The next step is to hook up to electric lines and start to extract groundwater for watering their crops. There are just initial capital investments and electric bills for whole system to work. There is no social structure to monitor the groundwater resources. For example, Ministry of Agriculture and Water Resources of Central Asian (MAWR) invests and monitors the objects of water management till the interfarm level, e.g. main canals and main drainage systems. So, they do not quit deal with water of private farms or shirkats (cooperative farms). Within MAWR there are few data about groundwater level and mineralization on provincial and district level but much generalized. This is to control salinity problems. Therefore, this project is dedicated to document the socio-economic basis of today's groundwater use at farm level.

Groundwater Use in Central Asia

The groundwater use extent in various basin countries varies from country to country and upstream to downstream. For example, groundwater is used for irrigation in upstream and downstream countries and less in downstream. For example, in Turkmenistan the groundwater table has increased and there is no need to use groundwater for irrigation. Waterlogging has created salinity problems and there is no need for using groundwater.In recent years, Uzbek rural agriculture production system dependent on groundwater pumped from private tube wells has grown increasingly. Nevertheless, few studies have revealed how water markets should be operated and what the social and environmental consequences of privatization will be. Private sector of tube well water extraction and operations are not monitored or regulated (Fuchinoue et al., 2002).

From the graph the Tajikistan's groundwater share in irrigation constitutes up to 70%, Turkmenistan's share is about 38% and Uzbekistan's is approximately 37%. Groundwater for drinking water supply is about 40% in Turkmenistan and Uzbekistan and 17% in Tajikistan. Thus we can speculate that the maintenance and operation of infrastructure is better managed in Turkmenistan and Uzbekistan. The situation in Tajikistan is not quite satisfactory due to civil war. Many reports state that the great part of networks water supply are deteoriated and worn-out without any considerable funding from state and relevant agencies. The vertical drainage is developed in Turkmenistan and Uzbekistan downstream countries. This indicates that groundwater levels are high and close to the surface in downstream part of the Amudarya basin. The vertical drainage systems have been installed in order to decrease groundwater level. Many farmers or dekhans tend to rent plots of lands ranging in size from 1-10 hectares and drill boreholes and wells and just start to pump groundwater for irrigating crops. The only costs are drilling, instalments of pump, engines. The electric costs are not paid regularly or at all. The locations of wells are tend to be placed near electric lines and they tend to just hook up the wires and operate pumps.The groundwater is extensively used in Uzbekistan about 99%, in Tajikistan and Turkmenistan about 30-40% for various uses. This can be explained by the fact that groundwater management infrastructure is well maintained in Uzbekistan with central funding from the government. Another explanation can be uncontrolled water extraction by local farmers and population for various uses.

Figure 2. Intensity of Groundwater Use

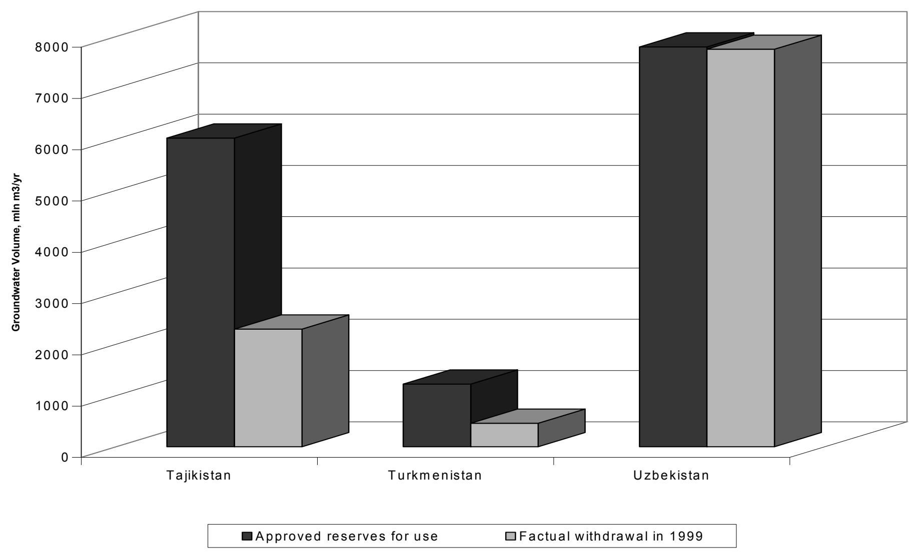


Figure 3. Relationship between Actual Groundwater Use and its Use per Capita, 1994

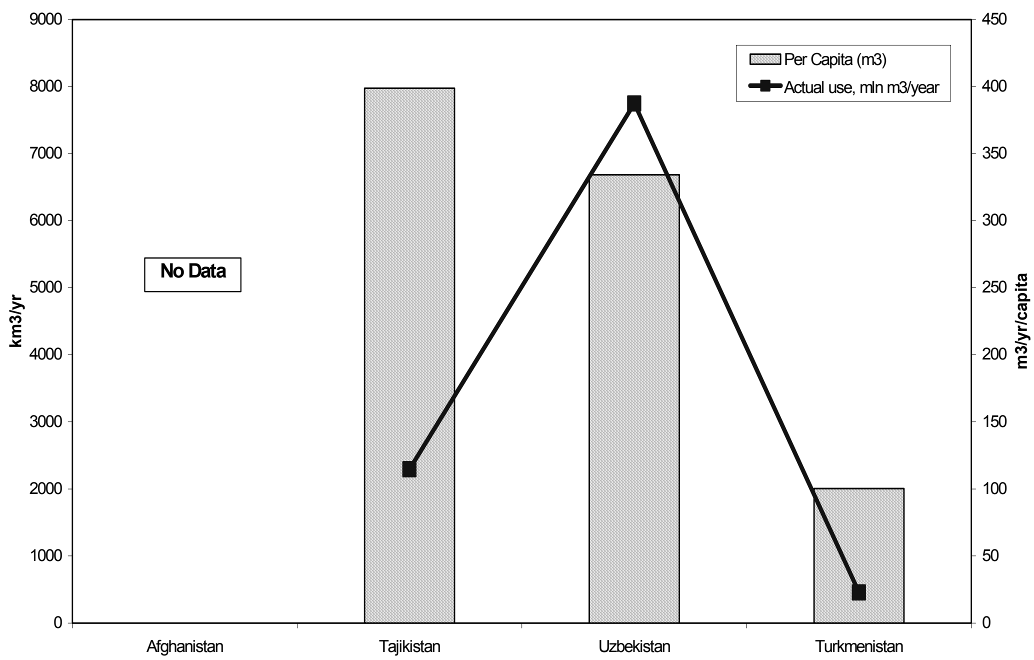


Figure 3 depicts per capita use and actual groundwater withdrawal in Amudarya River Basin. Per capita groundwater use is the highest in upstream-Tajikistan and decreases downstream in Turkmenistan. This can be explained by the groundwater table increase in downstream countries with waterlogging problems from irrigated croplands. The highest groundwater use is observed in Uzbekistan, the least in Turkmenistan. The irrigated areas of high groundwater table levels have increased in Amudarya River Basin was 1,290,000 million hectares in 1990 and 1,566,000 hectares in 1999, the total change was 21% (GEF Project, 2001). For example in Tajikistan the increase was about 21%, in Uzbekistan-20%, and in Turkmenistan-24%. However, one should take into account the fact that three drought years of 1999-2002 have probably resulted in decreasing substantially groundwater table levels.

Table 4. Irrigated lands with high groundwater table level in Amudarya River Basin from 1990-1999.

Amudarya River Basin	Areas with water table <2 m (thousand hectares)		% increase from 1990-1999
	1990	1999	
Tajikistan	**92**	**111**	**21**
Bukhara	62	62	0
Kashkadarya	5	4	-20
Karshi	5	3	-40
Navoi	28	40	43
Samarkand	37	48	24
Surkhandaya	16	19	19
Khorezm	192	234	22
Karakaplakistan (south)	107	128	20
Karakalpakistan (north)	218	263	21
Uzbekistan	**670**	**801**	**20**
Dashoguz	182	238	31
Akhal	43	107	149
Mari	136	116	-15
Lebap	162	187	15
Balkan	5	6	20
Turkmenistan	**528**	**654**	**24**
Total in Amudarya River Basin	***1,290***	***1,566***	***21***
Source: GEF Project Water Resources Management and Environment, 2001. Uzbekistan			

The total withdrawal of groundwater from Amudarya river basin within lower Amudarya reaches (Uzbekistan part) on 01.01.03 is about 2 km^3/year (Annual Information Bulletin of Ministry of Agriculture and Water Resources, 2003). In 1995 in Uzbekistan for industrial needs - 17.6 m^3/sec (0.56 km^3) was used.

Groundwater resources should be the main source for drinking and domestic water supply of local populations. In drought years (2000-2001) there were 5000 wells of manual pumping (depth of 10-15 meters) that were bored in Karakalpakistan, and Khorezm region for drinking and domestic needs. The mineralization of groundwater of bored wells is about 3,0 g/L (Annual Report of

HYDROINGEO, 2001). Farms are not charged for irrigation water, but in 1995 a land tax was introduced. The amount payable depends on irrigation and land quality, which is calculated by province on the basis of a soil fertility parameter. For example, in Karakalpakstan, the tax varies from $US 0.64/ha for the lowest fertility class to $US 6.5/ha for the best fertility class. In the south of the country, the tax varies between $US 1.1 and 11.2/ha.The total groundwater used (pumped) in 1995 in Uzbekistan was 206.2 m^3/sec (6.5 km^3), including for drinking water supply - 60.81 m^3/sec (1.92 km^3). Rural water supply and pastures - 22.17 m^3/sec (0.69 km^3), and for irrigation - 105.59 m^3/sec (3.32 km^3) (Vodproekt, 2001). Groundwater used for irrigation is almost 50% of the total groundwater use in Uzbekistan. In Karakalpakstan the groundwater use in 1995 was 0.71 m^3/sec (0.022 km^3) and groundwater use data for irrigation is not available.

Institutional Incentives for Groundwater Use in the Region

In north, central Tajikistan and Pamir, local communities, mining industry, and cattle-feeding farms satisfy their water needs from springs and mountainous streams. The water quality of those sources is of good quality. There are some areas of limited fresh groundwater such as loamy layers of paleozoic formations, gypsum sediments and distant from streams. District centers of mountain provinces and resorts (Obigarm and Hodjaobigarm) have water pipe systems. Springs that are used as sources of water supply are located 2-3 km from water users. The total water resources withdrawal through pipe systems amounts to 0,25-0,3 m^3/sec; of which 90-95% are from groundwater source. The existing water withdrawal comprises few percentages of natural reserves of groundwater resources (Water Resources of USSR, 1971).In south Tajikistan, water supply of local communities and industries had been supplied primarily from streams and in rare occasions from springs. However, during the last years, major water users were switched to groundwater supply systems. Water supply of district centers and many farms is carried out by captation of unconfined groundwater of alluvial deposits through single and group of boreholes. Latter sources are located in the distance of 5-6 km from water users and often in the centers of big collective farms. Small farmes and settlements use wells and irrigation water for water supply. The total groundwater extraction was 6450,5 thousand m^3/day in 1994. 2460,7 thousand m^3/day was used for irrigation and it constitutes about 38% from the total withdrawal (Salimov, 2001).

