INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE

REVIEW

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INDONESIA MAKES THE TRANSITION TO O&M

HYDRAULIC MODELING OF A MAIN CANAL SYSTEM:
The Next Best Thing to Buying a Canal

THE CHANGING CONCEPT OF MANAGEMENT IN IRRIGATION

PRELUDE

IRRIGATION RESEARCH: SHIFTING THE FOCUS FROM THE FARMER TO THE AGENCY

An interview with Jayantha Jayewardene, General Manager, Mahaweli Economic Agency (MEA).

IIMI Review:
In Sri Lanka, irrigation research has tended to focus on the construction and rehabilitation of the physical system and the capacity of water users to manage their resources below the turnout. The agency itself is rarely the focus of such research. Why is that? Do you think there is a need for research at this level?

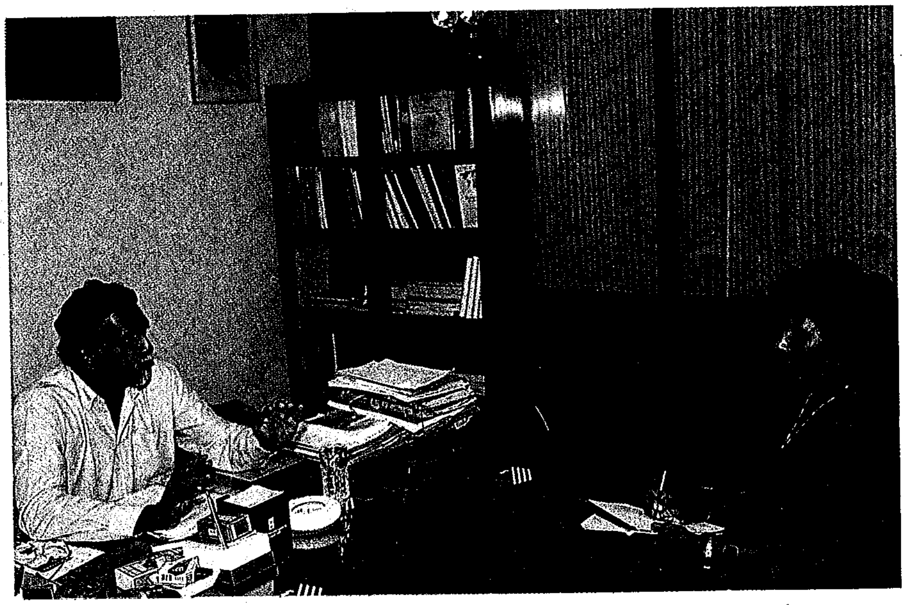
Jayewardene:
To answer your second question first, there is certainly a need for research on agencies managing irrigation systems. However, attention has been focused on the farmer. Farmers have had constant problems regarding availability of water, the quantities they require, and the timing of issues. Solving the problems of issuing, managing, and distributing water at the farm level has received a lot of attention because that is where the pressure comes from. That is the main reason why there has been no research upstream. It is not because agencies or researchers feel it is unnecessary, but because the need to satisfy the farmers immediately has been more pressing. There has evolved now a need for research and a need to look into the system in greater depth and greater detail, and that includes the managing agency.

Until IIMI came along we had no institution or organization that could look at irrigation management in the perspective that IIMI is looking at it. The Irrigation Department has certainly looked at irrigation management problems, but they have not had the resource strength, the wherewithal, nor the time to go into problems that crop up, or look at irrigation management in its broader sense. It has always been management of a system per se.

IIMI Review:
The Raby/ Merrey study (see RESULTS) of the MEA was undertaken during a severe drought -- a crisis situation. However, they suggest that crisis management, albeit under less intense conditions, is the norm for irrigation agencies, rather than the exception. Do you agree?

Jayewardene:
Broadly I agree. In most irrigation systems, it is only rarely that there has been adequate water. So it has always been a crisis situation, and the manager has been left with little time for planning. In Mahaweli Systems B and C, where we envisage cultivation of a larger extent, only part has been developed and cultivation is taking place. At present the system has sufficient water for those areas, but when the area under cultivation increases, water will become a problem. Even in System H, which is fully developed now, we have a problem of having to manage water very carefully and distribute it equitably. Attention again is focused at the farm level, and even in System H, which is now over ten years old, we have not looked at the overall system or the management of the system as Drs. Raby and Merrey have done. That is something which is useful and long overdue.

IIMI Review:
The Raby /Merrey report suggests that there is a two-tier management approach in managing irrigation agencies. They specifically suggest that at higher levels they use an administrative mode of management -- the implementation of rules and procedures -- and that at lower levels they use an entrepreneurial mode of management -- the manipulation of pragmatic rules in response to changing conditions and opportunities. Do you agree, and if so, what are the implications?



IIMI Post-Doctoral Fellow Namika Raby interviewing General Manager, Jayantha Jayewardene.

Jayewardene:
I agree. At the higher tier of management we set out the extent to be cultivated depending on the availability of water, and we plan out what we think is the ideal model to be used in the distribution of water for that cultivation season. We had an inclination that the model was not strictly adhered to when it was implemented in the field, and this study throws up the fact that there had been certain modifications and changes at the field level.

This study focuses attention on the fact that what actually happens in the field is not exactly what we set out to do. What happens in the field is the reality -- it is the workable model. That is what this study has revealed, and I think that it is important for that reason. We should take the actual field situation into consideration when we are planning our future cultivation seasons, rather than stipulate the ideal model from the planning board or from our concept of what it should be.

IIMI Review:
Do you agree that irrigation agencies in general need to implement procedures for monitoring the performance of managers against predetermined standards?

Jayewardene:
Yes. It is important for the top management to find out what exactly their managers are doing, rather than presume they are doing what you have asked them to do. As I said earlier, in most cases you find that they have adapted and modified irrigation plans, taking into consideration the situation in the field, the availability of water, when the farmers started their cultivation, etc. It is very important for us to monitor very closely what exactly goes on in the field as against what we have asked them to do. Once we get some feedback on the actual field situation, that data and information

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Groundwater and surface water supplies are used in conjunction by tail-end farmers in Java to compensate for water shortages.

INDONESIA MAKES THE TRANSITION TO O&M

John Colmey in cooperation with Hammond Murray-Rust and Douglas Vermillion

The development of infrastructure to exploit the potential of water resources has been a recurring theme in Indonesia's past four national plans. By the end of the fourth national plan in 1989, the Government of Indonesia will have invested, with foreign assistance, over US$12 billion in the construction, rehabilitation, and upgrading of irrigation systems.

Between the years 1969 and 1978, priority was given to construction and rehabilitation of dams and weirs, diversion structures, and primary and secondary canals, mainly in Java. In the 1970s major investments were made in new schemes and increased emphasis was given to tertiary development in the upgrading of small systems. Total public irrigated area now stands at 4.3 million hectares (ha), the largest agency-controlled irrigated area in any southeast Asian nation.

The development of water resources has been closely linked to agricultural intensification policies, which have had as their principal objective self-sufficiency in rice, the staple food of Indonesia's 170 million people. That goal was achieved for the first time in 1985. Productivity increases as high as five percent per year have been achieved through new rice varieties, greater use of inputs, and extending or upgrading irrigation systems.

To maintain self-sufficiency, rice production must increase at about three percent per year. Assuming that the bulk of the breakthrough in new rice technologies has been achieved, and that most of the irrigated area in Java (where more than two-thirds of the population lives) has already been developed, future production targets will have to be met through improved performance of existing irrigation resources. Moreover, if agriculture is to continue to contribute to the economy, Indonesia must fully exploit the potential for irrigating more profitable non-rice crops in the dry season.

The rate of increase in rice production is currently declining. A recent statement by Ir. Radinal Mochtar, Minister of Public Works, stresses the need to focus on improved operation and maintenance (O&M) to maintain rice production increases and arrest deterioration of existing irrigation systems that result from difficulties faced by provincial irrigation services (PRIS) in operating and maintaining relatively sophisticated facilities. The government must create the correct environment for adequate funding and staff support for O&M activities.

