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**Design Issues in
Farmer-Managed Irrigation Systems**

Design Issues in Farmer-Managed Irrigation Systems

*Proceedings of
an International Workshop of the
Farmer-Managed Irrigation Systems Network*

**Organized by
The International Irrigation Management Institute
and
The Thailand Research on Irrigation Management Network
and held at
Chiang Mai, Thailand
from 12 to 15 December 1989**

Robert Yoder and Juanita Thurston, editors

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Cover photograph by Dr. Uraivan Tan-Kim-Yong: Members of a "People's Irrigation System" near Chiang Mai, Thailand, making improvements to their diversion weir. Such weirs, made of local materials, are candidates for replacement by permanent structures.

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Foreword

IRRIGATION SYSTEMS BUILT by farmers using local materials, and then managed and used by farmers, experience problems and needs different from those backed by the larger resources of government agencies. Their mode of construction may be modest, based on hand labor; they may deteriorate rapidly and may only function for part of the year; the labor needed to sustain them is often substantial. Yet, though these systems tend to be small, they are numerous, and in several countries they produce a significant share of the total food supply.

The International Irrigation Management Institute (IIMI) recognized from its inception in 1984 that farmer-managed irrigation systems (FMIS) represent an important mode of system governance that may have transferable lessons for others; and that not enough was known about the performance, the needs and the management characteristics of these systems.

An international conference on "Public Intervention in FMIS," held at Kathmandu, Nepal, in 1986 led to the creation of the FMIS Network, which is an international system for advancing knowledge of these irrigation systems. The Network is supported by a coordinator, currently Dr. Shaul Manor, at IIMI, and guided by an international advisory committee.

Among the Network's most significant activities have been the organizing of a series of national, regional and international workshops, whose publications are now gradually filling some of the knowledge gaps, and - equally important - are creating a widening awareness of the potentials inherent in FMIS. The present volume of papers represents the output of the first fully global event that the Network promoted, in 1989; but already in the intervening months more ambitious plans have been laid for further events in this series, which now appears to be a well-established and productive mode of interaction. IIMI is proud of its association with this process.

All of this has been facilitated by various generous donors. The Network has been principally supported since 1987 by grants from the International Fund for Agricultural Development (IFAD), and the Federal German Ministry for Economic Cooperation (BMZ).

The Network Advisory Committee has identified knowledge gaps that need to be filled, and at an international workshop in 1988 it recommended that one such priority area, deserving attention, was the question of how systems should be designed so that they would be appropriate for management by farmers. This can be seen as part of the increasing process of interaction

between government agencies and FMIS. As governments focus upon the potential of upgrading FMIS, or try to help remote communities by giving them structures that are more durable, they encounter problems of appropriateness of technologies.

Information about what designs are appropriate is not yet well-developed. Structures designed and built by engineers are frequently modified or even removed by farmers because they do not allow operations to proceed according to long-established rules and practices. Little research has yet focused on the design/management/performance interactions in FMIS.

The Network Advisory Committee invited the Thailand Research on Irrigation Management Network (TRIMNET) to arrange and host the workshop. It was planned by Dr. Sacha Sethaputra of TRIMNET and Dr. Robert Yoder, Head of IIMI's Field Operations in Nepal.

IIMI and the Network are especially grateful to Dr. Sacha Sethaputra and his colleagues at Khon Kaen University, and Dr. Uraivan Tam-Kim-Yong and her colleagues at Chiang Mai University for handling all local arrangements, including an informative field visit to several FMIS.

Thanks are also due to Dr. Yoder and Ms. Juanita Thurston who undertook the preparation of these papers and proceedings for publication. A specific grant towards participants at this workshop and towards production of this volume was received from the United Nations Development Programme (UNDP).

Charles L. Abernethy
Director of Programs
International Irrigation Management Institute

Overview of the Workshop

Purpose and Objectives

MUCH OF THE completed research and proliferation of literature in recent years related to farmer-managed irrigation systems (FMIS) is heavily social science oriented and concerned with the institutions and organizations that farmers have created. How management capability or institutions such as water rights influence the way farmers have designed and maintained their hydraulic structures has received less attention. The FMIS Network initiated this workshop to draw attention to the importance of the design processes and design outcomes in searching for ways to improve and sustain farmer management of irrigation systems.

Most farmer-managed systems tend to be small and are often located in hilly topography, but a few as large as 15,000 hectares (ha) have been reported. Some farmer-managed systems have been built entirely by farmers but many have had substantial input from political rulers and government agencies. Increasingly, irrigation systems designed by engineers are to be managed entirely by the users. The distinction among systems for the purpose of this workshop, however, is not on the basis of size or who did the construction, but by management.

If farmers control, operate, and maintain the hydraulic infrastructure and the water that flows through the system, the system is farmer-managed. If staff not employed by the irrigation users operate and maintain segments of the system in ways that influence the timing and quantity of water delivery, such as deciding how much water to release into the main canal by operating the gates or pumps, while the farmers are responsible for the remaining operation and maintenance activities, the system is jointly managed. This distinction is important for this workshop only to clarify that the design issues of concern relate to continued farmer operation and maintenance of the physical structures resulting from the design.

Searching for the "correct" or "best" technical solution often blinds designers to what farmers face -- reliance on local materials and their own labor to keep the irrigation water flowing. The designs produced by engineers and procedures used by agencies for improving existing systems or building new systems that farmers are to manage are often scaled-down versions of what they would propose for large systems that are to be managed by engineers. The results seen in many locations are: structures built that are not functional and require farmer modification, farmers becoming dependent upon agency staff for maintenance and for water which can seldom be delivered on time if at all, and the cost of maintenance shifting from the users to the agency.

This workshop was called to share experience and examine issues in designing for farmer-managed irrigation systems that can help in overcoming these problems. This is a timely topic since the policy trend in many countries is to shift the responsibility for management and the total cost of operation and maintenance to the farmers.

The objectives of the workshop were to:

1. Create awareness that design for farmer-managed irrigation systems is an important issue if cost-effectiveness is to be improved.
2. Identify shortcomings of present design methods and procedures and their impact on operation and maintenance.
3. Present design innovations and cases where alternative approaches have been tested with an evaluation of their impact.
4. Describe methods for tapping farmer experience and knowledge during the design process.
5. Exchange information on farmer-managed irrigation system design ideas, experiences, and trends among countries.
6. Recommend new design ideas and strategies that could be tested.
7. Encourage follow-up of the information exchanged by providing materials useful for national-level seminars.

Introduction to the Issues[§]

"DESIGN" IS ANOTHER of those English words that can be used either as a noun or a verb. Since this term is so essential to the discussion of this workshop, we should keep in mind this important distinction and perhaps avoid confusion by using the term design process when referring to the activities related to preparing a design, i.e., data collection, site investigation, etc., and design outcome when we are speaking of the planned or constructed product of design, i.e., the physical structure.

FIVE FUNDAMENTAL QUESTIONS

It is useful to highlight selected general points that can provide context for the subsequent discussions which tend to be case-specific and rich with field details. The following are five questions of fundamental importance.

What Is It That Is Being Designed?

This is a simple, but fundamental question to reexamine. This is especially the case because designing usually occurs in the context of an agency skilled in and concerned with construction activities. What we need to keep in mind about the irrigation design process is that we are not simply planning a physical layout or merely designing an individual structure. Rather, the layout of a system, or various components of a system, involves a complex combination of elements of

[§] The material in this section is taken from the opening presentation made by Professor E. Walter Coward, Jr., of the Ford Foundation.

habitat, technology and techniques, and social organization. Likewise, each existing irrigation system has its own development history which may be reflected in contemporary patterns and activities. In short, irrigation designing involves dealing with what many have called a socio-technical entity.

What Are the Unique Aspects of Designing for Farmer-Managed Systems?

Farmer-managed irrigation systems are sometimes locally built but their most essential feature is that they are locally controlled systems. Thus the uniqueness of designing for farmer management is that both the design process and the design outcome should support past and future local initiatives.

What Is a Good Design Process and a Good Design Outcome?

Our traditional yardstick for judging design outcomes has been to give prominence to matters of technical effectiveness and economic efficiency. More recently, various people have highlighted the need to add to this list the matter of organizational appropriateness. All of these are important. But we also need to place these characteristics in the context of farmer-managed systems and to note that good design processes and outcomes are those that support the continuation of these systems as productive, dynamic, and largely self-supporting local entities.

What Do We Mean by Farmer Participation in Irrigation Design?

Over the past few years there has been noteworthy progress in understanding and implementing farmer participation in irrigation design. Large changes have occurred in the views and attitudes of agency staff. Novel approaches such as "walk throughs" have been invented and incorporated as regular procedures. This has been helpful and needs to be continued and expanded. But, there is another level at which local experience can be and needs to become blended with conventional designs. This is what might be called the "conceptual level."

The simplicity of the layouts and the technical crudeness of the structures found in many farmer-managed systems have often misled observers into false conclusions. This is because the observers have not always sought to understand the contextual meaning of the layouts and structures -- i.e., their relationship to location-specific environmental conditions, customary agronomic practices, established water rights, indigenous principles of equity, and so on. One unfortunate outcome is that externally driven design processes fail to appraise indigenous principles and incorporate them when appropriate.

Designing for farmer-managed irrigation systems could be enhanced with the use of a strategy one could term "principle analysis." This is examined further in the final question.

What Is the Role of Research in Support of Improved FMIS Design?

Since design activities for farmer-managed systems often occur in a situation in which irrigation facilities, organization, and practices already exist, a major challenge is for the designers and the design process to effectively link with and draw from that living socio-technical entity. But one must also be realistic -- the design teams will not be in a position to conduct "deep" ethnographic research in each small command in which they are working nor can they wait for this task to be completed by a separate research team.

However, we also know that farmer-managed irrigation systems tend to occur in types -- there is the subak "type," the muang-fai, the village tank, the kuhl, and so on. While, of course, there is variation within the types, there also are numerous similarities and common features -- both common organizational arrangements as well as comparable physical devices and techniques. Thus, researchers can study in depth examples of various types of systems and provide information to designers that can assist them.

In particular, a research strategy that could be called principle analysis may have considerable utility. Principle analysis would focus on several matters. First, understanding the engineering and hydraulic principles undergirding the architecture of farmer-managed irrigation systems and the individual devices that exist for capturing, conveying, distributing, measuring, controlling, and otherwise handling water. And second, discovering the linkages between those engineering principles and agronomic, economic, and social outcomes considered desirable by some, or all, of the local group.

THE TWIN CHALLENGE

The group that assembled at this workshop was diverse in national origin, disciplinary training, experience with irrigation, and current institutional base. What brought us together was the shared belief that good irrigation can contribute positively to improving the livelihood of rural people and make wise use of natural resources.

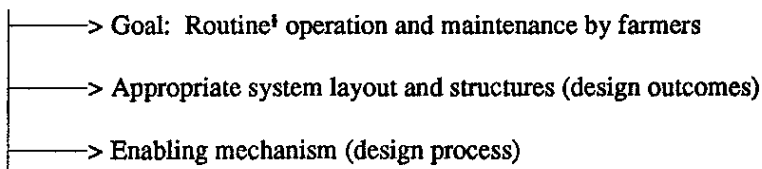
Improving the design process and design outcomes in farmer-managed irrigation systems is one important means to this end. Persistent progress along these lines will depend on two achievements: 1) continuing to deepen our understanding of the process by which local groups design their systems and the principles that undergird their design outcomes, and 2) accelerating the application of novel design processes that jointly involve local groups and agency staff and blend both indigenous and "science-based" concepts and knowledge.

Interpretive Summary of the Discussion

THE TASKS OF preparing a design and carrying out construction activities to complete the planned structures are usually major undertakings. The performance of the engineer assigned to these tasks is generally evaluated on the basis of completing the job rather than by the effectiveness of the design outcome. His attention is totally absorbed with getting the design and construction completed, and the purpose of the system layout and planned structures or how they are to be operated and maintained does not always remain the focus during this process.

Farmers also want the design and construction of the system completed but their major concerns are about the outcome of its operation -- will it deliver enough water? -- and what will be required of them to maintain the system. Having the farmer-users of the system work together with the engineer in all steps of the design process through completion of the construction helps direct attention to the goal of this enterprise and gives the farmers valuable information and experience for their continued role as the operators of the system responsible for its routine maintenance.

The goal of design for farmer management is more than construction of functional structures in a well-planned layout. The goal is that the system actually delivers water as planned, i.e., that it continues to be operated and maintained by the farmers. The following simple diagram highlights the themes of the discussion. The arrows indicate feedback.



¹ Routine refers to ordinary, "everyday" maintenance activities performed periodically, as opposed to emergency maintenance activities necessitated by landslides, flooding, or other unusual events.

The central question of the discussion is:

What are the essential features of the design process that will lead to producing design outcomes that are supportive of higher farmer involvement in routine operation and maintenance activities?

DESIGN PROCESS

Elements of a Good Design Process

Five elements of a good design process were identified. The process should: 1) be policy-driven, 2) be field-based, 3) have farmer participation, 4) include procedures for learning from experience, and 5) incorporate local logic, knowledge, and experience.

Policy-driven. Successful design is more likely to be achieved when there is a clear policy statement that supports farmer management and participation (see Acharya[†], Shrestha, Yabes). When consultants had clear, well-defined terms of reference stating the need for farmer involvement, a higher degree of success was achieved (Bhattarai). In the case of intervention by a Sri Lankan government agency to improve an existing system managed primarily by farmers, the rules for farmer involvement were not well-defined, nor were they followed. This resulted in structures being built that have little, if any, use (Abeyratne).

Policies have to be flexible in order to accommodate farmers' needs (Acharya, Bhattarai). This is a difficult problem in cases where government funds are being spent since budget rules tend to be rigid. Donor agency accounting needs and frequent changes in their policies further complicate this. To arrive at solutions to financial administration bottlenecks, audit and accounting staff need to gain a field perspective on implementation problems. Possibly they should share responsibility for timely implementation and receive equal reprimand for delays. These solutions must provide necessary control but allow flexibility. In many cases, government policies need to be modified to simplify the design process (Acharya).

To achieve the goal of routine operation and maintenance by farmers, it is also important for governments to give water rights and ownership of the irrigation infrastructure to farmers along with responsibility for operation and maintenance (Oad and King). Government policy should facilitate this property and water-rights transfer.

Field-based. Engineers must spend more time in the field if designs are to be improved and costs reduced. Farmers cannot be involved in the design process if it does not take place in the field. Decisions regarding where to place structures and what types of structures to build need to be made with the farmers while in the field. At this time, designers can see the actual physical conditions and the farmers can see and respond to designers' suggestions. Continuous interaction in the design phase allows designers and farmers to learn from each other. (For examples of field-based designs, see Acharya, Bhattarai, and Shrestha.)

[†] For further reading on the topics under discussion, see the papers in this volume by the authors cited.

To achieve field-based design, governments and agencies must reduce formal design requirements and simplify bureaucratic procedures. For example, scale drawings, multiple blueprints, and detailed quantity estimates are difficult to produce in the field, but also extremely time-consuming and inaccurate with respect to site conditions when done in the office. In the end, office-based designs must often be changed during construction to accommodate better information available at the site. This causes considerable time delays and frustration. Except where complex structures are needed for technical reasons, most design work can be accomplished and recorded by making sketches in a field-design book together with quantity and cost estimates (Acharya, Bhattarai, Shrestha).

Procedural constraints, such as requirements for detailed topographic survey and scaled engineering drawings, when the location and type of structure to be built do not warrant such detail, limit what the engineer can accomplish. With fixed and limited time available for the design work, it is the time for interaction with farmers that is usually cut out. Other constraints, such as lack of transportation and low field allowances limit field activity and dampen enthusiasm.

Farmer participation. If farmers are to be responsible for routine operation and maintenance, it is essential that they identify the system as their own and be involved in all aspects of the design. A number of activities that encourage farmer participation were identified by Workshop participants.

One of the most important considerations for effective farmer participation is the attitude of the individuals on the field-design team. The team must have a positive orientation and be sensitive in interpersonal relationships in order to encourage participation.

Holding frequent meetings and dialogues with farmers where information is shared between the farmers and agency staff is also essential for encouraging farmer participation.

In addition, farmers must have a clear understanding of the financing and what is required of them (Acharya). For example, if the budget is limited so that only part of the expected rehabilitation work can be done, they must be given a clear understanding of the budget allotment before they can set realistic priorities and determine their own contributions.

In the project reported by Corsiga, when funds were limited, the farmers decided to complete the work in phases. As farmers gained experience through phased implementation, they continued to improve the design. Phased implementation also allows greater farmer participation, since the work is spread over a longer time and can be scheduled to accommodate the agricultural cycle (Wipat).

All of the water users, or at least representatives that the farmers select themselves, should be made a part of the site investigation activities. A strong, cohesive farmer group, whether formally or informally organized, facilitates participation (Acharya, Corsiga, Reddy, Shrestha, Yabes). One exception, highlighted by Bruns, is a project in northeast Thailand which assisted farmers in replacing earth weirs with permanent structures. Farmer participation was high, but organized user groups were not required and no standard water-management package was presented. The work was done as a partnership between the farmers and the agency.

Learning procedures. Orientation, training, and experience are needed for engineers and social scientists to identify and accept the farmers' logic. Farmers also have much to learn from the technical team. This must happen through frequent exchanges with the team and is why the team needs orientation on ways to facilitate the learning process in both directions.

While farmers have observed the field conditions of their irrigation environment continuously for a long period of time -- sometimes for generations -- the design engineer usually has only a short period in which to collect information and make decisions. To improve the quality and expand the scope of the information, designers need to go to the field repeatedly. This allows them to see the actual conditions and get feedback from the farmers and to learn from mistakes -- those the farmers have made in the past and their own (Acharya, Bhattarai, Corsiga, Yabes). However, a procedure is also needed that allows utilization of the improved and expanded information in the design. This is not possible if the design cannot be easily amended.

Local logic, knowledge, and experience. (For examples where local information was used, see Acharya, Bhattarai, Corsiga, Thompson, Vermillion, Yabes. Documentation of cases where local logic and knowledge were not incorporated, which led to problems and inequities being introduced into the irrigation systems can be found in Abeyratne; Maurya, Ahmed, and Adewumi; Patil; Kariyawasam.)

An important strategy for tapping farmer experience is to involve them from the very beginning of the field investigation. This should be an interactive process to encourage designs that are flexible to meet the challenge of changing needs.

An understanding of the farmers' objectives and plans for operation of the system is fundamental to the type of structure that is designed. The design staff, whether irrigation engineer or social scientist, needs to be trained to identify the farmers' objectives and to be able to mesh the social and technical aspects of the objectives in designing physical structures.

During the data collection and design process, both the data and the agency's criteria of a good design need to be tested against the farmers' criteria. Water-use efficiency and equity, for example, are not necessarily the most important factors determining what the farmers may want in a particular system. It is important to first identify what the management objectives of the farmers are. For example, water conveyance or distribution may be the most important issues. (See Vermillion and Yabes for differences between farmers' and agency's criteria and Ambler for the influence of water rights.)

Mechanisms are needed which encourage a high degree of farmer participation. A simple forum for communication and negotiation between farmers and the design team is best. Rather than a large meeting where designs are discussed in the abstract, the discussion should take place at the site where stakes and strings could be used to mark dimensions. While at the site, farmers can easily relate past events such as floods and landslides that have bearing on the design.

Another practical suggestion is for engineers to use three-dimensional scaled models made from wood or styrofoam to give farmers a visual impression of how the structures would look. By presenting models representing different types of structures to perform a particular task, e.g., showing a model of a suspended aqueduct, a siphon, etc., for crossing a stream, the farmers can make the choice that best fits their needs. To make a good decision farmers also require a detailed explanation of the relative costs and operation and maintenance consequences.

Possibly the most effective means of communicating ideas about structures that farmers have not seen before is to take them on a visit to systems where such structures are in operation (farmer-to-farmer training). Farmers can discuss the operation and maintenance characteristics with other farmers and can then propose modifications that best suit their own conditions.

Design-Process Innovations

Transparent accounting. Opening the project accounts for inspection by farmers to reduce the misinformation that frequently disrupts field work is an obvious way to reduce conflict. It is included here as an innovation because it is so seldom done. (See Acharya and Bhattarai for a discussion of the importance they place on opening accounts for farmer inspection.) Several participants reported that open accounts (transparency in transactions) generate trust which reduces opportunities for local factions to make accusations that can divide the community or cause the farmers to mistrust the agency staff. Related to open accounts is the need to encourage and assist farmers to keep their own written records to reduce conflict over their internal transactions. This practice also enhances the farmers' ability to manage the system in the future.

Participatory rural appraisal. Participatory rural appraisal is a methodology for involving farmers in evaluating their problems and resources (see Thompson). Participatory rural-appraisal techniques need to be further developed for use in getting information about the farmers' past irrigation experience, management traditions, and knowledge of local hydrologic and stream-flow conditions.

User-labor mobilization. Insisting that irrigation users, rather than contractors, mobilize all of the labor for construction that they are technically competent to do has a number of positive results. These include: 1) constant feedback and modification of designs to meet local needs during the construction phase, 2) increased farmer experience in decision making and construction techniques that improves capacity for operation and maintenance, and 3) identification of ownership and willingness to continue full responsibility for managing the system.

Farmer-to-farmer training. A good communication tool for transferring irrigation design ideas and management concepts is to take farmers from systems that are being improved on a tour of other systems that are completed and operating. Where farmers can see structures that are operating and discuss with other farmers the advantages and problems of operation and maintenance of each structure, they readily identify what will work in their own system. From well-planned tours, farmers gain confidence and enthusiasm to implement what they have seen. Successful tours require a facilitator who is familiar with all aspects of the systems being visited and who knows what the visiting farmers face in developing their system. The facilitator does not lecture, but guides the two groups of farmers to ensure that all points are discussed by them.

THE DESIGN OUTCOME

Characteristics of Good Design Outcomes

The discussion highlighted a number of characteristics that identify a "good" design outcome. There was consensus that the following characteristics encourage cohesion among the water users and are supportive of high farmer involvement in routine operation and maintenance of the system.

Simplicity. Farmers need to be able to understand how their irrigation system works before they can operate and maintain it. If all users understand and accept the basis for water allocation they will assist in controlling the water distribution accordingly, thus minimizing conflicts with equitable distribution. In addition, the design needs to be simple so that all users can understand and participate in the operation -- not just the agency or certain water "guards," operators, or leaders. Many participants reported that simple structures and canal networks are more easily understood, managed, and maintained by farmers (see Ambler, Bruns, Pande, Reddy, Suprodjo, Wipat, Yabes). Vermillion and Suprodjo found that farmers prefer to minimize channel divisions and levels of network hierarchy.

Equity. The equity issue was not discussed at any length but surfaced frequently as a factor important to farmers in accepting a design outcome. The farmers' understanding of equity in a system has often evolved over a long period of time and usually reflects the water rights resulting from initial investment in the system. In some cases, equity in water distribution also accommodates differences in soils or topography. However, what farmers consider equitable among themselves often does not imply equal water to each farmer or equal water to each unit of land. Agency staff tend to see equity in terms of equal access to the irrigation resource and design structures on that principle. Nevertheless, if the design outcome does not reflect the farmers' rationalization of equity, conflict is likely to follow (see Vermillion, Yabes). On the other hand, there is concern that unjust access to resources may waste irrigation resources and should not be accepted automatically. Negotiation and agreement to allocation of water shares prior to providing assistance, with provisions in the design outcome for verifiable delivery of those water shares, are suggested steps for such cases (Ambler).

Affordability. Designing low-cost structures not only makes it possible to extend financial support to more systems, but it encourages mobilization of the users' own resources (Acharya, Bhattarai, Shrestha, Wipat). When the irrigators rather than an outside contractor provide the labor, farmers identify the irrigation facility as their own rather than that of the government and are better able and more willing to take care of the routine operation and maintenance.

Flexibility. Irrigation systems must respond to the changing needs of the water users, to existing social, physical, and technical parameters, and be able to adapt to future needs (see Acharya, Vermillion). The physical design must allow for flexibility in operation to accommodate high and low flows, rotation, crop water requirements, and flood/drought conditions (Ambler, Bruns, Oad and King, Ren Hongzun, Wipat). A good design can also accommodate multiple uses of irrigation water: agriculture, domestic, fishery, livestock, gardening, nurseries, tourism enterprises (see Bruns, Pande, Ren Hongzun, Sengupta). However, a physical system that can adjust to various requirements may need a high level of management, which in turn requires a high level of social cohesion, consensus, and confidence on the part of the water users.

Controllability. For farmer management to occur, the farmers need control over the water from the source to the fields. When farmers control the water distribution they are accountable to each other for their actions rather than to the government, which tends to make it less acceptable to steal or waste water. Lack of control leads to dependence on the agency for routine operation and maintenance (Abeyratne; Kariyawasam; Maurya, Ahmed, and Adewumi; Patil). Another frequent outcome when the farmers are not in control of the water is damage or removal of structures (Suprodjo, Vermillion). Simple structures using local knowledge and resources allow farmers to have greater control over operation and maintenance (see Bruns, Reddy, Wipat, Yabes).

Redundancy. A good design allows for use of multiple sources of water (see Reddy, Ren Hongzun). Vermillion found that farmers considered it important to use multiple water sources and to combine conveyance and drainage functions in the same channel. Slack/buffer (storage) capacity between blocks and main system or other irrigation systems should be considered to increase reliability (Patil). Farmer-designed structures tend to allow alternatives for temporary repair and continued operation even if there is partial failure. This concept needs to be incorporated in engineering designs.

Design Outcome Innovations

A number of design outcome innovations were discussed as being relevant for farmer management of routine operation and maintenance for specific environments.

Low density polyethylene sheet-lined tank. Lined tanks are used for storing water in extremely water-scarce areas of northern India (Pande). It is useful to install a tank of this type if water can be stored from one growing season to the next or if it will reduce conveyance losses. This has opened a range of new possibilities depending upon the quantity of water available from the source. In situations where hill-slope drainage and roof runoff can be stored (water harvesting), only high-value crops are feasible. However, if the source is a spring or small stream, temporary storage can improve the water conveyance efficiency, and if the water supply is adequate, provide irrigation in critical periods for cereal crops. An important example is the use of stored irrigation water for establishing rice seedbeds.

Water-proportioning weir. Another innovation which appears to have evolved independently in many countries is the proportioning weir for distributing water to users within the command area. It is useful if there is enough water available for continuous distribution at some level in the system and where there is enough gradient to allow small drops on the outlet side of the structure.

The proportioning weir is a simple device often made of wood. The openings have a fixed width to divide the discharge from a single canal into two or more lower-level canals according to the water rights of the users of each canal (Ambler, Yabes). The pattern of water rights may change over time as water is transferred among users to better reflect their needs, and openings in the weir need to be adjusted accordingly. In some systems the width of openings reflects many years of trial and error experience. Measurement of a few variables for a season cannot produce results of such accuracy. Careful analysis of the existing water rights as reflected by the weir openings must be incorporated into any improvements made in such a system if conflict is to be avoided. Advantages of the proportioning weir are that there is little variation in accuracy over a wide range of discharges, proportional division is easily verified, and it requires a low level of management for operation once it is installed and is operating successfully.

Standard diversion weir for northeast Thailand. In the flat to undulating topography of northeast Thailand, farmers traditionally have diverted water from small streams to adjacent fields using earth dams. Since these are frequently damaged, resulting in high maintenance costs, there is a desire to replace them with permanent structures (Bruns). A low-cost standard design structure was developed by the Khon Kaen University-New Zealand Small-Scale Water Resources Development Project to replace the earth dams. The design was based on the analysis of many

sites where dams had failed and by talking to villagers. Using a learning-process approach, new structures were built and revisited over a period of years to observe and learn about weaknesses to be corrected in the next weir built. In addition to costing much less than conventionally engineer-designed dams in the area, two of the main advantages of this standard design are the variable height crest -- using stop logs -- and a reduction in maintenance.

Modular precast concrete block weir for northern Thailand. Another innovation in diversion weir construction was inspected by participants near Chiang Mai, Thailand, as part of the workshop field visit. To assist farmers who were having difficulty maintaining traditional bamboo, wood, and stone diversions, a hollow concrete block was designed to be precast and then bolted together to form a diversion weir (Wipat). The precast hollow block is a 50-centimeter cube and weighs 145 kilograms. The precasting is done by the water users during the slack agricultural season using sand and gravel from the river. Assembly of the diversion is then done in stages as time and resources permit. This approach has allowed a very flexible design both in timing of construction and in the height of the diversion.

An Agenda for the Future

DISCUSSION DURING THE Workshop focused on identifying characteristics that contribute to effective design processes and outcomes. Successful design leads to appropriate system layout and structures which support high farmer involvement in routine operation and maintenance activities. As consensus emerged on experience and information already available and areas needing further investigation, the participants considered the next steps to be taken: further investigation, action research, and transfer of information to irrigation-agency staff responsible for planning and designing irrigation systems for farmer management. The following are some key issues and strategies that need attention.

INVESTIGATE THE VALUE OF FARMER-MANAGED IRRIGATION SYSTEMS

Few countries have attempted to gather statistics on the extent or impact of farmer-managed irrigation systems on their total food production. Many micro-studies have been done documenting productivity of individual irrigation systems but few in-depth macro-studies have investigated the extent and impact of these systems taken collectively. There was a call for proof of the value of farmer-managed systems at national levels. In many countries this will require collection of field-based data that identify individual irrigation systems. At a minimum, current land-use maps, aerial photos, and ground checks will be required for such an analysis since existing records do not include information about irrigation systems built and managed by farmers.

Evaluation of the economic benefits should include the value of the infrastructure created by the farmers. There should be comparative field studies of the economic costs and benefits of farmer-managed and jointly managed systems. Such studies are essential as competition for water increases and allocation among uses -- urban, industrial, irrigation systems built by government agencies -- increasingly becomes a problem.

Attention was brought to another area requiring study. While much study has been focused on the process of assisting and improving farmer-managed systems and developing methods for getting farmer participation in that process, few evaluations have been done on how this affects the performance of the irrigation systems. Has assistance caused the area irrigated to increase? Has the cropping intensity changed? Have yields gone up? Has there been a diversification of crops? Are operating costs lower? Have farmers been better able to operate and maintain the systems with less dependence on the government? Documentation of this is needed to influence policy and investment strategies.

COMMUNICATE THE LESSONS LEARNED

Much has been said about the sociotechnical nature of irrigation. However, with a few exceptions this important dimension has not found its way into the engineering curriculum that provides the basic foundation for training irrigation engineers. Improving the professional capacity of engineering graduates is one area of concern and in-service training of professional engineers is another. It was suggested that short-duration directed field studies and field-oriented training programs should be established to stimulate, support, and transfer the experience already gained.

Irrigation professionals should consider creating more national networks and professional societies such as TRIMNET to promote the exchange of ideas. An activity of the FMIS Network should be to foster these institutions and help establish regional links. An important function of newsletters and workshops that such groups support is to give professional recognition and acceptance to work farmers have done in creating irrigation infrastructure as "real" irrigation.

CONTINUE INVESTIGATION TO IMPROVE AND SUPPORT FARMER-MANAGED SYSTEMS

It was suggested that the FMIS Network should continue to seek ways to assist irrigation and donor agencies in identifying research and action priorities for farmer-managed irrigation systems. In addition to the communication role mentioned above, there is need in many locations to continue basic research and case studies, action research, and pilot projects that provide the policymakers and planners with ideas and information for formulating irrigation-development plans that include appropriate consideration for farmer-managed systems. Such programs must also examine the constraints engineers face -- rigid design requirements, inappropriate accounting rules, etc. -- in working with farmer-managed systems and provide information that allows development of practical solutions.

Workshop participants emphasized that the research must document actual farmer operation and maintenance practices. In addition to identifying problems, possible solutions must be proposed. Research to distinguish among the major different types of farmer-managed systems and then analysis of how each type performs the basic irrigation tasks (i.e., principle analysis as referred to in the introduction to the issues), were proposed as a way to more quickly identify appropriate designs within types.

In order to improve the design process, ways must be found to ensure that agency staff do not lose power, prestige, and perks in assisting farmers to improve their own systems. Recognition and promotion for those who are effective must be built into programs. Documenting success stories to show the impact of improving farmer-managed systems, sensitization field tours, incentives for those who take risks rather than reprimand are a few examples of positive action to accomplish this.

Papers Related to Design Outcomes

Summaries of Papers

Irrigation-System Design and Management in Mountainous Areas

Ramchand Oad and Phillip King (Page 25)

This paper evaluates designs used in mountainous areas of Himachal Pradesh, India, in relation to designing systems that can be managed by farmers and that can maintain the existing property relationships. Recommendations are offered for designs that could encourage local management and for formulating appropriate water-distribution schedules.

The Influence of Farmer Water Rights on the Design of Water-Proportioning Devices

John S. Ambler (Page 37)

Various designs for improved water-proportioning devices that can distribute water according to the changing needs of the water users and which reflect their water rights are discussed. In addition, designs that can accommodate to fluctuations in flows are presented.

Institutional Support in Design and Funding of Small Farmer-Owned Irrigation Tanks in the Central Himalayas in Uttar Pradesh, India

U.C. Pande (Page 53)

The rationale and procedure for constructing a low-density polyethylene-lined tank for conservation of water are explained. The tanks are easily constructed with local labor, low cost, and can be used to provide water for many purposes.

Low-Cost Assistance to Small Farmer-Managed Irrigation Systems
Lila Nath Bhattarai (Page 63)

This paper describes the author's experience as a consultant to a project that implemented low-cost assistance to existing farmer-managed irrigation systems in Nepal. Farmer involvement in the rehabilitation process from the very beginning, with the objective of enhancing the ability of the farmers to manage the system after rehabilitation, was given high priority.

A Prefabricated Modular Weir
Wipat Kiwanon (Page 77)

The construction and use of concrete blocks that are bolted together into walls to form a weir are described. The design is recommended by the author because of its simplicity, versatility, and flexibility, and because it utilizes local participation and resources for construction. The design has been used in northern and northeastern Thailand.

**Analysis of the Causes of Damage to Canals and Structures
Related to the Pattern of Tertiary Networks**
Suprodjo Pusposutardjo (Page 89)

The author examines the causes of damages to tertiary-level structures and proposes a range of values for optimal ditch density and structure density that can better meet the needs of the water users and can reduce damage.

Irrigation System Design and Management in Mountainous Areas

Ramchand Oad and Phillip King¹

INTRODUCTION

THE FUNDAMENTAL FEATURES of irrigation development in mountainous areas -- small scattered land parcels with steep and unstable slopes -- create both the need and opportunity for a strategy in which local people assume greater control and responsibility for irrigation management. The dilemma of irrigation design and management is: how can the government agencies provide assistance to the farmers without eroding local initiatives for managing the irrigation structures and related facilities? This paper seeks to investigate the system design and management relationship by analyzing research data from irrigation schemes in the northwest Himalayas.

The research reported in this paper is based on the premise that desirable engineering designs must support the creation of a social basis for local participation in irrigation management (Coward 1984). This means that the designs must improve irrigation in a way that increases farmers' ability to match main system water deliveries to crop water requirements. And, the system designs must create or maintain the existing property relationships among local people through their tertiary irrigation facilities.

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Approach of the Analysis

A primary objective of the system designs and control structures is to help farmers better manage their irrigation enterprise. However, the engineering designs may alter the existing property rights which the local people acquire in irrigation-related facilities (Coward 1986). With these concerns in mind, Uphoff et al. (1985) suggest that irrigation management analysis can be approached from any of three perspectives: 1) how water is managed, 2) how the structures that control water are managed, or 3) how the activities of users and agency personnel are managed.

To analyze the relationship between irrigation-system design and implications for management, we have used the first perspective that focuses on the water needed for production. The paper analyzes the engineering designs used in the mountainous areas of Himachal Pradesh to capture, allocate, and distribute irrigation water among the water users. The emphasis of the analysis is to evaluate why these designs may or may not help farmers better manage the irrigation systems. Improved engineering designs for encouraging local people to participate in irrigation development and management are then identified.

The Irrigation Setting

The state of Himachal Pradesh in India is a mountainous state located in the transition zone between the plains and the high Himalayas. The land elevations range from 400 meters (m) to 7,000 m above mean sea level. Much of the land is characterized by small narrow valleys, steep hillsides, and intensive farm terracing for agriculture. Because of the mountainous topography, approximately ten percent of the land area is cultivated. However, about 80 percent of the population derives income from agriculture. Population pressure on the land area is high, and the landholdings of most cultivators are small, about one hectare (ha) each.

Irrigation in Himachal Pradesh has been practiced by farming communities since early times. However, the scale of irrigation development and use is modest. In 1983, the Irrigation and Public Health Department reported an irrigated area of 136,000 ha, about 20 percent of the total cropped area. The high population pressure has resulted in an increased emphasis on the part of the state government to develop and efficiently manage irrigation facilities for increasing land productivity. The Hill Areas Land and Water Development (HALWD) Project plans to construct about 150 irrigation schemes to provide water for 15,000 ha of agricultural land. The HALWD Project (1984-1991) is jointly sponsored by USAID and the Government of India.

Water for irrigation is usually obtained by surface diversion from small mountain streams, and in limited cases by lifting it from major rivers such as the Sutlej and the Beas. In the southwest plains zone of Himachal Pradesh, groundwater is an important source of irrigation water. The average annual rainfall is about 1,130 millimeters (mm), of which about 75 percent occurs during the monsoon months from June to October and the remaining 25 percent occurs in the dry season from November to March.

In the main rainy season, the principal crop is maize with some rice. In the dry season, the principal crop is wheat with secondary crops of barley, pulses and oilseeds. With irrigation facilities, vegetables are very popular, particularly if they are out of season in the plains areas.

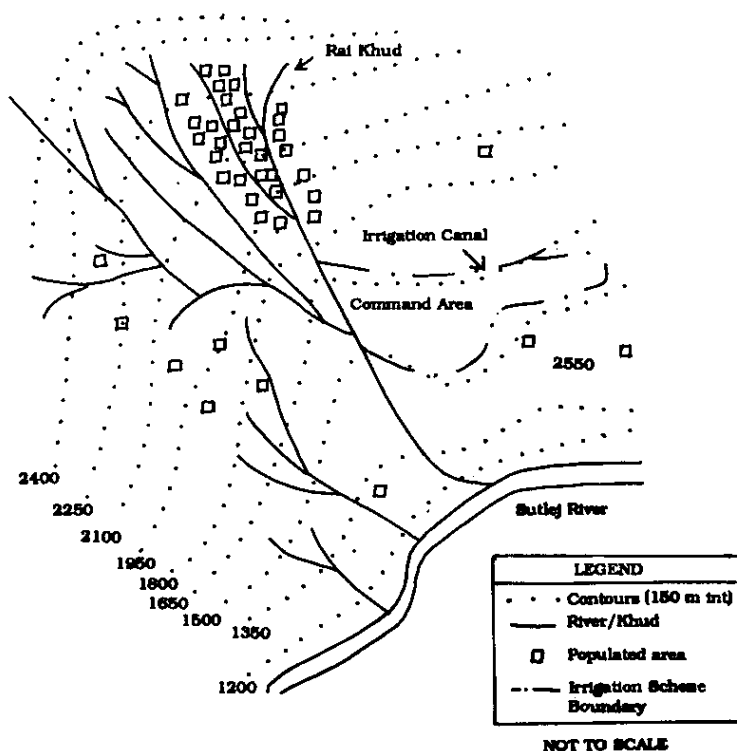
Fruit-growing has developed into a major industry in the state with apple as the lead fruit followed by plums, pears, peaches, and citrus.

DESIGN AND MANAGEMENT ISSUES IN GRAVITY-FLOW-IRRIGATION SCHEMES

Location

The gravity-flow-irrigation scheme A (Figure 1) studied in this research is located about 20 kilometers (km) northeast of Rampur city. The topography is very rugged and steep with slopes of about 50 percent. The land elevations rise from 1,000 m at the River Sutlej to about 1,700 m near the main canal intake. Irrigation scheme A diverts water from the Rai stream (locally called khud) which is the source of water for three other irrigation schemes.

Figure 1. Location of Irrigation Scheme A.



Note: int. = intervals

Design of Water-Capture System

Water from the Rai is captured by a surface diversion weir to irrigate about 85 ha of land. The diverted water is conveyed to the agricultural lands by a main canal. The design discharge of the main canal is 60 liters per second (liters/s)(2.2 cubic feet/s). The catchment area of the Rai is characteristic of other catchment areas in the sense that it is deforested and eroded. As such, the streams in the catchment area have high peak runoffs and low base flow. During the time of peak runoff, the diversion weir is often swept away, and is periodically rebuilt by the Department of Irrigation and Public Health.

We must recognize that any suggestions for improved diversion works in unstable mountain streams will have limited value without proper management of the stream-catchment areas. To design and construct stable diversion works in the mountain streams is expensive because of the extremely high flood flow compared to the base flow. To reduce the peak flow, the land surface in the catchment areas should be covered with grass and an effective tree cover must be developed. The local people have old rights to cutting timber and grazing animals in the catchment areas. The Departments of Forest and Irrigation need to work jointly with the people living in the catchment areas to reduce peak surface runoff and soil erosion.

Presently, the local people take their animals for watering to the river using the gullies as a walkway. Also, the gullies are used to slide timber logs down the mountain. The use of gullies as a means of transportation for animals and timber prevents the Forest Department from terracing and stabilizing the natural gullies. A local source of water for animals can be provided by constructing small ponds that will check surface runoff and store water in the catchment areas. These ponds will be very effective in reducing peak runoff and associated soil erosion from the watersheds.

A simple modification to increase the stability of the presently used gabion-type diversion dam in high velocity conditions is to bind the stones together by cement grouting. The grouted dam is a rigid structure, and its stability can be further improved by giving the dam profile an arch. The arch dams are inherently more stable against sliding and overturning as compared to a straight profile normal to stream flow.

Design of Water-Conveyance System

In irrigation scheme A, the diversion dam was completed in early 1987, yet water was not delivered to the farmers. All physical facilities and water were in existence except for a 50 m length of the canal located near the intake. A landowner refused to allow construction of the canal through his property until the government paid compensation for the land area.

This is an example of a common and complex issue facing irrigation development in Himachal Pradesh. The state policy is that the irrigation facilities developed by the Department of Irrigation and Public Health are property of the state. The development approach creates new government property and not water users' property. Hence, farmers are left without a sense of ownership or responsibility in the irrigation scheme. The landowners reported that they were not involved in the design and construction of the irrigation scheme; the majority of them came to know about

the project when the construction began. The local people were confident that their suggestions must be sought for the location of the diversion dam, alignment of the main canal, and the location of outlets for water delivery to the farmers.

The location and design of the outlet structures which deliver water to the farmers have important implications for subsequent management. The location of the outlets defines groups of farmers that must share water from a common field channel and maintain the channel and other control facilities. The engineering design of the outlet structure largely determines if the water users can regulate the flow discharge or if it can be regulated only by government-agency personnel.

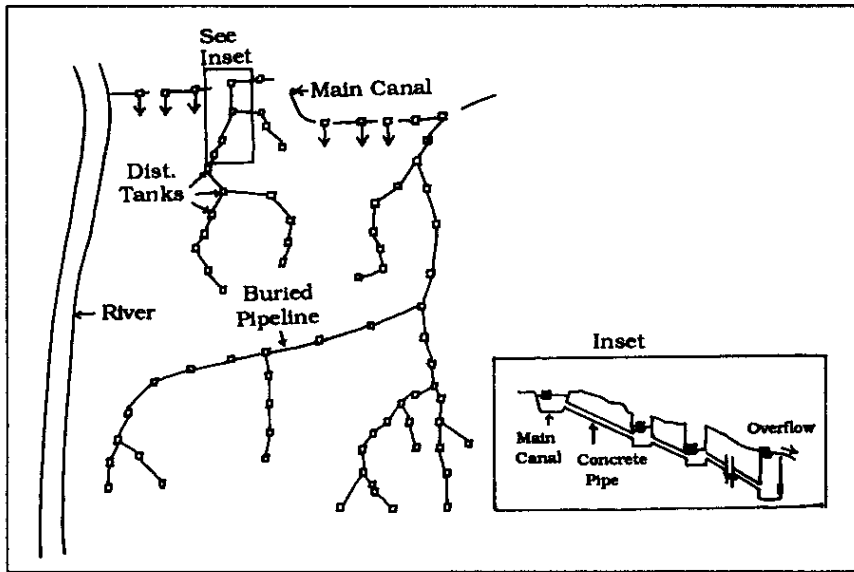
The outlet structures regulate discharge by establishing the condition of hydraulic control. There are basically two forms of hydraulic control, weir control and orifice control. In weir type control, the discharge through the outlet structure is a function of water level in the parent canal, in this case, the government canal. The structure does not respond to the hydraulic conditions in the offtake canal (farmers' channel), and as such, discharge through the structure cannot be regulated by the water users.

When the outlet uses a submerged orifice (a sluice gate is a gated orifice), the discharge through the structure is a function of water levels in the main canal and the offtaking farmers' channel. Therefore, the outlets using submerged orifice control provide better opportunities for user participation in the management of irrigation schemes. It should be recognized, however, that the greater flexibility associated with the sluice gate can be misused by changing hydraulic conditions in the offtaking field channel. The positive use of the management potential created by the sluice gates inherently requires a higher level of local organization and participation.

Design of Water-Distribution System

The design of the water-distribution system in mountain areas is challenging because the lateral distribution lines will have a steep slope (as high as 60 percent slope in irrigation scheme A). The distribution lines cannot be open channels and the experience with sprinkler pipe systems is limited. A common design adopted for water distribution to the farmers in many irrigation schemes, including scheme A, is shown in Figure 2.

Figure 2. Water-distribution network in Irrigation Scheme A, showing outlet tanks.



Water from the main canal is delivered to the farmers by means of concrete pipelines; each pipeline has a number of tanks situated on it. Each tank serves one landholding of about 0.5 ha. The original design envisioned water to rise in all the tanks on a pipeline so that farmers could apply it to their lands by means of siphon tubes. In practice, the design has major physical and organizational problems. The number of farmers, and therefore that of the tanks, on some lines range from 50 to 100. Because of the large number of farmers and no control valves anywhere in the pipelines, it is very difficult to organize rotational distribution of water.

Also, because of the steep slope, water rises only in the tank which is plugged on the exit side (last tank on a rotation) and then spills from this tank (Figure 2 inset). In all other upstream tanks, the water level remains too low for the farmers to use their siphon pipes. When water is available in the main canal, farmers with adjacent landholdings put pipes in the main canal and convey water to their lands. Farmers whose lands are down-slope either do not get water or it flows to them via their up-slope neighbors.

An alternative design for water distribution in mountain areas is to use a set of contour channels oriented parallel to each other down the slope. These parallel contour channels can receive water from the main canal by means of a chute, buried pipeline, or as is the case in scheme A, through a natural stream or depression. Farmers can take water from the channels by means of flexible rubber pipes for application to their lands.

The idea of using parallel contour channels in hill areas is not entirely new if we consider experiences in other countries. It is extensively used in the community-managed small irrigation systems of Java (Oad and Levine 1985) and Nepal (Yoder 1986). The distribution system consisting of two or three parallel contour channels divides the overall command area into small channel commands and as such management of rotational water distribution is possible. The

physical structures are simple (open channels) and can be maintained by the farming communities without continuous external help. Also, irrigation water can be efficiently used because the lower channels will pick up a significant portion of the surface and subsurface flow from the higher lands.

Formulating Water-Distribution Schedules

The design objective of formulating water-distribution schedules is to provide a pattern of water supply to the farmers that is logical and has a good probability of being useful. At present, the water duty (flow rate per unit land area) and irrigation interval are derived from experiences in the plains areas of India. This practice is inappropriate because the assumed water duty is for heavy textured soils and deep rooted crops. The logical approach to estimating irrigation interval and water supply rate is to use measurements of: 1) water retention in soils and release for plant use, and 2) crop water requirements.

Soil moisture retention and release for plant use determine the readily available water (RAW) that can be stored in a given soil type. The crop water requirement (CWR) is the quantity of water used daily by the growing crop. The combined knowledge of the two allows us to calculate the irrigation interval and the water duty:

$$\text{Irrigation interval (days)} = \frac{\text{RAW(mm)}}{\text{CWR(mm/day)}}$$

$$\text{Water duty (liters/s)} = \frac{\text{RAW(mm)} \times 10,000 \text{ m}^2/\text{ha} \times 1,000 \text{ liters/m}^3 \times A(\text{ha})}{1,000 \text{ mm/m} \times 3600 \text{ s/hr} \times T(\text{hr})}$$

T is the time duration of an irrigation event in hours and A is the irrigated area in hectares. The use of the above formula is illustrated below by applying it to irrigation scheme A.

Soil type is predominantly silt loam.

Total available water, TAW = 120 mm/m.

Effective root zone for vegetable crops is taken to be 0.3 m.

TAW for 30-cm root zone = 120 mm/m \times 0.3 m = 36 mm.

Readily available water, RAW = 0.7 \times 36 mm = 25 mm.

Crop water requirement, CWR, using Blaney-Criddle method is:

$$\begin{aligned} \text{CWR} &= f_c \times t \times \frac{p}{100} \\ &= 0.8 \times 81 \times \frac{9.7}{100} \\ &= 6.3 \text{ inches/month, or } 5.2 \text{ mm/day.} \end{aligned}$$

In this equation, f_c is the mean crop coefficient for vegetables over the entire growing season, t is mean monthly temperature in degrees Fahrenheit, and p is percentage of sunshine hours for the location of the scheme area. If we neglect rainfall, irrigation interval is:

$$\frac{\text{RAW}}{\text{CWR}} = \frac{25 \text{ mm}}{5.2 \text{ mm/day}} = 4.8 \text{ days} = \text{about } 5 \text{ days.}$$

If we consider a mean minimum monthly rainfall in May = 26 mm = about 1 mm/day.

$$\begin{aligned} \text{Irrigation requirement} &= 5.2 \text{ mm/day} - 1 \text{ mm/day} = \text{about } 4 \text{ mm/day, and} \\ \text{Irrigation interval} &= \frac{25 \text{ mm}}{4 \text{ mm/day}} = 6.2 \text{ days} = \text{about } 6 \text{ days.} \end{aligned}$$

The design irrigation interval used by the Department of Irrigation and Public Health is 12-15 days for vegetable crops and 21 days for maize. Farmers reported that to grow vegetables they must have irrigation water once every four to six days. From our elementary soil-water-plant analysis, it is evident that the present design criteria are not realistic, and as such do not create a basis for the farmers to effectively use the irrigation water.

DESIGN AND MANAGEMENT ISSUES IN LIFT-IRRIGATION SCHEMES

Location

The site for future lift-irrigation scheme B studied in this research is located in the district of Hamirpur, near the town of Nadaun. The landslopes characteristic of the Beas River valley are gentle compared to the steep slopes of the Sutlej River valley (including the Rampur area). The majority of the soils in the scheme area are of silty clay loam texture and are fertile and deep. Presently, approximately 95 percent of the area grows rain-fed low-value crops such as maize and wheat. The remaining area grows vegetables which are irrigated by water from hand-dug shallow wells. These wells are concentrated adjacent to the river banks.

Design of Water-Capture System

Irrigation scheme B is proposed to be a lift irrigation scheme. The water is to be pumped from the Beas River against a lift of about 40 m to irrigate approximately 100 ha of agricultural land. This lift is low compared to those involved in other parts of Himachal Pradesh where lifts of 100-150 m are common.

When water is pumped from major rivers such as the Sutlej and the Beas, two difficulties are encountered: the river water levels fluctuate by 10 to 15 m between the low and high stages, and the water carries a heavy sediment load. Under these conditions, the physical structures for water capture are bound to be sophisticated and expensive and yet may not be reliable. In irrigation scheme B, we have a most fortunate situation in that the river water level fluctuation is only six meters. Even then the cost of making the intake structure and installing pumps was estimated to be about US\$1,000/ha. The best internal rate of return estimate was 12 percent and the benefit/cost ratio was projected to be 1.1.

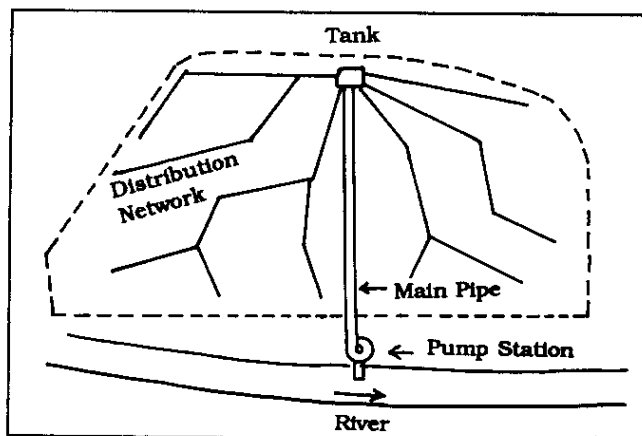
The primary reason for mentioning the numbers is to present the argument that it is extremely hard to economically justify irrigation schemes which lift water from uncontrolled major rivers. A better sequence of development -- which is not an option for the HALWD Project -- would control river water levels by major dams upstream, and then capture water for irrigation, power generation, and other purposes. Presently, with all the involved expenses, the irrigation schemes do not provide a reliable source of water. In the Nadaun area, we also studied four completed lift irrigation schemes. In two of the irrigation schemes, river water level was too low for water to be lifted by the centrifugal pumps. In the other two, actual irrigated area was not more than 15 ha as compared to the design irrigated area of about 100 ha.

A possible option for irrigation-water development in the River Beas basin may be to tap the river water through subsurface flow. Pump wells can be set very near the river bank to draw the river water through the subsurface aquifer. This method should not require the use of expensive surface structures and the subsurface flow will result in sediment-free water. It would require a careful design and management of the filter material surrounding the well pipe to avoid clogging of the entry holes.

Design of Water Conveyance and Distribution System

The command area in lift irrigation schemes is usually an inclined plane with slope towards the river. The existing design practice for water distribution is to lift all required water to a single point at the top of the command area (Figure 3). At this highest point, a distribution tank is made and water is distributed to all farmers from this tank.

Figure 3. Existing distribution system for lift irrigation.

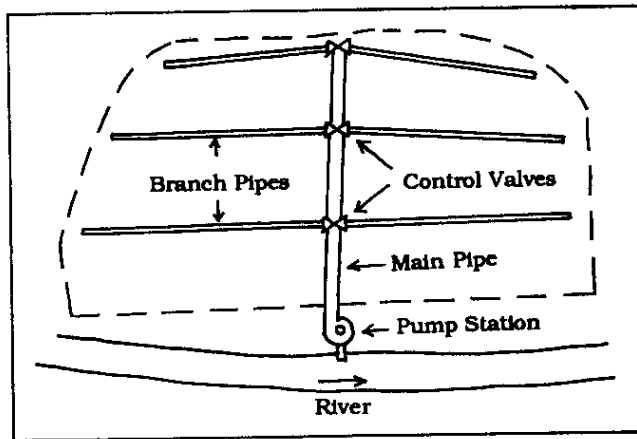


The design approach results in long distribution lines involving many farmers on each line. It is very difficult for the farmers to organize for water distribution and some farmers end up being far away from the water source (the distribution tank). In irrigation scheme B, the most fertile area along the river bank will be about three km from the distribution tank. Also, the system design results in high energy costs to operate because all water is raised to the highest point.

A better design for effective farmer participation and management should disaggregate the command area into small distribution units. These units can then be supplied irrigation water on a rotational basis. To accomplish this management objective, branch pipes should take water at suitable intervals from the main riser pipe (Figure 4). Each branch pipe delivers water to one distribution unit with a control valve at the intake point.

In addition to simplifying water distribution among farmers, the design can greatly decrease the energy costs for pump operation. In the proposed design for irrigation scheme B (Figure 4), water will be lifted through the total rise only one-third of the total rotational time. It will be lifted to one-third of the rise for 33 percent of the time, and to two-thirds of the total rise for the remaining 33 percent of the time. As such, the energy costs will decrease by a factor of one-third.

Figure 4. Proposed lift-irrigation distribution system, using variable lift pumping.



The reason for the existing design (Figure 3) is the incorrect belief that pumps can only operate at one head, so all water must always be lifted to one point. This is not true, because pumps merely react to the actual system head and discharge conditions. A pump designed for a certain head can be operated efficiently to deliver water at variable heads. The affinity laws (James 1988) governing pump performance state that pumping head (h) is related to impeller speed (n) as follows: $h_1/h_2 = [n_1/n_2]^2$.

As such, small changes in pump speed will result in large changes in energy head. The pump speed can be changed by using variable speed drives on motors or by installing variable frequency drives on the electric motors. The variable frequency drives change the motor speed by changing the electric cycles. It should be noted that early pumping technology in the U.S.A. also used pumps at constant discharge or constant head. With the rise in energy costs, the use of variable speed drives on motors and variable frequency drives has become desirable.

LESSONS LEARNED

The dilemma of irrigation development in Himachal Pradesh is similar to that in many other Asian regions -- how can government agencies provide assistance to the farmers without eroding local initiatives for managing the irrigation facilities? The studies conducted in Himachal point out that the engineering designs used by the government agencies are critical for sustaining effective farmers' groups at the local level.

The engineering designs must increase farmers' ability to match irrigation deliveries to crop water requirements, and should maintain the integrity of local property values. The consideration of property values in mountain areas is particularly important because of the small land base and high population pressure. To provide a reliable irrigation supply in hill areas is a design challenge because of large flow variations in mountain streams and rivers, heavy sediment load, steep hillsides, and erosive soils.

In the development of gravity flow irrigation schemes, engineers should seek information from the local people on stream flows, canal alignment, and the location and type of outlet structures. The canal alignment directly affects some farmers' landholdings. The farmers must be involved in these decisions, otherwise conflicts arise during the construction phase. The location of the outlet structures requires local participation because the design defines farmers' groups that must share water and maintain a common watercourse. The engineering design of an outlet will determine whether water users can or cannot regulate discharge through the outlet.

In lift irrigation schemes, the existing designs pump all irrigation water to a single highest point and then distribute water among farmers from this point. The design results in high energy costs and is difficult to manage for equitable water distribution. Instead, the pumping plant can be designed and operated to lift water to multiple elevations. At these supply points, branching pipes can take water from the main pipe and deliver it to various groups of farmers.

For irrigation water distribution among farmers, principles of soil-water-plant relationships must be used to formulate distribution schedules. Using these principles, irrigation engineers can formulate water-supply schedules that are realistic and can be useful for the farmers. The present designs use water duty and irrigation intervals which are based on experiences in the plains areas, and are not suited for crops and soil conditions of the hill areas.

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The Influence of Farmer Water Rights on the Design of Water-Proportioning Devices

John S. Ambler[§]

FARMER WATER-ALLOCATION SYSTEMS: REFLECTIONS OF WATER RIGHTS

WHILE THE PHYSICAL infrastructure of irrigation systems often draws most attention, the complexes of structures and rules that enable water to be systematically conveyed and applied to fields can also be analyzed in terms of property rights (Coward 1985). Water rights are often related to investments in the original construction of the system and its subsequent maintenance. In some irrigation systems water as property is highly articulated, while in others there may appear to be little codification. The degree to which rights (property) and responsibilities (investment in property creation) are correlated depends in large measure on the presence or absence of factors that promote solidarity among the irrigators and on water supply itself.

One of the most powerful forces for creating solidarity is the process of investing in the creation and maintenance of a system's physical structures. Labor, especially when performed communally, creates a social contract by which each irrigator both claims a portion of the water available to the system and agrees to acknowledge the claims of others. Working for months or years to build a new canal or sweating all day to clear a landslide on a canal some kilometers from home are onerous tasks irrigators in mountain systems frequently face. But these burdens also provide irrigators the opportunity to invest in the system and to claim or relegitimate claims to water.

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The effect of labor investment on the creation of water rights can be most clearly seen in how farmers divide water in new systems. Yoder and Martin (1986) and Sutawan (1983) have noted that in Nepal and Bali, respectively, when considerable labor is needed for constructing a new system, water is apportioned in the form of shares among the farmers who built the system according to the labor each contributed, not according to the irrigable area each owns.¹ Similarly, we can find cases, even in systems with generations-old rules for water distribution, where "traditional" water shares may be reapportioned if major new investment is needed.²

Subsequent investment in the maintenance of the system is also needed to preserve those property rights, as is evidenced by the strict sanctions, including suspension of water delivery, that farmers in many areas are subject to for failure to provide the required labor for system maintenance. Maintenance duties in these systems are usually proportional to water shares, not to land area (e.g., Leach 1961:165).

Farmers have developed mechanisms for realizing and verifying their hard-earned water rights. One common solution is to divide the total water available to the system into shares. To do this, farmers often use a small structure to act as a proportioning water-division device. Thus, the device is not merely an engineering structure but also a reflection of social organization and property creation.

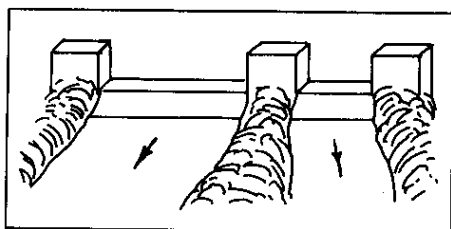
BASIC PRINCIPLES OF PROPORTIONING WATER-DIVISION DEVICES

Proportioning water-division structures divide water in a canal into two or more parts that correspond to the water shares due to each farmer or farmer group served by the branching canals. The proportioning device is usually a wooden block with rectangular notches. The structure is linear and is placed level in the canal perpendicular to the flow of water. Figure 1 illustrates a common design -- in this case showing a left canal that receives twice as much water as the right canal.

¹ In some systems, farmers later buy or sell water shares as they learn whether they have insufficient or excess water for their land area, soil type, crop, and cultivation techniques. See, for example, R. Yoder et al. 1987.

² One example from Bali is the Sungsang irrigation system which had well-defined water rights for each irrigator. After spending 13 years excavating a new irrigation tunnel by hand, the farmers revised the old water shares and reallocated shares based on each farmer's labor and cash contributions to the huge effort. See Sutawan 1989b.

Figure 1. Proportioning water-division device.

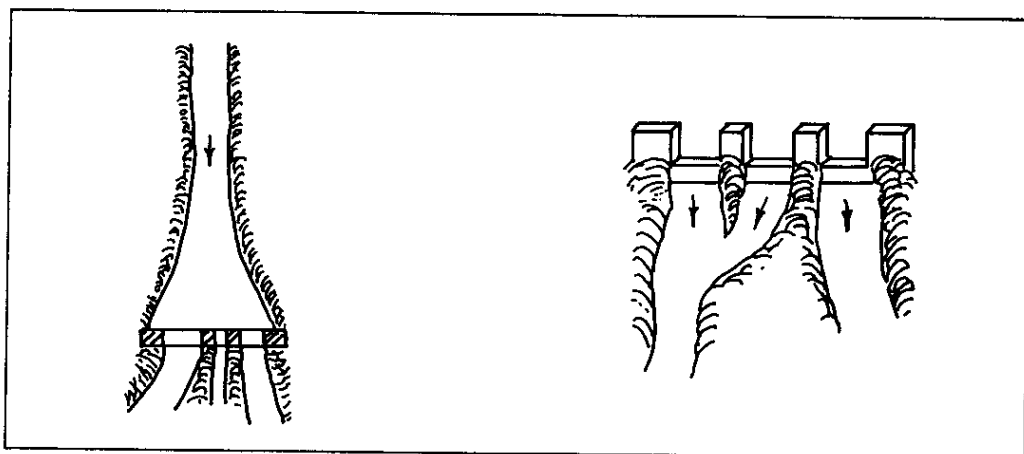


Several features distinguish linear proportioning structures. First, the notches in the wooden block are usually cut square and to the same depth.⁵ Keeping the sill level of each opening equal means that only one dimension, the width, needs to be calibrated to divide the flow correctly.

Second, farmers know by experience that water flows faster in the center of the current than at the edges and that the smaller the opening through which water flows, the greater the proportional energy loss due to friction. Farmers employ various mechanisms to compensate for the unequal energy of water as it flows in the channel and through slots of different sizes. One method, topography permitting, is to place the device in a straight stretch of canal with a stilling pond in the canal to distribute the water's energy more evenly as it approaches the division point (Figure 2) (Yoder et al. 1987:43; Lieftrinck 1969:59). Another method found in west central Nepal is to make all the slots of equal dimension but to rejoin two canals to make the proper proportions (Figure 3) (U. Pradhan 1989). A third is to make openings in the center of the canal slightly smaller than those near the edges of the canal (Dani and Siddiqi 1989:77).

Figure 2. Use of stilling pool on approach to division device (top view).

Figure 3. Use of multiple orifices to proportion water more precisely (division 2:1 shown).



⁵ In cases where large amounts of water need to be divided the apertures may be cut to different depths but for smaller canals the thresholds are cut to the same level.

Third, the structures are often positioned so that flows in the canal downstream do not affect the water proportions at the device. They are placed where a drop allows water to fall freely through the openings.

Thus, despite their simple appearance farmers often employ considerable engineering sophistication in sizing the openings in the proportioning devices. In older systems this fine-tuning may be the result of early experimentation and today's farmers may take the system for granted.

Advantages of Linear Proportioning Devices

The proportioning device is meant to be *automatic*. Thus, although changes in discharge in the canal will cause slightly different head loss conditions in openings of different widths the proportioning structure still divides water into roughly the same shares whatever the flow. And, farmers receive the same shares automatically thereby nearly eliminating the need to adjust the device as water levels in the canal fluctuate. This marks a major advantage over "modern" turnouts in which the sills of the lateral orifices are higher than that of the center opening. In such structures, farmers on the laterals may be left without water when flows are low. A common, "unauthorized" response to this situation is for farmers to partially dam the center opening in order to raise the water to allow it to flow into the laterals.

Because of the square slots and level sills in proportioning devices farmers can also verify visually whether water is being divided properly, reducing both guesswork and opportunities for conflict. Visual verification can be extremely difficult with division boxes using uneven sill levels or circular or semi-circular orifices (Sutawan et al. 1983:207-8).

Furthermore, because these proportioning devices are usually wooden the widths of the notches can be adjusted. Slots can be widened by cutting or narrowed by nailing a board to the inside wall of one of the openings, as when water shares are traded or as farmers gain experience with the operation of the system and decide that new proportions are needed. Thus, they are adjustable but also rigid enough to discourage capricious modification.

Finally, the structures are inexpensive to construct and maintain.

