CHAPTER 3

Suggestions for the Design Process[2]

Much of the success and failure of irrigation development depends upon getting the technical design process right. This includes selecting the right structure to capture and control the water supply, providing effective channels to convey and distribute water and, finally, the disposal of any drainage. Effective physical structures, whether temporary or permanent, are essential for system operation. However, structures alone are not enough. Irrigation is generally not possible without defining water rights and preparing and implementing appropriate rules and plans for operation and maintenance.

The design process in irrigation development has traditionally been the domain of the civil engineer. Hydraulic and physical design principles are applied in getting water from a supply source to the root zone of plants. Obvious information essential for carrying out the design process includes the crop water requirement, expected moisture contribution from rainfall, losses by evaporation and seepage, historical variations in the available water supply, etc. Less obvious and frequently neglected is information about water rights among systems, water allocation within the system, and the development of rules and plans for operation and maintenance.

A number of the citations in the bibliography discuss elements of the irrigation design process. Among them, Coward et al. 1988 and WECS/IIMI 1990 are particularly relevant. The brief discussion here draws attention to several important questions that must be answered before proceeding with the selection of a specific design: To what level of durability should it be built? Who will manage and pay for the cost of operation and maintenance? What skills and resources will be available? How can the technical design process be modified to emphasize the relationship to operation and maintenance plans and rules?

SUSTAINABILITY

In the abstract, design can serve many purposes. Design can be for function; it can be for durability; it can be for form, elegance, or professional pride. But perhaps one of the most neglected dimensions of design in irrigation systems has been the concept of designing for sustainability. This is particularly apparent in the design of irrigation structures in mountainous environments. The concept of sustainability assumes particular importance where transportation and communication may be rudimentary, where heavy reliance may be placed upon the mobilization of local resources for maintenance and operations, and where cost and value must be expressed in local, not national terms.

Designing for sustainability does not necessarily mean designing for permanence. Whether the structure lasts for one season or for a thousand years is independent of the concept of sustainability. Sustainability in the context of hill irrigation refers to the ability to mobilize resources to meet expected needs on a continuing basis to keep the system operating within tolerable limits.

From the point of view of an agency with the mandate to assist a myriad of small irrigation systems found in the hills of Asia, designing to keep initial costs low is vital. Most programs have limited resources and the program will not be sustainable if

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[2] Dr. John Ambler, Program Officer, the Ford Foundation, New Delhi, India made a substantial contribution to this chapter.

each individual structure absorbs too much of the available money. More important with regard to the overall effectiveness of such a program is the sustainability of the improvements made with the funds provided. Conventional wisdom generally has been to design for permanence. However, many structures in mountain systems are in high risk situations and the objective of spreading the high initial cost of a structure over many years of successful operation is often not realized.

Instead of making permanence or longevity a goal in itself, the objective must be to design structures in such a way that there is a high probability that resources can continue to be mobilized from various sources for the future operation of the system. Work needs to be done in finding better ways of factoring the probability of failure and cost of expected maintenance and rebuilding into the evaluation of alternative design options.

The sustainability issue starts from the engineering side. Will a particular design produce a structure that will work, that will do the things it is designed to do? If the answer is "yes," then the design has fulfilled the *effectiveness* criterion. The design may not be the most efficient one, but at least it is an effective design.

For the *efficiency* criterion, one must decide on the units of input and output. While it might be more comfortable to concentrate on the engineering efficiency (for example, lining the main canal to reduce leakage losses), without dealing with the economic efficiency of the design, it is in the area of costs that the sustainability issue demands attention.

COST-EFFECTIVE DESIGN

At what cost will the design be effective? Some deterioration in government-built and government-financed irrigation structures can be traced not to farmers' failure to grasp the importance of maintenance or any presumed lack of civic consciousness, but to the cold economic calculations farmers make as to how much benefit they will get out of keeping the structure at various stages of repair. Farmers allow some structures to collapse because they serve little or no function, others they keep repaired to a level commensurate with their contribution to the system. When the structure is overbuilt in the first place, the engineer will be annoyed to find that the farmers do not keep it in "good repair."