Like many Asian countries, Indonesia faces a dilemma over where these funds will come from. Unlike capital investments, which attract large amounts of donor funding, O&M costs come out of recurrent budgets from which donors shy away. Indonesia has been particularly hard hit by the drop in oil prices, forcing the Central Government to make a 50 percent cut in funding for irrigation O&M.

NEW POLICY ON O&M

The government's recent statement of policy for the irrigation sector is directed at improving O&M performance while at the same time moving the irrigation sector towards a self-sustaining future. In effect, the policy marks a turning point in Indonesia's irrigation sector from a construction-oriented perspective to a management-oriented perspective.

The policies call for transferring all responsibility for funding O&M in large systems to the PRIS and the complete responsibility for O&M in small irrigation systems (less than 500 ha) from the PRIS to water user associations (WUAs) over 15 years. The government will then encourage per hectare increases in O&M funding by PRIS to meet the actual needs of larger agency-managed irrigation systems, and to assist in strengthening irrigation institutions for the changes. Eventually the PRIS and the WUAs will be expected to finance all costs through the implementation of a new irrigation service fee (ISF).

To assist the government in meeting the current shortfall in funding, and in making the transition in general, the World Bank and the Asian Development Bank (ADB) recently approved irrigation sector loans to Indonesia of US$240 and 150 million, respectively. Both loans have as their objective more efficient O&M. At the end of five years, the government is expected to achieve its goal of financial self-sufficiency. Both loans include parallel components for the development of efficient O&M procedures, O&M needs-based budgeting (as opposed to area-based), introduction of the ISF, support for turning over small irrigation systems to WUAs, and institutional strengthening of irrigation agencies and WUAs.

Indonesia is re-evaluating its approach to O&M, like many Asian countries, to stop the deterioration of existng systems.

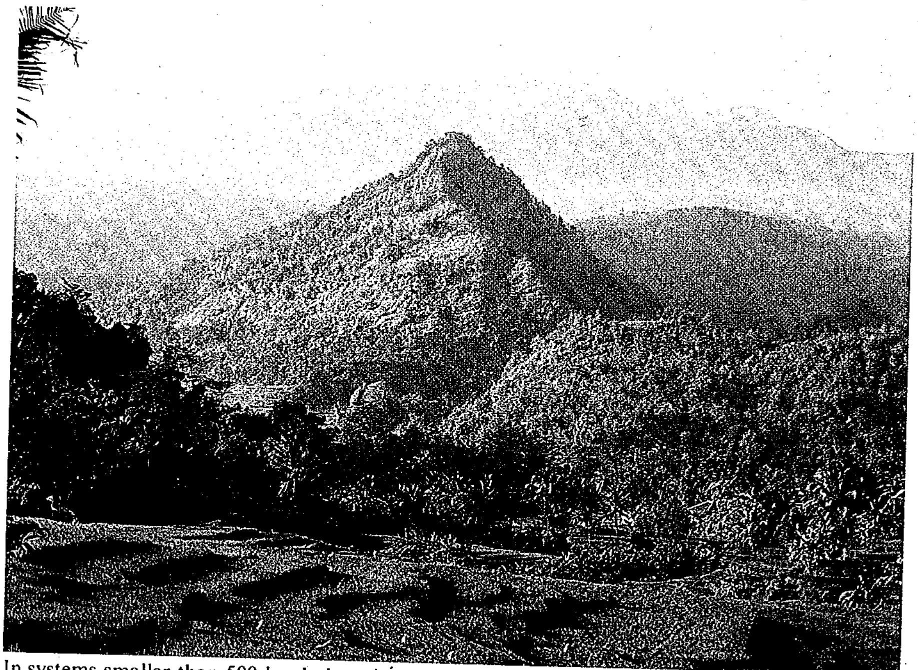
IIMI'S ROLE IN INDONESIA

As in other IIMI programs now underway in Nepal, Pakistan, the Philippines, and Sri Lanka, Indonesia staff collaborate closely with the national irrigation agencies and other institutions in action research and development on issues specific to the country's needs. Results generated in these programs are quickly disseminated to other countries where similar issues are important.

In Indonesia, IIMI has two internationally recruited staff, Dr. Hammond Murray-Rust, an agricultural engineer based in Jakarta, who moved from IIMI's Pakistan program to replace Dr. Sam H. Johnson III, and Dr. Douglas Vermillion, a social scientist based in IIMI's Bandung, West Java office, who has been with the program since its inception. Most of Indonesia field research staff have been seconded to IIMI from the PRIS where IIMI's sites are located. Two social scientists from Andalas University in Padang and Padjadjaran University in Bandung have been recruited near full-time to work on the turnover program. The Department of Agricultural Engineering of the Gadjah Mada University has been subcontracted to collaborate with IIMI on its research on agency system management in the Cikeusik and Cisanggarung areas.

IIMI began work in Indonesia in 1985 in response to a request from the government and the ADB to take part in a study with the International Food Policy Research Institute (IFPRI) aimed at improving irrigation management performance generally, and more specifically, adapting management to support dry season crop diversification in systems originally designed to irrigate rice. IIMI's program now underway in Indonesia has two components which support the government's current policy and strategies, as well as those of the two sector loans: 1) irrigation system management for "large" technical systems (over 500 ha) and 2) turnover of small systems to farmers.

Under Phase II, due to be completed in 1989, supported by the ADB and Ford Foundation, IIMI, together with the Directorate of Irrigation and the related PRIS, is identifying and testing a number of practical procedures to improve management in PRIS agency systems in West Java and Lampung, Sumatra. In the system turnover program, IIMI has field staff in three irrigation sections, Sumedang and Kuningan in West Java, and Solok in West Sumatra. Both of these provinces have been selected by the government as pilot learning areas for the turnover program.



In systems smaller than 500 ha, Indonesia plans to turn over responsibility for O & M to farmers.

MANAGING AGENCY SYSTEMS

As in many countries, Indonesia has a formal set of rules for allocating and distributing water in agency systems. In Indonesia, they require an accurate assessment of the current demand every, 10 or 15 days (depending on the province), which means determining the total cropping area and the type of crops. This becomes increasingly difficult in the dry season when farmers cultivate a mix of rice and non-rice crops, which requires an even more precise knowledge of crop areas, growth stages, and water demands. Indonesia's PRIS must manage irrigation systems in an environment of fragmented landholdings, variable cropping patterns, micro-level diversity in soils and landforms, and often considerable hydrological interconnections of systems.

"Field assessment of demand," says Murray-Rust, "is built up to make a total demand for the system, allowing for estimates of conveyance losses and other factors. Total demand is compared with supply, and the resulting ratio (factor K) is used to make operational decisions. With plentiful water, the system is run with continuous flows. If there is need for rotations, it generally begins at the tertiary level, where farmers rotate water among themselves. As supplies decrease further, the government begins to implement rotations among tertiary blocks, eventually among secondary canals, and perhaps between weirs along a rivercourse."

"We found two major constraints to this management system," says Murray-Rust. "First, estimates of the actual areas under different crop types are usually based on reports to the field irrigation officer from the village water master *(ulu-ulu)*. These are usually rough estimates as there are no adjustments for soil variation, and official records of block sizes are often inaccurate."

On the supply side, the prevalence of inoperative division structures, inability to measure water, and sediment buildup further complicate the planning. "Because most of the systems are of the run-of-the-river type," notes Murray-Rust, "sediment buildup is high. Also some systems often run at as low as 50 percent of design discharge. This can be as big a factor in performance as the difficulty in measuring demand. The agency does not have the staff or the funding to adequately maintain all its systems by itself." In systems examined by IIMI, which were considered to be above average, between 30 and 70 percent of main system measuring structures were operating.