Disadvantages of Proportioning Devices

The use of traditional proportioning devices throughout the canal network is ideally suited for continuous flow regimes where current fluctuations are low. Blocking an opening under a rotation regime is sometimes done when flows are very low (Yoder et al. 1987:61-2) or when consumptive demand is high, such as at land-preparation time but this can be awkward. Adjusting flows for diversified cropping systems is equally cumbersome.

The use of a proportioning weir sometimes requires more land for canals than would be necessary if a standard division box were used. Because the structure works best where there is a drop it is sometimes placed farther upstream than a rectangular turnout would normally be. Thus, it is common to see two or more canals running parallel for a distance below the

proportioning device before diverging toward their respective destinations. However, farmers may be willing to sacrifice some land to gain the advantages mentioned earlier.

Fixed proportions may also not necessarily be the best solution when water is abundant. With high flows, each opening receives roughly the same proportion of the total, whether it needs that much water or not. In some cases this may lead to flooding of certain head-end plots while depriving tail-end extension areas. This deficiency may be overcome through design modifications suggested later in the paper.

Negotiating the dimensions of the notches in the proportioning devices is also not an easy task. Arriving at the correct dimensions for each structure entails considerable negotiation and a level of social cohesion among irrigators that are not possible to achieve under all circumstances. The early history of proportioning systems is usually marked by a period of experimentation with the shares to ensure that each farmer who has invested in the construction of the system receives his/her fair share. This requires a capacity for negotiation and compromise that may involve all the farmers in the system. Reaching closure on contentious issues like water division is often not possible where large numbers of farmers are involved, where farmers have not been united in the common task of building and maintaining the system, or where farmers are divided by various social cleavages.

“Partially Proportioned” and “Fully Proportioned” Systems

In some irrigation systems proportioning-division structures are located only at important canal branches while other means are used to divide water at lower levels. These may be termed “partially proportioned” systems. However, the most articulated use of proportioning-division structures is that in which every farmer’s holdings are served by a terminal canal (i.e., there is no field-to-field irrigation between farmers in the system), and every branch in the canal network is equipped with a proportioning device. Water rights in these “fully proportioned” systems are highly developed and tend to be correlated with the combinations of water supply and conveyance conditions described below.

“Fully proportioned” systems are found in many areas of Asia, in systems ranging from under 5 ha to over 500 ha (Ambler 1989:414; Sutawan 1989:20). Each group has its own name -- most apparently linguistically independent -- for these proportioning devices, suggesting independent invention. The areas in which they have been reported (west central Nepal; Bhutan; Himachal Pradesh, India; Hunza, Pakistan; north central province of Sri Lanka; northern Thailand; Ilocos Norte, the Philippines; and Indonesia) are all mountainous. Climate in these regions ranges from arid cold to humid tropical.

TOPOGRAPHICAL AND WATER-SUPPLY CORRELATES

Fully proportioned systems usually face one or more major physical constraints that make water a precious commodity. First, the labor requirements for maintaining these systems are usually quite burdensome. Apart from labor investment in the original construction of the system, each farmer may spend 20-30 days or more per year just keeping the system in running order (Martin 1986). Second, water supply for the command area is usually limited.

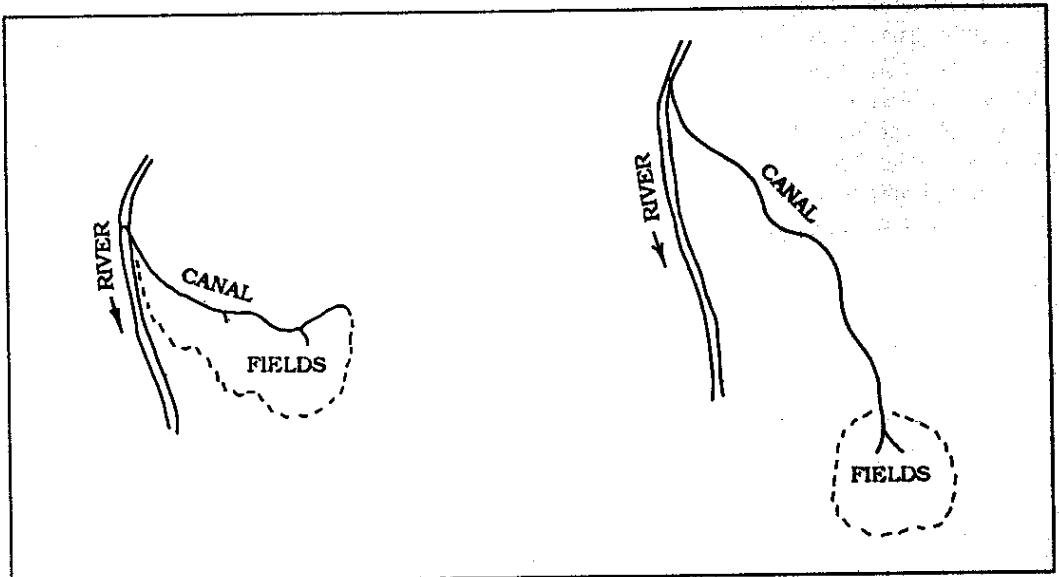
Importantly, however, relative water supply for the system at the headworks is not always the strongest influence on the choice of whether to divide water with proportioning devices or not. There are many examples of irrigation systems in which farmers do not use proportioning weirs, despite a low relative water supply. For example, when the uppermost fields are located near the headworks head enders may abuse this advantage by taking a disproportionately large share of water. If head enders are able to divert water with impunity, tail enders may receive little water, even if water supply for the system is high. A typical configuration of canal and irrigated land in this case might look like that in Figure 4.

In fully proportioned systems relative water supply for the system as a whole may or may not be low, but acquiring and conveying that water to the fields represents a major physical challenge. The weir may be a brushwork construction that often washes out. The canal may snake along steep sides of a ravine or precarious mountain slopes, losing water all along the way. The water that finally does reach the command area has become a highly valued commodity and is carefully divided. A typical configuration of canal and command area is shown in Figure 5.

The key difference between Figure 4 and Figure 5 is that in the latter large amounts of labor are required to keep the headworks and/or main canal operating. In fully proportioned systems, labor must be frequently mobilized to repair the headworks and/or to maintain the main canal.

Figure 4. Configuration of main canal and fields in which the use of proportioning water-division devices is unlikely.

Figure 5. Configuration of main canal and fields conducive to the use of proportioning devices.



The influence of this need for labor on the choice of water distribution method can be seen in Table 1, showing comparative data on 178 small irrigation systems in a region of West Sumatra, Indonesia. Here the critical dimensions are 1) conveyance losses from the headworks to the command area and 2) the relative water supply for the system.

Table 1. Relationship between water supply and conveyance losses on the choice of proportioning water-division devices.

Supply and conveyance conditions	Number of systems		
	Uses no device	Uses device at only selected branches	Uses device at all branches
HWS, LCL	118	12	0
HWS, HCL	12	4	6
LWS, LCL	10	4	0
LWS, HCL	0	0	12
Total	140	20	18

Notes:

HWS or LWS = High or low water supply for the system at the point of diversion into the main canal.
HCL or LCL = High or low conveyance losses from the weir to the command area.

Source: J. Ambler 1989:389.

Here, conveyance losses have been used as a proxy for the labor needed for maintenance.⁴ Table 1 suggests that when little labor is needed for reducing conveyance losses in the main canal fully proportioned systems are almost never found, regardless of the magnitude of the relative water supply (HWS, LCL; LWS, LCL).

However, when large amounts of labor are needed for reducing conveyance losses to the fields (HWS, HCL; LWS, HCL) proportioning water-division devices are often used at every branch of the canal system. These systems have an average command area of only eight hectares (ha) each. The 20 systems which use proportioning devices only at major branches in the canal system are larger systems (average command area: 60 ha) that use the devices because of significant conveyance losses *within* the command area.

⁴ Conveyance losses were only ranked by the length of the canal from the headworks to the command area: canal lengths longer than 1,500 m are assumed to have high conveyance losses, while those under 500m are assumed to have low losses. See Ambler 1989: 377-378.

Table 1 represents only a small sample of the types of systems that use proportioning devices throughout the system. None of these systems have difficulty diverting water at the headworks. In other areas, however, the headworks may also require major labor contribution (D.P.S. 1938:122),⁴ and longer canal lengths from the headworks to the command area -- ten kilometers or more -- can be found (P. Pradhan 1989:8, Dani and Siddiqi 1989:74). These conditions only further strengthen the desire of farmers to use proportioning weirs to implement water rights.

Nevertheless, it should be noted that absolute water supply is still an important secondary factor in influencing the decision of whether to use proportioning devices or not. Systems with high labor requirements but also with high *resulting* water supply are not likely to use proportioning devices because water is not a scarce commodity. Maintenance burdens in these systems may be carefully calculated but usually according to the size of each farmer's landholding in the system, not according to any calculation of exact water share (Ambler 1989:384, 412-3). Conversely, in systems that experience chronic shortages of water to the point of requiring frequent water rotations, proportionality in water distribution becomes time-based rather than volume-based, and weir-like division structures have little utility.

Unlike in situations where water is either plentiful or easily obtained, head enders in fully proportioned systems are heavily reliant on the labor of tail enders to keep the system operating. Thus, the maintenance tasks that irrigators find so onerous are also the ones that allow tail enders to leverage head enders regarding water distribution. Under these conditions, it makes little sense to talk about the classic difference between head enders and tail enders; both groups find themselves sitting at the end of a long and precarious canal, reliant on each other's labor to get any water at all.

CASE STUDY OF THE PARAKU IN WEST SUMATRA, INDONESIA

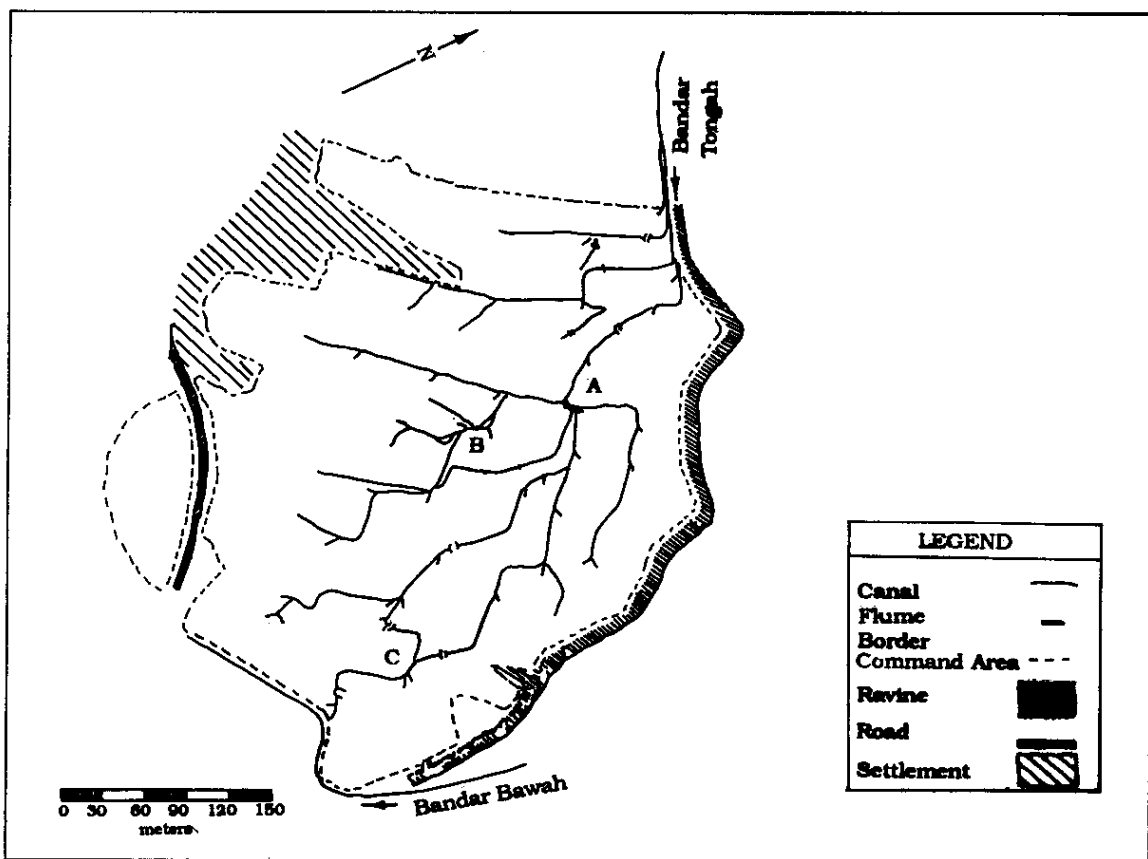
The use of traditional water-proportioning devices in Indonesia was once thought to be specific to Bali. Recently, however, identical devices have also been "discovered" in North Sumatra (Siregar 1989), West Sumatra (Ambler 1989, 419-36), South Sumatra (Pusat 1984), and West Java (author's personal observation; Vermillion 1989). Interestingly, the topography and water supply conditions in the areas where these devices are found are similar to those common throughout Bali.

Figure 6 shows the layout of Bandar Tongah, a 12-ha fully proportioned system in highland West Sumatra. The command area is located at the end of a 1.5-kilometer canal that traverses a nearly vertical ravine. Conveyance losses are a major problem. The stream itself has low but stable flows year-round.

⁴ One weir in West Sumatra was reported to be five m high, 80 m long, and required more than 6,000 bamboo stakes. Leach (1961:45) also describes a case in Sri Lanka where enormous labor was required to maintain tank bunds.

Farmers here have been willing to sacrifice scarce land to increase water control. The dendritic canal network reaches every corner of the system and each of the 52 plots is served by its own exclusive canal. The ditch density is 221 meters per hectare (m/ha), over four times higher than the 50 m/ha often suggested as a level necessary for good water control (Taylor 1981:179). The web-like layout appears to be the result of a long period of trial-and-error and adjustments to changes in landholding. A proportioning device called a *paraku* is placed at every canal branch. Each *paraku* has two to four slots called *takuak*.

Figure 6. Bandar Tongah irrigation system, West Sumatra, Indonesia.



Water Distribution in Bandar Tongah

Water distribution in Bandar Tongah operates on a continuous flow regime. Farmers allow no one to either obstruct openings or in any way disturb the *paraku*. With the *paraku* acting as fixed gates, the system operates automatically day and night.

Water property is calculated in terms of shares. Farmers consider these shares personal property.

Across the road that forms the southern boundary of the command area is a small adjunct that was created around the turn of the century, considerably later than the original command area. Some farmers in the original command area also own land in this extension area while other plots are owned by farmers who have no land in the main body of the system. As a rule, any excess water from head-end plots in the main body of the system must be conveyed across the road through culverts to the extension area rather than to lower-lying plots in the main command area. Thus, the extension area has only subordinate water rights; if there is no excess water from the main command area then it has no claim whatsoever.

These elaborate water allocation and distribution arrangements produce a high degree of equity in water distribution. Visual inspection of the fields during the exceptionally dry season of 1985 indicated that the height of the standing water in the fields was approximately the same in all plots. Moreover, no above-ground flows from higher to lower plots and no excess water for the extension area were observed. Thus, under low-flow conditions the system is "fine-tuned" so that seepage from higher to lower plots, differential percolation losses among plots (possibly higher losses in head-end plots), and conveyance losses in the system have all been factored into the ratios cut into the paraku to ensure nearly equal water availability to the plant root zone throughout the system. Farmers here have come to regard this system as a priceless inheritance.

System Maintenance

At the beginning of each cropping season, all the irrigators collectively repair and clean the main canal from the headworks to the first paraku. Every farmer provides labor in equal measure regardless of the size of his landholdings.

By performing this communal maintenance farmers gain the right to irrigation water but maintenance contributions *during* the cropping season actually determine each farmer's entitlement. During the season, farmers hire two or three men from within their ranks to patrol the main canal from the weir to the first paraku, to clear landslides and to repair breached embankments. Each farmer's maintenance assessment for the patrolmen is based on his water share. Farmers pay about 50 kilograms (kg) rough rice for each *ameh* of water or a rate of about 100 kg/ha.

How important are these contributions to maintenance for claiming water rights? First, farmers who only own land in the extension area are specifically *forbidden* from taking part in the communal canal cleaning at the beginning of each season. Thus, canal maintenance can be viewed not only as a duty but also as an investment that creates and relegitimizes water rights. By restricting access to canal maintenance -- thereby also limiting the "opportunity to invest" -- farmers also prevent the creation of permanent water rights that would exceed the assured capacity of the system. Logically too, because they have no primary water rights farmers in the extension area pay no fee to the water patrolmen.

In sum, farmers in Bandar Tongah have developed water-division rules and practices that are inextricable from the rules of maintenance. Just as maintenance duties are well-specified, so too is the water distribution system -- a system finely tuned through the use of carefully calibrated,

easily monitored, and automatic proportioning water-division devices. The simple-looking structures belie a sophisticated calculus that simultaneously embodies aspects of both operations and maintenance.

IMPLICATIONS FOR EXTERNAL ASSISTANCE AND NEW DESIGNS

Research on fully proportioned irrigation systems suggests that the amount of labor needed for construction and maintenance is the most important influence on the specificity with which farmers define water rights; water supply is also significant but ranks lower in importance. Furthermore, even systems with detailed water rights appear to go through a period of experimentation during which canal alignments and water shares are adjusted. As farmers gain experience with the operation of the system, they recalibrate the structures to distribute the water more equitably. This means that during the early history of a system, or when systems face rapidly changing circumstances water-division structures must be of a design flexible enough to accommodate modifications. Indeed, farmers in fully proportioned systems are often angered by the provision of government-built concrete turnouts, not only because the calibration of the openings frequently fails to accommodate local water rights but also because concrete structures are difficult to modify.

Outsiders planning assistance to such systems may conclude that farmer-built proportioning devices are suboptimal. However, it is often forgotten that "traditional" structures and systems are often only the most recent version in a long history of modifications based on rights and experience. Water distribution in Bandar Tongah is but one example of how farmers can gradually incorporate factors difficult to measure -- such as seepage and percolation -- into a total calculus. The sophistication of farmers' micro-ecological knowledge cautions against rigid adherence to estimates of water needs that have been based on the most easily measured factors alone.

Experience with fully proportioned systems also suggests that water rights among the irrigators are more related to their past and present investment contributions than to the amount of potentially irrigable land. This sets the stage for conflict when state irrigation officials with national food security priorities in mind evaluate a farmer-managed irrigation system primarily in terms of potential irrigated area and overlook the process of investment that led to the creation of the present system of water rights.

In the case of systems originally built by the government farmers may at first be willing to allow engineers to do the layout and design. However, in the case of farmer-built systems that are later assisted by the government the farmers may resist government designs that alter the water rights they have developed.

Farmers who have invested a great deal in the construction and maintenance of a system may, for example, wish to use the fruits of their labors to "overirrigate" their fields to reduce labor needed for land preparation, weeding, canal guarding, or night irrigation. Irrigation officials, on the other hand, may attempt to maximize irrigated area, given the calculated water supply.

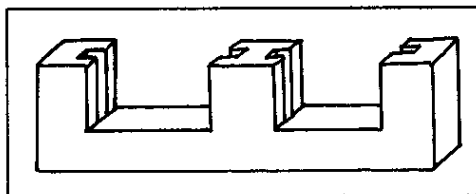
Consequently, the assumption is made -- one that later often proves unrealistic -- that the entire irrigated area including any extension area, will automatically have equal water rights. As farmers may continue to differentiate between "original" irrigators and "latecomers," external plans based on these assumptions may fail to achieve the state's objectives.

To mitigate this potential conflict between farmers and the state regarding control over irrigation water there may be some effective compromises. Providing external assistance to fully proportioned systems can be done in a way that both increases irrigated area and supports traditional water rights. The *sine qua non* of any such approach is involving farmers in planning, design, construction, and operation and maintenance decisions. Engineers can also present farmers with design alternatives that serve these objectives. The following are some preliminary design suggestions for improved proportioning water-division devices. Each needs further farmer testing under a variety of conditions.

Adaptation to Accommodate Rotations and High Flows

Farmers in some fully proportioned systems do practice water rotations under certain conditions but this can be difficult (Yoder 1986:111). Figure 7 shows a design to make rotations easier. This design was developed by Balinese farmers and engineers from the Bali Irrigation Project after farmers opposed the standard rectangular division boxes put in by the project.

Figure 7. Proportioning device equipped with slots for flashboards.



This design is appropriate for division structures at major branches in the canal network; division devices in smaller branch canals maintain the design shown in Figure 1. The concrete structure preserves the same proportions found in the farmers' wooden version but it has been equipped with slots for flashboards to block off either opening. Under low flows, one side can be closed to implement a rotation schedule (Figure 8).

Figure 8. Use of proportioning under a rotation regime.

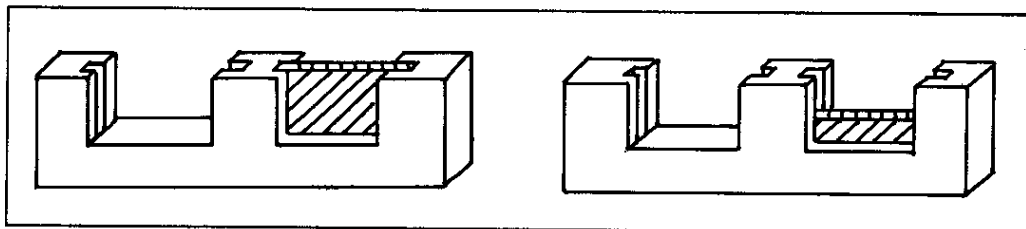
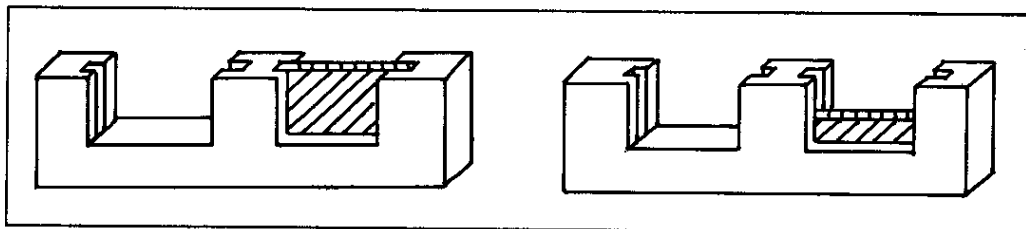


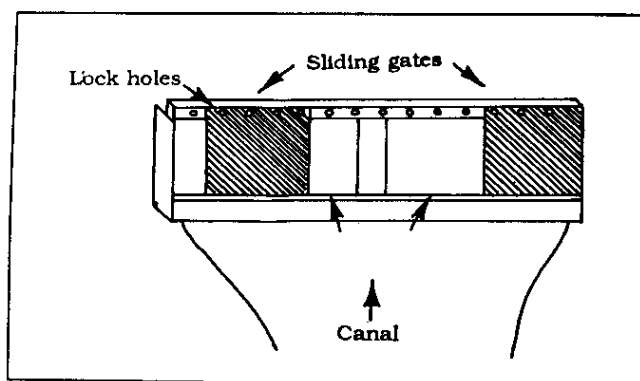
Figure 9. Use of flashboards to rotate under low flow conditions only.



Under high flow conditions, one side can also be partially blocked off with a narrow flashboard, both to protect that side from flooding and to send the excess water down through the system to an extension area (Figure 9). The same structure can be used in places where a canal branches but in which one side has primary water rights. The side with subordinate rights can be blocked off to a level which sends all water under low and medium flow conditions through to the primary location. High flows overtop the flashboard and serve the area with subordinate water rights while automatically preserving the water rights of the main canal. This feature is not possible in standard gated designs.

Another design is inspired by devices found in the western United States. Figure 10 shows the structure, here modified to follow the usual positioning of a proportioning device in Asia. The proportions of each opening can be adjusted incrementally by a gate that slides from the side. One side can be completely blocked off for water rotation, or both sides can be kept clear. If one canal needs more water, the other can be partially blocked by sliding the gate to a calibrated point along the top bar. Because all sills are the same height and the top of each channel unobstructed farmers can immediately see what proportion of the water goes to each canal. By contrast, in a conventional structure, a gate lowered part way in one channel reduces the cross-sectional area of the opening in a way that creates a differential pressure. This affects flow in a non-linear way making it difficult for farmers to visually calculate the water proportions for each canal.

Figure 10. Proportioning weir with sliding gates.

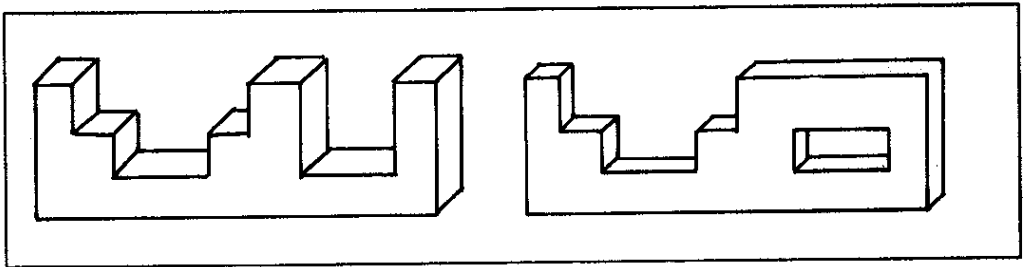


Designs for Increasing Irrigated Area in Tail-End Sections

Other designs are now being developed to take better advantage of higher-than-normal canal flows. One such design is shown in Figure 11. The structure is designed so that under low and normal flows one set of proportions is preserved while under higher flows a different rule is observed. This structure might be appropriate in cases where it is important to prevent flooding of fields served by the opening on the right side while also sending excess water down the left canal to serve an extension area which has subordinate water rights.

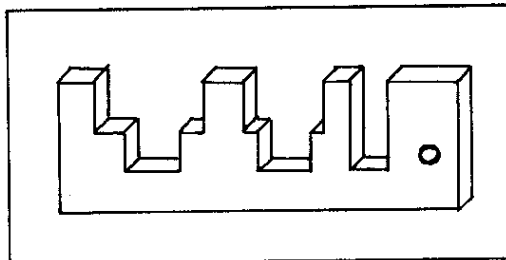
Figure 11. Device proportioned for shares under different levels.

Figure 12. Device proportioned so that one side receives all flow water above a certain level.



An alternative design would be to cap the top of the right opening to limit more severely the amount of water sent to that side (Figure 12). In both cases, the sill heights of all openings remain level. This design has emerged in some upgraded systems in Bali where the provision of a permanent headwork has increased the water supply to the system, allowing the possibility of more irrigation at the tail of the system. Either of these designs can be combined with pipe outlets for very small plots located near the division device (Figure 13).

Figure 13. Proportioning device fitted with pipe outlet.



Much work needs to be done in testing various forms of water-division structures that maintain the characteristics of proportionality, flexibility, and verifiability. Innovative designs can help preserve the water property rights that farmers have often worked so hard to create while improving the utilization of increasingly scarce water resources.

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Institutional Support in Design and Funding of Small Farmer-Owned Irrigation Tanks in the Central Himalayas in Uttar Pradesh, India

U.C. Pande[§]

INTRODUCTION

RAPID GROWTH OF minor irrigation constitutes a major achievement of the development planning process in the area of irrigated agriculture. In the grain belt of north and central India large reservoirs of good quality water at shallow depths below agricultural tracts in the Indo-Gangetic alluvial plain have encouraged exploitation of groundwater on an extensive scale. This, along with major irrigation projects has pushed India's food-grains output from a mere 50 million tons to 175 million tons in a period of four decades to usher in what has been acknowledged as a green revolution.

The need to conserve water in rain-fed agricultural lands as well as in forest and range lands in hills is quite obvious. Depleting vegetative cover in common lands and the need to push agricultural activity for an ever-increasing population far into degraded, steeply sloping, and occasionally ecologically sensitive locations have deprived soils of the capacity to retain rainwater in their profile deep and long enough to be available to the plants for sufficient duration as well

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This paper was prepared after many discussions and field visits to the pioneering institutions engaged in developing and propagating Low Density Polyethylene-lined tanks in the Uttar Pradesh hills. The author was helped by Sri Madhavashish of Mirtola Ashram, Almora; Mr. R.C. Srivastav, scientist at the Vivekanand Parvatiya Krishi Anusandhan Shala who has done much scientific work on the subject; and Mr. Kalyan Paul, executive director of the Central Himalayan Rural Action Group. To each one of these the author avows a deeply felt measure of gratitude. While the help received has contributed to the preparation of this paper the opinions expressed are entirely those of the author.

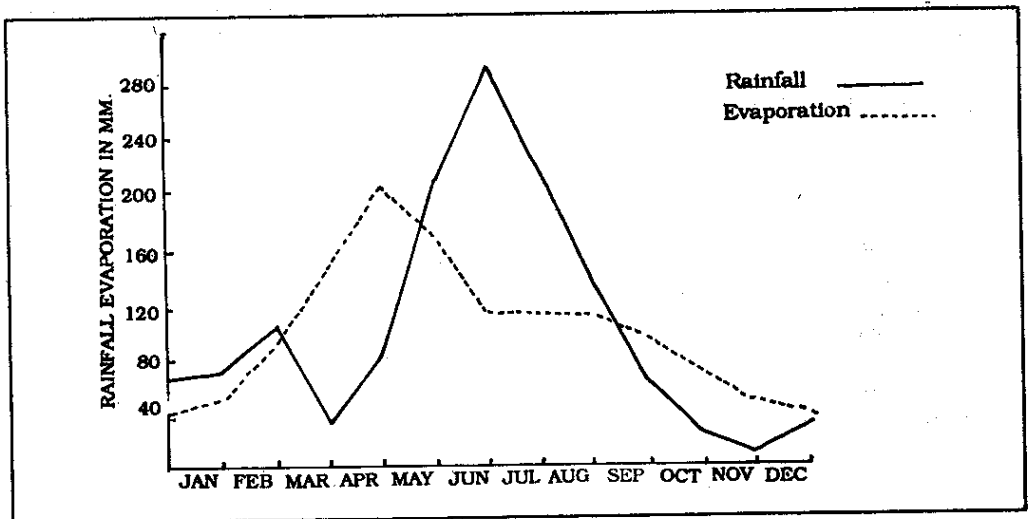
as to provide a constant trickle for downstream use. Valuable soil is being lost everywhere and periods of drought are getting longer. These have greatly reduced returns from agriculture and introduced new strains in the socio-politico-economic fabric in the countryside.

RAINFALL IN THE HILLS

Rainfall in the central Himalayan hill districts in the state of Uttar Pradesh India, henceforth referred to as the hills, is substantial and well-distributed during the year. In most of the area the monsoon rainfall (July-September) is between 100-150 centimeters (cm) and the winter-spring rain (December-March) of the order of 20 cm and above. There are some pockets which experience higher precipitation. Even before the regular monsoons begin in July rains are experienced between April and June. Germination and sprouting of upland (unirrigated) rice and other crops are very much dependent on rainfall during this period of the year which may be the first segment of effective monsoon. For antecedent moisture condition II which is generally to be expected in most of the cultivated area during the monsoon period, sufficient runoff is expected in the meteorological weeks 27 to 34 with somewhat lower runoff in the later weeks. Enough water is thus available for storage and subsequent use during critical dry spells.

Climatic water balance over the year for Almora, one of the cities in the hills (elevation 1,600 meters [m]), indicates that evaporative demand is higher than rainfall in February-May and October-December (Figure 1), and less during the rest of the year. It is in these two periods, respectively, that the filling and ripening stage of winter wheat and monsoon rice crops occur.

Figure 1. Climatic water balance in Almora, Uttar Pradesh (U.P.) hills.



Source: Sharma, B.R. Climatic zones and cropping patterns in U. P. hills.

A study of the monthly soil moisture balance for Almora for 26 crop years showed that the winter wheat crop faces a moisture deficit almost every year (25 out of 26) while the monsoon crop seldom faced it (only twice). A scrutiny of dry spells during the monsoon season indicated that irrigation was required during 8 out of 26 crop years (Sharma 1986).

MINOR IRRIGATION SYSTEMS IN THE HILLS

The seventh Five-Year Plan (1985-90) has specified the need for surface minor irrigation projects with social forestry and contour bunding on a watershed basis, giving emphasis to integration with small headwater tanks for soil and water conservation. The Planning Commission group for hill-area development has said that "the scope of major and medium irrigation being limited in the hills development of minor irrigation is the only hope," and has gone on to stress the need for technological innovation to harness minor irrigation potential. "It may be a low-cost, need-based technology suiting local conditions and upgrading the existing technology" (Planning Commission 1985). Planning of small water-storage projects for drinking-water supply and minor irrigation schemes has been recommended.

Technically speaking, minor irrigation systems include only projects with command areas under 2,000 hectares (ha). None of the millions of farmer-owned tube wells, bore-holes, dug wells, or surface pumping sets under the minor irrigation program command more than 8 ha at the most -- often much less. In the agricultural tracts in the hills minor irrigation systems cover between 0.8-240 ha. A vast majority of these are surface gravity canals with occasional lift schemes comprising electrically driven pump sets or hydraulic rams. Almost all the lift schemes are state irrigation systems. Farmer-managed irrigation systems far outnumber the state irrigation systems, and are smaller in size, and except for the tanks, are now confined only to remote areas in the hills. The design features of the farmer-managed irrigation systems are rather simplistic yet they are fully functional systems and have the additional virtue of being operated and managed by the farmers.

Farmer-managed irrigation systems in the hills can be further subdivided into community-owned and individually owned. Almost all the community-owned systems are gravity canals feeding a whole or a part of a village or a contiguous group of hamlets which may have an interest or right on the main water source. Such interests and rights have been in existence over a long period of time and find sanctity in custom and law. Areas commanded by such systems may range from 2-60 ha.

WATER-STORAGE TANKS

Most of the individually owned farmer-managed irrigation systems use water-storage tanks of varying size, between 6-20 cubic meters (m^3). There are quite a few larger tanks with capacities of 200-400 m^3 . Most of these are state-owned except for a few which belong to a religious institution. There is no exact information about the total number of water-storage tanks in the hills, operative or defunct. Based on the achievement of annual targets of the State Minor Irrigation Department during past years, this number has been reported as well over 10,000 in three out of eight districts in the hills (Executive engineer, personal communications 1989). However, up to 40 percent of these tanks have gone out of commission.

The tanks are built in stone masonry using cement mortar. A deficient design, land subsidence, inadequate technical guidance in site selection, lack of supervision of construction, and insufficient resources are some of the causes for the heavy failure rate. Absence of quality control in mortar preparation and lack of knowledge about the need for proper curing to achieve adequate mortar strength accelerate the process of damage leading to shortening of the life span of the tanks. Since it is not possible to provide technical guidance continuously at most places in the remote hill areas increasingly large numbers of tanks become defunct within three to four years of construction.

The importance of and need to build a large number of water-storage tanks in the hills for water conservation cannot be overemphasized. Water management through 1) rainwater harvesting -- storage and conservation, and 2) accumulation of minor perennial flows, so abundantly observed almost everywhere in the hills, can profitably modify the existing land use and cropping patterns. "Water harvesting often provides a useful source of water both in lean rainfall seasons and in low rainfall regions" (Indian Petrochemicals Corp. Ltd. 1985).

Individually owned small tanks provide succor to small crop areas particularly during periods of extreme moisture stress at critical periods of plant growth. Since February-May is a period of adverse climatic balance resulting in poor availability of water, stored water in tanks can be used for one last critical irrigation, and in the event of the tank remaining full even thereafter, for raising nursery rough rice for transplanting in July.⁴ Changing requirements of land use for production of fodder and fuel trees will result in maximizing profits, especially from small landholdings, by integrating the social forestry program with water harvesting efforts and at the same time increasing the availability of saplings. Small-sized tanks are ideal for such a program. Thereafter, the production of vegetable and flower seeds, high value spices, and medicinal plants should follow in due course, given the necessary support.

⁴ For the winter-spring wheat crop recommendations under conditions of limited water supply, the following schedule is considered best: 1) Where only one irrigation is possible it is best to apply water at the crown root initiation stage (25-30 days after sowing). Delay at this time results in upsetting the synchronous tillering (particularly in high-yielding varieties), and production of subnormal heads, poor root systems, and poor grain yields. 2) Where two irrigations are available water should be applied at the crown root initiation and flowering stages. 3) If three irrigations are possible, water should be applied at the crown root initiation, late jointing (boot) stage, and milk stage (Sharma 1986).

Size of a tank can be limited by such factors as physiographic features, slope, geology, and seismicity. Fields in the hills are small both in width and area. The unit for land area is a *nali*, which is one-fiftieth of a hectare, and field areas may be as small as 0.1 *nali*. Most farmers own less than one ha of land and this may be spread in more than one village and scattered in small bits all over a village. This factor alone can limit the size of a tank. A large number of small tanks to fulfill the needs of a village during critical periods cannot be a feasible proposition if the initial cost is high and if they are constructed in good, cultivable land. Common lands may be far removed from both the water source and fields to be irrigated. Large community- or state-owned tanks are likely to be beset with numerous problems of management and operation. Masonry-lined tanks are rather expensive, and making numerous small or a few large masonry tanks can be quite costly, apart from the problem of quality control in construction and other factors limiting their life span.

Assuming that each tank is designed to provide one critical watering of 7.5 cm to an area one-fourth of a hectare in size, the volume of water required works out to 188 m³. If the tank can be quickly and successively refilled, as in the case of spring-fed tanks so as to continuously irrigate one-third of the area at a time, the required capacity of the tank is 63m³. Assuming a runoff availability of 20 cm from a catchment of one ha, the yield is 2,000 m³. With a maximum depth of 1.5 m of water in the tank, its average surface area works out to 42 square meters. Since the fields in the hills are quite narrow a maximum width of six meters at the top can be achieved. In most locations it may be as little as three to four meters. The length of such a tank works out to 10-15 m.

For raising nursery fuel and fodder plants, the water requirement is quite low. Thus, a 10 m³-tank can support a nursery raising 10,000-15,000 plants with a rural water supply pipeline as its water source.

Water availability. Water for storage in minor irrigation tanks may be available as one or a combination of the following:

1. Stream flow runoff in sizeable quantity for filling a tank in 4-12 hours but not large enough to be transported in a minor channel.
2. Stream flow of small quantity from a spring to fill the tank in 12-48 hours.
3. Rainfall runoff of residential building roofs or roof of the water tank, if covered.
4. Rainwater collected into the tank from a micro-catchment.
5. Storage of return flow from higher terraces.

LOW DENSITY POLYETHYLENE-LINED (LDPE) TANKS

It would be unthinkable for a small farmer in the hills to build a suitably large stone-masonry-cement tank (60-100 m³). The cost of a properly designed masonry tank works out to an expensive Rs 1,250 to 1,500 per m³ (currently 1 US\$ = 16 Rupees). With the added disadvantage of its short life span, these tanks do not serve any useful long-term purpose.

It is in this context that LDPE-lined tanks appear to have an important contribution to make in storage and conservation of water and its management for agriculture, forestry, and drinking-water needs.

The concept of lining of canals to reduce loss of water through seepage is known and well accepted. LDPE film of varying thicknesses has been established as an effective and economical leakage-preventing material which is being used for lining increasingly large lengths of canals to reduce seepage losses. With LDPE lining the losses can be reduced to one-thirtieth or one-fortieth of that from an unlined surface.

The first LDPE-lined tank in the hills was constructed at Mirtola Ashram in Dhauladevi Block of Almora District nearly 12 years ago. On the basis of experience gained certain modifications have been incorporated in the design of tanks built thereafter. Subsequently, the Vivekanand Parvatiya Krishi Anusandhan Shala (VPKAS) in Almora which is a unit of the Indian Council of Agricultural Research proceeded to design and evaluate small LDPE-lined tanks at their research station at Hawalbagh. Apart from a few tanks at the Mirtola Ashram and the ones built by VPKAS for research work, no headway was made in propagating these tanks. There seems to be non-acceptability of the LDPE tank design at the appropriate governmental levels to entitle them for institutional and governmental financial support. A voluntary organization by the name of Central Himalayan Rural Action Group (CHIRAG) has constructed 14 LDPE-lined tanks in a cluster in a village in Nainital District in the hills and proposes to build a total of 40 such tanks, each of 10m³ capacity. This is a part of their action plan for vegetative regeneration of degraded and deforested land in a small area in the hills. Each tank supports a nursery raising 10,000-15,000 saplings of fuel and fodder trees. At least four tanks with water-storage capacity of 100-200 m³ are included in their ongoing plan (Executive Director, CHIRAG 1989).

Construction of LDPE-lined Tanks

The procedure for constructing an LDPE-lined tank is given below.

1. Water availability must be assessed -- whether rainfall runoff, small spring, return flow, or other source.
2. A suitable site must be chosen: A roof runoff tank will have to be placed near the house/houses from where water is to be collected. Tanks for irrigating fields will need to be constructed so that water reaches the command area by gravity flow.
3. The size and shape of the tank must be calculated: Once the storage volume is known average sectional area is calculated assuming a 1.2-1.5-m water depth. Depending upon the width of the field the surface dimensions of the tank can be determined.
4. The tank pit needs to be excavated to accept the LDPE film lining. The side slopes of the tank need to be calculated for proper workability and stability against slippage. The pit sides and bed are dressed smoothly so that no rock mass or sharp projections are left. Roots of bushes and weeds are taken out.
5. A strong weedicide must be sprayed on the excavated surface.
6. The thickness of earth/other cover needed to protect the LDPE film from damage due to

erosion and impact injury should be determined. Black LDPE films currently in vogue have to be protected from solar ultra-violet radiation and injury by impact or cut. Hence, earth/other cover on bed and sides is needed. A 2.5-cm layer of fine-screened soil should be put on bed and sides. Alternatively, the surface may be smoothed by trowelling with a slurry of silty clay.

7. LDPE film of adequate strength is laid down and covered with finely screened excavated material on bed and sides. LDPE sheet thickness of 100 micron (0.1 mm or 4 mil or 0.004 inches) is adequate if proper covering is given on top of the film. Even if a much thicker sheet is used it will not appreciably affect the total cost while ensuring higher resistance to root penetration and greater strength against dart impact.

Soil will remain stable in sides only if slopes are quite flat. In place of soil either stone slabs, boulders, pitching blocks, or sausage-shaped plastic tubes filled with screened earth can be placed either directly on top of the LDPE film or on top of the earth layer. Stone, brick, or concrete block masonry with cement mortar is needed to prevent subsequent vegetative growth through joint cracks which could eventually lead to root penetration.

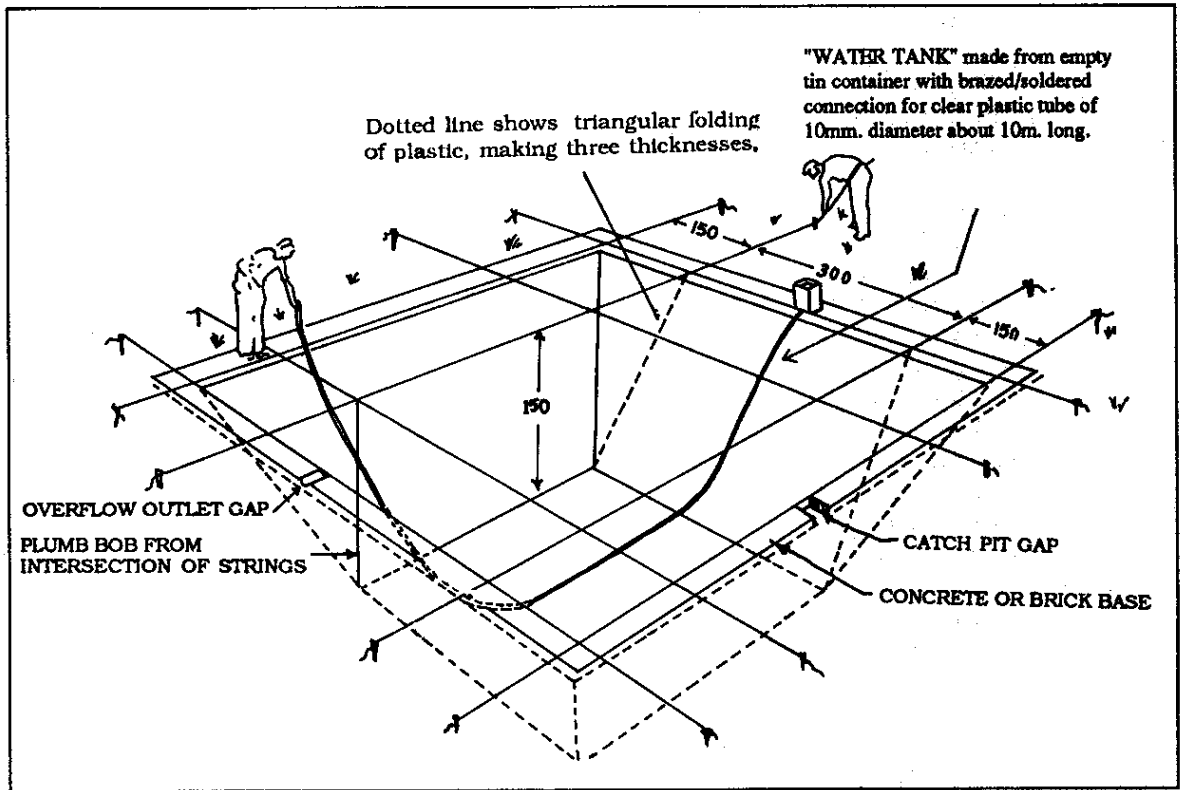
The most appropriate method for jointing the LDPE film to achieve large sizes needs to be considered. For the size of tanks proposed in this article the 12 m-wide LDPE film currently available in the market is more than adequate. Large-width sheets can be provided by the manufacturers on order. Jointing together of sheet lengths is very simple, using either the thermal-sealing process, a bitumen-jointing compound, or adhesive tapes.

8. The edges of the sheet need to be securely tucked under and an earth/masonry cover be spread over the anchored portion.
9. The tank should be roofed or fenced to protect the tank from damage and to prevent children and animals from falling into the tank accidentally.

Providing a roof does not help much in reducing evaporation losses. Evaporative loss from water bodies in the hills is not very significant and can be taken care of by spraying harmless vegetable fatty-acid compounds (Anonymous 1989). Evaporation control can also be achieved by 1) using other chemical retardants, 2) controlling parameters that affect the efficiency such as size of reservoir, and 3) compartmentalization. However, the effect of chemicals on aquatic and plant life must be carefully assessed.

Since it is not desirable to puncture the LDPE film to provide outlets for stored water it is best to release water by siphonic action. However, it is possible to provide an outlet at some height above the bed of the tank by folding the film back and jointing the portion properly with the outlet pipe. Figure 2 shows in some detail the construction of an LDPE tank. It is based on the write-up and drawings produced for the Mirtola Ashram tanks. The Planning Institute for the State of Uttar Pradesh has recommended the construction of such tanks on a large scale in the hills because of their low cost and simple construction. The cost of a 10m³ LDPE tank being constructed by the Central Himalayan Rural Action Group has worked out to around Rs 1,500 (US\$95) as against Rs 10,000-12,000 (US\$625-750) for a masonry-lined tank of the same size.

Figure 2. Laying out an LDPE-lined tank.



Source: Mirtola Ashram. Write-up on LDPE tanks.

INSTITUTIONAL ARRANGEMENTS FOR FINANCING OF MINOR IRRIGATION

The outlay for minor irrigation programs for the entire country including the program for hill areas as designated in the sixth and seventh Five-Year Plans is given in Table 1.

Table 1. Investment in minor irrigation programs for India.

Investment source	Target amount in million rupees	
	7th Five-Year Plan (1985-90)	6th Five-Year Plan (1980-85)
Institutional investment	35,000	17,000
Public sector funding	28,050	18,110

Source: Planning Commission Seventh Five-Year Plan (1985-90).

In the sixth Five-Year Plan, the actual utilization in institutional investment was only Rs 15,440 million, representing a shortfall of nearly ten percent. The seventh Five-Year Plan has spoken of institutional credit not picking up at the desired pace in eastern and northeastern parts and in many other states due to a deteriorating recovery position. Greater mobilization of resources through the Land Development Bank and commercial banks has been envisaged as a main policy plank for the minor irrigation program.

At the state (provincial) level, the minor irrigation program is implemented by governmental agencies with funds from various sectors of development in the state plan. However, there is a need to coordinate the different programs at the field level.

Under the sectoral program of the minor irrigation department, funds are provided for loans and subsidies to farmers in the hills. Experience has shown that the farmers always repay their minor irrigation loans within the scheduled period, causing no problems in loan recovery (Pande 1987) However, there is almost complete absence of institutional support for minor irrigation programs in the hills. The reasons for this lie in certain structural deficiencies in the entire loaning program of all sectors. Since these deficiencies cannot be overcome immediately other sources for financing and implementation of minor irrigation projects, especially the LDPE tank program, need to be devised.

Lack of appropriate institutions at the village level have hampered the development process including transfer of technology. Those institutions that exist are highly politicized and serve the rural elite only. Voluntary (nongovernment) organizations having no profit motive could act as catalysts for bringing about the necessary attitudinal changes in the hill villages so that new developmental strategies and technologies are accepted and "people take development in their own hands" (Planning Commission 1985). A chain of demonstration-cum-replication-cum-training could be established in the process.

Nongovernmental organizations can support the program only up to a point. The pace could be accelerated if private organizations could be encouraged to support the effort. The state government has supported the exploitation of groundwater by allowing cost-free boring up to Rs 3,000 (US\$190) for installation of farmer-owned tube wells. A similar subsidy could encourage the construction of LDPE tanks.

CONCLUSION

LDPE tanks hold a great hope for water conservation in the hills for supporting a host of activities in the fields of agriculture, horticulture and floriculture, and social forestry. These tanks are economical and simple to construct and maintenance costs are low. Institutional support for the program is needed so that small farmers can construct them over an extensive area. Nonofficial agencies may be encouraged to participate in the construction of tanks and subsequent training and education of the farmers for the best management of the stored water.

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Low-Cost Assistance to Small Farmer-Managed Irrigation Systems

Lila Nath Bhattarai[§]

INTRODUCTION

THE NEPALESE PEOPLE have practiced irrigation to increase crop production since the late 1600s. Surface irrigation has been, and remains, the predominant form of irrigation in the country. Some of the small farmer-managed surface irrigation systems constructed during the late 1600s still exist, having been repaired and extended by successive generations.

Studies of farmer-managed irrigation systems in several parts of Nepal have shown that the performance of many of these systems is excellent. However, some systems are experiencing constraints limiting 1) the expansion of the command area, 2) the intensification of crops, and 3) the yield due to unreliable irrigation. In some cases the constraints are physical and further improvement of the system is beyond the local resources and technology available to the farmers. In other cases the operation and maintenance costs are extremely high, making further expansion or intensification impossible without improvement of the physical system. In many systems the farmers are unable to achieve potential food production because management is poor. There is great potential to increase food production by providing low-cost assistance to overcome constraints in many systems.

The traditional mode of irrigation development is to successively conduct a pre-feasibility study, a detailed feasibility study, a design study, and finally implement the project using contracts. These steps may be appropriate for large new systems but are far too expensive for improving existing small farmer-managed schemes. For 100-hectare (ha) systems in the hills it

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is not uncommon for the government to spend up to US\$200/ha just to determine if improvement of the system is feasible.

The Water and Energy Commission Secretariat (WECS) initiated an action-research project to identify ways to reduce the cost and improve the effectiveness of providing assistance to existing farmer-managed systems. The main objectives of providing low-cost assistance to these systems consisted of: 1) preserving the farmer-managed characteristics of each system; 2) identifying ways to ensure and effectively utilize farmer participation in all steps of the intervention process; 3) developing and testing ways to strengthen existing farmer irrigation organizations to make them more effective in managing their water; 4) finding methods for mobilizing valuable local resources of knowledge, experience, and labor in improving the management and physical capacity of farmer-managed irrigation; and 5) testing appropriate, low-cost, design techniques and technologies for physical structures.

Some of the activities of the project were implemented through the consulting firm Hydro Engineering Services. This paper presents my views as project coordinator in the field for Hydro Engineering Services.

PROJECT DESCRIPTION

Phase I: System Identification and Selection

The Indrawati River watershed of Sindhupalchok District was selected as the project site. The work was planned in two phases, the first to identify all systems in the 200-square kilometer project area, and the second to select specific systems for assistance by applying systematic criteria chosen to maximize the project impact. A reconnaissance/inventory study was conducted to locate and identify the resource base of each system. In all, 119 systems were identified with canals longer than 0.5 km and potential command areas larger than 5 ha. Twenty-two of these were selected for improvement on the basis of having the greatest potential for command area expansion.

A rapid appraisal was carried out on the micro area of selected systems to further identify basic information about water availability and irrigation user organization to manage operation and maintenance, and to provide a rough idea of the need for physical improvement. After the rapid appraisal 19 systems were selected for assistance.

Phase II: Implementation of Improvements

The first step was to hold a dialogue with the irrigators and explain the project and start the process of collecting design data. At a later date, after the farmers had agreed to the terms under which they would receive assistance, the second step continued the dialogue and was used to set the priority of physical improvements to be made.

After the design was complete each system was notified of the total amount of money available for its improvements. This resulted in some shifting of priorities and necessitated changes in some designs in each system.

Finally, there was implementation of the physical improvements. During the implementation, the farmers requested many additional changes in design as they better understood the actual dimensions and other characteristics of the structures that were to be built. In addition, designs were modified to accommodate site-specific characteristics as excavation and building work progressed.

Hydro Engineering Services was given the responsibility of implementing the improvements in six of the systems. A team of engineers, a hydrologist, a sociologist, and supervisors worked on the project for over a year. It was the consulting team's task to mobilize the beneficiaries by helping them form a user's organization when one did not exist. The user organization was then required to select a management committee to oversee the day-to-day improvement work and to manage operation and maintenance of the system after the improvements were completed.

A large part of the consulting team's task was to motivate and direct the farmers. As a result of the team's effort the farmers agreed to do all the earthwork needed by arranging voluntary labor, and to conduct all other work including transport of construction materials, at a rate lower than both the village labor rate or the maximum set by district authorities. The project donors agreed that the savings made by using lower rates could be used on system-improvement activities beyond the first priority work for which the funding was allocated.

DETAILS OF THE DESIGN WORK

Data Collection

The design discharge was taken as either the existing discharge or that required to meet the crop water requirements on the total area, whichever was larger. Maximum water requirements occur for irrigating rice. The maximum water demand was estimated by assuming values for crop needs, different types of losses, and anticipated efficiency of water application to the crops. The existing maximum discharge was estimated by either measuring the discharge being diverted from the source if possible or measuring a suitable section of the canal that farmers indicated controlled the discharge. Manning's equation was then used to compute the maximum discharge.

For design purposes two methods were used to determine the proposed command and the larger of the two commands was used. The first method required the farmers to list all present and potential users and the area of the fields they irrigate. In some cases the beneficiaries were able to show their land titles which stated their land area as determined by plane table methods used in the government cadastral survey. A suitable factor was determined for correcting the total to irrigable land area. The second method was to use the cadastral map. While in the field, the map had to be carefully marked to delineate the area irrigated. Though the maps were of suitable scale determination of the irrigated area was difficult in the rolling topography highly dissected by drainage.

With the assistance of the water users the detailed survey of the headworks site, cross drainage, and canal alignment was carried out by technicians using surveying instruments. If it was clear from visual inspection that a reach of the canal had a steep slope, measurement of the physical parameters needed for design could be obtained using only a measuring tape. However, where a canal followed a new alignment such as the extension to previously unirrigated areas where a mild slope was desirable, detailed survey work was necessary using survey equipment.

The benefit of inviting experienced farmers to help with the survey work was that they knew the nature of the water source with respect to floods, problems with cross drains, severity of landslides, and other problems along the length of the canal. In addition to information about problems relating to operation and maintenance of the canal the farmers were able to give information about realignment of the canal to avoid difficult areas, and other possible uses of the canal water such as for household and animal consumption or grain milling. Inspection of the systems and inquiry with the farmers in the field showed that they had already made many modifications in the canal alignment and location of the intake based on trial and error. They had experimented with many types of construction techniques and structures to the extent of the resources available to them. In some cases such as shifting of the intake location it was a response to changes in the streambed caused by floods. In other cases, the experimentation was in response to making the system easier to maintain and deliver water more effectively. Usually, if the farmers had experimented with the canal alignment they had achieved good results and there was little possibility for improvement.

Design Considerations

A condition for the design work given in the consultant's terms of reference was that quantity and cost estimation be based on national norms published by the Ministry of Works and Transport, His Majesty's Government of Nepal. Labor and local material procurement costs were based upon the district panchayat (district political unit) rates. The consultant's terms of reference also required that the design consider use of local construction materials whenever possible. However, economic considerations were the primary deciding factor on choice of materials. Other considerations such as the type of structures to be proposed to the farmers or canal alignment were left to the judgement of the consultant. The farmers also had strong opinions on matters relating to cost. For example, it was immediately clear that it was best to use the existing canal alignment to minimize the excavation work.

The following are examples of structures that were designed for first priority needs of systems. The nature of the structures was discussed with the beneficiaries who readily agreed to them.

Conveyance structures. New sections of canal in earth and gravel and mixed soil, mainly where the canal was extended, were designed with a trapezoidal cross section, using Manning's equation with reasonable values of Manning's coefficients.

During design calculations reinforced concrete pipe (RCC pipe) proved to be relatively economical -- 40 percent less cost than high density plastic pipe (HDP pipe) for the same discharge -- and easy to design. It was proposed for road crossings, superpassages, and rocky sections where bench cutting is difficult. Normally, there is not much canal erosion at the ends of RCC pipe sections and it can be controlled by an appropriate masonry transition structure and riprap or gravel protection. Since all transportation in the project area is on foot, it was proposed

to cast the RCC pipe at the location of use. This required portable casting forms. Design calculations showed that a 300-millimeter (mm) diameter pipe was sufficient for the largest discharge if appropriate adjustment in the existing canal slope was made.

Bench and elevated flumes. Flumes were used to convey canal water along cliffs and over natural drainage. In order to minimize cutting in hard rock a half box section was also adopted in some places. Alignment of some portions of the existing canals passed through vertical rock where farmers had constructed retaining structures with stone and mud mortar. In such sections it was difficult to achieve the required cross-section by rock cutting. Since construction of masonry retaining walls with cement mortar was quite expensive, RCC pipe was proposed because only sufficient rock needed to be cut to rest the pipe. RCC pipe was also proposed for sections of the canal where leakage was excessive, causing mass slumping. In several locations the farmers reported that they need to shift canal alignment uphill every year or two.

RCC trough aqueducts (elevated flumes) are very costly. An alternative design was adopted by providing RCC pipe, supported by wooden beams, as aqueducts for spans up to seven meters. Side abutments were designed to support the beams. For spans longer than seven meters, aqueducts were designed using HDP pipe supported by wooden beams or trusses.

In many locations suitable slope protection was assured by constructing dry stone retaining walls or using wire crates. Most construction of side abutments, side walls, and wing walls used random rubble masonry with mud mortar and cement pointing. In the unstable landslide areas, polyethylene sheet canal lining covered with clay or silty clay up to a depth of 30 centimeters (cm) was proposed. Catch drains were also designed on either side of the landslide areas.

Diversion structures. Because the budget ceiling for improving the irrigation systems was low the farmers of most systems agreed to use the available money at places other than the diversion structure at the headworks. It is nearly impossible to build permanent diversion structures on mountain streams with high silt loads. To build a diversion that would potentially wash away in the first monsoon season was viewed as a poor investment by both the farmers and the consultant. Except for one system where wire crates were used to improve the diversion farmers decided to continue using high labor inputs to rebuild the diversion when necessary using brush and stones.

HDP aqueduct structures. The consulting firm designed and constructed two HDP pipe aqueducts for crossing streams. These were supported by galvanized cable in a similar manner to foot suspension bridges. One was for an 11-m span which allowed cost comparison of different pipe support alternatives. Compared to a wooden beam and a wooden truss support the cable suspension was the cheapest.

The other aqueduct was of 22-m length. It required design considerations for the total load, point load, sag, swing stability, and entry and exit hydraulic losses. The inlet end of the pipe was fixed in masonry but the exit end was free to reduce stress caused by movement of the somewhat flexible structure.

The most obvious advantage of the suspended aqueduct was the savings in cost from a shorter canal. Three hundred meters of rock cutting would have been required to continue the contour canal to the stream and back to the point reached by the outlet of the aqueduct. In addition, a superpassage would have been required at the stream. In other projects, piers instead of cable suspension have been used to support aqueducts but frequently they are in danger of being eroded by the stream or shifted by a landslide. Frequently the required height for a pier is more than can be built economically. Though the suspended pipe aqueduct required skilled supervision of labor for installation, the transport cost was low and erection time was short.

IMPLEMENTATION OF PHYSICAL IMPROVEMENTS

Supervision of the Construction

A construction book was established for each system. It was used to record all decisions regarding the modification of designs and procedures. It was also used to record a summary of each day's work, daily labor mobilization, quantities of local materials collected, costs for transportation of materials, and all transactions for cash and construction materials. The unique feature in this process was that the construction book was open for inspection by all farmers, the consultant, and staff from both the Water and Energy Commission Secretariat (WECS) and the International Irrigation Management Institute.

The consulting team actively encouraged the water users to make a commitment to the project, helped them organize their work efficiently, attuned them to future operation and maintenance activities, and mobilized them to undertake work in improving the canal beyond what the project could cover.

Revised Designs

During initiation of the physical improvements designed by the consultant and approved by the beneficiaries, the farmers complained about the size of some of the structures being built. They had not been able to visualize the dimensions from the drawings and discussion when they approved the structures, and now realized that if the structures were built as proposed it might limit future expansion or additional uses of the canal. Out of the 47 structures that were initially designed for the 6 systems, 30 were modified to meet the farmers' requests or to better fit the site conditions during construction. Eight of the 47 initial structures were dropped by the farmers during construction in favor of adding 42 others totaling the same cost but better fitting their priorities.

Project commitment to full farmer participation and farmer acceptance of the design required that farmer dissatisfaction over design be resolved. This required extensive discussion with the beneficiaries and in many cases, redesign. The case of extensively using RCC pipe is an example.

While the cost analysis during design showed RCC pipe to be more economical than open channels, the farmers objected, saying that the size was too small even though it was demonstrated in one system that the design discharge would pass through the pipe. The farmers also wanted flexibility to install a water-powered mill and expand the command area. In fact, within months after completion of the project two options were discussed by the farmers: to install a mill or extend the canal to new fields. The community decided to install a mill.

In addition to the size issue there were some technical problems with the pipe. Collection of the high quality materials required for fabricating the pipe was more costly than the analysis had estimated. Local skilled labor for casting the pipe was not available and hiring persons from outside the community proved far more expensive than anticipated. Finally, since the pipe

needed to be cast in many dispersed locations, usually far from water for appropriate curing, the quality was low, resulting in high breakage. All of these factors combined to require design changes and the elimination of all of the RCC pipe except in parts of two systems where there was no viable alternative. To offset the increased cost of constructing open channel stone masonry the farmers in some systems provided additional voluntary labor.

While seasoned wood to support short aqueducts had been proposed as a low-cost design using local materials it turned out to be unavailable at the rate given. This was due to the extreme scarcity of good quality construction wood in the area. High transportation costs made it necessary to change the design to another alternative.

The main factors that allowed costs to be reduced were the use of locally available materials and the ability to redesign structures on site as was necessary. For example, during excavation for the anchorage of the suspended pipe aqueduct a huge boulder was uncovered and the design was modified on the spot to incorporate this into the foundation. By treating it as an integral part of the foundation, the cost of removing it and refilling the hole with stone masonry was saved. Such simple and obvious solutions are often overlooked by the junior field staff supervising construction who have been instructed to follow the design drawings exactly. Furthermore, approval for effecting changes in the design is usually a long bureaucratic process.

OBSERVATIONS AND RECOMMENDATIONS

Hydro Engineering Services' experience with the WECS/Ford Foundation action-research project in six farmer-managed irrigation systems in the Sindhupalchok District highlights a number of observations which are the basis for a list of recommendations for planning, design, and implementation for future assistance to small irrigation systems.

1. The following is a list of the six systems that Hydro Engineering Services worked with, and the project funds granted to each.

<u>Irrigation system</u>	<u>Project grant (NRs)[‡]</u>
Majh	113,541
Siran	57,488
Chapleti	78,065
Baghmara	44,433
Chap Bot	71,630
Bhanjyang	65,178

The total amount spent including consultant's fee, staff stipends, tools, and other costs came to about US\$123,000 for effecting improvements in 19 irrigation systems covering 536 ha previously under irrigation and the extension of irrigation to 349 ha. The unit investment

[‡] The exchange rate of Nepali rupees to US dollars has gradually increased in recent years from NRs 21.9/US\$ in 1986 to NRs 28.2/US\$ in October 1989.

- cost came to about US\$126 per ha which is very low in comparison to the unit investment cost for irrigation development as implemented by His Majesty's Government through the Department of Irrigation.
2. The beneficiaries' capacity for management of their irrigation systems is improved if they are involved in decision making from the very beginning of the project.
 3. Estimates of the volume of work to be completed for each of the different types of work done were based on national norms established by the government. However, the farmers were capable of achieving much higher work outputs and the actual volume of work accomplished was about 70 percent higher than the estimate (Table 1). The estimates included only first priority improvements and project grants were made accordingly. However, the beneficiaries were able to complete improvements on almost all critical parts of their canals (including second priority improvements) within the budget ceiling granted by the project. They accomplished this by using locally available materials whenever possible accepting a lower wage rate than that set by the district panchayat and also providing free labor. If the work had been awarded to a contractor as is the usual procedure for government assistance the grant money would have been barely sufficient to cover the cost of only first priority improvements.
 4. Valuable local resources such as free labor can be mobilized with the cooperation of the beneficiaries. An average of 34 percent of the total cost of the improvements in the 6 systems assisted by Hydro Engineering Services was contributed as free labor.
 5. The beneficiaries were able to provide valuable inputs during problem identification, project design, and construction.

Table 1. Estimated and actual volume of work completed according to type of work for improvements in six farmer-managed irrigation systems.