According to specialists of GIDROINGEO institute, use of groundwater in little volume for irrigation is partially due to economical inefficiency (Mirzaev, 1996., Borisov, 1990). Production cost per 1m^3 of groundwater should be composed of the following:

a) Production cost per 1m^3 by inputs on hydrogeological design-exploration works. Cost of exploration per 1m^3/day of water makes 1-5 US dollars, in an average 2-3 dollars. Cost per $1m^3$ for amortization period (10000 days) by inputs on exploration works is 0.01-0.05 dollars.

b) Amortized deduction per $1m^3$ is estimated at 0.1 dollars (with borehole discharge of 2500 m^3/day or 29 L/sec).

c) Operational inputs per $1m^3$ of groundwater for average discharge boreholes make 0.3-0.4 dollars per $1m^3$ of groundwater. Thus, production cost per $1m^3$ of groundwater makes about 0.5-1.0 dollars.

Input per $1m^3$ of self-flowing surface water supply to farms is 0.13-0.15 dollars, and in the areas of mechanical (pumped) irrigation is about 0.3 dollars. Thus, production cost of groundwater resources is higher than of surface water. However, use of groundwater resources for irrigation purposes will be justified in water scarce conditions.

Production cost of groundwater resources during their operation for irrigation in unfavorable in meliorative degraded lands will be equal to production cost of surface water due to the following reasons: achievement of meliorative effect, increase coefficient of land use, prevention of deterioration of surface river-water quality as a result of drainage water discharge, economy of water due to reduction of evaporation from unconfined groundwater level, etc. According to S.Sh. Mirzaev, uncertainty in economical appropriateness of groundwater use for irrigation is not validated. According to HYDROINGEO Institute, in the Amudarya river basin by 01.01.03 there were drilled approximately 27000 boreholes with different depth, 50-500m, cost of drilling one borehole ranges within 500-2000 US dollars. The boreholes are equipped with pumps of different type with diameter of 6", 8", 12" inches, capacity of pumps is 10-70 L/sec, cost of pumping equipment ranges from 610 to 2000 US dollars depending on pump diameter. For operation there is often used electric power of state electric transmission lines, in desert and under-populated areas there are used movable electric power stations, cost per one unit is 6500 US dollars (Personal communication with farmers).

Two types represent existing water conveyance systems: water-pipeline, waterway and rarely transportation in cisterns. Cost of input per m^3/sec for different types of users only depends on technical-economic parameters of water intake and is given above, amounting to 0.06-0.07 USD/m^3/year. Decentralized water supply of rural population, especially downstream Amudarya River, is realized by operation of unconfined groundwater resources by construction and equipment of shallow wells of 15-20m, with setting interval between filters of about 7-15m. Extraction of groundwater resources is made by manually operated pumps, cost of one pump is 100 USD, drilling with equipping steel pipes is 100-150 USD (sands), capacity of pump is 1-2 L/sec. According to David Banks, in Afghanistan, dug wells are typically 3-4 times cheaper than boreholes. Typical drilling prices in Afghanistan are 350-400 Rp/m in soft strata, 900 Rp/m in hard/strata. In some parts of Afghanistan, where demand is high, prices can reach 18-20 USD/m (David Banks, 2001).

CONCLUSION

There is no available data or extensive research reports on groundwater use for agriculture and crop production in Uzbekistan. The existing reports and studies are limited to resource estimation, water balance calculations, water quality for very specific locations and advanced scientific studies or for large scale development assessments where the information about groundwater tend to have very technical purpose. The authors argue groundwater resources are used for agricutlure, livestock and private plots throughout Amudarya River Basin both in Central Asian countries and Afghanistan. Recent drought has facilitated groundwater use by peasents and private farmers in Lower Amudarya. Private farmers than cooperative farms (state owned) use groundwater more excessively due to quick access to cash and fewer bureacratic obstacles. Cooperative famrs need longer procedure in order to obtain and implement drilling and equipment from government bodies. The main methods of groundwater use are traditional and more sophisticated in forms of karezes in Afghanistan and pumping centrifugal mechanisms in Central Asian states. The cost of pumping groundwater varies by countries and the local geology, the deapth of groundwater aquifers. For example, in Uzbekistan the total cost of drilling, installation and hooking up to electrical lines approximately $2,500-5000. On the other hand, in Afghanistan the cost is about $100-1000.

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OPTIMIZING INTEGRATED WATER RESOURCES MANAGEMENT: DATA, TOOLS, AND EXAMPLES

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ABSTRACT

Best utilizing water resources requires coordinating their availability and use in time and space. Required can be: spatially and temporally distributed data; simulators to predict system response to stimuli; procedures for defining management goals, constraints, and scenarios; optimizers to compute optimal management strategies; and appropriate strategy implementation techniques. Here, a strategy is a set of controllable groundwater extraction and injection rates and surface water diversions. Simulation/optimization (S/O) models couple simulators and optimizers to compute optimal strategies for posed management problems. S/O models are becoming more commonly used for policy, planning, system design, and management. For example, water planners and managers sometimes must decide how to control groundwater use to cause a favorable future and avoid serious problems. S/O models can help determine the policies, physical systems, and management strategies that can yield the best consequences. 'Best' is defined by the manager/modeler in terms of water availability, sustainability, crop production, economic, social, or environmental criteria, or combinations of those. Addressing multi-objective optimization problems and developing quantified tradeoff curves is simple with a powerful S/O model such as SOMOS. Examples demonstrate data needs and S/O model power for policy and plan development and system design and management.

INTRODUCTION

Simulation models are useful for predicting physical system response to stimuli. Stimuli can include groundwater pumping, recharge, stream diversion, return flow. Some stimuli are manageable and some are not. Determining the best values for manageable stimuli (the best management strategy) is aided by simulation/optimization (S/O) modeling. An S/O model can determine how to maximize achievement of user-specified management objectives, subject to specified restrictions. An S/O model couples: a simulation module that can predict the consequences of management; and an optimization module that can compute the mathematically best management strategy for a posed management optimization problem.

An S/O model directly computes the mathematically best (optimal) management strategy for a management problem posed by the user. For example, a pumping

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(groundwater management) strategy is a set of spatially and possibly temporally distributed rates of extracting water from an aquifer.

S/O model use differs from use of normal simulation models (here termed S models), such as MODFLOW and MT3DMS. S models predict how the modeled physical system will respond to a user-input strategy. S models are not designed to compute optimal management strategies. Using them for this requires trial and error and yields the best strategy only for simple problems. S/O models incorporate S models or surrogates to predict system responses. An S/O model is only as accurate for prediction as the S model it includes.

S/O models for simple field situations use analytical equations for simulators, and generally use classical operations research (OR) algorithms for optimization. Analytical equations are used when problem simplicity or available capabilities do not justify use of numerical (finite difference or finite element) S models. Peralta and Wu (2004) describe S/O model applications for such field scale groundwater and conjunctive water management problems. S/O models for aquifer or regional groundwater or conjunctive water planning require numerical flow S models as simulators. Peralta and Shulstad (2004) describe evaluating water policy alternatives for different hydrogeologic and legal-institutional settings.

To optimally design pump and treat (PAT) systems for remediating groundwater contamination, S/O models require numerical flow and transport models. Peralta (2001) and Peralta et al (2003) list groundwater contamination remediation examples, using the SOMOS code (SSOL, 2001; Peralta, 2003). Such a pump and treat (PAT) system might include dozens of extraction wells to remove contaminated water, before treating it.

Peralta (2001) and Peralta et al (2003) describe several direct comparisons between designs developed by S/O modeling versus designs prepared simultaneously by trial-and-error S modeling. S/O modeling always produced superior designs, usually about 20 % better, but sometimes about 50% better.

Both S and S/O models require sufficient data to allow reasonably accurate prediction of system response to management or its lack. S/O models require additional data to define management goals and constraints. Necessary information can include distributed quantitative and qualitative data of existing and potential water uses, soil, and water, and limits on acceptable values of those and other variables.
In summary, S/O models are useful for a range of groundwater and conjunctive water management settings. Here we describe four settings: (a) sites having limited field data, suitable for analytic equation simulation; (b) sites needing numerical flow modeling; (c) contaminated sites using numerical flow and transport modeling; and (d) reservoir-stream-aquifer settings needing numerical

modeling. Respectively, the four examples use the SOMOA, SOMO1, and SOMO3 modules of Simulation/Optimization Modeling System (SOMOS), (SS/OL and HGS, 2001; Peralta, 2003), and a developmental model.

Conjunctive Use Of Simple Stream-Aquifer System

This example illustrates maximizing conjunctive use of groundwater plus surface water while achieving adequate blended salinity for irrigation (Peralta, 1999). The S/O model uses analytical equations and convolution integrals for simulation and a simplex algorithm for optimization. Field data is that needed for the analytical equations. Management data is that needed for the constraints, including water quality.

A farmer extracts groundwater using one well and diverts water from one point on a stream. He wants to maximize the sum of groundwater and surface water that is delivered to his crop during a two-month period. However, to ensure that stream flow departing his farm is adequate for downstream users, he should not reduce stream flow by more than 11,000 m^3 d^{-1} (385,000 ft^3d^{-1}) at the end day 30, or by more than 11,500 m^3 d^{-1} (402,500 ft^3d^{-1}) at the end of day 60. The maximum capacities of the well and the diversion are each 8,000 m^3 d^{-1} (280,000 ft^3d^{-1}). The most water that should be delivered to his crop is 13,000 and 16,000 m^3 d^{-1} (455,000 and 560,000 ft^3d^{-1}) in months one and two, respectively.

Other hydrogeologic and spatial information (including x,y location in meters) is: stream runs from Southeast to Northwest (800, 0) to (100,1000); diversion location is at (200,858); groundwater well (0.2 m radius), is at (450, 850); hydraulic conductivity is 80 md^{-1} ; Ground surface is at 45 m elevation, and potentiometric surface is initially at equilibrium at 40 m elevation; aquifer saturated thickness is 40 m.

Also, based on crop, soil, and salinity of the surface water and groundwater, for sustainability, at least 60 % of the water used during month 1 must be from the stream, and at least 48% of the total water delivered during the two months must be from the stream. The first constraint protects seeds during germination. The second causes enough leaching to prevent root-zone salinity buildup.