A cost-effective design takes into account four types of costs: 1) initial construction costs, 2) recurrent maintenance costs, 3) rehabilitation or replacement costs, and 4) costs to life or property if the structure fails. Structures that are designed to fail, as for example, those that have controlled breaching sections, may actually greatly reduce the risk to life and property or the risk of major repair, by allowing minor damage to prevent massive buildup of pressure and subsequent major damage.

To produce a cost-effective design, i.e., a design that serves the intended purposes and is not overbuilt, requires some system of incentives to seek a low-cost design. These incentives can come from: 1) some compulsory investment from the farmers (even if a high or very-high portion of the total costs are provided by the government), 2) a budget ceiling for the structure, and 3) an accounting system open to public inspection to give users confidence in the implementation process.

Requiring investment or contributions from the farmers for constructions gives them incentive to help control the cost of structures. Such investment also shows that the farmers are serious about the need for the structure and that they have a commitment to make the system work. If the government pays all the costs, it owns the structure, and there is a feeling that it is entirely the government's responsibility to maintain it.

When farmers invest in a structure they need to decide on investment rules. This forces the farmers to decide on how to mobilize resources. Will the amount of investment be according to the land area, according to the water share, according to the size of the household, or according to some other rule? Clear investment rules, in turn, create clear property rights in water and the structures to acquire, convey, and distribute it. These rights, in turn, create maintenance obligations that farmers must bear to keep the system running. Performing the maintenance responsibilities over time serves as a mechanism by which farmers maintain water rights within a system.

AVAILABLE RESOURCES

Who will mobilize what type and amount of resources, and according to what rules, is an important part of the sustainability concept. To answer this properly, resources need to be desegregated by type. Following the imperative to reduce all values to common units, economics often fails to distinguish between different types of resources. In mountain irrigation design, construction and maintenance, these different resources usually take the form of cash, materials, labor and information.

Cash

Cash is often in short supply in subsistence-oriented mountain communities. The time needed to mobilize cash for making repairs in an irrigation system may be greater than the time needed to mobilize an equal or even greater value of resources in other forms. Delays, especially in remote areas, mean production losses. An efficient design is one that helps to reduce the downtime of the system, i.e., a design that reduces the time it takes for resources to be mobilized to keep the system in working order at critical times in the crop season. In subsistence economies, low-cash needs may be one important element of an efficient design.

Materials

A process that seeks to produce an efficient design should also consider the use of local materials. However, it is also important to understand the nature of the *present* and *future* availability of these local resources. For example, wood may have been an important material in irrigation structures of the past, but depletion of forest reserves or restrictions on access to forest products may determine whether wood should be used in new structures. Frequently, however, designers underestimate the costs of importing other materials. For example, calculating the cost of cement and its transportation is a routine exercise, but the true cost of sand, which is often not available at the site for building structures in hill irrigation systems, is easily underestimated because it is assumed to be locally available and, therefore, free.

Labor

Labor is often assumed to be the most plentiful local resource for the construction and maintenance of hill irrigation systems. In many cases this may be true, but in a great many, labor is in short supply. Labor migration, circular or seasonal, is a common feature in highland areas, and labor may not be available at the right time to operate and maintain poorly designed irrigation systems.

Design needs to take into account the realities of labor availability. For example, can the structures be repaired by women, or by children if men migrate for seasonal jobs elsewhere? Do they ever need to operated at night? Can this be done by men, women or children? What if the structures are located far from the hamlet? Is it too dangerous to go out at night if paths or canal bunds are slippery or wild animals are a threat? Is it socially unacceptable for women to go out at night? Or has the design implicitly assumed that the able-bodied males will always be available under all circumstances to take care of the structure?

Precisely because labor is sometimes in short supply or because dangerous conditions exist in mountainous areas, farmers often choose designs that function with minimal direct management, even at the cost of some reduction in engineering effectiveness or efficiency. Design must incorporate demographic and dangerous realities if it hopes to achieve efficient use of local labor resources.