System	Majh	Siran	Chapleti	Baghmara	Chap Bot	Bhanjyang	Total
Earthwork m ³							
a	6	4	43	44	106	17	220
b	1,654	642	544	450	969	976	5,275
G.I. wire crating m ³							
a	--	9	80	--	--	--	89
b	--	10	101	--	--	--	111
Rock cutting m ³							
a	249	92	193	58	32	27	651
b	298	100	292	89	26	133	938
Cement pointing m ²							
a	73	70	105	83	82	119	532
b	311	230	47	118	89	98	893
Cement plaster m ²							
a	--	55	27	48	41	56	227
b	82	26	26	168	35	251	588

Table 1. (Continued)

System	Majh	Siran	Chapleti	Baghmara	Chap Bot	Bhanjyang	Total
Random rubble masonry m ³							
a	24	6	15	24	36	31	136
b	36	10	34	38	49	52	219
R.C.C. m ³							
a	--	1	3	1	3	2	10
b	1	2	2	1	3	4	13
P.C.C. m ³							
a	2	4	4	17	6	17	30
b	5	6	6	10	9	15	51
Stone work m ³							
dry, in mud/mortar/soil							
a	97	80	20	33	29	15	274
b	338	156	13	49	37	33	635
Fitting HDP pipe m							
a	33	6	--	--	50	--	89
b	33	--	--	--	50	--	83
Fitting hume pipe m							
a	24	--	33	--	4	--	61
b	17	--	27	--	5	--	49
Stone lining m ²							
a	--	--	--	--	--	--	--
b	156	--	--	--	--	--	156
Plastic sheet lining m							
a	--	--	--	--	--	--	--
b	20	--	--	--	--	--	20
Woodwork m ³							
a	--	--	--	--	--	--	--
b	1	--	--	--	--	--	1
Cable crossings (sets)							
a	2	--	--	--	--	--	2
b	2	--	--	--	--	--	2

Notes: a=Estimate of the volume of work that needed to be completed, based on government norms.
b=Actual volume of work completed by the beneficiaries of each system.

Recommendations for Identifying and Implementing Improvements

If the farmers' wishes are not incorporated into designing the physical system it is difficult to mobilize local labor and resources for low-cost improvements and it would be difficult to convince the farmers to continue future operation and maintenance activities.

During the design phase of the project it was necessary to revise the original design of the structures and to change the priority of the improvements during the construction phase in order to incorporate the beneficiaries' wishes. The beneficiaries considered additional uses for the canal water (e.g., installing a water-powered mill) than had been considered by the engineers in the original design. However, making these changes to accommodate the farmers delayed progress of the work by one month. Improvement work in the field was carried out through sketches so that revisions and construction work were carried out side-by-side in consultation with the farmers in order to avoid further, prolonged delays.

To avoid the need for many revisions it is recommended that the farmers' input be sought from the very beginning of the project during identification and diagnosis of the problems in the irrigation system according to a procedure such as that outlined below.

Procedures for the identification of irrigation systems and diagnosis of their potential/problems.

1. A reconnaissance/inventory study of existing irrigation systems and identification of potential sites for constructing new canals need to be conducted.
2. As a result of the reconnaissance study certain irrigation systems are selected for a rapid-appraisal study. Rapid-appraisal methodology consists of interviews with the irrigation users and collection of physical measurements such as the canal length and water discharge in the source. Difficulties faced by the beneficiaries in operating and maintaining the systems also need to be considered and the suggestions made by the beneficiaries must be included in the information gathering.
3. Either quick or detailed survey work¹ need to be done to gather all necessary physical measurements for the design and cost estimates. If improvements are to be made to an existing canal on steep slopes a quick survey is sufficient. During the survey it is important that several water users with many years of experience with the system accompany the survey team. The farmers are the most knowledgeable about the nature of the source, cross drainage, landslide-prone areas, and problematic reaches of the canal, and the survey/problem identification team must be sure to ask them about these subjects. The survey team should also seek information from the farmers regarding the worst possible damage that might occur, the frequency and extent of repairs, and about structures or practices that the farmers have tried and adapted or abandoned previously. Usually, the current alignment of the existing canal was determined after years of trial and error in response to site-situational problems. Hence, the alignment of an existing canal should not be changed without careful investigation that includes the experience of the farmers.

If a new canal is being designed or an extension made on an existing canal in areas of mild slope detailed surveys should be conducted.

¹ Quick survey work refers to the measurement of all the required physical parameters using only a measuring tape. Detailed survey work involves mapping of topographical features such as the headworks, canal alignment, cross drainage, and command areas with certain contour intervals.

Estimation of the command area by collecting information from the farmers is a good way to get them involved in the improvement process. Where cadastral maps or large-scale air photos are available the area can be marked directly on them by working in the field with the farmers. These methods are less expensive than conducting a detailed instrument survey of the command area and are accurate enough for good design results.

The main basic parameters needed for designing irrigation systems (e.g., Manning's coefficient, cross slope of the canal, free board, top width of canal bank, roads or farm paths for operation and maintenance) can be fixed according to the engineer's judgment.

Estimation of design capacity of irrigation systems is normally determined by calculating maximum water demand which depends primarily on the area to be irrigated, the crops to be grown, the demand system of turnout deliveries, water losses from evapotranspiration and seepage, and the anticipated efficiency of water application to the crops. However, the design discharge of the canal should not be calculated using only basic crop water requirements and anticipated loss but should also consider the farmers' suggestions and preferences. The beneficiaries in the six systems that were assisted in this project favored canals with larger capacities. If the existing discharge of the canal determined at a few stable cross-sections is more than the sum total of the capacity estimate, the canal discharge should be equal to the existing discharge.

4. Discussions with the beneficiaries also need to be held at this stage and should encompass the following:
 - a) Discussions should clarify for the beneficiaries the terms for the improvement work as stipulated by the implementing agency, and assure that the farmers understand and agree with the terms.
 - b) The role of the beneficiaries in the improvement process needs to be specified: e.g., collecting data for design and cost estimates, and collecting irrigable land resources data. The contributions to be made by the beneficiaries to the improvement effort need to be agreed upon: how labor or local materials will be contributed and the wage rate for paid labor needs to be determined.
 - c) A water users' committee needs to be organized to manage the beneficiaries' participation and contributions for the improvements.
 - d) The beneficiaries need to determine the priority of improvement works.

Procedures for the design phase. A draft design of all canal structures and priority works selected by the beneficiaries with alternative designs and estimates of resources required under different conditions and costs must be completed. The design should make extensive use of locally available construction materials to reduce costs. While designing the structures the designer must consider all the information collected in the identification/ diagnosis stage, being sure to consider the farmers' wishes. Sometimes the beneficiaries' wishes exceed practical possibilities and it is up to the designer to try to convince the beneficiaries to accept a reasonable alternative. Sound engineering judgment coupled with good theoretical background and supported by the beneficiaries' experience is essential to all phases of assistance to farmer-managed systems.

In the ideal situation, the following information should be available for consideration during the design of the irrigation improvements:

- 1) availability of land and water resources,
- 2) existing canal discharge at different, stable sections,
- 3) existing canal slope and bed material,
- 4) availability of local construction materials and transportation of these to the site,
- 5) availability of laborers for improvement work from among the beneficiaries and the wage rate for labor,
- 6) the farmers' past experience with construction, operation, or maintenance of the canal, and
- 7) uses for the canal water in addition to crop irrigation.

The designer of small farmer-managed irrigation system improvements should also consider:

- 1) the acceptability of the proposed design to the beneficiaries,
- 2) the simplicity of operational scheduling,
- 3) operation and maintenance costs,
- 4) equity in water distribution within the command area,
- 5) delivery of reliable water throughout the year,
- 6) ability of the system to respond to a wide range in seasonal water availability,
- 7) acceptable capital cost, and
- 8) overall economy.

Once the draft design has been completed the designer and supporting staff need to visit the site and explain all aspects of the draft design and alternatives to the beneficiaries. Alternative benefits and costs including resource requirements to be contributed by the beneficiaries need to be clarified so that the farmers can select the design innovations they prefer and change the priority of the improvements selected if they wish.

Final design. Completion of the final design process consists of updating the draft design to incorporate the beneficiaries' changes. All their suggestions and preferences should be incorporated as far as is practicable. If the beneficiaries participate fully in the problem identification and draft design stages of the improvement process further revisions in the design should be minimal.

Recommendations for Minimizing Costs

Usual government agency procedure for designing all irrigation improvements include a detailed survey of canal alignment, cross drainage, command area, and other physical features using survey instruments. These procedures consume a lot of time and money. Our consulting firm's experience with the WECS/Ford Foundation project supports the conclusion that in most cases only quick survey work is necessary when considering assistance to small farmer-managed irrigation systems and that the necessary data on irrigable land area can be obtained from the beneficiaries. Our experience also supports the conclusion that pre-feasibility and detailed

feasibility studies are seldom necessary for assistance to small farmer-managed systems. The author's experience is that these aspects of investigation, planning, and analysis for development of small irrigation systems can be made by the designer himself. The funds saved from avoiding detailed feasibility studies can be better used to extend financial assistance to a greater number of small irrigation systems.

CONCLUSION

The role played by the beneficiaries from the beginning of problem identification until the completion of the construction phase is crucial to preserving the farmer-managed characteristics of each system; to identifying ways to ensure and effectively utilize farmer participation in all steps of the intervention process; to strengthening the water users' capacity to effectively manage their water; and to mobilizing the local knowledge, labor, and materials for low-cost, effective irrigation. Beneficiary involvement in the earliest stages of the intervention process can also minimize the need for costly and repeated design revisions which cause delays in implementation. By being involved in the entire investigation, planning, and decision-making process, the beneficiaries also develop their management capability for improved operation, maintenance, and water delivery of irrigation.

A Prefabricated Modular Weir[§]

Wipat Kiwanon^{§§}

RATIONALE FOR USING A PREFABRICATED MODULAR WEIR

A WEIR is a type of irrigation structure built across a watercourse to raise the level of water flow and thus enable the diversion of water through canals to irrigate arable land. Weirs are useful during periods of low rainfall such as at the beginning of the agricultural cycle when it would otherwise be necessary to mechanically lift or pump water to reach fields, requiring expenditure of labor and providing water for only a limited area. Weirs also enable storage of water for dry-season use in streams that do not flow all year round. A weir is thus one form of labor-saving device.

Another important function of a weir is to serve as a spillway to prevent flooding that would damage crops during periods of heavy rainfall and high stream flows. Thus, a weir can serve two opposing functions: to raise the water level sufficiently for diversion of water for irrigation as well

[§] This is a 1989 translation by Roberta Sharples of a 1969 report. Prices quoted and project information have not been updated. In 1969, 20 baht = US\$1.

^{§§} Mr. Wipat Kiwanon was Head of the Design and Construction Section, Department of Land Cooperatives of Thailand when he wrote this report, and was later General Inspector of the Ministry of Agriculture and Cooperatives from 1981-88. He is now retired.

[Editor's note: This report was prepared by Mr. Wipat Kiwanon for the Department of Land Cooperatives in Thailand in 1969. It is very interesting to note that 20 years ago Mr. Wipat was advocating a design model based on principles of 1) simplicity; 2) low cost; 3) use of local participation and resources; and 4) durability, versatility, and flexibility. Despite his report on the construction of 12 modular weirs using funds of the Department of Land Cooperatives the design model received little attention. Nevertheless, many of these principles are of the same design and farmer participation principles are becoming recognized more and more as important and valid for farmer-managed irrigation systems today. The fact that Mr. Wipat began calling attention to these aspects 20 years ago suggests that acceptance of many fundamental ideas requires a long gestation period.]

as to enable the highest possible volume of water storage while allowing rapid and safe passage of excessive water flows. The construction of a weir thus requires thorough investigation of each site and a large degree of technical knowledge.

Weirs constructed under the Department of Land Cooperatives must consider three important conditions: 1) technical concerns, 2) financial concerns, and 3) the cooperation or participation of cooperative members.

Technical Concerns

Construction of a weir that will be useful requires thorough collection of quantitative statistical information for proper design. This process includes:

1. A detailed topographical survey specifying the relative elevations within the command area, profiles of the stream or watercourse at the site, and details of the areas expected to be flooded and the area downstream of the site.
2. A hydrologic survey to determine the volume and velocity of stream flows, the volume of water required for agricultural uses, as well as the volume required to pass over the spillway.
3. A geologic survey to determine soil strengths within the profile, soil permeability, and to identify sources for the materials to be used in construction.

In addition, to assure precision in construction, an experienced technician must be available at the site to resolve problems and effectively supervise construction.

Unfortunately, the Department of Land Cooperatives would have difficulty meeting the above conditions in implementing a weir construction program. There are not enough technicians, nor time nor budget to allow broad and precise collection of all the information required for use in design. The work at each site is too urgent to warrant as much time in technical preparation as would be desired, and instead must be carried out using local knowledge as much as possible. *These conditions mean that work of technical complexity must be reduced as much as possible and the majority of the information used in design must be collected from the local community.*

Financial Concerns

In general, important structures are designed and budget estimates are made prior to the request for funding for construction. However, when conditions are such that a complete and precise design is left open, budget estimates are uncertain. Considering the high cost of an individual weir, the government cannot guarantee to fund the entire cost. When the government can support only a part of the cost of any weir, the weirs that are designed should be amenable to intermittent construction to be carried out according to the financial resources available at any one time.

To reduce costs, wherever possible, local materials and local labor must be used. The design should also allow flexibility, so that gradual improvements or adjustments can be made. Of

critical importance is the capacity for continuing construction under financial conditions similar to an installment plan. *This means that construction is carried out in phases, and continued according to the availability of funds.*

Participation of Cooperative Members

Land development as carried out under the Department of Land Cooperatives focuses on the use of local cooperatives and their efforts to increase farmers' incomes. Members of a cooperative help themselves by helping one another. The construction of any type of public use facilities must thus be carried out under conditions that contribute to, or reinforce, this cooperative spirit. Opportunities and implementation are thus critically important to the success of this process. This includes the procurement of materials, contribution of labor, and collection of funds from each member. When people participate together in this manner there is a sense of ownership and a propensity for helping one another to maintain the structure.

Viewed superficially, it would seem that a structure developed in this manner would be less expensive. However, it actually turns out to be much more expensive because the work that should be completed within a month may take over six months. On the other hand, the extra time and money expended may be considered a fair tradeoff for the local community spirit and sense of unity generated among members during the process. This is the rationale underlying the argument that proper investment now will naturally lead to a gradual decrease in government financial support of community projects in the future. *This highlights the need to work in accord with and to the satisfaction of the local community, enlisting the ideas and cooperative energies of all members.*

Construction of weirs under the Department of Land Cooperatives has evolved within the constraints described above, with a modular design and implementation process amenable to these difficult conditions. Weirs can be built wherever needed almost immediately. The structure can be altered, augmented, or disassembled easily if necessary, to the extent that if the site is found to be unsuitable, the entire structure can be moved to a new location. Construction can be carried out intermittently according to the availability of financial resources over a relatively unlimited period of time. Opportunities are open for members to participate as much as possible according to their skills and energies and according to their convenience. (Usually, members are less busy after rice is transplanted and high stream flows prevent construction of traditionally designed weirs, or during the dry season prior to planting of seedbeds when the government is not easily able to allocate and disburse funds.)

The most important characteristic of the weir design is its appropriate use of technical knowledge and techniques in design. The design is an improvement over farmers' traditional methods, can be gradually developed into a useful complete structure, uses durable and easily available local materials, can be used even before construction is complete, is easily repaired, and is not particularly expensive.

DESIGN OF THE WEIR

This ingenious design uses separate modular blocks which can be easily and conveniently constructed as conditions allow and then assembled later. Weir size and proportions can be determined to fit with local conditions and later adjusted as appropriate by separating and reintegrating the blocks according to the newly defined needs.

The elementary unit used in this construction is steel-reinforced concrete plates which are fastened together using U-bolts and nuts to form standard-size, hollow cubic blocks. These modular blocks can then, in turn, be fastened together side by side using the same size U-bolts. The proportions of the weir -- the width across the watercourse, the crest height, and the upstream and downstream slopes of the design -- are thus constructed by joining a variable number of overlapping, interconnecting blocks (see Figure 1).

The weir is constructed by assembling the concrete blocks side by side into walls. The spaces between the walls are filled with sand, gravel, and large stones, if available. The concrete blocks can also be used to build head regulators or small weirs in canals for raising and diverting water to fields.

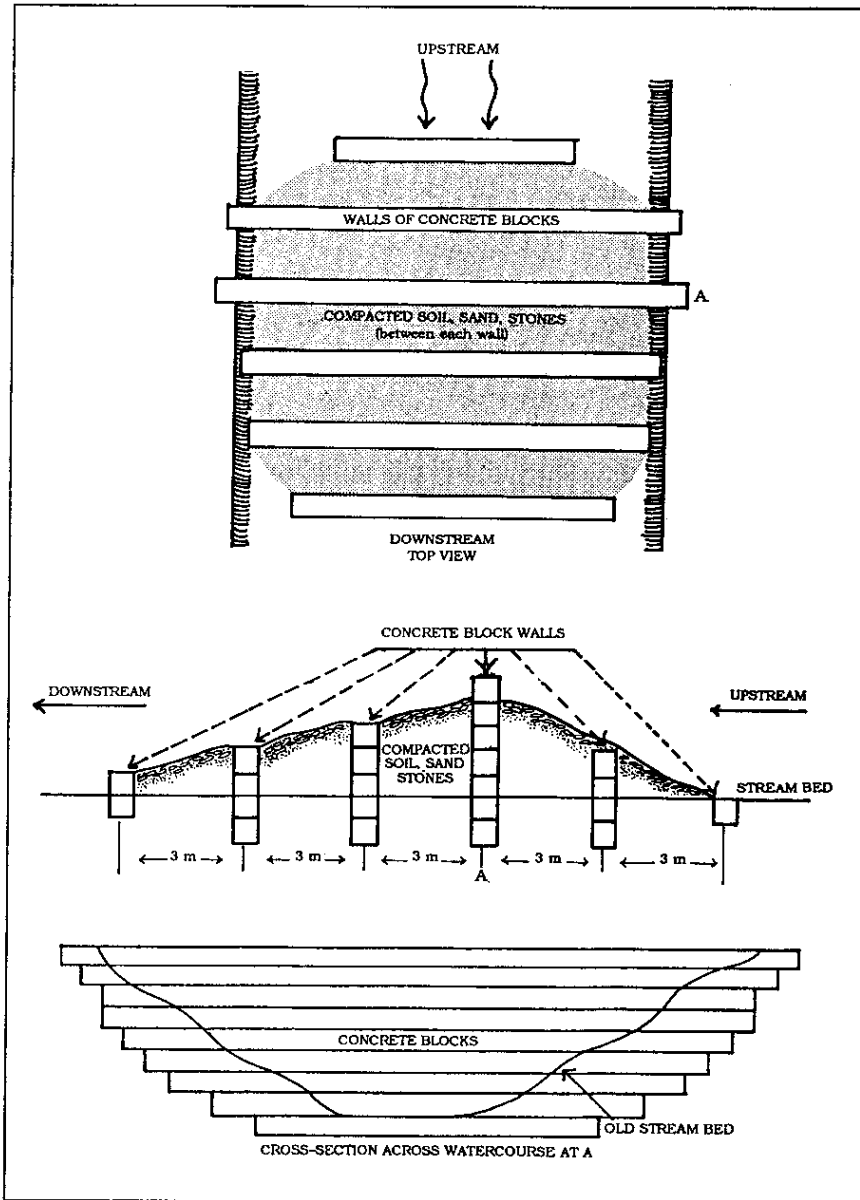
Physical Properties of the Reinforced Concrete Blocks

Dimensions. The concrete blocks are 50 centimeters (cm) wide, 50 cm long, and 50 cm high. Each of the concrete plates which comprises a block is 8 cm thick and is reinforced by 12 vertical and 4 horizontal rods of one-fourth inch steel. There are one-inch holes for inserting five-eighths-inch U-bolts used to fasten the plates together. The total weight of one reinforced concrete block is 145 kilograms (kg).

Materials needed for one plate:

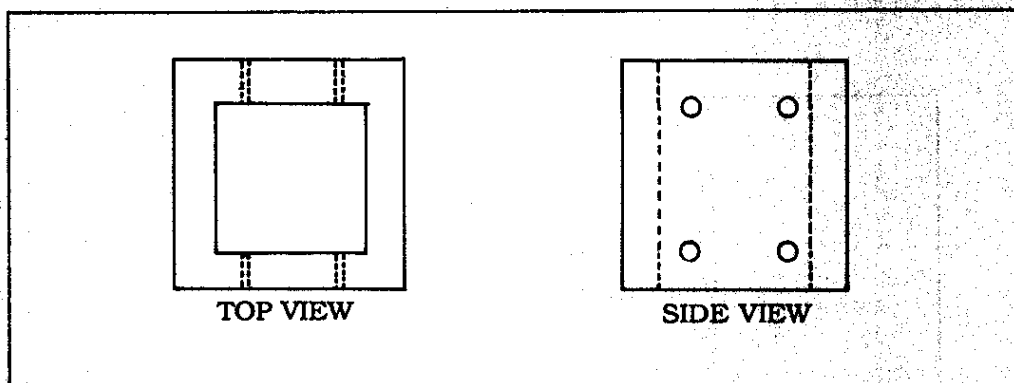
1. One-fourth-inch steel rods: 12 rods, each 50 cm long; 4 rods, each 2 meters (m) long.
Total weight: 3.5 kg.
2. #18 size wire: 10 m. Weight: 0.1 kg.
3. Concrete mixed in proportions of 1:2:4 : 0.064 cubic meters (m³).
 - a) 20.5 kg cement
 - b) 32 liters of rough sand
 - c) 64 liters of #1 and #2 stones or gravel.

Figure 1. Modular weir design. Example from the Northeast Region Land Improvement Cooperative Project, Muang District, Roi Et.



Source: Site Plan number SJ 001947/09.

Sketches of each cross-section:



Safe load:

	Top	Side
Uniform compression	53 tons	32 tons
Uniform tension	4.6 tons	3.1 tons

Five-eighths-inch screw nut, with tension of 2.3 tons and shear of 1.7 tons.

THE IMPLEMENTATION PROCESS

In general, when the prefabricated weir design is recommended for a site the Department of Land Cooperatives allocates a supporting budget. The first step is to quickly compile relevant information. Aerial photographs which show 10-meter contours are used to roughly estimate the expected command area and, wherever possible, data is collected from other government agencies such as the Royal Irrigation Department, the Department of Land Development, and the Department of Meteorology. An especially useful part of the process is the reconnaissance survey where technicians talk with local people in the project area. Sometimes it is possible to develop a site plan or profile of the proposed weir site and to plan the design immediately. The design designates the pattern for assembling the hollow modular concrete blocks. Local officials from the Department of Land Cooperatives and a technician carry out the implementation.

The specific proportions of each design are determined prior to construction with a large margin of safety provided. The size and proportions of the weir can be readily adjusted throughout the construction phase. This process is affected by several factors: 1) the willingness of the government to continue subsidizing the project by providing technical expertise and money, 2) the interest of the local community, and 3) the willingness to lower the design safety margin and risk some (repairable) damage to the weir and the banks of the watercourse.

Design principles. The principles for designing the weir are relatively simple.

1. Select a site where the height of the weir structure is as low as possible while still being capable of raising water to the level required for irrigation.
2. The crest of the weir should be about the same height as the elevation of the command area.
3. The weir should be designed as wide as possible to allow a large volume of water to be passed downstream when necessary. The combined cross-sectional area above the spillway, together with that of the canals constructed for irrigation, should be approximately equal to the cross-sectional area of the original watercourse at its narrowest point in that vicinity.
4. The slope of the upstream section depends upon the crest height and the abruptness of the stream banks. The slope should not be steeper than the banks but it should not be too gradual to avoid sedimentation. A slope of about 2:1 (horizontal:vertical) ratio is workable.
5. The slope of the downstream section depends upon the force of the stream. If the farmers describe the current as very strong the slope should be very gradual. Otherwise, it may be somewhat steeper but not less than 6:1 ratio in any case.

COSTS

An essential part of government assistance is to provide technical support. This consists of a survey, design, and direction of the process of weir construction both technically and organizationally within the cooperative. The cost of most of this assistance is in the form of monthly salaries for government personnel, per diem, transportation, and purchases of tools and equipment. Funds may also be required to purchase such materials as cement and steel rods that the local community cannot procure for themselves.

In the northern region, the amount of support required is minimal since labor, sand, and gravel are resources relatively easily obtainable and the people are generally willing to contribute almost all the necessary resources. At most sites it has become difficult to obtain the hardwood needed to repair the traditional wooden weirs. Persons cutting hardwoods in public forests run the risk of being arrested by forestry officials or police. The switch to a concrete weir from the traditional wooden weir enables the community to make use of sand and gravel which are more readily available.

In the northeastern region where people are less familiar with the construction of weirs and have fewer resources more extensive government support is required. The materials are not only more difficult to obtain but are also much more expensive than in the north.

Principal Expenses

Molds. The molds used to cast the modular concrete plates should be formed as thick and as precisely as possible. There are two types of molds, one appropriate for use where cement-mixing equipment is available and the other for hand mixing. Both types cost approximately 1,700 baht

each. Each mold can be used to cast more than 100 plates without impairment. The mold used with cement-mixing equipment allows faster production of up to four plates per day. The cost for additional molds is less because it is only necessary to construct an exterior shell. Each project should have at least 20 molds.

Concrete mixer. A concrete mixer, of size 7 input/5 output, and a small concrete vibrator are important. Together, these cost about 25,000 baht. Although work can be accomplished without these product quality is lower, production is much slower, and much more labor is necessary. When a concrete mixer and vibrator are available the average cost of labor is about five baht per block. Without this equipment labor cost averages about eight baht per block.

Tools and other equipment. Wire cutters, shovels, hoes, trowels, rope, concrete buckets, baskets, wrenches, a block and tackle, and a wheelbarrow are additional equipment needed for construction. Metal sheets are also needed. The molds are placed on these while the concrete plates dry.

Building materials. Cement, rough sand, stones and gravel, steel rods, and U-bolts are needed. Costs vary from area to area. In general, these expenses are less in the northern region as compared with the northeast. The cost of materials for one concrete block in 1968 ranged from 48 to 66 baht.

Transportation costs. The cost of transporting building materials varies from place to place. Most work is carried out at the cooperative unit or near the weir site, depending on which is more convenient. The average cost of transport per block depends on whether the unit owns a vehicle or must hire a private vehicle.

Labor costs. Calculated on the basis of the 12 projects implemented in 1968, labor costs average from 3 to 12 baht per block. The large range is a function of the differences between methods of employing labor. These methods are listed below in order of the least to the most expensive:

1. The cooperative uses its own funds to contract labor.
2. Government funds are used to contract labor.
3. The cooperative uses its own funds to hire labor on a daily-wage basis.
4. Voluntary labor of members is used on a rotating basis.

The last method is the most expensive because it requires continuous training of new workers, involves many workers arriving late, and leaves uncertainty about the exact number of workers who will participate each day. Another factor influencing the cost of labor is the availability of cement-mixing and vibrating equipment, with labor costs much higher where shovels and hoes must be used.

Labor costs and expenses for assembling the modular blocks, filling in and compacting the soil, sand, and gravel, as well as for placing rocks against the front of the weir are difficult to calculate precisely. In most cases, this is accomplished using voluntary group labor on a daily basis. Sometimes this is supplemented by some hired labor, as necessary. This category of expenses includes the cost of labor and its attendant expenses and materials such as soil and large rocks. These are generally paid for in cash, but a very rough estimate is approximately 30 to 40 baht per block.

Thus, very roughly, an estimate of the cost of one modular block for a prefabricated weir ranges from 85 to 155 baht or an average of 120 baht. The actual expenditure will depend upon the particular cooperative and its members and the degree of cooperation generated in the process.

PROJECTS

Twelve weirs were constructed with help from the Department of Land Cooperatives in 1968. At the time of this report most of these were still under construction. At some sites, the first set of blocks were still being cast. At others, the process of assembling blocks into a weir had just begun, and at still others, this process was more advanced but awaiting the next dry season to continue work. Thus, the available data are incomplete.

At some sites local people provided all labor and some materials. At other sites, all required resources except cement and steel rods were provided locally.

Projects vary greatly in size. Several include construction of head regulators or gates as well as the weir. Erosion of stream banks due to fine sand soils is a problem at some sites in the northeast.

REGIONAL DIFFERENCES

Aside from specific on-site considerations, application of this design on a nationwide basis would require consideration of regional differences which influence the general approach to be taken.

Northern region. The northern region is characterized by topography with very steep slopes, dense forests, and highly permeable soils. Rainfall runoff may cause rivers to overflow their banks but this subsides rapidly and thus there is seldom damage due to flooding. Rather, more than 3,000,000,000 m³ of runoff are unnecessarily lost (out of the region) each year. Water flows in the streams throughout the year. This is conducive to the development of gravity-based canal systems.

The farmers in the north have built weirs and dug canals to reach their fields for more than 700 years. In the two provinces of Chiang Mai and Lamphun, local people have worked together to build over 2,000 weirs, irrigating an area of approximately 96,000 hectares (ha).

In this region the Department of Land Cooperatives needs to provide both technical and financial support to the people in their efforts to improve and strengthen existing weirs thereby avoiding expensive annual repairs. Eventually, this should mean a replacement of the traditional weirs by more durable, technically acceptable structures.

Another important aspect of this work is the need to cooperate with the Royal Irrigation Department in promotion of water conservation:

1. Efforts should be made to organize and consolidate into a cooperative the many weirs that may jointly irrigate an area.
2. The crest height of existing weirs should be reduced as much as possible while maintaining irrigation capabilities. Regulators should be constructed at the head of all canals. The Royal Irrigation Department has already constructed head regulators in most areas and the Department of Land Cooperatives can be of the greatest assistance by arranging the construction of regulators or gates at points along canals or at the tail end of canals to facilitate the diversion of water into fields.

3. Assistance should be provided to local people in developing water-delivery systems and building various small irrigation structures that will enable both thorough coverage and increased conservation of water.

Implementation in this region has been primarily a matter of helping people in the rehabilitation of existing weirs. This requires planning to assure that the weirs can be used productively each year even while the process of construction may continue over several years. Cooperative members participate in construction by procuring sand and gravel and casting a portion of the blocks required in the dry season. These blocks are then assembled at the site prior to the beginning of the rice-production season. After rice transplantation when the farmers are less busy more blocks are cast to be used to augment the structure during the following dry season.

Northeastern region. The northeastern region consists of an elevated plain with gently undulating topography, sparse forests, and shallow topsoil of low permeability. The monsoon rains cover the entire lengths of the Moon and Chi Rivers and streamflow is strong and swift. Heavy rainfall alternates with dry spells in 2-3 potentially crop-damaging cycles throughout the rainy season. During the dry season water sources for most streams dry up. This is not conducive to the use of weirs. Hence, the people in this area are not familiar with weirs except for the construction of earth embankments at the end of the rainy season. These embankments serve to store water for dry season use but they are generally washed out each year.

Modular weirs may be useful in this region mainly for providing storage of water for dry season use, with at most only two out of every ten weirs actually serving to divert water for irrigation. The creation of reservoirs is a cost-effective and useful alternative, however, and modular weirs are also suitable for this purpose. Thus, the policy for this region should encourage people to cooperatively build as many modular weirs as feasible at intervals along streams so that sufficient water supply is available throughout the year. Even if weirs at some sites are washed out by heavy flooding they are easily repaired without much waste of either materials or labor because the individual concrete blocks will not be significantly damaged even under these circumstances.

Central and southern regions. No projects are as yet planned for the central or southern regions although the convenience of this process may lend itself to application in building other types of irrigation structures such as gates, head regulators, or small diversion structures.

BENEFITS OF THE PREFABRICATED, MODULAR WEIR

The weir serves as a rapid, effective means of accelerating water-resource development and can control water in a variety of situations. It provides a means for conserving or storing water or it can provide supplementary rainy-season irrigation or water for irrigating a second crop. In cases where many weirs are built along one stream they help control flood waters. At some sites it may provide water for a piped water system. At other sites the project facilitates communication.

The durability of the modules means that even where safety margins are low damage is not great. The versatility of the modules enables their application in construction of gates, dams, regulators, and even temporary bridges.

In the northern region, construction of the cement weir helps conserve forests by substituting the use of concrete for wood.

The opportunity to make extensive use of local participation and resources helps reduce the cost to the government.

Although the use of the prefabricated, modular blocks to construct weirs or other irrigation facilities is neither a precise methodology nor the most economical procedure available, it is capable of resolving a variety of problems and is worth considering as an option for water-resource development.

Analysis of the Causes of Damage to Canals and Structures Related to the Pattern of Tertiary Networks

Suprodjo Pusposutardjo[§]

INTRODUCTION

IN THE LAST 20 years, the Government of Indonesia made massive investments in the irrigation sector in an effort to achieve self-sufficiency in rice production. With respect to the targets for total irrigated area and self-sufficiency in rice, the irrigation development program was successful. The total irrigated area in the country increased from 3,388,000 hectares (ha) in 1969 to 4,779,000 ha in 1985 (IIMI 1987). Rice production increased at a rate of 5.6 percent per year. Since 1985, Indonesia has changed from being one of the world's largest importers of rice to become self-sufficient in it (Damardjati et al. 1987).

On the other hand, criticism, comments, and recommendations have been directed toward the implementation process that is part of the irrigation-development program. The existing irrigation networks were considered too complicated to be operated by irrigation-agency personnel at the main system level, and too complicated for the farmers to operate at the tertiary level (Horst 1984; IIMI 1987). As a result, several newly developed irrigation schemes were ineffective and inefficiently used. Most of them were also poorly managed so that they became inoperative within a short time (The Jakarta Post 1988; The Jakarta Post 1989; Kompas 1984; Kompas 1988). In an attempt to overcome the weaknesses of these irrigation schemes, Horst (1984) recommended simplifying the existing irrigation networks. In particular, he recommended that the water-division structures, water-measurement structures, and offtake structures at the tertiary level be simplified. Purba and Bhuiyan (1982) reported that before physical improvements could improve

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the effectiveness and efficiency of the irrigation system it is necessary to improve the capacity of the farmers (through water users' associations) to manage the tertiary system.

According to the Indonesian Irrigation Act, the responsibility for the development, operation, and maintenance of tertiary-level irrigation facilities rests with the water users' associations. The ability of the farmers to operate the network is a key factor for achieving a sustainable irrigation system at the farm level. By knowing the relationship between the complexity of the irrigation infrastructure and the causes of damage to the infrastructure, alternatives for simplifying the tertiary network pattern which match the ability of the farmers to operate the network can be formulated.

THEORETICAL BACKGROUND

Characteristics of Tertiary Irrigation Network Patterns

At present, tertiary networks in Indonesia do not follow any particular standard design. Guidelines issued by the Department of Public Works only mention the tertiary block size (50-100 ha), maximum tertiary canal length (less than 1,500 meters), and criteria related to structural specifications (DPU 1986). Since no standard criteria exist for classifying tertiary networks it is difficult to determine the level of complexity of a system.

To describe the characteristics of an irrigation network whose main function is to convey and distribute water, this study draws on an analogy to a transportation network. Two criteria were used:

1. The density of irrigation structures per unit service area (unit/ha), and the canal length per unit service area (unit/ha) were examined.
2. The complexity of the interconnections among the canal segments at the division box was examined using Kansky's (1963) terms: U-index, β ratio, μ ratio, and Ω ratio. Kansky defined these terms as follows:

$$U = e - v + p$$

$$\beta = e/v$$

$$\mu = M/e, \text{ and}$$

$$\Omega = M/v, \text{ where}$$

e = the number of canal segments,

v = the number of division boxes,

M = total canal length in a tertiary block

p = the number of tertiary offtakes; usually $p = 1$

The simplest tertiary network has $U = 1$, and $\beta = 0$. In this case, the tertiary network consists of only one offtake without any distribution canal. Irrigation water is distributed throughout the entire block from plot to plot. Both the β ratio and the Ω ratio express the dependency of the tertiary network on the function of the division box. With respect to the complexity of a tertiary network, the ratio expresses the complexity of water division. The higher the value of the β ratio,

the more complex is the network in terms of dividing water. On the other hand, a high Ω ratio merely indicates characteristics about conveying or distributing water throughout the blocks. A low β ratio and high Ω ratio indicate that water division in the tertiary block is simple but that the conveyance canal is longer than average. Therefore, the tertiary network is characterized as having a higher probability of water-conveyance problems despite being a network with simple water division.

Structural density is commonly used to indicate the level of complexity of a tertiary network based on the assumption that the work load, difficulties, and cost for operation and maintenance of the tertiary network are positively related to the structural density of that network. A similar assumption is applied to canal density (which is similar to the expression of the ratio -- the length of the canal divided by the number of division boxes).

RESEARCH METHOD

Site and Description of Sample Areas

Research was conducted in four irrigation schemes: Keyang Bawah of Ponorogo District and Andong of Ngawi District, East Java Province, and van der Wijk and Sorogenen of the Yogyakarta Special Territory Province.

The tertiary blocks were selected to represent different approaches to irrigation development: the van der Wijk and Sorogenen irrigation systems were developed by government personnel, Keyang Bawah was rehabilitated using a farmer-participatory approach, and the Andong irrigation system was rehabilitated through the efforts of the water users' association.

Where tertiary development is implemented by the government the water users are not involved in the process. However, after the project is completed the water users are trained to operate and manage the network in accordance with the operation and maintenance manual issued by the Irrigation Office. Typically, problems arise soon after management of the tertiary network is transferred from the government to the water users.

Where the farmer-participatory approach to irrigation development is used the water users' association is involved in all activities from designing the network to the trial-run stage. The tertiary network is constructed by a contractor after the proposed design (made by both the government and the water users) is approved by the water users' association. The water users' association acts as the counterpart to the government in supervising the construction. At the trial-run stage, the government personnel train the water users to operate and maintain the network according to the standard manual of operation and maintenance.

The most independent approach to the development of tertiary irrigation networks occurs when the project is fully implemented by the water users. In this case the government only acts as a technical consultant in the design and construction stages upon the request of the farmers. The government remains responsible for providing training in operation and maintenance of the network.

Categorization of Causes of Damage to Irrigation Networks

It is hypothesized that a relationship exists between the level of complexity of an irrigation network at the tertiary level and the water users' satisfaction with the system and their ability to manage it. Pusposutardjo et al. (1985) reported that in three newly rehabilitated irrigation schemes the farmers were not able to manage the tertiary network because they did not know the technical functions or purpose of some of the structures. Based on the above hypothesis, the causes of damage to irrigation structures were categorized.

Damages to irrigation structures were categorized as: 1) damages caused by natural forces such as landslides and floods; 2) damages due to improper design and construction, often indicated by unused structures; 3) damages resulting from improper operation and poor maintenance; or 4) damages caused by the farmers. The second classification relates to an irrigation network that does not meet the needs of the water users. The last two categories are related to either the dissatisfaction of the water users with the performance of the irrigation facility or their inability to manage the network. The last three classifications interact, e.g., farmers may destroy a structure that was not designed to meet their needs or ceased to be of use. Improper design and construction are often found in tertiary networks that were developed by government agencies.

In the field, a structure was considered damaged when it could not perform its functions without any measure of improvement. The degree of the damage observed was not classified, although the degrees were different.

It was often difficult to distinguish the exact cause of the damage observed because of the interaction among the different causes. When a structure did not perform well the farmers tended to neglect it. Moreover, the farmers might try to modify the structure to get it to perform according to their needs or they might destroy it because it was of little or no use to them. As a result, the damaged structure appeared to be poorly maintained, improperly operated, and destroyed. This research categorized the cause of damage according to the suspected primary cause.

RESULTS AND DISCUSSION

The Effects of Tertiary Rehabilitation on Irrigation-Network Patterns

Significant changes in the tertiary network patterns occurred after rehabilitation (Tables 1 and 2). The number of tertiary structures and the total canal length in the tertiary blocks increased as did the structure density and canal density. However, the function of the division structures became simpler because the number of canal segments to be fed decreased. Therefore, after rehabilitation, water distribution in a tertiary block tended to change from plot-to-plot distribution to distribution from canals, reducing the interdependence between adjacent plots.

The tertiary networks in Keyang Bawah and Andong were designed according to the farmers' preferences. This indicates that the farmers preferred to receive water from a canal with simpler

Table 1. General description of tertiary block samples.

Sample descriptor	Irrigation schemes					
	Keyang Bawah		Andong		van der Wijk	Sorogenen
	a	b	a	b		
No. of tertiary samples	5	5	4	4	3	5
Area of tertiary blocks (ha)						
average	25	25	212	212	74	13
maximum	50	50	265	265	85	22
minimum	14	14	176	176	60	3
No. of canal segments per block						
average	5	11	53	92	11	3
maximum	12	17	75	91	13	4
minimum	3	7	20	60	8	2
No. of division boxes per block						
average	2	5	23	3	5	1
maximum	5	8	36	39	6	1
minimum	1	3	9	26	3	0
Total length of canal per block (m)						
average	1,278	1,580	4,681	15,563	5,295	1,101
maximum	3,165	2,200	9,000	23,500	7,229	1,877
minimum	660	800	1,750	10,900	3,473	459
No. of tertiary intakes per block						
average	1	1	2	2	1	1
maximum	1	1	4	4	1	1
minimum	1	1	1	1	1	1
Procedure of tertiary development	Govt	FPart	Govt	Fmrs	Govt	Govt

Notes: a = before rehabilitation
b = after rehabilitation
Govt = development conducted by the government
FPart = development using farmer participation
Fmrs = development by the farmers

Table 2. Parameters of network patterns for tertiary block samples.

Parameters of network patterns	Keyang		Bawah		Irrigation schemes		Sorogenen
			Andong		van der Wijk		
	a	b	a	b			
U- Index							
average	4	4	29	41	7		3
maximum	5	6	40	53	8		4
minimum	4	3	12	34	6		3
β Ratio							
average	2.5	2.3	2.1	2.2	2.3		3.5
maximum	3.0	2.5	2.3	2.4	2.6		4.0
minimum	2.2	2.2	2.1	2.0	2.2		0
μ Ratio (m/unit)							
average	398	178	102	213	667		379
maximum	633	367	154	258	695		469
minimum	133	118	24	173	648		230
Ω Ratio (m/unit)							
average	662	342	217	477	379		1,583
maximum	992	550	50	603	469		1,877
minimum	330	200	342	395	230		0
Canal density (m/ha)							
average	45	71	26	82	90		113
maximum	91	93	42	109	117		185
minimum	18	41	7	66	49		73
Structure density (unit/ha)							
average	0.12	0.33	0.07	0.13	0.65		0.43
maximum	0.20	0.42	0.07	0.20	1.00		0.91
minimum	0.04	0.15	0.05	0.09	0.15		0.09

water division in the tertiary block rather than use plot-to-plot distribution where the control of water division was more difficult. As the interdependence between adjacent plots for water supply decreased the farmers were more able to control the water supply according to their needs.

Relationship between the Causes of Damage to the Tertiary Networks and the Values of Kansky's Parameters

Three parameters of Kansky's, β ratio, μ ratio, and Ω ratio, were adopted to test the relationship between the causes of damage to tertiary networks and the characteristics of the network pattern. The U-index was not used because it did not show a significant value for distinguishing differences among the characteristics of the tertiary network pattern in the research sample.

Kansky's parameters were applied to test the relationship between the characteristics of the tertiary network and the causes of the damages. Statistically, all tests showed that the different classes of tertiary network parameters were related to the different causes of damages at the 95 percent level of significance. Results from the test also confirmed the hypothesis that the most preferable tertiary network (as characterized by Kansky's parameters) would have the least damage (Table 3).

Table 3. Damages observed in the tertiary network samples as classified according to the primary cause of the damage.

A. Parameter: β ratio = (no. of canal segments/division boxes)

	No. of samples	Value of β ratio	Causes of damages observed					Percent
			DF	O&M	D&C	Nat	Total	
	6	<2.20	25	23	9	17	74	29
	5	2.21-2.50	8	15	0	1	24	10
	5	>2.50	68	54	18	16	156	61
Total	16		101	92	27	34	254	100
Percent			40	36	11	13	100	
Chi square		17.30						

B. Parameter: μ ratio = (canal length in block/no. of canal segments)

	No. of samples	Value of μ ratio	Causes of damages observed					Percent
			DF	O&M	D&C	Nat	Total	
	5	<250	16	14	0	10	40	16
	6	250-500	14	24	5	10	53	21
	5	>500	71	54	22	14	161	63
Total	16		101	92	27	34	254	100
Chi square		18.26						

Table 3 (Continued)

C. Parameter: Ω ratio = (canal length in block/division boxes)

	No. of samples	Value of Ω ratio	Causes of damages observed					Total	Percent
			DF	O&M	D&C	Nat			
	6	<500	20	14	0	12	46	18	
	6	500-1000	25	27	8	8	63	27	
	4	>1000	56	51	19	14	140	55	
Total	16		101	92	27	34	254	100	
Chi square		13.96							

Notes: DF = destroyed by farmers
 O&M = operation and maintenance
 D&C = improper design and construction
 Nat = damaged by natural causes

Table 3 shows that destruction by farmers and improper operation and maintenance are the two main causes of tertiary network damages. Further analysis (Table 4) indicates that 172 out of 254 cases of the damages to tertiary networks were damages to the canal from: 1) illegal offtakes (91 cases or 52 percent), 2) poor canal maintenance (46 cases or 27 percent), 3) improper design and construction (19 cases or 11 percent), and 4) damage due to natural causes (16 cases or 9 percent).

Table 4 also indicates that water measuring devices, especially the Romiyn and Cipoletti weirs, have not yet been accepted by farmers.

Table 4. Distribution of damages to tertiary network structures in the block samples.

Tertiary structure	Total	Damaged	DF	O&M	D&C	Nat	Percent of damage
Tertiary offtake	16	6	1	3	0	2	38
Water measuring devices							
Romiyn type	4	4	3	1	0	0	100
Cipoletti	1	1	1	0	0	0	100
Others	12	8	1	4	0	3	75
Quaternary division box	40	23	4	8	4	7	58
Road crossings	40	33	0	28	1	4	83
Elevated flumes	2	0	0	0	0	0	0
Others	14	7	0	2	3	2	50
Total	129	82	10	46	8	18	

Relationship between the Causes of Tertiary Network Damages and the Values of Canal Density and Structure Density

Using a similar procedure of analysis on Kansky's parameters, canal density and structure density were classified according to their values in the networks designed by farmers. The Asian Development Bank claimed that a canal density of 62 meters (m) per ha would be sufficient to achieve good water management in tertiary blocks (Anonymous 1988). Therefore, the canal density of 50-100 m/ha used in the hypothesis is a reasonable value.

Results of the analysis (Table 5) indicate that tertiary networks with a canal density of 50-100 m/ha and structure density of 0.1-0.4 unit/ha (1-4 structures per ha) were observed to have been damaged the least. The differences between the incidence of damage and canal density, and the incidence of damage and structure density were significant at the 95 percent level. Therefore, it can be concluded that both canal density and structure density can be used as reliable parameters, similar to Kansky's parameters.

Table 5. Number of damages in tertiary network samples classified according to cause of the damage.

A. Parameter: Canal density (m/ha)

	No. of samples	Value of canal density	Causes of damages observed					
			DF	O&M	D&C	Nat	Total	Percent
	7	<50	46	31	8	21	106	42
	5	50-100	16	20	0	2	38	15
	4	>100	39	41	19	11	110	43
Total	16		101	92	27	34	254	100
Percent			40	36	11	13	100	
Chi square		20.40						

B. Parameter: Structure density (unit/ha)

	No. of samples	Value of density	Causes of damages observed					
			DF	O&M	D&C	Nat	Total	Percent
	7	<0.11	27	22	9	21	79	31
	5	0.11-0.40	24	23	4	4	55	22
	4	>0.40	50	47	14	9	120	47
Total	16		101	92	27	34	254	100
Chi square		18.89						

Notes: DF = destroyed by farmers
 O&M = operation and maintenance
 D&C = improper design and construction
 Nat = damaged by natural causes

Characteristics of the Most Preferable Tertiary Network Pattern

Summarizing the results from the analysis of Tables 3, 4, and 5, the most preferable tertiary network pattern should have the following characteristics:

1. Canal density between 50-100 m/ha.
2. Structure density between 0.1-0.4 units/ha, or 1-4 structures per ha. Road crossings create maintenance problems. Therefore, it is recommended that the number of road crossings be kept to a minimum.
3. Each quaternary division box serving only 2-3 canal segments (ratio = 2.21-2.50) with only 2-4 division boxes per ha.
4. The optimum length for lower-level canal segments ranging from 250 to 500 m. Shorter canal segments are technically possible but may reduce the cropping area and increase the number of canal segments that have to be fed per division box.
5. The optimum length of a distribution canal served by one division box between 500-1,000 m.

The results of the research indicate the possibility for improving irrigation-management performance through improvement in the tertiary network pattern. Also, within the parameters given above, an irrigation network can be simplified.

CONCLUSIONS

The pattern of a tertiary network of an irrigation system can be characterized using Kansky's network parameters of β ratio, μ ratio, and Ω ratio. Canal density and structural density parameters are also reliable for this purpose, keeping in mind that the value of structure density sometimes does not represent the actual irrigation requirements because some structures such as road crossings are related to functions other than irrigation.

Based on their accumulated experience, farmers have the ability to design tertiary networks suitable to their needs as demonstrated by the value of the parameters of the farmer-designed networks in Keyang Bawah and Andong irrigation systems. In order to obtain the most preferable design for a tertiary network, the farmers' experiences related to water management at a particular site need to be considered in the irrigation design, especially for layout of the network. However, technical assistance is still needed for drawing and designing special structures such as siphons, elevated flumes, and water-measuring devices.

An additional observation related to the irrigation-development approach used for rehabilitation is that the existing design standards for tertiary networks as prescribed by the government must be revised to allow the flexibility necessary when the water users are partners or leaders in the rehabilitation effort.

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Papers Related to the Design Process

Summaries of Papers

Design for Participation: Elephant Ears, Crocodile Teeth, and Variable Crest Weirs in Northeast Thailand

Bryan Bruns (Page 107)

An innovative weir design developed by a project based at Khon Kaen University in northeast Thailand is presented. The design includes a variable weir crest and other features which help to enhance existing irrigation systems managed by farmers in areas of flat to undulating topography. A simple, standard design was developed utilizing a high level of local participation in planning, construction, and operation.

Design Issues in Farmer-Managed Irrigation Systems: Experiences in the Hills of Nepal

B. N. Acharya (Page 121)

Issues and innovations relating to beneficiary participation, techniques and technologies appropriate for farmer management, and institutional requirements are evaluated in relation to the author's experience in assisting existing farmer-managed irrigation systems in Nepal. The project mandated that the farmer-managed character of each system be preserved and strengthened while utilizing farmer participation and knowledge in testing low-cost design techniques and construction methods.

Second Approximations: Unplanned Farmer Contributions to Irrigation Design

Douglas L. Vermillion (Page 133)

The nature and range of socio-technical criteria and knowledge farmers may use in altering an irrigation network or in evaluating irrigation designs are analyzed. The author suggests that farmer knowledge has a number of distinctive and important characteristics which make it

essential that this knowledge be included in the design process and that the process permit interaction and revisions of the design criteria as the design teams and water users learn from each other.

Village Water Resources and State Administration: Rehabilitating Small-Scale Weir Systems in Sri Lanka

Shyamala Abeyratne (Page 143)

Problems that may arise as a result of design and layout of physical hydraulic structures where little attention is given to existing organizational patterns and water needs are documented in this case of government intervention to an existing farmer-managed weir system in Sri Lanka.

Indigenous Proportional Weirs and "Modern" Agency Turnouts: Design Alternatives in the Philippines

Ruth Ammerman Yabes (Page 153)

Different goals for irrigation performance and management and different evaluation criteria between the agency and farmers are identified in this study in the Philippines. The interactive design process which resulted in an improved design and greater farmer satisfaction is reported.

Small Farmer-Community Irrigation Projects in Nepal

Ganesh Ram Shrestha (Page 167)

Methodological and financial innovations of the Small Farmer-Community Irrigation Project are described. The key element of this project is to motivate the farmers to organize for irrigation construction and water management. The farmers contribute 50 percent of the project cost in the form of a loan and labor.

The Importance of Farmer-Irrigation Association Participation in the Development of Small Irrigation Schemes: An Engineer's Opinion

Eduardo P. Corsiga (Page 175)

The author highlights the lessons learned from the development and implementation of a communal-irrigation project with respect to farmer participation through irrigators' associations, data collection, and the training of farmers and agency personnel.

Of Dialogue, Debate, and Development: The Use of Participatory Rural Appraisal Methods to Improve Farmer-Managed Irrigation Systems in Kenya

John Thompson (Page 179)

A participatory rural appraisal approach is presented wherein a multidisciplinary team works with the community to assess its problems and opportunities relating to resource management. Water supply and distribution are one aspect of the approach which takes a holistic perspective of the factors that impinge on a community's progress and seeks to help the local people to identify their problems and select strategies to help mitigate the situation.

Design for Participation: Elephant Ears, Crocodile Teeth and Variable Crest Weirs in Northeast Thailand

Bryan Bruns[‡]

THE CONTEXT OF IRRIGATION DEVELOPMENT IN NORTHEAST THAILAND

- * Undulating topography
- * Unreliable rainfall
- * Stormflow irrigation
- * Earth weirs
- * Episodic mobilization

Farmers in northeast Thailand have developed a system of people's irrigation adapted to local social and environmental conditions, including unreliable rainfall, flat to undulating topography, sandy soils, and a farming system centered on the cultivation of glutinous rice. Villagers primarily rely on episodic mobilization for the creation and maintenance of collective goods such as irrigation weirs. These have formed the context within which local people have developed irrigation.

The primary crop in northeast Thailand is glutinous rice. Households grow one rice crop a year, relying primarily on rainfall. Upland crops such as cassava, corn, and kenaf are important

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sources of income. Rainfall ranges in different parts of the northeast from 800 to 1,800 millimeters per year. Rainfall in northeast Thailand is quite uncertain, especially in the first months of the rainy season from May to July. Dry spells frequently damage rice crops.

Most of the topography ranges from flat to gently undulating. Almost all streams stop flowing during the dry season. Wet-season flows are often very low between storms.

The key irrigation task is to divert storm runoff flows from streams. Villagers build and rebuild earth weirs to divert water to rice fields during the wet season. Earth weirs are also used to store water in the stream bed and adjoining aquifer for use during the long dry season. The need for water for livestock, fishing, domestic use, and dry-season gardening expands the pool of beneficiaries beyond just those whose rice fields can be irrigated.

Weirs are built by individual households, groups of people with neighboring fields, or village efforts. Episodic mobilization to build or rebuild weirs is the principal activity. There is little or no formally organized routine operation or maintenance activity. Instead, when a need arises an informal committee of senior villagers takes the initiative in consulting other villagers, deciding what needs to be done, mobilizing money and labor, and scheduling and supervising construction or repair of weirs.

Sandy soils are quite prone to erosion. The gentle slopes and the absence of rocks means that streams are not confined to a single channel location. The earth weirs traditionally built by villagers easily wash out or the stream may simply shift to go around the weir.

Weirs irrigate adjoining fields. Water is often diverted directly from the stream into the fields without canals. Natural and constructed levees along the stream help to control water flows. Gentle slopes reduce the potential for distributing irrigation water over wide areas, constraining the potential for developing irrigation. Reliance on storm flows places a premium on moving as much water into fields as quickly as possible before flows drop below the levels at which irrigation is possible.

Together, these natural conditions create a quite different environment for irrigation from the hilly areas where most studies of locally managed irrigation have been carried out. In northeast Thailand the principal irrigation activity has been the episodic construction and reconstruction of earth weirs in order to divert storm runoff flows.

As outside resources became available attempts were made to replace earth weirs with permanent concrete structures. In 1975 and 1976 funds were made available to subdistrict councils to spend on rural public works. Many small weirs were built under this program. Many other agencies also funded the construction of small weirs and reservoirs. During the late seventies the Royal Irrigation Department (RID) also began construction of many small weirs and reservoirs.

The results of such intervention were often disappointing. Many structures failed often during the first year of use. Streams washed around some structures, leaving them sitting on abandoned stream channels. Others had little capacity to divert or store water, especially in comparison to the amount invested in them.¹ This experience made it clear that simply providing funding was not enough to lead to successful development of weirs.

¹ See Asian Institute of Technology 1978 for an assessment of water-resources development in Thailand. This study helped to set the framework for much subsequent government investment. Unfortunately, many of the criticisms still hold true.

HISTORY OF THE PROJECT

The Khon Kaen University-New Zealand (KKU-NZ) Small-Scale Water Resources Development Project began in 1978 with the goal of helping water-resources development in northeast Thailand. It came to focus on construction of weirs because it was an area in which there was a need, and one in which civil engineering skills were required.[†]

During the first years of the project much time was spent on observing earlier water-resource projects in order to try to identify the reasons for their failures. The first project engineer, Brian Warboys, visited many sites of failed weirs and talked with villagers about what had happened.

Based on an analysis of previous experience a new design was developed, intended to be low cost and easily built by local people and to avoid the problems which often occurred in earlier weirs. The goal the project set was to design a weir which could be built for less than US\$5,000. The first structures were built by the Khon Kaen University (KKU) students who during their holidays went to help villagers. Subsequently, New Zealand government funding was obtained to build more structures. A KKU technician, Prasert Termsak, played a major role in communicating with farmers and supervising construction.

The performance of these new structures was followed up through repeated visits to the sites after the weirs had been built. Based on experience, the design and planning processes were revised and improved. Being in a small, independent project meant there was plenty of room for experimentation and learning. The approach used was very consistent with a learning-process approach to development (D. Korten 1980; Johnston and Clark 1982; F. Korten 1986).

Through 1985 over 50 small weirs and reservoirs were built, most using variations on the design principles which are discussed in this paper. A standard design was developed, and presented in a construction manual.

The use of the design and approach has since been spread by the People's Volunteer Weir Project of the Department of Local Administration, Ministry of Interior. Aspects of the design have also been used in the Job Creation Program and other interventions to develop irrigation in northeast Thailand. Hundreds of such weirs have already been built and many more are planned.

During 1985 and 1986 an evaluation was carried out which included visits to all the sites of weirs built by the project in the Khon Kaen province (Tantuvanit, Bruns, and Angsuwotai 1986).^{††} At three sites case studies for the evaluation were conducted by research assistants who lived in the nearest village for about three months. For the survey part of the evaluation all weir sites were visited and basic information collected and for half of the sites more detailed interviews were carried out.

Forty-five of the 50 weirs built by the project were still in operation. Two of the failures were connected with attempts to add to existing structures and were probably due to faults in the older

[†] For a good discussion of the project and design as of 1983 by the second of the two New Zealand Project engineers, see Mayson 1984.

^{††} Along with participating in the evaluation, during this period and afterwards the author studied an area in northern Khon Kaen which has seven KKU-NZ weirs.

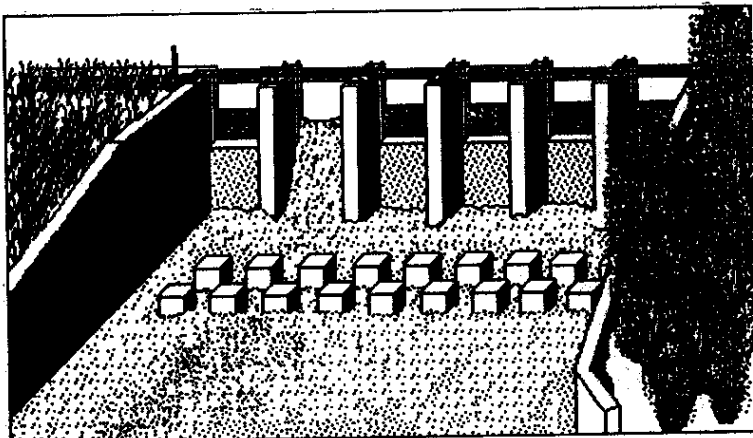
structures. Another weir was very poorly located, with the stream curving toward the weir from the side rather than coming straight on, and the stream eroded through the earth embankment next to the weir. Another weir was used as a spillway for a small reservoir with a very small catchment. It failed when the area below the spillway was flooded killing the grass which had previously stabilized the soil on the infrequent occasions when the spillway overflowed. The fifth weir seems to have been too narrow and not tall enough for the site so the stream washed around it despite repeated attempts by farmers to repair flood damage. After the evaluation in 1985 at least one more weir is known to have failed due to heavy sedimentation upstream of the weir, and because the weir was much narrower than the stream channel in contravention of the design guidelines.

The evaluation found that 90 percent of the weirs were still in operation and most were providing substantial benefits. In general, villagers were operating and maintaining the weirs on their own. Weirs were used for irrigation of rice and other crops, water for livestock and domestic use, and for fishing. An economic analysis suggested that for most sites, benefits substantially exceeded costs. In several cases the KKU-NZ weirs were located downstream of larger weirs built by the Royal Irrigation Department (RID). The KKU-NZ weirs provided similar or greater benefits for less than a tenth of the cost of the larger RID structures.

THE DESIGN

The variable crest is a key part of the innovative design developed by the KKU-NZ Project. Other elements of the design include sizing the structure according to the size of the streambed, routing flood flows through adjoining fields, and using simple standard dimensions, vertical sidewalls, wingwalls (elephant ears) and stilling blocks (crocodile teeth). Figure 1 illustrates a KKU-NZ weir. The standard design can be used on streams up to 20 meters (m) wide and up to 3.5 in depth.

Figure 1. Illustration of a KKU-NZ weir.



The use of stoplogs in the design means that boards can be put in the structure to raise the crest level so that it may be possible to divert water into fields even during periods of moderate or low flow. During periods of high flow the boards can be removed to pass large flows downstream, something which cannot be done with earth weirs. During the dry season two layers of boards can be put in and the area between sealed with mud in order to store water.

The width and height of weirs are set according to the dimensions of the existing channel. The standard design can be up to 20 meters wide and can have fixed crest heights of 1, 1.5, or 2 meters. The fixed crest is set to block at most 60 percent of the cross sectional area of the channel. The weir is designed so that it can pass the same maximum flow as the existing channel, albeit at a higher velocity, allowed by the use of a concrete structure. It is assumed that excess water will flow through adjoining fields just as it does already. Relatively flat topography and monocropping of rice on low-lying areas mean that there is usually little damage from such flooding.

This approach to design contrasts with usual design techniques which require some sort of estimation of maximum flows, after which the structure is designed to be able to accommodate the largest flood which could occur every 20 years, or some other assumed return period. Sizing according to the existing channel avoids the need for a survey or records of earlier stream flows. This approach leads to much smaller and cheaper structures compared to the Royal Irrigation Department's designs which are often more than twice as wide and ten times or more as expensive. It leads to much more effective structures than those built under the Job Creation Program and other programs which fund small weirs with costs similar to the KКУ-NZ weirs.

The goal was to develop a design which could be built for a total materials' cost of less than US\$5,000. During the project the cost of construction materials was about US\$400 per meter of width of the weir. The average width was about 8 meters. Costs have risen since. As a consequence of inflation and of construction of weirs through a government program, costs have risen up to twice as much per meter of width, compared to when the weir was built as part of a small university-based research project.

As part of the project's effort to produce a low-cost design, safety factors were set according to the needs of the design. These include construction using unskilled local labor. However, the weirs are built in relatively flat areas. When flooding occurs, water levels rise gradually so that the water level of the downstream side of the weir also rises reducing stress on the weir. The weirs are located on streams and do not usually hold back large volumes of water compared to reservoirs. The evaluation found that storage in the stream channel averaged only 5,000-10,000 cubic meters per site. As a result of these conditions, failure of the weir may cause some damage to fields but does not represent a major hazard to life or property. Therefore, the design can assume a higher level of risk than larger structures for which a more conservative approach to design is appropriate. Accepting higher levels of risk leads to substantial reductions in costs of construction.

Wayland (1987) carried out a structural analysis of the design which found that in general it was sound though safety factors for some aspects were low compared to more conventional design standards. He made several suggestions for strengthening it. The analysis was consistent with evaluation of completed structures in the field which did not find major structural problems. None of the weir failures seem to have been related to structural problems in the design.

Guidelines for designing and building the weirs have been provided in a manual prepared by the Water Resources and Environment Institute of the Khon Kaen University Faculty of Engineering (Khon Kaen University 1986). Weir operation was examined by J.R. Rinfret (1985)

in a simulation study based on case studies of three weir sites. Subsequently he looked at the consequences of adding weirs in a watershed (Rinfret 1988). The following discussion will focus on the ways in which different aspects of the design and the planning process act to facilitate local participation.

PLANNING

- * Sizing based on existing stream channel
- * Simple, standard design
- * Variable crest
- * Construction by voluntary local labor

Facilitates:

- * Making design decisions in the field
- * Responding to local requests
- * Enhancing existing people's irrigation systems

Several aspects of the design facilitate a more participatory-planning process, including sizing the structure according to the existing stream channel, use of a simple standard design, the variable crest, and construction by local voluntary labor. Most projects were initiated by requests from villagers. The planning itself was carried out through a series of meetings between project staff and village leaders (formal or informal) which allowed opportunities for developing a consensus on whether to build the weir and on other key decisions.

Sizing the structure according to the current stream channel makes the design more flexible reducing the technical considerations involved in design. The design takes up almost no land outside of the stream bed. This means that complicated negotiations to obtain land are reduced or avoided. The flexibility of the design increases the number of potential sites and the potential for being able to use the sites suggested by farmers. This makes it much more likely that the structure can be located at the sites of existing locally built earth weirs. About 80 percent of the weirs built by the project were built at sites where villagers had previously built earth weirs.

The standard design reduced the need for technical input in planning and allowed more scope for responding to local requests. There are additional guidelines such as locating on a straight stretch of stream and checking the foundation but these are not very restrictive. The main design factors which need to be taken into account are the depth and width of the current channel. Once the basic dimensions of height and width have been chosen there is little need for fine tuning of the design. This means that more effort can be directed to other activities.

The variable crest is a key part of the design which allows sizing the structure according to existing stream channels and assumes local participation in operation of the structure. One major area of disagreement between farmers and designers is the height of the fixed weir crest. Local people consistently prefer that crest heights be set at levels much higher than preferred by

engineers and technicians. The best explanation seems to be that local preferences are set by the desire to be able to divert water into fields even during periods of low flow. Despite the flexibility offered by stoplogs, villagers want to reduce the effort involved in adjusting the stoplogs and monitoring the stream.

There is also a problem of majority decision making because the costs of weir failure if the structure washes out or the stream channel shifts are usually heaviest for the one or two villagers whose land lies directly next to the weir. For most potential users failure does not represent a direct threat to their land but only the opportunity cost of lost irrigation. Constructing weirs which then wash out has already been part of the continuing pattern of construction and reconstruction of earth weirs.

What seems to have happened during the Khon Kaen University-New Zealand (KKU-NZ) project is that in the end, the weirs were designed with weir crests set according to the design guidelines, at most filling 60 percent of the cross sectional area of the stream and often less than that. Villagers were told that they could observe the use of the weir and raise the crest level later if they felt that was justified by experience.