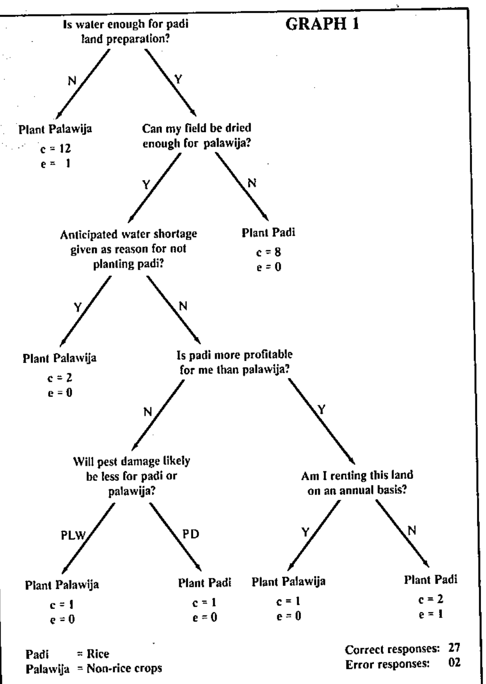
"Second, we found big differences between planned and actual discharges. As a result, some blocks receive much more water, others much less, than planned," says Murray-Rust. "On the demand side, the system usually doesn't cope well with soil variations, variable conveyance losses, inaccurate block sizes, and high variation between small landholdings in crop types with different water demands. On the supply side, additional water supplies from other canals, village weirs, drains, or conjunctive groundwater use are not included in calculations," Vermillion points out.

"Some areas IIMI observed in Phase I, for example, were getting as much as six times their planned discharge, others less than half. In the dry season, supply in the main canals, rather than being constant as assumed by the current management system, is often rotated or fluctuates widely. These effects become greater as water moves down the system," adds Murray-Rust.

The IIMI Phase I study helped clarify the high intensity of information staff and funds needed to implement properly the factor K system. The management requirements to collect the demand and supply data, to assess the demand every 15 days, and to adjust the gates in response to frequent discharge fluctuations tend to overwhelm general management capabilities. During Phase I, IIMI identified key weaknesses in field implementation of the current management systems in use in East, Central, and West Java, with particular regard to the information base and system operation practices.

IIMI also tested and recommended several new procedures to improve the information needed for management decisions. This included the use of a new pocket-size book by the gate operator to record discharges, the use of the management performance ratio to monitor and respond to variations in planned and actual discharges, and the making and using of tertiary block maps to improve information on actual crop areas. "We also interviewed farmers about their crop planting choices," says Vermillion, "and found farm-level water shortage or excess to be the most important factor across all sites in determining whether or not farmers will plant a non-rice crop in the dry season" (see Graph 1).

GRAPH 1



Farmer decision model to plant Padi or Palawija, Jarot 2 Block, Central Java, first planting period of 1986 dry season (Gadu I).

Vermillion says that in Phase II, "IIMI is not concerned with diagnosing management constraints and problems, but with identifying and testing new procedures to strengthen the information base and rationalize management decisions. PRIS and IIMI are involved in deciding which aspects of management performance should be improved through intensifying management capabilities and which should be improved through simplification." As Murray-Rust puts it, "The existing management system is technically quite sound, but is often beyond the capacity of the agency. In the same way, I think the systems are over-designed. Many were designed or rehabilitated in the capital intensive 1970s when a measured management down to the field level was assumed."

Under the agency-managed systems research, IIMI staff have been posted in the Cikeusik system, Cisanggarung river basin, and Ciwaringin system near Cirebon, West Java, and in the Way Jepara Irrigation Project in Lampung province in southern Sumatra.

Cikeusik System and the Cisanggarung River

At 7,500 ha, the Cikeusik irrigation system is the largest system currently under study. It is the last of seven relatively large systems (and numerous smaller systems) along the 60 kilometer long Cisanggarung River, which flows northward into the Java Sea. Cikeusik is a good example of irrigation under diverse cropping conditions. During the wet season it irrigates rice, sugarcane, and even some non-rice seasonal crops. During the dry season there is less rice, a fairly constant level of sugarcane, and about one-third of the area in non-rice crops. The mix of crops, occasional severe water shortage, and the location on the river leads to an intensive management requirement, under diversified cropping conditions.

Despite its unfavorable location on the river, the system maintains high cropping intensity throughout the year. "Part of the reason," says Murray-Rust, "is that farmers use a considerable amount of groundwater in the lower part of the system, to irrigate non-rice crops."

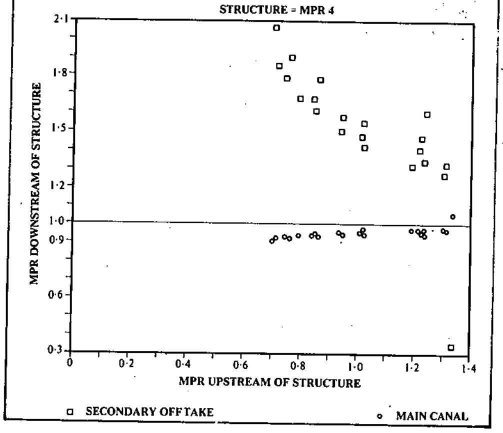
According to Murray-Rust, IIMI has an opportunity to study three main areas. "The first is system operation, how you manage a system that becomes increasingly short of water as the season progresses. This includes improving procedures such as adjusting gates in response to fluctuation, efficient rotational arrangements, and establishing proper planned discharges. The second is conjunctive use, how farmers cope with water shortage by tapping groundwater, either by hand or by pump. And third is the intensity of diversified crops. Cikeusik has large areas under onions, chilies, and various types of beans. Onions and chilies can be very profitable. Many farmers, for example, have found it worthwhile to grow only onion in some fields throughout the year, and can get as many as five crops per year, despite the heavy labor requirement, including manual irrigation."

"We are measuring planned and actual discharges and gate adjustment practices at 54 gates in the system," Vermillion says, "at main, secondary, and tertiary levels. We interview gate tenders and irrigation officers each week about their rationale for adjusting gates as they have. This information, together with data observations on actual gate adjustment practices, gives us a perspective on the real logic of management responses."

For example, as Murray-Rust points out, gate tenders generally favor their areas at the expense of downstream farmers. Graph 2 (Actual and Planned Gate Operations) demonstrates the practices of a gate tender at a secondary offtake in the upper part of the main canal during April 1988. The Y-axis is the ratio of actual to planned discharge, with the horizontal line at 1.0 indicating the optimal management performance ratio (MPR). The X-axis is the ratio of planned and actual discharge arriving at the division structure. The small squares show that the local gate operator gives more water than planned to his secondary canal, and less than planned to the downstream section of the main canal. Only when incoming discharge is at least 20 percent greater than planned will downstream areas receive close to planned discharge.

Because of the frequency of severe dry season water shortages, main system rotations are generally implemented by the middle of the first dry season. "Through repeating inspections of sample tertiary blocks we are uncovering the actual rules and

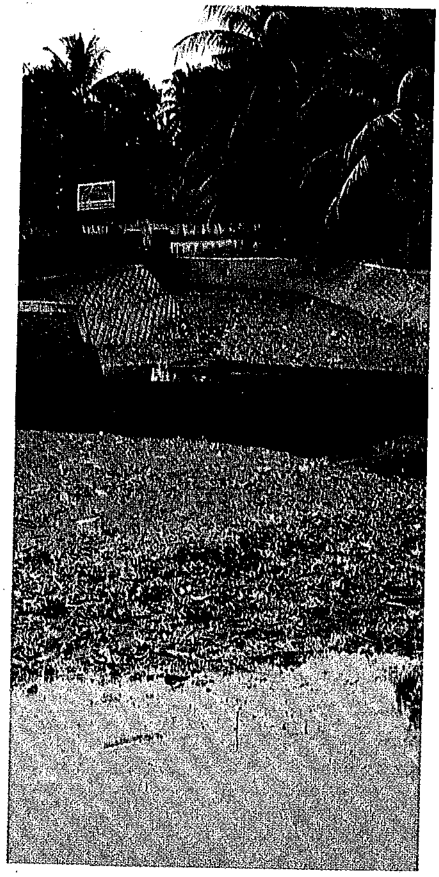
GRAPH 2
Actual and Planned Gate Operations



practices farmers use to distribute water at the tertiary level in response to changing main system conditions. This is important in a period where the agency is questioning the potential of farmers for increasing main system roles. Our weekly day and nighttime main system inspections are clarifying the structure and extent of divergence between plan and practice," says Vermillion.

