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A REVIEW AND AN ANNOTATED BIBLIOGRAPHY
OF STUDIES REGARDING IRRIGATION INSTITUTIONS,
MANAGEMENT AND INVESTMENT IN ASIA

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PREFACE

This report is part of the work done by the University of Minnesota and Colorado State University for the U.S. Agency for International Development under the Cooperative Agreement for Economic Planning and Policy Analysis for Irrigation. The studies have been concentrated in Asia and North Africa with special emphasis on South India, Northeastern Thailand, Egypt, and Pakistan. The work in Thailand and India is focusing on small scale irrigation while that in Egypt and Pakistan is concerned with large scale projects.

A number of individuals have been involved in putting together this review of literature. Dennis Ellingson and Sherin Sherif did the bulk of the work in searching the literature. Delane Welsch was very helpful in identifying literature and reviewing the paper.

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I. INTRODUCTION

Irrigation development is a complex endeavor. Problems and trade-offs arise at every stage of development and must be dealt with if funds appropriated for such projects are to be utilized effectively. Probably the most difficult of these problems is the trade-off between the efficiency with which resources are used and the distributional equity of benefits derived from such development. Efficient resource allocation is the use and allocation of resources in such a way as to produce a given set of goods at the least possible cost or that the marginal benefits per dollar of cost are equal across all activities. The desire of societies to redistribute income in favor of the poor often conflicts with the desire to maximize efficiency because the goals of economic efficiency and equity are often competitive and their simultaneous solution involves compromises or trade-offs between these objectives.

One of the few cases in which the goals of efficiency and equity are not in conflict is when the irrigated farms are of about the same size and on the average are able to support a reasonably sized family. On the other hand, in cases where land holdings in the area irrigated are large or there is a great variance in size of land holdings; these two goals are competitive. In the latter case, changes in tenure and ownership would have to occur before the irrigation system is started. Otherwise the equity goal would not likely be reached regardless of the management efficiency of the system. This trade-off between equity and efficiency is a problem that must be dealt with in the planning and design stage of the project as well as the operative stage. Specific objectives defining the scope of the project with regard to target population and productivity goals must be consistent and within feasible bounds.

For example, preventing crime and creating social and political stability in a particular society may depend on preserving a narrow distribution in the variation of income among the population. If an irrigation project is being contemplated then these considerations must be approached in the initial planning stage of the project and dealt with throughout the viable life of the scheme. Planners must consider the long and short run effects of the trade-off between efficiency and equity when deciding on the design of the project with regard to scale and type of system. The institutional arrangements and water allocation at every level from the water source to the farm also affect the trade-off between equity and efficiency and must be taken into consideration during the planning stage of each individual project. Once the project is operative, the same concerns are relevant and must be dealt with, although the task will be simplified if the problem was anticipated in the design stage. Finally, the effects that such development will have on society in the long run must be considered because capital, which always has alternative uses, will be tied up in the project for a long time.

This paper contains an annotated bibliography of studies pertaining to the problems associated with irrigation project development and implementation in South and Southeast Asia. Many of the articles found in the bibliography are also reviewed in the text of this paper. The text of the paper is divided into three separate sections. In the first section methods of water allocation are approached at three levels: 1) water source allocation, 2) transmission allocation, and 3) farm allocation. In the second section institutional and managerial arrangements for irrigation projects are presented at three levels: 1) national institutions involved with water resources, 2) institutions involved with the distribution of water, and 3) institutions involved with the distribution of irrigation benefits. The last section of the paper will deal with alternative investments in irrigation development where the discussion will be devoted to two questions.

(1) expansion vs. intensification, and (2) large projects vs. small projects.

II. WATER ALLOCATION

"There are generally three levels that should be considered in water allocation: (1) the water source (reservoir, river, or well), (2) the transmission of water to the farmer's fields, and (3) the allocation among farmers. Each level can be important in the success or failure of a project. What happens at one level may well limit what is possible at the others" (Easter, 1980).

Water allocation methods should be designed to fit the culture and the operational abilities of the farmers and may require special organizations and institutional arrangements. In addition, the allocation procedures should fit the design of the irrigation systems as well as the water supply conditions and the character of the production systems. In this section, selected articles are reviewed to gain an understanding of the issues involved in water allocation and what has been learned about the issue.

A. Water Source Allocation

A number of problems arise with regard to the allocation of irrigation water from its source. One such problem involves the allocation of water over time, both within a season and between seasons. According to Easter (1980), "Water in a reservoir or a groundwater aquifer represents a source of income generation in the current period as well as in future years. Evaporation losses impose a penalty on water stored in reservoirs for future use, encouraging large releases as does the existence of a discount rate. In contrast, the diminishing productivity of water and the uncertainty of next year's water supply both encourage water storage" (Easter, 1980, p 9) This problem has been dealt with by Cummings (1974) in his case study in Mexico but has been largely neglected in the literature in Asia. Similar research is needed in other parts of the world.

Another question concerns the allocation of water among different

uses. For example, if water is withdrawn for irrigation, what does this do to downstream users? Again, this area has been largely neglected in the literature of South and Southeast Asia although it is dealt with in the U.S. and Spain (Maass and Anderson, 1978). Kelso, et. al. (1973) also address this problem in their case study in Arizona where they consider the value of water in alternative uses, i.e., industrial, commercial, etc.

Finally, with regard to source allocation, what procedures can lead to an economically efficient allocation of groundwater and surface water supplies? Maass and Anderson (1978) studied the conjunctive water distribution to farms in the Kings River Service Area of Central California.^{1/} There, surface water prices are kept low as long as there is an adequate river flow. When surface water supplies drop, the price for the surface water is raised above the marginal cost of pumping. Young (1970) and Bredehoeft and Young (1970) used mathematical programming and simulation techniques to model the release of groundwater from aquifers. Their models could provide valuable insights into the question associated with conjunctive water management problems found in Asia. Burt (1963) derived an inventory model for the optimal management of water over time, under conditions of conjunctive use of ground and surface water. His model derives from a study of the same area in California that Maass and Anderson studied. Although these are studies of great significance, similar works are needed in Asia to adapt this knowledge to the specific resource and cultural situations that are found there.

B. Transmission Allocation

Water losses are often very high during transmission. The seepage of water through the banks of transmission canals accounts for most of the loss. If water is being transmitted over a vast area this problem of

^{1/} Conjunctive water use is the joint use of both surface and ground water.

water losses is aggravated. Therefore, an important question in transmission is how large an area should be served. This question involves a trade-off between the efficiency and equity of the system. The larger the area served, the more farmers that will receive water, provided farm unit size remains the same. However, a larger area will mean greater water losses during transmission. The key question is, "What is the cost in foregone income from expanding a command area and what are the improvements in income distribution?" The literature seems to avoid the issue.

An alternative that would allow expansion of the command area without taking water away from current uses is research devised to reduce water losses. Singh and Bhargava (1977) emphasize the need for conservation of run-off water during periods of heavy rainfall. They suggest the construction of small reservoirs with devices to slow evaporation as a possible solution to this problem. Chambers (1978) also recognizes the need for conservation and proposes research into devices that will reduce the evaporation from open bodies of water. Such devices include windbreaks, shade, vegetation and chemical films.

Another way of reducing water losses is through the lining or partial lining of canals. Gupta, et. al. (1973), studied several cases in India where there had been a change from ordinary canals to concrete lined ones. They found that such changes reduced water losses due to seepage and evaporation and also increased the cropping intensity because of the newly assured supply of irrigation water to a larger area. Hafid and Hayami (1979) discovered similar results to canal lining in the rehabilitation of the Subsidi Desa scheme in Indonesia. There is no doubt that lined canals will reduce the variability and uncertainty of the water supply. The question is: How much do these improvements add to the costs of providing

water and what are the benefits? Often, these are cheaper alternatives than complete concrete canal lining. One possibility is partial lining of the canals. Another is lining the canals with materials that are cheaper than concrete. Johnson, et. al. (1978), evaluated several methods of watercourse improvement including concrete and masonry linings and simple earthen improvements of the ditches with concrete control structures, junctions and turnouts. They found that the earthen improvements and installation of concrete control structures were the best investments in Pakistan with its low labor costs. Similar studies should be done in other situations with different soils, water availability and costs to determine specific needs with regard to lining the irrigation canals.

Probably the cheapest method of reducing transmission losses, where labor costs are low, is by proper and timely maintenance of the canals. Sparling (1981) approaches the problem of irrigation canal maintenance as a collective goods problem. This is due to the externality created by poor maintenance by farmers on the upper end of the canal. Farmers situated at these preferred positions on the canal have little incentive to maintain their portion of the canal if they are receiving enough water. This 'self serving' behavior compounds the problem of water losses which are associated with canal maintenance and the distance which the water must travel. Therefore, farmers situated at the lower end of a canal will receive less water because of poor maintenance and intervening farmers.

Sparling also demonstrates the organizational difficulties of maintenance and provides theoretical arguments and empirical evidence in support of his proposition that the watercourse maintenance problem is the cause of divisiveness among Pakistani farmers. Johnson, et. al. (1978), cite inadequate organization of the users as the major reason for the lack of

maintenance and resulting losses. Lowdermilk, et. al. (1977), also believe that this problem can be alleviated by effectively organizing the users to maintain and improve their watercourses.

Overall, research in the area of transmission allocation of water in Asia is too limited. Additional research is needed to analyze canal lining under varying conditions of soil, climate and pricing. Also, much more is needed to determine the optimum size of command areas under varying conditions of water scarcity.

C. Farm Allocation

Maass and Anderson (1978) list five objectives of importance when deciding on how to allocate water at the farm level: equity, efficiency, growth, justice and local control. Water managers, farmers and politicians tend to weigh these objectives differently which oftens leads to conflict between these groups. One source of conflict arises with the method of water allocation used. Easter (1980) described eight of the more common methods of allocating water ranging from no formal allocation procedures, to actual markets where water users bid each period for water needed to irrigate their crops or buy water shares for future irrigation. Each method is discussed along with the conditions under which they are most applicable.

Malhotra (1980) has provided a comprehensive account of the Warabandi system of distributing irrigation waters. This is a rotation system of water distribution that originated in the northern states of India and has survived there for over a century as the predominate method of water allocation. In this system, the distribution of water released at the outlet is based on a seven day cycle. Farmers are allowed to draw water from the canal for given periods of time depending on the size of their holding. Each farmer along the canal is allocated a specific time period during the seven day cycle. At the end of the seven day period the

cycle starts anew. Malhotra feels that this system has proven to be the best available for areas where the holdings are small and supplies not only fall short of the demand, but are also uncertain and irregular.