However, in the subsequent People's Volunteer Weir Program there has been more accommodation of local requests, leading in a number of cases to weirs with crests at or above the level of adjoining fields. Levees along the stream still allow for some water control but such sites are unlikely to stay in operation in the long run where floods occur with strong enough flows to dig new stream channels.

The variable crest thus is a key element of the design but one in which there is still a tension between local desires and the technical requirements of the design.

Requiring voluntary local labor encourages the planners to involve local people and be responsive to their needs, otherwise the project would be much less likely to be built. The requirement that the weirs be built using voluntary local labor plays a key role in improving site selection. It encourages local people to more carefully weigh their need for a weir. The design itself facilitates the use of this requirement by allowing for construction mainly by unskilled local labor, use of existing village technicians, and avoiding the need for extensive outside guidance in construction.

The project did not impose a particular model of how farmers were to organize. Formal water users' organizations were not established. For the most part the project left it to local people to decide how to organize themselves in planning and construction. The main recommendation the project did make was to divide workers into several groups with one group working each day so that people still had opportunities to carry out other activities. Leaving most decisions to villagers allowed a management pattern which fit much more closely with existing local institutions for resource management. These patterns were ones of episodic mobilization rather than routine activities through formal organizations.

The People's Volunteer Weir Project of the Department of Local Administration has taken up the approach developed by the KKU-NZ project and implemented it on a wide scale. However, in some cases, rather than spending the time needed to develop a strong local consensus about providing labor some officials have instead implemented the program in a top-down manner. In some cases local officials used such pressure for local people to build weirs that instead of being called people's volunteer weirs they were called conscript volunteer weirs. Thus, requirements for local contributions need to be carefully assessed in light of how they will actually be implemented in the field as routine activities in a large-scale program rather than in a special pilot

study. Nevertheless, if implemented through dialogue with villagers, with enough time, and where villagers have a real choice about whether to contribute or not, a requirement for local contributions can play a valuable role in making implementation more responsive to local people.

The consequence of the design characteristics discussed above is that the major design decisions can be made in the field in active consultation with farmers. They do not require preliminary analysis of expected flows, nor complicated modifications of the basic design. Planning does not have to be done by an agency with strong technical skills. In actually selecting the site the focus can be more on the local people's requirements rather than on technical considerations. The standard design is small and flexible and easily lends itself to being built at the sites of existing people's irrigation systems.

CONSTRUCTION

- * Standard dimensions
- * Vertical walls

- * Use and develop local skills

The design uses standard dimensions as much as possible for such things as the thickness of walls and the spacing of steel. This makes it easier to learn how to build the weir and reduces the need to rely on blueprints and careful planning of construction. This standardization involves sacrificing some opportunities for minimizing costs by reducing steel or concrete in less critical parts of the structure. At the same time it may also lead to lower margins of safety in some parts than could be obtained with some design modifications. However, it means that construction is easier and more likely to be done accurately than with a more complex design.

Use of a simple, standard design means that construction is within the capacities of trained local technicians. Every village has local people with experience working with concrete. Many villagers go off to work in construction in Bangkok or a provincial capital and then return to farming. A village technician who has helped to build one weir acts as a supervisor in the construction of later ones. There is still some need for supervision from a more experienced technician or engineer through visits every few days to help deal with problems or questions which cannot be answered by the village technician who stays at the site full time.

The weir is designed to be robust, "insensitive to inaccuracy in construction technique" (Mayson 1983:9). Use of vertical walls in the structure also means that compaction of earth fill is not a major problem. This avoids one potential source of failure which is a common problem even for weirs built by contractors.

Altogether, the design characteristics discussed in this section and the previous one mean that construction does not require much in the way of specialized skills. Construction does not require specialized agency staff or experienced contractors. Instead, village technicians are trained in how to build the structure and they work with unskilled local villagers to accomplish the task.

OPERATION

- * Variable crest
- * Berm flow through adjoining fields
- * Bridge

- * Allow responsiveness to variable stream-flows
- * Keep continuity with earlier patterns of water management

Use of stoplogs in the design assumes local participation in operation and maintenance. This contrasts with the design philosophy used by the Royal Irrigation Department which builds structures that can survive even if there is little or no local operation and maintenance, with no stoplogs or only low ones. The KKU-NZ weirs instead assume that stoplogs will be used and that boards will be removed in order to pass high flows through the weir.

The adjoining fields are an essential part of the irrigation system since they are used to handle flows beyond those which can go through the stream channel. Thus, the weir is not operated in isolation but is rather just an added component in the existing farmer-modified hydrological system. Like earth weirs, the KKU-NZ weirs divert water into fields adjoining the weir and even slightly upstream. Thus, they maintain the current irrigation pattern, rather than being built with the more conventional design assumption that canals are used to deliver water to lower lying fields located away from the weir.

Use of stoplogs may mean that a concrete weir requires more effort to operate than an earth weir. Earth weirs usually have only pipes through the weir or a narrow spillway in which boards can be placed. In either case, the main tactics for coping with floods are either to let them flow through the fields and hope there is not too much damage or else to intentionally breach the weir. Construction of a concrete weir with stoplogs means that it is possible to let much more water flow through the weir than can be done with an earth weir.

Stoplogs are also one of the key points of conflict over weirs. Fish are a major source of protein in the diet of northeastern villagers. The area just downstream of a weir is usually a good location for fishing. Removing boards from the weir can increase the chances of catching fish, and so fishermen often remove boards without permission, in both wet and dry seasons. This creates a major problem for farmers who want to manage a weir for irrigation. In areas where water becomes very scarce in the dry season villagers successfully forbid opening the stoplogs. In other areas where water is not as scarce, farmers may give up trying to prevent fishermen from opening the weir, with the consequence that the potential for water storage in the dry season is not fully used. In some cases farmers resort to nailing the boards in place. While this may not cause problems in the dry season, it does hamper operation of the weir in the wet season.

As best as could be determined, problems in weir operation were not the source of failure for the five weirs which were no longer usable at the time of the evaluation. Farmers often remove boards from the weir much later than would be optimal, i.e., they wait until the water is threatening to overtop the levees along the stream channel into adjoining fields rather than removing the boards as soon as water starts to rise after a storm. In part, this is because of the

uncertainty about how high water will rise and the desire to move as much water as possible into the fields as quickly as possible. Since irrigation relies on stormflows which often only last for a period of a few days or less there is a high premium on making the most of water while it is available. Usually the farmer or farmers with fields next to the weir, who are most threatened by flood damage, take the initiative in removing the boards.

In some cases the stream rises too quickly and flows become too strong for farmers to remove the boards at all, in which case the weir may operate more like an earth weir, with little of the stormflow carried through the stream channel. Despite this, the weirs seem to have survived well, perhaps because floods rise relatively slowly, because farmers are experienced in coping with floods going through their fields, and because the concrete structures do not wash out as easily as earth weirs when they are overtopped.

One of the results of the assessment of the weirs done in 1985-1986 was the recommendation that a bridge should be a standard part of the weir design. Without a bridge, removing boards can be difficult and dangerous during periods of high flow. Including a bridge thus facilitates local operation and increases the chances that the stoplogs will be used to manage flows.

MAINTENANCE

- * Elephant ears
- * Crocodile teeth --
riprap not relied on
- * Vertical walls

- * Reduce susceptibility to damage
- * Reduce need for preventive maintenance

Several aspects of the design prevent or reduce maintenance problems. This fits with the approach farmers generally take towards maintenance which emphasizes making urgent repairs when necessary. A major benefit compared to earth weirs is that it is no longer necessary to mobilize resources to rebuild earth weirs each year. When earth weirs fail after fields have been planted it is often impossible to repair or rebuild them since earth is no longer available.

Routine maintenance of private fields is done by individual households at the beginning of the growing season. Some repairs of collective goods such as weirs may go on but is much harder to organize and occurs fairly infrequently. As with construction, the pattern for maintenance relies on episodic mobilization rather than on routine activities.

The design does not have portions which require routine maintenance, e.g., oiling of gates. Wingwalls help to prevent water from washing or seeping around the structure. These walls flanking the weir on each side are often referred to as elephant ears. Many earlier weirs were built without such walls and have quickly failed. In addition to the walls on each side, there are cutoff walls reaching below the structure which again help to prevent seepage of water past the structure which could in time lead to failure.

Crocodile teeth is the name farmers give to the energy dissipation blocks which are placed on the downstream apron of the weir. These are intended to reduce the downstream erosion which is a common problem of small weirs. The evaluation suggested that these were at best partially successful and that further solutions should be sought. However, the cutoff wall at the downstream side of the weir does provide a substantial margin of safety against erosion actually damaging the weir.

The blocks are at least a better approach than the common use of rock riprap, placed on the areas downstream of the concrete portions of the structure. While riprap may in theory be effective at reducing erosion, it is ineffective in practice. The rocks tangle nets and make fishing difficult and so fishermen remove them. While those who irrigate from a weir usually only come from a few nearby villages, people who fish at a weir often come from a dozen or more villages. This means that it is very difficult to enforce regulations such as prohibiting removing riprap, unless the weir is located very close to a village. Thus, blocks and a deep cutoff wall at the downstream end of the structure are more suitable methods for preventing erosion.

In the case of maintenance, it can be said that the weir is designed to cope with the relative lack of maintenance, especially routine preventive maintenance which is accomplished by local management. Participation in construction does help give local people an understanding of how the weir was built and the skills needed to carry out repairs.

CONCLUSIONS

It is possible to design for participation. This paper has used the example of the Khon Kaen University-New Zealand (KKU-NZ) project weirs to illustrate some specific elements of a design which facilitates local participation in planning, construction, and operation of small weirs. Key aspects of the design include sizing the structure according to the existing stream; use of stoplogs to make a variable crest; a simple, standard, robust design; vertical walls; stilling blocks; and a bridge.

These design elements facilitate participation in a number of ways. They make it possible to make the major design decisions in the field in consultation with farmers. The design is flexible enough to be used at many locations, so it is easier to respond to local requests and to enhance existing earth weirs. The weir can be built by local technicians and unskilled villagers. This makes it possible to require construction by voluntary local labor which in turn provides a strong incentive for those involved in planning to work with villagers in a participatory way. The use of stoplogs assumes local operation and makes it possible to manage the weir in ways very similar to existing people's irrigation systems. Several aspects of the design prevent maintenance problems and avoid the need for routine maintenance which is difficult for villagers to organize.

The specific elements of the design are adapted to the particular conditions of northeast Thailand and may not be very transferable to other areas. The needs and opportunities in irrigation development in other areas differ. In northeast Thailand diversion of stormflows is the principal irrigation task, rather than acquiring water, conveying water to fields, allocating water, drainage, or other tasks.

Problems concerning the weir now are what might be called problems of success. Programs to build People's Volunteer Weirs have led to construction of the weir in mountainous areas where the hydrology is quite different and where the availability of rocks and better foundation conditions mean that construction can be done even more cheaply using mortar and local stone. Also, specific programs have urged building only weirs of this type rather than making them a part of a menu of options for developing water resources, to be chosen by local people according to their needs and conditions. What may be more relevant for other areas of Thailand and for other countries are not the specifics of the weir design but some of the processes and principles which underlie specific design elements.

The most important factor encouraging development of a more participatory design was the learning process of working with villagers, which went into creating and improving the design. Past attempts at irrigation development have yielded a rich diversity of natural experiments. Unfortunately, the lessons of this experience are too often neglected. A small, flexible, university-based project provided a good environment for innovation. The process of studying earlier projects and then of following up on new construction within the context of a flexible, applied research project has considerable potential as an approach for creating appropriate innovations.

The intervention in the project was highly focused on the key irrigation problem faced by farmers. Energies were not dissipated on creating formal water users organizations, constructing distribution systems, or training farmers in irrigated agriculture. The assumption was that farmers could manage these activities on their own. Construction took advantage of existing irrigation structures and existing institutions for mobilizing resources.

The design that was developed was adapted to the particular conditions of northeast Thailand. In developing such an innovation, engineering knowledge had to be combined with the knowledge of local farmers. The willingness to experiment and take risks and the goal of a truly low-cost design were major factors encouraging innovation. The development of variable crest weirs in northeast Thailand shows the potential benefits which can come from a process directed at learning how to enhance existing locally managed irrigation systems in a participatory way.

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Design Issues in Farmer-Managed Irrigation Systems: Experiences in the Hills of Nepal

B. N. Acharya[†]

INTRODUCTION

THIS PAPER IS based primarily upon case studies of an action-research project executed in 1988-89 in a remote mountainous region of Nepal. Our firm was commissioned as consultants to the Water and Energy Commission Secretariat (WECS) of the Ministry of Water Resources, His Majesty's Government of Nepal, to assist with the implementation of a WECS/Ford Foundation project aimed at seeking low-cost strategies for assisting farmer-managed irrigation systems. Our firm was involved with 9 out of the 19 farmer-managed irrigation systems that were included in the project in the Sindhupalchok District.

We are currently serving as consulting engineering advisers to an integrated rural development project launched in the Dhading District of Nepal. Our consultancy efforts for both the Dhading and Sindhupalchok projects have gone towards innovating effective low-cost alternatives to the methods and processes currently followed by government line agencies responsible for promoting small irrigation and building local roads in the mountains. This paper attempts to outline some of our experiences as consultants promoting farmer-managed irrigation systems in the Sindhupalchok and Dhading districts, where beneficiary participation in the design and implementation of the systems received emphasis as an alternative to the conventional line-agency approach of assistance. Information on the farmer-managed irrigation systems that received assistance in both projects is summarized in Table 1.

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BACKGROUND

All the projects we worked with were located 5-32 kilometers (km) from the nearest road head, and could be reached from Kathmandu, the capital, by motor vehicle and on foot within one to two days of travel. All the systems were located on mountainous slopes (about 10°-30°) at altitudes of 1,100-2,000 meters (m) above mean sea level, and 100-1,000 m above a main river. Most of the systems were served by secondary or tertiary tributaries of the main river of the area, which carry very large flows in the rainy season (June-September), and barely sufficient water flow for all the fields during the dry season (February-April).

Table 1. Farmer-managed irrigation systems receiving assistance in Sindhupalchok (Group 1) and Dhading districts (Group 2).

System name	A		B		Canal length		Canal capacity		Command area		C	D
	NRs		a	b	a	b	a	b	a	b	%	%
			km		lps		ha					
Group 1												
<i>Cluster 1</i>												
Chhahare Khola Ko Kulo	196	126,615	2.6	2.9	56	200	126	163	65	32		
Soti Bagar Ko Kulo	74	150,699	2.1	2.6	62	150	19	30	55	11		
Dovaneswar Ko Kulo	34	74,807	1.2	2.0	54	100	2	12	22	19		
Magar Kulo	183	160,805	1.1	3.4	125	200	100	143	44	19		
Siran Tar Ko Kulo	60	136,789	2.6	3.0	25	100	18	24	65	57		
Majh Tar Ko Kulo	144	114,321	2.6	3.0	130	260	71	87	28	25		
Ghatta Muhani Ko Kulo	81	124,321	1.9	2.5	65	100	23	33	42	37		
Tallo Jhankri Khet	61	91,707	1.5	2.3	100	200	18	31	62	17		
Chholang Khet Ko Kulo	84	116,066	1.7	2.5	107	200	23	37	71	17		
<i>Cluster 2</i>												
Naya Dhara Kulo	400	139,720	2.1	2.8	--	250	55	110	--	--		
Besi Kulo	400	119,839	--	3.7	--	200	65	85	--	--		
Subedar and Dhap Kulo	125	85,000	--	2.5	--	200	30	65	--	--		
<i>Cluster 3</i>												
Siran Ko Kulo	88	57,488	--	2.3	71	130	18	37	--	--		
Majh Kulo, Baguwa	126	113,541	--	3.1	88	119	13	33	--	--		
Tallo Chapleti Ko Kulo	80	78,065	--	1.5	74	98	8	23	--	--		
Baghmara Ko Kulo	16	44,433	--	1.5	83	83	3	9	--	--		
Chap Bot Ko Kulo	57	71,630	--	2.7	114	114	12	17	--	--		
Bhanjyang Tar Ko Kulo	141	65,178	--	2.1	107	108	21	35	--	--		
Group 2												
Karki Danda	20	256,000	--	2.0	--	--	--	17	--	--		
Mayang Khola	20	150,000	--	1.8	--	--	--	10	--	--		
Peritar	6	20,000	--	1.0	--	--	--	5	--	--		

Table 1 (continued)

A = Number of beneficiary households

B = Project grant

C = Percent of design changes necessary at implementation stage

D = Increase in work output over estimates

lps = liters per second

a = Before project improvements

b = After improvement work

Group 1 - Cluster 1 - Assisted by B.N. Acharya Consulting Civil & Structural Engineers, Nepal

Group 1 - Clusters 2 and 3 - Assisted by others

Group 2 - Farmer-managed irrigation systems currently receiving assistance from Dhading Development Project/German Agency for Technical Cooperation (DDP/GTZ) under the Agricultural Development Bank of Nepal/Small Farmer Development Project in Dhading District.

The majority of the beneficiaries in these systems were illiterate or near-illiterate farmers who pursued mixed subsistence mountain agriculture. Rice, wheat, and maize were the primary crops, grown on level terraced fields, mainly for home consumption. About 85-90 percent of the farmers grew sufficient food to last the whole year. About 50 percent of the farmers also sold some rice for cash. Most of the young females also wove carpets which was a significant source of off-farm cash income.

All of the farmer-managed irrigation systems contained canals and temporary intakes which were repaired and maintained by the beneficiaries as often as necessary. All the canals had been built by the farmers using local materials and indigenous, traditional knowledge and experience. The systems had contour canals built in steep mountain slopes, dissected by cross drains, ridges, valleys, and cliffs, susceptible to landslides and erosion. Canal lengths ranged from 1 to 2.6 km, and canal capacities varied from 25 liters per second (lps) to 130 lps, serving command areas of 2-126 hectares (ha). Table 1 gives these details for each system.

Each irrigation system had well-defined beneficiary groups but no formal water users' organization. The beneficiary groups worked together to deliver water to their fields in times of necessity. They all experienced difficulty conveying water and operating and maintaining their irrigation systems. In each system there were a few active members who took leadership and responsibility while other members were opposed to any new initiatives.

All improvement work was carried out within the existing structure of water rights and beneficiary groups so as to cause the least amount of social and political problems within the community. In Sindhupalchok, after improvement of nine of the farmer-managed irrigation systems (refer to Group 1 in Table 1), canal capacities almost doubled on the average. Command areas increased from a total of 459 ha to 623 ha, a 36 percent increase.

DESCRIPTION OF THE PROJECT ACTIVITIES

The purpose of the Sindhupalchok project was to develop and test methods, techniques, and technologies for low-cost assistance to farmer-managed irrigation systems in an action-research mode. Project activities were designed to:

1. Preserve the farmer-managed character of each system,
2. Identify ways and means to ensure and effectively utilize farmer participation in the entire process,
3. Develop and test ways to strengthen beneficiary groups to make them more effective in carrying out improvement work and managing their water,
4. Test methods for mobilizing local resources, knowledge, experience, and labor in improving the management and physical capacity of farmer-managed irrigation systems,
5. Test appropriate low-cost design techniques and technologies for physical structures, and
6. Capture and document all lessons and experiences and recommend improvements.

A specific amount of money (as seed money) was budgeted by the Water and Energy Commission Secretariat (WECS) for improvements in each system. This money was used for paying all the labor provided by the beneficiaries and for purchasing necessary materials. All material purchases were made by the WECS and all skilled and unskilled labor (except for weaving wire crate boxes) was provided by the beneficiaries of each system. Utilization of contractors for construction was prohibited. Our firm provided the necessary technical and managerial support and helped fulfill all formal requirements for both the WECS and the beneficiaries.

All activities were carried out with the cooperation, agreement, and assistance of the beneficiaries and the WECS. All accounts and records were open to public perusal. The major part of our effort went towards holding dialogues with the beneficiaries to strengthen beneficiary organization and allowing them a full voice in all decisions. The WECS field engineers arranged labor payments against muster rolls prepared by us on behalf of the beneficiaries. At the completion of the construction work, the WECS senior engineer conducted a final inspection in the presence of our engineers and the beneficiaries of each system. A brief outline of various stages of the process follows.

First stage: **Planning and Field Design**

- * Held first dialogue with the beneficiaries to form a formal user organization and collect data.
- * Held second dialogue to determine the physical improvements to be made and to conduct field design.
- * Prepared the field cost estimate report for the WECS.
- * Prepared the inception report.

Second stage: **Detailed Design**

- * Prepared and submitted working drawings and detailed cost-estimate and design report.
- * Followed up to obtain project approval from the WECS.

Third stage: **Implementation**

- * Supervised improvements.
- * Redefined needs and priorities of farmers, made design changes, formalized all changes according to the WECS requirements.
- * Helped the WECS make labor payments.
- * Carried out follow-up to final inspection.

Fourth Stage: **Post-Implementation**

- * Prepared and submitted completion report for each system.
- * Prepared and submitted draft of final report.
- * Conducted seminar on all aspects of the project to disseminate information on lessons learned.
- * Prepared and submitted final reports.

ISSUES RELATING TO BENEFICIARY PARTICIPATION AND ORGANIZATION

One of the most important lessons learned in Sindhupalchok was that beneficiary participation in all decision making and construction of physical improvements by the beneficiaries themselves turned out to be a viable low-cost assistance approach. Low-cost assistance was possible because the beneficiaries participated actively in all of the following activities:

1) forming and strengthening their water users' organization, 2) identifying their needs and priorities, 3) solving all local problems, 4) providing necessary logistics locally which reduced overhead costs, 5) arranging for collection and transportation of construction materials, 6) mobilizing the beneficiaries for all work performed, and 7) supervising and motivating labor. Inherently, by their active participation, the farmer-managed character of these irrigation systems was maintained.

In Sindhupalchok NRs 1,874,500 (approximately US\$72,100[†] at the exchange rate of NRs 26/US\$) was spent in providing assistance to 19 farmer-managed irrigation systems containing a total of 975 ha of land owned by 2,350 farmers. The assistance to these irrigation systems (excluding technical support), amounted to NRs 1,923 (US\$74 at the rate of NRs 26/US\$) per hectare of land served. In other government-managed irrigation systems this amount of investment may be used just in conducting a feasibility study. (The Department of Irrigation spends up to NRs 3,000/ha for feasibility studies of systems containing 100-150 ha).

Low-cost assistance more effective with strong, united beneficiary organization. Low-cost assistance was more effective in those farmer-managed irrigation systems where the beneficiaries

[†] The exchange rate of Nepali rupees to US dollars has gradually increased during the life of the project, from NRs 21.9 = US\$1 in 1986 to 28.2 in October 1989.

and their organizations were most active. For example, in 5 systems where the beneficiaries were more active and dedicated, they produced 57 percent, 37 percent, 32 percent, 25 percent, and 19 percent more output than the minimum required (column D in Table 1).

Only the beneficiaries were sufficiently qualified to identify their needs and determine their priorities. Very often when our field engineers and the WECS officials interfered and tried to set priorities for the beneficiaries problems arose and it became necessary to revise or amend the program.

Our experience with the project confirmed that a strong beneficiary organization was a prerequisite for achieving optimum involvement of the farmers in designing the improvements and making decisions. Work in those farmer-managed irrigation systems with strong beneficiary organizations progressed more smoothly and the amount of financial assistance received was less of a constraining factor. In systems with weaker beneficiary organizations, even when the financial assistance was high, it was observed that the funds could not be spent as effectively as in the case of the systems with strong organizations.

Whenever the beneficiary group was large (e.g., 183 households in one system) and divided into rival (communal and political) groups, management and organization posed great problems. These groups were not cohesive enough to strengthen their beneficiary organization and decision making was hampered by divergent factions. Project activities were implemented by creating a sense of competition between the rivals but this proved to be a very inefficient way of spending the money. In contrast, in a system with 196 beneficiary households pertaining to a united community it was easy to manage and organize the farmers into one of the best and most effective beneficiary organizations despite the large size of the group.

Flexible design necessary to accommodate beneficiary input. For 9 of the systems in which we worked, an average of 50 percent of the designed works required revisions related to either cost or implementation. In 5 of the irrigation systems, 55-71 percent of these changes were made at the requests of the beneficiaries. For 4 other systems, 22-44 percent of the changes were beneficiary initiated. An important lesson to be learned from this experience is that the design for improvements to farmer-managed irrigation systems must be flexible enough to allow for changes requested by the beneficiaries.

Beneficiaries need budget-ceiling information to establish priorities. At the time the first dialogue was conducted with the beneficiaries the farmers were asked to state their needs. However, given no financial parameters, the farmers at first produced a long list of needs and priorities that were unrealistic. Only when each system was advised of the amount of financial assistance available to it, could the farmers establish concrete priorities. At this time they were also able to demand changes in the design to suit the budget available and determine how to make optimal use of the financial assistance. Once they knew the limits of the assistance they were also able to determine how to raise additional resources to fulfill their needs. This experience points out and verifies the necessity that the farmers be told how much financial assistance will be given to them *before* the fixing of priorities and design of the improvements occur, thereby minimizing the need to revise both designs and priorities.

Beneficiaries require assistance with bureaucratic requirements. Experience in Sindhupalchok showed that only rarely are the beneficiaries capable of keeping records and performing bookkeeping and fulfilling formalities in accordance with government requirements. This task had to be performed by the consultant in the name of the beneficiaries.

DESIGN ISSUES PERTAINING TO TECHNIQUES AND TECHNOLOGIES

Detailed drawings and cost estimates should be kept to a minimum. Three-dimensional physical site details can never be reflected completely on two-dimensional drawings, and these drawings are only good for those who can read them. The farmers cannot read the plans, thus they must depend upon explanation by engineers and overseers to understand what is in the drawings. Because engineers and overseers from outside the irrigation system have different objectives and priorities from the beneficiaries, it would be wise to make the farmers independent of reliance on the drawings to the extent possible.

Also, theoretically there is no limit to the extent of details and possibilities that can be figured into an estimate for an improvement work. There can be unlimited unknowns for conducting proper estimates, and determination of all the unknowns costs energy and money. As a result of our experience with participatory rural works including farmer-managed irrigation systems, I recommend that only the basic minimum of detail regarding engineering, drawing, planning, and designing should be conducted as required by the government. Instead, the energy of the engineers and overseers can best be spent supporting the beneficiaries directly in the field. When the engineer provides the necessary expertise directly in the field, all the three-dimensional physical details are right in front of his eyes. At this time the engineer can provide the best design acceptable to the beneficiaries, with a minimum of drawing and detailed estimates, and in a manner more readily understood by the beneficiaries. Whenever there is a necessity for more complex explanations, it would be much more effective if the engineer would demonstrate how actual structures (or models) function.

Traditional techniques and technologies can serve as a valuable resource. To facilitate low-cost assistance to farmer-managed irrigation systems, simple and effective designs easily adapted to local conditions are most readily accepted by the beneficiaries. The hill farmers of Nepal have developed many appropriate skills and techniques based upon local materials and knowledge acquired over decades and sometimes centuries of experience. Many of the skills and techniques can be replicated in other settings. However, our experience in Sindhupalchok and Dhading revealed that there is no collection and consolidation of this valuable wealth of information. Collecting and reporting on these traditional practices would be a valuable resource for determining methods of achieving low-cost assistance and ongoing beneficiary participation.

Use of local resources enhances beneficiary participation and reduces costs. Utilization of local skills and techniques is a sustainable approach -- the farmers themselves can carry out necessary improvements in the future. With the optimum utilization of local materials as well, the need for imported material can be largely eliminated thereby greatly reducing the cost and making the farmers further independent of outside assistance. In the case of the farmer-managed irrigation systems with which we worked the beneficiaries mobilized all local labor for all improvement work. Funds from the Water and Energy Commission Secretariat (WECS) were used to pay the labor.

In Sindhupalchok we saw that motivated beneficiaries with a limited budget were able to accomplish exceptionally large work outputs wherever local materials, skills, and techniques were adopted. A limited budget did not prevent them from completing all the works. The beneficiaries were not dependent upon imported materials or labor, so they simply resorted to working a little longer and a little harder to fulfill their targets despite the budget limits. In

Dhading, the Bhumisthan-Karki Danda irrigation system was selected to receive loan assistance from the Agricultural Development Bank of Nepal (ADB/N) and the Small Farmer Development Project (SFDP). Improvements to the system were estimated to cost NRs 256,000. The farmers of Bhumisthan-Karki Danda decided to build and operate their system without taking out a loan from the bank. They used local materials, skills, and techniques. In the following rainy season they studied the system carefully and discovered its weak points, then used the loan assistance to build the necessary structures. Eventually the beneficiaries were able to complete improvement of the system at only about two-thirds the cost of the original estimate.

Experience in Sindhupalchok and Dhading demonstrated that wherever dependence upon imported materials and technology were proposed, the farmers were not able to manage the work. This resulted in work delays and loss of quality. For example, obtaining and installing a reinforced cement concrete slab casting took 15 management interventions while an alternative locally available flat stone slab was obtained and installed with only 3 management interventions.

The farmers' work output exceeds government norms. His Majesty's Government of Nepal has established a set of norms or standards that specify not only what to build and how to build but also set the limits of material and labor required to complete the job. These norms are used for executing works under the contract system used by government line agencies and they were used for estimation and specification of the improvement works to be done in the Sindhupalchok project. However, these norms were found to be generally inflated and not suitable for participatory assistance to farmer-managed irrigation systems.

Ecological issues in fragile mountain terrain need to be addressed. The government norms did not consider design factors that might meet the ecological needs and concerns of mountain farm communities. Nepalese mountains are young and fragile. Canal building in mountains without appropriate resource-conservation measures can seriously contribute to accelerated soil erosion. Appropriate resource-conservation technology requires mass balancing revegetation efforts on naked slopes, bioengineering measures integrated with stone structures, and prevention of water infiltration in steep fragile slopes. These measures can be incorporated using local materials, skills, and techniques and would not be unnecessarily costly while at the same time be locally sustainable. The government needs to give attention to this aspect and perhaps be prepared to spend a little more initially to support protection of the ecology of the mountains.

Large canals are extremely costly to build and are also environmentally risky in steep mountain slopes. Excavation costs increase at geometrically progressive amounts for every increase of the canal width or capacity. Traditional farmer-managed irrigation systems in the mountains have always been small. The farmers sometimes resort to building another parallel canal a little below the first one rather than enlarging the capacity of the first. Again, gathering more information on the traditional practices of farmer-managed irrigation systems would serve as a valuable resource for the design and implementation of other low-cost improvement projects. Meanwhile, it is clear that low-cost assistance to irrigation systems in the mountains is feasible only for small canals because they are manageable and pose the least danger to the mountain ecology.

ISSUES PERTAINING TO STRUCTURAL ADJUSTMENTS IN THE DESIGN

Multiple, repetitive design requirements waste time and energy. During the second dialogue of the Sindhupalchok project a field design book was opened for each system. In the field design books all the measurements of possible improvements for each system were recorded and design sketches were made with all pertinent dimensions for each structure based upon advice and suggestions of the beneficiaries. Material quantities and cost estimates supported by analyzed rates were also prepared in the field for each structure. Based upon the costs calculated priorities of the farmers were also established.

The field design estimates were utilized by the government agency for fixing budget ceilings for each system. In addition, preparation of detailed designs, working drawings, and detailed quantity and cost estimates were completed in the conventional line-agency approach for the purpose of getting the project officially approved and sanctioned for implementation. Later, during the project-implementation stage needs and priorities established during the second dialogue demanded major changes. The government agency's official was flexible enough to allow such changes. However, a considerable amount of the consultant's energy was required to fulfill the official formalities of making and arranging such changes. It took us 99 man-months to fulfill all the requirements of the project whereas our original estimate was 49 man-months. The consultant's energy could have been better utilized in helping the beneficiaries solve their problems directly in the field.

A very high degree of the consultant's time was spent in preparing the working drawings, revised quantity estimates, revised rate analyses, revised priced bills of quantities, and revised breakdowns of materials and labor required for each work or structure of each system. The energy spent to undertake field design work was a waste when it had to be repeated at the detailed design stage when design details, working drawings, and estimates were again required. And later, when changes were made during the implementation stage this same work had to be redone. All of the field designs in all of the systems required revisions once the farmers were advised of the amount of the project grant. An average of 50 percent of the detailed designs had to be revised again when the project reached the implementation stage due to revisions requested by the farmers' group and technical or economic considerations encountered at the specific sites. (Column C, Table 1). Our experience supports the recommendation that field design work and the necessary changes in the detailed design be made during the implementation stage. Other drawings and estimates are unnecessary.

At the implementation stage, the conventional line-agency approach was followed from the beginning to the end. One senior engineer and one field engineer with supporting temporary staff from the WECS, and two field engineers, one overseer, one monitoring engineer, one coordinator, and nine field supervisors with our firm were constantly engaged in fulfilling the official formalities to release the money from the government bureaucracy and transfer it to the beneficiaries. Compliance with the many official formalities required so much of the field staff's time that field personnel often were not able to supervise the field work to the extent desirable. In contrast, in Dhading, for participatory rural works and farmer-managed irrigation systems supported by the Agricultural Development Bank of Nepal/Small Farmer Development Project

and Dhading District Panchayat Secretariat, only a few field design sketches prepared by overseers on A4 size white paper and a few pages of quantity and cost estimates were formal requirements.

For low-cost assistance to small rural farmer-managed irrigation systems, the government will have to find a simpler approach than that applied to larger civil works. This approach should set priority on the minimization of dependency of the farmers upon engineers, overseers, supervisors, and accountants from outside the system. First, the need for technical knowledge and expertise, and strict financial controls must be simplified. Our experience demonstrated that most of the necessary knowledge and skills lie with the people themselves. This approach should also require only the absolute minimum of technical and administrative manpower which would be best engaged in fulfilling minimum official formalities such as transferring the money from the government to the people and assisting the farmers directly in the field, tackling outstanding technical and organizational problems.

Facilitator role is extremely time-consuming. In Sindhupalchok, the beneficiaries participated in making decisions in all phases of the process, mobilized labor, and carried out the work plan. The consultant motivated and assisted the beneficiaries and supervised all technical and administrative work to ensure as far as possible the integrity of the design and control of quality. The WECS purchased the necessary construction material, arranged labor payments, and did the final inspection of the completed works. The consultant acted as intermediary between the beneficiaries and the WECS officials. The consultant's role was that of a facilitator to help transfer the project funds from the government to the beneficiaries. The government's role was that of a controller. The triangular relationship of the beneficiaries, the consultant, and the government could be compared to the legs of a three-legged table whose equilibrium was assured only when the three legs were of equal length and strength.

In this delicate relationship the consultants had a heavy burden. Cost overruns exceeded double our estimates. If we were to do the job over again and meet the same bureaucratic requirements we would have to charge a consulting fee two-and-a-half times more. However, the rehabilitation work can be accomplished for the same consulting cost if the administrative burden of completing the many bureaucratic requirements for government are simplified, made more flexible, and unnecessary procedures eliminated.

Labor mobilization on "piece-work" basis is a workable option. The Sindhupalchok experience clearly showed that mobilization of beneficiaries to accomplish improvements in their irrigation systems instead of employing the conventional contract system is a very viable low-cost assistance strategy. Labor payments were made against prepared muster rolls. However, whenever the beneficiaries were not fully motivated there was a tendency for the laborers to cheat in the work output. Thus, a piece-work system was experimented with. In this system, a group is assigned a specific task to be performed within a specific time for a certain amount of money. Our experience supports the use of a participatory piece-work system as an option for labor mobilization. Care must be taken to assure that such a system is not interpreted as a "contract award." Under a properly supervised piece-work system low-cost assistance can be realized optimally and effectively. In order for a piece-work system to be an option present government rules and regulations need to be changed. Our experience also supports a recommendation that contract awards for labor should be completely ruled out of low-cost assistance packages.

LESSONS LEARNED AND CONCLUSIONS RELATED TO INNOVATIVE APPROACHES

Local materials and local labor are the two most significant resources required for promoting assistance to farmer-managed irrigation systems. What is needed most is not so much "bureaucratic handouts" as strong village-level organizations to enhance the self-help potential of the people. Using external funds as "seed money" to organize the people can give good results. Also necessary are guidance, motivation, training, and orientation to help the people help themselves. The self-help approach appears to us as the only sustainable approach for assistance to farmer-managed irrigation systems, in particular in the context of mountainous Nepal.

Once local organizations are established and strengthened the only bottleneck to low-cost assistance for planners in the future would be how to organize the necessary technical and financial support while fulfilling official bureaucratic requirements. For this, planners would need to simplify the process and organize the technical support package innovatively.

Where necessary, the capacity of the people should be enhanced through training, orientation, and motivation organized at the local or regional level. An innovative financial support package would need to be flexible to meet the needs of the farmers and would be feasible if the government would recognize and trust the beneficiary organizations to help them utilize the financial assistance effectively. Without flexibility, low-cost assistance would be virtually impossible.

After the technical and financial supports are organized the government should next ensure that the work is scheduled so that the farmers are able to work when they are free to work and not when the government is ready to spend. Timely budget releases, timely decision making, and timely labor-payment arrangements are frequently recurring problems while dealing with the government budgetary system. An innovative alternative would be to channel funds through commercial banks so that funds are not frozen. The beneficiaries would receive loans from the banks and carry out necessary improvements, receiving funds as needed. The loans can easily be converted into grants after the beneficiaries complete the work. The government agency would have to provide necessary managerial and technical support in assisting the beneficiaries and in fulfilling the official formalities. It would be an added advantage if the same promotor would assist with implementation and strengthening of the beneficiary organization.

At the project-implementation stage all processes and procedures should be completely comprehensible to the farmers and open for their discussion and review. This would strengthen the beneficiaries' hand and would be a key to its success. Wherever there is lack of candidacy there is a chance for middlemen to enter and benefit at the expense of the people. This should be avoided. If the user organizations are strong, capable, and self-sustaining, there is much less chance for middlemen to enter and exploit.

For low-cost assistance to farmer-managed irrigation systems the government's central line agencies in particular do not appear to be the best partners because they follow complicated procedures, are inflexible, and are difficult to monitor, evaluate, and control. District-level line agencies like the district panchayat, the Agricultural Development Bank of Nepal, and the district's technical units can be appropriate partners. Also, local consultants/engineers are essential to the implementation process that seeks to incorporate farmer participation. Expatriate engineers do not have the necessary insight and understanding of the complex local, traditional,

political, and sociological aspects that operate within the farmer community which influence farmer participation and resource mobilization.

Second Approximations: Unplanned Farmer Contributions to Irrigation Design

Douglas L. Vermillion[§]

INTRODUCTION

AS PEOPLE DESIGN irrigation systems they either explicitly or implicitly predict future cropping patterns, irrigation-demand requirements, water supplies and use efficiencies, probability of drought or flooding, and command-area boundaries. In essence, irrigation design has to anticipate a mode of management (Levine and Coward 1985). This includes conceptions of whether management will be demand or supply-driven, what kinds of information will guide management decisions, what operation and maintenance tasks will be handled at what levels of the system, whether by the agency or farmers, and what performance standards will be acceptable by future managers -- including equity, distributional efficiency, adequacy, timeliness, reliability, and sustainability (Abernethy 1988:5-7).

In the design process, often the assumptions are more imposing than the amount of actual local information utilized. The reasons design so often does not adequately reflect management tend to be the following:

1. The range and intensity of relevant information are inadequate.
2. In rehabilitation or upgrading, technical design criteria are usually "satisfied" solely by the application of hydrologic and structure theory to "collectable" information (i.e., design often is not aided by any transfer of knowledge based on local management experience).
3. Design engineers may assume too narrow a definition of management (e.g., it may include demand/supply parameters but not account for expected rotational practices, timing constraints, or adaptability of distributional procedures to changes in crop patterns such as

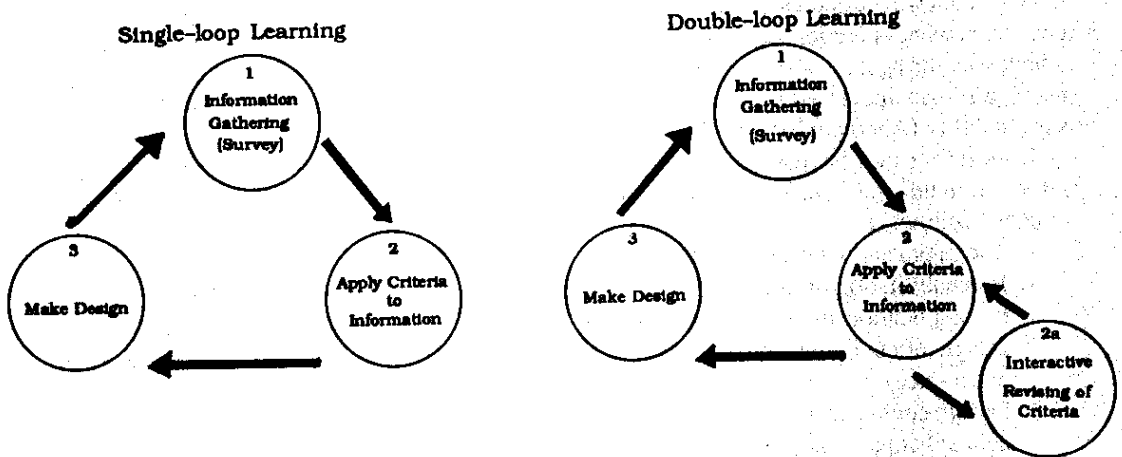
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- a trend toward crop diversification).
4. Design is conceived and implemented as if it were a single task which produces a definitive product (a project mode precludes a phased trial-and-error approach).
 5. Design and construction are done by multiple parties who are not accountable either to one another or to the future users and managers of the system.

The physical, institutional, and financial sustainability of irrigation systems has become one of the most important indicators of management performance success (Easter 1986:245-255). If done properly, especially with farmer involvement and investment, the design process can be the cornerstone of system sustainability. If done improperly, structures tend to get damaged or to deteriorate quickly, management is hampered, and farmers are less inclined to pay irrigation-service fees when they perceive structures as being faulty, unmanageable, or extravagant.

In information theory (cybernetics) conventional irrigation-design processes can be depicted as "single-loop learning processes," where the actor (design engineer) learns about what action to take (design layout) on the basis of selective information (survey) which is obtained and evaluated solely in reference to given, operating norms (technical design criteria). (Figure 1; also Morgan 1986:84-95.) By design criteria, we mean principles specified by designers by which the existence, type, location, shape, size, materials or function of a given physical irrigation structure can be determined for a given location.

Figure 1. Alternative irrigation design learning processes.



This approach would be acceptable as long as two conditions are met: 1) information utilized reflects the relevant complexities of the environment, and 2) design criteria adequately determine what aspects of the environment are relevant to successfully design a given network. Unfortunately, these two conditions are not often realized in dynamic socio-technical environments where system objectives and needs may change over time and where design problems may wax and wane and require locally evaluated trade-offs against competing criteria.

For example, an enlarged cement weir was constructed in Solok, West Sumatra, in 1981, to replace a brush and stone gabion weir. This increased water levels in channels which then stimulated a crop-planting schedule with a higher water demand. However, the added flows also caused higher conveyance losses. These two factors prompted subsequent demands for lining. Eventually, much of the main canal was lined which in turn restricted the number of direct farm offtakes permissible from the canal. This created the need for additional field channels which then gave rise to land use and right-of-way issues to be settled between farmers.

The study referred to herein was an exploration of the nature and range of socio-technical criteria and knowledge farmers may use in evaluating irrigation-design options. Field observations and interviews were conducted with farmers in order to identify instances where farmers revised, or were revising, what had been designed and built by engineers in the tertiary network development of the Kosinggolan Scheme of the Dumoga Irrigation Project in North Sulawesi, Indonesia, in the early and mid-1980s. This study was done while the author was doing field research for his Ph.D. dissertation (Vermillion 1986).

Criteria used by farmers to make the design changes were identified to demonstrate both the nature, range, and relevance of knowledge inherent in the farmers' experience, as well as the kinds of information which tend not to be available to engineers. Farmer-redesign cases were identified along a major secondary canal, within all tertiary blocks in Ihwan village (in the upper part of the system) and at tertiary blocks 17, 18, and 24 (in the middle part of the system). Tertiary network construction had not yet been completed or used long enough by farmers in lower blocks of the system (i.e., for at least three seasons) to be represented in this sample.

Farmers interviewed frequently reported that they had approached construction laborers or supervisors in the field to suggest changes and were usually told that the design had been established by the government and could not be changed. Often farmers relocated the construction markers when the crews had left. Others waited until construction was finished and the contractors had moved on before altering the structures. Altogether, 27 case locations of design alterations were identified in the sample blocks. Many cases involved multiple alterations which were interconnected.

The Dumoga valley has about 30,000 farmable hectares (ha) surrounded by steep mountains originating many streams which snake onto the plain, many of which were checked for irrigation prior to the irrigation project. The valley has had a rapid expansion of population mainly due to immigration growing from about 8,000 in the early 1960s to over 50,000 by the mid-1980s. In the area studied, single landholdings were one hectare for transmigrant land allotments and less for non-transmigrant land allotments. Blocks often contain considerable micro-variation in soils, topography, cropping patterns, and planting dates. Also, they frequently have multiple water sources, interconnectedness (between fields, blocks, and even systems), and return flow from drainage or seepage into lower areas. Hence, this was a formidable place to design an irrigation system.

The Dumoga Irrigation Project was designed utilizing topographic surveys which focused primarily on information about landform, soils, and natural waterways. Local information on prior use of natural waterways, farmer-built structures, landholding boundaries, and land use was not integrated into the design. Tertiary layouts were based on topographic surveys using a 1:2000 scale and one-half meter elevation interval lines. Design and construction were done by multiple consultants and contractors. Tertiary blocks generally were between 50 and 150 ha in size.

Farmers had prior experience irrigating rice fields and many farmer-built structures were in use in the area prior to the project. Before the project weir was completed in 1976 farmers were already irrigating 2,000 of the planned 5,500 ha of the scheme by their own efforts. By 1983, approximately 3,000 ha were being irrigated. Hence, generalizations herein may be less applicable in other settings where farmers have had no prior experience with irrigation or where new irrigation is introduced.

FARMER DESIGN ALTERATIONS

The most common kinds of alterations observed were channels being relocated (involved in 11 of the cases), streams being diverted or ponded (8 cases), project channels being abolished or not used (7 cases), and channel offtakes or division points being relocated (6 cases). Other actions included redirecting project channels into drains or streams, making new channels, adjusting division box gates to alter water divisions, making new flumes, destroying project flumes and lining channels. Several cases involved relocating channels to follow farm boundaries, to accommodate low water requirement crops or to continue to make use of preexisting structures built by farmers such as small weirs, channels, and ponds.

In their need for small-scale manageability within tertiary blocks farmers often mentioned reasons for making design changes which were different from and incompatible with project criteria. One type of rationale was the wisdom of diversifying one's water sources wherever possible as a strategy for avoiding the risk of dependency upon only project channels. Farmers frequently tapped multiple water sources as supplements to system channels or individual fields. Such sources as small streams, springs, marshes, ponds, and drains were prevalent throughout the command area and were commonly exploited by farmers as water sources additional to the project. The project was originally designed without reference to such alternative sources, assuming that the Kosingolan weir would be the sole source.

Another strictly farmer criterion was that of, wherever possible, combining conveyance and drainage functions in the same channels so as to maximize reuse and the utility of the channels and to minimize the number of channels. The project design required the separation of the two functions into different channels. Farmers frequently redirected project channels into streams which were checked to make collecting ponds. This had the effect of maximizing water reuse and redirecting drainage water to add to the centralized supply being conveyed through project channels. Water was then diverted out of the ponds to downstream users. This common pattern helped ensure that the channel had value, at any given point, to both upper enders (for drainage) and to lower enders (for supply). Maintenance was more important to both upper and lower enders than was the case where supply and drainage functions were kept distinct in different channels. However, project design criteria separated supply from drainage channels. The project defined all natural streams as drainageways. Every six months it routinely destroyed farmer-built brush weirs along small streams and natural depressions within the command area with the intent of "normalizing the drainageways" to prevent obstruction of drainage.

Farmers were inclined to minimize both the number of channel divisions (especially at the upper ends of blocks) and the levels of network hierarchy. The project however, was based on a four-tier design, with the assumption that farm-level offtakes would be made only along quaternary channels. Farmers did not like to have lower-order channels branching out from higher-order channels and running parallel to each other for "long" distances (more than 200 m). Many farmers were convinced by experience that such "excessive dividing" (especially if done too far upstream) increased conveyance losses. Light-textured soils were especially prevalent in the upper sections of the tertiary units. Hence, many quaternary channels were abolished or not used by the farmers. Turnouts were relocated downstream to where they more directly branched away from mother canals. The effect was to tend to consolidate flows into fewer channels.

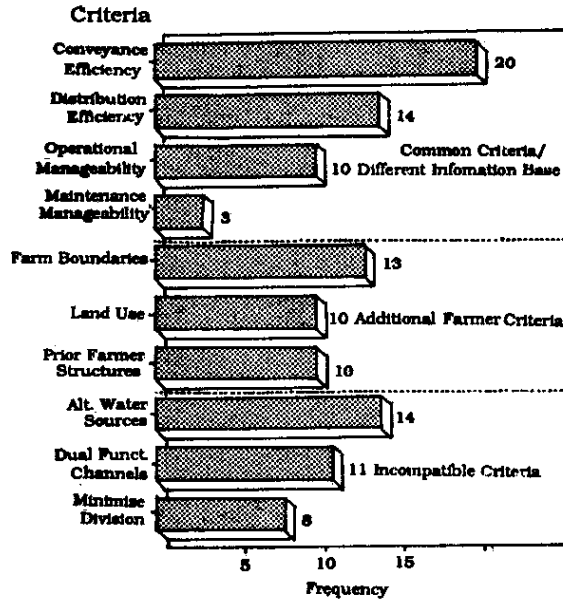
One example of how farmers altered the design in a step-wise, trial-and-error approach involving socially evaluated tradeoffs was in Block 18 where farmers chose to relocate a tertiary channel in accordance with farm boundaries rather than in strict accordance with topography. They knew this would make it difficult or impossible for at least one or two relatively high terraces on one farmer's landholding (A) to get water from the realigned channel. They also knew that having the channel follow the boundary was very important to the farmer's (A) productive capacity. And they knew that the field neighbor (B) always had more than adequate groundwater entering his field (as he was situated in a very slight basin) and that this water could be drained across the channel, via a small bamboo aqueduct, into the needy terraces of the other farmer (A). Both farmers were on good terms, so the local water users' association decided that the "receiving" farmer (A) would have an individual right to make private use of the neighbor's drainage (B) (which otherwise would have gone back into the public channel). Only he (A) could pull out the aqueduct as needed for drying.

Nevertheless, when the small aqueduct did dry up under conditions of water scarcity the needy farmer opened up a new, temporary intake in yet another location to direct water into the terrace. Ordinarily this would not be allowed. But the group recognized the farmer's right to make this alteration temporarily. This decision to relocate a tertiary channel along farm boundaries instead of following the exact topographic line was dependent upon a period for testing water adequacy from multiple sources, negotiating rights of access to alternative water sources, and evaluating the tradeoff between land served by the channel and part of a landholding not being served by the channel.

ANALYSIS OF FARMER-DESIGN CRITERIA

From the farmer interviews, criteria used by the farmers were elicited and categorized based upon the functional implications of the design alterations as expressed by the farmers. A total of 113 criteria were specified in the cases which represents an average of 4.2 related criteria per case. Criteria expressed or directly implied by the farmer-design changes were grouped into ten categories. Their frequencies of occurrence are displayed in Figure 2. The criteria are of three types: 1) farmer criteria which were also conceptually used by the project (although obviously quantified into hydraulic theory by the engineers), 2) farmer criteria which were additional to project criteria, and 3) farmer criteria which were incompatible with project criteria.

Figure 2. Frequency of occurrence of farmer-redesign criteria (27 cases, 113 total frequency of criteria).



Regarding the first order of criteria, both farmers and project engineers accepted the rule that water head should be relatively even and adequate to reach the intended service area. Both were in agreement that distribution should be equitable according to area served. Both agreed that the tertiary-level structures should be within the abilities of farmers to operate and maintain. The problem was in the different information base which the farmers brought to bear against the criteria. It was micro-level, socio-technical, and grounded in local experience. Farmers have told this author about significant variations in soil textures (sandy to loam) within single rice-field terraces of their parcels. The project's information was naturally survey-based, primarily limited to technical criteria (hydraulic, structural, agronomic, and meteorologic) and based on hydraulic theory. Forty-two percent of all redesign criteria elicited were cases where more detailed local knowledge prompted a different design although the criteria were not in dispute between the agency and farmers (Table 1).

The second order of criteria comprised those which were additional to, but not necessarily incompatible with those used by the project. Three types of these criteria were expressed by farmers: 1) channels should follow farm boundaries whenever possible, 2) actual farmer land use preferences (such as planting tree crops) needed to be considered, and 3) the design should incorporate prior farmer-built structures where these are still deemed useful by the users. These additional criteria accounted for 29 percent of the total elicited criteria.

Table 1. Frequency of occurrence of the three types of criteria.

Type of criteria	Frequency	
	Number of cases	Percent
Compatible criteria but different information base	47	42
Additional farmer criteria	33	29
Incompatible criteria between farmers and engineers	33	29
Total related criteria	113	100

The third order of criteria comprised those which were incompatible with project criteria. These were: 1) the utility of using multiple water sources, 2) combining conveyance and drainage functions in the same channel, and 3) minimizing channel divisions and levels of network hierarchy. This type of criteria constituted another 29 percent of the total criteria identified.

The most frequent criteria reported by farmers as rationale for making design changes were on questions of conveyance and distribution efficiencies, farm boundaries, and the conjunctive use of alternative water sources. Together, these criteria accounted for 61 of 113 incidences of elicited criteria (54 percent). Farmer criteria which were either additional to or incompatible with project criteria accounted for 58 percent of the farmer criteria elicited. Hence, the majority of redesign criteria were outside the scope of the project criteria.

CONCLUSIONS

This paper has sought to demonstrate the nature of contributions farmers can make in the design process. It has not evaluated the actual performance effects of the farmer alterations although this should be a research priority. Farmer knowledge has five characteristics which make it a distinct and essential asset for the design process. Farmer knowledge is: 1) holistic (cutting across disciplines of expertise), 2) experimental, 3) historical and dynamic, 4) sensitive to micro-level contextual diversity, and 5) in part, derived from locally evaluated trade-offs and negotiations. This is not to say that these characteristics are only positive. Sensitivity to the micro-level context may include vested factional interests or preclude a system-wide perspective. However, a design process which is interactive and has system-wide performance objectives should be structured to incorporate the positive aspects of local knowledge at the system level.

Sometimes it is asserted that farmer participation is needed so that the "social aspects" of irrigation will not be left out implying that the technical aspects are the realm of the engineers. However, the cases observed contained aspects which were as much of a technical nature as of

a social nature. Design revision sometimes required negotiation and testing over several planting seasons. However exhaustive, resilient, or flexible a set of design criteria may be it cannot substitute for the local knowledge obtained through dialogues with the farmers and the negotiated settlements of design trade-offs.

In settings such as this conventional system designs should be considered as only preliminary approximations. What is usually needed in the irrigation design process, particularly where farmers have prior irrigation experience and will be future managers, is a "double-loop learning process" which would permit the questioning and potential revising -- in process -- of "operating norms" (i.e., design criteria). (Refer to Figure 1.) This is also referred to as a management capacity for "learning to learn" and "self-organizing." Such a process requires two-way communication and mutual adjustment between design teams and the water users -- because part of the essential local knowledge and management criteria is only in the minds of the users (Smith 1988:93-107). In such agency-farmer meetings attention should be directed toward anticipated functional outcomes, performance expectations, local sustainability of new structures and water users' associations' operation and maintenance work plans (Coward et al.:IV-74).

Where agency staff or consultants are not trained or oriented to engage in such activities the use of institutional organizers has often proven to be effective in ensuring a more participatory process. There is evidence that this does effect better designs and system performance as well (see de los Reyes and Jopillo 1986). However, it has proven difficult to replicate this model on a national scale. Nevertheless, the Indonesian program to turn over small-scale irrigation operation and maintenance to the farmers is currently attempting to do just that by using agency staff as institutional organizers (Helmi and Vermillion 1989).

The fact remains that most of these intensive efforts for more participatory design processes have been pilot projects, not routine national-operating procedures. However, largely as a result of lessons learned from such pilot studies, the Indonesian Directorate General for Water Resources Development has recently formulated national policy guidelines to support farmer participation in future small-scale irrigation development (DGWRD/LP3ES 1989). These guidelines include such propositions as:

1. The agency will react to farmer requests for assistance (rather than being the primary initiator).
2. Farmers will submit a list which ranks the priorities of proposed improvements.
3. Water users' association (WUA) participation is required in each stage of the assistance process.
4. An agency field person will function as a motivator, mediator, and facilitator for the WUA.
5. A simple farmer version of the design will be prepared with the assistance of an agency staff and will form the basis for preparation of a technical version.
6. The WUA will have a role in construction supervision.
7. Local WUA investment along with agency assistance will be encouraged.

It will be no small challenge for the Indonesian provincial irrigation services to reorient themselves toward implementing such progressive policies.

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Village Water Resources and State Administration: Rehabilitating Small-Scale Weir Systems in Sri Lanka

Shyamala Abeyratne[‡]

INTRODUCTION

SMALL-SCALE IRRIGATION SYSTEMS^{††} irrigate about 235,000 hectares (ha) or about a third of the total irrigated area under rice in Sri Lanka. From ancient times they have been important as sources of subsistence and references to them exist from at least the first century B.C.

There are two main types of small-scale systems: tanks (reservoirs) and anicuts (weirs). Small-scale tanks are a distinctive feature of the dry-zone areas of the country and are usually dependent on direct rainfall or runoff water from their own catchment areas. Anicut systems tend to be located in the more mountainous regions which correspond to the wet and intermediate zones.^{†††} While small-scale anicuts and tanks number roughly the same (9,795 and 9,294 respectively) the area under village tanks is estimated to be about 148,589 ha of which 87,074 ha are irrigated by anicuts.

Historically, village tanks featured more prominently than anicuts as items for government intervention and administration. This was for several reasons. First, tanks had physical structures (notably sluices) which were deemed to require a certain degree of sophisticated expertise to be kept in working order and it was believed that villagers could not handle this without government

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^{††} Also referred to as village irrigation and minor irrigation systems. The three terms are used interchangeably in this paper.

^{†††} The ecological zones are delineated on the basis of annual rainfall as follows: dry zone = 1,270-1,900 millimeters (mm); intermediate zone = 1,900-2,540 mm; and, wet zone = over 2,540 mm.

assistance. And second, tanks were often hydraulically interdependent, so that the lack of maintenance of some could lead to deleterious results in others. The state was particularly concerned about tank-bund breaches that could result in loss of life and property under village tanks further downstream. Despite government intervention, because of the topography and relative remoteness of the dry zone, tank villages tended to be relatively cohesive communities ordered around the tank-water source. In turn, they provided an economic livelihood and social status and identity to the villagers.¹

Until about the mid-1960s, anicuts on the other hand, remained temporary constructions usually made of large boulders plugged with mud and straw. When floods and heavy rains washed away the weirs local effort was expended to replace them. Thus, repairs and maintenance to the anicuts were locally based efforts and the government saw little need to intervene. To this was added the peculiar nature of the land-tenure structure in areas where anicuts predominated and where much of the land was owned by both monasteries and feudal land-owning families having tenants to farm the land. Tenancy conditions were highly exacting,² and gave little motivation to invest extraordinary efforts in irrigation-system maintenance. Anicut-irrigated rice agriculture remained, as a result, at low levels of productivity while a major part of the people's livelihood was based on slash-and-burn cultivation. Given the marginal contributions of irrigated agriculture to peasant welfare in these areas, coupled with private temples and land-owning manors operationally owning extensive tracts of land, the government saw little need or possibility in investing in improvements of these systems. This was evident in the government-administrative framework for supervision of irrigation which was less intensive in the anicut areas, as was its investment in rehabilitation activities.

From the 1960s, following the enactment of the Paddy Lands Act in 1958 when the Department of Agrarian Services was set up and became formally entrusted with *all* small-scale irrigation systems,³ the government began to look into village anicut refurbishment. Typically, this was to replace temporary weirs with concrete ones. Sometimes channels were also lined. But besides obviating the need for seasonal replacement of the washed-away weir, rehabilitation was rarely aimed at augmenting water supplies. Also seldom, unlike in the case of tank systems, did the government become involve in land-settlement programs in the immediate area. These two factors were in fact interrelated: more land was available for government-sponsored land distribution/settlement programs in the dry zone and as a result, tank rehabilitation also had the goal of extending the command area. Anicut rehabilitation on the other hand, was aimed purely at obviating the need for maintenance of the headworks. Thus, arrangements for water-distribution devised at the local or rice *yaya* (rice tracts/fields) level flourished undisturbed and worked well to distribute water within the system.

¹ Leach's study on Pul Eliya (1961) provides a detailed description of the socioeconomic organization of a tank village.

² Fifty percent of the harvest share had to be given to the landowner and tenants could be seasonally evicted.

³ All systems with command areas of 200 acres (80 ha) or less were designated as minor systems.

BACKGROUND TO THE RESEARCH STUDY

One of the major programs aimed at rehabilitating minor or small-scale irrigation in Sri Lanka today is the Village Irrigation Rehabilitation Program (VIRP). Sponsored by the World Bank it seeks to rehabilitate over 1,500 tanks and anicuts in 14 districts of the island. This paper is based on some of the data collected under a larger research study conducted by the author and it focuses on the intervention process and its impact on a weir system. The paper will first present a description of the organization of irrigation prior to rehabilitation. Thereafter it will review the process of rehabilitation, and finally, it will investigate the implications of intervention for the long-term management of the system.

The anicut or weir under consideration is located in Ratnapura District, in the south-central part of the island. This area falls into the agro-ecological area of the intermediate low country with an average rainfall of 75 to 100 inches distributed bi-modally. Agriculture is predominantly rice, along with plantation crops of tea and rubber. Recently, fruit crops and high-income cash crops such as pepper have been introduced. Ratnapura District is famous for its gems and many farm families combine mining with agriculture or sometimes convert rice fields into gem pits, temporarily taking them out of production. Fifty-one percent of Ratnapura District is irrigated by small-scale irrigation systems, mostly by anicuts.

Thambagamuwa, the anicut system under review here was selected because it had a long irrigation history, was consistent with the national picture, and had experienced relatively little direct outside intervention to the irrigation system until the VIRP in 1987. We were in the field during this time and as a result, we had the opportunity to obtain a firsthand view of the actual rehabilitation process and ascertain the immediate and long-term consequences for system management.

SOCIAL ORGANIZATION OF IRRIGATION PRIOR TO THE VIRP

Thambagamuwa is located about 50 km from the district capital, immediately off the main road leading from Colombo to the southern part of the island. Though the two main rice tracts belonging to the village are on the side of the asphalt road the rest of the village is located deep in the interior and is accessible only by steep and winding footpaths. The main anicut is a 20-minute walk from the two main rice tracts and consists of a large natural rock dam with lined channels leading off it. The concrete construction of the main structures was done in the 1960s by the government-sponsored local organization in existence then. However, six of the remaining eight anicuts in the Thambagamuwa system are still temporary constructions of boulders plugged with straw, needing repair a few times each season.

The two main rice tracts are the Mahawelyaya and Kanathiriyawelyaya. The Kanathiriyawelyaya tract was developed as an extension to the Mahawelyaya in the 1950s in response to population pressure. However, the capacity of the anicut has set limits to the further expansion

of cultivation, as has topography. As a result, we see an elaborate form of rotational or *thattumaru* tenure where people, land, and water are rotated. This is a local adaptation made possible as a result of government legislation, notably the Paddy Lands Act of 1958 which allows for the registration and security of tenure on a rotational basis.

Briefly, rotation of owners of rice land functions as a mechanism to prevent excessive land subdivision through inheritance. In this manner, nominal ownership rights to rice land and the associated social status are maintained. A *thattumaru* rotation by tract as a response to a scarce water supply is evident in the rotation of water rights so that either the available water supply is used alternately by each tract each season, or on an annual basis. Since 1985, there has been rotation by season whereby Kanathiriyawelyaya (being further from the anicut) gets wet season water rights and Mahawelyaya gets dry season water rights. In the event of a water shortage within a season, a rotation is instituted and water is first delivered to the tail end of the tract⁴ and then worked up towards the head-reach areas. At other times, there is continuous irrigation with water being delivered to a series of land shares through earthen- and wooden-proportioning devices and to single land shares through pipe outlets of predetermined width. These reflect the property rights in the system which in turn reflect the rights of prior appropriation enjoyed by certain land sharers.

How are irrigation/cultivation rights determined when there is a rotation of people, of access to land, and of water? In this case, it was found that rotation of water takes precedence and determines ownership and tenancy rights. Thus, access to land (i.e., tenancy rights) and land ownership rights are defined in terms of the season when irrigation-water rights are accorded and cultivation is made possible. Hence, if irrigation rights are given only in alternate years, a tenant cultivator whose turn comes quarterly would have to wait eight years to get his cultivation turn. However, if irrigation rights were given for both wet and dry seasons his turn would come every two years. Thus, overall irrigation rights determine the frequency of the "people" and "land" rotation.

For all intents and purposes the water rotation by tract works smoothly and every effort is made to stick to the cultivation schedule and not extend it into the alternate *yaya's* "season." Similarly, though highly elaborate, the different forms of rotational tenure bind the community together and spread each cultivator's cultivation risks and interests as widely as possible. This also serves to equalize access to the critical resource of water and the system appears to work with little conflict.

IMPLEMENTATION OF THE VIRP

The agencies involved in the Village Irrigation Rehabilitation Program (VIRP) are the Irrigation Department, responsible for physical construction and rehabilitation, and the Department of Agrarian Services, entrusted with the task of formulating water-management programs for the

⁴The amount of water delivered is based on a calculation of time (in Sinhala, "reckoning time") per acre.

rehabilitated systems. The vehicle utilized for the latter is the Agricultural Planning Team which consists of three officers who are expected to visit the rehabilitated system and function as catalysts to organize farmers to undertake improved water-management practices. In addition, the project aims to strengthen the major government departments involved with small-scale irrigation systems by providing the staff with necessary training, equipment, and transport to ensure their proper maintenance (Abeyratne 1986).