Local Knowledge

A valuable resource for developing irrigation is the knowledge and experience of present and would-be irrigators in the community. While some areas may not have established irrigation systems, the information available from many that do has been underutilized. Engineers are not trained to examine and improve traditional technology. Often, the facilities that farmers have built are not recognized as irrigation systems. If field investigation is done during the dry season when water is not available for irrigation, farmer systems may not be in use and therefore may go unnoticed.

The first step in the design process should be a careful assessment of all irrigation facilities that exist, determination of the experience irrigators have with system management, and evaluation of all other locally available resources. A useful question guide that can be used as a checklist for making such an assessment is given in Pradhan, et al. 1988. Recent work with participatory rural appraisal (PRA) has evolved even better procedures for making the knowledge and experience of rural people accessible (see, for example, Thompson 1990 and IIED 1991).

Adapting PRA for irrigation design data collection holds great promise. The premise of PRA is that local people know their area and activities best. PRA is a process using many different tools that enable local people to describe their environment. For example, rural people can make a map of their village or irrigation system; they may not be able to use pen and paper to do this but can use sticks, stones, cigarette packets, tree leaves, and colored sand to create a map on the ground. Local people can prepare seasonal calendars of irrigation activities, descriptions of management roles, histories of relative stream discharge, inventories of maintenance material, traditional management practices, etc. By developing a profile of local conditions, the availability of skills, experience and knowledge will merge together with technologies that have been successful.

This profile, together with information about the agencies' capacity to manage irrigation systems, budgeting procedures and access to the site, can be used to make a decision about management of structures to be built in future and about who will pay the cost of operation and maintenance. Determination of who will actually manage the system and pay the costs is essential because it helps define the level of technical expertise available and access to external resources.

The technology used for a structure has implications for the organizational arrangements needed to operate and maintain that structure. To some extent, organizational arrangements can be replaced with technical devices and vice versa. Hence, knowing who will manage operation and maintenance is an important factor in selecting among alternative designs because it will determine the complexity that can be managed and the type of material and supplies needed for maintenance. It will also influence the rules and plans for operation.

IRRIGATORS' GOALS

At the system level, of course, the designer must understand what the irrigating enterprise in a particular system is all about; whether the people are irrigating for cash-crop production or for subsistence production, for grain or for fodder, for high yield or for high coverage, etc. PRA can help here as well.

In designing for local management, do we outsiders have sufficient knowledge about not only *how* the system is likely to be managed, but also *for what goals*? The "how" refers to the rules and roles for the operation and maintenance of the system: Who does what? According to what rules? Are the rules designed to deal with averages or with extremes?

If we follow the theory that fine-tuning in rules and roles is designed to help systems deal with crises, then the design of irrigation structures should help the irrigators deal with extreme situations, not with the average situation. In many hill systems, the gabion structure is an example of a structure that is poorly suited to dealing with extremes—when water supply is low, it leaks (just when the farmers need it not to leak), during floods it gets shifted downstream or gets washed away. In other cases, structures may be specifically designed to leak as a way of enforcing water distribution between units during times of low flows. The designer has to be aware of the different goals irrigators may have for each structure. Putting it all together means that a good design combines engineering effectiveness with economic efficiency and social feasibility.

USER PARTNERSHIP IN DESIGN

Farmers are not trained engineers and should not be responsible for overall technical design decisions. However, they can be effective partners with agency staff in the design process if they are given useful information in language they understand. Because of their intimate familiarity with local conditions, farmers can help designers avoid costly mistakes. For example, they can provide useful input into the general layout of canals and turnouts. They can also negotiate the right-of-way for canals.

For farmers to participate effectively in the design process, they need to be treated as intellectual equals. Site investigation for design is too often made by technical staff with local people being treated as curious onlookers. Lacking empowerment, sometimes illiterate, and seldom able to communicate in anglicized engineering terms and dimensions used by the technical staff, they are easily dismissed. For example, discussion about placement of an escape structure may not be understood by hill farmers until construction brings form to abstract terms; then it is too late to incorporate important suggestions. Most irrigation systems built by local people have ingenious, well-placed escape structures. The materials used may make the structure look primitive but the function is clearly understood by the users. The challenge for agency technical staff is to identify such structures and the language, skills, materials, etc., used in their creation, operation and maintenance and then to capitalize on local understanding of problems with the structures to develop improved designs.