Reidinger (1974) studied the same system and found a major problem with it. He discovered that this system prevents the distribution of water to areas of highest need because the reserved times of allocation are non-transferable among farmers. One possible way to resolve this inefficiency would be to sanction intra-watercourse markets which allow water trading to take place among farmers. Similar studies are needed to evaluate the other methods of allocating water. Findings from each can be used to formulate models that will satisfy the objectives and lessen the conflict between groups affected by the allocation of water.

A number of authors, Patel (1977), Neghassi and Seagraves (1978), Doppler (1977), Easter (1980), Dhawan (1974), Asopa (1977), Tagarino (1977), and Torres (1973), defend the need for water charges to meet the objectives set forth by the government or agency in charge of the irrigation scheme's implementation and operation. Torres found that underpricing irrigation water results in the capitalization of irrigation benefits into land values that mainly benefits landowners. Dhawan contends that underpricing leads to uncertainty with regard to water supply and results in the under-utilization of water even when available. Although this seems contradictory to what one might expect, it occurs when underpricing leads to the overuse of water at the upper reaches of the canal. During times of scarcity the supply is depleted before it reaches users at the end of the canal. The net result is that even during times of abundance, tail-end farmers who have learned to expect a shortage will hesitate before investing in crop inputs because of their past experience with uncertainty in water supply.

Easter (1980) provides six methods by which water charges can be levied to cover the fixed and variable costs of the system: (1) direct charges based on measured volume of water, (2) direct charges per share of the stream or canal flow, or per irrigation, (3) direct charge per acre irrigated, (4) indirect charge on crop outputs marketed or on inputs purchased such as fertilizer, (5) development rebate or promotional water charges, and (6) a general land or property tax. Which method should be used will depend on the value of the water, dependability of supply, ability to control the flow, desires to subsidize agriculture, tradition of ownership, types and patterns of cropping, return flows, drainage problems, staff training information available, etc.

Two specific areas in which research should be devoted would be that patterned after Maass and Anderson's (1978) studies in Spain and the U.S. where they evaluate water allocation changes as water conditions change from year to year. In the same study they analyzed changes in water allocation procedures as farmers adopted new, more complex, methods for allocating water.

III. INSTITUTIONAL AND MANAGERIAL ARRANGEMENTS

Institutions are considered at three levels: (1) the national level--organizational structures, such as a ministry of irrigation or national planning authority, (2) the distribution of water--organizational structures that deal with the distribution of irrigation water and the maintenance of the irrigation systems, i.e., a water users' association, (3) the distribution of benefits--institutions that directly affect the distribution of benefits, i.e., water rights, tenure.

At all three levels there are problems relative to the effects that institutions and management arrangements have on the efficiency and equity

question of irrigation projects. Bromley, et. al. (1980), suggest five general principles for institutional design from Rawls's, A Theory of Justice, as guidelines for dealing with this problem. These five principles are: (1) compatible liberty--each participant in the irrigation system should possess an equal right to the most extensive liberty compatible with similar liberty for others, (2) knowledge and participation--any institutional system must be widely understood by all of the participants, (3) shared concept of justice--there must be a shared concept of what is just and what is unjust, (4) formal system of justice--there must exist a system of formal justice in which there is impartial and consistent administration of the rules, (5) rational rules--rules should be designed so that the predominant self-interests of individuals leads people to act in ways which further desirable social ends.

A. National Institutions

One important question with regard to institutions at the national level is: How should authority over water project formulation and implementation be delegated? A number of authors, Abel (1976), Hutapea, et. al. (1976), and Thornton (1975) have found that the most efficient form of administration was that where all the development activities within an irrigation project were coordinated by a single institution. In cases where separate institutions exist whose authorities overlap, i.e., a department of irrigation and department of agriculture, conflicts arise and blame is placed on one for shortfalls perceived by the other. Delegation of responsibilities is a source of more conflict between two such departments. According to the authors mentioned above, to eliminate problems in cases where both departments exist, one overseeing agricultural activities and one concerned with irrigation, they should be combined. Abel (1976) takes this finding one step farther in his contention that the

efficiency of irrigation systems management in Taiwan depends on the legal administrative basis for centralized planning of irrigation investments but decentralized management of irrigation systems. He also states that the recognition that water is a scarce factor in agricultural production is a factor influencing the efficiency of irrigation systems management. Therefore, irrigation development should be given high national priority.

All of the authors mentioned in this section on national institutions and their role in irrigation project design and management concur that there is a crucial need for a central planning and evaluation group. This group must confront the efficiency-equity trade-off in the initial planning stage of any project, decide upon their priorities with regard to this question and implement them in the design of the project.

B. Distribution of Water .

It is widely agreed that effective organization and management of irrigation systems by water user organizations is necessary for the efficient and equitable distribution of irrigation waters (Abel, 1976; Andreou, 1979; Bottrall, 1977 and 1981; Oh, 1978; Nickum, 1977). The question is how to establish effective user organizations to meet the objectives of the project planners and at the same time be adaptable to local conditions.

Bottrall (1981) provides an analytical framework for monitoring and evaluating irrigation project management in developing countries. He has taken the inequities of water distribution into account in the development of this framework and recommended organizational structures and management procedures which will benefit the poorest people in the irrigated areas.

Bottrall (1977) provides a description of the decentralized approach to irrigation administration followed by the Irrigation Associations of

Taiwan. With this system much of the responsibility for decisions about water allocation and system maintenance is delegated to the users themselves. Although this is an institution that was developed in a specific environment and is not widely applicable, Bottrall feels that the knowledge gained from the sequence of developments that took place in Taiwan may be useful in devising such successful water user associations elsewhere. One of the conditions under which these associations were developed in Taiwan was that of strict enforcement. At the time of their implementation, Taiwan was subject to colonial rule by Japan. User associations were implemented by official decree and their rules were enforced by police power. Although this is a condition that is difficult to find today and may be undesirable to emulate, it does not rule out the possibility of using the Taiwan example to pattern one's user cooperatives after. It does, however, point out that without strict control, farmer associations can probably be attained only in areas that have a history of successful cooperative organizations, such as in Gujarat, India and parts of the U.S.

De los Reyes (1981) conducted a study on the organization and management of Philippine communal gravity irrigation systems. He discovered that the nature of groupings which farmers adopt, and the ways in which they carry out system management, vary with system size. The smaller the system, the more loosely organized will be the organization managing it. He also discovered that methods of management vary with system size. Allocative procedures and systems maintenance are greater tasks for larger schemes. Therefore, more complex methods are required to handle these tasks in larger irrigation systems.

Another question which is often asked is: Are the incentives for both the managers of the irrigation systems and the farmers compatible with

the efficient and equitable allocation of water within the irrigation system both in the short run and the long run? Abel (1976) concluded from his study of canal irrigation systems in Taiwan that one of the main factors upon which the efficiency of these irrigation systems depended was the use of incentive structures for both the managers of irrigation systems and the users of water. In Taiwan's case the irrigation associations are made up of the farmers who operate the irrigation system themselves. Until recently the irrigation associations can hire and fire managers at their discretion. As a result of this relationship, good managers are usually rewarded whereas poor managers are penalized. This adds to their management efficiency which results in more consistent availability of water for irrigation. This, in turn, enhances the users' willingness to pay any water charges that are due and to contribute labor to the maintenance of the system.

Hutapea, et. al. (1976), reviewed the historical development of four farm level irrigation management systems in Indonesia. They found one of the factors which influenced the effectiveness of farm level irrigation services is the nature of village values and leadership and the extent of economic and social disparity within villages. They discovered that local organizations in communities with wide economic and social disparities were less effective. It seems that in those cases there is a danger of conflicts of interest among village leaders who seek to improve their personal welfare at the expense of the community. He suggests that to attenuate some of these problems local officials should be elected rather than appointed. Also, they should be paid by means other than compensation from the harvest of village owned land. According to Abel (1976), they should be paid directly by the farmers who receive the water and this payment should depend on the quality of service received.

Coward (1977) discusses irrigation management alternatives based on cases of indigenous irrigation systems that exist around the world. He found several factors common to successful management organization. One factor which is often a problem with developing organization for the terminal unit is identifying and maintaining adequate leaders. According to Coward, the similarities of traditional irrigation leaders are that they serve relatively small groups of water users. Secondly, they are selected by the local group which they serve. Finally, they receive compensation directly from the group members they serve. A second factor which he found common to successful indigenous organizations was the fact that many of these small systems were further divided into smaller sub-units with their own set of local leaders to operate the system at this level. Finally, Coward found that irrigation associations in these indigenous systems were established along the lines of the irrigation community which is not necessarily one and the same with the village community. Hutapea, et. al. (1976), also found that command areas often do not coincide with village boundaries because of topographical features. In those cases where these boundaries do coincide, irrigation systems are easier to manage and conflicts are less likely. Therefore, it appears optimal to establish irrigator groups along boundaries so that their jurisdiction approaches that of village government and the command area as nearly as possible.

Finally, there is the question: How do local water distribution and maintenance institutions or lack of them affect water use efficiency and equity? The vast majority of authors dealing with this subject (Abel, 1976; Johnson, et. al., 1977; Khuspe and Sawant, 1979; Sam and Chaubey,

1975; Thornton, 1975; Wade and Chambers, 1980) defend the need for effective organization of the local level if the distribution of water is to be both efficient and equitable. A major constraint to this lack of efficiency and equity is the absence of knowledge about irrigation technology. All of the authors mentioned above emphasize the need for effective information systems that will permit the exchange of agronomic and engineering information between the users of water and the managers of the system. In most cases the way to do this is to establish extension services and regular training sessions for the farmers and the agents about water use technology. Bottrall (1981) contends that within the organization responsible for providing agricultural services a specialization of functions is needed between advisory and other activities. Without this division of labor the demands made on the extension agent's time by other tasks will erode his effectiveness in performing his primary advisory function. Thus there should be a separate cadre responsible for the collection of agricultural statistics, either within the same organization or outside it. The same applies to input supply and credit.

C. Distribution of Benefits

The final level of institutions to be considered are local institutions, those which directly affect the level and distribution of irrigation benefits. Several factors that directly affect the distribution of irrigation benefits and should be included in this section are the location of a farmer's fields along the irrigation watercourse, the nature of land ownership, water rights and land tenure as it affects the users of water. Bromley, et. al. (1980), found that farmers whose fields are most distant from the source of water frequently have the least secure water supplies. First, as the distance between water source and field increases, there is

a greater cumulative effect of seepage and evaporation losses in delivery channels. Second, there is greater possibility for intervening irrigators to disturb intended water distribution as the water flows from head-end to tail-ends fields. Other studies in the Philippines (Wickham and Valera, 1979; Tabbal and Wickham, 1977) also found location of fields along distribution canals to have a significant influence on the distribution of water among users. The solutions suggested to alleviate this problem of location include stricter control of water rotations, better maintenance practices, canal lining, land leveling and land reform. One author (Bottrall, 1978) believes that radical changes in the structure of land ownership would have to accompany improvements in management and design so that benefits of development could reach the poorest. Case studies of areas that have experienced programs of land reform are needed so that their influence on irrigators within those areas can be determined. Knowledge derived from such analysis could be used to design specific land reform programs with the interests of irrigators in mind.