According to the established procedures for VIRP (World Bank 1981) there are several preliminary steps both for informing farmers and for eliciting their participation in the rehabilitation process. These include ratification meetings where farmers come to an agreement with the Irrigation Department personnel as to the components of rehabilitation and their own contributions to the process. However, in Thambagamuwa the actual process was as follows. Thambagamuwa was selected for rehabilitation sometime in 1987, a fact brought to the notice of the villagers only because piles of quarry stones were unloaded and left in different parts of the village. In early May, the technical assistant of the Irrigation Department along with the contractor, met with the farmer representative and the three of them walked up to the anicut and took some measurements. A few days later the stipulated farmers' ratification meeting was called by the farmer representative (on the instructions of the technical assistant) and farmers gathered as requested. But the Irrigation Department personnel and the Agricultural Planning Team members were absent. This was repeated a few days later when the farmers gathered for the meeting but once more the officers did not come.

At the end of May, construction began with no warning and consisted of building several feet of retaining walls along the main canals and laying 28 controlling pipe outlets to individual fields in Mahawelyaya and to clusters of fields in Kanathiriyawelyaya. Two regulators were also constructed on the main canal. By this time however, the cultivation season was in full swing in Mahawelyaya for the dry season. Fields had been plowed and the rice sown approximately two weeks earlier; hence the demand for irrigation water was high. The technical assistant discussed the matter with the farmer representative and they came to an agreement that there would be intermittent water issues so that construction work could be done. But two cultivators towards the tail end of the tract who were facing water shortages broke some of the structures and started taking water to their fields.

In the meantime, farmers had no idea of the kind of construction being installed until the structures were literally in place. When asked, the contractor said that the locations of the controlling pipe structures were stipulated in "the plan;" likewise, when farmers suggested modifications, or more frequently, a change in the angle of an outlet, the contractor said he could not deviate from "the plan." The fact that all 28 controlling pipe outlets had a uniform diameter of four inches irrespective of the acreage they were to irrigate caused even more acrimony. When some farmers protested that acreages less than their own received the same volume of water as their own fields they were told that the Irrigation Department had only four-inch outlet pipes in stock. In frustration, a tenant-cultivator originated a petition requesting a proportioning weir, a device that farmers were familiar with and which they relied on for water distribution within the tract. All the farmers signed the petition and gave it to the cultivation officer. However, when we checked the Agrarian Services Center files a few weeks later, there was no such petition on record, suggesting that it had been "lost" en route.

The petition also mirrored the farmers' displeasure with the farmer representative who, having had the first and sole contact with the contractor and technical assistant, had obtained a separate

and strategically placed pipe outlet to his field. He had also managed to obtain the subcontract to provide labor for the earthwork component of the project. However, as the position came to naught farmers had to accept the designs and structures imposed on them. Before the season was over, farmers had on their own "modified" several of the controlling pipe outlets. Mostly, they tended to circumvent the impositions and to irrigate as before.

The technical assistant who had done the preliminary investigations was interviewed. He insisted that the farmer meetings had been held and that "procedures" had been followed according to established rules. He also insisted that the district irrigation engineer visited the project every two weeks to supervise the work when in reality no one other than he himself had come there. He was also emphatic in maintaining that the designs had been modified to suit farmers' wishes/needs though several times he stressed that the Irrigation Department was a "technical department" and therefore "must construct mechanically." In other words, alterations to fit individual and/or tract requirements would be impossible. When questioned repeatedly on what the anticipated project benefits were, he spoke of better water management that would lead to increased cropping intensity, meaning cultivating both seasons in both tracts, but that to ensure this "we have to forcibly control water." When probing his views on how this would be achieved he talked of the need for "a strong farmer representative" and "disciplined farmers" but was quick to add that water-management would be the "task of the Department of Agrarian Services."

The technical assistant who replaced the above-mentioned technical assistant halfway through the project knew even less about the system as he had not done the "preliminary investigations." He was however more conscious of the limitations of the technical solution and said that he could not anticipate more benefits from the rehabilitation work than a small reduction in seepage and wastage in the conveyance system. He did not believe that this would be significant enough to allow for simultaneous cultivation of both tracts in the wet and dry seasons. He was also ready to admit that the concrete controlling pipe outlets may in fact require extra management on the part of the farmers and that to elicit this extra effort may prove to be difficult. He even went on to say that there really was "no point to the expense but for the fact that an external donor agency was paying."

IMPACT OF THE NEW STRUCTURES

Despite the rhetoric of local participation contained in VIRP documentation the rehabilitation process in Thambagamuwa was externally orchestrated. In fact, this followed the pattern of preceding rehabilitation programs that had been undertaken for small-scale systems, especially tanks. The Thambagamuwa anicut was selected on criteria determined by national policy and recommended by the political representative of the area. Despite recommendations for a "pre-construction phase" that would enlist farmers, if not at least inform them of what was to take place, construction work was started without the farmers' knowledge. The Irrigation Department personnel talked of the irrigation system belonging to the Department of Agrarian Services but

“handed over” to the Irrigation Department for the duration of the rehabilitation since the latter had the technical skills. It was a “taking over” and “handing over” exercise between two government departments.

In terms of the impact of the new structures, from preliminary observations and discussions with farmers, we could observe and/or predict the following overall outcomes.

1. The controlling pipe outlets (CPOs) have allowed for inequities to be introduced and made permanent by their very positioning in the system.
2. The CPOs' permanent size has introduced rigidity into the rotational water schedule as the width has set limits on the time/flow measurements and cannot be adjusted.
3. The CPOs have introduced other inflexibilities into a system that was able to adapt to constraints in land and water including land fragmentation.
4. The CPOs have gone against entrenched property rights in the system. Where earlier, only one pipe inlet was allowed per land share and subdivided land shares had to rely on plot-to-plot irrigation, now, subdivided land shares sometimes have several CPOs while a single land share may not even have one CPO.
5. Traditional patterns of water distribution have been disrupted as uniform CPOs have been introduced irrespective of the acreage to be irrigated. This has increased the incidence of conflict within the system.
6. In the context of continuous flow irrigation, CPOs tend to favor head-reach irrigators which has resulted in heightening existing inequities.
7. Regulators can be made to favor irrigators at the head reach. Also, regulators may require increased management, necessitating skills beyond those of the farmer representative (requiring government assistance) and/or concentrating in him discretionary powers in managing water that he could abuse to the detriment of other farmers.
8. The new structures are “management intensive” and may require more time (and skills) in management than farmers are willing to contribute in a system not solely dependent on irrigated rice farming.
9. The retaining walls in most locations were useful in preventing submersion of the rice-field plots below. Some, however, were put in merely to spend budgeted funds.

Consequences for the old water-distribution system are most evident in Kanathiriyawelyaya where an earthen-proportioning weir made seasonally by farmers has been replaced by complicated concrete structures that do not match the old division of water and in fact, defy description. Moreover, whereas continuous management in the form of alterations to the proportioning weir were possible earlier in accordance with property rights and reflected changes in the water supply, the new concrete structures do not afford the same flexibility.

In the questionnaire survey conducted to assess views on the VIRP, 71 percent of the cultivators said that the CPOs adversely affected intra-yaya water distribution. In fact, most farmers were explicit in stating that the old outlets were much better and the traditional system of water distribution much more equitable than what had just been introduced. In terms of individual water supply, one third of the farmers stated that the new structures made their own water supply much worse. The only part of refurbishment they talked about favorably was the reinforcing of walls. Farmers felt that they played a useful role in protecting the channel bunds and preventing seepage.

The overall management of the system seemed to pose a further problem and many farmers had already voiced their apprehensions. The most basic fear was the supposed enhancement of the farmer representative's position as a result of the new structures. Where earlier the farmer representative played an informal leadership role but most of the actual water distribution was done by the farmers -- albeit more or less individually -- now decision making plus actual implementation of water distribution had become concentrated in a single individual. Farmers were concerned that the farmer representative could abuse his new status as was already evident in the construction phase. Certainly there are no checks, physical or organizational, on his future actions.

CONCLUSIONS

Based on the farmers' responses plus our own observations in the field,⁴ it appears that sometimes the Village Irrigation Rehabilitation Program (VIRP) is undertaken in a blueprint mode with little understanding of the patterns of water distribution or leadership in the local community. The merits of a system like Thambagamuwa were precisely those that the new structures hoped to change. Thambagamuwa, because of the nature of its land history, its tenurial interactions, and its social/kinship bonds had a relatively well-defined pattern of water allocation and distribution. The water-"thattumaru" by yaya was accepted and adhered to, as was a switch to a rotational schedule when water was perceived to be inadequate. During times of continuous irrigation the system functioned more or less automatically underscored by property rights in the system. The farmer representative in this context functioned mostly as an "ombudsman" and more weighty decisions were left to the government officers at the seasonal cultivation meeting.

Consequently, VIRP rehabilitation should not have taken place within the realm of intra-yaya water distribution as this was the strength of the system. Expenditure may have had better returns if it had been made higher up in the system -- for example, at the level of the headworks or the conveyance system. A clear place for intervention, for example, would have been the temporary anicuts irrigating parts of the system. When we asked the technical assistant why money was not put into making these anicuts into permanent structures we found him to be unaware of the temporary anicuts in the system. The fact that he was not informed of their existence highlights the problems that exist when we expect farmers to act as a community, with homogenous interests which would be articulated to the officers.

The result of the VIRP intervention can be summarized as follows. New physical structures have been introduced, supposedly to prevent wastage in the system and therefore to increase cropping intensity (i.e., cultivation of both tracts in both seasons). But in reality their advantages are in providing more control and more predictability; both advantages however are contingent

⁴In this site and elsewhere in Sri Lanka. See Abeyratne and Perera 1986.

on a relatively abundant water supply. As soon as there is water stress the controlling pipe outlets (CPOs) introduce inflexibilities into the system while the previously existing system was able to adapt to both land and water constraints.

The new structures are also management increasing, requiring a different mode of organization than the one currently in operation. Whether a suitable adaptation will be made is yet to be seen. Meanwhile, the new structures run counter to the existing organizational fabric, have heightened inequalities in the system, and have made it more open to individual abuse. Even worse, the imposition of structures that appear to be incompatible with existing traditions and practices may in time destroy the merits in local organizational and/or leadership resources that exist.

The consequences are far reaching. Land and irrigation policy in Sri Lanka, from at least the middle of the 19th century, demonstrates that the government has thought it fit and proper to intervene in the rehabilitation and management of small-scale irrigation systems, particularly tanks. Interventions made for the rehabilitation of anicuts were at the level of the headworks or main irrigation structures. As these facilities were thought to belong to the government, this was considered appropriate from the people's point of view (Abeyratne and Perera 1985). However, cultivators expressed their right to the use of irrigation water through their access to land, and this was evident in the intricate patterns of water distribution developed at the *yaya* level under anicuts. This, in Sri Lankan small-scale systems, was the only realm that could be considered "farmer-managed." However, with VIRP intervention, even that realm appears to have become wholly government-managed.

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Indigenous Proportional Weirs and "Modern" Agency Turnouts: Design Alternatives in the Philippines

Ruth Ammerman Yabes¹

ONE FORM OF agency assistance to farmer-managed irrigation systems is the rehabilitation of existing irrigation structures and facilities. When some irrigation agencies provide this kind of assistance they expect farmers to take active roles in the operation and maintenance of their irrigation systems after rehabilitation work is completed. The experience of the National Irrigation Administration (NIA) and its participatory programs in national- and communal-irrigation system development demonstrate how an agency helped develop these systems with the close interaction and participation of the people who use them. The National Irrigation Administration's emphasis on cost-recovery measures was one factor which prompted it to encourage farmers to participate in planning and design decisions on the irrigation facilities being constructed. It also encouraged farmer responsibility for operation and maintenance of these irrigation systems through its structure of irrigation fees and amortization payments (Korten and Siy 1988:148).

The design criteria and procedures of these agencies need to incorporate and build on farmers' technical expertise where appropriate so that farmers can operate and maintain rehabilitated or newly constructed irrigation systems without further agency assistance. Few detailed accounts discuss particular cases of farmer experience and how this expertise is incorporated into the design of structural improvements in irrigation systems. This paper examines a Philippine case where the NIA, with input from a farmer-irrigation organization, chose between two design alternatives for flow-dividing structures -- an indigenous proportional weir and a "modern" agency turnout.

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The paper looks at three parts of this case. First, it describes the project context of the design alternatives and the parties involved in the design activities. Second, it considers the two alternative flow-dividing structures. Third, it looks at the decision-making process followed by the agency and the *zanjera*¹ as they appraised the two alternatives. Agency and farmer arguments for and against the two structures are analyzed to see how the choice of an improved, indigenous, and proportional weir might have an impact on farmer operation and maintenance.¹¹ The paper examines the different priorities that the National Irrigation Administration (NIA) and farmers gave to a variety of design criteria -- including water-management efficiency, technology, existing versus new operation and maintenance procedures, training needs, and actual experience -- when designing and selecting a structure.

PROJECT BACKGROUND

The choice between the two flow-dividing structures was made in the context of the National Irrigation Administration's Ilocos Norte Irrigation Project (INIP). The INIP is located in eastern Ilocos Norte where almost 200 communal-irrigation systems called *zanjeras* are operating, some existing for over 200 years. In 1978, the plans for the two-phase INIP designed by the National Irrigation Administration included a pilot area with a total project area of 22,600 hectares (ha). The National Irrigation Administration created the INIP as a "new," large-scale irrigation system which would absorb the *zanjeras* and be operated by the Administration as a "national" system. The INIP plans aimed to increase agricultural production which would benefit 17,500 farm families in the area through the provision of improved irrigation facilities (JICA 1980:3). *Zanjera* officers and members were seldom consulted in the preparation of these initial INIP plans. As a result, farmers protested loudly against the project. The Administration also ran into implementation and scheduling problems. The NIA administrator from Manila and some social scientists investigated the project's problems for themselves. Based on their reactions, the agency decided to undertake a revised, more participatory planning approach in October 1981 (Visaya 1982; Siy 1987; Yabes 1990). The case discussed in this paper occurred during the revised planning approach period.

¹ The term *zanjera* is derived from the Spanish word *zanja* which means ditch or conduit. *Zanjeras* are organizations that build and maintain irrigation ditches. They are known worldwide in the irrigation field for their enduring, gravity-fed, communal-irrigation systems, and for their rules and regulations governing water allocation and distribution, system operation and maintenance, and conflict management (Christie 1914; Lewis forthcoming; Lewis 1971; Siy 1982, 1987; Thomas 1978; Coward 1979; Coward and Siy 1983; Visaya 1982; Yabes forthcoming).

¹¹The impacts of the improved proportional weir on farmer management and operation were not known when research for this paper was conducted (1985-86).

Three parties were involved in making the choice between the two dividing structures: 1) the National Irrigation Administration's INIP managers; 2) one of the INIP's divisions, the Agricultural Coordination Division (ACD); and 3) one of the communal-irrigation groups included in the INIP, Zanjera San Marcelino. The Ilocos Norte Irrigation Project (INIP) management staff composed primarily of civil engineers, makes the final design and implementation decisions at the project level. It is only when required by the NIA central office, does the INIP management forward designs to the central office. Personnel from the ACD include staff from agricultural engineering, economics, and other nonengineering fields. The ACD staff coordinates the institutional and agricultural activities of the INIP. The Agricultural Coordination Division (ACD) staff often fields both requests and complaints by zanjera officers and members, and forwards this information to the INIP management. Zanjera San Marcelino, with approximately 960 ha and over 550 members is one of the largest and strongest zanjeras in the INIP area. Zanjera San Marcelino was incorporated into the INIP's Madongan Right Irrigation System.

THE TWO ALTERNATIVE STRUCTURES

In its irrigation projects the National Irrigation Administration (NIA) often used turnouts to allocate and distribute water to rotational areas. Thus, the NIA/INIP planners designed double-gated turnouts to distribute irrigation water throughout the project area. However, Zanjera San Marcelino used a type of indigenous proportional weir to allocate and distribute water to 33 subunits each called a *gunglo*. In September 1985, the zanjera with the support of the ACD, asked the NIA to consider using the proportional-weir structures, with improvements, instead of the double-gated turnout for water allocation in their area.

Double-Gated Turnout (Calibrated)

The double-gated turnout is located at the junction between lateral canals and main farm ditches. It measures and controls the volume of water which flows into the farm ditches (Reyes 1982:23). The turnouts are designed to serve areas of 30-50 ha. The double-gated turnout includes two spindle gates that are raised and closed with a hand wheel. One gate opens to the lateral canal while the other gate opens to the main farm ditch. There is a pooling area between the two gates. The gates are opened and closed according to a water-delivery schedule with calibrated measurements made in the pooling area by the gatekeeper. Measurements are made according to flow charts which correlate specific levels of water in the pooling chamber with the area to be served in the rotational area. The hand wheel is removed from the turnout structure and kept in the possession of the gatekeeper when not in use. The size of the turnout is designed to correlate with the rotational area served by the turnout.

The double-gated turnout was installed in the INIP's pilot area, and it was used by the agency and the *zanjeras* to allocate and distribute water. Farmers in the pilot area had complaints about water distribution and problems with operating and maintaining the turnout of the pilot area irrigation system. Some farmers in the area could not read. Many of the farmers did not understand or know how to calibrate or record the measuring devices. The gatekeepers did not open or close gates according to the schedules agreed upon by the agency and the affected *zanjeras*. Water flowed when it was not scheduled, and did not flow when it was expected. The double-gated turnout was subjected to damage due to natural causes and apparent sabotage. The spindles on the gates were bent so the hand wheels could not move. Thus, the gates were frozen in an open or closed position until the spindles were replaced. Siltation and floods also damaged or completely destroyed some of the turnouts which were not designed to handle the excess water flow. Damage also occurred in the turnouts when the National Irrigation Administration's field data underestimated actual flows to be handled by a turnout and the turnout was undersized.

Existing Padila and Tablon[†]

Zanjera San Marcelino diverts water from the Madongan River through two brush dams into a main canal which distributes the water into three lateral canals. The *zanjera* is subdivided into three zones which correspond to the laterals: eastern, central, and western. The *zanjera* is sectioned into 33 subunits, called *gunglos*, each with its own farm ditch served by one of the three laterals.

San Marcelino's pattern of organization reflects its physical irrigation system. There is a major headman, a secretary, a treasurer, and one headman for each of the three laterals. Each of the 33 subunits is headed by a leader. When the *zanjera* was organized sometime in the 1850s there were conflicts over water allocation and distribution (Cabanos 1983). The *tablon* and *padilla* structures were built by the *zanjera* to mediate these conflicts (Viernes 1986).

According to Viernes, *tablon* (no translation) is a term used for a piece of thick lumber reinforced with concrete which is installed on the canal bottom of the section where water is divided (1986:4) (Figure 1). The *tablon* is supported by a *sangi* or concrete protection wall. On the same page, Viernes describes the function of the *tablon* and its relationship to the *padilla*:

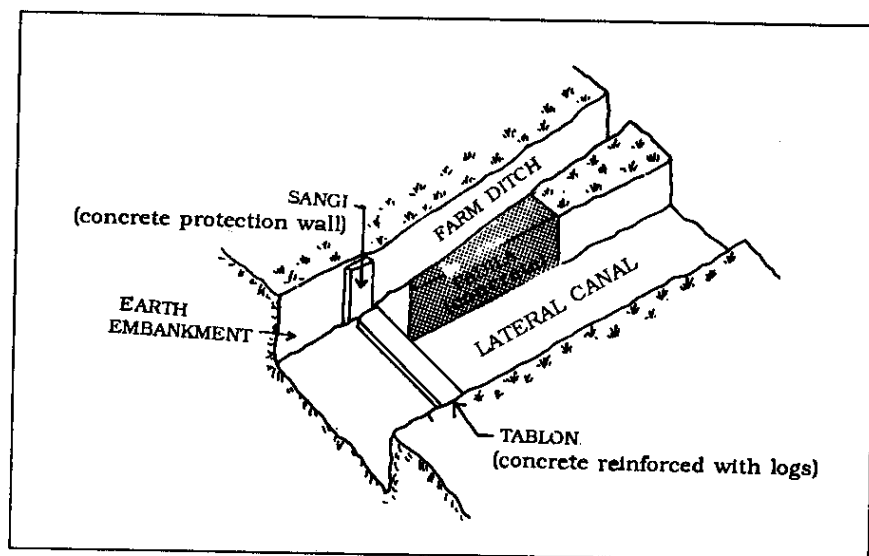
This *tablon* serves to maintain a level crest on the canal bed of the said section. On the same section the *padilla*, a tongue-shaped structure, is also constructed with its tip pointing upstream and resting on the *tablon*.

Like the National Irrigation Administration's double-gated turnout, the *padilla* divides water between earthen, unlined lateral canals and farm ditches (Figure 1). The *padilla* is a form of

[†] These two structures were found specifically in Zanjera San Marcelino and are not widely used by other *zanjeras* in the INIP area.

proportioning weir used to allocate water. Originally made of wood and/or bamboo, some concrete padilas came into use beginning in 1919. The width of the farm ditch and lateral intake openings on each side of the padila corresponds with the area to be irrigated by each intake. In Zanjera San Marcelino a two-centimeter canal width is proportioned for each membership share¹ served by the intake (Viernes 1986:5). Padilas divide water into farm ditches which serve subunits with areas of approximately 7-40 ha.

Figure 1. The existing padila and tablon.



Source: Viernes 1986.

During periods of water scarcity water is rotated among the three laterals and numerous farm ditches by blocking off the farm ditch intakes with sticks, bamboo, leaves, rocks, and sand. The intakes can be blocked partially or fully according to the zanjera officers' decision. However, when a farm ditch has been "fully" blocked to divert water to other farm ditches, precious water often leaks through these porous blocking materials.

The tablon and padila structures and the proportional widths of the intakes combine to equitably divide whatever water is diverted by the zanjera's brush dams:

Since the tablon maintains a constant elevation of the canal bed on the section where water is divided and since the width of the intakes is also constant, whenever water

¹ One membership share, locally known as *atar*, is equivalent to about one-and-a-half ha of land in San Marcelino.

is released into the canal, it is automatically divided into the different intakes along the way. So, as soon as it reaches the end check, all gunglos along the canal will have taken [a] proportionate share of water (Viernes 1986:5).

Zanjera San Marcelino organizes labor in *sarungkar* (working) groups for routine maintenance and repairs, and operation of the irrigation system during water-rotation periods. Subunit members are assigned into these groups which work on three and one-half duty periods in rotation with other *sarungkar* groups from the other subunits (Coward 1979:3).

During periods of water scarcity the zanjera uses a water-rotation system where the zanjera is divided into two parts, the north (lower zone) and the south (upper zone). When under a water-rotation schedule, water is delivered to each zone from 4 p.m. to 4 p.m. on alternate days (Coward 1979). The *sarungkar* groups are responsible for the operation of the padilas to open or close the intakes during the rotation period. Unlike the few "specialized" gatekeepers who operate the agency's double-gated turnout, the *sarungkar* groups rotate the responsibility for the operation and maintenance of their irrigation system during periods of water rotation:

When water is flowing to the lower zone and is to be changed to the upper zone, this is achieved by having the on-duty *sarungkar* groups from the upper [gunglos] open the canal inlets for the [gunglos] and be responsible for the parcel-by-parcel distribution of water within their respective [gunglo] units.

When water is flowing to the upper zone and is to be shifted to the lower zone, the changeover is effected by having the on-duty *sarungkar* groups from the lower zone proceed to the upper zone and close the inlets serving the upper [gunglos]. As the water moves to the lower zone, they also assume responsibility for the distribution to each parcel in their respective [gunglo] (Coward 1979:32).

According to the zanjera's officers no cases of water stealing have been reported since the padila and tablon were installed. But because water leaks through intakes blocked with sticks and brush some zanjera members have complained that these structures do not provide enough water to their gunglos.

Proposed Improvements in the Padila and Tablon

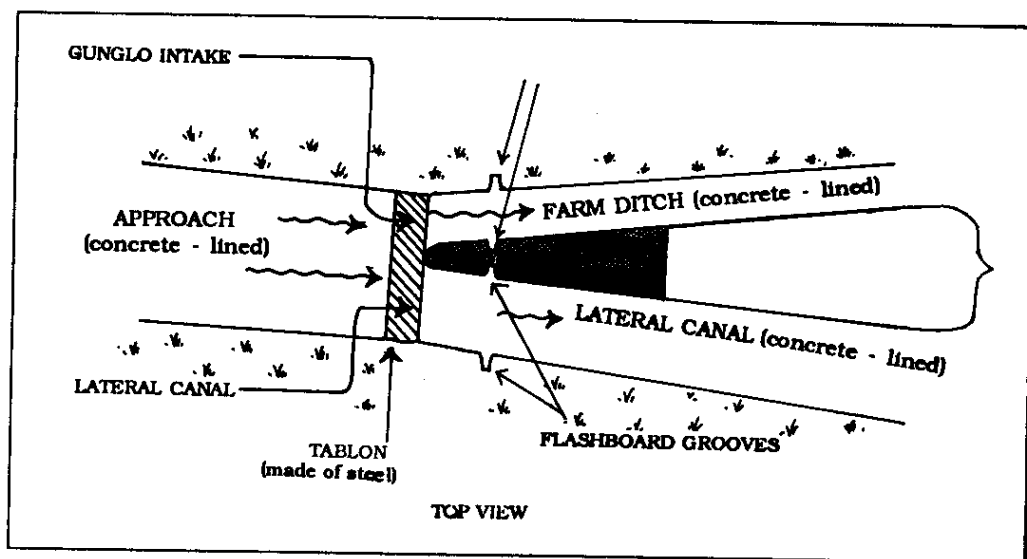
In a zanjera resolution Zanjera San Marcelino asked the National Irrigation Administration (NIA) to either use the existing padila or to construct a turnout structure very similar to the padila instead of the double-gated turnout designed by the NIA (Zanjera San Marcelino 1985). The zanjera asked the NIA to retain the same location and numbers of turnouts to correspond with the existing padila and tablon structures. Retaining the equitable division of water among the subunits was emphasized by the zanjera, as described by Viernes (1986:5):

If the canal sections at the site of the [padila and tablon] are maintained [retained], the elevation of the tablon and the width of the padila should be maintained. Any

change in the section should have a corresponding change in the elevation and width of the tablon and intakes respectively. But this has to be approved by the zanjera.

With the caveat that further study of the technical feasibility and viability was needed, the ACD position paper recommended keeping the existing padila and tablon structures but rehabilitating them with a few improvements including: 1) lining the canal bed and embankment with concrete, 2) changing the tablon from a thick piece of lumber and concrete to a piece of steel, 3) inserting grooves on the sides of the padila and the canal embankment for flashboards, and 4) providing measuring devices for monitoring water discharges (not shown in Figure 2).

Figure 2. Proposed improvements in the padila and tablon.



Source: NIA blueprints 1986.

These two flow-dividing structures, the NIA's turnout and the zanjera's padila-tablon were discussed and analyzed for over four months by the agency and the zanjera. This four-month period was marked by a series of activities where the National Irrigation Administration (NIA) and the zanjera interacted in the effort to decide which dividing structure should be used ultimately by Zanjera San Marcelino in the INIP's Madongan Right Irrigation System.

THE DECISION-MAKING PROCESS

In mid-1985, the National Irrigation Administration proceeded to prepare detailed designs for the Ilocos Norte Irrigation Project (INIP) canals and structures along the main canal and laterals in the INIP's Madongan Right Irrigation System which included Zanjera San Marcelino. In line with the guidelines for the INIP's revised, more participatory planning approach most of Madongan Right Irrigation System canals were designed to follow San Marcelino's existing zanjera canals.⁴ But these plans failed to acknowledge or consider the zanjera's padila and tablon as a viable alternative to the agency's standard turnout for measuring and controlling water distributed to farm ditches.

When some of the members of Zanjera San Marcelino heard that the NIA was going to install double-gated turnouts they presented the INIP management with a resolution on 3 September 1985. The zanjera asked the NIA to construct padilas or an improved turnout like the padila and tablon currently used by the zanjera instead of the double-gated turnout (Zanjera San Marcelino 1985).

The INIP management asked the Agricultural Coordination Division (ACD) to informally follow up and investigate the zanjera resolution. After the ACD staff held discussions with Zanjera San Marcelino farmers and the NIA engineering staff and made several trips to look at the indigenous structures, the ACD prepared a position paper for the INIP manager recommending that the possibility of adopting the proportional weir structures, with some improvements, be studied further (Viernes 1985, 1986). During a routine NIA meeting in October 1985, the INIP management, representatives from the Engineering, Construction, and Agricultural Coordination Divisions, and the INIP contractors reviewed Zanjera San Marcelino's request. Based on the recommendations of engineers from the Design Section and Construction Division, the INIP management refused the zanjera's request and adopted the double-gated turnout as the dividing structure for the Madongan Right Irrigation System.

Despite the INIP management's decision during the next two months several INIP engineers made formal and informal visits to the Madongan Right Irrigation System area to assess the strengths and weaknesses of the padila and tablon for themselves. Also, most of the zanjera and gunglo officers from Zanjera San Marcelino visited the INIP's pilot area to examine the pros and cons of the double-gated turnouts. Because of ongoing discussions among the INIP management, engineers, the ACD staff, and the zanjera farmers, the INIP management eventually reversed its decision, and agreed to improve the padila and tablon in Madongan Right Irrigation System instead of building new turnouts. This reversal was formally adopted as an INIP policy in a workshop in December 1985 at the NIA central office. During the workshop it was agreed that the INIP should use improved, existing zanjera structures for turnout purposes and officially discontinue the use of the double-gated turnout (NIA 1987:5).

⁴ Four guidelines for the revised planning approach were recommended by the social-scientist team and endorsed by the NIA administrator and the NIA central- and project-field offices: 1) preserve the identity of the zanjera groups; 2) follow existing canal lines as much as possible; 3) conceive the project as rehabilitation of existing communal-irrigation systems, not as construction of a new, large-scale system; and 4) involve farmers in planning and implementing the project (Visaya 1982:4).

The NIA and Zanjera Debate on the Two Structures

Irrigation agencies and farmers have differing goals and viewpoints about irrigation systems. Common goals of farmer-operated systems cited by Maass and Anderson (1978) include the orderly resolution of conflict, popular participation, local control, increased income, justice in income distribution, and equity. In a more recent literature survey of local-irrigation systems, Levine and Coward (1986) concluded that a fundamental principle of the systems studied was equity operationalized through a fair allocation and distribution of water (Coward and Levine 1986:19). On the other hand, agency improvement programs emphasize system performance, "water efficiency," irrigation fee payment, and administrative control (Coward and Levine 1986; Robinson 1982; Bottrall 1981).

These different agency and farmer perspectives on irrigation-system goals were reflected in the NIA-zanjera discussion on the padila-tablon versus the double-gated turnout. Both parties raised and emphasized different points about the two flow-dividing structures. The pros and cons for each structure (double-gated turnout, existing padila, improved padila) as argued by the NIA and zanjera farmers are highlighted in the remainder of this paper.¹

THE NIA/INIP management and the ACD criteria and arguments. During meetings and in informal conversations, the NIA management argued that the double-gated turnout allowed "efficient" water management, with "exact" measurements, and little or no leakage when the gates were closed during the rotational period. The INIP engineers preferred the turnout's design for a standard rotational area (30-50 ha). They were trained to design the turnout's "modern" technology, not to design or improve indigenous structures.

Some of the ACD staff pointed out the following problems with the turnout. The turnout is only as effective and efficient as the operators themselves who open and close the gates. The turnouts require skilled operators with sufficient technical background and mobility to travel from one turnout to the next in order to open and close the gates. System operation is affected when an operator is absent or doesn't know when or how to properly calibrate or operate the gates. In the pilot area the spindles in the turnout gates were bent so the hand wheels could not open the gates. One possible reason for this suspected sabotage was farmer frustration with the turnouts and the corresponding rotational areas which did not match the preexisting zanjera-irrigation systems and organizations in the area. Pilot area farmers were not involved in project-planning activities; the NIA staff recognized that this may explain why few pilot farmers participated in the operation and maintenance of the pilot's irrigation facilities.

The NIA/INIP management initially disliked the padila-tablon, with or without improvements because "it is a type of structure being used by non-technical people" and it "doesn't give enough control" (comments at a NIA meeting). Also, the zanjera frequently used the padila for continuous flow of irrigation water, not checking the intakes, which the NIA considered "inefficient." Even when the padila-tablon was checked, according to some of the engineers, strict water management was not possible because water leaked through the checks. After

¹ These were compiled from research notes of meetings and ongoing discussions between the NIA and Zanjera San Marcelino, and from relevant secondary documents (Zanjera San Marcelino 1985; Viernes 1985, 1986).

examining the structure, the NIA engineers also concluded that the existing padila could not allocate water exactly according to their fine-tuned, calibrated standards or distribute exact amounts of water to different locations. Another general but unconfirmed apprehension was that the padila-tablon improvements would be much more costly and time-consuming to construct since there were at least 49 padilas needing improvements as against 37 NIA turnouts.

The ACD suggested three advantages of using an improved padila-tablon instead of the NIA turnout: 1) construction-cost savings, 2) simplicity and economy in operation, and 3) zanjera acceptance of the structure (Viernes 1986:5, 28). First, the estimated per unit cost of improving the padila-tablon was US\$150 as against an average cost of US\$500 for constructing a double-gated turnout. Originally, 37 turnouts were designed for construction, compared to 49 improved padila-tablons, or a total cost of US\$18,500 (turnouts) as against US\$7,350 (padilas).¹ Second, the ACD argued that the simplicity of water division is retained with the proportional canal-intake widths and the improved padila-tablon. The zanjera's existing operating and maintenance sarungkar activities would not change much with the substitution of flashboards for the previous leaves and brush which checked the canals. The same rotating gunglo work teams would open and close the flashboards. The ACD argued that the additional training which farmers would require to read measuring devices and record data would not be too difficult. Third, the ACD emphasized that members of Zanjera San Marcelino had expressed their preference for the padila-tablon. The ACD pointed out that if the padila-tablon were adopted "it will facilitate the turnover [future operation and maintenance] of the whole system" (Viernes 1986:28).

Zanjera arguments. Most Zanjera San Marcelino farmers were doubtful about the NIA turnout as many of them had never seen a double-gated turnout before. After seeing some of the turnouts in the pilot area some farmers commented that the turnout seemed complicated to operate, with calibrations, pooling areas, and gates which had to be opened and closed according to exact measurements. In the zanjera's resolution to the INIP management they indirectly referred to the fact that the proposed NIA turnouts did not match the number or location of the existing padila-tablons. Thus, the turnouts would require a new set of operation and maintenance procedures entirely different from the existing and well-functioning practices of the zanjera. Another zanjera concern was that the turnout would be used for rotational irrigation practices year-round while farmers were used to a continuous-flow system. A few Zanjera San Marcelino farmers mentioned in conversations that they favored the double-gated turnout because of the turnout's perceived ability to tightly control water management, thus reducing leakage and hopefully providing additional water supplies from the source from where water supplies were previously wasted.

The zanjera listed several advantages of an improved padila-tablon structure some of which overlap with the ACD's list of padila benefits. Improving the padila would retain the existing number and location of padilas, and not change their corresponding zanjera and gunglo operation and maintenance organizational set-ups. The zanjera also emphasized how the padila helped water-sharing practices rather than focus on exact measurements: "...Whereas since these structures [padila] were built, problems regarding water sharing, including operation and maintenance

¹ Actual expenditures are not available for discussion here. The total-cost figures do not reflect the cost of additional NIA staff-time which was required to re-inventory the Madongan Right Irrigation Systems area in order to enumerate and field-check all of the padilas and tablons for the paper designs.

work, stopped'' (Zanjera San Marcelino 1985). Not much more training would be necessary for the zanjera members to learn how and when to insert the flashboards at the canal and farm ditch intakes to rotate water. Zanjera farmers also mentioned that the improved padila would not have expensive parts like the turnout's spindles, gates, and hand wheels which were subject to damage in the pilot area and which often took a long time to be replaced, if at all.

CONCLUSIONS

If, for example, one views a turnout not only as an element that defines a unit of service area but one that also defines a unit of management organization, it follows then that the location of turnouts should be based not only on questions of physical performance but also organizational performance (Coward 1977:15).

After several months of discussion on the two structures, the NIA agreed to improve the padila and tablon instead of building double-gated turnouts. In supporting the choice of an improved padila, the zanjera stressed simplicity of operation and maintenance, equity, location, and cooperation, without much emphasis on water efficiency or acute measurement accuracy. The NIA emphasized strict water management, control, and cost in recommending the adoption of the double-gated turnout. Later, the NIA was willing to reverse that decision and choose the padila, because with improvements, the agency realized that the padila could control water almost as efficiently as a turnout in a cost-effective manner.

In the design of irrigation structures in farmer-managed irrigation systems there is a need to assess existing and future expected operation and maintenance activities. Design decisions about turnout structures in this case discussed how the indigenous proportioning weir facilitated the zanjera's existing operation and maintenance practices when choosing flow-dividing structures. Thus, in the design of turnouts water-efficiency criteria valued by irrigation agencies should be considered and, equity, operation, and maintenance factors important to the farmers who will operate and manage the irrigation systems should be examined.

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Small Farmer Community Irrigation Projects in Nepal

Ganesh Ram Shrestha[§]

FARMER-MANAGED IRRIGATION SYSTEMS IN NEPAL

FOR CENTURIES, FARMERS in Nepal have been successfully involved in irrigation development using their own resources for construction and management of community systems. These systems are mostly small and simple, constructed with labor-intensive technology and locally available materials such as bamboo, wood, and stones. The use of cement and iron reinforcement is a recent practice. The construction of brushwood dams for water diversion from a river or stream and the use of wooden aqueducts for conveying water across ditches are very common. Most of these systems have temporary diversion structures which are affected by monsoon floods and require constant maintenance for which hundreds of man-days of labor must be mobilized.

Farmer-managed systems occupy an important role in Nepal's irrigation development. The total number of these systems is around 1,700 in the plains and over 15,000 in the hills (Pradhan 1988). They fulfill the irrigation needs of 21 percent of the cultivated land as compared to government systems which irrigate only 11 percent of the cultivable area. Farmer-managed systems range from less than 50 hectares (ha) to 5,000 ha but the majority of them are small (WECS 1981).

An important feature of farmer-managed systems in Nepal is the sense of community ownership of the system. The water users exercise full control for the system's management. Different types of informal group or community organizations exist with primarily unwritten rules and regulations for carrying out the necessary tasks of water allocation, distribution, maintenance, and conflict management.

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A major strength of the farmers' community system lies in its low cost and its ability to mobilize local labor and resources for construction and maintenance. A review of farmer-managed systems has shown that several systems with command areas of 30-50 ha regularly mobilize more than 2,000 man-days of labor in a year. One organization with 55 members raised NRs 70,000 (approximately US\$2,500⁴) in a month to install a pipe across a major river (Martin and Yoder 1983).

Other strengths of farmer-managed systems are their good record on production, good communications among water users, and ability to respond quickly for maintenance requirements.

The main weakness of farmer systems is the unreliability of the physical structures mainly due to increasing instability of the environment caused by landslides and soil erosion. The lack of capital investment and technical skill are two major constraints. Support for rehabilitation, improvement, expansion, and management of these farmer-managed systems is extremely important for increasing farm production, income, and employment.

FUTURE DIRECTION OF IRRIGATION DEVELOPMENT IN NEPAL

In recent years the government has realized that its past approaches and policies on irrigation development have not proven to be effective. The major role of the water users in irrigation development has also been recently recognized. As a result, new policies and programs have been formulated with emphasis given to the development of cost-effective systems that include the active participation of the water users. The basic tenets of the new working policy are that 1) the participation and consent of the beneficiaries are compulsory for project identification, selection, design, construction, operation, and maintenance, and that 2) the government's contribution to improvement of projects is fixed (75-93 percent). The Agriculture Development Bank of Nepal (ADB/N) provides loans to the beneficiaries based on a fixed formula.

The new Irrigation Sector Program designed within the framework of the Basic Needs Program which sets a target of developing an additional 816,000 ha for irrigation by the year 2000 A.D. emphasizes the following: 1) development of small- and medium-scale systems because these systems can be developed within a relatively short time and the critical participation of the farmers can be readily achieved by forming and strengthening water user's associations; 2) rehabilitation and upgrading of existing farmer-managed systems where water user associations are in place; 3) construction of new small and medium gravity or shallow tube well schemes; and 4) improvement of the operation and maintenance of public irrigation schemes through joint agency-farmer management. Human resource development, communication, and motivation as key elements for capacity building within the farmer communities have also been given emphasis in the new program.

⁴ The dollar/Nepali rupee exchange rate has been gradually increasing over the past ten years. In October 1989 it was NRs 28/US\$1.

DEVELOPMENT OF SMALL FARMER COMMUNITY IRRIGATION PROJECTS

Emergence of the Small Farmer Development Program (SFDP)

The small farmers of Nepal constitute a strong base numerically but a weak link economically in the rural economy. The problems they face are limited access to credit, small landholding size (averaging 0.5 ha in the hills and 1.2 ha in the plains), lack of irrigation facilities, and socio-institutional constraints.

To improve the socioeconomic situation of the small, marginal, and disadvantaged farmers the Small Farmer Development Program was initiated in 1975 by the ADB/N with two pilot projects. Major objectives of the program were 1) to promote self-help among the small farmers by organizing and assisting them to formulate and undertake development activities using local resources and 2) to assist these groups in building their capacities to receive services from government agencies.

By August 1989 the SFDP had already been extended to 416 project sites and had provided credit and other support packages to 95,968 small farmer members organized into 11,596 groups (Agricultural Development Bank 1983/84-1988/89).

Operational Strategies

The operational strategy developed to meet the objectives of the Program included identifying small farmers and motivating and organizing them into homogeneous groups with the assistance of a group organizer to initiate income generation and social-community or welfare activities. The Program provided institutional credit, technological support, and skill-development training to the group's members. Each group was required to elect a leader, a deputy leader, and a treasurer, and meet monthly to formulate their plan and meet the credit requirements.

Concept and Initiation of the Small Farmer Community Irrigation Project (SFCIP)

A farmer-centered approach to irrigation development was conceptualized by the ADB/N when support was extended to the Balthali Farmers' Project in Khopasi Panchayat of Kavre District in 1981 for the rehabilitation and extension of its 25-ha irrigation system. Built by the farmers in 1969 with some grant assistance from the district *panchayat* (political unit) the system worked for only a few years before it was damaged by landslides and silt problems. Unable to acquire an additional grant to rehabilitate the system the farmers asked the Small Farmer Development Program to help them restore the system with an extension to bring an additional 25 ha under

irrigation. An engineer from the Bank and a group of farmers jointly conducted a survey and proposed that water be brought by gravity flow from the Ladku River, some seven kilometers away because the existing water source was insufficient to meet the needs of the whole village. Detailed design and cost estimates were prepared and finalized after a series of consultations with the farmers. The farmers agreed to contribute labor amounting to NRs 100,000, and the Program provided a loan of NRs 380,000 to be repaid in 7 years.

The construction committee worked closely with the technical staff and rebuilt the system after 18 months of hard work. After the rehabilitation those farmers served by the irrigation system were able to double their rice yield. In addition, the value of the land under irrigation doubled.

As a result of the Balthali Farmers Project, many lessons were learned while attempting to resolve problems that arose, ranging from organizational and social, to technical. The experience was valuable to the ADB/N in helping formulate working procedures for financing gravity-irrigation development and provision of technical support. The project demonstrated that irrigation development could be effective if it is need-based and if the beneficiaries are involved in the decision-making process from the very beginning. The Small Farmer Development Program also demonstrated that it could serve as a viable institutional mechanism to mobilize local participation, and channel credit and technical support to community-oriented activities.

The experience from the Balthali project gave impetus to the formulation of a plan for financing a project to bring 1,150 ha under irrigation within three years. A collaborative agreement was signed with CARE, an international nongovernment organization to assist the ADB/N in implementing the SFCIP.

The key element of this project is to mobilize the farmers to organize for irrigation construction and water management and secure their commitment to actively participate in all phases of project development and management. Project support includes rehabilitation, renovation, and new construction of small projects ranging from 10 to 500 ha. In this program the farmers are asked to contribute 50 percent of the project cost in the form of a loan from the ADB/N (30 percent) and labor (20 percent). The other 50 percent of the cost is provided as a grant by the CARE and other agencies. Project assistance includes support for agro-forestry, crop, and vegetable production centered on the irrigation project. Technical support for these activities is provided jointly by the ADB/N and the CARE.

On completion of the project crop production, processing and marketing activities are integrated through credit and other support interventions designed to provide optimum benefit to the beneficiaries. Under this approach more than 50 small-irrigation systems have been developed on a sustained basis.

Financial innovations. A recent innovation of the SFCIP is the provision of "total credit" for the total farm-family cash flow instead of for specific project cash flows. Loans are sanctioned at the beginning of the period for the whole year so that the borrowers' transaction costs can be reduced. Another innovation is the mobilization of savings generated from the increase in farm production and income. In many areas some portion of the earnings from increased production is being mobilized to create a project-maintenance fund for future needs. These innovations including group savings, regular campaigns, and the issue of savings passbooks, seek to develop a habit of saving among the farmers to make them self-reliant in the future.

Features of the SFCIP. Some important features and impacts from the project are mentioned below.

1. By 1986, the active participation of the small farmers in executing the community-irrigation systems had brought 1,400 ha of land under irrigation, exceeding the initial target of 1,150 ha. From 1987 to August 1989, an additional 3,900 ha have been brought under irrigation through the development of 33 systems.
2. The projects have been cost-effective because the farmers' committee organizes the construction tasks without involving contractors. The cost per hectare ranges from NRs 4,000 to 12,000 (US\$143 to 430) depending upon the topography of the site (hills or plains). Annual maintenance costs per hectare vary from NRs 300 to 1,100 (US\$10.8 to 39.3) which is very low compared to the cost incurred in government-managed systems.
3. The farmers have a very high sense of project ownership. They have full control of the system and of the use of the water resource. Disputes regarding water rights and water distribution are internally resolved.
4. The integration of tree plantations along the canal alignment and watershed areas has helped reduce the risk of landslides and soil erosion around the irrigation systems.
5. Although the project is managed by small farmers the benefits are often shared by medium- and large-scale farmers. The project can accommodate the irrigation needs of other farmers provided the land they irrigate does not exceed 30 percent of the project area. In this case, while the small farmers receive group irrigation credit from the Small Farmer Development Program (SFDP), the bigger farmers obtain credit directly from the ADB/N branch office.
6. Farmer-exchange visits from one project to another and interaction between farmer groups have proven to be an effective approach for solving many issues in irrigation development. In many cases, farmer-to-farmer communication has been found more useful than formal agency-farmer orientation and training.

PROJECT DESIGN AND IMPLEMENTATION PROCEDURES

One important aspect of the SFCIP is the involvement of the beneficiaries in all stages of the project from identification through design and construction to operation and maintenance. This aspect is essential to the success of the project.

Process of Irrigation Design

Project identification. Irrigation projects are identified mostly by the farmers themselves. In some cases, projects are jointly identified by a team consisting of farmers, an SFDP group organizer, and an overseer. Projects identified for the ADB/N assistance consist of new systems as well as improvement, repair, or extension of existing farmer-managed systems. Once potential projects are identified, small farmer groups, usually assisted by a group organizer request the SFDP office to make a project feasibility study. The farmer group submits an application which

contains information about the water sources, the distance of water source from the command area, and the number of farm households and their landholdings in the proposed command area.

Preliminary site survey. The group organizer, the overseer, and the farmer leaders inspect the proposed site, meet with all the farmers, and discuss various aspects of the proposal. Details related to the regulations and requirements for credit and cost sharing are discussed with the farmers. If an agreement is reached a site survey is undertaken by the SFDP personnel with farmer assistance. The survey includes physical-, agronomic-, technical-, and social-data collection.

Detailed feasibility survey. If the information gathered is favorable a feasibility study is conducted which includes the technical, agronomic, and socioeconomic aspects that help determine project feasibility. If the project is less than 50 ha an experienced overseer conducts the study. Larger and more technically complicated project-feasibility studies are carried out by an engineer and an agronomist in association with the SFDP office and with input from the farmers.

Design and cost estimates. During the project design the following factors are taken into consideration: 1) the structure should be simple and durable; 2) labor-intensive construction technology is used to maximize farmer involvement; 3) the use of locally available materials should be maximized; 4) Project cost should not exceed NRs 10,000 (US\$358) per ha for rehabilitation or NRs 15,000 (US\$536) per ha for new project construction; 5) measures such as tree plantations should be taken to protect the environment; and 6) the farmers' recommendations should be incorporated into the design to the extent feasible and practical.

Since most of the projects are small with simple designs, overseers stationed at the project sites are entrusted to prepare the design and cost estimates based on local rates and the specified guidelines. Project design and cost estimates for projects exceeding 50 ha are prepared by an engineer with the assistance of the site overseer. To be approved, a design must include details of the intake and site plan, a profile of the land alignment with types of structures described, and quantity and cost estimates for materials. In addition, the farmers must accept the design and estimates and the Small Farmer Development Program must recommend that the project be undertaken.

In hilly areas simple intake structures are designed which may be temporary or permanent, depending on the nature of the source. Usually, locally made regulators are used to regulate water into offtake channels. Aqueducts and superpassages are constructed with local materials either with stone slabs or timber, whichever is available.

In the plains, temporary headwork structures are usually destroyed during each monsoon season. However, the farmers in this region do not have the skills or materials needed to build permanent structures. Therefore, the project lends assistance to build permanent headwork structures in the plains. The use of cement is minimized, preference being given to dry stone work, gabion, and masonry, in that order. This reduces the cost and allows maintenance which can be accomplished by the farmers.

Project-Implementation Process

Implementation of the community-irrigation projects is the responsibility of the farmers. The group organizer helps the farmers to form a construction committee the members being elected

by the beneficiaries. Training or orientation sessions are held at the project site to finalize and agree on construction schedules and procedures, tasks, and responsibilities for the committee members and the overseer.

Construction is usually carried out during the dry season when farm activities require less time. Small systems in the hills can usually be completed in one dry season while relatively larger systems in the plains may take two or three dry seasons to complete. Following project completion, the construction committee evolves into a water-management committee. The group organizer and the overseer from the Small Farmer Development Program continue to assist the committee for several years until the system is well-established and functions effectively. Agricultural credit for improved farming practices is provided.

Some Innovations

The successful adoption of a farmer-participatory approach to small-scale irrigation development through the Small Farmer Development Program with 50 percent of the project cost being shared by the beneficiaries is in itself a recent innovation in Nepal where the participation of the farmers in government-managed irrigation systems continues to be a major problem.

In some areas, usually at higher altitudes, gravity-irrigation systems are technically and economically not feasible, and alternatives are needed. A turbine-lift irrigation and power-generation system was designed for one village in Gorkha District. With the active collaboration of the ADB/N engineers, private entrepreneurs, and community members, this project generates 16 kilowatts of power to lift water up to 21 meters to irrigate 15 ha belonging to 41 small farm families. Agro-processing units are also attached to the turbine for rice milling, grain grinding, and oil expelling (Asian Development Bank 1988). The successful implementation of this project has opened up possibilities for the future development of such projects in numerous hilly areas in need of irrigation and electrical power.

Landslides, siltation, and soil erosion are some of the common effects of irrigation development in Nepal. Developing irrigation without creating environmental degradation is an important issue addressed through the incorporation of activities such as planting tree seedlings and grass in unstable areas along the canal alignment and the watershed. Plant nurseries are developed in some project areas.

CONCLUSIONS

The adoption of a farmer-participatory approach by the ADB/N in the development of small-scale irrigation projects in the Small Farmer Development Program areas has proven to be an effective way to achieve an increase in agricultural production and farm incomes. As a result, demand for support to develop small farmer-managed irrigation systems has increased significantly in recent

years. The potential exists for the development and extension of irrigation on a sustainable basis. Priority for such small-scale irrigation should be given to areas where farmer groups already exist to facilitate the design and implementation of projects. For the irrigation system to be manageable and functional, the design of the structures has to be simple and durable, with the maximum use of the farmers' skills and knowledge as well as the use of locally available materials.

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Importance of Farmer Irrigation Association Participation in the Development of Small Irrigation Schemes: An Engineer's Opinion

Eduardo P. Corsiga[§]

THE SIWARAGAN COMMUNAL IRRIGATION PROJECT

THE SIWARAGAN COMMUNAL Irrigation Project is situated approximately 56 kilometers northwest of Iloilo City in the Philippines. Its water source is the Siwaragan River. The total irrigable area is 300 hectares (ha) comprised of 7 sectors, 1 on the right bank of the Siwaragan River and the other 6 sectors on the left bank. The irrigation project benefits 309 farmers and water rights are registered with the Natural Water Resource Council.

Development of the Project

During the initial stages of the project decisions were made based on inadequate data collected by an engineering staff with insufficient training in the participatory approach. This led to the introduction of certain biases which later resulted in problems and increased costs during the construction phase.

Feasibility stage. A site-selection survey was conducted in 1980 to identify candidate areas for irrigation development under the pilot project of the Participatory-Approach Program. As a result of this survey Siwaragan was selected for a feasibility study. However, before all the data

[§] This paper presents the opinion of the author, as a result of his experience as a former Provincial Engineer who worked with the farmer irrigators' association as partners in the construction of the Siwaragan Communal Irrigation Project. The author is presently Division Manager B of the Engineering Division, National Irrigation Administration, Region VI, Iloilo City, the Philippines.

for the feasibility study were completed the scheme was selected to be the first participatory-pilot project. In addition, the feasibility study did not collect sufficient socio-technical data and used some incomplete baseline data from a preliminary study made in 1977.

It is this engineer's opinion that the site should not have been selected until the feasibility study had been completed and sufficient and accurate data had indicated that construction of the scheme was viable. Furthermore, the engineering staff should have been better-prepared in the farmer-participatory approach. If the staff had consulted extensively with the farmers the incorrect data could have been corrected by the latter. Despite being a farmer-participatory project, at the feasibility study stage insufficient farmer input was sought.

Detailed engineering stage. During the detailed engineering stage, the Siwaragan irrigators' association was promoted among the beneficiaries.

The detailed engineering process began in May 1980 with a differential-leveling survey. Farmers participated in the technical activities. Staff-gauge readings at the dam site were begun. Rice-field mapping results revealed that the discharge at the river would irrigate approximately 330 ha.

During these months, the design preparation was simultaneously undertaken at the regional irrigation office. The slope-area method was used for the design of the diversion dam and Manning's formula for open channels was used to design the channels. In March 1981, the final design and project cost estimate of US\$100,000 were discussed by the engineers and the irrigators' association.

Once again, insufficient data were obtained at the detailed engineering stage so that certain factors were not considered early enough to prevent the need to make changes during the construction stage which resulted in increasing the cost of the project. For example, the staff-gauge readings at the dam site were recorded for only eight months. Readings collected over the course of an entire year would have given a better indication of the seasonal fluctuations of the discharge. Also, no formal and extensive soil analysis of the land along the main canal was conducted, nor was a cross-section survey 20 meters to the left and right of the proposed canal lines done. Boring of test pits would have informed engineers whether the soil was suitable for the construction of open canals and alerted them to seepage problems. Cross-section surveys would have allowed the engineers to compare the volume of work that would need to be done among alternative canal alignments.

Despite neglecting the collection of this engineering data, if the farmers had been more thoroughly consulted and educated during the design process their knowledge of the soils and topography would have allowed for some corrections to be made while the infrastructure was still being designed.

Although the irrigators' association's members were involved in the survey activities, particularly in the determination of canal alignment the technical staff failed to explain to the farmers the various alternatives that could have been considered. Technical staff also failed to explain to the farmers the implications and costs of the choices that the farmers had made. Had these explanations been made it might have been possible to prevent the necessity for making alterations to the designed structures and alignments during the construction stage.

Construction stage. Construction of the scheme began in April 1981. As the construction progressed new technical problems were discovered which made it necessary to revise, adapt, or add structures to the design of the scheme. Bench flumes had to be constructed for portions with

loose soil; covered bench flumes, reinforced concrete pipes, or barrel-type structures needed to be installed at deep-cut sections in lieu of the berm-type open channel that had been originally designed. Reinforced concrete pipes or perforated vinyl pipes were needed for drainage inlets or drainage-crossing structures along small water passes. And plain boulder or grouted riprap was added to canal portions with a tendency for scouring. Other stretches of the canal were relocated which necessitated the deletion or addition of certain canal structures. Additional problems resulted because of the increased work required of the manpower and machinery, all of which increased the cost of the project.

During this process both the irrigators and the engineers learned to work together and make better use of the knowledge and skills of each other so that they were able to formulate a contingency plan. They realized that there was no turning back despite the additional costs involved and by this time, the irrigators' association felt confident that the project was technically feasible. Because of limitations of manpower, construction equipment, and funds, the irrigators' association opted to implement the project in phases. Phase I was completed in late 1983 with a service area of 37 ha and was turned over to the farmers for operation and maintenance. Phase II was completed in February 1986. By then the total service area comprised 146 ha. Funding for Phases I and II came from the regular government budget at an actual cost of approximately US\$217,650.

As the irrigators' association gained experience operating and maintaining the sectors developed under Phases I and II it consulted with the technical staff and requested modifications for improving the area already being operated. It also contributed recommendations for the improvement of the design of the Phase III area (154 ha) then under construction. Some of the significant changes were the increase of the dam-crest height by 30 centimeters, improvement of the sluice gate, and widening of portions of the main canal to reduce regular manual-desiltation activities.

The actual cost of Phase III, funded under the Communal-Irrigation Project loan from the World Bank came to about US\$77,275. In February 1989, the whole irrigation scheme was finally turned over and accepted by the Siwaragan Irrigators' Association. The total cost of the project was approximately US\$245,500. After deducting the equity generated by the farmers the development cost of the scheme came to US\$895 per ha.

For the entire scheme, approximately 43 canal structures were built along the main canal. Ten structures were installed at lateral A, and five along lateral B. Discharge at the main channel starts at 0.54 cubic meters per second (m^3/s), distributing 0.06 m^3/s to lateral A and 0.14 m^3/s to lateral B. Areas irrigated by the main canal receive 0.3 m^3/s per second.

CONCLUSIONS

The lessons learned in the design process of the development of this pilot scheme are now being applied by the National Irrigation Administration in the design and implementation of new projects as well as in the rehabilitation of existing schemes.

These lessons can be summarized as follows:

1. The participation of the Irrigators' Association is essential from the project identification stage through operation and maintenance of the scheme.
2. Extensive hydrological, topographical, socioeconomic, agronomic, and institutional information must be gathered in collaboration with the farmers at the feasibility and detailed engineering stages so that the best development plan with accurate costing can be framed.
3. Project scheduling must accommodate the limited resources of both the implementing agency and the farmers so that the capacity and timing of activities can be kept within affordable limits.
4. The training of individual farmers in water-control procedures and the use of the irrigation facilities should begin prior to the detailed survey stage so that they have the knowledge to make the best choices and can provide accurate and pertinent input during the survey and engineering phases.
5. An irrigators' association can provide the necessary liaison between the individual farmer and the agency. The farmers and the irrigation agency have different objectives for water control and irrigation benefits. Engineers are interested in ensuring timely delivery of water to the entire scheme but the individual farmer is primarily concerned with obtaining water at the right time and in the quantity he needs. An irrigators' association can provide the link between the different objectives of the two groups to achieve a workable irrigation system acceptable to both.

Of Dialogue, Debate, and Development: The Use of Participatory Rural-Appraisal Methods to Improve Farmer-Managed Irrigation Systems in Kenya

John Thompson[§]

INTRODUCTION

THIS PAPER-AND the research from which it draws its conclusions are based on the premise that much of the problem with agro-ecosystem management in Kenya, and Africa in general, rests with the processes of generating and utilizing ideas and innovations, and that much of the solution lies in the local land managers' abilities to understand their own collective capacities and actively participate in decision making. It is about promoting practical discourse, critical reflection, and communicative action among farmers involved in the management of small-scale gravity-irrigation systems. It is informed by the literature on basic human needs, agrarian change, farmer participation in agricultural research, and social theory (cf., Wisner 1988; Berry 1984; Farrington and Martin 1988; Giddens and Turner 1987).

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IRRIGATION DEVELOPMENT IN KENYA

From the Ground Up

Over the past year, the National Environment Secretariat (NES) of the Ministry of Environment and Natural Resources (MENR), Kenya, in association with the Clark University, U.S.A., has carried out a series of local-level studies on environmental resource management as part of the program, *From the Ground Up*. *From the Ground Up* is a collaborative effort of institutions in Africa and North America committed to improving environmental resource management in Africa. The program is administered and coordinated by the World Resources Institute.

The objectives of *From the Ground Up* are threefold: 1) to learn what institutional and managerial elements contribute to effective environmental resource management at the local level, 2) to discover how community institutions and self-help groups can serve as effective agents of resource management, and 3) to ascertain how communities can better identify long-term needs and opportunities for enhancement of the resource base and sustainable⁴ resource use.

Irrigation Development in Kenya: A Policy Shift

Various sources have estimated that Kenya has an irrigation potential of between 350,000 and 540,000 hectares (ha), and another 300,000 to 1,000,000 ha amenable to valley bottom drainage (FAO 1986; Tidrick 1983; GOK 1989a; IBRD 1984). Despite this potential, the level of investment in irrigated agriculture has been relatively low since independence and only somewhere between 36,000 and 41,000 ha are currently under irrigation (GOK 1989a; Ruigu 1988; Coward et al. 1985). The bulk of this irrigated land is found on large commercial enterprises (producing coffee, pineapples, etc.) and large public schemes operated by the National Irrigation Board and the Bura Irrigation Settlement Project on the lower Tana River. Less than 5,000 ha are irrigated and controlled by modern and traditional small landholders (Table 1).

In the past, the emphasis on large-scale irrigation was part of a broader government policy to stabilize food supplies on drier lands, to absorb the growing labor force, and to intensify food and cash crop production (GOK 1986). Recently, however, attention has shifted towards smaller schemes and the agro-economic potential they hold. Size alone is not enough to determine the sustainability of a system. Yet, smaller often does mean less technically complex and more socioeconomically and environmentally manageable, particularly when the level of active farmer involvement in decision making is high (Chambers 1988; Alila 1986; Uphoff 1986; Coward et al. 1985).

The government's new policy calls for the promotion of small-scale, largely farmer-managed, socioeconomically and technically viable irrigation systems. For this reason, a detailed investigation

⁴ The term sustainable is used here to mean the capacity of resource-management strategies to both conserve local agro-ecological resources and ensure social and economic viability.

of the core elements affecting the performance of those systems and the development of realistic approaches to improving their management were considered both relevant and timely.

Table 1. Irrigated area by type of scheme and crops in Kenya, 1988.

Type of irrigation development	Principal crops	Area (ha)
Large commercial schemes	Coffee, pineapple, and horticulture	23,500
National Irrigation Board	Rice, cotton, and horticulture	9,000
Bura Irrigation Project	Cotton and maize	2,500
Modern small landholder (promoted by GOK or NGOs)	Rice, maize, and horticulture	2,500
Regional authorities	Maize, rice, and horticulture	1,200
Traditional small landholder	Maize, legumes, sorghum, and millet	800
Modern small landholder (farmer-managed)	Maize, legumes, and horticulture	500
Total		40,000

Sources: GOK 1989a; GOK 1989b; Ruigu 1988.

PARTICIPATORY RURAL-APPRAISAL METHODS

Rapid rural appraisal gained popularity among rural development specialists in the late 1970s as a means to quickly mobilize resources to mitigate the problems of the rural poor (Carruthers and Chambers 1981).

The From the Ground Up researchers at the National Environment Secretariat concur with the view that smallholder farmers must have a strong voice and countervailing power to hold government- and external-support agencies accountable and to ensure some measure of control over their productive resources. The National Environment Secretariat believes local people must be active and be equal partners in the research and development process, not simply "project clients" or "beneficiaries."

These considerations have led the National Environment Secretariat to take rapid rural-appraisal methods one step further by promoting the active participation of smallholder farmers in the appraisal and amelioration of their local environmental resource-management problems.

The result has been the development of participatory rural-appraisal (PRA) methods for local-level environmental resource-management assessment and planning.

Like rapid rural appraisal, participatory rural appraisal selectively combines methods from formal surveys and detailed participant-observation studies in a flexible framework and seeks to foster a constructive dialogue between the investigators and the local people. Unlike rapid rural appraisal which generally relies on technical specialists to apply techniques, analyze findings, and select the proper course of action, participatory rural appraisal brings the local land managers into the center of the diagnostic activities, working with them in the critical appraisal and analysis of their own environmental resource-management problems and opportunities, and supporting them in their efforts to generate and implement viable plans of action for the sustainable utilization of their natural resources. This flexibility and grassroots orientation make participatory rural appraisal useful for conducting action-oriented research on farmers' perceptions, values, objectives, and indigenous knowledge systems, as well as on their interactions with the underlying biophysical and economic environments. Perhaps even more importantly, it encourages local people to critically reflect on their own situations and needs and the obstacles to meeting them. As the National Environment Secretariat witnessed firsthand, such critical considerations can sometimes lead local people to set new priorities and channel their collective efforts into activities that bear lasting results.

The information garnered from the participatory rural appraisals is used to create and implement village resource-management plans (VRMPs). Each village resource-management plan is a realistic, community-based plan of action in which resource-management options are clarified, priorities are identified, and roles and responsibilities are clearly spelled out. The village resource-management plans are used by the communities -- with the assistance of external authorities and agencies where needed -- to develop, utilize, and conserve their local resource base.

Eight Phases of Participatory Rural Appraisal

The participatory rural-appraisal methods utilized by the National Environment Secretariat have eight well-defined phases.¹

1. *Site selection.* Sites for participatory rural-appraisal (PRA) analyses are chosen either after requests from community representatives are received or upon the recommendations of government administrative and/or technical officers. Locations tend to be areas which have experienced prolonged ecological stress or declining productivity.
2. *Introductory site visits and planning sessions.* A PRA team of six researchers from the National Environment Secretariat (three physical scientists and three social scientists - in this case three women and three men) headed by a senior research officer, makes a preliminary visit to the site and local government offices. The team meets formally with local community and government officers and conducts an informal reconnaissance of the

¹ A detailed description of each of these phases can be found in the handbook, *Conducting Participatory Rural Appraisal in Kenya* (1989), prepared jointly by NES, Egerton University, and Clark University. Write: the Director, NES/MENR, P.O.Box 67839, Nairobi, Kenya.

site by vehicle and on foot. A considerable amount of time is spent describing the PRA procedures and stressing the need to interact with a representative crosssection of the community (e.g., women and men, poorer farmers and wealthier farmers, tail enders and those close to the sources). To avoid misunderstandings or misconceptions, special emphasis is given to clarifying what the PRA cannot do as well as what it can do. During those initial meetings, mutually acceptable project objectives and field schedules are developed.