To determine the maximum conjunctive water use strategy, subject to constraints, one can use the SOMOA (Peralta and Wu, 2004) module of SOMOS. (SOMOA is the successor to CONJUS). In using SOMOA one would specify: Options A and B; one extraction well; one diversion; two thirty-day stress periods; upper limits of 8,000 m^3 d^{-1} in each period on pumping and diversion; 0.6 lower limit on the water quality ratio {diversion/(diversion + pumping extraction)} for period 1; 0.48 lower limit on that ratio for the two-month total; stream flow depletion upper limits of 11,000 and 11,500 m^3 d^{-1} , respectively; and pumping plus diversion.upper limits of 13,000 and 16,000 m^3 d^{-1} , respectively.

Table 1 shows the computed optimal conjunctive use strategy and responses of state variables. Tight constraints are groundwater pumping in month 2, stream depletion in both months, the water quality ratio for month 1, and the total season water quality ratio. Relaxing any tight constraint (for example, decreasing the required proportion of surface water) would allow the optimizer to increase total provided water.

Table 1. Optimal conjunctive use strategy and system responses (Peralta and Wu, 2004).

	Period 1	Period 2	Season Avg.
Groundwater pumping, (GP), [$m^3\ d^{-1}$]	4,774	8,000	
Surface water diversion, (SD), [$m^3\ d^{-1}$]	7,001	4,573	
Stream flow depletion, [$m^3\ d^{-1}$]	11,000	11,500	
Total delivered water, GP + SD, [$m^3\ d^{-1}$]	11,774	12,573	12,174
Water quality ratio, {SD/(SD + GP)}	0.6	0.36	0.48

Aquifer Sustained Yield Planning With Stream Depletion Constraints

This example emphasizes maximizing sustainable groundwater use without harming existing ecosystems and legal surface water rights (Das, 2002; Das et al, 2004). The employed S/O model simulator is MODFLOW, and the optimizer is a simplex algorithm. These are included within the SOMO1 module of SOMOS. Necessary data includes: MODFLOW inputs concerning hydrogeology, wells, and historic water use; SOMOS inputs about candidate well locations, bounds on head, aquifer-stream seepage, and pumping

The 113 by 26 km (70 by 16 mile) Cache Valley area and aquifer is in northeastern Utah and southeastern Idaho (Figure 1). Most surface water, the primary irrigation source, originates in mountain snow. Groundwater results from precipitation, irrigation deep percolation, and seepage from surface waters. Wells provide domestic, industrial, public supply and irrigation water. Groundwater pumping reduces surface water flow. Legal surface water rights and environmental protection should limit groundwater use. One compares ways of maximizing sustainable groundwater pumping by performing optimization for several groups of scenarios. Resulting optimal strategies are evaluated with respect to the heads and flows that would result from continuing 1990 pumping (termed the "background pumping rates") to steady-state. Continuing 1990 pumping to steady-state is the 'unmanaged scenario.'

Figure 2 shows the difference in flows between the unmanaged scenario and some Group A optimized scenarios. Group A scenarios maximize sustainable groundwater supply to 18 towns using one candidate new well site for each town subject to: (a) head at new pumping cells cannot decline more than 9 m (30 feet) in layers 1-4; (b) springs continue flowing where they flow in 1990 and in the unmanaged scenario; (c) saturated aquifer-river seepage continues where it occurs in 1990 and in the unmanaged scenario; and (d) total aquifer seepage to river cannot decrease by more than 10%.

Group A results show that sustainable pumping can increase 113-556 liters per second (4-20 cfs) above background rates. Other scenarios showed that even with more restrictive river depletion constraints, some sustainable groundwater pumping increase is possible. Such results encouraged the office of the state engineer to relax a moratorium on groundwater development.

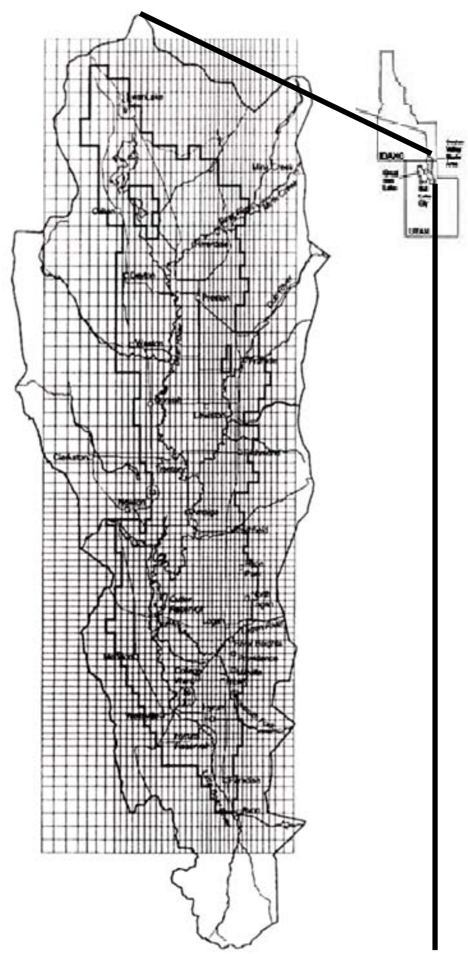

Figure1. Cache Valley location in Utah and Idaho, and groundwater model grid (from Kariya, et al., 1994).

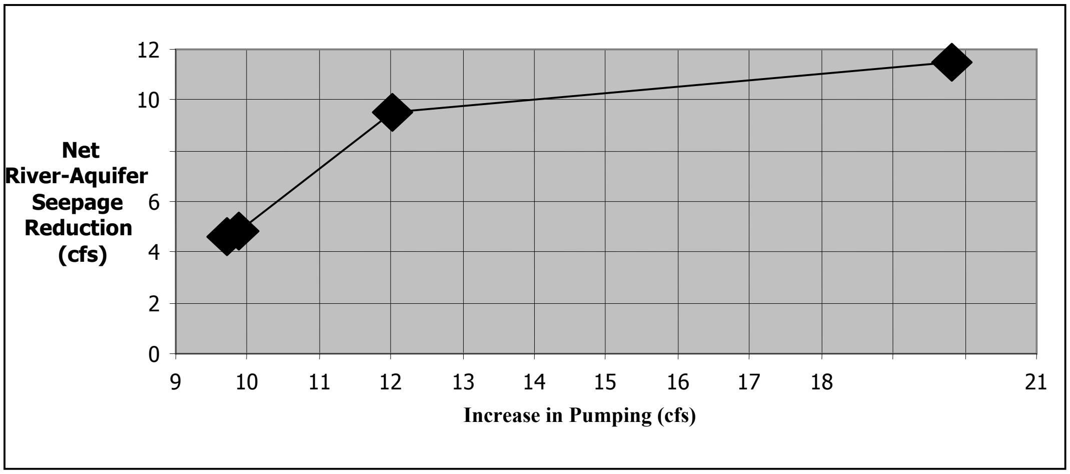

Figure 2. Tradeoff curve of groundwater pumping increase versus net river-aquifer seepage decrease (Peralta and Shulstad, 2004). (To convert cfs to m^3s^{-1} multiply by 0.0283.)

Remediation of Complex Aquifer Contamination

This study employed numerical groundwater flow and contaminant transport simulators, artificial neural network simulators, and heuristic optimizers (HOs), including genetic algorithm (GA), simulated annealing (SA), and tabu search (TS). Data includes that for the finite difference simulators, candidate well locations, concentration control zones, unit costs for the economic objective function, and bounds on head, pumping, and concentration.

The example is from work by Peralta et al (2002) optimizing PAT design for containing and removing a 7.5 mile (12 km) plume of trichloroethylene (TCE) and trinitrotoluene (TNT) at the Blaine Naval Ammunition Depot (NAD), in Hastings, Nebraska. Figure 3 shows the center of the 134 square mile (347 km^2) study area. The 66,912-cell model required 1.5 hours for one MODFLOW and MT3DMS simulation. They solved three optimization problem formulations requiring determining optimal pumping strategies for 12 to 25 wells and six five-year periods (60 stress periods) simultaneously.

Within three months, they developed optimal strategies for all three formulations using the SOMO3 module of SOMOS, (SSOL and HGS, 2001). Simultaneously, an experienced consultant team used the same MODFLOW and MT3DMS simulation models and the normal S model trial-and-error approach for designing strategies for the same problems. Both teams used a post-processor to compute the objective function value and evaluate results.

Figure 4 shows the Formulation 1 problem. SOMOS-developed strategies were 20-33 % better for all formulations than the trial-and-error-developed designs.

This is representative--for 8 sites at which our S/O-developed strategies were compared with trial-and-error designs, the S/O strategies were usually 20-40 % better (Peralta 2001b, 2003; Peralta et al, 2003).

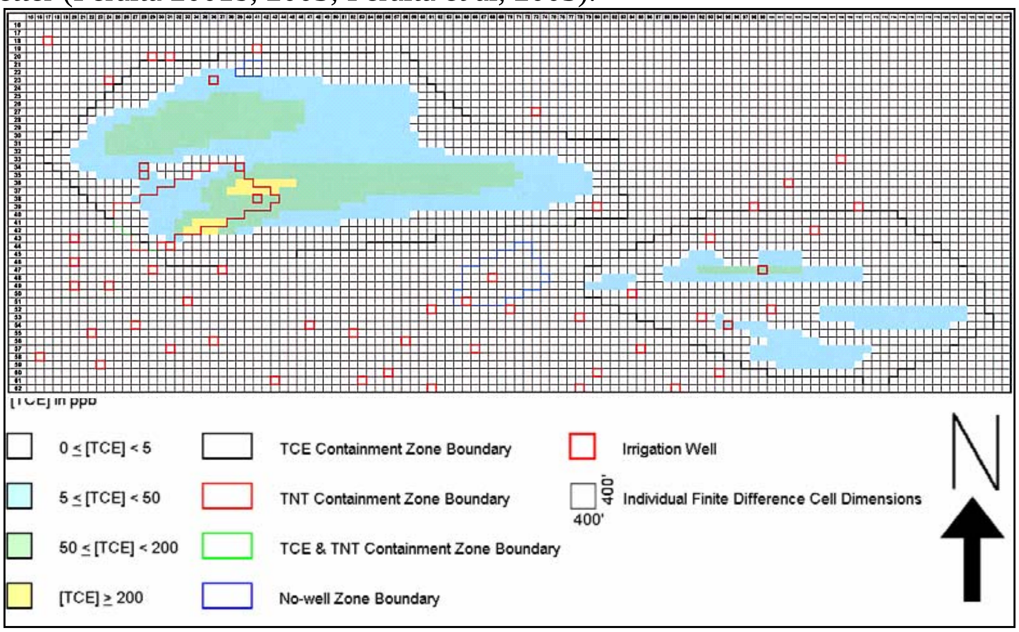

Figure 3. Initial (simulated 1 Jan 2003) TCE concentrations exceeding 5.0 ppb in layer 3, and part of finite difference grid (Peralta et al., 2003, 2004). (To convert from feet to meters multiply by 0.3048 m.)