The study of institutions brings us back to the question of efficiency and equity in irrigation system operation. How can institutions be reformed to improve the efficiency of water as a productive factor input and at the same time distribute the benefits from this reformation equitably among the population? Research in this area has been largely neglected even though the results could help government decision makers.

IV. ALTERNATIVE INVESTMENTS IN IRRIGATION DEVELOPMENT

There are many questions that arise with regard to alternative investments in irrigation development. These questions deal with trade-offs between investment in one area as opposed to investments in another.

Levine (1980) lists some of the investment alternatives: (1) Irrigation vs. rainfed--should investments be focused on developing irrigation schemes which mainly benefit those included in the targeted area or should the investment strategy be to improve the potential use of natural rainfall throughout the population? (2) Wet season irrigation vs. year-round irrigation--should irrigation development supplement natural rainfall or should it be developed to meet the year-round water needs of all crops in the irrigated area? (3) Expansion vs. intensification--should investment be concentrated in expanding the area under irrigation by building new schemes or should the emphasis be to improve the irrigation potential of existing schemes by rehabilitating them? (4) Large projects vs. small projects--should the emphasis of irrigation development be to invest greater amounts in large irrigation projects or small ones? (5) Government vs. private--should government investment policy be to develop irrigation through the public sector or should it provide incentives to allow the private sector to do the job?

Due to their importance, the emphasis will be on large vs. small projects and expansion vs. intensification. However, many of the same issues involved in expansion vs. intensification also occur when considering irrigation vs. rainfed agriculture and wet season vs. year-round irrigation.

A. Expansion vs. Intensification

In most Asian countries, existing irrigation schemes are not realizing their full potential in terms of area irrigated and production per acre. Two of the constraints to meeting this potential are the deterioration of the physical irrigation infrastructure and the lack of knowledge on the part of farmers and managers of irrigation technology. The solution

to the first problem would be to rehabilitate these schemes. Investments in canal lining, land leveling and water saving devices to reduce evaporation from open bodies of water would result in more water being delivered to the fields where it would be utilized more efficiently. Training programs for farmers and managers which teach modern cropping techniques would help deal with the second problem.

There is a trade-off that exists with decisions to rehabilitate existing irrigation schemes. Although rehabilitation will improve the water use efficiency within each scheme that is rehabilitated, the benefits from such rehabilitation will be felt mainly by those farmers within the scheme. If the rehabilitation results in greater water delivery, the command area of the scheme could be enlarged which would benefit more farmers. There are also positive secondary impacts which might be felt in the local economy from rehabilitation, but most of the benefits are felt by the farmers in the scheme targeted for rehabilitation. No article appears to deal with this question directly, although one study (Hayami and Kikuchi, 1978) found that the spread of high-yielding varieties in the Philippines increased the relative advantage of improving the irrigation infrastructure over opening new land because high-yielding varieties perform better under controlled irrigation. In contrast, under poorly controlled irrigation, local varieties were superior.

Most of the studies dealt with methods of rehabilitation and reasons for it. Kandiah (1978) criticizes the practice of the Sri Lanka government investing huge capital outlays exclusively in large development projects with little or no attention given to the individual farmers' management practices. He contends that part of the investment for irrigation must be devoted to teaching the farmers improved management practices and another part to the leveling, terracing, bunding, and drainage at the field level.

Sharma (1972) agrees with Kandiah and has provided several key points for improving farm irrigation efficiencies. They are: (1) The creation and improvement of physical facilities. Included in this category would be land leveling, installation of an efficient water conveyance system, fixing of water measuring, control and distribution structures and developing the water source to provide a more assured water supply. (2) Adopting the suitable methods of water application. Here one must adapt the irrigation method (sprinkler, surface, or subsurface) to the crops, soil and slope of the land. (3) Management improvement by proper operation of the system. Specifically, the application of water at a rate, determined by the water holding capacity of the soil and the crop's needs, in such a manner that the crops can use the water efficiently. (4) Extension of scientific techniques of water management. That is the dissemination of appropriate and up-to-date information regarding all aspects of cropping under irrigation. Such things as frequency of irrigation, seed, crops, fertilizer, insect and disease problems should be included.

One study evaluating the economic returns to investments in land leveling was done by Johnson, et. al. (1978), in Pakistan. Their study showed a benefit-cost ratio of 1.62 for investment to upgrade traditional land leveling to a precision level. Their findings implied increasing returns to added investments in land leveling.

Khattak, et. al. (1981), studied the effect of land leveling and application of fertilizers on the physico-chemical properties of soil, water use and yield of wheat. They found that leveling significantly increased phosphorous, exchangeable potassium and the infiltration capacity of soil. They also attributed a saving of 24 to 47 percent of irrigation water to leveling.

Some of the problems associated with inefficiencies due to the lack of water control at the field level may be alleviated by investments in system redesign and control structures. Easter (1977) and Kumar (1977) evaluated a pilot program in India designed to improve existing flood irrigation systems by constructing field channels or laterals which take water from the canal outlets directly to each farmer's field. Each farmer controls the flow of water on his fields without affecting the flow to his neighbors' fields. Both found the program to be successful with regard to an increase in the area under irrigation, increased cropping intensity and an increase in production inputs and output.

Other studies involving the economic evaluation of rehabilitating existing infrastructure in Asia include Johnson, et. al (1978), Hafid and Hayami (1979) and Taylor (1979). Johnson's study (already discussed in Section II of this paper) found that rehabilitation of canals with labor intensive earthen improvements was the best investment that the Pakistani government could make.

Hafid and Hayami examined the impact of national subsidies on the rehabilitation of two small-scale, river-diversion irrigation systems in Indonesia. The rehabilitation involved the repair and raising of the diversion dams and the lining of some canals. Their study shows that the subsidies were substantial inducements to the mobilization of local resources, and that as a result, high rates of return on the rehabilitation project were achieved.

Taylor studied the rehabilitation of the 274,000 Ha. river-diversion Pekalen Sampean irrigation project in East Java, Indonesia. This rehabili-

tation primarily emphasized desilting of channels and the repair of water control structures rather than the restoration of original water-diversion capacities. In this case there was no immediately observable impact of rehabilitation on production, perhaps mainly because the rehabilitation did not improve this project's water supply situation by increasing its water diversion capacity.

B. Large Projects vs. Small

Investment decisions with regard to developing irrigation via large or small scale projects involve the ever present trade-off between equity and efficiency. The presumption is that smaller irrigation systems are more rapidly developed and utilized. Local capital and labor resources are more fully mobilized with small projects. Small projects minimize adverse environmental impacts. They involve a broader dispersal of investment resources; and the potential for involvement by the local community in system operation and maintenance is greater with small projects.

On the other hand, large projects hold several major advantages over small projects: (1) Large projects frequently are necessary for the effective utilization of relatively large but variable water supply. (2) Large projects permit more efficient and effective use of limited managerial and technical skills by drawing these people together to work on the same project. (3) Large projects are more easily financed because it is easier to obtain external financing for large projects than for small ones.

Puttaswamaiah (1977) conducted an economic analysis of major and minor irrigation projects in India. He found that large projects often require large public investment in selected areas that benefit relatively few people. Minor irrigation schemes generally involve lower investment

costs per hectare and are favored because they have relatively slower depreciation and lower operating expenses than large projects. He also claims that the time gap between creation and utilization of irrigation potential is substantially less for minor works than for major and medium projects. Finally, he contends that because of the inefficiencies in water delivery, actual irrigated area in many of the larger projects are substantially less than the potential created by the irrigation system. This results in an increase in the cost per hectare actually irrigated over the planned cost per Ha. based on the full irrigation potential of the system.

Contrary to the above study, Taylor and Tantigate (1979) found that considerable economies-to-scale exist in the construction of irrigation schemes in Malaysia. They found that larger schemes have higher yields per unit of water than smaller schemes. They also contend that diversion headworks are generally less costly than pumping facilities. Taylor and Tantigate advocate caution in policies to encourage small-scale irrigation.

There is much work that needs to be done to resolve this question of small vs. large projects. The literature at present is too limited and neglects some very important questions. Questions which remain in need of research are presented by Easter (1980). (1) Can large scale irrigation projects be operated and managed in small scale units? (2) How does the size of the terminal management unit affect project performance? (3) Are there fewer socio-cultural and economic problems associated with the development of small irrigation projects as compared to large projects? These are questions that need to be addressed and provided with answers before this small project vs. large project issue can be resolved.

Abel, Martin E. (1976). "Irrigation Systems in Taiwan: Management of a Decentralized Public Enterprise," Water Resources Research 12, pp. 341-348.

The author describes the operation of canal irrigation systems in Taiwan. He contends that the efficiency of irrigation systems management in Taiwan depends on four factors: (1) the recognition that water is a scarce factor in agricultural production, (2) the legal administrative basis for centralized planning of irrigation investments but decentralized management of irrigation systems, (3) the information systems which permit the exchange of agronomic and engineering information between the users of water and the managers of a system, and (4) the use of incentive structures for both the managers of irrigation systems and the users of water that appear to be compatible with the efficient use of water within the irrigation system.

Andreou, P. (1979). "Economic Appraisal of Irrigation Cooperatives in Agricultural Development in Ganges-Kobadak Project, Bangladesh," Agricultural Administration 6(2), pp. 111-122.

The author contends that the setting up of cooperatives in Bangladesh has allowed considerable progress to be made in the establishment of new irrigation schemes and, as a result, the productivity and intensity of cropping has much improved. He outlines the features of the projects to set up farm cooperatives and discusses the ways in which the cooperatives are administered.

Asopa, V. N. (1977). "Pricing Irrigation Water," Artha-Vikas 13(1), pp. 51-64.

The author examines the issue of pricing irrigation water and postulates the need for developing an analytical framework to reconcile the contradictions in economic, financial and social functions of a pricing policy for irrigation water. He contends that such a framework would have to take into consideration the value of water under different conditions, the water release policies and the identification of beneficiaries.

Asopa, V. N. and B. L. Tripathi (1978). "Command Area Development in Mahi-Kadana," CMA Monograph, Centre for Management in Agriculture, Indian Institute of Management Ahmedabad, India, No. 76, 112p.