This year, the transition from wet to dry season was very abrupt. "The system went from having rotations within some tertiary blocks, usually below 100 ha in size, to rotations between secondaries serving from 2,000 to 3,000 ha each in less than two weeks. When the rains suddenly stopped, the river discharge into the system dropped by almost 75 percent," says Murray-Rust.

IIMI has begun to collect and analyze data on water supplies and demand for, and operation of, the Waduk Darma reservoir and seven systems along the Cisanggarung rivercourse (of which Cikeusik is the last weir). The purpose is two fold. First, IIMI would like to help to improve forecasting of water supply and water availability along the rivercourse and into the systems, on the basis of historical and immediate data on rainfall and stream flows. Second, we are attempting to develop a standard, rationalized contingency management system for adjusting the reservoir outlet and weir intakes in response to fluctuating water supplies. Along the river, some upper-end systems get three rice crops a year



Although Indonesia has sophisticated irrigation systems, the difficulty has been in mobilizing the resources necessary.

while others have only one or two crops and some fallow lands. Some annual cropping intensities exceed 275 percent, while others are below 200 percent.

IIMI's activities in Cikeusik and along the Cisanggarung River are being undertaken with cooperation not only of PRIS but also the Provincial Agricultural Service, the International Rice Research Institute (IRRI) in the Philippines, the University of Gadjah Mada, Sukamandi Research Station, and the Soils Research Institute with additional funding provided by the Rockefeller Foundation.

Ciwaringin System, West Java

Typical of Java, the 2,420 ha Ciwaringin irrigation system is a run-of-the-river system in a network of interconnected irrigation systems that pick up drainage water from small weirs, suppletion canals from other systems, and residual flows out of the rivers. Despite water shortages in the dry season farmers tend to either plant rice or leave the land fallow. There are extreme discharge fluctuations in the main canals because the system utilizes more than one river, unlike Cikeusik. "The number of intakes makes for a completely different set of management activities from that in a system like Cikeusik which has a centralized water source," says Murray-Rust.

"There is a need to make official distinctions between different management systems, which would be seen as contingencies arising from variable levels of management sophistication and measurability relative to local needs and capacities. In fact we have seen that only a minority of PRIS systems actually attempt to implement the factor K management system," notes Vermillion. Ciwaringin is a clear case where local adjustments need to be made in the management system due to the extent of unmeasured supplementations at all levels, substantial spatial variations in percolation and seepage rates, and frequent inaccurate or out-of-date block area figures.

In Ciwaringin, water begins to get scarce early in the dry season, often dropping to one-third of the requirement before risk status develops by mid season. Farmers in the lower half of the system avoid the risk of planting any irrigated crops in the second dry season, partly because of scarce water being used in the upper area in continuing cultivation and partly because of severe rat infestation in the lower area.

In both these systems, IIMI is taking a wide range of climatic readings, such as rainfall and evapotranspiration rates, to assess better what the actual demand is as opposed to the estimated demand. Public agencies use a formula to assess the estimated demand based on an assumption of crop water requirements. "We are going to see how close the estimated demand is to the real situation in the field," says Murray-Rust. "Our readings tend to show much greater variability, because government estimates tend to be averaged at the section level. System specific management approaches will improve management performance in both systems. If they begin to move in that direction we can assist in developing a process which takes into account questions such as local actual and probable rainfall, likely evapotranspiration, or the likely contribution of groundwater. Only then can a system be managed truly according to location-specific information, rather than using general administrative guidelines from above.

"However much we may attempt to quantitatively account for all the demand and supply-related factors, in the end the fact remains that irrigation is not only a science but is also an art, requiring some scope for official agency accommodation for qualitative judgement, negotiated adjustments, and experience-based decision making," says Vermillion. The crux is how to balance measurable accountability with qualitative flexibility. PRIS field operations staff often of necessity exercise well-intended initiative given local complexities. And yet since this cannot be incorporated into the present official management system, staff are often discouraged from reporting actual conditions and practices in a way which could enable performance to be monitored, and hence, improved."

IIMI is now moving towards a more regional examination of management practices and the potential for improved performance. Murray-Rust notes that "We had to start with more specific system studies to gain an understanding of what is a very complicated management system. However, we do not have the staff or the resources to look at many systems in this kind of detail. Also as IIMI tests and recommends new procedures to the government, they have to be generic enough for them to apply over a range of systems." IIMI has begun this year examining water management of a reservoir and multiple weirs along the Cisanggarung River. IIMI will also soon assign staff to monitor implementation of new O&M procedures in several of the pilot "advanced operations units" of PRIS subsections in West Java in conjunction with the West Java Irrigation Project.

Collaboration plays a central role in IIMI's Indonesia program. System engineers and officials allow IIMI to research existing systems, and provide IIMI with valuable insights and feedback on research.

Way Jepara, Lampung Province, Sumatra

In 1987, the Directorate of Irrigation asked IIMI to expand its research outside Java to field test innovations under different physical and management conditions. The government feels a strong need to increase dramatically the management performance and hence productivity of irrigation systems in such provinces as Lampung, where the government has invested heavily in constructing new systems during the 1960s and 1970s.

Way Jepara is part of a transmigration resettlement project, with the first major inflow of migrants coming from Java and Bali in the late 1950s and early 1960s. Each family received about two hectares each and subsisted on rain-fed agriculture until the government decided to develop the project for irrigation in the 1970s.

The Way Jepara irrigation project was built in 1976. Originally designed to irrigate 6,650 ha, the current irrigated area is about 4,700 ha, and is still being extended. Although it is only 12 years old, the system is already in need of rehabilitation.

"Although we have only been in Lampung for a short time," says Murray-Rust, "it is already clear that there are a number of ways in which management efficiency can be improved. The reservoir spills every year, which suggests that it does not have enough capacity to meet the potential demand once the system is fully developed. During the wet season the agency rarely shuts off the reservoir, which allows the reservoir level to drop a little earlier than necessary at the end of the rains. This suggests there are opportunities for managing the reservoir to maximize the amount of stored water for the dry season."

There also appears to be significant opportunity for increasing dry season production during high rainfall years. "The allocation of rice is almost the same every dry season. The top half of the system is allocated rice one year, and the bottom half the next year. So this year, for example, the rains extended for two extra months, and yet we have a peculiar situation where the upper half of the system is not being irrigated, and the lower half has more water than it can use. There is virtually no rice being grown in the upper half of the system. They underestimated the amount of rice that could be irrigated, though eventually they did allow more rice to be grown."

There is also a peculiar weed problem. The reservoir traps the sediment, so that clear water allows weeds to grow and reduce flow by as much as 50 percent. It is a system where farmers play a significant role in maintenance of the main canal. Three or four times each year 200-300 farmers assist the PRIS in cutting the weeds. "This is an example where farmers are willing to assist the agency because they know it would not be able to maintain the canal by itself given its current staff and funding levels," says Murray-Rust.

As a transmigrant system, Way Jepara offers IIMI the opportunity to investigate various organizational aspects of the system. Farmers in the system come from different areas including Bali, and East, West, and Central Java. They bring their own rules and procedures for how to manage water at tertiary level.

"Balinese villagers," says Murray-Rust, "allocate water proportionately with a continuous flow of water into everybody's field based on area. In Javanese villages, it is more common for one person to receive all the water until his field is full. The Balinese approach requires less labor, whereas the Javanese approach requires someone to be in the fields all the time while diverting water into a set of fields. One sees some interesting differences within a single system because of the different backgrounds of the people."