Formulation 1 minimizes cleanup cost:

MINIMIZE Σ
{ Capital Costs of: wells ($400K); treatment ($1.0K gpm^{-1}); pipe ($1.5K gpm^{-1}) }+
{ Fixed Costs: management, O&M ($115K yr^{-1}); sampling & analysis ($300K yr^{-1}) }+
{ Variable Costs: electricity ($0.046K gpm^{-1}); treatment ($0.283K per gpm^{-1});
discharge ($0.066K gpm^{-1}) }

SUBJECT TO:
•Layer 1 and 2 cells not allowed to become dry
•350 gpm extraction limit per well per layer; no injection
•No remediation wells in layer 6, restricted areas or irrigation well cells
•Concentrations cannot exceed Concentration Limits (CLs) outside containment zones at end of any MP, (CL_{TCE} = 5ppb, CL_{TNT} = 2.8 ppb)
•Cleanup to CLs must be achieved within 30 years for Layers 3-6

Figure 4. Blaine NAD Formulation 1 optimization problem (Peralta et al., 2004). (Multiply gpm^{-1} by 264 to obtain m^{3}min^{-1}).

Optimizing Multi-objective Reservoir-Stream-Aquifer System Use

Fayad and Peralta (2004) report using multi-objective GA with ANNs for optimizing conjunctive use in a hydraulically connected reservoir-stream-aquifer system (Fig. 5). This approach reduces computer processing time yielding trade-off curves and surfaces for maximizing hydropower versus maximizing water delivery versus minimizing water delivery cost (Fig. 6).

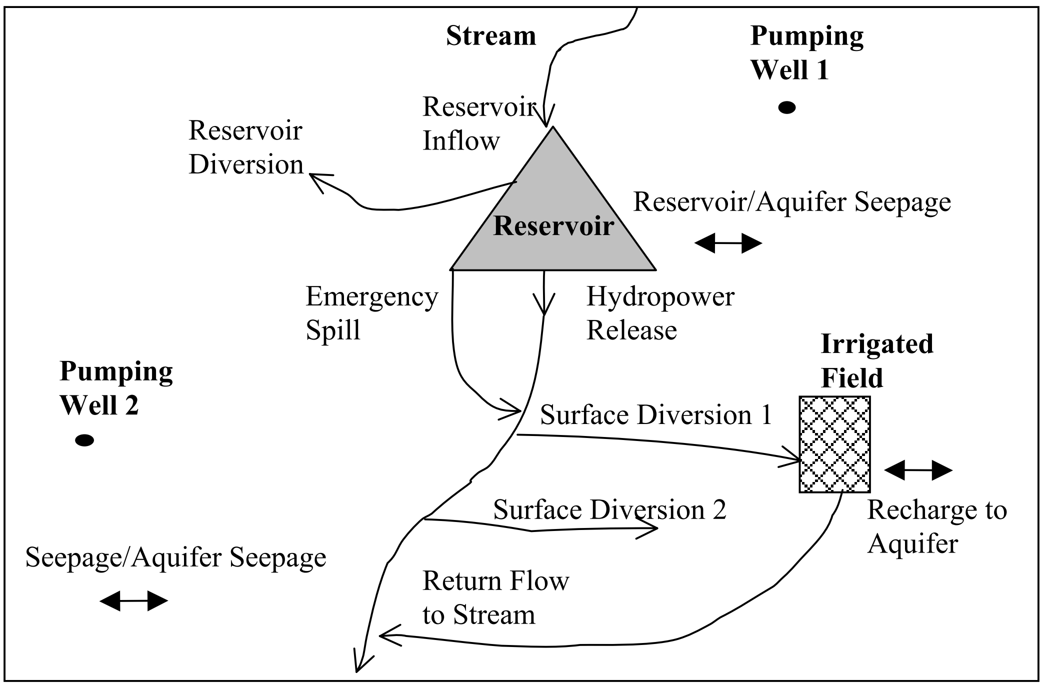

Figure 5. Study area conceptual view (Fayad and Peralta, 2004).

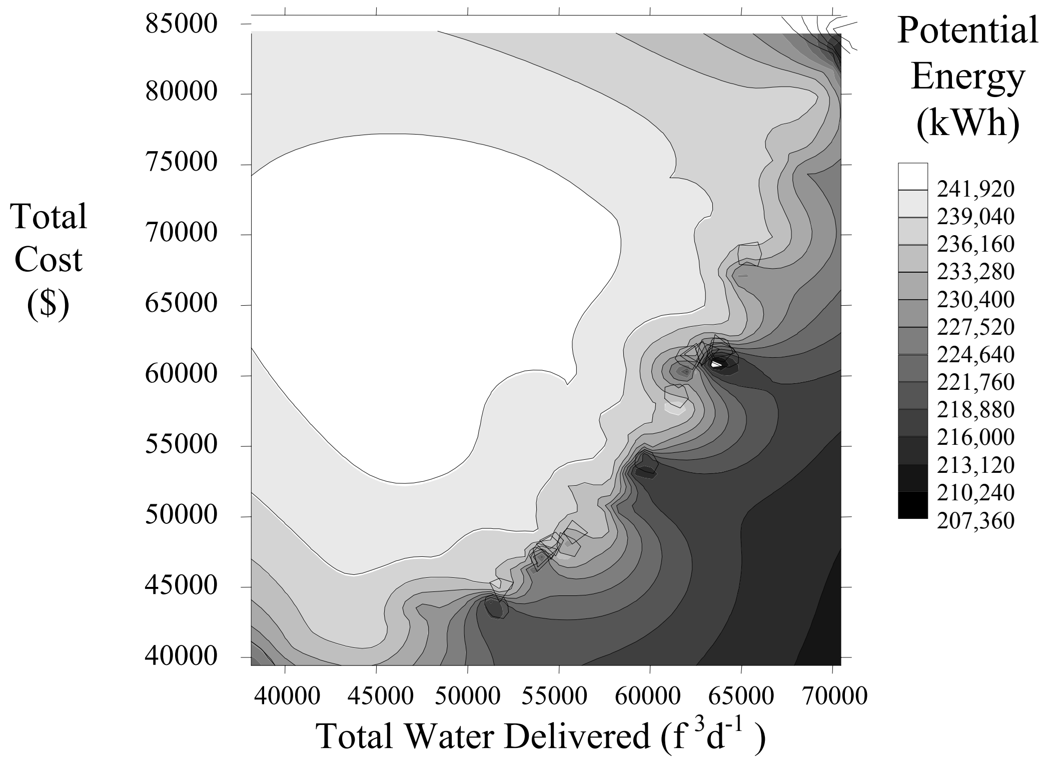

Figure 6. Tri-objective (water cost, water delivered, hydropower) trade-off surface (Fayad and Peralta, 2004).

SUMMARY

Simulation/Optimization models are becoming more flexible and powerful, leading to their increased use for aiding water policy-making, planning, systems design, and management. S/O models require data to: employ a suitably accurate simulator, and represent the objective function, constraints and bounds of the management problem. Thus, S/O models require more data than normal simulation models.

Different types of simulation and optimization approaches are better for different situations and management problems. For field settings where analytical flow equations are appropriate, an S/O module such as SOMOA can readily design optimal management strategies. SOMOA uses analytical and convolution (superposition) equations as simulators and classical operations research optimizers (simplex, branch and bound, and gradient search algorithms).

For heterogeneous aquifers describable via numerical flow models, optimization can also generally be performed using classical optimization algorithms. The

SOMOS SOMO1 module is appropriate for such aquifer and stream-aquifer systems.

For contaminated aquifers, where concentrations must be manageable state variables, it is usually best to employ numerical flow and transport simulators and heuristic optimizers. The SOMO3 module of SOMOS is applicable for most such sites. The SOMO4 generic optimizer can address systems for which more complicated simulation models are needed.

Designs or management strategies developed using S/O models are usually about 20-40 percent better than those developed using trial and error with simulation models alone. This is because simulation models are designed merely to predict system response to stimuli, but S/O models are designed to develop optimal solutions to user-specified problems.

SOMOS allows easy preparation of trade-off curves to evaluate the effect of constraints on objective function values, and to address multi-objective optimization problems. This is important because many water management problems are multi-objective. For example, trade-off curves can show how to use groundwater to achieve the best mix of sustainable population support and crop production, and ecosystem protection.

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TMDL FOR THE NANICOKE RIVER

W. F. Ritter[1]

ABSTRACT

A TMDL has been set for the Nanticoke River Basin. The TMDL calls for a 30% reduction in nitrogen loads and a 50% reduction in phosphorus loads. There are over 500 poultry growers in the watershed. Agriculture is the major land use. The EPA Qual E2 was calibrated for all the tributaries and run for 7Q10 and nonpoint source load reductions of 30% for nitrogen and 50% for phosphorus. All tributaries met the state water quality standard for dissolved oxygen of 5.5 mg/L. Nitrogen and phosphorus concentrations were above state target levels in some tributaries.

INTRODUCTION

The Nanticoke River Basin of Delaware is located in the southwestern part of the State, with the major part of the watershed in Sussex County. The Upper end of the Nanticoke Basin is located in Kent County. There are many small tributaries and ponds in the basin that drain into either the Nanticoke River or its major tributary Broad Creek.

The drainage basin consists of 253,906 acres, with 51% of the total land area in agriculture. Other land use includes forestland 39%, brush land 5% and urban areas 2.4%. Geologically, the basin lies within the Atlantic Coastal Plain that consists of deep unconsolidated and semi-consolidated sediments. The topography is extremely flat with land slopes of less than 0.50%. Soils are generally sandy and porous.

WATER QUALITY CONDITIONS AND DATA COLLECTION

The 1996 and 1998 303(d) State of Delaware reports listed 22 water body segments in the Nanticoke Basin as impaired because of low dissolved oxygen and/or high nutrients. These segments consisted of 61 stream segments and 11 ponds. Water quality in the Nanticoke Basin has been monitored for more than 25 years but an intensive water quality monitoring program was conducted during 1998-99. Quarterly water samples were collected from 50 monitoring stations in the basin and analyzed for 24 water quality parameters. Continuous data monitors were deployed at 9 sites in 1999 and dissolved oxygen, water temperature and other chemical parameters were monitored continuously for 7 days twice at each site in July and August (DNREC, 2000).

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There is only one USGS stream gauging station within the Nanticoke Basin. It has a drainage area of 75.4 square miles. The annual mean flow was 70.22 cfs in 1999 and the 7Q10 (7 day, 10 year return period flow) is 14.92 cfs. Annual mean flows and 7Q10 flows for the tributaries were calculated based on ratios of tributary drainage area at the drainage area at the USGS gauging station.

Streams in the Nanticoke Basin are relatively small. The tributaries involved in the TMDL study ranged from 2.5 to 30.0 ft in width and from 0.5 and 2.0 ft in depth. The Basin also has 13 ponds that range is surface area from 8.6 to 102.8 acres.

Based upon the 1998-1999 water quality monitoring the average dissolved oxygen concentrations in the 22 tributaries segments ranged from 4.5 to 9.8 mg/L. The minimum measured dissolved oxygen was below 5.0 to 4.5 mg/L and average total phosphorus concentrations ranged from 0.02 to 0.25 mg/L.