The authors present a study of the integrated area development approach used in the command area development of the Mahi-Kadana irrigation project. They pursue the following objectives: (1) To study the planning of the integrated area development program with a view to understanding the economic and social considerations underlying the activities envisaged. (2) To understand the implementation processes vis-a-vis the tasks to be performed and the coordination among various agencies involved in the implementation of the CADP. (3) To assess the

farmer's perception of the program, his needs and receptivity to equate farm level demand with program level outputs.

Since the Kadana dam has yet not been completed, it becomes very difficult to evaluate the performance of the project. Therefore, the authors just identified the general problems associated with water utilization and recommended solutions under the following headings: (1) Utilization of irrigation potential, (2) On-farm development work, (3) Water losses, (4) Distribution of water, (5) Extension of knowledge, (6) Farmer's participation, (7) Cooperatives for water distribution, and (8) Pricing of irrigation water.

Asopa, V. N. and B. L. Tripathi (1975). "Irrigation Agriculture in Gujarat: Problems and Prospects," CMA Monograph, Centre for Management in Agriculture, Indian Institute of Management, Ahmedabad, India, No. 53, 154p.

The authors examine the technological, institutional and organizational factors responsible for the underutilization of irrigation potential. They stress the need for making a systematic assessment of groundwater resources and developing an appropriate strategy for the management of the available ground water as well as for organizing a federal structure of water cooperatives for distributing irrigation water in a compact region.

The authors also provide a framework for pricing irrigation water. They mentioned that a water pricing policy should be economically desirable, politically tenable, and socially acceptable. In any such framework for pricing water, it will be necessary to have a precise idea of the productive value of water for different crops and its productive value under different conditions of natural precipitation. This understanding can be gained only through continued agricultural experiments for a number of years with the same cultural practices. The results of these experiments can be used in evolving a general pricing policy. Assuming that the direct and indirect benefits of an irrigation project are approximately equal, the direct beneficiaries should be made to pay at least half of the cost of creating and maintaining such facilities. Direct revenues should be realized so as to cover the interest on capital charges incurred and the variable cost of operating the irrigation systems. The additional revenue should be ploughed back into the irrigation system so that it can be maintained properly.

Bottrall, A. F. (1977). "Evolution of Irrigation Associations in Taiwan," Agricultural Administration 4(4), pp. 245-250.

The author provides a description of the decentralized approach to irrigation administration used by the Irrigation Associations of Taiwan. With this system, much of the responsibility for decisions about water allocation and system maintenance is delegated

to farmers. The author suggests that the knowledge gained from the sequence of development that took place in Taiwan may be useful in devising such successful water user associations elsewhere.

Bottrall, A. (1978). "Technology and Management in Irrigated Agriculture," O.D.I. Review 2, pp. 22-50.

The author contends that the poor performance of many irrigation schemes is due not only to deficiencies in technology, management and policy but also to the constraining structure of land ownership. He implies that in many cases land reform is a condition that would have to accompany better management practices in order for an equitable distribution of irrigation water to take place.

Bottrall, Anthony F. (1981). "Comparative Study of the Management and Organization of Irrigation Projects," World Bank Staff Working Paper No. 458, The World Bank, Washington, D.C.

The author uses a management framework to analyze four irrigation projects in developing countries. The central focus of this study is on the performance of water distribution and management activities. The six factors that were important in judging the effectiveness of the systems were (a) consistent and clearly-defined objectives, (b) an appropriate organization structure, (c) management framework including job descriptions, information and monitoring systems, (d) specific policies for staff recruitment, promotions and salaries, (e) provision of adequate finance support, and (f) provision of legal framework to support attainment of objectives.

The author feels that this area has been largely neglected and has an immense potential for improvement. Management and organizational improvements would generate large increases in overall agricultural production and the benefits would be realized by all; but in particular, the poorest people in the irrigated areas, especially small farms located at the tail-end of the canals.

Bredhoeft, John D. and Robert Young (1970). "The Temporal Allocation of Groundwater -- A Simulation Approach," Water Resources Research 6(1), pp. 3-20.

The authors investigated the effects of two policy instruments, a use tax and a quota, on the withdrawal rates of irrigation water by users. They compared a policy of regulation against a policy of unrestricted use and found that policies which reduced the rate of withdrawal increased the discounted net economic yield.

Bromley, Daniel W., Donald C. Taylor, and Donald E. Parker (1980).

"Water Reform and Economic Development: Institutional Aspects of Water Management in the Developing Countries," Economic Development and Cultural Change 28(2), pp. 365-387.

The authors examined irrigation literature and found two factors that seem to underlie most cases of inequitable water distribution: farm location on the water course and farm size. Farmers whose fields are most distant from the source of water frequently have the least secure water supplies. Farmers with larger holdings and other forms of economic power frequently have more secure water supplies. The authors refer to five general principles for institutional design from John Rawl's, A Theory of Justice as a basis for institutional reform. These five principles are: (1) compatible liberty, (2) knowledge and participation, (3) shared concept of justice, (4) formal system of justice, and (5) rational rules.

Burt, Oscar R. (1963). "The Economics of Conjunctive Use of Ground and Surface Water," Hilgardia 36(2), pp. 31-111.

The author addresses the problem of optimal management of water over time under conditions of conjunctive use of ground and surface water. The question for which he attempts to provide an answer is: given physical storage and distribution facilities for water, how can present value of net output from a basin operating under conditions of conjunctive use of ground and surface water be measured empirically?

The primary objective of this study is to explore methodological procedures for measuring expected present value of net output from a basin under specified storage and distribution facilities for water, and to illustrate these procedures by an empirical application.

Coward, E. W., Jr. (1977). "Irrigation Management Alternatives: Themes from Indigenous Irrigation Systems," Agricultural Administration 4(3), pp. 223-237.

The author discusses irrigation management alternatives based on cases of indigenous irrigation systems that exist around the world. He discusses the organizational themes of accountable leadership, mini-unit organization and canal-based organization. He also considers the relevance of these themes to the following cases: (1) when irrigation development policy includes the improvement of existing traditional systems, (2) when a nation is investing in the development of new small-scale systems, and (3) where large-scale systems are being designed so as to create smaller sub-units relatively independent of the total system.

De Los Reyes, Ramona P. (1981). "Managing Communal Gravity Systems: Farmer's Approaches and Implications for Program Planning," paper presented to the Agricultural Development Council, Inc., Kasetsart University, Bangkok.

This paper discusses the major findings of a study on the organization and management of 51 Philippine communal gravity irrigation systems and the implications of these findings for the communal assistance program of the National Irrigation Administration, the agency responsible for irrigation development in the Philippines.

Dhawan, B. D. (1974). "Utilization of Ground Water Resources - Public Versus Private Tubewells," Economic and Political Weekly 9(39), A75-A81, India.

This paper is basically a review article. The author picks a few studies of tubewells in India and attempts to probe into some of the major economic claims being advanced in favor of private tubewells. The economic bases for the thesis that private tubewells are superior to public tubewells appear to be weak on closer scrutiny. The available ex post benefit-cost analysis for private and public tubewells shows the ratios are not much higher for private tubewells as compared to state tubewells. The author indicated that the financial loss on a public enterprise occurs because of: (1) underpricing of water, (2) leakage of water, and (3) inability to produce water up to the rated capacity of the pumps. Dhawan feels that from the viewpoint of social justice a given benefit-cost ratio for public tubewells is superior to the same magnitude of benefit-cost ratio for private tubewells.

Doppler, W. (1977). "Towards a General Guideline of Irrigation Water Charging Policy," Agricultural Administration 4(2), pp. 121-129.

The author considers the objectives of levying water charges, the criteria for determining water charges and the different methods for calculating and levying water charges. Doppler considers cost pricing, benefit pricing and equilibrium pricing.

The author recommends: (1) indirect water charges coupled with close administrative control over water distribution and production in the initial phase of a scheme involving farmers inexperienced in irrigation, (2) conversion to a system combining fixed and variable charges as farmers gain more and more relevant experience, (3) application of a purely equilibrium price-based water price in more highly industrialized countries, and (4) for most developing countries, a flat rate charge the level of which will depend on a country's political objectives and the stage of development.

Easter, K. William (1980). "Issues in Irrigation Planning and Development," Staff Paper P80-5, Department of Agricultural and Applied Economics, University of Minnesota, 32p.

The main focus of this paper is on irrigation water use with an emphasis on irrigation issues important to developing countries. Those issues dealt with are as follows: (1) Water allocation rules, methods, and customs. (2) Institutional and managerial arrangements for irrigation project implementation and rehabilitation. (3) Alternatives for design, scale, and geographic distribution of irrigation investments. (4) The selection of irrigation projects and the timing of irrigation developments relative to other alternatives for achieving agricultural and rural development. (5) Information systems for improving water resource decisions. (6) Water use allocation between irrigation and alternative uses. (7) Improving system-wide performance.

Easter, K. William (1977). "Improving Village Irrigation Systems: An Example from India," Land Economics 53(1), pp. 56-66.

This article evaluates a program in India, operated since 1966, designed to improve existing flood irrigation systems by constructing field channels or laterals which take water from the canal outlets directly to each farmer's field; thereby allowing each farmer to control the flow of water on his fields without affecting the flow to his neighbors fields.

The program impacts are analyzed in terms of changes in cropping patterns, yields and input use. A Cobb-Douglas production function is used to isolate the direct effects of the field channels. The net present value and internal rate of return are calculated for the program.

Concluding remarks held the program of providing field channels to be successful and profitable for the farmers, and for India.

Easter, K. William (1980). "Capturing the Economic Surplus Created by Irrigation," Staff Paper Series, Department of Agricultural and Applied Economics, University of Minnesota, 23p.

This paper deals with the options available to extract more of the economic surplus created by irrigation projects. The first section of the paper lists the objectives of making charges for irrigation water. The second section considers the types of fees or charges that are used to collect revenues from irrigated farms. The third and fourth sections present discussions of some of the issues and factors that influence the type and level of fees used.

Eckert, Jerry, Niel Dimick and Wayne Clyma (1975). "Water Management Alternatives for Pakistan: A Tentative Appraisal," Water Management Technical Report No. 43, Colorado State University, 61p.

The authors define the most common watercourse situations found in Pakistan. They summarize the delivery losses and determine the value of water used for irrigation. They evaluate alternative solutions to causes of inefficient water use and suggest criteria for selecting project watercourses with high potential payoffs.

Gopalakrishnayya, K. (1979). "An Integrated Approach to Command Area Development Program," Indian Journal of Public Administration 25(1), pp. 74-85.