3. *Data collection.* Data collection begins as soon as a commitment is made after the diagnostic analysis of the site. It starts with the collection of all available documents and secondary sources of data on the systems' respective histories and performances to date. Short background reports are prepared from this information. Following this, three basic types of data are collected during the actual PRA:

a) *Spatial.* A natural resources map of the site is drawn by members of the National Environment Secretariat PRA team and a group of farmers. The farmers identify land-use patterns and problems, agro-ecological variations, and other physical, economic, and social characteristics of the area. The map is further developed over the course of the investigation. It provides a simple, yet accurate visual record of the resource-management activities occurring within the community. With the aid of the resources map, a number of representative routes or "transects" through the area are selected along which the researchers walk accompanied by small groups of farmers. The informal discussions held with the farmers encountered during those walks were useful in highlighting resource-management problems and opportunities on the spot. Similar transects were made with various technical officers from relevant ministries (e.g., agriculture and water development). Their insights and observations also contributed to a better understanding of local activities and conditions. The bulk of the spatial data are typically collected in one to two days.

b) *Temporal.* Two days are generally spent working with small representative groups of farmers. The focus is on temporal information and local institutions. For these meetings, the National Environment Secretariat PRA team divides into pairs (one physical scientist and one social scientist, one woman and one man). Each pair of researchers leads groups of between 8 and 18 farmers through specific exercises such as descriptions of seasonal calendars (land- and resource-use practices occurring throughout an agricultural cycle), major historical events within the community, long-term trends and changes in land-use patterns and resource-management practices and local institutional capacities and their internal and external linkages and influences. Visual aids -- diagrams, charts, and cutouts -- are used to direct the discussions. These help both the National Environment Secretariat researchers and the farmers to keep the meetings on course.

The emphasis is on practical discourse and critical reflection. The National Environment Secretariat investigators, acting as facilitators, encourage the farmers to critically assess their resource-management situation and consider appropriate measures for improving conditions. To encourage free and open debate, no local government, technical, or administrative officers are

present during these meetings. Once the participants understand the format, the group discussions become generally lively, very informative, and occasionally heated.

- c) *Socioeconomic*. During the transects, the farmers help the National Environment Secretariat PRA team to identify a socioeconomically representative cross-section of farm households. The heads of these households are later contacted and asked if they would mind being interviewed. The National Environment Secretariat PRA team then spends approximately two days formally interviewing those farmers and drawing rough sketches of their farms with their assistance.

To complete this activity relatively quickly the PRA team splits into pairs. Each research pair interviews six to seven persons. Every effort is made to interview an equal number of women and men (approximately 20 in all). The informants are asked their views on water supply and distribution, system maintenance, agricultural production, crop-pest and disease management, forestry and agro-forestry, marketing of cash crops, the organizational capacity and linkages of the water users' organization, and a number of related matters. Their responses are later combined with the information collected during the semi-structured group discussions to produce detailed lists of local resource-management problems and opportunities.

Neighboring farmers are encouraged to listen quietly to the questions and answers and after these are completed they are invited to take part in informal group discussions. These discussions are often useful for clarifying points raised during the interviews.

4. *Data synthesis and analysis*. This diversity of appraisal is known as "triangulation" -- the use of various sources and means of gathering relevant information. Triangulation is one of two central themes of rapid appraisal (McCrackin et al. 1988).

The other theme is the pursuit of "optimal ignorance," which is the amount, relevance, accuracy, timeliness, and actual use of information required to produce tangible results effectively and efficiently (McCrackin et al. 1988). Working within a realistic and acceptable range of ignorance and imprecision, the National Environment Secretariat PRA team, along with a number of farmer-representatives, synthesizes the information to produce a summary document of the primary resource-management problems and opportunities, for possible action. It requires approximately two to four days to process this information and prepare the preliminary document on problems and opportunities.

Once completed, this document enables the investigators to target a number of specific problem areas which are beyond the technical competence of both the local farmers and the environmental scientists at the National Environment Secretariat (e.g., the marketing of cash crops, the development of grain grinding facilities, etc.). Using this information, the researchers can request the assistance of the appropriate agencies. The technical experts generally participate in a workshop to analyze and rank the problems and opportunities with the farmers, local government officers, and the PRA team.

5. *Ranking opportunities*. With the problems and opportunities in mind, community members, with the aid of the National Environment Secretariat PRA team, local-government officers (and other technical experts, when needed), analyze and rank the problems and opportunities identified during the course of the appraisal. Different ranking criteria and exercises may be employed to achieve consensus about the most feasible opportunities, depending on the

group's wishes.⁴ In general, the farmers are encouraged to rank opportunities based upon social suitability, cost-effectiveness, technical feasibility, and ecological sustainability.

A total of 40 to 50 farmers normally attend a workshop. They represent most of the local institutions and self-help organizations in the community (e.g., the water users' organization, women's groups, church groups, and the road-construction group). The National Environment Secretariat PRA team coordinates the discussions with the assistance of local farmer-leaders and administrative officers. The local-government technical officers and technical advisers are asked to address the group on their respective areas of expertise and answer specific questions as the workshop proceeds. They play an important role in ensuring that the selected opportunities will be feasible in economic, ecological, and technical terms. Chalkboards and wall charts are utilized for listing important comments and considerations.

The workshop lasts one to two days. It is held in a centrally located community center. Lunch is prepared by local residents and paid for by the government. Where possible, transportation is provided for those farmers who live farthest from the meeting place.

6. *Preparing the Village Resource-Management Plan (VRMP)*. A detailed village resource-management plan emerges from the workshop. In it, the major opportunities for solving the primary problems are noted, roles and responsibilities are spelled out, and required resources and realistic time frames are identified. Before closing the workshop, all parties must agree to the overall form and content of the village resource-management plan.

The workshop is particularly useful in bringing the farmers and officers face to face and opening up lines of communication not used previously. Positions and perspectives can be clarified on both sides. By the end, the participants are generally satisfied with the outcome of the discussions.

7. *Adoption and implementation of the VRMP*. The VRMP may be seen as a contract between the farmers, the government, and external support agencies (where involved). While the existence of the VRMP is not a guarantee that all objectives will be accomplished or that differences within a community will be lessened it has been the National Environment Secretariat's experience that significant and tangible changes can and do take place -- and in a relatively short period. Moreover, those changes can be sustained largely with local resources and local leadership.

Where external support is required the VRMP clearly states what needs to be done, when the project should begin, where it will take place, and who is responsible. What remains is how it should be done, and even that is discussed during the workshop and is outlined in the VRMP.

8. *Follow-up: monitoring and evaluation*. Once the process is set in motion, the VRMP acts as a kind of baseline from which all future changes can be measured. Monitoring of progress can be achieved by comparing a condition or situation today to that when the VRMP was implemented. While few sanctions exist to take direct action against those who fail to fulfill

⁴ The National Environment Secretariat has employed the ranking criteria developed by the International Institute for Environment and Development (McCrackin et al. 1988) -- stability, equity, productivity, sustainability, and feasibility -- with some success. It has also found pairwise ranking to be effective. Be forewarned, however: ranking, no matter the approach, is a time-consuming and exhausting exercise.

their roles and responsibilities, social pressure and opinion can often be used to reprimand or motivate laggards.

The entire process of diagnostic analysis and planning and implementation of the VRMP provides valuable managerial and technical experience to local institutions and increases their capacity to act meaningfully on their own. The essence of sustainable development is to have local institutions and responsible leaders in rural communities who can direct the course of local initiatives as they see fit. Monitoring, evaluation, and project modification can take place with little external direction or major investment of resources because local people have the capacity for follow-up.

PARTICIPATORY RURAL APPRAISAL AND FARMER-MANAGED IRRIGATION SYSTEMS

The National Environment Secretariat used the PRA methods in its work in two small-scale, farmer-managed, gravity-irrigation systems, the Njoguini, Gitero and Kabati Self-Help Water Project, Nyeri District in the central part of the country, and the Njukini Irrigation Project, Taita-Taveta District in southern Kenya. A multidisciplinary team of six scientists spent a total of six weeks conducting PRAs at the two sites. Emphasis was placed on the active participation of the local people in the appraisal and analysis of their environmental resource-management problems and opportunities. The National Environment Secretariat team acted primarily as a catalyst in this process, promoting a constructive dialogue between the local people and the relevant government authorities, and among the community members themselves.

With the National Environment Secretariat's assistance, the farmers assessed their problems and opportunities relating to water supply and distribution, agricultural production and marketing, crop pests and diseases, livestock and dairy production, marketing, mechanized agricultural services, road construction and transportation, tree-nursery improvements and agro-forestry techniques, fish-pond development, public-health problems and services, and income generation. Site-specific village resource-management plans emerged from these appraisals. The major opportunities were selected, roles and responsibilities were agreed to, and required resources and realistic time frames were identified. In actuality, even before written copies of the VRMPs were made available action had been taken both locally and by the National Environment Secretariat and a collection of ministries, parastatals, and external-support agencies to rectify a number of the more pressing problems. These included new crop-production strategies and marketing arrangements, engineering adjustments in water delivery, improvement of local tree nurseries, reconstruction of local roads, and the development of a grain-grinding facility. The social energy released during the appraisals and analyses had set the wheels in motion. Ideas were put into action and actions led to results.

According to informal discussions with farmers, these activities are a direct result of the PRA/VRMP process of appraisal, analysis, and action in which they were central players. They expressed satisfaction with the ideas and information that had been generated and made special note of how the process had enabled them to better understand their own institutional capacities.

SUMMARY AND CONCLUSIONS

It has been the experience of the National Environment Secretariat that, through a process of practical discourse, critical reflection, and communicative action, participatory rural-appraisal methods can help local people to identify their problems and opportunities and select strategies that will help mitigate the situation. The National Environment Secretariat has now tested the PRA methods in five different locations in Kenya and is continuing to monitor the progress of the farmers at those sites. More time is needed before the longer-term effects of the PRAs and VRMPs can be evaluated. Nevertheless, preliminary results indicate that the PRA holds the potential to: 1) intimately involve a community in the appraisal and analysis of its own environmental resource problems and opportunities; 2) facilitate community mobilization and participation, particularly of women; 3) move beyond the conventional sectoral approach to evaluation and offer a holistic perspective on the factors that impinge on a community's progress; 4) provide high-quality information in a short period and at a low cost; 5) generate a clear picture of local institutional capacities and linkages; and 6) offer a simple, yet effective method of system monitoring without the need for foreign experts or a large investment of resources.

After reviewing the National Environment Secretariat's research in Kenya, the World Resource Institute recently decided to initiate field trials of participatory rural appraisals and village resource-management plans in eight other African countries involved in the From the Ground Up program. This broad range of experience should further illuminate the potential applications and limitations of those methods and plans.

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Case Studies

Summaries of Case Studies

Interaction Between Design and Operation and Maintenance of Farmer-Managed Irrigation Systems

M. R. Biswas (Page 193)

Institutional and technical interventions for farmer-managed groundwater irrigation systems are discussed. Alternatives for improving conveyance systems and involvement of the farmers in projects to improve water-conveyance systems in Bangladesh are also examined.

Design Issues in Farmer-Managed Irrigation Systems: Three Case Studies in Gravity Irrigation in Maharashtra, India

R. K. Patil (Page 207)

The operation and maintenance functions of farmer-managed and large, jointly managed gravity-flow systems are compared. Key design issues are identified: 1) simplicity, 2) manageability, 3) frequency of water application, 4) redundancy, 5) water sharing, and 6) conjunctive use of surface and groundwater. Recommendations for accelerating the process of establishing farmer management on small- and large-irrigation projects are also proposed.

Local Adaptations and Basic Designs: An Example from India

Nirmal Sengupta (Page 217)

This paper proposes that a well-planned network of chain or system tanks can offer adaptable design alternatives for irrigation and other uses. Several tank designs are suggested.

Rehabilitation of Village Tanks: Redesign or Consolidate?

C. Kariyawasam (Page 223)

The rehabilitation of village tanks in Sri Lanka is described. Problems encountered are noted and a recommendation made that unless comprehensive (but expensive) social and economic studies are conducted it is better to strengthen the existing structures and organizational patterns instead of imposing major changes.

Farmer-Managed Irrigation Systems: A Case Study From India

M. Venkata Reddy (Page 229)

This case study demonstrates how a relatively simple design layout and structure can serve the needs of a complex socioeconomic community and physical environment over time.

Towards Farmer-Managed Irrigation Water-Distribution Systems in Nigeria

P.R. Maurya, A. Ahmed, and J.K. Adewumi (Page 237)

Three large-scale agency-managed surface-irrigation systems in Nigeria and the commonly used water-distribution network designs and their constraints are described. Suggestions are offered for improving the water-distribution systems for management by the water users.

Design Issues in Controlling Drought and Waterlogging/Salinity in Farmer-Managed Irrigation Systems on the North China Plain

Ren Hongzun (Page 247)

A comprehensive system of irrigation and drainage networks, wells, and agronomic and forestry measures to deal with the dual problems of drought and waterlogging/salinization on the North China Plain are described. The manipulation of economic and management policies to achieve improved water-use efficiency and production is also related.

Interaction Between Design and Operation and Maintenance of Farmer-Managed Irrigation Systems

M.R. Biswas[§]

INTRODUCTION

FARMER-MANAGED IRRIGATION SYSTEMS are located all over Bangladesh where most of the fertile agricultural land is either low-lying flood plains under deltaic influence or flood-free upland beyond the scope of gravity-flow water supplies. Unlike in other countries, the farmers are less acquainted with gravity irrigation which is limited due to the absence of water-diversion opportunities. However, lift irrigation is prominent. There are a few primitive devices for lifting water for limited irrigation. Modern lift irrigation either from surface sources by low lift pumps or from groundwater aquifers through deep or shallow tube wells has taken the key role in both agricultural and rural development programs in Bangladesh for the purposes of increasing farm outputs against recurring food deficits and growing rural unemployment. Because of the costs involved in installing and managing lift systems the government has sponsored a program in both public and private sectors to involve the farmers in increased agricultural production.

Agriculture is Bangladesh's primary industry and lift irrigation has a vital role in the nation's economy. The role of minor irrigation in increasing food production and employment is already well-documented (Hamid 1977; Hanratty 1983; Palmer-Jones 1985). Introduction of irrigation technology may open new outlooks and create an impact on both the social structure and the rural economy, but in reality, experience has shown that only a few elite farmers have gained enormous benefits (Hamid 1977; Hanratty 1983; Biswas 1988). The performance of these irrigation systems was in general unsatisfactory (Hamid 1977; Biswas 1988). Engineering, economic, social, political, legal, and especially institutional problems were responsible for creating greater inequities in the rural areas (Biswas and Mandal 1982; Hanratty 1983; Palmer-Jones 1985). Improved management strategies were sought in order to combat the inequality in benefit

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distribution and make the irrigation installation workable at full capacity (RD-I Project Series 1980). The irrigation schemes are primarily planned by state planners while the irrigation systems are managed by the farmers. The latter is neither independent of state bureaucracy nor able to tackle local problems easily in a complex socioeconomic environment. Thus, operation and maintenance activities are not simple although the farmers are made responsible for providing water to the fields using the minor irrigation installation.

In the early stage of introducing modern irrigation technology water was neither considered a priced commodity nor thought a scarce resource (Hanratty 1983). However, the growing demand for irrigation water and the increasing trend of rising irrigation costs have created an awareness of the wastefulness of present methods of irrigation and made the farmers concerned about crop water requirements and losses in the conveyance system. In addition to the poor performance of the irrigation systems the pumps in some cases cannot supply adequate irrigation nor can they cover the area as planned (Biswas 1988).

Use of the irrigation installations is limited to the dry season only remaining idle for the rest of the year despite the potential for providing supplemental irrigation in other seasons. Ordinarily, irrigation is applied only on high-yielding rice and some wheat. Nevertheless, other high-value crops could simultaneously receive water through improved water allocation and distribution systems (Biswas 1988; Gisselquist 1989).

Given the limited availability of both surface water and groundwater which constrains the expansion of irrigated area under low lift pumps and shallow tube wells and the costs involved with deep tube-well installation and maintenance, new strategies are being sought to increase irrigation efficiency, to replace traditional and water-loving crops with high-value crops requiring less water, and to improve water distribution and water-application methods (Palmer-Jones and Mandal 1988; Gisselquist 1989). These strategies are aimed at making the irrigation systems more productive with increased participation by the farmers. However, to achieve increased productivity, considerations for appropriate methodological interventions need to be incorporated in the design of an irrigation system to encourage crop diversification and increase crop intensities.

Though literature documents, and experience exists for evaluating water requirements of plants the design of an irrigation system is usually based on either thumb-rules or "field experience." Because it is complex, plant-water relationships are deliberately ignored in designing irrigation systems in Bangladesh.

CONSIDERATIONS FOR IMPROVING WATER DISTRIBUTION

Water Losses at Pumping Sites

Water is lost through seepage, leakage, overflow, and in excess application. The pump delivers flows with high velocity that cause soil erosion, and water spills cause drainage problems resulting in inferior crop production near the pump sites. Regulated water flow is desirable and a brick discharge box is ordinarily constructed with a view to protecting the soil surface, avoiding

water spills, and directing the flow to the field. Alternatively, small ponds are sometimes dug to form water cushions although water flow to the main canal suffers from insufficient head developed in the pond. Other low-cost measures such as placing sheet metal, wood planks, bamboo strips or straws around the pump may diminish soil erosion substantially. However, water spills and logging and loss of space cannot be avoided with these alternatives. Eventually, inclusion of a control structure at the pump site is essential to the water-distribution network.

Improving Conveyance Systems to Reduce Water Losses

Most of the water-distribution systems in minor irrigation scheme areas are locally initiated, constructed, and managed by the farmers. Ordinarily, a small earthen canal is used to convey water and losses occur in various ways. Losses of water may account for about 50 percent of the total water pumped (Khair and Hossain 1978; Biswas et al. 1984). This loss varies according to the soil and relative elevations of the canals (Biswas et al. 1983). Extra pumping is necessary to compensate for losses or the command area is reduced for want of water, and overall irrigation efficiency declines (Biswas et al. 1983; Gisselquist 1989).

Some of the losses including waste can be greatly minimized through efficient water-management practices (RD-I Project Series 1980). In addition, some physical interventions including structural measures are recommended to avoid water losses (Jenkins 1983; Biswas et al. 1983 and 1984; Arif 1984; Hoque 1984; Ahmed 1984). Of these, improvement of existing earth canals is about the most effective. Other suggestions include shortening and straightening the canal. However, existing land-tenure patterns, fragmentation, and irregular subdivisions of the command area make some of these measures difficult to implement (Biswas and Mandal 1982). Construction of raised and graded canal beds including compaction of the canal subgrade are also advocated. Local labor can be trained in the skills required for these tasks but obtaining extra earth for raising the canal bed and the extra land area needed is difficult (Biswas et al. 1983 and 1984; Hoque 1984). The low-cost lined canal, being the second choice, also suffers from similar problems of establishing right-of-way for shortening and straightening. Nevertheless, lined canals reduce both costs and materials. The low-cost canals are cast concrete, soil-cement, and asphalt-mat. The concrete canals may be pre- or in-situ cast. Consolidation and compaction of canal subgrades, casting of joints, uniform cross-sections, maintaining sufficient bed slope, and uniform thickness and passage for random movements at the sides are some of the critical design issues of low-cost linings (Hoque 1984; Arif 1984). Flood-free sandy soil areas may favor soil-cement canals, while asphalt-mat cover has limited use (Biswas et al. 1983).

Buried concrete pipe is an alternative although it needs high initial investment and construction skills (Palmer-Jones and Mandal 1988). To its advantage, it does not consume valuable agricultural land, offers regulated water flow even against undulation and broken topography, and promises to irrigate more area at minimum water loss (Jenkins 1983; Gisselquist 1989). Besides low-pressure concrete pipe other main components of the system are standpipes to act as both discharge boxes and sediment traps, risers with suitable valves to serve the area blocked, dividers for diverting flow, anchors for balancing the internal forces, and vents for releasing entrained air. The standpipe also provides the necessary head and dampens surges or water hammer during unsteady flow. But the flow between risers may be affected by both differences in elevation and

pipe-friction losses. Above all, the design of a buried pipe system requires technical knowledge of the applications of hydraulic principles including the impact of hydrostatic pressure, surges, and changes in momentum.

The success of an irrigation system relies on ease of operation and maintenance as well, and the system should be kept simple and flexible so that farmers can easily resolve the problems on site. Quite often, major maintenance work jeopardizes the system under many socio-political-economic variables (Biswas 1988). The importance of these variables should be considered and incorporated in the design for a farmer-managed irrigation system.

DESIGN ISSUES

Institutional Interventions

In Bangladesh, different categories of farmers are engaged in irrigation, making the formation of users' groups that take into consideration the social and economic characteristics of the farmers, an important issue in achieving farmer participation in irrigation. Policy formulations including bylaws for procurement, construction, operation, and adoption of management strategies are necessary keys to the success of farmer-managed irrigation systems.

Technical Interventions

Mapping. A map of the irrigation project area is needed. It should show the pump site and the water-distribution network based on relative land elevation. Stratified crop areas based on soils and topography should be identified on the map as one of the design steps. Cropping patterns including sequential rotation should be evaluated for the potential area. The potential command area must be delineated on the map, with blocks and sub-blocks earmarked with reference to topographical settings, cropping areas, and water-application techniques.

Assessing irrigation water. A chart should be prepared which should include information on the water requirements for each crop at each growth stage. Additional water requirements for land preparation or pre-sowing should be included. Water allocation based on crops, soils, land positions, and irrigation methods should be estimated for different locations within the scheme area and evaluated.

Assessment of water sources. Sources of irrigation water in terms of water-level status, replenishment opportunities for surface water (especially in the dry season), and augmentation scopes for groundwater with the indices relating to storage coefficients, transmissibilities, and permeability of the aquifers need to be investigated. Pumps selected for the system must be appropriate for the water source and for the power available.

Water-conveyance systems. Improved open earth canals, low-cost open lined canals, and buried low-pressure pipe systems are primarily referred to as irrigation water-conveyance systems. Any one or a combination of these systems may be considered in relation to cost and the farmers' preferences.

Improved earth canal is an obvious choice unless the other two types are partly or fully subsidized. The design of earth canals for the best flow using stream size, permissible velocity, side slope, bed slope, and roughness coefficient calculations is not complicated. The design dimensions for freeboard and berm can also be readily calculated. Designs to carry sufficient water with minimum loss must be sought. Raised and graded canal beds with adequate right-of-way improve the efficiency of the water-conveyance system. Aqueducts may be placed over the ditches or the depressions to help maintain grade, and humps need to be leveled. Above all, the canal subgrade should be well-compacted to reduce seepage. The effectiveness of this technique depends on the soil textures of the canal subgrade.

Some water losses occur in earth canals even after the canal beds are raised, graded, and compacted. Whenever financial assistance is available the farmers want brick-lined canals. However, because of the cost brick lining is usually discouraged (Biswas et al. 1983) and low-cost canal linings are often advocated (Khair and Hossain 1978; Biswas et al. 1983; Hoque 1984; Arif 1984). Nevertheless, brick-lined canals do minimize water loss as well as provide potential to control and regulate water flow according to need. Basic construction requirements for earth-lined and brick-lined canals are almost identical. Canal subgrades require extra land and earth. Retaining walls and other support structures are sometimes necessary to avoid breakage and to safeguard the canal from external pressures.

Some critical issues should be carefully watched when constructing a low-cost lined canal to assure durability:

- a) Cracks in the reaches of the canal subgrade should be avoided by careful compaction and consolidation before installing the lining materials. Proper casting of joints is essential and the embankment should be protected from side cutting.
- b) Uniform canal slope should be maintained to avoid overflow. Careful siting of the pumping unit can overcome these problems as well as make it possible to extend irrigation to higher elevations.
- c) The edges of the canals should be uniform and protected with concrete to prevent random movement caused by people and animals.

Allowance for right-of-way for the canal causes serious problems in the midst of acute land scarcity. Topographical variables and unplanned settlement patterns discourage the use of open-canal conveyance systems. Buried low-pressure pipe may be considered as an alternative conveyance system, although it is more expensive. Nevertheless, buried pipe systems can be stretched over hilly areas and broken topography to serve different blocks and sub-blocks using risers fitted with suitable valves. Water is directly pumped into the buried pipe lines and the flow is influenced by hydrostatic pressures. Accordingly, a sufficient knowledge of hydraulics is necessary, and certain precautions should be taken when designing a buried pipe system:

- a) The standpipe should assure structural stability and sustain hydrostatic forces. The inlet of the standpipe should have a flap valve to prevent flow back to the well. The inlet and outlet should be offset a minimum of twice the sum of their diameters and the outlet invert should

- be at least 0.65 meters above the bottom of the standpipe. The cross section of the standpipe must be large enough to assure a maximum downward velocity of 0.60 meters per second (m/sec) for a deep tube well irrigation project. If the standpipe is to serve as a sediment trap the downward velocity should not exceed 0.10 m/sec. Access to the standpipe for cleaning is essential. A minimum of 0.70 meters freeboard is desirable to avoid overflow.
- b) Selection of pipe size is usually based on maximum permissible velocity and head loss encountered in the flow system.
 - c) Vertical risers with appropriate valves at the top should be fitted to the pipe line for releasing water to the ground surface or the field canals.
 - d) A vertical standpipe fitted at the top with overflow weirs should also be accommodated in the pipe network in order to divide the flow proportionally. Installation of flow dividers is essential for regulating flow in variable topography.
 - e) Any abrupt change in pipeline grade or alignment must be secured with an appropriate anchor. This will balance internal forces caused by hydrostatic pressures, surges, and changes in momentum.
 - f) Vent stands should be installed on the pipeline, preferably near the junctions, for releasing the entrained air in the pipe.

Particular attention must be paid to the installation of the pipe in respect to grade and alignment, placement in the trenches, curing of collar joints, and backfilling the trenches. The bases of the standpipes must be carefully constructed in order to reduce the need for repair.

Control structures. A discharge box, some division boxes, and turnouts may be needed for open canal systems. A discharge box will help avoid soil erosion and water spills. Concerns to be considered when designing the discharge box are the impact of flowing jets on the floor, storage capacity, and appropriate openings. Division boxes with control gates can divide the stream according to the water-allocation plan. Similarly, turnouts with control gates allow water to be distributed to the blocks. If the canal bed is at a higher elevation than the area to be irrigated, a drop structure is essential. For buried pipe systems, the principles of pipe flow influence the structural design of standpipes, risers, flow dividers, anchors, and vent stands.

Drainage outlets. Drain outlets should be installed at low elevations in the irrigated area to remove excess water. Construction of simple culverts is also needed to avoid ponded water.

PARTICIPATION OF THE FARMERS

The designer of a farmer-managed irrigation system should carefully examine operation aspects so that both institutional and technical interventions can be adjusted to local resources and needs. Efficient management of a farmer-managed irrigation system depends on the reliability of a power supply (electricity/diesel), ability to respond quickly when repairs and maintenance are needed (including mechanical servicing), and training facilities for updating irrigation practices including production technology.

Table 1 provides details of the involvement of the farmers and the agency at various stages of projects to improve water-conveyance systems in Bangladesh. As Table 1 reveals, field investigation showed that most decisions for improved water-conveyance structures are made by persons outside the irrigation system which contradicts the basic concept of incorporating the participation of the farmers in decision making for both design and construction. Nevertheless, operation and maintenance are left to the farmers who can generally carry out such activities if external cash assistance is provided. On withdrawal of such help, operation and maintenance do not function effectively (Biswas 1988).

Even for decisions involving the construction of discharge boxes controlled by the farmers' cooperative society, farmer involvement is low. The field investigation revealed that 3 out of 21 boxes were below specifications, causing overflow, water spills, and drainage problems near the pump sites. Another nine boxes have bulky designs involving excess masonry works and materials. In addition, one discharge box has an outlet that is too small, resulting in overflow. Complaints of design errors related to canal alignment, flow requirements, and weak construction are often heard. (Design defects are fewer in certain special project areas where technicians are involved in construction and are charged for their mistakes.) Most of the design and construction defects are due to poor extension services. As a result, the farmers face problems with operation and maintenance of the system.

Table 1. Involvement of the farmers and the agency at various stages of some projects to improve water-conveyance systems.

Stage	Buried pipe		Low-cost lined canal		Earth canal		Discharge box	
	F	A	F	A	F	A	F	A
Initiative	0	9	0	6	17	0	5	16
Design	0	9	0	6	14	3 ^a	4	17
Construction	0	9	0	6	16	1 ^b	4	17
Operation and maintenance	8	1 ^c	6	0	17	0	19	2 ^b

Notes: F = Farmer involvement

A = Agency support:

^agovernment extension service

^bsupervision from a nongovernment organization

^cproject component

F+A = Total number of structures investigated

Source: Field investigation 1989.

EXTENDING COMMAND AREAS

Table 2 shows that there is no real difference in the size of command areas that are irrigated by buried pipe systems or earth canals despite earth canals incurring greater water losses. Nor does a change in cropping patterns occur as a result of installing either buried pipe or lined-canal systems, despite lined canals being generally found in flood-free highlands capable of growing a variety of crops. However, earth canals are predominantly found in low-lying rice-growing areas. Thus, technology has failed to influence changes in cropping patterns -- instead, land morphology is the determining factor.

The concentration of pump installations or limitations of the pipe extension may be reasons for such disappointing irrigation coverage by buried pipe systems. These problems, resulting from planning errors, frustrate the achievement of improved agricultural production.

Table 2. Command area, crops irrigated, and water usage in the dry season.

Conveyance system	Area ^a	Water distributions						
		Applied		Used by crop		S & P in field		Conveyance losses
	ha	ha.m ^b	%	ha.m	%	ha.m	%	%
Buried pipe (Q = 46) (H = 1,158)	11.1	14.0	76	1.0	54.1	3.7	20	1.9
	10.4	3.5	19	2.9	14.0	0.8	4.2	0.8
	1.3	0.5	3	0.5	2.6	0.1	0.4	-
	<u>1.4</u>	<u>0.4</u>	<u>2</u>	0.3	1.8	0.0	0.2	<u>-</u>
	24.2	18.4	100					2.7
Low-cost Lined canal (Q = 47.5) (H = 1,561)	15.6	21.6	81	14.0	52.6	5.2	19.5	8.9
	10.8	4.0	15	2.6	9.8	0.9	3.2	2.0
	1.2	0.5	2	0.4	1.6	0.1	0.3	0.1
	<u>1.3</u>	<u>0.5</u>	<u>2</u>	0.4	1.4	0.1	0.3	<u>0.3</u>
	28.9	26.6	100					11.3
Earth canal (Q = 48.9) (H = 1,828)	21.0	30.6	95	16.8	52.8	5.8	17.9	24.9
	0.8	0.3	1	0.2	0.6	0.1	0.2	0.2
	<u>2.8</u>	<u>1.3</u>	<u>4</u>	0.8	2.4	0.2	0.7	<u>0.9</u>
	24.6	32.2	100					26.0

Notes: Q = Average flow rate in liters per second

H = Hours of pump operation

S&P = Seepage and percolation

^a Refer to Table 3 for the sequence of crops cultivated in the area given.

^b Hectare meters: One hectare meter is the volume of water required to cover one hectare of land one meter deep, or 10,000 m³.

Source: Field investigation 1988.

POTENTIAL FOR CROP DIVERSIFICATION

Improved water-conveyance systems should also have the potential for increasing agricultural production by providing irrigation year-round, making it possible to grow diversified crops. Table 3 shows that while irrigation water is applied in the dry season as is usual, very little use is made of irrigation in both the early monsoon and main monsoon seasons.

Table 3 shows that irrigation facilities are used only for a few hours in both monsoon seasons. Early monsoon irrigation may overlap with some dry-season watering. The use of irrigation is limited to land preparation for early-monsoon rice and as supplemental water for some main-monsoon rice, particularly during the grain-filling stage. These practices are neither remarkable nor significant irrespective of the type of conveyance system. The physical improvement of a system does not necessarily increase cropping intensities throughout the year. Improvements in

Table 3. Use of different irrigation installations in different seasons.

Conveyance system	Crop	Dry season ^a		Early monsoon ^b		Main monsoon ^c	
		Area (ha)	Time (hrs)	Area (ha)	Time (hrs)	Area (ha)	Time (hrs)
Buried pipe	Rice	11.1	--	11.5	--	14.9	--
	Wheat	10.4	--	--	--	--	--
	Vegetable	1.3	--	1.6	--	1.8	--
	Others	1.4	--	2.0	--	1.8	--
		----	----	----	----	----	----
		24.2	1158	15.1	28	17.5	86
Low-cost lined canal	Rice	15.6	--	16.2	--	26.3	--
	Wheat	10.8	--	--	--	--	--
	Vegetable	1.2	--	0.8	--	1.3	--
	Others	1.3	--	--	--	--	--
		----	----	----	----	----	----
		28.9	1561	17.0	17	27.6	116
Earth canal	Rice	21.0	--	5.9	--	19.5	--
	Wheat	0.8	--	--	--	--	--
	Others	2.8	--	--	--	--	--
		----	----	----	----	----	----
			24.6	1828	5.9	6	19.5

Notes: ^aDry season = November-February (Rabi)

^bEarly monsoon = March-May (Kharif I)

^cMain monsoon = June-October (Kharif II)

Source: Field investigation 1989.

cropping intensities reported by Ahmed and Gisselquist (1989) are not generalized; they were possibly gained with non-irrigated crops grown annually and seasonally in the potential command area. Nevertheless, the cropping intensities were higher in the dry season with improved water-distribution techniques.

PRODUCTION TECHNOLOGY TRAINING FOR FARMERS

Improvements in the water-conveyance system are not the only input for improving farmer-managed irrigation systems. Other production technologies are equally important for achieving efficient operation and maintenance of the irrigation system. Field investigations (Table 4) show that traditional sources are the main means by which farmers learn about agricultural practices. Projects have trained some farmers in high-yielding varieties, fertilizer use, water allocation, and irrigation scheduling. Local-level training in the Irrigation Management Programme (IMP) has trained some farmers in water allocation and irrigation scheduling. However, training in the production techniques mentioned in Table 4 is uncoordinated and unbalanced so that the expected results in farmer operation and maintenance are not achieved.

Table 4. Unbalanced training in production technology for farmer-managed irrigation systems.

Source of training	HYV	Ferti- lizer	Tillage	Water alloca- tion	Irrigation scheduling	Banking
Traditional methods	32	31	77	--	--	66
Extension services ^a	0	0	0	0	0	0
Projects	37	40	--	18	15	3
IMP training ^b	10	2	--	45	26	2
Booklets	2	4	--	--	--	1
Unknown	11	15	15	29	51	17

Notes: Number of respondents = 92 (farmers)

^a Extension refers to the government extension service

^b Locally organized training through the Irrigation Management Programme

HYV = High Yielding Varieties

Source: Field investigation 1989.

CONCLUSIONS

Farmer-managed irrigation systems are an integral part of Bangladesh's irrigation program for increasing agricultural output. All phases of activities starting from procurement and installations to operation and output disposal need to be included in this program. However, such a synchronized action program is unfortunately not found in Bangladesh. Moreover, frequent changes in government policies breed socioeconomic disorders which seriously affect operation and maintenance of farmer-managed systems. Therefore, farmer-managed irrigation systems are not free from state bureaucracies. A firm and steady government policy is important towards achieving the design goals for farmer-managed irrigation systems. Nevertheless, a few basic issues which influence both design parameters and operation and maintenance activities for farmer-managed irrigation systems should be investigated:

1. The farmers' participation in all stages of planning, design, and installation should continue to be emphasized. How can a participatory approach be made effective?
2. State planners need to ponder and develop a proven irrigation policy. Design and installation criteria must be coordinated with a state policy while satisfying the operation and maintenance requirements of the farmer-managed systems.
3. In many farmer-managed irrigation systems, physical interventions are sponsored without investigating local resources such as water reliability, land productivity, energy reliance, and the capability of the farmers' cooperative society. A thorough inventory of all these resources is essential.
4. The farmers' interests, choices, involvement, and commitment are vital to operation and maintenance of irrigation facilities. How can the designer get a true picture of these vital aspects?
5. All production inputs are not equally stressed during planning and operational stages. For example, the importance of adequate plowing is deliberately ignored for want of draft-power sources. Should not all the cultural aspects be emphasized in designing the irrigation system?
6. Irrigation activities concentrate on the dry season. Can the irrigation systems be designed so that they will stimulate the use of supplemental irrigation of high-value crops in other seasons, and encourage crop diversification?
7. Most production technologies are learned informally using traditional sources, and local-level training conducted by the Irrigation Management Programme (IMP) has been found ineffective. Should not the Programme's training be reoriented to provide more effective training?

The imposition of new technology is less important than achieving the active involvement of the farmers. The best way to encourage the farmers to participate is to make them understand the benefits or profit potentials they may obtain from irrigation and to promote their participation in planning, designing, and constructing their systems.

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Design Issues in Farmer-Managed Irrigation Systems: Three Case Studies in Gravity Irrigation in Maharashtra, India

R.K. Patil[§]

INTRODUCTION

FARMER-MANAGED IRRIGATION SYSTEMS are defined as systems where construction, operation, and maintenance activities are the responsibility of the beneficiaries. A caveat is added that in some such systems, the beneficiaries might have received external assistance for the construction phase. But the distinguishing characteristic of farmer-managed irrigation systems is that irrigators themselves carry out operation and maintenance of the systems. In general, these systems are designated as traditional, indigenous, communal, or people-managed systems.

However, there exists a subset where construction, operation, and maintenance of the system up to a designated point is farmer-managed while the management above this point is entrusted to the government-owned irrigation agency. This situation pertains to large irrigation projects (irrigating an area of 10,000 hectares [ha] or more) where because of technical and organizational complexities the total system management cannot be entrusted to the beneficiaries in the existing socioeconomic environmental setup. The large system is sectioned into smaller units where the management (of construction, and operation and maintenance) is entrusted to the beneficiaries. The irrigation agency is responsible for delivering the allocated volume of water (measured or left to the judgement of the agency) according to schedule at the head of the minor or distributary channel while leaving further operation, distribution, and maintenance of the downstream physical system to the beneficiaries. It stands to reason that the management above the designated point, which may be called "main system management," has to be entrusted to the irrigation agency. As these systems are now being experimented with in Southeast Asian countries they have to be included as farmer-managed irrigation systems. They also face design problems similar to those of the traditional, indigenous farmer-managed systems.

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That farmer-managed systems are superior to agency-managed systems (where the agency personnel deal directly with myriads of small farmers on an individual basis) in terms of cost and irrigation efficiencies is now well-acknowledged. Where farmer-managed systems have failed or weakened, the causes are traced to certain external factors such as degradation of storage and conveyance facilities, lack of knowledge of crop technology to suit the changing environment, the mismatch of water delivery to crop water needs, bureaucratic interference (laying down restrictions on crop patterns, fresh levies, etc.), and organizational decadence arising from social conflicts among the beneficiaries. Every failure needs to be studied individually and solutions found for restructuring the systems.

DESIGN ISSUES

In any farmer-managed irrigation system, either in the traditional small or medium size or in any segment of a major project, the following design issues need to be considered to ensure success:

1. Designs should be simple enough for the farmers to understand: the farmers should have a prior knowledge of when, how, and how often water is delivered to individual farms. This would help them make a reasonable estimate of reliability, predictability, and stability of water supply.
2. Size of the flow should be such as to be manageable by an individual or by a group of farmers. This would depend upon how water application is organized.
3. The frequency of water application should meet crop water requirements. If there is crop diversity, this factor should be taken into account at the design stage.
4. Principles for sharing water storage/surpluses should be clearly laid down. A minimum equity should be ensured among the farmers and groups of farmers.
5. Design should provide for the "Principle of Redundancy." Thus, if a system has high sensitivity to environmental accident or decay, certain redundancies, or slacks, have to be provided for shock absorption. In the case of irrigation systems, this would mean provision of en route or buffer, or night storage, or escapes in case there are probabilities of heavy rainfall or floods. Such safeguards promote the stability of the system.
6. In order to increase water-use efficiency, conjunctive use of groundwater and flow water has to be considered. Conjunctive use can ensure regularity in water supply despite irregularities in canal operation. It can be organized collectively, via water associations/societies or on an individual basis, stipulating that canal water would not be supplied at designated frequencies. How these issues were resolved in three farmer-managed irrigation systems in Maharashtra State, India, is discussed in this paper.

THE PHAD SYSTEM

Farmer-managed irrigation systems are not new to Maharashtra, especially in the northern districts of Nasik and Dhule. In the mid-seventeenth century, water from three rivers in these districts was regulated by building a series of weirs/bunds and diverting it through canals to the nearby croplands. Historical records are scanty on who constructed them but available evidence suggests that local leaders built them and then approached the rulers for hereditary rights as village heads. They were then made responsible for maintenance and distribution with the help of local farmers. These systems are locally known as phads.

British rulers did not disturb the system. However, in view of the poor maintenance of the physical system they systematized the organization and management around the 1860s by imposing responsibilities on the groups and by giving powers to impose taxes/fees on the beneficiaries. Guidelines were framed for maintenance activities and water distribution and also for managing financial accounts and funds. The government did not take any responsibility except that of broad supervision.

Until 1960, about 70 small farmer-managed systems were in existence irrigating an area of about 4,800 ha. Today, only about 33 groups are functioning as the river flows are affected by catchment degradation and/or water-resource developments on the upstream side. The extinct groups are generally located on the downstream weirs where water availability in the post-monsoon season has become critical or nonexistent.

Physical System

The physical system consists of a weir, a canal, and then secondary and tertiary channels irrigating the fields. The group of beneficiaries on a given weir is responsible for maintenance, operation, and distribution. Depending on the topography, a weir commands an area of 50-400 ha. As the height of the weir is the concern of both the designated beneficiary village and of the beneficiaries of successive downstream weirs (as these are fed from the overflows of the upstream ones) no single group can tamper with it. A watch is kept and if any group tries to raise the height quick action is taken.

In most of the weirs there is only one canal. If the command is available on both sides, two canals are designed. However, to ensure equity between the two groups, sill levels of both canals are fixed to be equal so that in case of scarcity water is shared on an equitable basis.

The canals run for a distance of two to ten kilometers (km) through a ravine to the command area. Along its length, a few escapes are provided for diverting excess flows. These are also used for the disposal of silt during maintenance activities. The canal system is very elaborate, consisting of deep cuts, tunnels, and a number of aqueducts. Wherever topography is favorable, free catchment is tapped and integrated in the system. There are distributaries to the canal for feeding different sub-areas. However, distributaries have the same discharge capacity as the canal. Therefore, only one distributary carries the full canal water at a time. There is a masonry

structure at the head of the distributary and diversion of water is controlled by putting wooden planks or earthen temporary bunds across the canal.

As there are yearly variations in water availability, the command is divided into permanent and temporary irrigated areas. Only in good rainfall years does the temporary area get water. Generally this area is at the tail end.

One aspect of the canal and distributary design is worth noting, viz., existence of a large canal capacity in relation to irrigation requirements. The capacity of the canal is practically constant from the weir down to, and including the distributaries. Thus, the capacity factor increases from head to tail. This design provides greater flexibility for operation at the field level.

The command area is divided into blocks (phads, from which the system takes its name), ranging from 4 to 30 ha. Whatever may be the ownership in a given block (and there are up to 70 landholders in the block), only one crop is grown in the given block. The rotation sequence of crops in the block is decided by the managing committee at the beginning of the season and is binding on the members. This design avoids differences in requirements of water application.

The sequence of irrigation in the block is from head to tail. In this sequence the efficiency of water application is relatively better. When the upper farm is irrigated, any excess flow reaches the farm below but before the irrigation in the upper farm is completed. There is also no need for fine adjustments of flows in the distributaries to avoid wastage of water in the channel. The only care needed is to divert the water from the outlet in advance of the flow reaching the last segment of the tail field so that the water in the "pipeline" is not wasted.

This type of sequence requires high social discipline, ensured by two organizational innovations. In this system, water application is not performed by the landowner; it is an exclusive prerogative of the waterman appointed by the committee. Second, no second watering is allowed until the last tail end plot is irrigated. This ensures that water scarcity in any season or year is equally distributed.

Maintenance

As the whole system is managed and operated by the farmer groups, annual maintenance has to be organized collectively. The weirs do not need much maintenance and repair. But the canals and distribution system have to be cleaned at the start of each irrigation season. Two months ahead of the irrigation season a general meeting is held where all the irrigators are informed of the maintenance and repair needs. Each irrigator has to provide a pair of bullocks and three men for one day. Those who cannot provide these have to bear equivalent monetary charges. The work consists of cutting the bushes and weeds, removing silt, and cleaning with bullock-drawn scrapers. Bed stones are provided in the canal and distribution system to indicate the levels beyond which silt and other debris are not to be removed. The farm watercourses are maintained by individual irrigators. In addition, individuals have to maintain the channel length between the upstream offtake and their own farms.

Management Aspects

For overall management and supervision of the system, a committee is elected by the assembly of irrigators to hold office for three years. The committee appoints irrigation staff (supervisors, watermen, and watchmen) every year, hears complaints from the irrigators and the staff, and is responsible for policy decisions on water allocation and maintenance. For a command of about 150 ha, there are 2 supervisors, 6 watermen, and 6 watchmen. Supervisors and watermen are responsible for flows in the canals and distributaries and water application in the field. Watchmen are responsible for crop protection, particularly in the harvest season. Generally, the staff is paid in kind by the irrigators. If the crop is a cash crop like sugarcane payment is made in cash. This method of payment does away with keeping accounts at the committee level, besides providing incentives to the staff for careful tending of the crops at different growth stages, as they get a share in kind. The share is fixed in terms of crop rows in the field or some percentage of the total produce.

Financial accounting is kept to a minimum as it is confined only to collection of fines in case of defaults.

Finally, two more organizational innovations aimed at resolving conflicts may be noted. The command is demarcated on the basis of average annual flows. It is only in good rainfall years that the temporary irrigation tract receives water. The farmers in this area know by October whether they will or will not get water and plan their crops accordingly. In low-rainfall years, average water flows are not available. To the extent this is predictable early in the season, the cropping plan and the area in the permanent irrigation tract are suitably adjusted in consultation with the irrigators. As most of the irrigators in a given system reside in one village, this type of consultation poses no difficulty. If the scarcity is noticed late in the season water is rationed by extending the irrigation interval.

Second, in most of these systems there is an idle length of the canal between the weir and the command. As this length sometimes passes near an upstream village, the villagers are likely to divert water for unauthorized use. Therefore, a convention is arrived at whereby a day or a half day in a week is allowed to the upstream village. This is a very practical solution for avoiding potential conflict.

In conclusion, it may be said that this 350-year-old farmer-managed irrigation system meets all the design criteria of equity and efficiency, considering the "state of the art" available then. That it has survived until now demonstrates the inherent strength of the organizational and technical design.

SAMVATSAR WATER DISTRIBUTION SOCIETY

With the advent of British rule in the 19th century the administration created large-scale irrigation facilities in the latter part of the 19th century, building large dams and reservoirs commanding over thousands of hectares in the arid areas of eastern parts of Maharashtra. These systems were

not only government-designed and -owned but were operated and managed by the bureaucracy right down to the farm level. The government agency fixes the crop pattern, decides water distribution frequencies and water allocation, maintains the physical system down to the farm gate, and deals directly with individual irrigators. Though not anarchical, the system as it developed was inequitable, water wasting, and prone to manipulations in the hands of influential irrigators and self-serving government employees, especially at the lower levels.

The state government prepared plans for the active involvement of the farmers in the large irrigation systems but most of these plans remained on paper. In isolated cases, some local farmers took the initiative to form small groups for water management. One such group was formed in the 1930s in Samvatsar village in Ahmednagar District.

Genesis

In 1912, a large dam was built in Nasik District on the Darna River, a tributary of the mighty Godavari River. The dam has a potential of irrigating 25,000 ha in Nasik and Ahmednagar districts. Samvatsar village is located on the tail-end distributary of the left bank of the Godavari canal. Though the dam is on the tributary, canals take off beyond the confluence and hence, the canals are named after the Godavari River.

The genesis of the Samvatsar Big Bagayatdar Cooperative Society, a water-management group, is rather interesting. On commissioning of the canals in 1912, it was found that there was no demand, as the local farmers did not have the necessary technical background or the financial ability to employ irrigated agriculture. A few Mali families (a progressive agricultural community) migrated to the area from the nearby Pune District and took lands on lease or by outright purchase for sugarcane cultivation. As the joint-stock sugar companies were in the vicinity marketing was not a problem. However, these companies also secured lands on long lease for sugarcane cultivation and executed agreements with the irrigation agency for supply of canal water on a volumetric basis. Due to state politics, the Malis were concerned that they might lose land to the companies. They were advised to form a cooperative society for obtaining water on a volumetric basis and then distribute to the members for sugarcane cultivation.

The society was formed in 1936, with 11 members (now 45) having an area of 160 ha, lying at the tail end of the canal. The society command is not continuous, as there are patches of land belonging to local farmers in between, who are denied membership. To date, only Malis are members. In this sense it is a closed group.

Agreement with the Irrigation Agency

An agreement was signed with the irrigation agency for water supplies. The terms and conditions are: 1) The agency shall supply water on a volumetric basis to a maximum area of 40 ha for sugarcane cultivation; other crops can be irrigated, and be assessed on a volumetric basis. 2) Water allocation is calculated at 280-centimeter (cm) depth for sugarcane, at the minor heads.

Measuring devices would be installed. 3) Water bills are to be paid by the society. 4) Rotation frequencies and timings would be fixed by the agency. The society shall indent for water for every rotation, 15 days in advance.

A managing committee elected by the members looks after the delivery and further distribution. The committee has appointed a secretary and gaugeman-cum-waterman.

Management of Water Distribution

Before the start of the season, the society invites water indents from the members. These are consolidated and sent to the irrigation agency. The agreed-upon quota is then proportionately divided by rotations and the agency informed accordingly. The discharge at each of the three supply points is six cubic meters per second (cusecs) and this is measured jointly. The society's waterman then controls this discharge and delivers water to the farm gates of the members by sectioning it among four to six outlets. Water application in the field is the responsibility of the members, with the help of the waterman. From experience it is found that one hectare can be irrigated in 3.75 hours with a flow of six cusecs. Within this time allocation, the depth in the field per rotation is quite high (18 cm) and water is wasted. It appears that the society has not paid much attention to field-irrigation efficiency.

Water management at the field level is a bit complex because of the plots within the command area owned by nonsociety members, and because of different water charges for sugarcane and other food crops. Though the agreement provides for volumetric charging, over the years convention has established that a volumetric rate is charged only for sugarcane whereas the grain crops are charged on a crop-area basis. This system is in the interest of the society, as the volumetric rate is higher than the crop-area rate in respect to grain crops because of the concessions given for raising food crops. When water is released in the minor channels the society's area is irrigated first and records of water deliveries are kept. The allocation of water between sugarcane and other crops is only judgmental and the agency accepts the version offered by the society.

The society has worked satisfactorily for the past 55 years and has declared dividends. Of late, however, some problems have arisen. The agency has not been in a position to supply the guaranteed allocation in view of the rising nonagricultural demand for dam water. Agricultural yields have been adversely affected. To overcome the water shortage, members have dug wells. The well waters are not managed nor monitored by the society and the society has no intention of integrating well waters with the variable canal flows.

Maintenance of the parts of the physical system is primarily the responsibility of the concerned members, with the society having a supervisory role. In view of the family relations among the members, this work is executed smoothly and no conflicts are reported. Further, the physical system is quite small compared to the phad system.

The technical design of the system was determined prior to the formation of the society. The group had to adapt its performance to the given design. Not enough attention has been given to build up slack in the form of en route or buffer storage. The need for this is urgent in view of the variable canal supplies and the fact that the command is situated at the tail end, which affects reliability adversely. There is also no provision in the design for conjunctive use of groundwater.

It appears that the society is now at the crossroads. It requires guidance on buffer storage, water-application methods, crop technology, and irrigation efficiency. Crop pattern may also need a drastic change in view of the shortage of canal waters. It also appears that by sectioning the command of major irrigation systems, it is possible to involve the farmers in water management. What is needed is a strong legal and technical framework. Discussions with the society members show that they would never abandon their group management as it has benefited them over the last 50 years. However, they expect assurance from the government agency of reliability and delivery of agreed-upon water supplies. Alternatively, they want to change the crop pattern stated in the agreement. There is no need for changing the organizational design as the group is coherent and compact. However, for achieving the wider goal of social integration and for operational efficiency, non-Mali irrigators should be included in the society.

DATTA COOPERATIVE WATER DISTRIBUTION SOCIETY

The third case does not refer to any established water group but to the attempts made so far to establish one by the farmers. The society became operational only from July 1989 and more experience has to be gained. This case is included here as it highlights the problems that have to be faced and resolved for establishing farmer management for large irrigation systems.

Physical System

In the late 1960s, the State Government built a major dam on the Mula River, another tributary of the Godavari, waters of which were to benefit 80,000 ha in 149 drought-prone villages. The service area was demarcated on the basis of a design pattern with only five percent of the area for perennial crops (mostly sugarcane), the rest being allocated to seasonal monsoon, winter, and hot-weather crops. The system became operational in 1972-73. Water management, distribution, and maintenance were entrusted to bureaucracy, as was the practice in government-owned systems. The system has not irrigated more than 40,000 ha in any year. In addition, the bureaucratic management was prone to several abuses, and in general, farmers were not happy.

In early 1986 the Center of Applied Systems Analysis in Development approached the farmers in the command of Mula Minor 7 with a suggestion that they form a water users' association for managing distribution in the command by taking deliveries at the minor head. The response from the farmers was enthusiastic but they wanted help in organizational design and for sorting out technical details with the irrigation agency which was not amenable to their entreaties.

Minor 7, with a discharge capacity of 450 liters per second, is located 40 km from the dam site and draws water directly from the main canal. The service area is fixed at 500 ha. The number of farmers is around 250. With a length of 2.2 km, Minor 7 feeds 13 outlets, each with a 30 liters/second discharge capacity. The physical system was designed according to government norms.

with no consultations with the farmers. The system is not well-maintained; management of distribution is with the agency and the agency deals directly with every irrigator. There is considerable dissatisfaction with the present management practices.

Organization

The farmers decided to form a cooperative water users' association. It took almost two years, as the concerned department created many obstacles. It was necessary to finalize a Memorandum of Understanding between the society and the irrigation agency, which is controlled by the government. It took two years to finalize the Memorandum of Understanding in which the agency allocated an annual quota of 1,775,000 cubic meters (m³) of water to the society to be distributed in the proportions of 31, 55, and 14 in the monsoon, winter, and summer seasons, respectively. The society would be charged specific rates based on volume delivered in each season, and all restrictions on crop pattern were removed. The irrigation agency agreed to carry over the unutilized quota from winter to hot weather under certain conditions. Finally, the society was given total responsibility for maintenance of the physical system, for which the government agreed to give an ad hoc grant.

Though these terms emerged after protracted discussions, the members felt a bit disappointed on the quantum of allocation. They expected that the allotted water would be in the same proportion to the society's service area as the ratio of water availability in the reservoir to the total service area of the project. In fact, the allocation was only two-thirds of the proportion.

Tasks for the Future

The tasks before the society now include designing an operational plan for water distribution among the members, upgrading and maintaining the physical system in the command, developing rules and sanctions for efficient water use, introducing innovative crop technology, and providing en route storage for canal-water supplies as well as integrating the canal water with groundwater supplies.

RECOMMENDATIONS

This brief description of three gravity irrigation systems leads to some affirmative conclusions for accelerating the process of establishing farmer management on small and large irrigation projects.

1. The water group must not be too large nor too small. The range should be 150 to 300 farmers with a command not exceeding 500/600 ha. In the major systems, the command should be sectioned on the basis of topography, hydrology, social cohesion, and harmony, with one or two delivery points.
2. There is a need for providing a legal, financial, and organizational framework defining the action arena and the roles of the government agency, the group/association, and individual members. Experience shows that the irrigators are willing to come together provided they feel that their interests are better served. The organizational design should be such that the group is close to the problems of each irrigator and is in a position to provide reliable, stable, and predictable service. It should be emphasized that water delivery is only part of the solution; the group also has to work for the introduction of crop technology.

The design of the physical system should be settled in consultation with the group and members. Where a system is already built, further modifications should be discussed with the farmers. Cost aspects need to be discussed and formulas for sharing costs determined.

3. Main system management should be held responsible for regular, agreed-upon supplies and penalties should be provided for nonperformance. Today, whatever agreements and memorandums of understanding that have been drafted are lopsided in the sense that penalties are provided only for the groups/farmers and not for the agency, for nonperformance of the tasks.
4. The crop pattern is controlled and regulated by the bureaucracy. Once water is allocated on a quota basis, groups should be left to decide their own cropping patterns. Maintenance should be left to the groups, as they can do it with less costs and on time.
5. If there is crop diversity, outlets need to be gated for efficient use. It would be inadvisable to fix standard-sized pipes, throttled to the authorized discharge. Gated outlets would provide for variable supply and flexibility.
6. Rules have to be formalized as to when, where, and in what amounts, water would be provided to the members. Rules should provide for equity and efficiency. Penalties should also be specified for noncompliance.
7. The agreement between the irrigation agency and the society should provide incentives, financial or otherwise, to create an environment for farmer participation.

SUMMARY

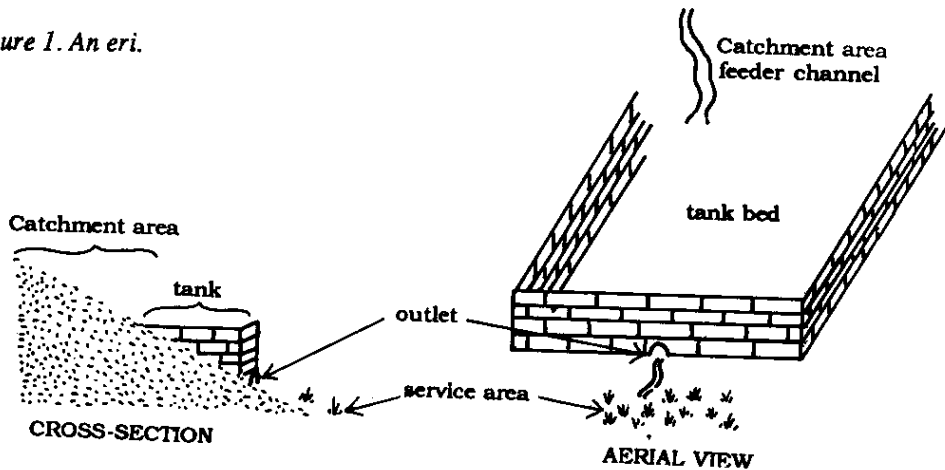
The environment in Maharashtra is favorable for large-scale experimentation with water users' associations. Some experience has been gathered. Careful attention needs to be given to organization and technical designs, and details have to be worked out in consultation with the farmers. In order to obtain the participation of the farmers in managing irrigation systems at various levels the government bureaucracy must also be reoriented to accept and encourage farmer management and ensure equity for water users.

Local Adaptations and Basic Designs: An Example from India

Nirmal Sengupta¹

THE INDIAN PENINSULA and its foreland are a very old eroded plateau with a gentle gradient. Throughout this area one finds a distinctive system of irrigation, called locally *ahar*, *eri*, or *keri*. These are three-sided runoff reservoirs providing water for gravity irrigation. In irrigation literature some of these have been named "tanks." However, this is misleading since these are very different from regular tanks (Figure 1). An eri basically consists of an embankment constructed above ground level across the line of drainage on sloping terrain. Two side embankments are then constructed along the line of drainage which lose their height because of the slope of the ground, finally merging with ground level. The fourth side is then left open for runoff to enter. Thus, the eri looks like a three-sided reservoir above ground. Water can be drawn out from the base of this reservoir and used for gravity irrigation of fields at lower levels.

Figure 1. An eri.

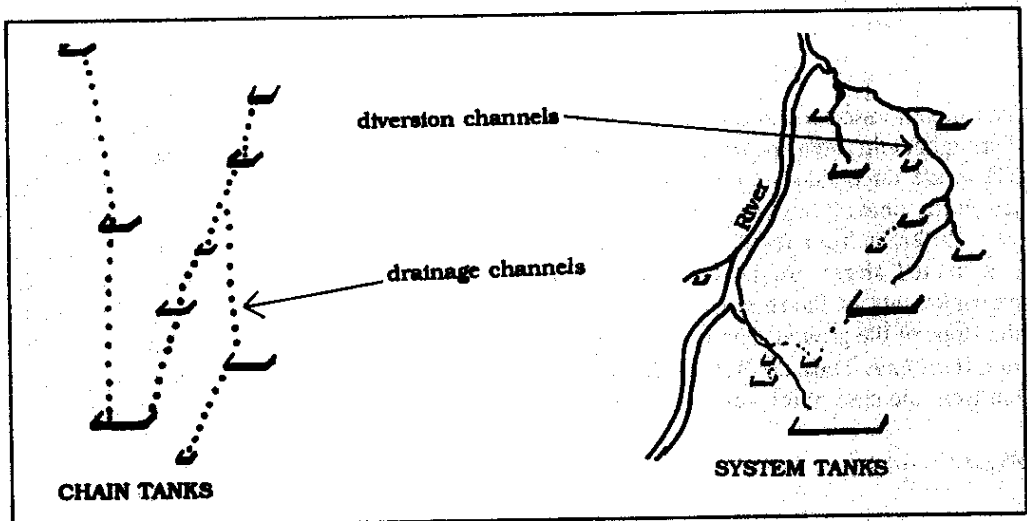


¹ Dr. Nirmal Sengupta is a Professor at the Madras Institute of Development Studies, Madras, India. He is thankful to Somsekhar Reddy, A.S. Kolarkar, I.Q. Khan; and Irchamni Suleiman from whose works he has collected much of the information on one or the other of the local systems.

Government reports indicate that there are still thousands of tanks in India which provide irrigation to about 4,000,000 hectares (ha) of land. However, the government statistics are incomplete since it is unknown how many ahars, eris, or keris may have been included or ignored in the count.

A tank with an independent catchment area is called an isolated tank. But the same catchment area may have another tank at a higher elevation which releases its surplus water as runoff that feeds the lower tank. This, in turn, may release its supply to another. Thus, a series of tanks located at different elevations may divide the whole runoff of a watershed among themselves. These are called chain tanks (Figure 2).

Figure 2. Chain tanks and system tanks.



If the runoff takes the shape of a river, that too can be diverted through canals for feeding tanks. In this way a large number of tanks may be supplied by diversion works on a single stream. These are called system tanks of that river (Figure 2). Chain tanks are generally found in the upper catchment area of watersheds. System tanks are confined to the middle lower plains of rivers. Tanks at steeper gradients are small. Those near the coast are usually larger.

A MAJOR FARMER-MANAGED IRRIGATION SYSTEM

A well-designed network of chain tanks and system tanks may utilize every bit of runoff flowing through a watershed above the deltaic plain. When appreciated from this perspective, the whole

design could be considered a major irrigation system. Indeed, these tank systems could be an effective alternative to modern multipurpose river-valley projects. Except for the fact that they require a high level of participation from the farmers, their potential as an alternative design for major irrigation projects would be easily acknowledged.

For example, a major multipurpose river-valley project may have a reservoir capacity of approximately one billion cubic meters. It can provide flood protection to about 10,000 square kilometers (km^2) and irrigation benefits to about 100,000 ha. The same effect may be obtained by a network of about 2,000 tanks, each irrigating an area between 15-200 ha. Indeed, the irrigation benefit from tanks would be greater since the total ponded area (about 1,000 km^2) would be dispersed over the whole region, and would provide indirect irrigation benefits through substantial recharging of the aquifer. In addition, farmers could also use the tank bed for cultivation in the dry season since the land retains moisture in the subsoil.

The tank-based design requires the construction and maintenance of nearly 4,000 km of embankment spread throughout the 10,000 km^2 area. This is simply not possible without the involvement of the farmers in the region. Instead, a single reservoir with a 20-km embankment and a central allocation mechanism is far more attractive to both technocrats and bureaucrats.

In India and Sri Lanka there are some districts where all runoff is appropriated in a network of tanks existing since pre-modern times. That other regions did not witness such development or that major rivers were not utilized for system tanks was due to the rudimentary nature of civil engineering knowledge of that time. For modern engineering it is possible to divert major rivers and arrange for interbasin transfer in conjunction with the farmer-managed design. Nevertheless, this is ignored and instead, farmer-managed irrigation systems are being replaced. Every year, thousands of hectares formerly served by these farmer-managed tank systems fall into disuse.

Topographic Adaptations of Chain and System Tanks

In this very old and extensively found type of farmer-managed irrigation systems wide variations in design are observed. A few are described below:

1. The design of the tank is modified to suit the terrain. It is a technique especially suitable to terrain with a gradient of 5:1000 to 1:1000. It is possible that the technique is viable only in arid and semiarid areas, as it is found today only in areas with average annual rainfall of 150-1,000 millimeters. The huge ponded areas may have undesirable effects in high rainfall regions while evaporation loss may have a more serious effect in drier areas.
2. On steeper slopes, tanks are kept small. Because of the high water pressure large tanks may be prone to crack. In areas with gentle gradient larger tanks are viable. Sometimes, tanks are constructed with a main embankment as long as 30 km.
3. Instead of having a rectangular shape tanks are also constructed semicircularly. This probably reduces the thrust of the water over a wider area.
4. In flood-prone loamy soil areas tanks are sometimes provided with embankments within the bed. These partition the tank bed and are provided with outlets to allow the flow of water from one section to another. If one wall collapses, the farmers rush to close the outlets before the other sections are emptied (Figure 3).

- Sometimes the feeder channels are first impounded in a chamber from which only the overflow reaches the main tank (Figure 4). This may be done to contain siltation. This design was usually found along the margins of arid areas. In general, the feeder channels are left without a scoured passage once they reach the margin of the tank bed.

Figure 3. Sectioned tank.