"In general, we feel that the opportunities for improving water use in Way Jepara are quite high. The annual crop planning process imposes a simple but rigid plan at a high level, inhibiting the opportunity for making short-term management decisions. Once you've decided to split the system into two halves (one half receiving water for a season and the other half not), you leave little room for flexibility. It may be necessary to determine a way of finding a minimum irrigable area, but allowing for upward adjustments according to what the hydraulic conditions become. If there is more water than normal in the reservoir you could then devise a system for giving water to some of the farmers in the unirrigated half of the system.

TURNING OVER SMALL SYSTEMS

As part of the turnover component of the new irrigation sector loans, the government has agreed to transfer small systems (at first those less than 150 ha) serving a total of 20,400 ha to WUAs

Many farmers find it worthwhile to grow onion year round, with some growing as many as five crops annually.

within the first 3 years, and to begin, in the third year, to prepare for transferring an additional area of 48,000 ha. After 5 years, the transfer of systems between 150 and 500 ha will begin. After 15 years 70 percent of all systems currently in the government's inventory, totalling some 899,599 ha or 21 percent of the total government irrigated area, will be turned over to WUAs.

"By turning over responsibility for O&M to farmers (and perhaps eventually system assets as well)," says Vermillion, "the government hopes to reduce its administrative burden and free additional resources for use on larger, more technical irrigation systems. Reallocating funds and staff from smaller to larger systems will also help the government in meeting the O&M funding target of Rp 23,500/ha (US$14) for agency systems."

The government is implementing the turnover program first in West Java and West Sumatra because of the large number of small systems in these mountainous provinces. IIMI has staff in three sections in the pilot provinces, in Sumedang and Kuningan sections in West Java and in the Solok section in West Sumatra.

IIMI's research is designed to produce prompt information, analysis, and frequent suggestions aimed at improving the turnover process, as it is being implemented in pilot areas, so that the pilot stage will be as much a learning process as possible in the emergence of a national program. IIMI is examining the implications of turnover for the PRIS budgets and staff allocation and new PRIS and farmer management roles.

IIMI has been collecting data on PRIS investment patterns in staff, routine O&M funds, and construction, in large and small systems in each section (with over 70 systems per section). This will help clarify both the levels of current farmer dependency on the agency as well as the likely scope for real government savings due to turnover. Preliminary findings indicate that smaller systems have already been getting much lower levels of investment per hectare than larger systems. IIMI is also beginning to examine patterns of farmer investment in selected systems and to monitor management performance in eight systems in Sumedang and Solok sections before, during, and after turnover. This will help address the concerns about how capable farmers are of operating and sustaining small systems.

Turnover is not simply PRIS in retreat but an effort to reorient responsibilities with capabilities. PRIS will move away from O&M within small systems and focus on coordination of water allocation between systems, strengthening of water user associations, and providing longer term, low-level service to systems. The aim is an optimal mix of government and WUA investment which takes full advantage of farmer capacities.

Irrigation officials are now being asked to document O & M activities. Here, a field manager photographs weeding.

The Ford Foundation is funding both IIMI and LP3ES (Institute for Socioeconomic Research, Education, and Extension), a local non-governmental organization (NGO), to assist in turnover. LP3ES is responsible for training, program development, and field advisory support. The Ford Foundation, through Dr. Frances Korten, has encouraged the formation of a national-level working group to discuss turnout planning and issues. The groups consist of national and provincial level irrigation officials, the Ford Foundation, LP3ES, and IIMI. IIMI has participated in this working group since February 1987 and is now closely interacting with PRIS officials as the turnover process unfolds in the pilot provinces.

The first stage in the turnover sequence is a regional rivercourse inventory of small systems (conducted by PRIS staff after being trained). This is done to determine the level of past and current PRIS investment in systems. The inventory distinguishes between three types of systems. First are those systems which have never received government investment and simply should be reclassified as non-PRIS systems. (Some sections have incorporated systems into the PRIS without any PRIS investment. Budgets are based on area irrigated by sections.) The second type are those systems that do not need any physical repairs, but only require a change in management roles, or a strengthening of the WUAs. Third are those systems that require both repairs of physical structures and a change in rules for the WUAs. Those systems that received government assistance, and therefore may have become dependent on PRIS investment, are then brought to the next stage in the process, the socio-technical profile.

The profile is an information gathering method, first developed in the Philippines, to determine the farmers' existing organizational structure and practices, the division of responsibility for O&M between the farmers and government, the location of functional or faulty structures, and the cropping patterns. This provides a basis for planning what needs to be done in a system prior to turnover. The survey is currently completed by lower level government officials, called "TP4." The TP4 are trained to act roughly like a community organizer for WUAs. Significantly, inside this acronym is the phrase "farmer water managers," used by the government, rather than the more passive, conventional term, "water users," Vermillion points out.

In the third stage, the TP4 works with the farmers to design and plan the construction or rehabilitation of new or existing structures, and the development of the WUAs. The government has created a special maintenance fund that will provide about US$90/ha in improvements. The total turnover preparation time expected for most systems is about 15-18 months.

Sumedang Section, West Java

Cinnangka 2 is a small irrigation system in a hilly upland area, typical of systems in the Sumedang section, just west of Bandung, the provincial capital of West Java. The command area is 104 ha, most of which is planted to rice twice a year. Originally built by the farmers with temporary brush stone weirs, it received intermittent assistance through a government subsidy program to aid villages. In the late 1970s, as part of the Sederhana irrigation project, the government built a dam at the intake to the system to supplement water to the lower section and then reclassified it as an agency system. Now the system has six PRIS gate and channel tenders helping to cut weeds in the channels and operate main offtake gates. These roles will be transferred to farmers after turnover.

The system includes two villages. During dry season rotations, the upper village receives water during the day and the lower village receives water during the night, with subunits receiving flows on different days or nights. The village-based WUAs organize and police the rotations, not the agency staff, and also mobilize farmers for heavier maintenance activities, such as de-silting channels four or five times a year.

IIMI's first activities in the section have been to collect data on PRIS and farmer investment in several systems and to observe and document the inventory and profile activities in sample systems. "We evaluated," says Vermillion, "how well the TP4s understood their tasks, how they interacted with farmers, the adequacy of their information sources, and how well they met their objectives."

"We are recommending," he continues, "that the profile be extended from the current 10-15 days, to about a two month period in order to include directly, completion of a farmer version of a design for system improvement, as well as the farmers' own plan for their investment in the improvements, before the technical design people arrive on the scene. This would also include a plan to develop new WUA management roles relative to the new investment and advent of turnover. We think it is crucial that the farmers make some group investment in the system prior to turnover, both in order to strengthen their sense of ownership and to provide a 'physical event' as a basis for organizing. It is also important that the farmer-designed version precedes preparation of the 'technical' design so that the former will be the basis for the latter, rather than the reverse."

Kuningan Section, West Java

Another system, Cinnangka, in the Kuningan section has been selected as a pilot system for the larger class of system turnovers. Its command area is 441 ha. The system has evolved over time, through various rehabilitation projects both by farmers and the government. At first, in known history, was the brush and stone weir at the top of the system. It was later replaced by a slightly more sophisticated weir, and later by yet another weir. The farmers built a 1-1.5 meter high masonry retaining wall 800 meters long. The first three weirs were built by the farmers. The government built the last one in 1980, which is about 50 meters across and 7 meters high. There are two other stone-and-earth suppletion weirs built by farmers for the lower part of the system, requiring heavy yearly farmer labor inputs.

"This system is an example," says Murray-Rust, "of how the irrigation development process tends to move from a low-capital-cost/high-maintenance-cost system to a high-capital-cost/low- maintenance-cost system. The system has had very high levels of both farmer and government investment, the latter providing lined channels, measuring structures, and sliding metal gates." Vermillion adds, "That's what makes it such an interesting, and problematic, pilot test case for the larger class of systems being turned over. As part of the turnover, the agency plans to form a WUA that will cut across the seven villages served by the system. There already is an embryo inter-village WUA which meets regularly with representatives from different villages. However, its management requirements might be expected to climb significantly after turnover."