The author states that the main objective of the command area development program is to maximize agricultural production within the constraints of water available for irrigation. These constraints being: (1) Where water availability is abundant, maximize production per unit of land. (2) Where water availability is medium, maximize production per unit of water. (3) Where water is scarce, minimize as large an area as possible from the effects of drought. He has found that there are many difficulties in implementing this program because of farmers' unwillingness to accept programs relating to land localization, water distribution, land development and cropping patterns. He develops a model for a command area development management system consisting of three important sub-systems: a policy level, an implementation level, and the farmer level. Every level has responsibilities. Among these three sub-systems, policy and implementation levels belong to the government (CAD authority), whereas the farmer level represents the individual farmer responsibilities. The effectiveness of the total system depends on the efficiency of the interface between the sub-systems. The interface between the implementation level and the farmer level is very critical for the success of the total system. He concludes with recommendations for project implementation.

Gupta, D. D., A. Singh, and M. V. George (1973). "Water Management Practices in Sandy Arid Zones," Agriculture and Agro-Industries Journal 6(6), pp. 34-38.

The authors found from case studies that a changeover from ordinary channels to concrete-lined ones with underground pipes benefited farmers with an increase in the irrigation potential by reducing water losses due to seepage and evaporation. They found that such changeovers also increased the cropping intensity due to an assured supply of irrigation water to a larger area. With this assurance of a water supply, the level of technology improved and net returns to the farmers were higher.

Hafid, A. and Y. Hayami (1979). "Mobilizing Local Resources for Irrigation Development: The Subsidi Desa Case of Indonesia," in Irrigation Policy and Management in Southeast Asia. The Agricultural Development Council, Inc., Bangkok.

The authors examined the impact of national subsidies on the rehabilitation of two small-scale, river-diversion irrigation systems in Indonesia. The rehabilitation involved the repair and raising of the diversion dams and the lining of some canals. Their study shows that the subsidies were substantial inducements to the mobilization of local resources, and that as a result high rates of return on the rehabilitation projects were achieved.

Haque, M. F. (1975). "A Comparative Analysis of Small Scale Irrigation Systems in Bangladesh," Bangladesh Development Studies, 3(1), pp. 43-52.

The author did a comparative analysis of small scale irrigation systems in Bangladesh and found that at the existing level of capacity utilization, the shallow tubewell irrigation system is relatively more efficient than other systems.

Hayami, Yujiro and Masao Kikuchi (1978). "Investment Inducements to Public Infrastructure: Irrigation in the Philippines," The Review of Economics and Statistics LX(1), pp. 70-77.

The authors test the hypothesis that, in spite of apparent political muddles, government investment in public infrastructure is, in fact, guided predominantly by the rational criteria of the social profitabilities of such investments. They did a case study and found that government decisions are rational but tend to be beguiled by short-run economic fluctuations, resulting in long-run inefficiencies in the social resource allocations.

Hutapea, R., Prajarta Dirjasanyata and N.G.S. Nordholt (1976). "The Organization of Farm-Level Irrigation in Indonesia," Irrigation Policy and the Management of Irrigation Systems in Southeast Asia, The Agricultural Development Council, Inc., Bangkok, pp. 167-174.

The authors review the historical development of four farm-level irrigation management systems in Indonesia and suggest five factors that influence the effectiveness of farm-level irrigation services: (1) The congruence of the boundaries of irrigation groups, irrigation command areas and village jurisdictions. Ideally, they should coincide as nearly as possible. (2) Coordinated organizational responsibility for irrigation. The most efficient of which would be by a single institution. (3) The nature of village values and leadership, and the extent of economic and social disparity within villages. The central issue here being the danger of conflicts of interest among village leaders who seek to improve their personal welfare to the disadvantage of the community. (4) The perception by irrigators of who owns their water supplies. Local irrigator organizations

are usually strongest where water is viewed as village property. (5) The uniformity in the structure of irrigation organizations and the speed at which they are introduced. Here one must take into consideration those variables that most significantly influence local institutional change.

Johnson, Sam H. III, Alan C. Early, and Max K. Lowdermilk (1977). "Water Problems in the Indus Food Machine," Water Resources Bulletin 13(6), pp. 1253-68.

The authors analyze some of the practical, field level water management problems that restrict the output of agricultural products in many developing countries. Among the problems encountered are lack of water management knowledge on the part of both farmers and extension agents, corruption and underlying institutional factors. They make recommendations for requirements that must be met before a large-scale irrigation scheme will actually increase the welfare of LDC's farmers.

Johnson, S. III., M. Hussain, Z. Khan and Ch. B. Ali (1977). "The Economics of Precision Land Leveling in Pakistan," in Improving Irrigation Water Management on Farms, Annual Technical Report for 1977-78, Fort Collins: Water Management Research Project, Colorado State University.

The authors evaluated the economic returns to investments in land leveling in Asia. Their study showed a benefit-cost ratio of 1.62 for investment to upgrade traditional land leveling into precision land leveling. They used regression analysis to relate yield to a series of variables, one of which was the maximum range of variation in evaluation within individual fields. Their findings implied unexpected increasing returns to added investments in land leveling.

Johnson, Sam III., W. Doral Kemper, and Max K. Lowdermilk (1978). "Improving Irrigation Water Management in the Indus Basin," Water Resources Bulletin 15(2), pp. 473-495.

The authors contend that water losses through the banks of watercourses amount to over half of that water which is delivered. They cite inadequate organization of the users as the major reason for the lack of maintenance and resulting losses. Various methods of watercourse improvement are evaluated; but a constraint which limits the rate of implementing these water management practices is the rate at which personnel can be trained to help the users with this implementation.

Kandian, A. (1978). "Some Technical and Social Problems in the Irrigation Projects of Sri Lanka," Agricultural Mechanization in Asia 9(4), pp. 49-53.

The author criticizes the practice of the Sri Lanka government, investing huge capital outlays exclusively in large development projects (specifically irrigation schemes) with little or no

attention given to the individual farmer's management practices or system design. He contends that part of the investment for an irrigation scheme must be devoted to teaching the farmers improved management practices and another part to the leveling, terracing, bunding and drainage at the field level, rather than leaving this entirely up to the farmers themselves.

Khattak, Jehangir K., Abdur Rashid, S. U. Khan, Kermit E. Larson and Riaz A. Khattak (1981). "Effect of Land Leveling and Irrigation on Wheat Yield," Agricultural Mechanization in Asia, Africa, and Latin America XII(1), pp. 11-14.

The authors studied the effect of land leveling and fertilizer application on the physico-chemical properties of soil, water use and wheat yield in Pakistan. They found that land leveling significantly increased phosphorus, exchangeable potassium and the infiltration capacity of soil. A saving of 34% to 47% irrigation water was recorded and attributed to leveling.

Khuspe, T. E. and G. K. Sawant (1979). "Constraints in Utilization of Canal Irrigation Water," Agricultural Situation in India 34(6), pp. 381-384.

The authors carried out a survey in Maharashtra, India and found that the reasons given by those underutilizing irrigation water ranged from lack of credit to purchase crop inputs, through various cost and technical problems as well as other sources of water. They conclude that the most important action to overcome the general problem of underutilization would be to arrange regular training sessions for farmers about water use technology.

Kumar, P. (1974). "An Economic Study of Water Management Programme in Sambalpur District (Orissa)," Indian Journal of Agricultural Economics 29(2), pp. 43-51.

This study attempts to evaluate the impact of field channels on cropping pattern, cropping intensity, irrigation problems faced by the farmers, and the effect of field channels on spreading the available water to larger areas. It also studies the structure of input use, farm income and the benefit-cost ratio of the project.

Kumar, Praduman (1977). "Economics of Water Management: A Study of Field Channels," New Delhi: Heritage Publishers.

This is a study of a pilot program in India to increase the efficiency of irrigation water use via a network of field channels which enable each farmer to control the water supply to his field without affecting the supply of water to his neighbor's fields. Objectives of the study are as follows: (1) To assess the impact of construction of field channels on the cropping pattern, cropping intensity, enlargement of irrigated area, irrigation problems faced by the farmers and on-farm income. (2) To compare the mean levels of inputs

used and outputs obtained in the villages with and without field channels. (3) To study the input-output relationship for the paddy crop grown in the villages with and without field channels. (4) To study the allocative efficiency of farm inputs in the villages with and without field channels. (5) To measure the impact of the improved irrigation system on the utilization of family, as well as permanent and casual labor. (6) To identify the factors affecting the demand for hired labor in the villages with and without field channels.

Lenton, Roberto (1980). "Field Experimentation and Generalization in Irrigation Development and Management," Irrigation Management Network Paper 2/80/1, Overseas Development Institute.

This is a paper by an engineer, originally written for an audience of other engineers. It represents a criticism of the narrow, predominantly technical, assumptions on which most field irrigation research is conventionally based. Lenton refers to three cases where a broad interdisciplinary research approach has been adopted and argues that a new kind of decision-making framework is needed if field experiments are to have a substantial beneficial impact on the development and management of irrigation schemes beyond the research area. The three field research projects in the study are: The CSU water management project in Pakistan; the CSWCRTI-Sukhomajri project; and the IRRI/NIA studies in water management and distribution.

(1) The analysis of two field research projects -- CSU/Pakistan and IRRI/NIA -- has provided evidence that interdisciplinary action research programs done in pilot areas by research teams in collaboration with government agencies, can yield results capable of extension to a larger area by government agencies.

(2) One field research project -- Sukhomajri -- has illustrated the potential for field experimentation in small scale irrigation leading to development models extendable to a larger area by non-governmental organizations.

(3) Research autonomy is an important characteristic of successful irrigation field research projects.

(4) Two of the field research projects (CSU/Pakistan and IRRI/NIA) involved international efforts. They indicate that international interdisciplinary research groups can work with researchers in national centers and government agencies to undertake field research, provide training, develop new and improved research approaches, and link pilot project research results to larger-scale implementation.

Levine, G. (1977). "Management Components in Irrigation System Design and Operation," Agricultural Administration 4(1), pp. 37-48.

The author concludes from studies in the Philippines and Taiwan that designs based on preconceived norms of efficiency often fail to recognize the role of water as a factor substitute for such inputs as labor, capital and managerial skill. Similarly, they fail to recognize that public objectives for system performance are usually not congruent with farmer objectives or even with those of the irrigation bureaucracy. He suggests that significant improvements can result when these different objectives, with their management implications, are considered in design and operation along with more effective feedback and response mechanisms.

Levine, Gilbert (1980). "Irrigation Development and Strategy Issues for the Asian Region," draft of Issues paper submitted to USAID, Cornell University.