WATER QUALITY MODELING

The stream water quality model Qual 2E was used to develop the TMDL. Qual 2E is a one dimensional model developed by EPA for modeling streams and lakes (Brown and Barnwell, 1987). It models nutrient cycles, algal growth and dissolved oxygen reactions. The tributaries and ponds that do not meet water quality standards in the Nanticoke Basin are not physically connected to one another so the model had to be used on each tributary stream separately. A total of 12 stream segments and ponds were modeled. The model was calibrated for each tributary (DNREC, 2000).

Initial conditions were assigned to each segment of each tributary model for DO, BOD, Chl-a, organic nitrogen, ammonia nitrogen, nitrate nitrogen, nitrate nitrogen, organic phosphorus, dissolved phosphorus and water temperature. The average concentration of each parameter from the monitoring station within the segment from the 1998 - 99 intensive monitoring was used for initial conditions. Water quality data from the nearest water quality monitoring station were also used to define the headwater boundary conditions of each tributary stream model. Each tributary model consisted of two or more reaches depending on the stream physical dimensions. Each reach was then divided into equal 0.35 miles length segments for computation.

The tributary inflow input data into the modeled stream segments was obtained from the nearest water quality monitoring station. Again average parameter concentrations from the 1998-99 water quality monitoring were used. While tributary inflow is treated as a point source there is also incremental inflow or distributed source inflow, that has to be accounted for along the steam segment. Data was assigned from the nearest water quality monitoring station to define the incremental flow water quality conditions.

In calibrating the Qual 2E model for the tributaries and ponds, emphasis was placed on achieving reasonable agreement between the observed field data at the downstream segments and model predictions. The reason for this was the downstream segments provide tributary loads to the mainstreams. During the calibration process some of the parameters were manually adjusted to meet the downstream observation data.

The relative difference between model predictions and observations for each pollutant modeled were calculated by the following equation:

$$DO = \frac{\Sigma \left| M - O_{avg} \right|}{\Sigma\, O_{avg}} x \quad 100$$

DO = relative difference in %
M - model output, concentrations at monitoring locations
O_{avg} = average of field observation at the monitoring locations

The relative differences for a number of the parameters are presented in Table 1 (DNREC, 2000). As it is shown in Table 1, DO predictions for the model are very good, as only two of the tributaries had relative differences greater than 10%. Total nitrogen differences ranged from 1.0 to 53.3% and total phosphorus differences ranged from 4.0 to 48.9%. Ranges of relative differences for DO that have been cited for other modeling studies are 5-58%. Total nitrogen differences range from 6-33% and total phosphorus differences range from 6 to 48% (Tetra Tech, 2000). The Qual 2E results are within the general ranges of other water quality model studies.

Table 1. Summary of Tributary Models Relative Differences For DO, TN and TP

Tributary	DO	TN	TP
Bridgeville BR	8.7	1.0	14.1
Butler Mile Br.	3.0	17.0	48.9
Chapel Br.	6.0	9.7	27.3
Chipman Br.	6.1	23.6	21.6
Clear Brook	15.5	29.8	10.6
Deep Cr.	3.4	39.5	24.7
Gravely Br.	1.3	25.9	12.5
Gum Br.	2.6	3.0	21.3
Hitch Pd Br.	7.7	53.5	44.1
Horsey Pond	8.8	14.2	4.0
James Br.	13.9	21.6	28.9
Tussocky Pd. Br.	2.7	11.7	16.2

TMDL LOAD REDUCTIONS

The Delaware Department of Natural Resources and Environmental Control established a TMDL for the Nanticoke River and Broad Creek that called for a 30% reduction in nitrogen loads and a 50% reduction in phosphorus loads from nonpoint sources within the watershed. The Qual E2 model was run on all the tributary streams and ponds with the TMDL load reductions after the model was calibrated to see if water quality standards were met. It was assumed all stream flows were at 7Q10 conditions. The 30% nitrogen and 50% phosphorus reduction loads were applied to the model by reducing concentrations of nutrients from headwaters tributaries and incremental flows by 30% for nitrogen and 50% for phosphorus respectively.

The concentration of DO along all tributaries and ponds met the state water quality standard for DO of 5.5 mg/L with the calibrated Qual E2 model for 7Q10 and nonpoint source load reductions of 30% for nitrogen and 50% for phosphorus. Concentrations of total nitrogen exceeds 3.0 mg/L in some segments and total phosphorus concentrations exceeded 0.1 mg/L in some of the tributaries, which were the state targets for nitrogen and phosphorus (DNREC, 2000).

After the tributaries were modeled, the new nonpoint source tributary loads were applied to the main stems of the Nanticoke River and Broad Creek using the WASP model. The WASP model had been used in the Nanticoke River and Broad Creek by DNREC in the 1998 TMDL analysis (DNREC, 1998). Flow rates and point source loads were not changed in the WASP model from the previous analysis. Dissolved oxygen concentrations were above 5.5 mg/L in all segments of the Nanticoke River and above 7.0 mg/L in the Broad Creek segments. Total nitrogen concentrations were between 1.5 and 2.7 mg/L for all segments of the Nanticoke River and ranged from 2.2 to 3.5 mg/L in Broad Creek. Only the last few segments of Broad Creek had nitrogen concentrations above the state target of 3.0 mg/L. Total phosphorus concentrations were below 0.10 mg/L for most segments of the Nanticoke River but were above 0.10 mg/L for almost all of Broad Creek (DNREC, 2000).

NUTRIENT BUDGETS

Ritter and Scarborough (1995) developed nutrient budgets for the Nanticoke Basin for six subwatersheds based upon 1992 land use data. For all the subwatersheds, cropland was the largest sources of nitrogen and phosphorus. The percentage nitrogen and phosphorus loads from different land use for Broad Creek and Nanticoke Creek are presented in Table 2. Broad Creek and Nanticoke Creek have the largest number of poultry houses and cropland in the watershed. There are over 500 poultry operations in the Nanticoke Basin.

Table 2. Percent Nitrogen and Phosphorus From
Different Land Uses

Land Use	Broad Creek		Nanticoke Creek	
	N	P	N	P
Cropland	77.6	69.2	44.9	50.3
Feedlots	<1.0	1.1	<1.0	<1.0
Forest	11.4	18.9	6.0	8.4
Orchards	<1.0	<1.0	<1.0	<1.0
Pasture/Grassland	<1.0	<1.0	<1.0	<1.0
High Density Housing	2.0	1.6	3.0	2.0
Low Density Housing	1.1	1.3	1.0	1.0
Industrial/Commercial	<1.0	<1.0	<1.0	<1.0
Recreation	<1.0	<1.0	<1.0	<1.0
Water	<1.0	1.2	<1.0	1.1
Wetlands	0	0	0	0
Septic Tanks	3.1	1.4	2.9	1.1
Point Sources	<1.0	3.7	38.5	34.5

The largest loads of nitrogen and phosphorus come from cropland. In order to meet the TMDL load reductions for nitrogen and phosphorus, best management practices for cropland and poultry have to be implemented along with nutrient removal at the larger wastewater treatment plants.

POULTRY BMPS

In recent years there has been an effort to improve the balance between nitrogen and phosphorus in broiler litter. Many soils where broiler litter has been applied test excessively high in phosphorus. Phytase additions to feed is being used and is being promoted. Chickens lack the enzyme phytase making it difficult for them to digest phytate phosphorus. This is critical to broiler health and growth as nearly 70 percent of the total phosphorus found in many feed grains is phytate phosphorus. Due to the importance of phosphorus to poultry health and bone structure and uncertainties as to the exact amount of phosphorus in the feed ration that can be utilized by the bird, phosphorus is generally overfed to create a margin of safety (Sutton, et al., 2001). The intent of adding phytase to the broiler diet is to reduce the amount of excreted phosphorus by making more of the phosphorus contained in the feed grains bio-available to the birds. Thus limiting the need for inorganic phosphorus supplements to the feed ration. Besides phytase, some *lactobacillus*-based pro-biotics have shown to improve growth and feed conversion in broilers. Angel and Applegate (2000) found that phosphorus retention was increased 22% and nitrogen retention was 10% higher in birds fed a low phosphorus, Ca and protein diet containing *lactobacillus-based pro-biotics* than birds fed the control diet. Citric acid has also shown to reduce phosphorus excreted in the manure along with 25-hydroxycholeciferol (25(OH)D3). In experiments to determine the level of non-phytate phosphorus required by broilers and the effect of the feed additives phytase, citric acid and (25(OH)D3), Angel and Applegate (2000) found that 24% less phosphorus would be excreted in the manure with reduced non-phytate phosphorus diets they found were sufficient for broiler performance to meet phosphorus requirements. When phytate is added to the diet with lower phosphorus levels, the phosphorus excreted in the manure was reduced by 36%. The use of citric acid and (25(OH)D3) reduced phosphorus excretion in the manure by another 10% with the low phosphorus diet. High available phosphorus corn (HAP) is another approach. HAP corn is a plant genotype that contains lower levels of phytate phosphorus, however it contains the same level of total phosphorus as normal corn varieties. In HAP corn 35% of the total phosphorus is in the form of phytate phosphorus, while in normal corn 75 to 80% of the total phosphorus is composed of phytate phosphorus (Angel and Applegate, 2000).

The use of HAP corn reduces the need to supplement broiler diets with inorganic phosphorus, and reduces the phosphorus concentrations of excreta as less of the phosphorus within the feed is non-available and excreted. The seed company, Pioneer, has conducted studies with both swine and poultry that suggest a 3 to 5 fold increase in the bioavailability of phosphorus from HAP corn. With appropriate feed formulation, HAP corn can provide up to a 40% reduction in excreted phosphorus (Iragavarapu and Doerge, 1999).

Finding alternative uses for broiler litter is another approach being used. Some of the alternative use practices include:

- Composting of poultry litter. Composting reduces the litter's volume and moisture content making it easier to handle. Composted poultry litter can be more readily transported to nutrient deficit farms easier than litter due to its increased density and reduced moisture content. It can also be sold in bulk or bag to nurseries and landscaping industry. The primary constraints to composting are transportation costs, consumer bias against litter as a compost feedstock, lack of consumer education regarding the attributes and benefits of compost, and entrance into a highly competitive market (Carr and Brodie, 1997).
- Broiler litter can also be utilized as a cattle feed supplement is fed to beef cattle. Total Digestible Nutrients (TDN) is a measure of the CP and crude fiber values. Litter that has a TDN of 50% is comparable to a quality hay. The CP content of litter, after five or six flocks have been grown, ranges between 20-25 %. Feed costs represent 60% of the total cost of raising a cattle herd; by using broiler litter as a feed supplement, feed costs can be reduced by as much as a third. Two methods exist for processing broiler litter to be used as a feed supplement. The litter can be deep stacked and ensiled or it can be heated and pelletized. Litter that is pelletized can be combined with molasses, soybean hulls, corn or fat to improve the nutritional content of the pellet. Regardless of the method chosen, the litter must be heated to destroy pathogens

- Pelletized poultry litter. Pelletizing poultry litter offers several advantages over raw manure. There is little if any odor, it is pasteurized to destroy any pathogens or weed seeds, and the product is easily handled and much denser, thereby reducing transportation costs. The nutrient content of the pellets can also be manipulated by adding chemical or organic nutrients to the litter prior to drying it to achieve the desired nutrient ratio.
- Electric generation. Electricity can be generated from the combustion/gasification of poultry litter. However, manure has a relatively low energy content.