"The implications of transferring systems of this size," says Vermillion, "are much more pronounced than the smaller class -- the structures are much bigger, use permanent materials, are more technical and difficult to operate, and involve more farmers living in several villages."

Solok Section, West Sumatra

The Pauk system is about a two-hour ascending drive inland from Padang, the provincial capital on the coast of West Sumatra. It is in a mountainous area and irrigates rice year-round. The system has received minor investment from the government to build reinforcing walls along some of the channels. In contrast to the Cinnangka 2 system in Sumedang, there seems to be an absence of farmer organization, a case of a WUA that "doesn't function." The channels are overgrown with weeds and are filled with sediment. "The reason for this deterioration," says Helmi, IIMI field coordinator, "is that farmers have more than enough water."

"Because there is water throughout the year, farmers tend to plant their rice crop at different times of the year, and use different varieties, in accordance with their money flows. If there is a landslide or collapsed embankment which obstructs channel flow, those farmers who need water at that particular time have an incentive to participate in the maintenance activity, while others who may be harvesting do not. Farmers near the head of the system rarely have an incentive to get involved. Any organization or resource mobilization is strictly event-specific," he continues.

The Bunian system takes water from the same river, immediately adjacent to the Pauk system. But Bunian has received considerable PRIS investment, including a cement weir, lined channels, and steel gates. Despite the added investment, the system is in much the same condition as Pauk. The channels have heavy sedimentation and the gates are locked in place by rust, so that the system always runs on continuous flow. Farmers seem to be responding to a situation of water abundance and (at least in the case of Bunian) of expectations of the possibility of government assistance should the system deteriorate too far.

According to Vermillion, "There is a tendency in the mountainous areas of West Sumatra as well as West Java, for the agency to bring a lowland, large system orientation into investing in small, hilly systems -- namely, an emphasis on diversion and division structures. Whereas farmers tend to emphasize investment in conveyance - which is much more problematic in hilly, relatively water abundant areas than water acquisition and divisioning. Also farmers tend to make structures with low intensity management requirements. One example is farmer-built flood/silt control walls, built over the top of the canal just below the offtake to divert flood water back into the river automatically, rather than having an adjustable overflow gate which requires someone to adjust a gate on short notice to avert flooding, structural damage, and heavy siltation.

"It is essential," he continues, "that farmers play the key role in designing pre-turnover improvements not only to instill a sense of local responsibility and facilitate formation of a vibrant WUA, but also to ensure the appropriate design of structures for which farmers are capable of managing and sustaining."

"For PRIS, turnover will mean first a significant amount of staff and resource reallocation and training," says Vermillion. "Under different conditions PRIS staff may be either moved to larger systems, simply released, given a more macro-level assignment, become part of a mobile, incidental maintenance service team, or perhaps stay put but be paid by the WUA instead of PRIS. Reassessments of actual staffing requirements in larger systems need to be made."

"Second, there will be a change in the role of irrigation officers from an intra-system role to a macro inter-system role with responsibilities for coordinating and supervising rivercourse water distribution. Third, the turnover program invokes a reorientation of the PRIS towards providing incidental assistance to systems after turnover. This must be done in a way that does not replace local farmer resources but discriminates between repairs that can be handled locally and those which require joint agency/farmer investment. Fourth, the PRIS will need to set up a needs-based budgeting system which incorporates the emerging incidental or indirect costs which will characterize the post-turnover orientation, whereas the current budgeting structure is based on a direct investment orientation towards O&M.

THE CHALLENGE: TRANSITION TO AN O&M FOCUS

The Indonesian irrigation sector is in a fascinating but critical stage of transition. Current policy is to achieve self-sustainability in irrigation O&M by reducing expenditures, either directly or through subsidies, and by introducing fees for irrigation services. Without adequate financing, the irrigation systems will deteriorate, which will make it more difficult to sustain and increase food production. And there will be fewer loans available for rehabilitation of these systems in the future.

"But Indonesia faces more than a budget challenge," says Murray-Rust. "Indonesia has to continue to manage water in a way that maximizes its productive value. Water resources are becoming increasingly scarce. There are more people, there is more urban and industrial demand for water, particularly in Java. Irrigated agriculture has to become more efficient. So the government has the task of not only finding the money to run the systems, but it has to develop the methods to run them cost-effectively."

"Getting a steady increase in production of two or three percent a year through management improvements is not going to be easy. Some of that increase has to come through greater diversified cropping, because of the lower water requirement. But that will be limited, as rice will have to remain the priority."

"By looking at the management requirements of a system," says Vermillion, "you can begin to see what the government will need to do in terms of technical change, redeployment and retraining of staff, and new procedures -- all of which would help to make those systems more productive. It will need to develop more precise records of water supply conditions, and season by season plans which are more responsive to the actual, variable conditions."

"To do this the government requires information and analysis of how to realize its policies through improved management, which our research is aimed at providing. Like most irrigation agencies, the government agency does not have a research branch. IIMI's role," concludes Murray-Rust, "is to work closely with the agency to fill that gap."

There are few illusions that the transition towards O&M will be rapid. Ir. Winarno Tjiptorahardjo, Head of Irrigation O&M in Indonesia and Ir. Soekarso Djunaedi, Head of Irrigation Tertiary Development, agree that it will take several years for the agency to move from a design and construction orientation to a self-sustaining management orientation. However, he is confident that this will be achieved through the recently revised policy for the irrigation sector that emphasizes self-sustained O&M funding and more site-specific management roles for the Provincial Irrigation Services.□

PERFORMANCE CONTROL FOR PROFESSIONAL MANAGEMENT OF AN IRRIGATION SYSTEM:

Summary of a Case Study from System H in Sri Lanka

Namika Raby and Douglas Merrey[1]

This report[2] summarizes an IIMI case study of the management system of the Mahaweli Economic Agency (MEA) of the Mahaweli Authority of Sri Lanka (MASL). The study focused on Kalankuttiya Block in Galnewa Project in 1986/87, during a water crisis resulting from a severe drought. Taking a systems approach to the study of an irrigation system that is large-scale, multipurpose, and agency-managed, we have documented the formal organization -- the *structure* for allocating authority to individual functionaries for the realization of objectives -- and the *process* which emerges out of this and results in an adaptive, self-regulating system of behavior.

This managerial process is the product of the hardware -- the nature and state of the physical system -- and an environment within which the system is embedded and open to its influence. The environment includes the goals of the national government, the desires of politicians, the interests of donor agencies, and the demands of the electorate. Whether the physical system and the environment are constraints or opportunities depends on the capacity of the management system, in particular its strength at the interface between the agency and the political environment.

The strength of management at this interface rests ultimately on the capacity and strength of the professional manager. This in turn depends on the *management control system.* The management control system, as we use the term, includes five integrated dimensions: a work plan and resources, standards of performance, a system of monitoring actual performance, comparison of actual performance against planned targets, and corrective action. The performance of a management system hinges upon all five elements for the optimum realization of objectives. Taking the management system as the dependent variable, and the severe shortage of water in 1986/87 as the independent variable, we examined the capacity of the agency to respond to the crisis. To do this we analyzed the role of management at crucial points in the irrigation system, focusing on the strength and capacity of the management controls in place, or the repercussions of their absence.

This is a study of descriptive decision making. We examined the idealized goals, the limited alternatives, both the formal and informal dimensions of the managerial process within the agency, and the outcomes. The case study thus investigates a field still largely unexplored, "the black box" of irrigation management -- the agency and its capacity to manage an irrigation system. Hitherto in Sri Lanka, research efforts have focused on the construction and rehabilitation of the physical system and the creation and enhancement of the capacity of the water users to manage their resources below the turnout. These projects have taken the agency and the professional capacity of those who manage it as given because it is the least understood and somehow most sensitive -- hence the black box metaphor. However, the degree of success of all large public irrigation projects rests ultimately upon the performance of the implementing agency.