The author identifies the issues associated with the attempt to use irrigation to increase agricultural production while benefiting the rural poor of Asia. He develops a set of irrigation investment strategies and categorizes the issues separately. The development issues which are addressed include: (1) irrigation vs. rainfed, (2) wet season vs. year-round, (3) expansion vs. intensification, (4) large projects vs. small, (5) government vs. private. The investment strategies include: (1) direct vs. indirect, (2) hardware vs. software, (3) main system vs. on-farm, (4) early vs. late, (5) easy vs. difficult.

This draft paper on development and investment strategies is intended only to open the discussion about AID's future directions in investment in irrigation in Asia. It provides neither answers nor suggestions for what is appropriate. It is anticipated that the forthcoming field visits, coupled with the subsequent discussions with USAID field staff and other professionals and academics will refine and amplify the choices, and ultimately will result in a statement of policy.

Lowdermilk, Max K., Wayne Clyma, and Alan C. Early (1975). "Physical and Socioeconomic Dynamics of a Watercourse in Pakistan's Punjab: System Constraints and Farmers' Responses," Water Management Technical Report No. 42, Colorado State University, Fort Collins, Colorado.

The authors present a detailed study of the physical and socio-economic conditions of a watercourse in Pakistan. Objectives of the study are as follows: (1) To identify the physical problems of the watercourse subsystem and gain an understanding of how the farmer interacts with the irrigation systems' constraint. (2) To examine the influence of the social systems of farmers with respect to leadership roles, status, decision making processes and patterns of cooperation and conflict. (3) To examine farmers' irrigation practices, adoption behaviors, and

cropping patterns and develop ways to facilitate the increased adoption of relevant technologies. (4) To understand the linkages, interactions with, and utilization of government agencies by farmers for essential inputs and services.

They make four recommendations: (1) Farmers in Pakistan must be provided with information about watercourse losses and maintenance of the existing and improved systems. (2) Farmers should be provided with incentives to organize for improving water delivery through institutional encouragement from the irrigation and agriculture departments, and through special assistance to farmers who have organized and made improvements. (3) An effective extension program must be developed to provide services to the farmer to improve crop production and use of irrigation water. (4) Because canal operations have remained the same for over 100 years, legal, administrative, and policy procedures should be reviewed. The objectives of the review would be to change water distribution procedures to eliminate extra-legal distribution of water, enhance revenue collections through increased water rates, develop revised collection procedures to reduce bribes and evasion of revenue payments and provide protection to each farmer's water supply while providing flexibility to legalizing trading and purchase of turns between farmers.

Lowdermilk, M. K., D. M. Freeman, A. C. Early, G. Radosevich, and D. Kemper (1977). "Organizing Farmers to Improve Irrigation Water Delivery: The Problems and Prospects for Solutions in Pakistan," Pakistan Economic and Social Review 15(3/4), pp. 152-173.

The authors found large water losses occurring due to poorly constructed watercourses. These losses can be reduced at great savings to the national economy. To do this farmers must be organized to provide themselves with a collective good, a well-designed, well-constructed system of watercourses which will reduce waterlogging and salinity at the head of the channel and increase water supplies at the tail.

They suggest that with appropriate technical assistance and information, farmers will be responsive to an opportunity to improve their watercourses. Three alternatives are available, at present, for establishing the necessary water users' associations -- (1) an informal organization, (2) an association established under the authority of the companies act, and (3) an association established under the authority of the cooperative act. Farmers can elect to organize in any of these three ways, but it is essential to carefully evaluate the outcomes of their efforts before major policy commitments are made.

The authors argue that a limited water supply is one of the most important constraints to increasing agricultural production. Rational farmers with inadequate irrigation water supplies will apply fertilizer at low levels in order to ensure that their marginal costs do not exceed marginal returns. Such low input levels and production will increase if watercourses are improved. Currently watercourses lose over 50 percent of the water between the mogha and the field outlet. The problem is to organize the farmers to reduce this loss.

Lowdermilk, Max K., Alan C. Early and David M. Freeman (1978). "Farm Irrigation Constraints and Farmers' Responses: Comprehensive Field Survey in Pakistan," Water Management Technical Report No. 48, Colorado State University, Fort Collins.

In their research the authors attempt to ascertain the significant farm level constraints which confront farmers in their irrigation systems and which are responsible for low crop production. Volume I includes the following: (1) major findings and policy implications, (2) suggested criteria for selection of water management watercourse areas for comprehensive improvements, (3) implications of the delivery and application data regarding decisions to continue surveys or implement improvement programs. Volume II states research objectives and describes major features of the irrigation system being studied. Volume III establishes the consequences of the existing irrigation system. Volume IV examines major constraints confronting farmers within the existing system. Volume V presents farmers' responses to those constraints. Volume VI contains supplementary appendix materials relating to methodology, data summaries, watercourse profiles and maps.

The six volume report includes many findings and policy recommendations including the following: (1) Social organizational variables are critical to effective local water management. Improved watercourses, to increase delivery efficiencies and reduce waterlogging, represent collective goods which can only be constructed and maintained by farmers organized to control the potential free rider who would rationally seek to secure benefits of watercourse improvement without paying a proportionate share of the costs. (2) Villages in which farmers enjoy the greatest centrality and equality of power are those which are the most productive and most able to sustain successful local level watercourse organization if they are not polarized by reinforcing lines of conflict cleavages. (3) In general, the more water available for a watercourse, the lower the watercourse conveyance efficiency. (4) Wherever and whenever ample water supplies are available, farmers tend to over-irrigate. (5) Large farmers (25 acres or more) had lower mean application efficiencies (64%) than did small farmers (80%), but large farmers tend to secure greater tubewell supplies. (6) Farmers served by public tubewells or who have access to private tubewells had average crop yields per acre higher than farmers with no tubewell supplies. (7) Water supply significantly affects cropping intensity. (8) Extension workers, serving the world's largest contiguous irrigation system, are not minimally trained in water management. (9) If watercourses are to be improved and maintained to a higher standard, farmers must be organized to provide themselves with this collective good. (10) Along with programs of watercourse improvements on pilot watercourse commands, the needs of tail farmers merit special attention. (11) Increased supplies of irrigation water do not provide the answer for improving farmers' field application

efficiencies. (12) Public tubewells increase total irrigation supplies but do not have the flexibility of private tubewells because public tubewell water is delivered with canal water.

Maass, Arthur and Raymond L. Anderson (1978). ... and the Desert Shall Rejoice, The MIT Press, Cambridge, Massachusetts and London, England.

The authors compare six irrigation settlements in Spain and the U.S. in terms of how they approach such goals as successful conflict resolution, popular participation, local control, economic growth, justice in income distribution, and equity. Methods of computer simulation are also used to explore comparisons not only with what is observed to exist but to answer the "what if" questions of how different distribution rules and institutional arrangements might have worked in similar situations.

Maass and Anderson found that: (1) The objectives sought by the six irrigation communities in Spain and America are the same in broad outline. (2) Irrigation technology has certain special characteristics: (a) Water flows, so the status of the resource at any point in time and place is very sensitive to changes which occur at other points in the river basin. This means the location of irrigators along a stream or canal determines their social relations to a significant degree. (b) Water supplies are uncertain and unpredictable. (c) Technology limits the set of operating procedures from which a community of irrigators can choose for the purpose of gaining its objectives.

The authors go on to conclude that (1) local control was the dominate characteristic of the systems study. The farmers of each community have determined both the procedures for distributing a limited water supply and the resolution of conflicts with other groups over the development of additional supplies. (2) The strength and coherence of local irrigation organizations in developed regions appears to be correlated with an irrigation community's success in limiting or stabilizing growth, thereby gaining security for its members. (3) The less automatic the procedures, the stronger would be the community organization to operate, control, and patrol the distribution systems and resolve conflicts among users.

Malhotra, S. P. (1980). "Discovery of the Warabandi System and Its Infrastructure," paper presented to the Ford Foundation, New Delhi, 113p.

The author provides a comprehensive account on the Warabandi system of distributing irrigation waters. He feels that this system has proven to be the best available for areas where the holdings are small and supplies do not only fall short of the demand, but are also uncertain and irregular. The system is a classic example of the joint management of irrigation waters, partly by the state and partly by the farmer. The management on the upstream side of the outlet is done by the state whereas that on the downstream side is handled by the farmer.

Mellor, J. W. and T. J. Moorti (1971). "Dilemma of State Tubewells," Economic and Political Weekly VI (13), pp. A37-A43.

The authors compared state tubewell performance with private tubewells and found that state tubewells are overused and undependable because of frequent breakdowns. The authors feel that the state wells should be used more like private wells even though this would reduce state revenues because of reduced pumping times.

Mirza, Ashfaq Hussain (1975). "A Study of Village Organizational Factors Affecting Water Management Decision Making in Pakistan," Water Management Technical Report No. 34, Colorado State University, 129p.

The author examines the social factors which affect the water management decision-making of farmers in the Punjab. His research focuses on the following three aspects of this decision-making process: (1) decisions of farmers to clean watercourses, (2) decisions to change from "kacha" to "pacca" Warabandi systems of water allocation, and (3) decisions to interact with lower level irrigation department employees. He found that the presence of public tubewells is a disincentive to willingness to improve on-farm water management.

Mishra, G. P. (1977). "Land Use in Agriculture (An Empirical Verification)," Economic Affairs 22(6/7), pp. 233-244.

The author contends that there is an inverse relationship between the intensity of cropping and farm size in Indian agriculture. He finds that large farms use land less intensively because of the unavailability of water to irrigate the entire area of the larger holdings. He also believes that larger farmers are disinterested in making optimum use of their land holdings and calls for a maximum size of land holding, and better land distribution for more intensive use of agricultural land.

Moore, M. P. (1980). "Approaches to Improving Water Management on Large Scale Irrigation Schemes in Sri Lanka," paper presented to Institute of Development Studies, U.K. and Agrarian Research and Training, 50p.

This paper is structured as a commentary on each of the main reforms which have been proposed or attempted with regards to improving water management on large scale irrigation schemes in Sri Lanka. These reforms include the following policy options: (1) greater discipline and enforcement of distribution rules, (2) establish farmer organizations, (3) increase the density of irrigation field staff, (4) farmer representation at scheme level, (5) represent junior staff at scheme level, (6) involve the Revenue Department in water management, (7) reform the irrigation department

and service, (8) revise procedures for system operation, (9) plan staggering of cultivation seasons, (10) develop procedures for managing the Mahaweli System, (11) improve system design where needed, (12) make non-rice crops more profitable, (13) other issues include: (i) communications, (ii) domestic water supplies, (iii) encroachments, (iv) water charges, (v) representation of "tail-enders", (vi) water management training, and (vii) unified scheme management.