AGRONOMIC BMPS

The USDA and USEPA have developed a joint strategy for sustainable nutrient management. As part of this strategy three management options for land application of phosphorus that are proposed include:

1. Managing phosphorus based upon agronomic soil phosphorus thresholds, so that phosphorus applications are based upon crop needs.
2. Managing phosphorus based upon environmental soil phosphorus thresholds, by identifying a critical environmental soil phosphorus concentration above which phosphorus enrichment is unacceptable.
3. Using a phosphorus index to limit phosphorus application on fields at greatest risk for phosphorus loss.

Recent research has shown that new soil tests such as water soluble phosphorus, easily desorbable phosphorus (Fe-oxide coated filter paper) phosphorus flux and the degree of soil phosphorus saturation can better predict the loss of phosphorus to surface and groundwater than agronomic soil tests (Sims et al., 1998).

Accounting for all nitrogen sources is an important BMP. Nitrogen available from manure applications, legumes, soil organic matter, and other sources should be accounted for before supplementary applications of nitrogen are made. The importance of accounting for all sources of nitrogen varies greatly from farm to farm and region to region, depending on the relative contributions of various sources of nitrogen to the soil-crop system. Another important BMP is setting realistic yield goals. One of the important facets in determining nitrogen requirements for crops is yield. It is important to set realistic yield goals when deciding how much nitrogen to apply. Methods to set realistic yield goals include using farm averages, using a rolling 7- to 10-year field average or adjusting the past average and increase it by a chosen percentage (usually less than 5%) to take advantage of higher-yielding varieties.

The most efficient method of using nitrogen fertilizer and minimizing it loss is to supply it as the crop needs it. Maximum nitrogen use occurs near the time of maximum vegetative growth. If irrigation is used, nitrogen may be applied through the irrigation system in four or five applications. For non-irrigated crops, split applications or side-dressings are two effective methods for controlling the timing of application. Manure should be applied as close as possible to planting except when used as a nitrogen source to top-dress small grains.

Early-season soil (preside-dress soil NO_3 test)and plant NO_3 tests have been developed for estimating available nitrogen contributions from soil organic matter, previous legumes, and manure under the soil and climatic conditions that prevail at specific production locations. These tests are performed 4 to 6 weeks after the corn is planted. Early-season soil NO_3 tests involve taking soil samples in the top 12 inches of the soil profile. Early-season plant NO_3 testing involves determining the NO_3 concentration in the basal stem of young plants 30 days after emergence. One disadvantage of the early season soil and plant NO_3 testing is that there must be a rapid turnaround between sample submitted and fertilizer recommendations from the soil testing laboratory. If side-dress nitrogen fertilizer is being used in conjunction with manure, the early-season NO_3 test should help reduce the potential for over fertilization (Magdoff et al. 1987; Iversen et al. 1985).

The use of leaf chlorophyll meters is a relatively new method to measure N in corn. Girardin et al. (1985) demonstrated a strong relationship between nitrogen crop deficiency, photo-synthetic activity, and leaf chlorophyll content. They can be used to schedule fertigation later in the season.

CONCLUSION

The TMDL for the Nanticoke River Basin requires large nitrogen and phosphorus reductions from nonpoint sources. Broiler manure and agricultural cropland are the two major sources of nitrogen and phosphorus. Nutrient reduction load plans need to concentrate on finding other uses for broiler manure and reduce the phosphorus content of broiler manure. Agronomic BMPs also need to be implemented for nitrogen and phosphorus. Since Delaware now has nutrient management regulations, agronomic BMPs will be more easily adopted and all farmers are to have nutrient management plans.

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REGIONAL ET ESTIMATION FROM SATELLITES

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ABSTRACT

Crop evapotranspiration (ET) is a major component of the hydrologic system. ET values are used in irrigation water management, water rights allocation, hydrological modeling and water resource planning and management. Traditionally, ET has been estimated using crop coefficient and climatic parameters. Point measurement of ET can also be made through soil moisture monitoring, vapor flux measurement or energy balance using the eddy-covariance method. However, traditional methods will only provide point measurements of ET and do not account for spatial variability of ET in large scale. Recent advances in remote sensing have made it possible to develop regional maps of ET with high precision. A procedure was developed to use the combination of satellite data, ground level weather stations and point measurements of ET, to estimate and develop regional ET maps. The Regional ET Estimation Model (REEM) is based on energy balance at the crop canopy. The model uses incidental values of NDVI, near infrared temperature and albedo, from satellites to calibrate the sensible heat flux equation. The sensible heat flux equation is calculated daily and is modified spatially using well defined nodes in the watershed based on an optimization technique. The REEM based ET values were compared with direct measurement of ET in pecans in Southern New Mexico. The comparison showed that the crop ET can be calculated from REEM model with high precision.

INTRODUCTION

Evapotranspiration (ET) is a key factor in agricultural water management and other hydrologic studies. There are various methods for estimating ET. The most common approach is to calculate reference crop evapotranspiration (ET_o) and

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multiply it by a crop coefficient (K_c) (Allen et al., 1998). The ET_o is generally defined as evapotranspiration from well-watered grass, thus ET is calculated as:

$$ET = K_c \times ET_o \qquad (1)$$

Various equations have been developed to estimate ET_o from weather data. These equations range from complex theoretical equations such as Penman-Monteith (Allen et al., 1998) to simpler equations which use one or two climatic parameters (Hargreaves and Samani, 1982, 1985; Priestly and Taylor, 1972). Crop coefficient values have been developed by various investigators based on direct field measurement of evapotranspiration. This traditional method of estimating ET assumes a well watered crop growing under optimum conditions and does not account for the impact of stress where the crop is growing under less than optimum conditions. The stress could be caused by water shortage, disease or other adverse environmental factors.

Recent developments in satellite technology have provided an opportunity to estimate crop ET from remote sensing using surface energy balance (Bastiaanssen et al., 1998a, 1998b; Bastiaanssen, 2000; Allen, 2000). Surface energy balance can estimate ET regardless of stress and does not require detailed soil and crop water information. In addition, estimating ET from satellites is not limited to point measurement of ET, and can be used to provide large scale ET estimates.

METHODOLOGY

The surface energy balance calculates ET as a residual of surface energy budget as:

$$ET = R_n - G - H, \qquad (2)$$

where ET is the latent heat flux (W/m^2), R_n is the net radiation flux at the surface (W/m^2), G is the soil heat flux (W/m^2) and H is the sensible heat flux to the air (W/m^2).

Net Radiation

Samani et al. (2004) presented a methodology to estimate daily net radiation by combining clear sky incident solar radiation with short wave radiation from climate stations. The results of daily R_n values estimated from this method was significantly better than those estimated from the standard FAO 56 net radiation equation (Allen et al.,1998).

Soil Heat Flux (G)

Surface heat flux (G) is the component of the energy which enters or leaves the soil. Several empirical equations have been suggested to estimate G. Choudhury (1991) suggested the following equation for dense, short vegetation under daytime conditions and was suggested by Allen et al. (1998) for general application:

$$G/R_n = 0.4e^{-0.5LAI}, \tag{3}$$

where LAI is leaf area index. Choudhury (1991) indicated that factors affecting G/R_n ratio are soil moisture, soil structure and soil texture. The G/R_n ratio can be as much as 0.5 for bare soil, but only 0.03 to 0.05 for a dense vegetation cover (Choudhury, 1991). Clothier et al. (1986) reported that soil moisture did not significantly affect the G/R_n ratio in alfalfa.

Bastiaanssen (1995) suggested the following empirical equation for estimating G/R_n:

$$\frac{G}{R_n} = [\frac{T_s - 273.1}{\alpha}(0.0038\alpha + 0.0074\alpha^2)(1 - 0.98NDVI^4)], \tag{4}$$

where α is surface albedo and T_s is the surface temperature.

Sensible Heat Flux (H)

Sensible heat flux (H) can be calculated using aerodynamic resistance and the difference between surface and air temperature (Tasumi, 2003) as:

$$H = \rho_a C_p \frac{dT}{r_{ah}}. \tag{5}$$

where ρ_a is the air density (kg/m3), C_p is air specific heat (1004j/kg/K), dT is the temperature gradient across the canopy (K). .According to Kustas and Norman (1996), it is more appropriate to use aerodynamic temperature instead of surface temperature. Aerodynamic temperature is defined as the temperature obtained by extrapolating the air temperature profile to an apparent canopy height given by displacement height plus the roughness height. However, accurate estimation of aerodynamic temperature is difficult and therefore surface temperature is used instead of the aerodynamic temperature (Kustas et al., 2000).

Predicting Daily ET

Remote sensing algorithms use satellite images combined with some ground information to calculate regional ET based on surface energy balance (Kustas and Norman, 1996; Kustas et al., 2000; Bastiaanssen et al., 1998a, 1998b; Timmermans et al., 2003). Satellite images can be obtained from various sources which include NASA-Landsat, NOVAA- AVHRR, NASA-MODIS and NASA-ASTER. The satellite data used in calculating ET are normalized difference vegetation index (NDVI), surface albedo and surface temperature. The main advantage of a remote sensing technique is that it can provide regional estimates of surface energy balance, while most conventional techniques are based on point measurements which represent only a small area.

In this study, ASTER images were used due to their high resolution. High resolution images were necessary due to the small and diverse nature of agricultural fields in Southern New Mexico. 3-D eddy covariance systems were installed in a pecan orchard and an alfalfa field. The 5 ha, 21-year old pecan orchard was located about 11 km south of Las Cruces (Lat. 32.225^o N, 106.757^o W). The pecans had an average height of 12.8 m, and average diameter of 30 cm with tree spacing of 9.7 m by 9.7 m.

The alfalfa field was a three year old 8 ha field located about 13 km south of Las Cruces (Lat. 32.206^o N, 106.742^o W). Weather data were obtained from a nearby Campbell weather station. Energy fluxes were measured on 30 min intervals using the eddy covariance equipment. The 30 min values of net radiation (R_n), Soil heat flux (G) and sensible heat (H) were used to calculate daily ET values for the pecan and alfalfa fields using equation 2.