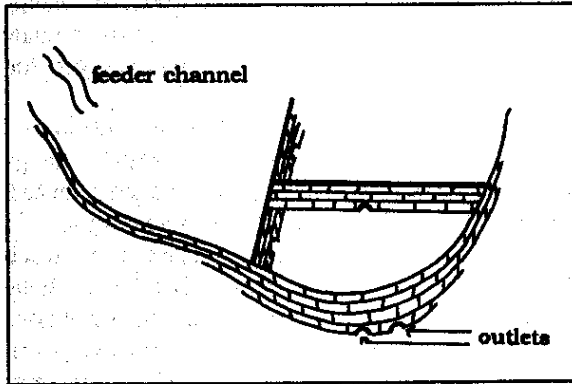
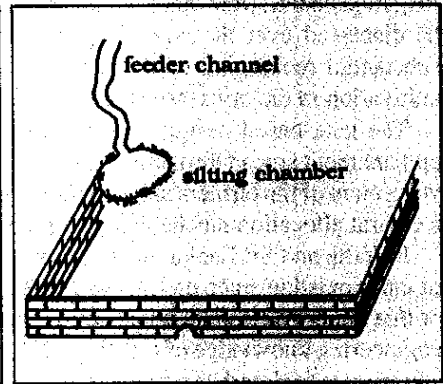


Figure 4. Tank with silting chamber.



- In arid regions, wells are often dug within the tank bed. These probably act as subsoil reservoirs whereby evaporation loss is reduced. Since tanks also provide drinking water in these areas retaining some water throughout the season is critical.
- In chain tanks and system tanks the ponded area can be increased by multiple impounding of the same volume of water. It is often found that certain tanks have capacities in excess of their direct service-area requirements. But the reservoir helps recharge groundwater which may be why multiple impounding is very common in drier areas.

AGRICULTURAL ADAPTATIONS SUITABLE FOR FARMER-MANAGED TANKS

The reliability of the water supply rather than the volume of water available is the more important factor which contributes to efficient water utilization. A captive reservoir where the volume of supply is visibly evident allows the water users' maximum flexibility in determining their options for water use. This allows the farmer to have a very high control over the available water supply. A number of agricultural adaptations utilizing the tank resources are described below.

- Because the captive reservoir enables the farmers to calculate how much water is available for use in the near future they can plan their agricultural and other requirements accordingly thereby reducing the risks of crop losses. In those areas where alternate flooding and drying

of rice fields is followed, a drying operation may be skipped if the water level in the tank is low. If the tank contains insufficient water for normal crop requirements, the farmer group may decide to irrigate only a part of each landholding. Alternatively, the farmers may decide to plant a grain requiring less water in a time of acute water shortage.

2. In most areas the government does not allow the farmers to cultivate on tank beds. However, this practice provides the farmers with an additional option in the few areas where it continues to exist. In times of acute water shortage the water-rich tank bed can be converted to rice fields and the service areas can be used for the cultivation of unirrigated crops. In normal years, in those areas where tank beds are still cultivated, the tanks are emptied after the monsoon season and winter cash crops are sown. During the monsoon season the farmers may also harvest a water-resistant variety of rice from the margins of the tank bed. These are reaped along with two irrigated crops in the service area, the first by direct irrigation from the tank and the second by groundwater irrigation.
3. In very dry areas, in a year of drought, the farmers may decide to use only water from shallow wells in their fields and not undertake gravity irrigation. The scanty supply in the tanks is left for the use of livestock.

In arid western India, in those parts where cultivation of tank (*khadin*) beds is still possible there are a number of examples of systems where the agricultural irrigation options described above are practiced. If rainfall is very high the service area outside the tank is irrigated by gravity flow. If rainfall is normal only percolation from the tank is used in the service area. When rainfall is far below normal the tank bed is used for cultivation. This array of options helps the farmers to adapt to a wide range of rainfall variation from year to year.

CONCLUSION

Tanks for irrigation and other purposes -- drinking water supply, water for livestock, flood control, fisheries, and control of soil erosion and salinity -- are a viable option for improved conservation and utilization of water resources. All these farmer-managed irrigation systems in a catchment area could be developed into spatially well-planned systems that should be regarded as potential major irrigation systems.

Rehabilitation of Village Tanks: Redesign or Consolidate?

C. Kariyawasam[§]

OVER THE PAST ten years the Government of Sri Lanka has invested several million US dollars to rehabilitate village tanks. A major component of the rehabilitation process was the redesign of the irrigation system, including headworks. It was observed that in most systems several social and economic problems cropped up in the villages after the rehabilitation. This paper discusses the problems and their causes and suggests that in the case of village tanks it is better to consolidate the existing systems rather than redesign them.

THE ROLE OF TANKS IN SRI LANKA

Because the dry zone of the country receives 75 percent of its annual rainfall during the months of November, December, and January, a large number of reservoirs were constructed in ancient times to store irrigation water. These reservoirs, most of which are over two thousand years old, are grouped into three categories: 1) Major reservoirs, with the command area exceeding 600 hectares (ha); 2) Medium reservoirs, with the command area between 600-80 ha; and 3) Minor reservoirs, with the command area less than 80 ha.

It is estimated that there are over 25,000 minor reservoirs in Sri Lanka. In certain areas the density of minor reservoirs is about one per square kilometer. They are commonly known as village tanks, and are a special feature of the ancient civilization of the country. At present, about 10,000 village tanks are in use and the others are abandoned. Land irrigated by village tanks

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produces about 25 percent of the rice requirement of the country. In addition, the tanks reduce land erosion and flood damage from major rivers during the wet months (Kariyawasam 1989).

HISTORICAL DEVELOPMENT OF VILLAGE TANKS

In ancient Sri Lanka each village had a temple, a tank, and a hamlet, and was an independent ecosystem. The tank-irrigated village consisted of three clearly demarcated areas: rice lands, the settlement area, and the fallow area. The tanks were constructed and owned by one or more families. The size of a village tank was determined by social factors rather than by hydrologic, economic, or technical factors. Initially, the villagers decided on the area that needed to be cultivated to meet the demand of the village. The capacity of the tank was defined by the volume of water required to irrigate this area. Then a reservoir was built by constructing a bund across a stream. Generally, these streams had no water during the dry season and construction work took place at this time. The tank bund was made of earth and the spill out of rubble masonry. A dead storage of about ten percent of the reservoir capacity was kept for domestic use during the dry season.

When the increase in population demanded that more land be brought under irrigation the capacity of the tank was increased by raising the bund and the spill. When the capacity was large, an additional sluice was installed at a higher level. This sluice irrigated the area above the normal rice area during years with above average rainfall. During normal years only the area under the lower sluice was cultivated. This process of raising the bund and the spill was carried out until either the limits of the hydrological capacity or the technical ability of the villagers was reached. The villagers had the technical knowledge to construct bunds up to six meters only.

When the population of the community increased further, supplementary tanks were constructed around the main village tank. These tanks were without settlements. Generally, these tanks were designed without any dead storage. The construction of these supplementary tanks and channels was planned so that the villagers' descendants could inherit them. Water-management policies were formulated and implemented by the community (Alwis 1989).

Even though these village-irrigation works were constructed by the villagers, the ancient kings recognized their importance in sustaining the economy and they made it compulsory for the people to operate and maintain the tanks.

VILLAGE TANK REHABILITATION PROGRAM

In the past ten years the Government of Sri Lanka has received financial and technical assistance from several national and international organizations to rehabilitate village irrigation systems.

The World Bank has been the largest donor, providing about US\$26,000,000 to rehabilitate about 1,200 village-irrigation works (an average of about US\$25,000 per tank) under the Village Irrigation Rehabilitation Project (VIRP).

Under the Integrated Rural Development Project (IRDP) another 1,000 village-irrigation works were rehabilitated. The funds for these projects came from different donors. The total allocation for the rehabilitation of village-irrigation works under the IRDP was US\$22,000,000. The Asian Development Bank rehabilitated 600 village tanks in the Anuradhapura District at a cost of US\$20,000,000. These figures indicate that the average cost of rehabilitating a village tank is US\$25,000-35,000.

Structure of Village Tanks

Village tanks are formed by constructing earth bunds across streams during the dry season. Low ground within the catchment is usually used as a spill. Some of these tanks had two sluices, one at each end of the bund, and rice fields were located close to the bund. When there is sufficient water in the catchment, these two sluices are located at the same level. When the water from the catchment is not sufficient to irrigate the entire command area, one sluice is located at a higher elevation than the other. The area under the higher sluice is irrigated only during the wet years, which is about once every four years. There are some reservoirs with three sluices. In one exceptional case there were five sluices to feed 80 ha. Out of these, two were placed above the others. Some reservoirs have one central sluice. In these systems the rice fields are located a distance from the reservoir and water is carried to the fields by long supply canals.

In most systems water from the sluice is directed to a supply canal. Pipe outlets in these supply canals feed the fields. In some instances several farms share one pipe outlet. There are some reservoirs without supply canals. In these systems water from the sluice goes directly to the first farm. Drainage water from the first farm is channeled to irrigate the second farm, and so on throughout the command area.

Rehabilitation Process

The major cost of the rehabilitation process is the civil construction work. This amounts to about 75 percent of the total cost of rehabilitation. The civil construction work begins with the redesign of the irrigation system and usually involves raising the bund, constructing a new spill or raising the existing spill, redesigning the canal system, and introducing a new water-management plan.

The Irrigation Department is responsible for the redesign and reconstruction of village tanks. The Department recruited several foreign and local consulting firms to redesign the systems. These firms made several changes to the structure of the village tanks which were the major cause for most of the problems that cropped up subsequently. The changes they instituted are discussed briefly below.

Replacement of local technology. Village tanks were originally constructed using low-level local technology. However, the redesign process employed imported technology. The engineers involved in the redesign attempted to incorporate all the features of large irrigation systems into the village tanks. Furthermore, the designers had little or no knowledge of the social and economic status of the village.

Water-management plan. Water-management plans in the old systems were based on social factors and not hydrologic or technical factors. In early times, the social status and caste of the farmer were the major factors that determined the water-management plan. The redesign process considered only technical and hydrological factors in preparing water-management plans.

Land allocation. In the ancient irrigation systems the allocation of land was based on the needs of the individual farmers. For example, a farmer with fewer dependents received less land. Similarly, the location of the land allotted to an individual depended upon his social status. For example, the village head would receive land located closer to the tank. In the redesign process land allocation was based purely on the topography of the command area. Furthermore, in certain old systems each farmer had three farm plots, one at the head, one in the middle, and one at the tail of the system. In this way, if only a part of the command area could be irrigated in any particular year, each farmer got a share of the water.

Cropping calendar. One of the major changes initiated by the redesign was the new cropping calendar. In village-tank systems cultivation is carried out only once a year, in the wet season. In some tanks where there is sufficient storage, a second crop is cultivated. The farmers usually waited until the tanks were full to commence planting. This reduced the risk of crop failure as a result of water shortage. If the tank was more than half full at the end of the season a second crop was planted with the expectation that there would be little rain.

In the redesign a three-crop year was recommended. This had been very successful at an experimental plot. Under this plan, land preparation commences with the first rain which normally occurs after a long dry period. Short-term rice varieties are grown. The first crop can be harvested at the end of the third month of the wet season and a second crop is planted immediately. When the second crop is harvested there is still some water in the tank. The third crop is planted immediately using tank water.

Problems Encountered

High engineering costs. The contracting of experienced consulting firms resulted in high engineering costs. Since most of the donors placed limits on the cost per hectare, farmers from small tank systems were at a disadvantage and several smaller tanks were not selected for rehabilitation.

Because the designers treated these schemes as miniature versions of large systems several new complicated structures were incorporated into the systems which escalated the construction costs.

In the case of tanks whose command areas are less than ten hectares the engineering cost was higher than the construction cost. In the case of large systems the engineering cost is generally about ten percent of the construction cost. This itself suggests that the level of expertise contracted exceeded actual requirements.

Conflicting technology and interests. The farmers, used to traditional technology for the management of water resources, were generally reluctant to accept the new technology.

The interests and objectives of the designers were different from those of the farmers. For example, hydrologists seek to make optimal use of the water, and the agronomist will design for maximum production per hectare. The irrigation engineer will try to irrigate as many hectares of command area as possible. However, the farmers' main objective is to make the maximum profit per hectare.

Water management. Under the rehabilitation, a pipe outlet was provided for each hectare. If the size of the farm is less than a hectare, which is true in most cases, two or more farmers had to share one pipe outlet. This reallocation of pipe outlet caused several problems. Traditionally, the ability of the farmers to cooperate was a major factor that was considered in allocating pipe outlets. In one instance there were two farms of about a half hectare each, side by side. Under the old system these farmers had two separate pipe outlets because they would not cooperate with each other -- their families had not spoken to each other for the past two generations. Under the rehabilitation program these two farmers were asked to share one outlet. This did not work. The first farmer diverted the excess water to the drainage canal instead of sending it to the next farm.

Land allocation. In reallocating land under the redesign the farmers were each given a hectare of land irrespective of what they had earlier. This created two types of problems. First, it disturbed the social structure of the village. Traditionally the amount of land allocated to an individual depended on need and the social status of the farmer.

The second problem is related to periods of water shortage. During these years only part of the command area can be irrigated. As a result, the farmers at the tail end do not get any water in dry years.

CONCLUSION

The previous discussion suggests that if one needs to redesign a village scheme a comprehensive social and economic study to understand the behavior of the farmers is needed in addition to the physical survey. However, such a study will be very expensive, and if attempted, will make every rehabilitation project economically unfeasible. As such, the next-best option available is to consolidate an existing scheme. In other words, it is preferable to strengthen the existing structures and organizational patterns, than to impose major changes.

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Farmer-Managed Irrigation Systems: A Case Study from India

M. Venkata Reddy⁵

INTRODUCTION

IN INDIA, AS in many other developing countries, farmers have built irrigation systems suitable to local needs and conditions, and have managed them successfully for generations. The designs, based on environmental considerations and technical solutions seem to be simple but have contributed effectively to the success of farmer-managed irrigation systems. In addition, the hydraulic designs and local dynamics associated with the socioeconomic conditions of the beneficiary groups have interacted for years to ensure the sustainability of the systems. Hence, a number of lessons can be learned from examining well-founded and time-tested farmer-built and -managed systems to incorporate measures for initiating new projects or rehabilitating old ones. With this objective in view, an attempt is made to present a case study of a farmer-managed irrigation system in an economically backward and frequently drought-prone district of Andhra Pradesh, India. The salient features of the system, the canal design, operation and maintenance procedures, irrigation organization, cropping pattern, and conflict-resolution methods are discussed.

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A PROFILE OF THE KUTALA MADUGU NALA IRRIGATION SYSTEM

The Kutala Madugu Nala (KMN) farmer-managed irrigation system is a centuries-old, spring-based system, located in the village of Nyamaddala in Anantapur District of Andhra Pradesh, India. The village is situated 5 kilometers (km) from the National Highway and has a total area of about 4,523 hectares (ha). According to the 1981 census there are 913 households with a total population of 4,479. Out of the total cultivated area of about 2,141 ha only 192 ha, or 9 percent, are irrigated.

The total number of beneficiaries is 23. Elders among the beneficiaries report that the system was originally built and managed by the farmers of a shepherd community and of a community of oil extractors. Over a period of time, ownership appears to have changed so that now the majority of the beneficiaries are weavers and traders. Only three members of the shepherd community are presently beneficiaries. About 80 percent of the present landowners are absentee landlords who rent their lands. The majority of the tenant cultivators are from the oil-extractor community.

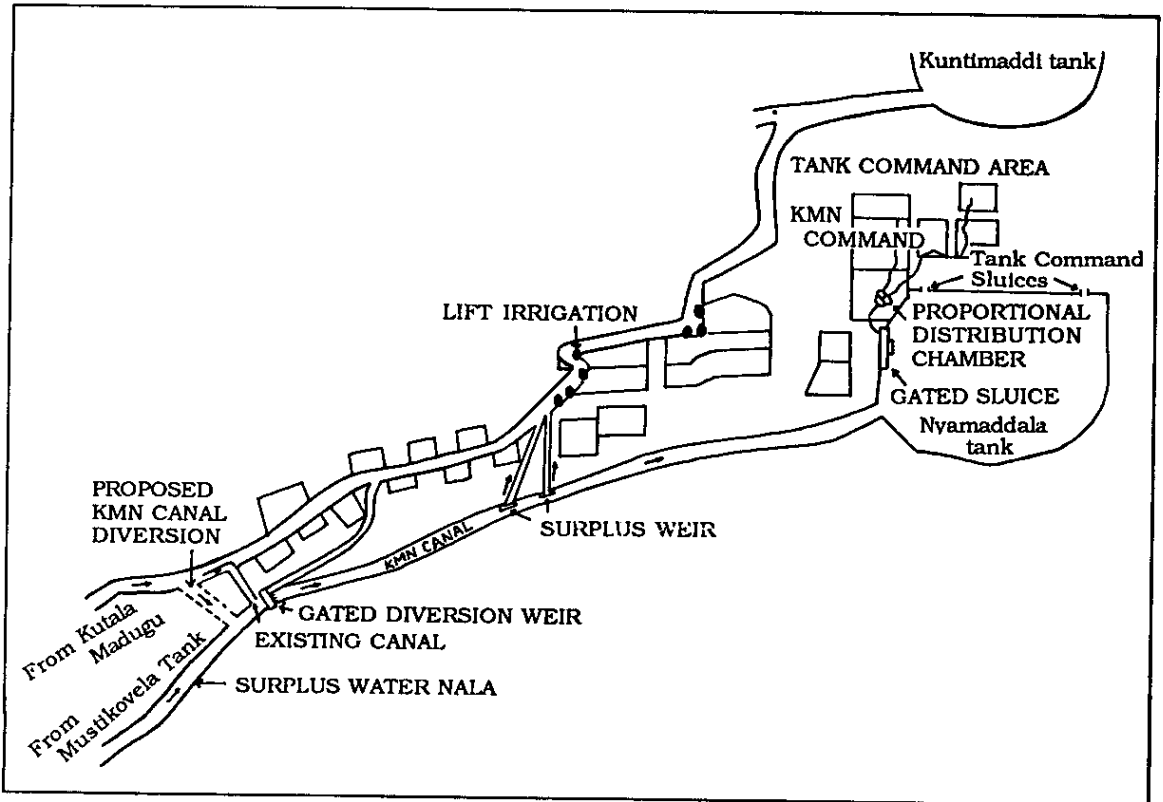
Physical Design of the Kutala Madugu Nala Irrigation System

The source of water for the Kutala Madugu Nala irrigation system is a natural spring from which a small stream called the Kuntimaddi Vanka originates. The stream cuts across the boundaries of three villages and a tank is built in the third village to harness the water. The Kutala Madugu Nala canal, which takes off from the stream is about eight kilometers in length from source to fields. The culturable command area¹ served by the canal is 13 ha, divided into 20 parcels of equal size, each 0.65ha (1.6 acres).

The design, execution, and operation of an irrigation system by the farmers tend to be simple and need-based, mostly free of complex hydraulic engineering technology. This is particularly true in the case of traditional and old systems like the Kutala Madugu Nala system. The system was designed for gravity flow. The alignment of the canal follows the natural ravine through which the stream runs for about five kilometers. By using the natural ravine, the cost of canal construction was greatly reduced. A separate canal which runs along the contour of the landform diverts water from the stream. It is connected to another stream across which a gated diversion weir is constructed (Figure 1). From the diversion weir the canal runs along the contour of the land through the embankment of the Nyamaddala tank and through a gated sluice in the tank to the command area. There are no control structures between the weir and sluice from where water is diverted to the system's command.

¹The net area irrigated by an irrigation system is the culturable command area.

Figure 1. Kutala Madugu Nala farmer-managed irrigation system (sketch).



The Kutala Madugu Nala sluice is a gated, masonry structure located at the surplus water weir of the tank. As the canal leaves the sluice it crosses the road and reaches the command boundary where it branches off into two field-irrigation channels. A proportionate dividing chamber made of wood is installed here. The water flow is directed through vents made in the wooden chamber to discharge water in proportion to the area irrigated by each field channel. There are no other irrigation structures on the farms. Maintenance of canal bunds and irrigation structures is the collective responsibility of all the beneficiaries.

An interesting feature of this irrigation system is that the spring-fed channel is linked with the village tank. Because the village is situated close to the tank bund and because of the topography of the area it is necessary for the canal to pass through the ponded area of the tank. When the tank is filled the canal becomes part of the tank. Thus, the Kutala Madugu Nala command area has two sources for irrigation water.

Although the canal is linked with the tank it maintains its water rights. The Kutala Madugu Nala command area has a separate gated sluice so that water can go either into the tank or water from the tank can be used for the command area. There are two other sluices in the tank which are controlled and operated by the government agency. These sluices are only opened when the water level in the tank reaches a certain level to insure a water supply to all farmers in the tank's

command area for a minimum time during a crop season. Individual farmers have no control over the operation of those sluices. However, the farmers of the Kutala Madugu Nala command area are not governed by the tank-irrigation rules. Their canal committee has the exclusive right to operate and maintain their sluice as they wish. This right was granted because the Kutala Madugu Nala command area does not necessarily depend upon irrigation from the tank but rather upon the water in the canal.

Although the Kutala Madugu Nala irrigation system's design is simple it is suitable for operational efficiency. The alignment of the canal along the natural ravine has facilitated a smooth flow of water as well as reduced construction costs. Because the canal runs in a ravine there is no possibility of the bunds being broken and water being stolen. The canal is vulnerable to breaches between the diversion point (brush dam) and the gated weir. In order to prevent canal breaching by the downstream farmers and cattle trampling, the farmers hope to realign the canal between the diversion point from the Kutala Madugu and the weir so that the canal will be tamper-proof from the source to the field.

Water Users' Organization

The Kutala Madugu Nala system has a well-knit organizational strategy to maintain and operate the system and its irrigators' association has legal recognition from the government. Rooted in caste factors related to the original formation of the system, the executive body of the organization has only two members. The headmen positions are held by the owners of certain specified parcels of land. For example, the parcel owned by the headman representing the original caste of oil extractors has been purchased by another farmer belonging to a different caste who has thus received the position as one of the headmen. At present the executive committee also includes a treasurer.

The farmers' organization is headed by the executive committee which resolves any dispute regarding operation and maintenance, and water use. The executive committee coordinates all operation and maintenance activities. General issues pertaining to canal repairs, cropping pattern, and sowing and harvesting dates are discussed in a meeting of the general body of irrigators which convenes when called by the executive committee. All beneficiaries are obligated to attend general meetings. If the head of a household is away someone else from his family must attend or a fine is levied against the absentee. All farmers who attend the meeting, irrespective of age or social status must wear a special head covering called a turban, or be fined.

Operation and Maintenance of the System

The Kutala Madugu Nala irrigation system has only six structures from the source to the field: one gated diversion weir, three road crossings where cross drainage is provided, a gated sluice, and a proportioning distribution box at the outlet. Except for the weir, all are of simple design. The weir was constructed by the government during the British colonial period after the original

farmer-built one was washed away. As there are only a few structures problems associated with main system management are less. Desilting and weed clearance are the major maintenance tasks performed by the farmers. As long as the tank is full the irrigators' association pays little attention to desilting and weed clearance. The problem becomes acute only after the monsoon, particularly when the tank becomes empty.

The association raises its own funds for system maintenance. All beneficiaries must contribute labor in proportion to their landholding size for desilting and canal repairs. Those who fail to contribute labor are fined. All cash expenditures for canal repairs are shared by the beneficiaries in proportion to landholding size. However, many landowners are not the actual cultivators. They lease their land on a share-cropping system. The tenant cultivators usually represent the landowners in all meetings and irrigation activities. If a tenant fails to comply with the rules and regulations of the association the owner is held responsible.

Operation of the system below the outlet point is the responsibility of the watermen. They are appointed by the association and are responsible for distributing water to all the parcels of land in the command area.

A peculiarity of the Kutala Madugu Nala irrigation system is that it has two sources of water supply by being linked to the village tank. The tank has three sluices of which one is exclusively for the irrigation system. Water release from the tank is regulated by the Public Works Department. Farmers from the same village using the same source of water are governed by two different sets of rules for water use, which sometimes leads to conflicts because the Kutala Madugu Nala command need not follow the government water-release schedule. The special rights of the system were once challenged by the other farmers in the tank-command area but the courts upheld the Kutala Madugu Nala system's special rights and allowed them to operate their sluice as they wished.

Cropping Pattern

The cropping pattern is decided by the irrigators' association at a meeting of all the beneficiaries. Water availability, crop rotation, and other issues are taken into consideration when deciding upon the cropping pattern. Once the crop pattern is decided all the farmers are required to follow it and are restricted to mono-crop cultivation. Sowing and harvesting dates are decided collectively by the farmers. These operations are staggered over a week to accommodate labor constraints.

Rice is the main crop. Crop intensity is usually 200 percent and may go up to 300 percent in some years. In contrast, the tank-command farmers are not assured of even one crop. The average yield of rough rice in the Kutala Madugu Nala command is about six tons per ha whereas in the adjacent tank command yield varies between 2 and 3 tons per ha. The assured, adequate, and timely supply of water for the Kutala Madugu Nala system makes sure of a higher yield. Because of the higher returns the demand to obtain land on lease in the command is quite high. However, there is a trend in recent years of reduced demand to lease land in the command area. Reasons for this are government land grants being given to the landless poor, and the cultivation of groundnuts under rain-fed conditions which has become more profitable than cultivation of irrigated crops.

If the water supply is insufficient, the area irrigated is reduced accordingly. Each farmer is allowed to cultivate only 50 percent of his usual area. In drought years the association may reduce the area under cultivation to save water for use by households and livestock. During years of water surplus water may be sold to the farmers in the tank command.

Conflict Resolution

The Kutala Madugu Nala executive committee resolves conflicts among the farmers. Water distribution below the outlet point is the exclusive concern of the waterman appointed for that purpose, and if some parcels are not irrigated properly, the waterman is held responsible. Farmers who are found guilty of stealing water are fined and if they do not comply with the rules they do not receive irrigation water and are also ostracized.

Social Contributions

The Kutala Madugu Nala irrigators' association performs a number of social services in the village. The first and most important of these is the provision of drinking water for livestock in times of drought. In addition, the association helps in arranging social, religious, and community functions in the village.

Physical Improvements for the Future

The Kutala Madugu Nala irrigation system maintains its uniqueness in the region. To date the basic management structure has not changed. However, the system needs minor changes in the design of the original canal, for which the farmers have sought help from the government. The alignment of the canal upstream of the existing weir needs to be changed. A small weir has to be constructed a few hundred meters upstream to connect the stream with the existing weir to prevent downstream farmers from breaking the canal bund and stealing water. Although the government did provide a grant to effect the change in alignment, the work was not accomplished by the contractor, and the irrigators are again organizing to seek government help.

The existing proportioning-distribution box made of wood needs to be replaced by a reinforced concrete or a stone structure.

CONCLUSION

Because it has two sources of water supply and special privileges for operating the sluice from the tank the Kutala Madugu Nala farmers are able to obtain higher cropping intensities and higher yields than the farmers in the adjacent tank-command area. The alignment of the canal along the contours of a ravine and a few and simple irrigation structures make operation and maintenance of the irrigation system relatively simple and free from intensive maintenance. Furthermore, a strong irrigators' association which has operated in essentially the same way for generations assures the beneficiaries of adequate and timely water supply and reduces conflicts.

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Towards Farmer-Managed Irrigation Water Distribution Systems in Nigeria

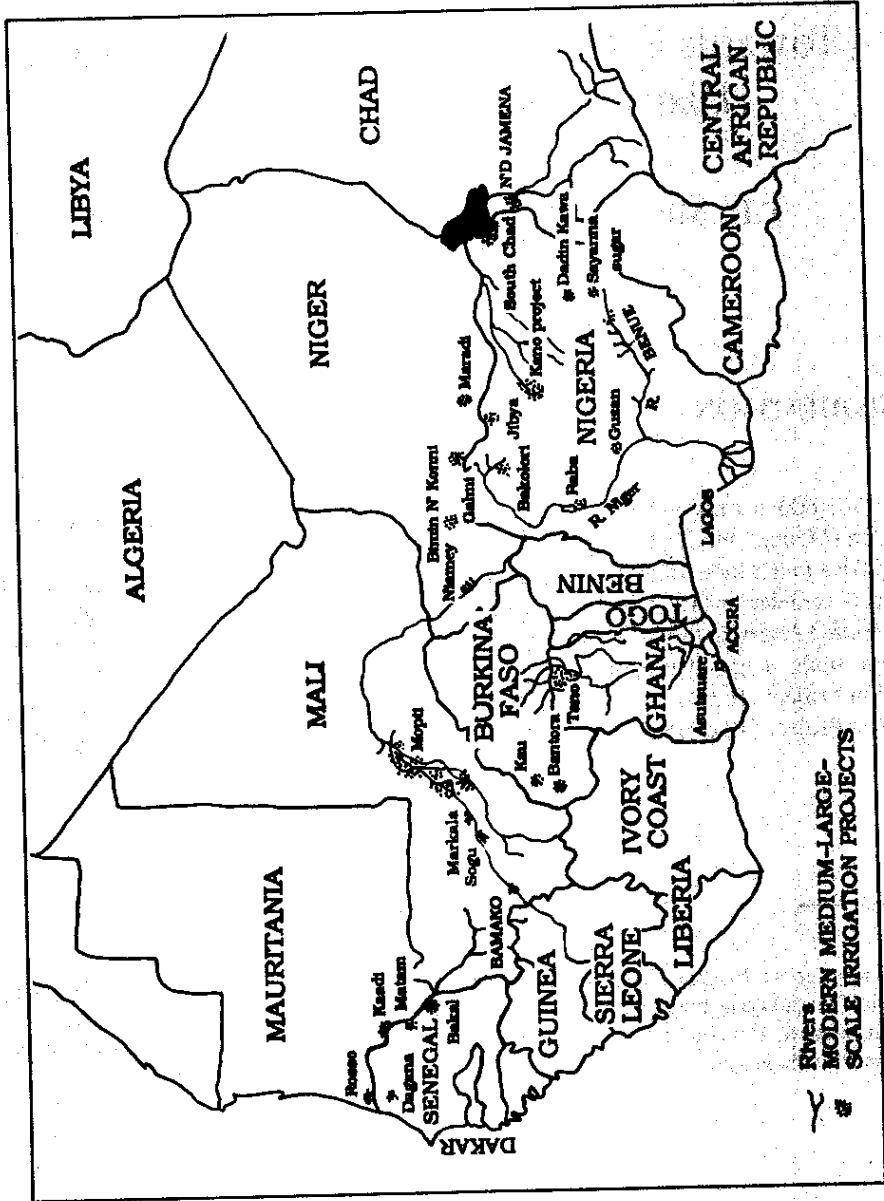
P.R. Maurya, A. Ahmed, and J.K. Adewumi¹

INTRODUCTION

ABOUT 101,600 HECTARES (ha) in Nigeria are under modern medium-scale and large-scale irrigation (Maurya and Sachan 1984). This accounts for around 20 percent of the total land in West Africa under modern irrigation (Figure 1). Of the total irrigated area in Nigeria more than 80 percent is under surface irrigation. Large-scale irrigation systems in Nigeria consist mainly of big dams and reservoirs and their associated canal networks along with necessary infrastructure for large-scale irrigated cropping systems. Three large irrigation projects, the Kano River Irrigation Project (16,600 ha), the Bakolori Irrigation Project (23,300 ha), and the South Chad Irrigation Project (12,000 ha) cover a total of 51,900 ha made up of small holdings of 0.5-6 ha each.

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Figure 1. Map of West Africa showing modern medium- and large-scale irrigation projects.



The entire water distribution system of these projects is presently managed by the River Basin and Rural Development Authority. However, the projects are plagued by enormous problems:

1. Unrealistic assumptions about the available water supply, inaccurate estimates of crop water requirements, and losses in transit and seepage have contributed significantly to over-estimation of the area that could be irrigated so that there is a shortage of water.
2. Poor water management resulted in soil erosion and waterlogging and salinity problems with resulting low soil productivity. The changes in the environment might have also affected the health of the people and their livestock (Maurya and Sachan 1985).
3. Lack of effective farmer organizations and poor coordination between the various agencies concerned with extension and operation and maintenance of the systems have resulted in low productivity, with average yields of 1-1.5 tons per ha for the irrigated wheat crop.

Most of these problems can be solved by increasing the efficiency of the irrigation water distribution network under small landholdings and increasing participation by the farmers.

OVERVIEW OF THE LARGE-SCALE IRRIGATION PROJECTS

The three large-scale irrigation projects are in semiarid zones in the northern part of Nigeria. These projects intended to irrigate about 300,000 ha. However, only about 52,000 ha are presently under irrigation.

Kano River Irrigation Project

The Kano River Irrigation Project is one of the major irrigation schemes in Nigeria, initiated in 1970 under the Hadejia-Jamaare River Basin and Rural Development Authority. This project is the country's pioneer project, with a development potential of 62,000 ha net irrigable land. Presently, 16,600 ha of irrigated land have been developed together with a 22-kilometer (km) main canal from Tiga dam which has a three billion cubic meter water-storage capacity.

Climatic data are given in Table 1. Soils of the project area belong to the Eutric Gambisol type (FAO/UNESCO system). Soils are moderately deep, well-drained, and of a sandy loam texture at the surface with sandy clay loam subsoil. A layer of iron-pan underlies most of these soils at depths between 80 and 150 centimeters.

Table 1. Meteorological data for Kano, Bakolori, and South Chad Irrigation Projects.

Month	Air mean temp. (°C)			Rainfall (mm)			Wind speed (km/day)			Pan evaporation (mm/day)	
	K	B	SC	K	B	SC	K	B	SC	K	B
Jan	23	25	22	0	0	0	198	131	167	8.3	8.8
Feb	21	28	24	0	0	0	181	198	135	9.1	10.7
Mar	27	27	28	0	12	0	140	178	200	8.1	9.7
Apr	28	31	32	7	0	0	131	120	182	8.7	10.0
May	32	30	32	138	21	15	219	179	176	8.6	9.4
June	28	30	30	148	13	23	226	195	176	9.4	9.2
July	26	28	30	246	156	186	163	142	151	5.5	4.0
Aug	26	28	26	173	267	225	128	184	108	5.5	6.3
Sept	26	27	27	103	192	186	119	168	90	6.9	6.0
Oct	24	30	28	0	0	22	119	164	104	6.7	7.0
Nov	25	27	25	0	0	0	133	101	153	7.5	7.0
Dec	21	23	23	0	0	0	165	154	153	7.9	8.0

Notes:

- K = Kano River Project
 B = Bakolori Irrigation Project
 SC = South Chad Irrigation Project
 temp. = temperature

Source: Institute for Agricultural Research irrigation cropping-scheme report. 1975-1986.

Bakolori Irrigation Project

The Bakolori Irrigation Project was executed in 1982 with an irrigation network (including a dam reservoir with a water-storage capacity of 420,000,000 cubic meters and a 30-km main canal) and infrastructural facilities for 14,500 ha under sprinklers and 8,800 ha under surface irrigation. The main canal, fed from the dam, is divided into secondary and tertiary canals which serve irrigation units of about 20 ha each. Each unit is divided into plots approximately one-half to one hectare in area, irrigated by field ditches. The water authority usually allows each farmer to irrigate 0.4-0.5 ha in the project area. All responsibilities for irrigation and management rest with the Sokoto River Basin and Rural Development Authority. There are a few farmers' cooperatives for social, cultural, and some limited farm input supplies.

Soils in the project area are sandy to sandy loam with low available water-holding capacity and high infiltration rates.

South Chad Irrigation Project

The South Chad Irrigation Project is located within the narrow climatic band situated between the deserts of the Sahara and the region of tropical wet savanna. The area is a relatively flat clay plain bound on the north by a wide sand ridge and in the east by a natural drainage channel (Macdonald and Partners 1973). The dominant soils in the project area are vertisols that absorb water very rapidly and swell, then shrink and crack widely when dry (Siewierski et al. 1982).

The total area proposed for irrigation development is 67,000 ha under surface irrigation. However, only about 12,000 ha have been developed. Water for this project is extracted from an inland lake via a 28-km dredged intake channel leading to the primary pump station at Kirinowa. The water level in the intake channel depends on the lake water level. The main canal of 23 km starts at Kirinowa with a raised water lift pump and delivers to the branch canals (Figure 2). The smallest basin for wheat or cotton is about 0.4 ha.

The system is designed for irrigation only during the day with night storage in the distributary canals. During the period of peak demand, irrigation can be completed in 12-15 hours. Rice, wheat, cotton, and vegetables are the major crops grown in this project. Check basins for rice, wheat, and vegetables, and borders for wheat and furrows for maize and vegetables are the common irrigation methods employed.

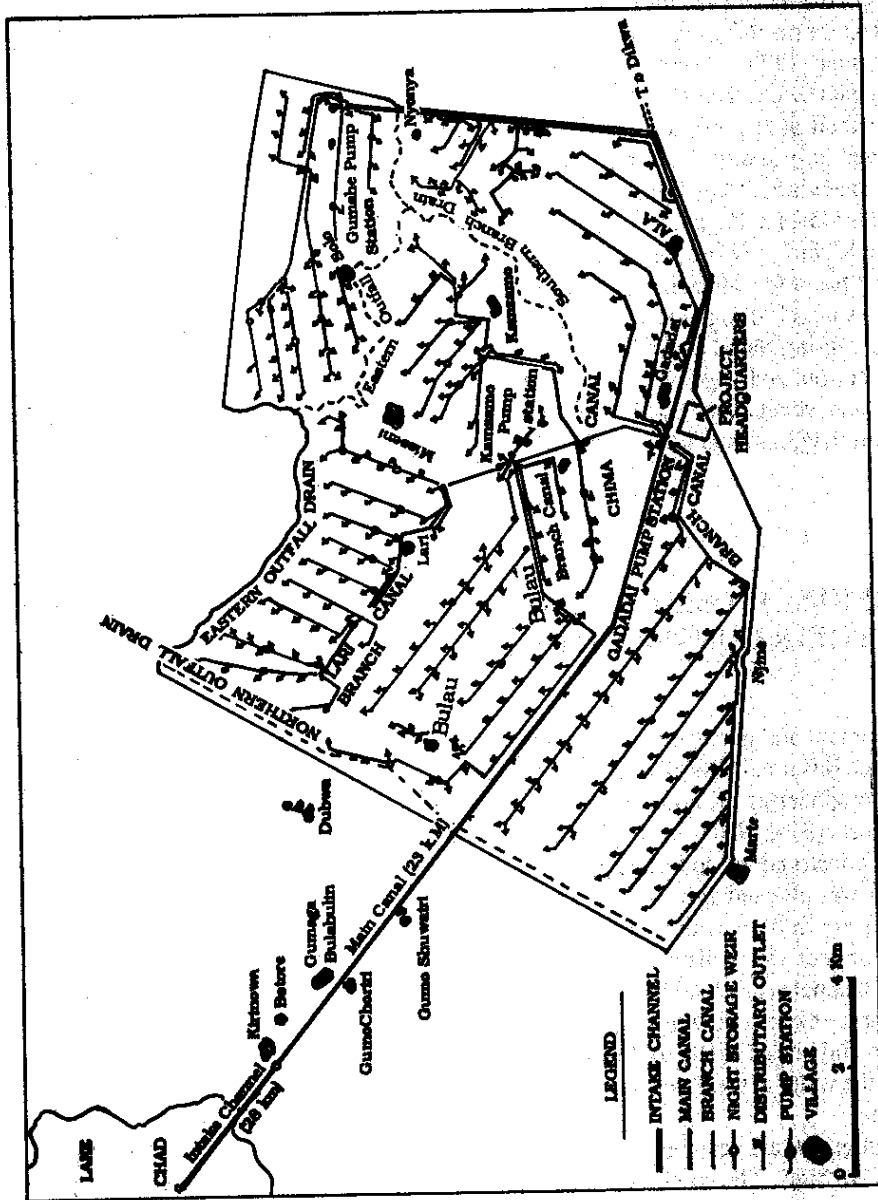
COMMONLY USED WATER-DISTRIBUTION NETWORK DESIGNS AND THEIR CONSTRAINTS

Development and management of large-scale formal irrigation schemes is the responsibility of the River Basin and Rural Development Authority. Project planning has been dominated by narrow engineering criteria and insufficient thought given to the social and economic effects of the projects (Bird 1984). In all of the large-scale projects input from the farmers regarding initial design, construction, and management has been nonexistent. The project water-distribution network was planned to be operated and managed by a highly skilled individual, forgetting that the users are farmers with small landholdings.

The project water-distribution network has been designed so that most of the field-water supply channels (blocks of 10-20 ha) end in drainage channels (Figure 2). Unfortunately, the small farmers cannot control the water released to a block so that 20-50 percent of the water at the head end goes directly to the drainage channel from the irrigation channel. However, at the tail end the water in the field channel is not enough to irrigate even half of the area it was designed to irrigate.

The channels are designed to carry less water than the capacity of the release gate. Losses due to spills are high. The combined conveyance, average application, and distribution efficiencies for border strips were as low as 26, 62, and 86 percent respectively in the Kadawa sector of the Kano River Irrigation Project where most of the conveyance systems are unlined. This gives a very low overall irrigation efficiency of about 14 percent (Adewumi et al. 1985).

Figure 2. Water distribution network of the South Chad irrigation project. (After Macdonald & Partners 1973).



In the Bakolori Irrigation Project, the water-distribution schedule was designed to irrigate fields in six-day cycles between 7 a.m. to 6 a.m. The surface-irrigation system was designed for a peak demand of one liter per second per ha in 24 hours. However, the farmers are very reluctant to irrigate their fields at night. An irrigation schedule of five-day cycles is better for their crops. The initial design of gross application of 65 mm water on a six-day cycle is insufficient for wheat cultivation in this region (Maurya and Kuzniar 1988).

The design of the water-distribution network for the South Chad irrigation project is based on a very long intake channel feeding the pump intake before the main canal. The water level in Lake Chad has receded drastically due to erratic weather in the last few years and the construction of dams upstream in neighboring countries. Hence, the long intake channel has dried up and the project is facing severe water shortages. No irrigation was possible in 1984.

The project areas have suffered from undependable and inadequate water recharge, especially in the Chad Basin project. It is believed that an unrealistic assumption of the available water resulted in overestimation of watershed yield and perhaps a change in the hydrologic system within the last two decades has contributed to the problems.

SUGGESTED IMPROVEMENTS

Although the projects were designed to be operated and managed by government-agency personnel financial cutbacks in the agency's funding have forced it to cease a number of services such as input delivery, maintenance of field channels, and operation of water distribution. As a result, the projects are near collapse.

Experiments were recently started in an action-research mode to look for ways to improve the water-distribution systems in the Kano River Irrigation Project. It was observed that the project could be handed over to the farmers for management provided the following modifications could be made in the water-distribution network of the Kano River Irrigation Project:

1. Presently, water is released to all sectors from 6 a.m. to 6 p.m., and farmers irrigate as they choose during this period every day. As a result, there are always only a few farmers in each block irrigating at the same time, and the released water is not fully utilized. About 40 percent of the water conveyed to the farms is lost to the drain unutilized. Therefore, it is suggested that water be released only to a particular sector or block on a schedule that will ensure more effective use of the water. Alternatively, the field channel or tertiary canal which serves each irrigation unit (especially at the head end of the system) should be connected at the end to the next irrigation channel (and not to the drain) so that excess water can be recaptured for use.
2. Good drainage water, especially channel runoff, should be reused. There are many areas where the drainage water can be diverted to a delivery channel downslope simply by means of an inverted siphon.
3. A water-measurement device should be installed at tertiary-canal inlets.
4. Water users' groups must be organized and trained for water management. The present study is ongoing. Several aspects of farmer-managed irrigation will be studied and a pilot project

for farmer management will be established. However, it is difficult to change the existing design of the Bakolori and South Chad Irrigation Projects where water shortage is a chronic problem. Also, the farmers in the Bakolori Irrigation Project live 5-10 km away from their fields, which makes it difficult for them to manage their irrigation.

CONCLUSIONS

The modern, large-scale surface irrigation projects in Nigeria were designed to be operated and managed by government technicians. Input and participation from the farmers were not considered during either the design or the construction of the projects. The projects are suffering from the common problems of low water-utilization efficiency and low productivity due to either faulty irrigation design or poor water management.

As a result of financial cutbacks, many government services to these irrigation projects are being curtailed and ways are being sought to have the farmers take over the operation and management of water distribution. Some improvements have been suggested for changes in the water-distribution network that will make it possible for the farmers to distribute and utilize the water more effectively. Water users' groups must be organized and the farmers trained to manage the water.

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Design Issues in Controlling Drought and Waterlogging/Salinity in Farmer-Managed Irrigation Systems on the North China Plain

Ren Hongzun¹

THE BASINS OF the Yellow, Huai, and Hai rivers in the North China Plain account for the greatest regional share of China's agricultural production. Encompassing 352,700 square kilometers, the North China Plain is the largest plain in China, making up about one-third of all of the nation's flatland. Its cultivated area of 18,265,000 hectares (ha) is one-sixth of the national total. Agricultural output from the Plain is significant. In 1983, total grain output was 70,770,000 tons, more than one-sixth of the national total, and cotton production was 2,686,000 tons, or more than half of all cotton produced in the country.

The North China Plain has a semi-humid monsoon climate, with drought and wind in the spring and early summer, followed by a hot, rainy season. Mean precipitation is about 500-1,000 millimeters (mm), decreasing from south to north, well below the potential average evaporation. Precipitation is seasonally concentrated and differences between precipitation and field-water consumption are below zero in most parts of the Plain. Rainfall meets only one-third of the total crop demand for water for winter wheat, which makes irrigation indispensable to agricultural production on the Plain.

The soil of the Plain is formed from the alluvium of the Yellow River. All the parent soil material is somewhat saline. With the Plain's flat topography, groundwater movement is almost entirely vertical. After the introduction of surface-water irrigation, an increase of groundwater recharge via canal and land seepage occurs. Thus, mean recharge becomes positive and the water table rises near to the surface in the absence of proper drainage. With an elevated groundwater table the soil's capillary action can carry saline groundwater into the cultivated layer where the salts remain after evaporation. Secondary salinization and waterlogging in the wet season can occur easily without an appropriate drainage system.

The state and farmers have made great efforts to increase agricultural production through irrigation on the North China Plain. There are 7,100 large, middle, and small reservoirs with a

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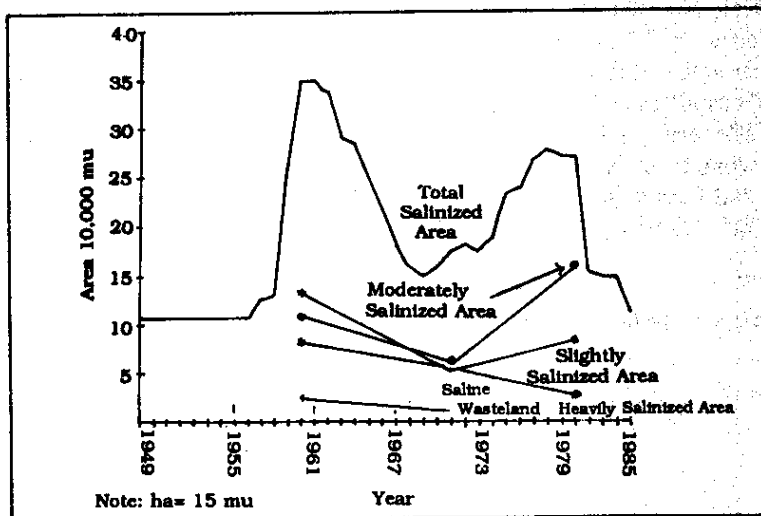
total storage capacity of about 52.5 cubic kilometers, controlling 50 percent of the natural recharge of the Yellow, Huai, and Hai rivers. One million four hundred thousand tube wells pump 60 percent of the groundwater recharge. In recent decades both surface and groundwater have been exploited on a significant scale. The total irrigated area in the North China Plain was roughly 10,000,000 ha, about 54 percent of the total cultivated area. Despite many efforts to use water effectively, agricultural production is still low. The average grain yield is only 3.23 tons per ha, which is 5-20 percent lower than the national average, and the low-yield area (less than 2.25 tons per ha) covered about one-third of the total cultivated area on the Plain in 1983. One of the primary reasons for the low yield in this area is that there is poor linkage between design, construction, and operation of water-conservancy facilities.

TRADE-OFF BETWEEN DROUGHT CONTROL AND WATERLOGGING/SALINITY IN THE NORTH CHINA PLAIN

Efforts to increase the agricultural production of the North China Plain must take into consideration the design and construction of facilities which can provide protection against both drought conditions (lack of water) and waterlogging/salinity problems (too much water/accumulation of salts). The history of the North China Plain reveals a gradual learning process about the design of facilities for water control.

Despite the installation of many brick wells and ponds there was little evident change in irrigated area between 1949 and 1955 because the principal task for agricultural production during these years was alleviating drought conditions. The groundwater table was kept lower than the critical depth, so groundwater evaporation was considerably lower. Figure 1 shows the fluctuations in salinized area in Yucheng County between 1949 and 1985.

Figure 1. Salinized area in Yucheng County.



Generally speaking, drainage presents a major problem on the North China Plain. At the beginning of the 1950s there were no drainage ditches or culverts, and the rivers were choked with weeds, seriously impeding drainage. The Plain was under the continual threat of waterlogging. In large floods such as in 1937, over 60,000 ha (90 percent of the usable land) were submerged in Yucheng County. The drainage situation was aggravated in 1958 when the North China Plain began to divert and store irrigation water from the Huang He. The people soon found themselves faced with a rise in the water table. After the heavy flood of 1961 neither the surface water nor the groundwater could be drained promptly, causing severe waterlogging and secondary salinization of the soil. The saline area of Yucheng County increased from 8,000 to 23,000 ha, and virtually all of the grain crop was lost.

Thereafter, the people refocused their attention on the design of drainage works, especially for surface drainage although in so doing they not only failed to complete their original irrigation systems, but even destroyed some of the existing facilities. The consequences of this strategy were brought home with a major drought in 1968 when both the rivers and the wells dried up and there was no water for irrigation. Grain output again collapsed.

It was realized that a more balanced approach to controlling drought and waterlogging/salinization was needed. First, attention was given to designing and implementing a system which could handle both irrigation and drainage. Beginning in 1972 there was a rapid increase in irrigated area. However, the saline area also increased slowly between 1972 and 1975. After 1975 the people began to neglect the facilities used to prevent increased salinity. Some of the drainage canals were again allowed to fill with silt deposits, reducing the drainage capacity of the original design and bringing about a sharp increase in the saline area between 1976 and 1981. A net decline in saline farmland during the 1980s is primarily the result of a succession of dry years, and coexists with large salinity increases in some areas. Obviously, continued and increased use of interbasin surface water or successive years of heavy precipitation can reverse the county-wide trend. Monitoring of soil salinity and groundwater level, and the management of groundwater level are critical to sustain increased agricultural production.

DESIGN INNOVATIONS IN FARMER-MANAGED SYSTEMS⁴ TO CONTROL DROUGHT AND WATERLOGGING/SALINITY

The realization that irrigation design needed comprehensive facilities for combatting drought, waterlogging, and salinity evolved gradually. An experimental district with an area of 130 square

⁴[Note: Mr. Ren Hongzun has used a different definition for farmer-managed irrigation systems from that used by other authors in this publication and at the International Workshop on Design Issues in Farmer-Managed Irrigation Systems. His use of the term farmer-managed irrigation systems in this paper actually refers to farmer participation in operation and maintenance of jointly managed irrigation systems. Workshop organizers.]

km, including 9,270 ha of farmland was established in Yucheng County in 1966. Inasmuch as 7,300 ha, or 80 percent of the farmland was subject to varying levels of salinity, and 87 percent of the farmland was under irrigation. The main purpose of establishing the experimental district was to explore ways of controlling drought, waterlogging, and salinity in the North China Plain.

The Yucheng Experimental District

The Yucheng Experimental District is surrounded on all sides by rivers: the Tuhai on the north, the Old Zhaoniui to the east, the New Zhaoniui to the west, and the New Shentun to the south. The Nanying storage gate was built on the Tuhai River north of the district. The Panzhuang main canal transporting water from the Huang He passes through the western part of the district. Based on the topographic situations, the district can be divided into three areas: 1) higher land with better drainage conditions, 2) depressions with poor drainage, and 3) higher land with poor drainage.

Components of Comprehensive Water Control

Comprehensive water control is a combination of design innovations for irrigation to alleviate drought conditions and for drainage systems to control waterlogging and salinity. Efforts to achieve an effective system for water control in the experimental district included the following components:

- 1) design and implementation of a drainage and irrigation system,
- 2) establishment of a network of wells to tap groundwater resources, and
- 3) consideration of agronomic and forestry factors.

Setting up a drainage and irrigation system. A six-level canal system was set up in 1972 using the Tuhai River as the principal natural channel. The Tuhai was widened from 30 meters (m) to 300 m, deepened from 3 m to 5 m, and straightened to carry a flow of 614 cubic meters per second. Three other natural channels, the Wei, the Chaoniui, and the Tuma rivers, are 4-5 m deep. The 14 branch canals are 3-3.5 m deep and about 2,000 m apart. The 80 subbranch canals are 2.5-3 m deep and 500-1,000 m apart. The 206 farm ditches are 1.5-2.5 m deep and 500 m apart. In addition, there are 3,660 field ditches with a depth of 1-1.5 m each, 100 m apart.

The system has two roles. First, in the flood season, it drains the surface water and some of the saline groundwater to help maintain a low groundwater level. This allows rainfall to infiltrate deeper into the soil and strengthen the role of precipitation in leaching out salts. Second, at other times, excess water from the Yellow River diversions can be stored for later use. The main channel stores water for half a year or more and the branch ditches hold water for two months or more. The objective is to keep the groundwater level below the critical depth where salts may be carried into the cultivated layer of soil. Experimental data estimate the critical level to be about 2 m for the fine sand soil in Yucheng County. Hence, when storing water in the canal, it is necessary to limit the tributary level on the gate to no less than 2.5 m from the surface. The storage

capacity of the system is about 20,000,000 cubic meters (m^3). Water can be stored three times a year, providing a total storage capacity of about 67,000,000 m^3 including a capacity of 7,000,000 m^3 in 2,935 ponds scattered throughout the area.

Establishing a network of wells. There are abundant groundwater resources in the experimental district which can provide good quality water. The waterbearing strata consist principally of fine or medium sand and silt. The average depth of the groundwater level is about 0-0.5 m in depressions along the slopes. A network of 1,050 pump wells 50-100 m deep was established in the experimental district. The mean yield of each well is 60-80 cubic meters per hour. The network of wells functions as a water supply and lowers the groundwater table, decreasing the evaporation of salts at the surface.

Other agronomic and forestry measures. Hydraulic measures must combine agronomic and forestry measures as supplemental methods to control drought and waterlogging/salinity problems. Leveling of cultivated land has increased the efficiency of water application and leaching of salts. Improving soil fertility has changed the soil structure, increasing its porosity and moisture storage capacity to facilitate the downward movement of water and salts. Setting up a field-tree network has helped raise the relative humidity and lower average daily temperatures. The tree root systems also aid drainage and help reduce the water table.

Effects of the Water-Control Innovations in the Experimental District

Positive effects of the design and construction of the canal system in the experimental district for the control of water scarcity, excess water, and salts have already been observed. Farmers have had abundant water for irrigation. Waterlogging can be controlled when daily rainfall remains less than 200 mm. The groundwater table has been lowered to 2.5 m or more in depressions, and the salinity area has decreased from 7,333 ha in 1949 to 2,133 ha in 1984. Despite an increase in 1975-77 in the saline area, fluctuations have been less in this zone. Soil salinity was reduced from 0.19 percent to 0.12 percent. Grain yield increased from 1.6 tons per ha in 1975 to three tons per ha in 1979. Currently, yields are more than 7.5 tons per ha.

The total investment in the experimental district was about US\$3,210,000 from 1966-79, including US\$2,140,000 from state funds and US\$1,070,000 of collective investment. Average cost per ha was US\$344 of which US\$315 was invested in digging canals and wells. According to an estimate made by the Chinese Academy of Agricultural Sciences, the average return on this investment in terms of income from increased production of grain and cotton is US\$350,000 per year calculated on the basis of a production comparison at 1980 prices between the 1976-80 period and the pre-improvement period. The comprehensive measures implemented in the experimental district are an example of a successful investment experience in transforming low-productivity land.

INTERACTION OF DESIGN AND MANAGEMENT OF THE SYSTEM

In the past, China's irrigation projects have emphasized construction of physical facilities and neglected the water-management aspect. Many problems arose in water use and distribution resulting in underutilization of the capacity of the irrigation system. In order to improve the linkage between the design of the physical facility and the management of the water for more efficient, extensive use, the Production Responsibility System was introduced. Here, the basic technique used to improve water management is the manipulation of economic incentives. It is envisioned that in the future the state may give the responsibility for maintaining and renewing water projects to the local water-management organization to run as a business that can recoup its own costs. However, at present, the state continues to provide some financial assistance.

There are three fundamental parts of economic reform in water management: 1) Individual income should be related to individual work performance rather than to communal obligations and consumption. This is known as Post-Responsibility. 2) Economic contract responsibility or the management of water resources as a business, transfers the sole responsibility for profits and losses to the managers. 3) Development of a diversified economy to increase income is the third aspect of economic reform related to water management.

Instituting Post-Responsibility

The purpose of the concept of having the individual's income related to his work performance is to institute a sense of responsibility for good job performance. Each staff member and worker is responsible for carrying out the clearly specified duties of his or her position. At fixed intervals performance is evaluated and he or she given differentiated compensation based on economic criteria. For example, the water-management office of the Wei Shan Irrigation District located north of the Yellow River in Liaocheng Prefecture of Shangdong Province distributes water based on the area irrigated or the volume of water used and gives the lower reaches priority in water use to ensure equitable water distribution. Water-measurement stations were set up and people assigned to measure the amount of water used. The income of the staff is related to the area irrigated and collection of the water fee. Some people were assigned to improve or build 300 delivery and diversion aqueducts. Their income and rewards were based upon the degree to which they completed the assignment. Also, households or individual farmers were given contracts to maintain banks, trees, and small structures for ten years. Seventy percent of the total income from the sale of the trees and other agricultural products belonging to the households or individuals is kept by the individual. Thirty percent of the income is given to the water-management organization.

Through the implementation of the post-responsibility system the following benefits resulted:

1. The gross irrigation requirement has decreased from 2,250-2,550 m³/ha/time to 1,800-2,100 m³/ha/time in the irrigation district. The effective rate of water use was increased from 0.35 in 1984 to 0.4-0.5 in 1986.

2. Uneven spatial distribution was improved because diversion of water in the upper reaches was carefully controlled so that there was sufficient water to convey to the lower reaches.
3. More efficient use of existing water resources led to an increase in the area irrigated. The increase in the average total volume of water diverted was only 89,000,000 m³ while the area irrigated increased by 53,000 ha during 1984-86.
4. The previous system had led to a relatively egalitarian income distribution contributing to a low level of staff incentive and the need for an annual government subsidy. In recent years individual income related to individual work performance has initiated high economic payoffs.

Economic Contract Responsibility System and Development of a Diversified Economy

The economic contract responsibility system refers to the concept that water management should be more like business management. Management should assume the sole responsibility for profits and losses. For example, the Tuhai River Management Section of Yucheng County received only US\$550 from the Water Conservancy Bureau since 1981. The example of the Tuhai River Management Section also demonstrates that the development of diversified enterprises as parts of water management helps to improve the economic efficiency of projects. It manages various enterprises such as a department store, a restaurant, and a pressing oil plant, and collects a water fee as well to pay operating costs. If its income exceeds the development/production funds quota, 40 percent of the extra income is given to the Water Conservancy Bureau, 40 percent is used for developing production funds, and 20 percent goes to the staff as rewards.

CONCLUSIONS

The North China Plain is subject to very uneven year-to-year precipitation. Rivers, diversion canals from the Yellow River, and a massive complex of underground aquifers are capable of providing water of greatly varying quality. This complicates the design of water projects. The history of the North China Plain reveals a gradual learning process about water-control design resulting in the development of comprehensive control works for combating drought, salinity, and waterlogging in the experimental district in Yucheng County. At the same time, economic reforms which encourage individual income being related to individual performance, management being responsible for the profits and losses of water-management enterprises, and which have encouraged economic diversification, have extended to the management of water resources. These reforms have increased the sense of responsibility of management units and their personnel so that water management and economic efficiency of projects have improved.

Country Papers

Introduction

PARTICIPANTS FROM TEN COUNTRIES prepared short overview papers to identify the extent and importance of farmer-managed systems in their countries. A short summary of the papers is presented in the following sections. Professor E. Walter Coward, Jr. gave an overview of the country papers. The following points are drawn from his presentation.

There is very little data collected specifically regarding farmer-managed irrigation systems (FMIS). This suggests that the formal irrigation sector has not caught up with the concept of identifying systems according to who manages the irrigation property. Nevertheless, farmer-managed irrigation systems exist in a very wide range of settings: in rich and poor countries; in newly industrialized countries; in various political and economic systems; and in wet and arid zones. Governments have diverse policies regarding these systems but the trend in recent years is becoming "FMIS friendly." However, government policies are not all working smoothly.

In many cases, governments are beginning to recognize the contribution these systems make to national food production and employment goals and policies and are seeking to strengthen them. Governments are beginning to see farmer systems as dynamic and adaptive and are increasingly taking the approach that farmers will be responsible for all operation and maintenance of new small-scale irrigation. There is a trend to turn agency-managed systems over to be managed entirely by the farmers and in some cases, large systems are being divided into smaller groups for easier management by farmers.

The country overview papers show that farmer-managed irrigation systems are a dynamic, widespread, policy-relevant part of the irrigation sector in many countries and design issues for farmer-managed irrigation systems are very relevant to what national-policy makers are interested in today.

Village Irrigation Systems in Sri Lanka: An Overview

Jayantha Perera[§]

THERE ARE THREE types of irrigations systems in Sri Lanka: minor or village, medium, and major irrigation systems. This overview focuses only on minor or village irrigation systems, where farmer participation in management is an objective.

The Agrarian Services Act of 1979 defines a village (minor) irrigation system as an irrigation work serving up to 80 hectares (ha) of agricultural land. In Sri Lanka, farmer-managed irrigation systems do not exist because the State has penetrated the village communities during the past hundred years and established its control over village property, particularly over irrigation sources. In recent years, both the State and nongovernmental organizations have intervened in the rehabilitation of village irrigation systems. All programs have emphasized the participation of the water users in rehabilitation, operation, and maintenance activities at the field-channel level.

Village irrigation systems account for about 50 percent of the 450,000 ha under irrigation, cover 35 percent of the land in rice production, and contribute 24 percent of the total rice production in Sri Lanka. According to an inventory conducted in 1986 by the Department of Agrarian Services, the country has 9,796 anicuts (weirs) and 9,294 reservoirs (tanks) in working order. Under these systems, it is possible to cultivate about 235,000 ha.

It is estimated that about 50,000 ha of new land can be irrigated by refurbishing existing village irrigation systems. This means that 50,000 to 75,000 farm households can be provided with adequate irrigation facilities without resettling them. Such a program is cost-effective, as the average cost of village irrigation rehabilitation is estimated at US\$350 per ha, which is only about 20 percent of the cost of developing a hectare under a major irrigation system, for example, the Mahaweli Development Project.

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Village irrigation systems play an important role in the Sri Lankan economy and society. However, low yields and minute holdings, which characterize irrigated lands under village irrigation systems, pose policy and welfare questions. Ninety percent of landholdings under village irrigation systems are below 0.4 ha each. There is an urgent need to rehabilitate these systems and introduce land or tenure reforms. Sri Lanka has very little land to open new farmholdings in the future. Therefore, the State has evolved a strategy to intensify and diversify agricultural production on existing cultivated land.

VILLAGE IRRIGATION REHABILITATION PROGRAMS

Although there are several agencies to deal with village irrigation, all of them follow Irrigation Department procedures. The Department of Agrarian Services which is responsible for repairs in village irrigation systems consults with the Irrigation Department when technical expertise is needed. Nongovernmental organizations obtain approval from the Irrigation Department and the Department of Agrarian Services to rehabilitate village systems; their general performance and progress are monitored by these two government departments.

Process of Rehabilitation of Village Irrigation Systems

Village irrigation systems are selected for rehabilitation from a list maintained by irrigation officials at regional and divisional levels. Practically all village rehabilitation projects specify that highest priority be given to those systems that would yield maximum returns with minimum investment. The cost for a project including all civil works and physical contingencies should not exceed US\$775 per ha, plus US\$1,500 per ha for the incremental area that will be served.

When a system is selected, first a preliminary feasibility investigation is conducted followed by a pre-construction survey by a technical assistant from the Irrigation Department. The farmers are usually not consulted during the preliminary investigation stages. At the ratification meeting held before the commencement of construction work the villagers can discuss the proposals with agency officials.

Recently, the Department of Agrarian Services has formed Agricultural Planning Teams to seek suggestions from the beneficiaries on how physical implementation could best be accomplished. Having the Team work with the beneficiaries early in the rehabilitation exercise has helped the construction agency in designing and planning the rehabilitation program and in coordinating proposed water-management programs with the physical improvements. In conjunction with the Team, a cultivation officer is responsible for implementing the water-management program in his area. He organizes farmer groups and assists the group leaders. The irrigation headman, elected by the farmers, operates the sluice and supervises water delivery. Water rotation schedules are prepared by the local Agricultural Planning Team.

CONCLUSION

The State agencies and nongovernmental organizations involved in rehabilitating village irrigation systems have consistently reiterated the importance and the need for having the beneficiaries manage the systems. However, recent experience shows that officials often fail to consult farmers in the rehabilitation process. Very little research has been conducted to understand the main characteristics of communities, and bureaucratic interventions have sometimes had negative impacts on sustaining effective management systems. It is urgently necessary to reformulate the intervention strategies to allow farmers to develop local capacity in management.

Crop-Share Payment System in Farmer-Managed Irrigation Projects in the Tangail District of Bangladesh

M.T.H. Miah[†]

ALMOST ALL CULTIVABLE land (8.9 million hectares [ha]) in Bangladesh is now under crop cultivation and there is little scope for bringing new land under crop production (BADC 1981). In addition, the amount of cultivable land is gradually decreasing because of other infrastructural and industrial-development activities. The only feasible way to increase agricultural production is to increase intensive cultivation and assure the efficient and judicious use of scarce resources. As part of the effort to increase agricultural productivity farmer-managed minor irrigation projects such as deep tube wells and shallow tube wells have been introduced in Bangladesh. The main advantage of these projects is that they are less capital-intensive, are feasible for small landholdings, and are capable of increasing production more quickly than in large-scale irrigation projects (Biswas 1985; Miah 1987).