The main message is perhaps a questioning of whether the right balance of strategies has been found. At the level of institutions the concentration of effort on the farm level and the field channel is judged unlikely to be worthwhile until more attention is paid to main system management and thus to the structure and procedures of the government agencies responsible. Similarly, current experiments with innovative channel layouts for new and rehabilitated schemes do not promise to circumvent management problems, and have not been matched by an equal concern to experiment with alternative main system management.

Neghassi, H. M. and H. J. Seagraves (1978). "Efficiency in the Use of Water for Irrigation: The Role of Prices and Regulations," Natural Resources Forum 3(1), pp. 53-72.

The authors emphasize the role of water pricing in their discussion of physical and economic efficiencies and their interrelationships. They contend that the conflicting goals of equity and efficiency with regards to irrigation water allocation are reflected in the combination of regulations and prices used. They also believe that the systems of regulation and pricing should depend on the value of water, the dependability of supplies, systems of delivery and the extent to which flows can be regulated.

Nickum, J. E. (1977). "An Instance of Local Irrigation Management in China," Economic and Political Weekly 12(40), pp. 1714-1716.

The authors summarized a Chinese pamphlet which describes the management structure of the Meiquan Reservoir irrigation district in Hupeh province, China. This is recognized as the preeminent national model in irrigation management in China and is based on a decentralized inter-village technically based entity. He summarizes the modes of Meiquan's responses to irrigation water scarcity under the following sub-headings: (1) expansion of supply through new construction, (2) coordination of works, (3) promotion of more efficient water application, (4) land improvement, (5) establishment of adequate water allocation procedures, (6) development of multiple side-line operations.

He concludes by raising the following questions:

(1) What are the rights to the use of collective owned ponds and how are these rights transferred to the irrigation district?

(2) What levels within the commune sector are operating and being operated on?

(3) What procedures are used to select the management staff and to set the level and form of remuneration?

Oh, H. S. (1978). "Customary Rules of Water Management for Small Irrigation Reservoirs in Korea," Journal of Rural Development 1(1), pp. 96-110.

The author describes the rules used in the management of publicly funded small irrigation reservoirs in Korea. He states that these rules are influenced by traditional customs and places blame on them for the systems' poor performance and maintenance. He also mentions the flexibility of this system and feels that because of this flexibility, the rules could easily be changed to guarantee the security of water rights and change the structure, so that the incidence of costs and benefits fall upon the users equitably.

Pande, H. K. (1976). "Present Status and Problems of Water Management of Rice in India," paper presented by the Tropical Agricultural Research Series, pp. 13-20.

As the title suggests, this article includes statistics, maps, and graphs of Indian rice production as of 1976. Illustrations included are as follows: (1) State-wise area and production of rice in India during 1973-74. (2) State-wise yield per unit area of rice in India during 1973-74. (3) Dates of onset and withdrawal of monsoon. (4) Annual rainfall in India. (5) Weekly rainfall distribution during 'kharif' season in 1971-73. (6) Percentage of the rice area under high yielding varieties. (7) Relative coverage of high yielding and local varieties in different years.

Pang, L. H. (1979). "Fiberglass-reinforced Polyester Flumes as Tertiary Channels in Malaysian Irrigation Development," in *Irrigation Policy and the Management of Irrigation Systems in Southeast Asia*, The Agricultural Development Council, Inc., Bangkok, Thailand.

The author advocates the use of fiberglass-reinforced polyester (FRP) flumes to carry water above ground and serve as tertiary channels for irrigation projects. According to the author FRP can be installed more quickly than conventional earth channels, thus precluding the loss of a crop season. They require less right-of-way acquisition, less maintenance, and save irrigation water. He feels that the agricultural and engineering benefits associated with FRP flumes more than compensate for their high capital construction costs.

Patel, S. M. (1977). "Need for Establishing Model Water Cooperatives in India," Artha-Vikas 13(1), pp. 65-75.

The author contends that one of the solutions to the problems inherent in canal irrigation is to hand over the distribution of irrigation water to organizations owned and managed by the farmers themselves. He suggests that organizations be in the form of water cooperatives and provides guidelines for their implementation. He also postulates the need for pricing irrigation water and suggests modes of recovery of water charges.

Puttaswamaiah, K. (1977). Irrigation Projects in India: Towards a New Policy, Nrusimha Publications, Bangalore, 93p.

The author analyzes the economics of major and minor irrigation projects in India. He finds that even though India has the highest irrigation potential in the world, its utilization has been very slow in meeting that potential. He concludes the following obstacles to the full utilization of irrigation potential as follows: (1) lack of synchronization of completion of the main dam and the canals and distributaries, (2) lack of adequate infrastructure facilities in the command areas, (3) existence of large holdings and the unwillingness of the farmers to change over to irrigation, (4) preparation of the land for irrigation would involve huge investments, and (5) unwillingness of the owners of the land to pay betterment levy and water rates.

Radosevich, George E. and Craig Kirkwood (1975). "Organizational Alternatives to Improve On-farm Water Management in Pakistan," Water Management Technical Report No. 36, Colorado State University, Fort Collins, Colorado.

The authors study the effects of water laws and institutions upon the water user. Objectives of the study are as follows: (1) Description of the water laws, both legislative and customary or Islamic, and the water institutions of the country. (2) Analysis of the water laws and institutional framework identifying constraints or facilitators to implement improved water management practices by the agricultural water user. (3) A description of local water organizational alternatives in countries having similar characteristics to this arid nation. (4) An assessment of existing laws in Pakistan that could be used as a legislative base and vehicle for development and implementation of water user associations. (5) Preparation of a water user association development and implementation scheme and possible organizational relationship between the macro and micro levels of administration and water utilization.

The legal analysis of the status of local water user organizations in Pakistan and selected countries has led the authors to conclude that: (1) Pakistan has no formalized pattern of local association or organization concentrating upon water use and

conservation. (2) The laws and regulations for water use as well as the design and operation of the water delivery system do not encourage creation of cooperative efforts among water users at the farm level. (3) No insurmountable constraints are detectable in either legislative or customary water laws of Pakistan. (4) Effective water control and management is facilitated by having an expeditious institution for equitably resolving disputes.

Some of their recommendations are: (1) Induce the establishment of associations through governmental incentive programs. (2) Allow the association to levy assessments for the operation and maintenance of the system. (3) Provide the association with jurisdiction over main and minor watercourses within the command area. (4) Prohibit associations from becoming involved in politics. (5) Minimize, through cost sharing, the initial and subsequent costs of improving the delivery system. (6) Examine the impact of land tenure practices and regulations upon proposed programs of improved water management.

Rao, V. M. (1978). "Linking Irrigation with Development," Economic and Political Weekly 13(24), pp. 993-997.

The author takes findings from three field studies of the economics of irrigation in order to bring out some of the links between irrigation and development. He presents comparative indicators of the impact of different modes of irrigation -- tank, well, and canal -- on the farms located in the relatively homogeneous region of Southern Mairan in Karnataka. He suggests that the crucial constraints to irrigation development in the Indian case are likely to be institutional and socioeconomic in nature. He also advocates the design and management of irrigation systems for less water-intensive irrigation because he feels there is a wider distribution of benefits among irrigators from less intensive water use.

Reidinger, Richard B. (1974). "Institutional Rationing of Canal Water in Northern India: Conflict Between Traditional Patterns and Modern Needs," Economic Development and Cultural Change 23, pp. 79-104.

The author examines the rationing system used on canal systems in Northern India. There are three levels at which water rationing in this system occurs. Decisions with regards to this rationing are based on institutional or administrative rules rather than market forces. He contends that this system causes uncertainty in the timing and quantity of water received by farmers, and calls for the development of water users' associations which would allow greater flexibility and place greater control in the hands of the farmers. The author also mentions water trading among neighbors as a solution to inefficiency.

Roy, S. and L. R. Singh (1977). "An Assessment of Optimum Command Area, and Economic Feasibility of Private Tubewell Installation in Lucknow District of Utter Pradesh," Financing Agriculture 9(2), pp. 20-23.

The authors estimate the optimum command area for a given size of tubewell under existing and optimum cropping patterns. They also use cost-benefit analysis to compare the feasibility of tubewell installation under different situations. They found that the tubewell under the existing cropping pattern was under-utilized.

Sam, M. J. and B. K. Chaubey (1975). "An Analysis of Causes Associated with the Non-utilization of High Level Canal Irrigation from Tungabhadra Project," Mysore Journal of Agricultural Sciences 9(4), pp. 663-670.

This study was conducted in Bellary taluh to analyze the causes associated with the non-utilization of irrigation water from high level canal. The study included interviews with 50 users and 50 non-users of high level canal irrigation selected by purposive random sampling. The results of the study revealed that non-users were older in age, lower in socioeconomic status and had poor contact with change agents. Lack of money for leveling, tedious loan procedures, small land holdings and lack of experience about irrigation were found to be important reasons for not using irrigation water from the high level canal in the Tungabhadra Project.

Sharma, T. C. (1972). "On Improving the Efficiency of Farm Irrigation," Indian Farmers' Digest 5(8), pp. 50-52.

This article, adapted from USDA bulletins on water management in 1972, lays down key points for improving farm irrigation efficiencies. Those being: (1) Creation and improvements of physical facilities such as land leveling; installation of water conveyance system and measuring, control and distribution structures; development of water source for assured supply. (2) Adopting the suitable methods of water application. (3) Management improvement by proper operation of systems. (4) Extension of scientific techniques of water management.

Singh, D. and P. N. Bhargava (1977). "Conservation of Water and Its Utilization," Indian Society of Agricultural Statistics: Journal 29(2), pp. 66-75.

The authors emphasize the need for conservation of run-off water during heavy rainfall and its efficient utilization for agricultural production. They propose methods of conservation tailored to the availability of run-off and suggest small reservoirs with devices to slow evaporation as possible solutions.

"The Social and Ecological Effects of Water Development in Developing Countries," (1978). Water and Society 7(1), 406p.

The studies contained in this volume were presented at a seminar on the social aspects of water exploitation in

developing countries organized within the framework of a research project, "Water Related Problems in Developing Countries." These studies deal with the following issues: (1) Planning and management of rural water development. (2) Health aspects of water development. (3) Technological and economic aspects of water development. (4) Research priorities in water development.