ASTER satellite images for the year 2002 were used to calculate ET values. Clear sky incident short wave radiation (Rs_i) was calculated from equation 2 and was used to calculate incident net radiation (R_{ni}, W/m^2) from equation 1. Equation 8 (Bastiaanssen, 1998a) was initially used to estimate G values from satellite NDVI and albedo, but resulted in large and inconsistent errors. Local soil heat flux data from the year 2001 were used to develop a relationship between ground flux (G) and NDVI (figure 1). The resulting equation is:

$$G/R_n = -0.35\ln(NDVI)-0.0505. \quad (6)$$

Equation 6 was used to calculate soil heat flux. Combining equations 2, 5 and 6, the daily ET values for pecan were calculated and compared with ET values measured through eddy covariance flux towers (figure 2).

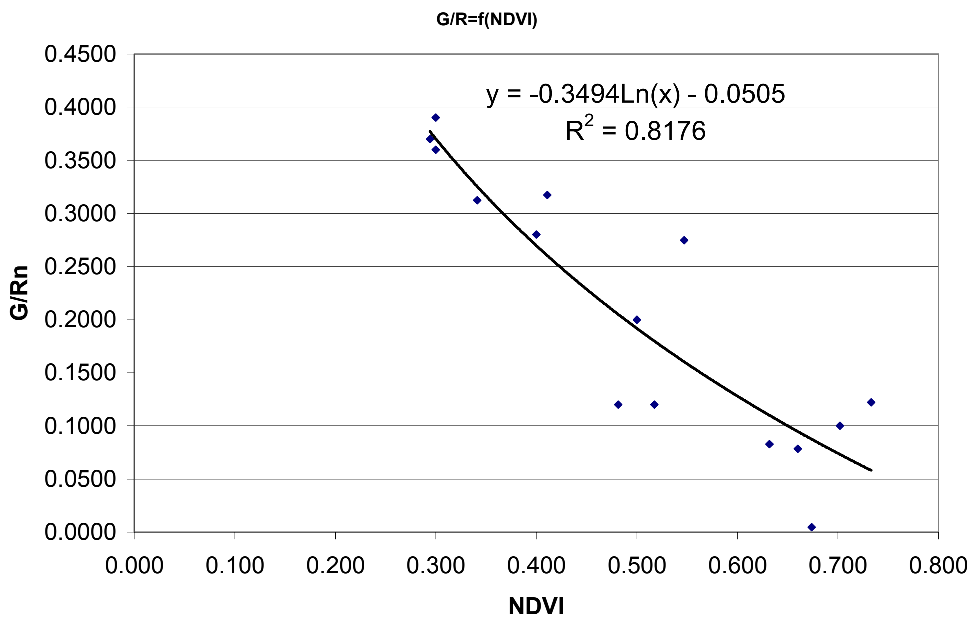

Figure 1. Relationship between (G/R_n) and NDVI.

Figure 2 compares daily ET values calculated with the REEM algorithm and measured by the eddy covariance system. In figure 2, instantaneous sensible heat values (H_i) from the alfalfa field and sensible heat values from a dry field were used to calculate daily ET for the pecan field.

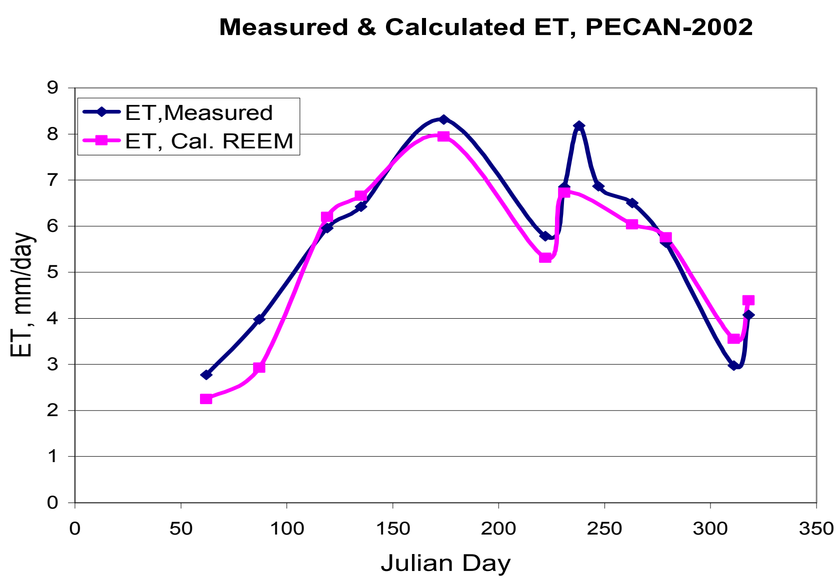

Figure 2. Comparison of ET values predicted from REEM algorithm and measured with 3-D eddy covariance energy flux system.

CONCLUSIONS

A remote sensing algorithm (REEM) was developed using surface energy balance theory. Instantaneous values of albedo, NDVI and near infrared temperature from NASA-ASTER were used to calculate daily ET values for pecans in Southern New Mexico. 3-D eddy covariance flux stations were installed in two fields. The comparison of measured and predicted daily ET values showed that surface ET can be estimated from satellites with good accuracy.

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IRRIGATION DISTRICT EFFORTS TO ACHIEVE WATER QUALITY OBJECTIVES IN THE SAN JOAQUIN VALLEY

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INTRODUCTION

In recent years several state and federal agencies have implemented new public policies to address issues regarding water supply and water quality in California's San Joaquin Valley. State agencies have worked to improve water quality in the San Joaquin River and its tributaries, while the federal government has reallocated water from agricultural to environmental uses. New restrictions on the discharge of drainage water into the River and persistent reductions in water supply have motivated farmers to improve water management practices. Many farmers also have changed their cropping patterns and implemented new cultural practices to increase the net values they generate with limited waters supplies. Such changes include switching from annual to perennial crops that can be irrigated with microsprinklers or drip systems and planting trees along the edges of fields to intercept subsurface drain water.

Irrigation and drainage districts have assisted farmers responding to changes in water supply and water quality policies by implementing farm-level incentive programs and providing technical support to farmers and their irrigators. Regional associations of districts have been formed to coordinate the activities of several districts and to implement regional water quality monitoring programs required by new public policies. The districts and regional associations have played important roles in mitigating the farm-level economic impacts of new policies. Many districts have increased the quality of services provided to farmers in support of their efforts to improve irrigation practices. Regional associations represent farmers in policy discussions and inform public agencies about the farm-level challenges and costs involved in responding to new policies.

The costs of operating district and regional programs are paid by participating farmers. Those costs have risen over time with increases in the cost of water deliveries and in the amount of monitoring required to comply with water quality regulations. Many of the policies implemented in recent years have raised the cost of farming in the San Joaquin Valley. However, the impact on net returns likely would be greater in the absence of district and regional programs that provide farmers with economic incentives, technical support, and other services at reasonable cost.

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The goal of this paper is to describe several programs implemented by irrigation districts and regional associations in the San Joaquin Valley in response to public policies that have been implemented in recent years. We focus primarily on policies that have reduced agricultural water supplies and restricted the amount of surface runoff and subsurface drain water discharged from farms. District and regional programs were started in the mid-1980s when state and federal agencies began implementing policies to reduce the load of selenium in waterways and wetland areas in the San Joaquin Valley. The programs were continued through the early 1990s when Congress passed the Central Valley Project Improvement Act that reallocates a substantial portion of the Valley's surface water supply from agriculture to environmental uses. New regional associations have been formed recently in response to changes in California policies regarding nonpoint source pollution from agriculture. The new associations also coordinate farm-level and district efforts to comply with Total Maximum Daily Load programs (TMDLs) for salt, boron, and selenium in the San Joaquin River.

PUBLIC POLICIES AND PROGRAMS

The Grassland Bypass Project

California water quality authorities have been working since the mid-1980s to reduce the volume of agricultural drainage water entering the San Joaquin River. The drainage water contains salt, boron, and selenium that degrade water quality. Public policies regarding agricultural drainage water were implemented when elevated concentrations of selenium at the Kesterson National Wildlife Refuge were attributed to drainage water that had been used there as a source of water supply (Letey *et al*., 1986; California 1987; National Research Council, 1989; Posnikoff and Knapp, 1997). State and federal agencies stopped the flow of drainage water into Kesterson and they began encouraging irrigation districts to remove drainage water from ditches and streams used to provide water supply to other wetland areas.

The movement of subsurface drain water from irrigated farmland into the San Joaquin River can be described as a classic case of nonpoint source pollution. It is very difficult and costly to measure the volume of drain water generated by individual farmers. Rather than attempting to regulate the irrigation and drainage activities of individual farmers, California's Regional Water Quality Control Board for the Central Valley worked with irrigation and drainage districts to develop a regional association that would assume responsibility for reducing selenium loading to the River. This approach was approved by farmers and environmental organizations concerned with improving water quality in the San Joaquin Valley.

The regional association, known also as the Grassland Bypass Project, was initiated by farmers in September 1996 with the primary goal of transporting agricultural drainage water around private, state, and federal wetlands. The association was formed by representatives of seven irrigation and drainage districts that shared the goal of complying with new policies requiring reductions in selenium loads. Operating procedures and evaluation criteria pertaining to the Grassland Bypass Project were developed in consultation with state and federal agencies. The regional association agreed to reduce the load of selenium discharged from member districts to the San Joaquin River. State and federal agencies agreed to allow the association to use a portion of a local waterway to carry drainage water from a regional collector drain to the River.

Participation in the Grassland Bypass Project has required farmers to improve irrigation and drainage practices, leading to higher fixed and variable costs of production. In addition, several irrigation districts have had to re-use drainage water to reduce effluent volumes, causing substantial increases in the salinity of water deliveries. Re-use of drainage water will cause soil salinity to increase, over time, particularly if leaching opportunities are limited by restrictions on the disposal of saline drainage water. Participation has enabled farmers to continue farming in the region, but the long-term viability of productive agriculture in the region cannot be guaranteed without an affordable method for discharging salt.

Reductions in Agricultural Water Supplies

Federal legislation also has placed upward pressure on agricultural production costs in recent years. The Central Valley Project Improvement Act (CVPIA) of 1992 reallocated a substantial portion of federal water deliveries in California from agricultural to environmental uses (Loomis, 1994; Weinberg, 1997, 2002). As a result, farm-level water supplies have been reduced and the average fixed cost of water delivered to farmers has increased. Water supplies have been reduced also by recent applications of the Endangered Species Act (ESA) of 1973. Water project operations have been modified to achieve flow and temperature criteria designed to protect aquatic species, resulting in smaller water deliveries to farmers.

The combined impacts of the CVPIA, the ESA, and new water quality regulations have been sharpest on water districts located south of the Delta formed by the convergence of the Sacramento and San Joaquin Rivers. Pumping stations that lift water from the Delta for delivery to those districts must be operated to minimize harm to fish in the Delta. As a result, annual water deliveries to some districts have been reduced from 100% to 60% of the volumes specified in contracts that were signed originally in the 1950s and 1960s. In addition, some districts have been required to reduce their discharge of saline drainage water to the San Joaquin River by more than 30% since 1996, and further reductions will be required through 2010 (Oppenheimer and Grober, 2003). These changes in water supply and water quality policies have reduced farm-level expectations regarding net revenues in a large portion of the San Joaquin Valley.