Further, the study, while labeled as an exercise in crisis management, may be equally labeled as decision making under uncertainty and at times even decision making under risk (in contrast to decision making under certainty). We contend this is the norm rather than the exception in irrigation management. Thus even though this was *not* a study of "routine" management, it is in fact "normal" in many large systems for the agency to be forced to manage under the pressure of a crisis.

Following from the above, in borrowing from management science, models of decision making under uncertain conditions are better suited to studying Third World irrigation systems than models based on fixed assumptions. We have adopted the commonly accepted distinction between the administrative and entrepreneurial management modes of operation. Briefly, these are characterized by a distinction between implementation of rules having a normative basis, and the vigorous manipulation of pragmatic rules to respond to changing opportunities. We argue that at the higher levels of the irrigation system (i.e., at the system and project level), the agency was "successful" in dealing with a severe water crisis by adopting a special innovation, the System H Water Management Coordinating Panel (WMCP), which legitimized the application of a strict allocation principle using an administrative mode of management. This mode involved issuing only as much water from the reservoirs as was received in a given period, in order to stretch the supply to the end of the season. Thus, while control defaulted upward under conditions of stress, it did so efficiently in an administrative mode and within a large proportion of the system, which was successfully administered as a conveyance rather than a distribution system.

However, problems arose at the lower levels of the system, the block and unit levels, because the agency did not clearly recognize that different management principles apply. At these levels, it is necessary to shift to an entrepreneurial mode of management, in order to distribute the water supply to the users. The agency was unable to maintain the water levels at intermediary reservoirs necessary to insure reliable water delivery, and it was unable to control excess use of water by head-end farmers.

One major factor at this level was the lack of adequate and appropriate performance monitoring and control of the block and unit level staff -- the point of interface with the users. Thus, when a unit manager acts in an entrepreneurial mode, as is required at this level, the legitimacy of this behavior is questioned by higher level management. We conclude that the modern entrepreneurial style of management is better suited than the administrative or bureaucratic mode to smaller systems and to lower level sections of larger systems which deliver water directly to consumers (distribution systems). The bureaucratic mode is most appropriate for higher levels of large systems where water is allocated among smaller subsystems according to clearly defined rules.

The case study leads to some practical conclusions and recommendations for the agency under study. These include:

1. The MEA is an open and flexible organization with a willingness to incorporate change -- as evidenced by its history of responsiveness to the recommendations of consultants, as well as the response to our own suggestions in the course of our on-going dialogue with the agency during this research.

2. Despite an impressive list of consultancies, and frequent references to the *people dimension* of management, this has not been implemented as effectively as it could be. It has not been a high priority because of the temporary "project nature" of management. But the agency has simultaneously gone ahead with implementing "integrated management," certainly an advance over the preceding system. At the present time, when the agency is going through a reorganization phase with amalgamation of projects, blocks, and units, and a transfer of personnel, it is opportune to evaluate what it has achieved and assess what needs to be done. As it stands, the *management* of the project, as distinct from the physical operation of the system, is in a perennial transition phase. This has an impact on whether or not the project can evolve to a further stage of economic and social development.

3. At the system level, this transitory nature of management has concentrated on construction, development, and settlement as measures of performance, and much of this monitoring is left to the individual discretion of project staff. The question asked in this type of monitoring is what is the return on investment, and not whether it is the optimum return or is sustainable.

In our examination of micro-system management controls we found a strongly developed set of control tools for financial and production control. There was also a more than adequate presence of control through rules, orders and procedures, control by reports, and the sporadic presence of "control by exception" -- written inquiries seeking justification after the fact.

However, appraisal of performance of managers against predetermined standards, the identification of their areas of strengths and weaknesses, and the utilization of strengths to tap employee potential were not present. Officer and farmer training is an area in which the agency has focused some attention. However, we believe that training alone, irrespective of its adequacy or appropriateness, is not a solution to these problems, and will not motivate personnel to give their best performance.

Adequate and timely feedback of information and swift corrective action were also largely absent, as were preventive and warning controls. For instance, warning controls would have alerted the management that the existing arrangement for allocation of water from the Kalawewa Reservoir was unsatisfactory before MEA/Colombo, too late to have an impact, exercised control by exception. In the absence of key preventive and warning controls, other controls do not perform at optimum levels.

4. As a multipurpose project with both *macro-* and *micro-* system goals, and a micro-system dependent on diversion of water from another river basin, management at the interface between the macro-system boundary of MEA and the micro-level at System H is essential, to exercise strategy in planning and implementation. However, micro-system planning seemed to be ad hoc in character. Systematic communication of changes to the system operators is required, so that they can take these into account in their decision making *before*, not after, the fact. A telephone and computer link with the Colombo-based Water Management Secretariat computer seems an easy solution.

5. Within the boundaries of the project, effective communication of decisions will, by assuring a predictable supply of water, strengthen the hand of the agency in coming to terms with the political environment, and will enhance the agency's credibility in the eyes of the farmers. Together with performance monitoring controls, this will also strengthen the role of the resident project manager as project monitor not only for water but for the integrated monitoring of all key areas. In the case of System H, the mode of operation best suited for the project level is the administrative mode, that is, *management in a bureaucratic style.*

6. The picture changes radically at the hydrological boundaries of the Kalawewa Left Bank Main Canal (LBMC). Here water is the single focus and the main system is a system for both allocation and distribution. However, it is evident that as a management exercise the agency views the system as the former and not the latter, leading to serious distribution problems. The impact of the lack of a coordinating mechanism at this level, similar to the System H WMCP with the project engineer at the helm, and the absence of performance monitoring controls, was apparent. We recommend establishing both a coordinating mechanism and effective performance monitoring procedures.

7. The absence of performance monitoring and control at the LBMC in turn has an impact on the administrative block, where the absence of monitoring and control was also evident at the reservoir and branch canal. Given that the financial budget, the water budget (weekly releases), the targets of the cultivation program, and progress monitoring are all focused on the block, this is the core of the main system. It is here that the Mahaweli Block Manager has a challenging opportunity to mediate between the administrative bureaucracy and an entrepreneurial style of management by systematically manipulating management controls and translating them within the context of the Mahaweli goal-oriented work culture to guide his unit managers. Instead, we find an absence of performance control, dominance of administrative routine, and lack of independent authority of the block manager.

Furthermore, since it is a distribution system, conflict resolution is a key managerial task. It was originally envisaged that participative management with the farmers would logically begin here. The block manager, while managing the unit managers, must, through them, manage the interface between the agency and farmers through participative management, trying out innovations and taking occasional risks. The goal should be divestiture at the turnout and the distributary, as originally envisioned by the planners, since the agency has been unable to deal with conflict resolution among water users at these levels. This could perhaps be done through a management by objective (MBO) approach.[3]

Participative management training, and not simply training in agriculture extension or water management, is indicated here. Further, in this age of microcomputers, it is not too far fetched to suggest that MEA install a computer in the office of the block manager and train him in its use. Then he may construct trade-off curves among selected performance measures, by examining the set of possible optimal solutions for any objective function. With this information he may select the preferred schedule making the best trade-off between cost and optimum solution.

8. Given the managerial arena of the block and the objectives for settler development, it is the unit manager who must translate the goals set at the block level into action. A unit manager is ideally a mini-version of the block manager. In practice we found that the problems which ailed the block also affected the unit, only more so. This is because the unit is the lowest level of management and yet the point of maximum impact on field operations. As in the block, though the physical system is primarily a distribution system for water, water management cannot stand alone. To make sense it must be functionally integrated with agricultural inputs, credit, and marketing. It is the task of the unit manager not to be a bureaucrat or extension agent but to be a *manager* at this point of the interface. In the MASL/MEA management structure, a form of management by results (MBR)[4] would be most appropriate.