The following papers are included in the volume: Social and Economic Aspects of Water Exploitation by C. Widstrand; Environmental Implications of Water Development for Developing Countries by A. K. Biswas; Planning and Management of Rural Water Development by I. Carruthers; The Management and Operation of Irrigation Schemes in Less Developed Countries by A. Bottrall; Management of Rural Water Supplies by G. Schultzberg; Health Aspects of Water Development by L. E. Obeng; Domestic Water Supplies, Health and Poverty: A Brief Review by R. Feachem; Technological and Economic Aspects of Water Development by D. Henry; Economics of Water Development in Less Developed Countries by L. D. James, Research Priorities in Water Development by R. Chambers.

Sparling, Edward W. (1981). "Collective Goods and Conflict: An Example of a Positive Feedback Mechanism at Work in Rural Pakistan," Colorado State University, Fort Collins, 28p.

The author approaches the problem of irrigation canal maintenance as a collective goods problem. He contends that this problem is characterized by externalities resulting from individual action and vulnerability to opportunistic behavior by other farmers. He demonstrates the organizational difficulties of maintenance and provides theoretical arguments and empirical evidence in support of his proposition that the watercourse maintenance problem is the cause of divisiveness among Pakistani farmers.

Tabbal, D. F. and T. H. Wickham (1979). "Effects of Location and Water Supply on Water Shortages in an Irrigated Area," in Irrigation Policy and the Management of Irrigation Systems in Southeast Asia, The Agricultural Development Council, Inc., Bangkok, Thailand.

The authors studied the effects of location and hydrologic factors on drought occurrence in the 5,700 ha. command area of a lateral in the Philippines' Peñaranda River Irrigation System. They observed greater moisture stress on fields located further along major canals. They also found that minimum water requirements for rice increased substantially when fields were allowed to dry out and crack during periods of water scarcity because of increased seepage and percolation through the cracks when water was resupplied.

Tagarino, R. N. and R. D. Torres (1977). "Potential Farm Value and Equitable Pricing of Irrigation Water: A Case Study of the Upper Pampanga River Project," Journal of Agricultural Economics and Development 7(1), pp. 1-21.

The authors conducted a study to provide water authorities in the Philippines with some economic insights for formulating

adequate water use policies and for setting equitable water charges. They measured the farm level cost of irrigation water supply from a storage system and quantified the net economic contribution of water and the repayment capacity of farmers in different land use classes. They also identified the economic consequences of different water charges.

Taylor, D. C. (1979). "Financing Irrigation Services in the Pekalen Sampean Irrigation Project, East Java, Indonesia," in Irrigation Policy and Management in Southeast Asia, The Agricultural Development Council, Inc., Bangkok, Thailand.

The author studied the rehabilitation of the 274,000 ha. river-diversion Pekalen Sampean Irrigation Project in East Java, Indonesia. This rehabilitation primarily emphasized desilting of channels and the repair of water control structures rather than the restoration of original water-diversion capacities. In this case there was no immediately observable impact of rehabilitation on production, perhaps mainly because the rehabilitation did not overtly improve this project's water supply situation by increasing its water-diversion capacity. The author also cautions against increasing the water charges payable by farmers who were bearing the costs while reaping a less than proportionate amount of the benefits of the project.

Taylor, Donald C. and Kanaengnid Tantigate (1979). "Alternative Strategies for Developing Malaysia's Irrigation Resources," Kajian Ekonomik Malaysia XVI (1&2).

The authors provide a framework of analysis for generating insights for the formulation of long-term policies to develop Malaysia's irrigation resources. Attention is given to three strategic policy variables: size-of-scheme, type-of-scheme, and location-of-scheme.

They found that considerable economies-to-scale exist in constructing irrigation schemes. Larger schemes have higher annual yields than smaller schemes; and diversion headworks are generally less costly than pumping facilities. These findings suggest caution should be taken in policies to encourage small-scale irrigation and controlled drainage schemes.

Taylor, Donald C. and Kanaengnid Tantigate (1981). "The Economics of Irrigation Scheduling: The Kemuba Agricultural Development Project, Malaysia," paper prepared for a workshop sponsored by the Agricultural Development Council, Kasetsart University, Bangkok, Thailand, 29p.

The authors reported on research in Malaysia with the purpose of describing the nature of irrigation schedule non-adherence and determining factors influencing this schedule non-adherence. They paid special attention to the relationship of infrastructure intensity and its economic implications to schedule non-

adherence. They found six variables which were closely associated with schedule non-adherence. They were: (1) late water arrival, (2) late tractor availability, (3) the late harvesting of last season's crop, (4) the actually harvested yield, (5) duration of the paddy crop, and (6) percentage of off-farm income.

Thornton, D. S. (1975). "Some Aspects of the Organization of Irrigated Areas," Agricultural Administration 2(3), pp. 179-194.

The author contends that controlling water for irrigation depends on successful organization both at the project level and the national level. He considers the factors which must influence the nature of organization in irrigated areas, the classification of systems and changes in organization by which the effectiveness of irrigation may be improved.

Torres, R. D. (1973). "Pricing Irrigation Water," Water Management in Philippine Irrigation Systems: Research and Operations, papers presented at the Water Management Workshop, International Rice Research Institute, pp. 183-194.

The author contends that besides the inefficient allocation and use of water caused by underpricing irrigation water, it results in the capitalization of irrigation benefits into land values which mainly benefits the landowners. He calls for the charging of an irrigation fee consistent with the opportunity cost of water under optimum management, which he feels would improve the economic efficiency of water use and encourage the collection of government revenues for further public investment.

Vamadevan, V. K. and S. Patnaik (1974). "Water Management Practices for Small Land Holdings," Oryza 11(2), pp. 11-16.

In this paper, the authors list the improved water management practices for rice and policy changes which could improve irrigation on small holdings. These include the following: (1) land preparation for irrigation, (2) field distribution systems, (3) water lifting devices, (4) water control in fields, (5) irrigation with underground pipes, (6) timely application of water, (7) raising rice crop in drought-affected areas, and (8) suitable cropping pattern.

Van Aart R. (1979). "Minor Irrigation in Madhya Pradesh State, India," Annual Report 1979, International Institute for Land Reclamation and Improvement, Wageningen, Holland.

The author describes the tank irrigation systems used in Madhya Pradesh and offers solutions to some of the management problems encountered in these systems. He contends that a restructuring of village 'panchayats' is needed to increase agricultural production. The 'panchayati ray' is each village's government which he feels could perform a major function in the planning, development and operation of the minor irrigation schemes, and could fulfill the function of the Irrigation Department at the village level.

Von Oppen, M. and K. W. Subba Rao (1980). "Tank Irrigation in Semi-Arid Tropical India," (3 parts), Progress Reports - 5, 8, and 9 from the International Crops Research Institute for the Semi-Arid Tropics.

The study is presented in three parts. The first part gives a brief review of historical records documenting the development of tank irrigation over time, and discusses the relationship of population density and physical factors to the development of tank irrigation. Historical records give ample evidence that tank irrigation has been practiced for centuries in many parts of India. Statistical analysis of district data on tank irrigation densities in former British and princely territories in semi-arid India indicates that spatial distribution of tank irrigation has been determined primarily by physical conditions. The data reveal significant differences between formerly British districts and princely states in this respect. The tank irrigation capacity which we find today in the country was created during different periods in different regions. These regional differences in the timing of tank construction may be explained by differences in population density.

The second part is an attempt to determine the economic performance of irrigation tanks. The authors conclude that tank irrigation is an economically and socially profitable technology; but under present conditions of management tank irrigation is deteriorating rapidly. In view of this decay of valuable capital, the creation of an authority that would be responsible for revenue collection as well as for repairs and overall tank management, including identification of water users, should be considered. Under such a tank irrigation authority the farmers could be charged higher water rates because a better service would be provided. The level at which these rates would be fixed largely depends upon political considerations. However, as a principle, the tank irrigation authority should operate on a no-gain, no-loss basis similar to other state corporations.

The third part discusses the drawbacks in terms of instabilities and low water use efficiency of tank irrigation as it is practiced today. In aggregate, tank irrigation was found to be a relatively risky activity because of unreliable water availability. The economic performance of irrigation tanks depends largely upon the degree of command area utilization. The low utilization rates are largely caused by inefficient water control and lack of appropriate maintenance and repairs of tanks. There is need for an investigation into the possibilities of an institutional framework for increasing the efficiency of water control in order to capitalize on the existing tank irrigation facilities. The aim should be to not only arrest continuing decay but to expand tank irrigation as a socially high return proposition if placed within a proper institutional framework of water control and maintenance works.

Wade, Robert (1976). "Performance of Irrigation Projects," Economic and Political Weekly 11(3), pp. 63-66.

The author investigates the problem of under-utilization of canal irrigation water in India and their less than expected contribution to agricultural output and return on investment. He points out those structural characteristics of irrigation projects -- their economic, technical, and organizational attributes -- that explain their systematic veering from preassigned paths. Among these problems he cites political pressure, poor system quality, command area development problems, refusal to accept responsibility and domination by irrigation engineers.

Wade, Robert (1979). "The Social Response to Irrigation: An India Case Study," Journal of Development Studies 16(1), pp. 3-26.

The author examines the argument that because canal irrigation is a resource which has to be managed collectively, it is an important determinant of the forms of social organization of villages which benefit from it. He concludes from evidence in Southern India that there is a positive relationship between the degree of corporate organization and the scarcity and uncertainty of water supply.

Wade, R. (1976). "Water Accounting in Irrigation Projects," Economic and Political Weekly 11(35), pp. 1436-1439.

The author describes a demand-oriented method of water accounting which provides exact information as to where the water is going. He contends that this method would facilitate water control and result in more efficient water allocation.

Wade, Robert and Robert Chambers (1980). "Managing the Main System: Canal Irrigation's Blind Spot," Economic and Political Weekly 15(37), pp. A107-A112.

The authors find two factors which affect the generally disappointing performance of large, publicly-operated canal systems. They contend that one of these problems is technical in nature (inadequate physical structures) and the other is that the problem originates below the outlet. They contend that a wide range of actions will be needed. Among these are the need to develop rural institutions, the need to supplement farm ditch construction with intensified extension efforts and the need to organize users for the protection of their common good and the reconciliation of conflicting interests.

Wickham, T. H. and A. Valera (1979). "Practices and Accountability for Better Water Management," in Irrigation Policy and the Management of Irrigation Systems in Southeast Asia, the Agricultural Development Council, Inc., Bangkok, Thailand.

The authors provide an overview of the results of several recent field studies on water management and distribution in the Philippine provinces of Laguna, Bulacan, and Neuva Ecija. The diversion irrigation systems studied ranged from 3,600 to 75,000 ha. in size. They found that the distances of farms from turnouts, and the rotation of water supplies at the farm level had an insignificant influence on the performance of the systems. But the location of farmers' fields along distribution canals and the rotation of water supplies among laterals or sublaterals markedly influenced the performance of the systems.