One step in empowering local people is to help them organize. Assisting farmers in organizing water-user groups and an association at the irrigation-system level is recognized as an important step in participatory irrigation management. Social organizers are frequently used to assist farmers in this process. For detailed examples and discussion on the role of social organizers in a number of countries see Manor et al. 1990 and Uphoff 1991.

One word of caution about assisting farmers in forming user groups is in order. In many cases, informal groups, i.e., persons with a common cause working together in a loosely structured fashion, already exist. While they may be informal in their ties to the world beyond the local community, frequently within the community they have recognized legitimate authority. Ignoring the existing structure by requiring a prescribed organizational format may reduce rather than increase local participation. The local situation must be understood before taking action or prescribing solutions. Again the PRA methods described above are a useful tool in this process.

PHYSICAL AND HYDROLOGIC DATA

Design problems sometimes arise because information-intensive design procedures are used when such information is typically unavailable. Collection and analysis of design information constitute one bane of effective engineering design for mountainous areas. Measured time series data on discharge are seldom available. The information problem is further complicated by the physical difficulty in collecting it in rough terrain for small command areas. Therefore, approximations and assumptions are made in order to use standard methods for calculation. Several suggestions have been made to deal with this (Coward et al. 1988).

One suggestion is to tap the knowledge of local people by having them become partners in the design as already mentioned above. Another suggestion is that under conditions of insufficient data, the design staff should concentrate on structural improvements that are essential to good system performance but less sensitive to inadequate data. For example, in a small, steep-gradient mountain stream prone to flash floods, it may not be possible to design a reliable, permanent diversion weir using existing flood data. A low-cost temporary diversion may be best until further information is available. However, it would be possible to prepare a reliable design for the accompanying control structure to limit the entry of flood water into the canal. Recognition of limitations allows concentration of design on structures less sensitive to data limitations while monitoring possible improvements. Using a temporary diversion structure with the view of replacing it after collecting the necessary data is an incremental approach to design that compensates for poor or missing data. This approach can be applied only in cases where it is planned that the designer will maintain contact with the system, after it becomes operational, and can introduce some elements of enhancement or redesign in the light of the first seasons of operating experience. Such a continuing relationship is highly desirable as a way of dealing with situations of deficient data.

DECIDING AMONG ALTERNATIVES

When irrigators are partners in the design process they need to have a voice in selecting among design alternatives. This is particularly true if the irrigators are to take responsibility for maintenance. There must be considerable dialogue between the technical design team and the farmers. This means frequent visits to the field and doing more of the design work in the field. Field design helps overcome the problem of designs not "fitting" the local situation and farmers removing or modifying the structure before operation of the system is possible.

One source of frustration for technical staff is that farmers do not have experience with interpreting drawings on paper or discussing them in the abstract. A suggestion for overcoming this handicap is to use a three-dimensional scale model made of wood or styrofoam to give farmers a visual impression of how the structures would look (Yoder and Thurston 1990). Another option is to take groups of farmers on tours of systems that are in operation to see and discuss with other farmers the benefits and limitations of each type of structure (WECS/IIMI 1990).

Agency design staff need to recognize that while they usually present the process of design as "technical" decisions it is also a process that incorporates many personal and professional preferences. The end result may be more of a negotiated design rather than a technically imposed one (Coward et al. 1988).

LEARNING-ORIENTED DESIGN PROCESS

In many irrigation agencies, persons who design structures are seldom directly involved in their construction. Perhaps it is even more unfortunate that the design and construction staff seldom have any responsibility in operating and maintaining irrigation systems. To improve the design and performance of irrigation structures it is essential to get systematic feed-back on the performance of those already built.

One way to accomplish this is to establish a program where the design staff visit and provide back-up support each year for at least some of the structures that they design. They should visit the field while the structures are in use to observe operation and maintenance, discussing with farmers and agency staff the good and the bad characteristics. They should examine modifications that may have been made in the design with the view of understanding why changes were desired. By incorporating this information into their design manual, incremental improvements can be incorporated in the design process and past mistakes avoided. Recognition or reward of design staff who document design changes based on field observation would help in implementing such a plan.