In Bangladesh a farmer can acquire a deep tube well by renting one from the Bangladesh Agricultural Development Corporation for a fixed yearly charge, or buy one from the government or a nongovernment organization. Criteria were defined by the Corporation for approval of the acquisition of a tube well which included conditions regarding the minimum amount of land to be irrigated and the minimum distance required between tube wells.

To obtain a picture of the status of tube-well irrigation systems ten shallow tube wells and ten deep tube wells were surveyed in 1986, selecting Basail *Upazila*, Tangail District as the site. All but three deep tube wells had been purchased by managers (owners, or representatives of owners who sell water to farmers). These three had been rented from the Bangladesh Agricultural Development Corporation. The deep tube wells had been installed between 1976 and 1984 and the shallow tube wells between 1982 and 1985.

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Despite the criteria set by the Corporation none of the deep tube wells complied with the requirements and most shallow tube wells violated the requirements as well. The average command area of a deep tube well was 16.4 ha in 1984 and that of a shallow tube well in the sample was 5.8 ha. The average command areas gradually decreased from 1984 to 1986 to 15.5 ha for deep tube wells and to 5.0 ha for shallow tube-wells, respectively, resulting in considerable underutilization of potential services. Inappropriate government policies that made it difficult for farmers to have access to the tube well services and profiteering by managers have been blamed for the trend of reduced command areas.

Starting in the late 1960s, the experience had been that farmers paid the full amount of water charges in cash either at the beginning or within the period of rice cultivation. The managers bore all investment and operation and maintenance costs of the tube-well projects. About 40 percent of the farmers did not pay their water charges on time or at all. As a result, the managers were reluctant to supply adequate water to the crops of those farmers with unsatisfactory payment histories. Hence, the crop yields of those farmers diminished, making it even more difficult for them to meet their obligations. This feature was a chronic problem in these small irrigation systems.

In the mid-1970s a crop-share payment system for water was initiated by a few managers of Basail Upazila which has been successful in increasing crop yields and farm incomes. Under this new system the managers bear all investment and operation and maintenance costs of the tube-well projects in exchange for 25 percent of the harvest of high-yielding variety (HYV) boro rice from each client farmer. Since the managers' profits are directly and proportionately related to crop productivity they have an incentive to see that water is applied appropriately to assure a good yield. Under this system water supply has been improved and there are hardly any farmers who default on their water payments. Farmers prefer this system because they do not have to pay water charges during the period of rice cultivation when they need cash for agricultural inputs, and the managers prefer the system because they have the opportunity of obtaining higher returns. A recent study by Miah (1987) shows that farmers in these projects are making profits from the cultivation of HYV boro rice. Farmers using deep tube wells are making slightly higher net returns per hectare (US\$47 [Tk 1,546]) than farmers in shallow tube well projects (US\$39 [Tk 1,283]).

The internal financial rate of return of tube-well projects from the managers' viewpoint, considering average command areas in 1986, was three to five times higher than the true opportunity cost of capital. Managers of diesel-operated deep tube wells achieve an internal financial rate of return of 48 percent, those of electrically operated deep tube wells achieve 54 percent, and diesel-operated shallow tube well managers have an internal rate of return of 74 percent. This implies that these projects are highly profitable to the managers/owners of the tube wells, and the crop-share rate should be less than the existing 25 percent. Policymakers should pay immediate attention to determine a reasonable crop-share rate equitable to all.

In conclusion, the government policy on selling tube wells through various organizations may have some advantages due to the competitive nature of the market. This policy, however, is one of the causes of gross violation of the recommended spacing- and command-area requirements for the projects. Policymakers must pay attention to the matter so that proper utilization of tube wells can be assured.

Since this paper is based on only ten deep tube-well and ten shallow tube-well projects in low-lying areas of Bangladesh the results should be interpreted cautiously if any further generalizations are sought for different regions with distinct topographies.

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Reorientation Towards Farmer-Managed Irrigation Systems in Nepal

K.P. Rizal¹

NEPAL, ABOUT 47,181 square kilometers in area, lies on the southern slope of the middle belt of the Himalayas between China and India. Most of the area is covered by mountains and hills and only about one-sixth of the total area is cultivated. Nepal's economically active population is about 46 percent and 91 percent of this population is employed in agriculture.

Water is one of the primary resources of Nepal. The people have been utilizing the water resources for agriculture through the construction of irrigation systems for many centuries and irrigation development has remained the domain of the farmers for many years. This tradition gave birth to the farmer-managed irrigation systems scattered all over the country. The total area under irrigation is about one million hectares (ha), or about 33 percent of Nepal's cultivable land. Thirty-three percent of this total area is presently under agency management and 66 percent under farmer management. These farmer-managed irrigation systems are primarily autonomous, self-governing entities. Their contribution to the national economy is quite substantial, producing about 50 percent of all rice grown in the country.

INSTITUTIONAL REARRANGEMENT FOR IRRIGATION DEVELOPMENT

For the last 30 years irrigation agencies have focused on the technical questions of construction of systems. Limited attention was given to strengthening and developing institutional and

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management capacity through water users' associations and the participation of the farmers in irrigation management. One of the major thrusts of the 1988 Sectoral Loan Strategy was to promote the participation of the farmers during the identification, construction, and operation and maintenance of the system.

Presently the most important institutional development issues are the legalization of water users' associations, sharing of responsibility by farmers for operation and maintenance of the system, and the establishment of a water-fee collection mechanism; and for some systems the most important issue is either increased participation by farmers in joint management or transfer of management responsibilities from the agency to the farmers.

Recent legislation allows water users' associations to achieve legal status. According to Irrigation Regulation of 1989, after the construction of an irrigation project is completed it may be handed over to the water users' association.

A water users' association may be formed in the area to be irrigated by every branch canal or in the absence of branch canals, by the main canal within the irrigation area. Functions, duties, and powers of water users' associations are clearly written in this Irrigation Regulation.

PROJECT-SELECTION CRITERIA

Included in the project-selection criteria for irrigation systems seeking government assistance is a provision that suggestions from the beneficiaries be considered while doing feasibility studies of medium- and large-scale irrigation projects. Also, small-scale irrigation projects are to be identified through the joint efforts of the unit member of the District Panchayat (district political unit) concerned, the unit member of the corresponding District Peasants' Organization, beneficiary groups, the Department of Irrigation, and the Agriculture Development Bank of Nepal. Priority is given to those feasible projects which have greater internal rates of return, are less expensive, and have more chances of participation by the beneficiaries.

RECOMMENDATIONS FOR FARMER-MANAGED IRRIGATION SYSTEMS

In an irrigation-sector coordination meeting held in Nepal in 1988, the following recommendations were made for consideration in the development of an irrigation master plan:

Recommendations to Give Appropriate Recognition

Identify existing farmer-managed irrigation systems in the area of each new agency project and incorporate their physical and organizational structures into the system with minimum disruption.

Recommendations for Providing Assistance

Establish uniform assistance policies for each geographical region of the country.

Systematically identify all farmer-managed irrigation systems in the country on a watershed basis by making an inventory that establishes a database giving pertinent details about each system.

Establish criteria for selecting systems for assistance.

Enable beneficiaries to improve the effectiveness of operation and maintenance activities in their system and to fully participate in any physical improvements that are made by providing assistance in strengthening their organizational and management capacity.

Encourage beneficiaries to take responsibility in assisting with selection of the design and in implementation of physical improvements that are to be made to their system.

Keep the design process for improvements to farmer-managed irrigation systems simple and field-based.

Recommendations for Administrative Reorientation

Provide assistance to farmer-managed irrigation systems in the form of loans (subsidized to the extent necessary) instead of grants.

Establish a division in the Department of Irrigation responsible for such assistance. Orient and train all levels of Department of Irrigation staff dealing with farmer-managed irrigation systems so they can implement a participatory approach for assistance.

Farmer-Managed Irrigation Systems in Bhutan

Tshering Dorji⁶

THE IMPORTANCE OF FARMER-MANAGED IRRIGATION SYSTEMS IN BHUTAN

SMALL-SCALE IRRIGATION HAS been practiced in Bhutan for many hundreds of years. Until about two decades ago all schemes evolved without any outside assistance and were managed by the beneficiary communities. Since then the Royal Government of Bhutan has increasingly promoted irrigation development. Primarily, this comprised of assistance for the expansion and improvement of main-canal physical infrastructure of small-scale schemes. In very few instances is there any ongoing management input by an outside agency. Therefore, the vast majority of the irrigation schemes in Bhutan can be classified as farmer-managed irrigation systems.

Even though only an estimated 3 percent of the total area of Bhutan is used for agriculture it employs 90 percent of the population, gives rise to roughly half of the gross domestic product, and accounts for more than a quarter of export earnings. Of the approximately 140,000 hectares of agricultural land, only about 10 percent is considered to be actively irrigated, and of this, 80 percent might be considered farmer-managed. Irrigation is believed to have great potential for contributing to meeting overall national goals and achieving specific objectives such as self-sufficiency in certain cereals and other foods.

The important areas for irrigation in Bhutan are the southern belt bordering India and the valley bottoms of the mid-hill region. There is little scope for irrigation in the high Himalayas to the north and east, and irrigated agriculture is less important in eastern districts.

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AGENCIES INVOLVED IN ASSISTING FARMER-MANAGED IRRIGATION SYSTEMS

The main agency involved in supporting irrigation is the Department of Agriculture. It provides human and technical resources through its Irrigation and Land Use Division (ILUD) to assist district authorities to draw up and implement annual irrigation-development programs. Through the Department's Policy and Planning Division periodic evaluations are carried out.

The Department of Agriculture provides assistance to two nongovernmental agencies, the Asian Development Bank and the International Fund for Agricultural Development that are involved in area-development projects covering specific areas and that are multi-sectorial in nature. Both agencies have given emphasis to working closely with beneficiary-groups in improving and renovating mostly very small existing canals. Much attention is also being given to the development and improvement of beneficiary operation and management of structures.

PROCESS FOR CONSTRUCTING OR ASSISTING FARMER-MANAGED SYSTEMS

Schemes implemented through district authorities are almost without exception initiated by the concerned communities. Submissions for assistance are made by beneficiaries through local representatives. All requests are then considered at quarterly meetings held at the district centers at which all the parties involved are represented. Schemes are rejected or placed on development-plan priority lists depending on local information and the limits set by National Directives. The Irrigation and Land Use Division has staff placed at all district centers where irrigation is of importance. Owing to a lack of sufficient staff the head office of the Department of Agriculture provides section officers to assist district authorities with the tasks of carrying out feasibility surveys and drawing up designs and estimates. District proposals are later considered by the central government. Once plans are finalized, funds are dispersed to the district authorities. Detailed investigations often still remain to be carried out and final designs and estimates drawn up. Construction of infrastructural works is carried out in all cases under the direct supervision of section officers.

At the various stages of screening projects no fixed set of selection criteria have as yet been employed. This has tended to be a subjective process based on general considerations of irrigable area, number of beneficiaries, length of canal, difficulty of conditions, and remoteness.

For those projects undertaken by the nongovernmental agencies project teams have actively searched for development sites. Project managers have day-to-day responsibility for running the projects and have immediate financial control. Accounts are submitted to the Department of Agriculture.

BENEFICIARY INVOLVEMENT

Beneficiaries are required to provide all labor for renovation works without remuneration. For new construction, beneficiaries provide unskilled labor for which they are paid a daily wage. Apart from the labor contribution provided by the beneficiaries no real consideration has been given to formalizing their involvement in the implementation of schemes. Appropriate involvement of beneficiary groups in the ongoing development process is currently the major issue being addressed by the Irrigation and Land Use Division.

Because of the small-scale nature of irrigation in Bhutan the Royal Government has, over the past four years, realized the need for an approach of full participation of beneficiaries in irrigation development. Two years ago the Department of Agriculture began to draft a proposal for irrigation policies with a view to obtaining satisfactory routine operations and maintenance of government-assisted schemes by the beneficiaries themselves. The policies aim at nurturing self-reliance by beneficiaries and encouraging a sense of community ownership. Regulations regarding the formation of water user associations and how they are to be involved in the development process are outlined in the policies.

To field-test the policies the Department has set up a project which will gradually establish a model scheme in each of the 17 districts. A research project has also been started which is studying three typical farmer-managed irrigation schemes for a complete year cycle. Information from these two projects will be analyzed with a view to finalizing the draft irrigation policies. The Irrigation and Land Use Division has set up an Irrigation Supports Unit that will be expected to provide the necessary support to beneficiary communities as the projects evolve.

CONCLUSION

National development in Bhutan began just under 30 years ago, and about eight years later an irrigation division was formed within the Department of Agriculture. Added to this very short irrigation-development history are the extremely difficult conditions in which such development has to take place in almost completely mountainous terrain with extremely high-intensity rainfall. Well-established selection and design criteria and a design process have not been realized as yet. Nevertheless, the Royal Government of Bhutan has recognized the importance of supporting farmer-managed irrigation systems, and policies and projects are being formulated to guide this development process.

Obstacles Facing Farmer-Managed Irrigation Systems in the State of Cambodia

Luc P. Dumas[‡]

THE COUNTRY AND IRRIGATION

THE DEVELOPMENT OF farmer-managed irrigation systems in the State of Cambodia (the name was changed from the Peoples Republic of Kampuchea in 1989) presently exists only at a minimal level. The disruptive events of the last 20 years have caused the loss and/or breakdown of many of the country's irrigation systems of the pre-1970s, whether farmer-managed or state-managed. Furthermore, many activities which occurred during the Khmer Rouge regime resulting in changes in the society and physical changes in the topography and hydrological balance of the land now pose severe obstacles for the proper development of the country's water resources.

Rice growing and fishing are the mainstay of the economy of this small Southeast Asian country, with 80 percent of the working population employed in the agricultural sector. Although statistics vary, it is generally accepted that the extent of land presently cultivated and the area under irrigation are less than those 20 years ago.

Most of Cambodia consists of lowlands and slightly elevated flatlands located within the basin of the Mekong River which flows from Laos for 500 kilometers before entering Vietnam to the south. All other rivers are tributaries of the Mekong.

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The author does not profess this paper to be an authoritative and complete representation of the farmer-managed irrigation systems in the State of Cambodia, since his involvement consisted of only short-term visits to a few provinces of the country. However, along with his personal observations, he consulted with some Khmer government officials and with expatriate workers of other development agencies.

Recent History and Effects on Irrigation

Between 1969 and 1973, as the Vietnam war spilled into Cambodian territory and the Khmer Rouge waged a revolutionary war, more than half a million tons of bombs were dropped on Cambodian territory killing or wounding more than one million people. The destruction of lives and property brought agricultural production to a standstill.

In April 1975, the Khmer Rouge, led by their leader Pol Pot, took power and imposed a reactionary regime based on the philosophy of creating a rural society purged of all Western influence. Educated people were regarded as a threat to the regime, and thousands were killed.

Of the many disruptions caused to the country by the Khmer Rouge regime, one of the most significant and lasting was to the hydrological balance of the land. The Khmer Rouge leaders focused on the creation of elaborate irrigation systems as a key to achieving great agricultural gains. However, there was little experience or knowledge to guide the process. The regime sponsored the creation of a grid of irrigation canals to cover the whole country. Instead of using the contour of the land to determine the location of the canals, the Khmer Rouge decided to simplify and standardize everything by matching the alignment of these with topographical map grid-lines. In other words, the canals ran north-south and east-west. Main canals and ditches were spaced at specified intervals to surround units of four hectares. Control structures were almost nonexistent and rapid drainage of upper lands occurred, followed by extended flooding of lowlands.

Another Khmer Rouge idea was to build large earth dikes along some of the canals to create reservoirs for impounding excess runoff water which could later be released into the canal system downstream. However, many were built in flat areas with no real storage capacity causing large areas of land to be wasted. In cases where there was some potential for useful storage, improper design resulted in the failure of the dikes or the structures within a few years.

OBSTACLES FACING CAMBODIAN FARMERS

After liberation of the country by Vietnamese forces in early 1979, the country finally began to return to somewhat normal conditions and started rebuilding. But the Cambodian people are faced with the immense task of rebuilding almost everything under very difficult conditions, with very little assistance from foreign countries.

Some of the traditional small irrigation infrastructures have begun to reappear as an attempt is being made to rehabilitate the systems, effacing the effects of the "Pol Pot" systems, as the people call them. Canals are blocked off to prevent unwanted drainage, or in other areas they have been made part of rice fields. In some cases, farmers have tried to reestablish the original courses of the streams. The main problem is that many farmers have settled into new lands as a result of the dislocations that occurred under the Khmer Rouge regime. They are still unfamiliar with the rainfall and flood conditions of the new areas to which they have moved. Even farmers returning to their original lands are faced with changes in the hydrology of their area. Even if rural areas

are still poor, conditions are much better than they were during the early years after liberation. Overall, resources owned by farmers have increased and as a result they are becoming more independent and water management is now performed more and more by individuals.

Until recently, all land was the property of the government and farmers were reluctant to make great efforts to improve it. In April 1989, the government decreed that the people may own their land. Nevertheless, because most "Pol Pot" irrigation schemes affected large areas it will be difficult for farmers or single villages to overcome the various problems those schemes caused. Therefore, some work will need to be coordinated among villages and some government assistance will be needed.

GOVERNMENT STRUCTURE AND POLICIES

Under the present government, matters pertaining to irrigation are the responsibility of the Department of Hydrology under the Ministry of Agriculture. This consists of departments at both the central and provincial levels. Among the major problems faced by the new government are the lack of material resources and qualified personnel. Most engineers, technicians, and administrative personnel, like all educated people of the earlier regimes, have either died during the Khmer Rouge regime or have fled the country.

Initially, the Department of Hydrology expected to implement large irrigation projects to satisfy the irrigation needs of the country and to provide a training ground for its personnel. However, in the last few years it has begun to encourage organizations to promote small community-based projects after observing the success of an American Friends Service Committee (AFSC) small-scale project in Kompong Chhnang province. It now appears that small community-based projects will become the responsibility of the provinces, while the responsibility for medium- and large-scale ones will be left to the central department.

Present Attempts at Government-Assisted Farmer-Managed Irrigation

The current small-scale irrigation program conducted by the Department of Hydrology of Kompong Chhnang province (located about 100 km northwest of Phnom Penh) with the assistance of the AFSC is now five years old. Through this program, the province has been able to build, repair, or replace small water-control structures, either in natural streams or in various "Pol Pot" systems as part of rehabilitation. Most projects consisted of reinforced concrete weirs or small drop structures in canals which replace the earth and wooden ones previously built by farmers.

For these projects, the AFSC provides construction materials which must be imported; cement, reinforcing steel, and some tools; plus the services of an expatriate engineer to oversee certain aspects. The provincial Department of Hydrology is responsible for providing local materials

such as sand, gravel, and formwood, and for covering transportation costs. Labor for the construction is provided by the villagers while supervision and coordination of the work are the responsibility of the province and the district. Once the project is completed, it belongs to the beneficiary village(s). They become responsible for the management of the structure and the system. When a system serves several villages, the subdistrict officials coordinate the management.

In the beginning, the American Friends Service Committee (AFSC) engineer supervised the site survey and prepared the plans for the structures to be built. The Khon Kaen University-New Zealand standard spillway was chosen as an appropriate design model. A few years ago another standard design for larger structures, the Khon Kaen University-New Zealand II (Chaiyaphum model) was introduced. At present, Kompong Chhnang hydrology personnel are able to survey and design these projects with minor outside assistance. This concept of teaching by showing, and learning by doing, has been the AFSC's working philosophy from the beginning of the project, and is one that will allow the project to eventually sustain itself.

Agency Responses to Farmers' Design Needs: Farmer Participation in Small-Scale Irrigation Projects in Northeast Thailand

Sanguan Patamatamkul and Sa-at Rengsirikul¹

NORTHEAST THAILAND ENCOMPASSES approximately one-third of Thailand's total area, with approximately one-third of the country's population. About 80 percent of the population live in areas that cannot obtain water from large rivers or large-scale irrigation projects. Therefore, the farmers in this area rely on small-scale irrigation projects which include small reservoirs and weirs.

The principal agency in charge of constructing small-scale irrigation projects is the Royal Irrigation Department (RID) of the Ministry of Agriculture and Agricultural Cooperatives. From 1976 to 1988 the Royal Irrigation Department constructed 2,666 small-scale projects in the northeast. Although the projects are agency-built, operation and maintenance work of the small-scale irrigation systems is managed by the water users who receive assistance from the Department of Local Administration (DOLA) of the Ministry of the Interior. The mandate of the DOLA is to carry out the organization of farmer groups and provide water-utilization extension and system-maintenance guidance services. In the past, however, these activities were seldom implemented and most projects constructed before 1985 did not involve the farmers in any of the stages of project development. In addition, there was generally a lack of coordination between the Royal Irrigation Department and the DOLA. As a result, only about 10-20 percent of the small-scale irrigation projects have been effectively utilized and maintained.

In 1985, the RID and Khon Kaen University, with support from the Ford Foundation initiated the Small-Scale Irrigation System Projects to study and develop farmer participation in small-scale irrigation projects constructed in the northeast by the RID. The project was renamed "Farmer Participation in Small-Scale Irrigation Projects" (FPSS) in 1987. Its goal is to develop and enhance the farmers' capacity in planning, utilizing, and maintaining small-scale irrigation projects constructed in the northeast.

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The FPSS uses community organizers to actively facilitate the participation of the farmers in all stages of the development of an irrigation project. The community organizer, a temporary RID employee, works closely with the farmer community, RID officials, and other district officials at all stages of the project from feasibility assessment to coordination with the survey, design, and construction units. The community organizer acts as a liaison to inform the farmers of agency procedures and requirements; assists the farmers to reach agreement on their needs as related to the project; relays any local requests or concerns to the design engineer; assists with organizing the community for implementation of the project (organizing labor, materials, transportation); and arranges for the training of the farmers in maintenance of the project.

Two types of small-scale irrigation projects are usually constructed in northeast Thailand: a small reservoir and an irrigation weir. The small-reservoir type consists of an earth embankment, a spillway, and outlet structures. The irrigation weir consists of a spillway and outlet structures, occasionally with a berm or dike. In both project types short sections of lined canals with a maximum length of about 30 meters are constructed. The farmer groups are responsible for extending the canal to their fields.

Design issues raised by the farmers generally focus on the spillway component of both project types. Ogee-crested spillways, broad-crested spillways, or vertical-drop spillways are usually designed for the small-scale projects. The farmers are most often concerned about the elevation of the spillway because it affects the storage capacity of the reservoir or the stream. Moreover, for weir projects, the elevation of the spillway also dictates how easily water can be diverted. Table 1 provides details of examples of farmer participation in project design and the agency's responses to the farmers' requests.

Table 1. Examples of farmer participation in project design and the agency's responses to the farmers' requests.

Design requests by farmers	Number of requests	Number of agency responses	
		Positive	Negative
Bridge for man or animal	6	6	-
50-centimeter stop log	8	8	-
Stream-bank berm	5	4	1
Change stream-bank berm alignment	1	1	1
Increase storage level	3	2	1
Bridge for small cart	1	1	1
Adjust weir location	1	1	-
Shift outlet location	1	1	-
Increase/decrease number of outlets	4	4	-
Increase outlet size	2	2	-
Vehicular bridge over weir crest	3	3	-
Dredging for more storage	2	2	-

The number of positive responses from the Royal Irrigation Department's design engineers to accommodate the farmers' needs in the design of the small-scale irrigation projects is a good sign that should stimulate more active farmer participation in the operation and maintenance of the irrigation projects. The initial experience of the FPSS, while monitoring and evaluating operation and maintenance activities in projects involving community organizers, has also been positive.

The Status and Institutional Issues of Farmer-Managed Irrigation Systems in China

Ren Hongzun¹

FARMER-MANAGED IRRIGATION SYSTEMS in China are those systems where operation and maintenance activities are controlled by mass organizations such as villages and townships.¹¹ As such, they can be divided into two types: 1) farmer participation in the management of large-scale or medium-scale irrigation systems from the tertiary-to-field levels [lateral and sub-lateral canals and farm ditches], while the government bureaucracy manages main and branch canal levels; and 2) farmer management of small-scale systems (less than 3,333 ha) diverting water from rivers, small reservoirs, ponds, dams, and wells. Therefore, despite differences in the size of irrigation systems, ultimately, the farmers participate at some level of irrigation management.

Because the farmers have limited economic and technical capacities the county Water Conservancy Bureau (WCB) in the area supplies technical, material, and financial assistance for small-scale, on-farm projects and for well digging. For example, more than 50-60 percent of the total expenditures for farmer-managed systems in Yucheng County was financed by the government before 1982. Farmers or townships and villages contributed to the remainder of the costs including the imputed cost of labor.

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¹¹[Note: Mr. Ren Hongzun has used a different definition for farmer-managed irrigation systems from that used by other authors in this publication and at the International Workshop on Design Issues in Farmer-Managed Irrigation Systems. His use of the term farmer-managed irrigation systems in this paper actually refers to farmer participation in operation and maintenance of jointly managed irrigation systems. Workshop organizers.]

INSTITUTIONAL SUPPORT OF FARMER-MANAGED IRRIGATION SYSTEMS

The Water Conservancy Bureau has the following responsibilities: 1) It organizes the survey and evaluation of water resources and balances water-resources supply and demand in relation to the Development Plan for the National Economy. 2) It determines the distribution of funds and materials for water projects within its jurisdiction. 3) It organizes the design and construction of small projects and operates and maintains key canals and projects.

Township water-management stations are separate entities from the Water Conservancy Bureau (WCB) of each county. The water-management stations are staffed by people from the county WCB, the township, or farmers. They design some of the simple, small water projects.

In the design process the WCB collects agricultural, meteorological, topographical, and economic data on the proposed project area. After a design paper is completed it is discussed with the beneficiaries -- township and village leaders or representatives of the township's water-management station. Farmers can present their ideas to the Bureau through their mass-organization leaders. However, they are seldom directly involved in the design process.

Initiatives to Encourage Increased Farmer Participation

Although projects at the tertiary level have been built with government investment the labor for construction and maintenance has been borne by the farmers.

After the introduction of the Production Responsibility System, a certain amount of unpaid labor for water conservancy works may be required of each beneficiary. Some farmers prefer to pay US\$1.00 or a little more per labor-day to have another person perform the required work. Some villages or townships collect a labor fee from the beneficiaries based on the assigned labor quota and this fund is used to contract labor to construct and maintain water projects.

Since July 1985 a water-charge system has been set up. Water users are required to pay a fee for the use of irrigation water. The fees are intended to be a main source of funding for farmer-managed irrigation systems. However, the water fee is too low to cover the cost of operation and maintenance. Nevertheless, many water users find it difficult to pay the charges, especially those in the poor, mountainous areas.

To date, a serious shortage of financing exists for the rehabilitation and maintenance of water projects, and it appears that it will be necessary for the government to again increase its investment in farmer-managed irrigation systems.

CONCLUSION

In the past, the government played a strong role in the development of irrigation systems so that the farmers became reliant upon government initiative and support. Irrigation facilities were not used efficiently leading to a waste of resources and financial difficulties. These problems led to a number of economic and institutional reforms in recent years which encourage farmer participation in the design, construction, operation, and management of irrigation systems, at least in policy. Because China's conditions are very complex, finding a single approach and imposing it may be more harmful than helpful. To date, the institutional problem continues while a flexible procedure for increasing farmer participation and agricultural production that fits local conditions is sought.

Some Experiences Encouraging Farmer Water Users' Participation in Irrigation System Operation and Maintenance

Jiang Ping[†]

IRRIGATION DEVELOPMENT IN CHINA

IN ITS LONG history of agricultural production, irrigation has played an important role in the economic progress of China. Before the founding of the People's Republic of China in October 1949, the total irrigated area made up about 20 percent of the arable farmland.

Since the founding of the People's Republic of China irrigated area has expanded. Feudal customs have been abandoned, modern technology has been introduced, irrigation management has been organized based on agency/farmer joint management, and new water-utilization rules have been instituted. About 48 million hectares (ha) are presently irrigated, making up 46 percent of the farmland in the country. There are 137 major irrigation projects each with command areas of 20,000 ha comprising 16 percent of the country's irrigated land. Four hundred fifty-eight medium projects with command areas from 6,667 to 20,000 ha each cover about 10 percent of the overall irrigated area. Land covered by numerous minor projects (less than 6,667 ha each) amounts to 74 percent of the country's total irrigated area.

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RESOURCE MOBILIZATION FOR MEDIUM/MINOR IRRIGATION SYSTEMS

Huge investment has been put into irrigation construction. The total financial expenditure from the state for water-conservancy construction up to 1985 was US\$72 billion of which more than US\$30 billion were used for irrigation construction primarily of major and some medium-scale projects. Because of limited financial resources the government encourages farmers to construct and manage most of the medium and all of the numerous minor projects in the country. In China, this means that the farmers should be responsible for the construction of medium/minor irrigation projects and their management, including payment of agency staff salaries, costs of repairing, cleaning, and desilting canals, costs of fuel and electricity, and all operation and maintenance overhead costs.

Despite the policy of having the farmer water users support the costs of constructing, operating, and maintaining minor irrigation projects, it has been difficult to obtain the collaboration of the water users because of economic and institutional constraints. The farmers are mainly interested in the returns from their annual crop production and income and find it difficult to invest in construction that will provide them with a return over a long period. Also, in China all farmland is social property, and the farmer has the right to use his share of farmland only for as long as he is engaged in farming in the village. Every two or three years the area and location of the farmland cultivated by a farmer may be adjusted according to changes among the village households. Inequities in water distribution and labor and cash obligations among different water-user groups also cause the farmers to resist making long-term investments in irrigation projects.

Labor and Cash Mobilization by Farmer Water Users

Three types of payments are usually collected from farmer water users: 1) payment of labor costs involved with system construction and maintenance, 2) payment of a water fee, and 3) payment of operating expenses.

Payment of labor costs for system construction and maintenance. Usually, the number of labor-days required to construct, repair, clean, and desilt the canal is estimated and the total divided into a quota per unit of area irrigated or unit of irrigation water consumed. Then each village is assigned to contribute to construction and maintenance costs in proportion to the area it irrigates or the volume of water it utilizes. The number of labor-days is converted into a cash sum required of each household in proportion to the area of land it irrigates or the volume of water it uses.

To complete the work, the village-management group organizes a work team from among the beneficiaries, or contracts a construction team. Farmers who contribute labor are paid a daily wage. Those who supply manual or animal-drawn carts are paid for these contributions.

Payment of a water fee. Irrigators are required to pay a water fee calculated on the basis of the water used. At present this fee is very low; the average price of irrigation water is reported to be

3 to 4 yuan (US\$1 = 3.6 yuan) per 100 cubic meters in north China. Although the water fee is supposed to cover overhead costs including salaries of agency staff, heavy repair, and depreciation of main structures the water fee seldom covers these costs. As a result, the development of diverse enterprises such as fisheries or nurseries in conjunction with water management is encouraged by the government.

The volume of irrigation water is usually measured at the water intake of the lateral canal. The lateral-canal supervisor then collects water fees from each household. The water fee may be calculated according to the amount of water used or according to both the area irrigated and the amount of water used. Water fees may be paid in cash or in kind, e.g., 15 kilograms of grain at the current price per hectare, annually.

(Although well irrigation is one of the major types of irrigation in north China making up 65 percent of the total irrigated area of the region many areas do not collect any water fee for agricultural use of groundwater resources. However, in a few areas, a water fee of approximately 30 yuan per ha per year is collected and used for operation, maintenance, and the development of conveyance and groundwater recharge systems.)

Payment of operating costs. Water fees are calculated to cover only the cost of water management. Beneficiaries are required to pay an additional fee to cover operating costs. Operation costs fall under two categories: 1) those associated with the operation and maintenance of the main and branch canals, usually managed by the government agency, and 2) costs for operating the lateral and sub-lateral canals and farm ditches, which are managed by the farmers.

The fee for operating costs is collected with the water fee calculated on the basis of cubic meters of water delivered or used. The portion of the fee corresponding to the agency-managed part of the irrigation system is administered by the system administration and is used for operation and maintenance of main and branch canals in the irrigation season. The operating fee corresponding to the farmer-managed part of the system is returned to each county water users' association and is combined with other county funds to pay for wages incurred for canal supervision and operation of the infrastructure at lateral-to-ditch levels during irrigation.

Farmers of the same sub-lateral canal elect several canal tenders who undertake canal supervision and irrigation management and they are paid by each farmer in proportion to his length of rotation during irrigation.

RECOMMENDATIONS FOR MORE EFFECTIVE RESOURCE MOBILIZATION

In China, both farmland and irrigation facilities are public property. However, since the increase of irrigated crop production and more efficient use of irrigation is in the interest of the farmer water users, irrigation management in China consists of two partners: the agency and the farmers. The agency is responsible for irrigation performance, and irrigation performance is dependent upon the active participation and collaboration of the farmers. Therefore, with respect to more effectively mobilizing labor and cash resources, agency policy should strive for the following:

1. Water allocation among beneficiaries should be equitable.
2. The distribution of irrigation should be scheduled so that water can be delivered when it is needed, in the right amount, and in a manner that allows for optimal performance. Irrigation should be scheduled so that full flow is delivered to uplands and minor flow to the lowlands. Rotation should be organized among laterals to concentrate water flow for some laterals in each rotation to avoid dispersion of water supply.
3. Patrolling should be organized and allocation and distribution schedules enforced, with appropriate penalties.
4. A variable water-price policy should be developed to encourage the most efficient and maximum use of the water available.

Farmer-Managed Irrigation Systems in the Valley of Senegal

Sidy Mohamed Seck¹

IRRIGATION IN THE VALLEY OF SENEGAL

DURING PAST YEARS irrigated areas exploited by farmers in Senegal have increased from 9,000 hectares (ha) in 1975 to 35,000 ha in 1988. Ninety-five percent of these areas are located along the river in the Senegal valley where a society of exploitation and planning (SAED) is working. However, inspite of an increase of irrigated agriculture by almost 300 percent in 13 years, it continues to occupy a very weak place in the economy of the country. Less than 5 percent of the cultivated area is irrigated, and irrigated areas contribute only 8-10 percent to food production.

Senegal is one of the participants in a subregional program begun in 1972 called the Organization for the Development of the Senegal River Valley (OMVS) that groups together the countries of Mali, Mauritania, and Senegal for the development and management of water resources. The program is the largest multisectoral project covering West African river basins. Its objectives are to control the discharge of the river and bring 375,000 ha (240,000 ha in Senegal) under irrigation, produce 800 gigawatts of hydroelectric power, and develop inland navigation. As part of this program, an anti-salt dam in Diama in Senegal and a storage basin in Mali have been completed.

The Senegalese government started a water control policy aiming to develop irrigated agricultural production. The seventh Plan of Social and Economic Development (1985-89) allocated 75 million CFA (315 CFA = US\$1) to the development of irrigation, approximately 70 percent of the budget for agriculture. The national cereal program of 1985 targeted an increase in irrigated area of 4,200 ha per year from 1986 to 2000.

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SMALL VILLAGE-IRRIGATION SYSTEMS (PIVs)

Village-irrigation systems of 20-30 ha or less are installed in clay and sandy ground, employing a group of water pumps to supply water. The model was introduced in 1972-74 by the FAO/OMVS researchers, and was rapidly adopted by village groups without outside intervention or any imposed hierarchical structure. Organizational and financial assistance from government or non-government organizations were given later.

The creation and dissemination of village-irrigation systems occurred due to the continuing food and climatic crises in an area of dense population, the introduction of high yielding varieties of rice and improved agricultural techniques, and the action of farmer leaders who were able to transmit the innovation without breaking sociocultural traditions (Seck 1981, Bethemont 1986). Village-irrigation systems spread rapidly along the river basin: 1,000 ha in 1975, 10,000 ha in 1982, and 32,900 ha in 1988 with more than 1,000 irrigation systems, composing approximately 67 percent of the total irrigated area exploited by farmers. These farmer-managed systems represented 35 percent of the agricultural irrigation systems and contributed 45 percent of the agricultural production from irrigated areas in Senegal.

Village-irrigation systems are constructed by the farmers using local labor and traditional tools following recommendations and design from technicians. Because the farmers contribute their labor installation costs are between 400,000 and 800,000 CFA (US\$1,270 and 2,540) per hectare, approximately 5-12 times less expensive than the cost per hectare for the development of large-scale irrigation systems. In addition, the village-irrigation systems can be completed within approximately 5-8 months as compared to 4-10 years for completion of large-scale irrigation systems.

The average size of a village-irrigation system is 20-30 ha. Each farmer manages his plot as he wishes, abiding by the rules fixed by the management committee regarding water distribution, resource contributions, and individual charges.

Results and Limits of PIVs

Although the irrigation structures for village-irrigation systems are simple, using traditional methods, these systems have been able to realize satisfactory production levels, averaging 4.5 tons of rough rice per ha, to a maximum of six tons per ha. Nevertheless, production is insufficient to meet the needs of the population: the overall harvest amounts to between 900-1,500 kg per family, and once investment costs (factors of production, irrigation charges, amortization) are paid, only 500-900 kg remain for the consumption of an average family of 10 persons.

As rainfall conditions have improved since 1984, many farmers have abandoned the use of small irrigation in favor of the traditional rain-fed subsistence cultivation because it requires less financial and labor investment.

At present there is a need to increase the agricultural area exploited by the small farmer. However, the small farmer cannot cultivate larger areas of land unless he mechanizes, because the more easily cultivated soil in which PIVs had been developed in the past is no longer available.

Further, irrigation expansion will have to be extended into areas with clay-soil types that will need mechanical cultivation. This will increase the cost per ha and the PIV model will have to be adapted to meet these requirements. The increased investment costs (infrastructure, labor, animal traction, and tractors) required are beyond the means of the average Senegalese farmer. For the present, it may be necessary to give attention to other ways of exploiting irrigation because it is not feasible to continue the expansion of PIVs in the present model.

INTERMEDIATE-SIZE MODELS FOR IMPROVEMENT SCHEMES

An alternative to both large and small village-irrigation systems is currently being examined in the form of intermediate-sized irrigation systems which combine the advantages of large systems (reliable infrastructure, economy of scale) and those of small ones (farmer participation in operation and maintenance). In the Ndombo-Thiago area, the government financed 12 irrigation units of 50 ha each. The structures were constructed on contract, with the farmers' participation. Each irrigation unit composed of a water-pump group, a chain of agricultural materials, and storage infrastructures, is allocated to a group of 50 to 70 water users holding plots from 0.75 to 1 ha in size. The water users' group is trained and assisted by SAED in technical and financial management and is responsible for operation and maintenance of the unit. However, the proximity of a sugar agro-industrial complex creates a particular economic and technical environment in this area that makes it difficult to duplicate this experience. Therefore, various models continue to be investigated, and at present, a successful model is still being sought.

CONCLUSION

The absence of a tradition of irrigated agriculture in the Senegal basin and the lack of a politico-economic will to develop irrigation resulted in the government formulating a policy and plan that included designating the type and design of irrigation systems to be developed, as well as stipulating the production process, organization, and funding. However, the State is no longer able to support this role today. The management of the systems that were installed in the past two decades has been too expensive and has given small returns. At present, the government is trying to disengage itself from construction and management of large irrigation systems. However, technical and management capacity, investment capacity, agricultural credit, and farmers' organizations that would allow the water users to operate and maintain the systems are absent or very weak.

While village-irrigation systems have been successful in many areas, they need to further increase their crop yields to meet the subsistence demands of the dense and growing population.

The low economic capacity of the small farmers and the amount of investment needed make it difficult for them to make a much larger impact on family food production. Meanwhile, successful, replicable irrigation models continue to be sought.

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Farmer-Managed Irrigation Systems in the Tras-Os-Montes Region of Portugal

Jose Portela[‡]

IN PORTUGAL, THE national agricultural irrigation policy has almost exclusively been concerned with new, large-scale schemes, usually biased towards big landowners. Until the mid-70s schemes were essentially concentrated in the south, where often there was no tradition of irrigation. Hydraulics engineering-oriented state agencies aimed at the irrigation of vast areas,[†] and the respective systems were to be loosely managed by state-imposed water users' associations. These were led by government technicians and big landowners. The schemes frequently did not work as planned: potential and actual irrigated area did not coincide, crops planned to be irrigated were substituted for others demanding more water and not mitigating seasonal employment, on-farm investments were not made, water fees were not paid, and tenancy and sharecropping arrangements increased.

The efforts of the Tras-os-Montes Rural Development Project (TRDP) to rehabilitate farmer-managed irrigation systems obviously diverged from that policy, and it has surely been a pioneering case at the national level. This paper is a short overview of the contribution of the TRDP for supporting farmer-managed irrigation systems. It draws on the work of the evaluation unit of the project.

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[†]A 1938 plan set 106,000 ha as the area to be irrigated. The target of the 1961 Alentejo Irrigation Plan amounted to 173,000 ha of which 161,700 ha would comprise big schemes. The remainder was divided among 73 smaller systems. For more on the Portuguese irrigation policy until the mid-70s, see Baptista 1984:95-285.

FARMER-MANAGED IRRIGATION IN THE TRAS-OS-MONTES REGION OF PORTUGAL

A 1979/80 water resources inventory carried out by the Regional Directorate of the Ministry of Agriculture (RDMA) for the Tras-os-Montes Rural Development Project revealed that a large number of streams exist all over the area: excluding the hot climate central area, 1,038 farmer-managed irrigation systems were surveyed, serving an estimated area of 40,800 hectares (ha). The schemes are small (the irrigated area per scheme varies between 3 and 82 ha), being concentrated in the mountainous areas and the high valleys. In summer they show very reduced discharges or even no discharge at all. In some cases the schedule of water distribution in summer is documented. The allocation of night irrigation for permanent natural pastures appears to be a common trait, vegetables being watered during the day. A traditional farming practice is winter irrigation (Goncalves 1985).

THE TRAS-OS-MONTES RURAL DEVELOPMENT PROJECT: ASSISTANCE TO FARMER-MANAGED SYSTEMS

Concept and Guidelines for the Project

It was estimated that the farmer-managed irrigation systems in the region would irrigate nearly 12,500 ha, the costs of improvement being nearly US\$187/ha. Rehabilitation would consist of reconstruction or repair of diversion weirs, lining earth canals with cement, and structures and offtakes equipped with steel slide gates. Ultimately, water losses during storage and transport would be reduced.

The designers accepted that direct water users' participation in the implementation of the rehabilitation works was important. The explicit rationale was twofold: reduction of implementation costs and local finance for subsequent operation and maintenance. Knowledgeable technicians, however, argued that rehabilitation of regional farmer-managed irrigation systems would not be viable without irrigators' direct contributions. Moreover, this action would help lower eventual conflicts among water users and increase the extensionists' reputation and power to advise on water-management issues and production techniques.

The Regional Directorate of the Ministry of Agriculture is responsible for the selection and design of rehabilitation projects and supervision of their implementation but any specific farmer-managed irrigation system can be rehabilitated only if two-thirds or more of the water users are willing to do so and subscribe to the respective protocol. An irrigators' council should call together and organize a task force and act as a link between the Regional Directorate and the water users. The works should take place at off-peaks without disrupting winter and summer irrigation. The irrigators' council should also look after subsequent operation and maintenance.

It was also established that water rights existing at the beginning of the rehabilitation would not be questioned. Another basic rule states that rehabilitation work should not alter the configuration of the scheme. Thus, only minor, approved changes of direction of the canals are possible and the number of traditional offgates, even if apparently excessive, should be unchanged. Similarly, if the irrigation system is a multipurpose one, due regard should be paid to other functions besides irrigation. For example, the operation of water mills, water reservoirs for animals, or washing tanks should not be disrupted.

The total costs of skilled labor, construction materials, and transportation used in rehabilitation are completely met by public funds. The irrigators' share which should represent a minimum of 20 percent of rehabilitation costs (CCRN 1982) consists of supply of unskilled labor and storage, and transport of materials from the village to the sites along the canals. Producers are responsible for earth canals, drains, and land leveling on their own plots.

The selection of systems for the project was based mostly on technical factors (access paths, length of the main canal, size of weirs, water flows, irrigated area, soils, and size of village population) which were biased towards quick implementation. Factors such as farmers' expressed wishes for rehabilitation schemes or water-management conflicts or even local integration of rehabilitated systems with other project inputs were not considered.

The gap between planned and real targets increased from 1983 until 1987. In December 1987, 61 schemes were rehabilitated, 69 units being the deviation. Six months after the planned completion date, that is, in December 1988, the final target (150 units) had not been reached. At this time, the practically rehabilitated irrigation systems totalled 114. Between March 1983 and December 1986, on average, nine months were spent in rehabilitating a scheme. In brief, implementation has been relatively slow, especially the take-off.

The pace of implementation and final success of the rehabilitation of farmer-managed irrigation systems depend on attitudes and behavior of numerous internal and external agents, and multiple local and institutional factors. Rocky ground, steep slopes, and limited space, as well as low temperatures and frosts make rehabilitation work difficult. Labor contributions are hard to get from an ageing and scarce village population or may represent a burden for those who have to guarantee the share of emigrated relatives, particularly when there are no wage workers around. To pool labor among part-time farmers and tenants related to absent landowners may also be hard. Other factors such as the cooperation to facilitate transportation, the ability of local leaders to obtain the active support and coordination of the water users, and local sociopolitical relationships within the community may serve to either help or hinder progress.

The Regional Directorate has reported the lack of timely funds, equipment, and skilled staff as institutional bottlenecks. Other probable ones are obviously the organization and administration of the implementing agency itself.

Positive Effects and Limitations of the Project

In general, water users vividly agree that the Tras-os-Montes Rural Development Project's intervention to rehabilitate farmer-managed irrigation systems produced multiple, definitely appreciated benefits at both the farm unit level and the village level. At the farm level summer-

water scarcity has been visibly reduced, and this has allowed more flexible water-management practices, increased independence from bigger water users (with whom water would be exchanged for labor or 'favors'), reduced expenses concerning complementary lift irrigation, and lessened physical effort and hardship, particularly with night irrigation. In fact, the time needed to divert water and the labor required for maintenance of reservoirs and canals was greatly reduced. In some cases, a few unirrigated plots became watered or permanent natural pastures could be irrigated at an unscheduled time. In an exceptional case, the number of village water users increased. Last, but not least, two specific studies indicate that increased yields and profits can be expected in rehabilitated schemes.

At the village level also the rehabilitation fostered positive effects. In several cases it required the opening or improvement of local paths or roads, complementary drainage, and construction of physical structures such as washing tanks and reservoirs. For a limited number of villagers the rehabilitation works offered an off-farm remuneration, albeit temporarily. It seems very plausible that the rehabilitation projects also contributed both to the lowering of social conflicts related to water management and to the positive reputation of the Regional Directorate.

Of course, there are also several points to be considered, of which the following need to be stressed: water users' direct participation in planning of rehabilitation of farmer-managed systems, data collection, capacity for water collection and storage, and formation of dynamic groups of irrigators. The Tras-os-Montes project staff did not pay sufficient attention to the first point. As a consequence, some interventions happened just because the people did not want to lose the opportunity for financial assistance, but they did have more urgent "felt needs." Out of 53 rehabilitated irrigation systems 8 have reduced canals and this disrupted the winter irrigation, reducing the yields of permanent natural pastures. In some cases the plots changed to cereal production.

Farmers' viewpoints were not considered. In these cases rehabilitation has meant retrogression instead of progress. Data collection about the systems also did not receive much care. For example, there are no "hard" data on the reduction of water losses through rehabilitation. The achieved reductions certainly represent a step forward as to the *status quo ante*, but are apparently insufficient for a more intensive cropping and steady output. To reach this aim the capacity for water collection and storage would have to be increased. Finally, rehabilitation of the farmer-managed systems could have been perceived as a good opportunity to empower groups of water users, regardless of their informality.

In conclusion, the State experience with assistance for rehabilitation of farmer-managed irrigation systems in the Tras-os-Montes region produced generally positive results. Next, the recommendations resulting from the evaluation need to be considered and adapted in order to facilitate greater success and increase the number of small-scale systems that can be included in the project.

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The North Poudre Irrigation Company: Farmer-Managed Irrigation in Northeastern Colorado, USA

J. Phillip King and Ramchand Oad¹

THE BASIC APPROACH of this paper is to analyze a successful farmer-managed scheme, the North Poudre Irrigation Company (NPIC), in fundamental terms of water control. The aim of this analysis is to identify the principles that make the system management effective so that they may be applied to irrigation systems elsewhere.

Irrigation development in Colorado began in the southern part of the state as Spanish settlers migrated north from Mexico. The Colorado gold rush of the mid-nineteenth century caused a rapid increase in farming in the area, particularly after the close of the Civil War. Because of the erratic and minimal rainfall, irrigation was a necessity for effective agriculture. Farmers began diverting stream flows to their fields with hand-built ditches. Most of the land currently irrigated by surface water was developed by 1900 although significant groundwater development has occurred more recently (Howard 1986).

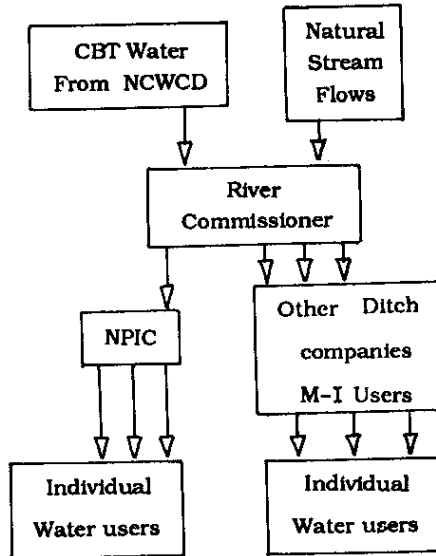
The basic principle behind water rights in Colorado is the Doctrine of Prior Appropriation or "First in Time, First in Right." In essence, if water user A began using water before water user B, user A has the right to take his full allocation before user B gets any, regardless of their respective locations. If the river flow is so low that no water is left after user A takes his allocation, then user B gets none. User A is said to have the senior right and user B has the junior right.

The progression of water through the system is summarized in Figure 1. Water rights are administered by the River Commissioner, a civil servant paid by the State Engineer's Office. The River Commissioner is generally a retired farmer from the local area. His job is to release water to users' oftakes (usually irrigation companies, municipalities, or industrial users) as they request it, in accordance with the water rights. The Colorado-Big Thompson (CBT) reservoir water is released into the Cache la Poudre River by the Northern Colorado Water Conservancy

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District (NCWCD) and the River Commissioner is responsible for making the appropriate deliveries to users.

Figure 1. Generalized diagram of delivery of water from sources to end users.



One of the most successful irrigation companies on the Cache la Poudre River is the North Poudre Irrigation Company. The NPIC is a mutual (nonprofit) company whose stockholders are water users. At its inception, ownership in the company was divided into 10,000 shares of stock. A shareholder has the right to use a volume of water proportional to the number of shares he/she owns. The amount of water available to the NPIC varies from year to year depending on snowpack, weather, and the consumption of water by more senior users. The total amount of water available in a given year is divided into 10,000 shares so that each share gets the same amount of water (NPIC 1988a). In addition to river water, NPIC gets about 1,230 cubic meters per share of Colorado-Big Thompson water. This figure also varies with climatic conditions from year to year. The 10,000 shares are currently owned by about 625 stockholders, and 80 to 85 percent of the system's water goes to agriculture. The remainder goes to municipal and industrial (M-I) users (Stieben 1989).

One of the main features of the management of the Cache la Poudre Basin that makes for an effective system is the buffering effect of the institutions between the regional-scale operations of the Northern Colorado Water Conservancy District and the farm-scale operations of individual irrigators. The Conservancy District facilities are spread out over northern Colorado, on both sides of the continental divide. At this level, reservoir management and forecasting must plan on a five-year or longer basis (Howard 1986). The system gains flexibility as water control is handed to the River Commissioner, who operates on a basin-wide scale, and then to the NPIC which is more local. By the time water reaches the farmer the system has gained enough flexibility to allow the farmer to schedule irrigations only one day in advance. The farmer has the ability to exactly match irrigations to crop water needs.

The NPIC is currently experiencing a very dry year. The seasonal allocation of water is only 4,286 cubic meters (Stieben 1989), the least allocation since 1956 (NPIC 1988b), and no water is available for rent. Farmers have either planted less area than in previous years or are suffering yield loss due to moisture stress. Tension is high, with many arguments between irrigators and ditchriders. During one very hot spell, when the daily high temperature was in the 41-44°C range for five consecutive days, water orders exceeded the capacity of some of the canals. The company bylaws specify what should be done in such situations. The canal capacity is divided equally among the water users who own their own stock, and rented shares get whatever is left. While no one gets the total amount of water they want, the distribution is equitable and follows the rules laid down in the bylaws. As long as each farmer knows that the established rules are followed, equity is preserved. In the words of system manager Robert Stieben, "Conflict comes and goes, but the company always delivers water exactly the way the rules say. When you buy stock, you agree to follow those rules."

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Small-Scale Irrigation in South Asia: Some Preliminary Findings from Case Studies

Salehuddin Ahmed[§]

THERE IS NO uniform definition or criterion for small-scale irrigation in South Asia. In Bangladesh, small-scale irrigation includes low lift pumps, deep tube wells, shallow tube wells, and a few indigenous gravity-irrigation and lift-irrigation schemes. In India, minor irrigation includes those schemes having cultivable command areas up to 2,000 hectares (ha). In Pakistan, dug and tube well systems, low lift pumps, tanks, and small irrigation dams are considered small-scale irrigation systems. In Nepal, small-scale irrigation covers systems up to 50 ha in the hills and 2,000 ha in the plains. In Sri Lanka, a minor irrigation scheme covers up to 80 ha of agricultural land.

Small-scale irrigation schemes play an important role in national food production and in particular, in the direct food requirements of subsistence farm communities that undertake this type of irrigation.

Various studies of small-scale irrigation systems in Asia suggest that the peasant organization is an important adapting mechanism for management of irrigation (Coward 1984). There is a growing realization that the success of an irrigation project depends largely on the active participation of the individual farmers, and there have been growing efforts to involve farmers in the management of irrigation, at least at the field level. In late 1987 CIRDAP launched an interdisciplinary study in five of its member countries in South Asia (Bangladesh, India, Nepal, Pakistan, and Sri Lanka) to analyze the impact of small-scale irrigation on the rural poor. The interaction of design, implementation, and management issues of small-scale irrigation schemes is highlighted here.

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In each of the five countries two cases were selected for in-depth study at the field level: one small-scale irrigation system with high intervention from an outside agency, and the other with no (or low) intervention from an outside agency. The second category is similar to farmer-managed irrigation systems. However, intervention in some form or other is present in almost all types of small-scale irrigation systems in Asia.

DESIGNS OF SOME SMALL-SCALE IRRIGATION SYSTEMS

In most of the irrigation projects in South Asia the design is done by engineers without much reference to other disciplines such as agronomy, social science, and economics. The most underrated and forgotten "dimension" or agent in large-scale irrigation is the farmer. In analyzing the five country situations, the comparison between high and low intervention cases will bring out the extent of the use of local skill and information on irrigation practices and participation of the beneficiaries in design, implementation, and management of small-scale irrigation systems. The hypothesis of this paper is that "the structures and systems designed for small-scale irrigation will create facilities and procedures that reduce the dependency of the system on an external agency, and the impact of the scheme will be high on the rural poor if local knowledge, skill, and people are utilized to the maximum."

Bangladesh. In Bangladesh, two deep tube wells in Comilla District were studied, one owned by a village agricultural cooperative society and the other by a few enterprising farmers with reasonable land and access to financial resources. The design for the village agricultural cooperative society's deep tube well was drawn up as prescribed by the Bangladesh Academy for Rural Development and the design for the other tube wells was similar to it. The members of the village agricultural cooperative society designed the construction of the water courses to different plots. The slope, materials used (cement, brick, mud) and the length and width of the water courses were decided in meetings and consultations with the cooperative members. A water distributor was appointed by the cooperative to oversee the distribution of water.

India. In India, two bore wells in Ranga Reddy District in Andhra Pradesh were chosen as case-study locations. The one with high intervention was implemented, managed, and operated by the Andhra Pradesh Small-Scale Irrigation Development Corporation. For purposes of day-to-day management and maintenance, the corporation has placed an operator for every 50 wells. The second bore well was installed by the Andhra Pradesh State Dairy Development Cooperation which handed over the operation and management of the well to the farmers of the command area. In both cases, the design process did not involve beneficiaries much, but in the second one, there was involvement of the beneficiaries in the operation and management of the scheme.

Pakistan. In Pakistan, one small dam in Khasala in Rawalpindi District, and one irrigation scheme in the hilly areas of Gilgit were taken as examples of intervention and nonintervention schemes, respectively. The intervention scheme was constructed and managed by the Small Dam Organization of Pakistan. The nonintervention scheme was constructed by local initiative under the motivation of a nongovernmental organization. In the intervention scheme the actual release

of water is far less than the design releases mainly because the water courses are not properly maintained. It was found that at the tail end the elevation of the farmers' fields was greater than that of the water courses. This is a design fault which could be corrected through construction of suitable water courses in that zone. In the Gilgit area, the farmers were consulted before the installation of the scheme and maintenance of the scheme was entrusted upon the representatives of the farmers. The motivation of the farmers in the Gilgit case was high and as such the impact on the rural poor was much higher in the nonintervention case.

Nepal. The Majhuwater farmer-managed canal system in Dhading District was constructed by traditional canal cutters without any technical consultation with external experts. The beneficiaries were involved from the very beginning and they are very conscious of the status of the system which they maintain through mutual agreement. The government-managed Pipaltar system in Dhading District was constructed by a contractor under the supervision of the Department of Irrigation. There were some design and construction problems which were reflected in a leak that developed due to landslides near the command area. The Pipaltar scheme was constructed with all necessary permanent structures. Although the Majhuwater scheme has no structure high density polyethylene pipe siphons were installed near the command area. The canals of the intervention system were not functioning well compared to those of the nonintervention systems although the design of the government-managed system was more sophisticated. Due to lack of popular participation its maintenance has not been satisfactory.

Sri Lanka. In Sri Lanka, two anicut (weir, or enclosure across a river) minor irrigation systems in Ratnapura District were studied in depth. State support of the high intervention system was mainly restricted to constructing the physical infrastructure and then handing it over to the Department of Agrarian Services for operation and maintenance. In the other system the water users, using coconut and rubber tree trunks, constructed an anicut to raise the water level enough to irrigate 5.5 ha. In this farmer-managed scheme, two social aspects have facilitated operation by the farmers: community property rights over land and water, and the homogenous nature of the community (most of the farmers belong to a single kinship pattern).

IMPACT ON THE RURAL POOR

Irrigation water, if properly utilized, can bring about significant changes in the production and socioeconomic situation of the community concerned. The small-scale schemes covered under the present paper were supposed to benefit the small and subsistence farmers. Next, some selected indicators are discussed to show the direct and indirect impacts of small-scale irrigation. Table 1 presents the cropping intensity and rice yields per acre in the case-study locations.

Cropping Patterns and Intensity

Crop intensities, in general, have increased in all the cases under study. In Bangladesh the respondents were asked about the changes in cropping patterns and the nature of the changes. After the installation of deep tube wells, in both cases, farmers shifted from traditional aus to irrigated boro high yielding variety (HYV). They also grew HYV aman rice. The change in cropping pattern was associated with the changes in sowing system (from broadcasting to transplanting), and increases in the use of fertilizer and modern agricultural tools.

Table 1. Indicators of agricultural productivity.

Country	System studied	Cropping intensity (%)	Rice yield/acre (kg)	Wheat yield/acre (kg)
Bangladesh	Intervention	190	2190	NA
	Nonintervention	200	2010	NA
India	Intervention	200	1872	NA
	Nonintervention	158	862	NA
Nepal	Intervention	209	704	319
	Nonintervention	251	1194	486
Pakistan	Intervention	49*	NA	925
	Nonintervention	NA	NA	NA
Sri Lanka	Intervention	NA	819	NA
	Nonintervention	NA	758	NA

Note: * Cropping intensity increased from 18 percent covering 44 ha in 1979 to 74 percent in 1988-89. Planned cropping intensity for 1988-89 was 126 percent.

NA = Not available

In India, in both cases, farmers put more emphasis on crops other than rice, such as tomato, chili, potato, and wheat. This is because these crops are more profitable and consume relatively less water than rice.

In Nepal and Sri Lanka there has been no significant change in the cropping pattern in the sense that rice remains a major crop in the project areas. However, cropping intensity has increased because of irrigation.

In Pakistan, increase in water supply has encouraged the production of vegetables and fodder in the project area coupled with the production of wheat which is the major crop.

In Bangladesh and Nepal the cropping intensity is higher in the nonintervention case than in the intervention case. In India, it is the reverse. In Pakistan the cropping intensity increased from 18 percent in 1979 to about 74 percent in 1989 in the intervention case. Data for the nonintervention case in Pakistan are not available.

Production/Yield

In Bangladesh, the area chosen for the case studies is one with the highest yield of rice per acre in the country. In both the case studies, the yields per acre are well above the national average.

In India, the yield is high for the intervention case compared to the nonintervention case. In the nonintervention case the farmers cultivate a package of crops which yield low return. Consequently, the gross income of farmers from crop production in the area is comparatively lower. The farmers there do some non-crop activities such as livestock rearing.

In Nepal too, the difference between yields in intervention and nonintervention cases is very high. In the nonintervention case, more emphasis is given to the high return crop of that area which is rice.

In Sri Lanka, the average yields of rice in both the cases were lower than those of the national level. There were a few cases where per acre yields of rice were very high (compared with very low return for some households).

In Pakistan, per acre yield of wheat in the intervention case is well above the national average.

FARMER PARTICIPATION IN THE DESIGN PROCESS OF SMALL-SCALE IRRIGATION

In the formulation of small-scale irrigation projects in most countries of the world a great deal of attention is given to the technical aspects. Irrigation planners and designers make a number of decisions on the basis of certain assumptions and choices. These decisions have direct or indirect political, socioeconomic, and cultural consequences. As a result, many small-scale irrigation projects of sound technical design might fail to meet political and socioeconomic goals. The interaction among planning, design, management, and socioeconomic consequences should be

considered by both irrigation engineers and social scientists. Therefore, interdisciplinary irrigation research is a prerequisite for developing comprehensive guidelines for all types of irrigation schemes; large, medium, and small.

The five country studies in South Asia bring a mixed picture of farmers' participation and the use of local information and skill in the planning and management of small-scale irrigation projects.

Table 2. Participation of the farmers in irrigation water managements.

	Bangladesh		India		Pakistan		Nepal		Sri Lanka	
	I	NI	I	NI	I	NI	I	NI	I	NI
A. Participation of farmers in the design process										
1. Preliminary idea	H	L	L	L	-	M	-	L	M	H
2. Land/water resources inventory	L	-	-	-	-	M	-	L	M	M
3. Preliminary plan	M	M	-	-	L	M	L	H	-	H
4. Feasibility study	M	-	M	M	L	H	-	H	L	M
5. Design										
Hydraulic design	L	-	-	-	-	M	-	M	L	M
Building structure	M	M	-	-	-	M	-	L	L	H
Operation	H	H	-	M	-	H	-	H	L	H
Training of staff	M	-	M	-	-	M	-	-	-	-
B. Farmer management										
1. Use of local information by designer	H	M	L	L	L	M	L	L	L	M
2. Use of local skill by designer	H	H	L	L	-	M	-	H	L	H
3. Users' group formation	H	H	-	-	-	H	-	-	L	H
4. Operation of system	H	-	-	M	-	H	-	H	L	H
5. Repair and maintenance	H	H	-	M	-	M	-	H	L	H
C. Manifestation of design fault										
1. Conflicts among farmers	-	-	L	L	H	-	H	-	M	-
2. Head- versus tail-end inequality	-	-	M	M	H	L	H	-	L	-
3. Marginalization	-	-	-	-	M	-	M	-	-	-
4. Underutilization of system	M	M	-	-	H	-	M	L	M	M

Notes: I = Intervention scheme

NI = Nonintervention scheme

H = High M = Medium L = Low

Table 2 shows a matrix of various important aspects of irrigation water management. The design issues play a crucial role in the success of small-scale irrigation systems. The participation of farmers in the process of design has been divided into five major components (A1-A5), and the participation of farmers in each component has been indicated for each country. Out of the available information for 28 cases for the first four components (A1-A4), only in 6 cases (21 percent) is the farmers' participation high; in about 12 cases (43 percent) it is medium, and in 10 cases (36 percent) the participation is low. If the actual design process (A5) is taken, out of 21 available cases, the farmers' participation is high only in 6 cases (28 percent), and the figure for medium is 10 (48 percent) and for low it is 5 (24 percent). It should be pointed out that many of the blocks in this component are empty implying insufficient information on farmers' participation.

An important issue related to the design process is participation by the farmers in the operation and maintenance of the irrigation facilities. Five major components (B1-B5) have been identified under this and the situations in countries have been depicted in part B of Table 2. Out of 36 cases reported, 17 cases (47 percent) have high incidence of farmer management; seven cases (19 percent) have medium incidence, and the remaining 12 cases (34 percent) have low incidence. The nonintervention schemes performed well in this respect because out of 17 high instances of farmer participation, 12 are for nonintervention schemes. All the 7 medium-incidence cases fall under the nonintervention schemes. Even in the management aspect where farmer participation should have been overwhelmingly high, we observe a low incidence of their participation. Though information on some likely results of design fault is not readily available, we attempted to indicate those in the third broad category of our matrix (C1-C4). Out of the 20 cases reported here, in five cases (25 percent) the incidence of design fault is high; in ten cases (50 percent) it is medium and in five cases (25 percent) the manifestation of fault is low. Due to lack of interaction among the design, implementation, and operation and management issues and due to lack of farmer participation in all phases of water management in small-scale irrigation in the five countries, there has been less impact on the rural poor than envisaged or expected.

CONCLUSION

The evidence presented in the paper relating to the case studies of small-scale irrigation in five South Asian nations somewhat supports our hypothesis: that the impact of small-scale irrigation on the rural poor will be high if local information, knowledge, skill, and commitment are blended in the design and management processes of small-scale irrigation systems; and that there is a need to design small-scale irrigation to reduce dependency of the system on an external agency. A participatory design process should be adopted by the agency responsible for implementation of a project. Intervention by a government agency or nongovernment organization should be accompanied by organizational/institutional development at the local level. What is needed most in the design stage, to use the language of computer technology, is the "user-friendly" design.

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