TMDL Programs and Conditional Waivers

The federal Clean Water Act requires states to implement Total Maximum Daily Load programs to reduce effluent loads in waterways out of compliance with national water quality criteria. Several waterways in the San Joaquin Valley appear on California's 303(d) list of streams and rivers requiring such attention. As a result, the Regional Water Quality Control Board for the Central Valley has implemented TMDL programs for salt, boron, and selenium (McCarthy and Grober, 2001; Oppenheimer and Grober, 2002). Those programs require farmers and other dischargers to implement measures that will reduce the loads of those constituents in the Valley's waterways.

The Regional Water Quality Control Board also has adopted new rules pertaining to the discharge of pollutants from irrigated lands. In the summer of 2003, the Board adopted a resolution providing conditional waivers of waste discharge requirements to farmers who demonstrate efforts to reduce their discharges. Prior to adopting the resolution, farmers had not been required to obtain waste discharge permits. The conditional waiver program enables farmers to continue operating without those permits, but they must implement best management practices and monitor the impacts of their activities on water quality in local waterways. The program allows farmers to comply with these requirements as individuals or as members of regional water quality coalitions.

Several water quality coalitions have been formed in recent years and many farmers have joined them. The cost of complying with new water quality regulations likely will be smaller for farmers participating in coalitions than for those operating as individuals. In addition, the risk of being declared out of compliance with water quality regulations might be smaller for members of water quality coalitions.

IRRIGATION AND DRAINAGE DISTRICT PROGRAMS

Irrigation and drainage districts have assisted farmers in responding to the policies and programs implemented in recent years. District efforts have included the implementation of economic incentive programs to motivate farm-level improvements in water management practices that would reduce the volume of subsurface drain water. Those programs have included increasing block-rate prices for irrigation water, farm-level allotments of a district's annual water supply, and low-interest loans for investments in gated pipe and sprinkler irrigation systems (Wichelns and Cone, 1992a, 1992b; Wichelns *et al*., 1996; Ayars *et al*., 1998). Districts also have implemented restrictions on the discharge of surface runoff to support regional drainage management efforts. District programs largely have been successful in motivating farmers to improve water management, resulting in smaller water deliveries per unit area and smaller volumes of surface runoff and subsurface drain water.

Many districts have enhanced the services they provide to farmers, while implementing incentive programs. Some districts have upgraded their water delivery facilities to increase the scheduling flexibility they provide to farmers, while other have implemented measures to improve the quality of water deliveries. Greater flexibility and better water quality are needed to support the use of sprinklers and drip systems. Farmers using surface methods also need greater flexibility to reduce irrigation set times. Many districts have conducted irrigation and drainage workshops and provided consultants to assist farmers in determining optimal strategies for improving irrigation practices while maintaining crop yields. District managers and selected staff members also have begun representing farmers in meetings of regional associations and in state and federal policy discussions regarding irrigated agriculture.

REGIONAL ASSOCIATIONS

The Grassland Bypass Project

As noted above, the Grassland Bypass Project was implemented in 1996, when it became necessary to re-route the region's agricultural drainage water around a large area of managed wetlands. Seven irrigation and drainage districts formed a joint powers authority, and they agreed to implement farm-level and district-level efforts that would reduce the load of selenium discharged into the San Joaquin River. Selenium is the primary focus of the program, but salt loads also have gained attention in recent years because the Regional Water Quality Control Board has implemented a TMDL program for salt and boron in the Lower San Joaquin River.

The seven irrigation and drainage districts are known collectively as the Grassland Area Farmers. Member districts include the Broadview Water District, Charleston Drainage District, Firebaugh Canal Water District, Pacheco Water District, Panoche Drainage District, Widren Water District, and the Camp 13 Drainage District. The area represented by these districts is about 97,000 acres and the estimated annual value of crop production is $113 million (SFEI, 2002).

The primary activity of the Grassland Area Farmers is coordination of efforts to reduce selenium loads reaching the San Joaquin River. Other activities include a water quality monitoring program in which samples are obtained from 12 to 15 sites at frequencies ranging from weekly to annual, for the purposes of describing program success and evaluating the potential impacts of selenium on aquatic organisms in the region. The monitoring program is reviewed periodically by an Oversight Committee comprised of senior level representatives of state and federal agencies (SFEI, 2002). The Oversight Committee receives input from a Technical and Policy Review Team and a Data Collection and Reporting Team. Both Teams include staff members of state and federal agencies.

The Grassland Area Farmers conduct their drainage water reduction programs with the assistance of a Regional Drainage Coordinator who works closely with each district and maintains communication with state and federal agency personnel. The Coordinator is responsible for implementing the regional monitoring program, helping districts to reduce selenium loads, and preparing reports that describe program activities and results. The Coordinator also seeks grant funds for conducting research and outreach programs pertaining to improvements in water management that might reduce drain water volume.

Districts participating in the Grassland Bypass Project are charged an annual fee to generate revenue for managing the regional program and to pay for the monitoring program. The annual fee for the Broadview Water District has ranged from $60,000 to $69,000, in recent years, or from $6.67 to $7.67 per acre (Wichelns *et al*., 2002). Broadview farmers are charged $18.00 per acre each year for drainage service within the district. Hence, the annual charge for participation in the regional program represents about a 40% increase in the farm-level fixed cost of drainage service.

All of the seven irrigation and drainage districts participating in the regional drainage program have been assigned monthly district-level selenium discharge targets. The data collected in Broadview's water quality monitoring program enable district staff to estimate the loads of salt and selenium discharged each week. Those estimates are helpful in determining when the district will reach its monthly selenium discharge allocation. When the data suggest that Broadview is approaching its target, the staff can increase the proportion of drainage water blended for irrigation deliveries, provided that the salinity of the water delivered to farmers does not exceed 800 parts per million of total dissolved solids, in accordance with District policy.

Regional Water Quality Coalitions

Several water quality coalitions have been formed in the San Joaquin Valley in response to the conditional waivers program for irrigated lands adopted by the Regional Water Quality Control Board in the summer of 2003. The coalitions have assumed responsibility for preparing and submitting information describing water quality in a watershed and for developing programs to motivate farm-level use of management practices that will reduce pollution discharges.

To date, the Regional Board has approved the formation of eight coalitions in California's Central Valley (CVRWQCB, 2005). The area included within these coalitions is about 8.3 million acres (Table 1). The first reports from coalitions were due to be submitted in the spring of 2004.

As noted above, the costs of complying with new water quality regulations likely will be lower for farmers who join coalitions that address water quality issues from a regional perspective. Coalitions also might be helpful in identifying and implementing regional programs that enhance the likelihood of achieving desired improvements in water quality. Some of the activities that coalitions will implement include the following:

- Defining a management structure for the coalitions,
- Determining a program for recovering coalition costs,
- Recruiting farmers to join the coalitions,
- Describing current water quality conditions,
- Implementing an effective water quality monitoring program,
- Identifying management practices that will reduce pollution,
- Developing measures to encourage farm-level adoption of recommended management practices, and
- Preparing reports that describe coalition efforts and accomplishments for submittal to the Regional Water Quality Control Board.

Some coalitions will implement several of these activities, while others will have a more limited scope. The characteristics of individual programs likely will vary among coalitions with differences in watershed characteristics, cropping patterns, and local water quality issues.

The information developed by the coalitions will be helpful in gaining new knowledge regarding water quality issues in the San Joaquin Valley. The Regional Board has supported the notion of establishing coalitions, in part, because regulating nonpoint source pollution is quite challenging and very costly, particularly in agriculture. The size of irrigated areas and the methods used for irrigation can vary substantially on farms within a watershed. The direct and indirect costs of uniform regulatory policies can be very large and yet the policies might not be successful in achieving water quality objectives. California's water quality legislation allows the Regional Board to provide time in which dischargers can modify their production practices to comply with water quality regulations. The establishment of regional water quality coalitions is consistent with that perspective. The coalitions also provide an opportunity to gain insight regarding the linkages between irrigation activities and water quality conditions before imposing stricter regulations or implementing measures that might not generate the desired improvements in water quality.

SUMMARY

Irrigation and drainage districts, and regional associations of districts, have been helpful in responding to changes in policies that alter the distribution of water supplies in California and require improvements in water quality. The districts and associations can implement projects and data collection efforts at lower cost than might be required by individual farmers. They also serve important roles in providing information to farmers, advising irrigation and drainage districts, and reporting to regional water quality agencies.

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Table 1. Watershed Coalition Groups formed recently in California's Central Valley

Coalition Group	Watershed Description
Southern San Joaquin Valley Water Quality Coalition 4,000,000 acres	Tulare Lake Basin (Kings, Kaweah, Tule, and Kern Rivers), bounded by the San Joaquin River to the north, the Tehachapi Mountains to the south, the Sierra Nevada crest to the east, and the Temblor Range to the west (Fresno, Tulare, Kern, and Kings Counties)
East San Joaquin Water Quality Coalition 660,000 acres	Farmlands encompassed by the lower Stanislaus, Tuolumne, and Merced River sub-watersheds (primary eastside tributaries to the San Joaquin River) and that lie within Stanislaus, Merced, Calaveras, Mariposa, and Tuolumne Counties
Westside San Joaquin River Watershed Coalition 550,000 acres	Area primarily on the west side of the San Joaquin River from the Stanislaus River on the north to 10 miles south of Mendota on the south. The area includes irrigated farmland and private, state, and federal wetland areas (Stanislaus, Merced, Madera, and Fresno Counties)
San Joaquin County and Delta Water Quality Coalition 500,000 acres	San Joaquin County and lands within the Delta formed by the confluence of the Sacramento and San Joaquin Rivers
Sacramento Valley Water Quality Coalition 2,000,000 acres	Irrigated lands within the Sacramento River Basin (includes all or portions of Amador, Butte, Colusa, El Dorado, Glenn, Lassen, Modoc, Lake, Napa, Nevada, Placer, Plumas, Sacramento, Shasta, Sierra, Siskiyou, Solano, Sutter, Tehama, Yolo, and Yuba Counties)
California Rice Commission 500,000 acres	Rice production in the Sacramento River Basin (covers Butte, Colusa, Glenn, Placer, Sacramento, Sutter, Tehama, Yolo, and Yuba counties)
Root Creek Water District 9,400 acres	Consists of about 9,400 acres located in Madera County, lying between Avenue 12 to the north and the San Joaquin River to the south, and between the Road 37 alignment and Highway 42 on the west and east respectively.
Westlands Water District 600,000 acres	Area on the west side of Fresno and Kings Counties that includes irrigated farmland at the base of Diablo Range of the California Coast Range Mountains from Mendota to Kettleman City
Source: Central Valley Regional Water Quality Control Board, 2005. List of Coalition Groups Within the Central Valley. Available at: http://www.waterboards.ca.gov/centralvalley/programs/irrigated_lands/coalition-grp.pdf (Accession Date is January 23, 2005).	