We recommend that the agency recognize and define what the unit level officials are best able to do, given the incentives and the pressure from above and below, and evaluate their performance by results. The unit manager's credibility hinges upon the success of managers at other points in the main system, but as he must himself face the farmers, it impinges on him directly. The absence of performance controls is most acutely felt here, as is the lack of managerial skills and training. In the absence of performance controls, water is issued to reduce complaints, and written off by management as operational or managerial losses. In other words, the irrigation laborer and the unit managers compensate for management problems above them by issuing additional water as demanded and by extending rotations.

It is often said that crop production in an irrigation system depends on water as the crucial independent variable. In System H during a drought year, the total amount of water made available was more than adequate. Some problems arose because water was not delivered in a reliable and timely manner. Our conclusion, then, is that *management*, broadly defined, and not water *per se* is the key independent variable determining the productivity of irrigated agriculture. Agencies responsible for managing public irrigation systems therefore have a unique opportunity to contribute to achieving the twin goals of increasing agricultural productivity and raising farmers' incomes by improving the performance of their own management systems. □

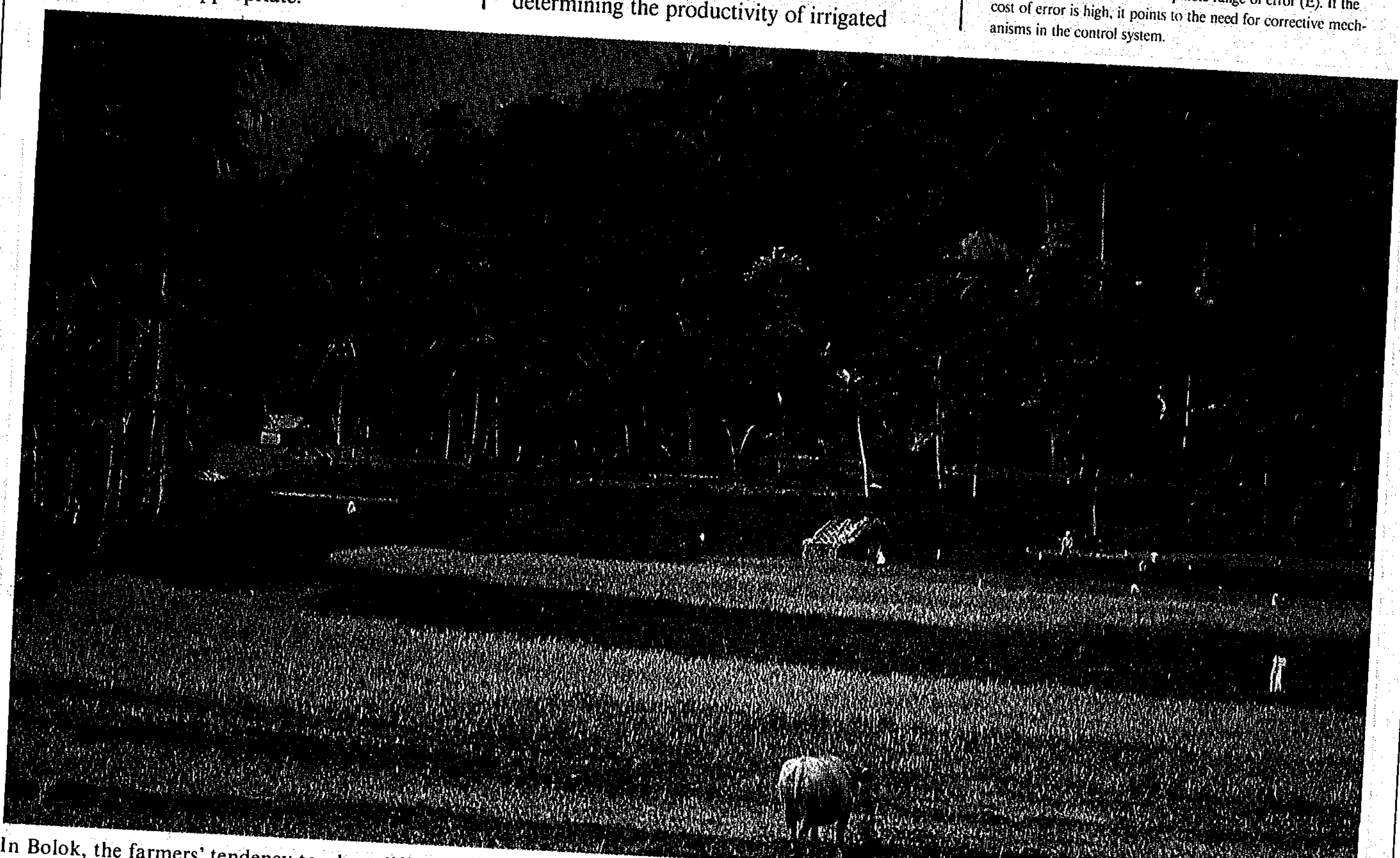
Notes

[1] Post-Doctoral Fellow, and IIMI Social Scientist respectively. Digana Village via Kandy, Sri Lanka. The authors wish to thank Jayantha Jayewardene, Additional Managing Director/General Manager of the Mahaweli Economic Agency, and T. Karunatilleke, Additional Secretary, MASL, for granting permission to conduct the research and for their cooperation throughout the project.

[2]The report is a summary of an IIMI Research Paper (RP6) to be published in October 1988 and will be available from IIMI on request.

[3]In the management by objective approach, the organization has clear objectives and sound long-term plans, and the manager is clear about the results he must achieve to realize these objectives. Objectives are quantified and broke down into the results expected from the main operating areas. Managers in those areas clarify their objectives by identifying the most important results to be achieved and the means by which they can achieve this.

[4]The management by results approach is a take-off on the above and is expressed in the following manner by David Seckler in *On the Management of Public Organizations:* result (R) is the relationship between the predicted outputs (PO) of an organization as specified in objectives and the actual outputs (AO) from the operations of the organization. R=AO/PO results in the acceptable range of error (E). If the cost of error is high, it points to the need for corrective mechanisms in the control system.



In Bolok, the farmers' tendency to plant different rice varieties at different times of the year, has a negative impact on Water Users' Associations.

THE CHANGING CONCEPT OF MANAGEMENT IN IRRIGATION

Mark Svendsen[1]

It was only a few years ago that most definitions of "water management" looked something like the following:

> The application of the right amount of water to the root zone of a growing crop at the right time.

Definitions might be more elaborate than this, speaking of delivering water to "the farm" instead of the "crop root zone," or adding qualifications related to drainage, production, or sustainability. At their core, however, was a concern with measuring and meeting the demand for water generated by plant physiology.

In recent years, the use of the term "water management" has been largely overtaken by "irrigation management," implying a broader scope of interest and the inclusion of things other than water in the management equation -- things such as people, finances, and equipment. The central idea of this short note is that while we as irrigation system managers or researchers or advisors have embraced the term, we have not yet completely accepted or understood its implications. Moreover, to take advantage of the opportunities for improving irrigation performance that it offers, we must change the categories in which we think, not marginally, but radically.

To get started on this, a number of us have turned for guidance toward the literature on "management" as applied in the world of business and public administration. This literature has a powerful and somewhat mysterious aura about it and borrowing from it offers promise of energizing and enriching our own quest. This is an exciting prospect, but at the same time a bit daunting since the literature is vast and many of us are not particularly conversant with it.

One indication of the stage of development of our thinking here is that we have yet to frame a succinct, widely-accepted definition of irrigation management such as we had for water management. Perhaps the management literature can offer some guidance.

DEFINITIONS AND TERMS

Management

Assembling and examining a dozen more or less explicit definitions of "management" taken from texts and other books and articles reveals some common threads and a good deal of diversity. Most authorities frame their definition of management in terms of "actions", "processes," or "functions." Of these, process definitions are the most common, though in fact this does not seem to be a terribly important distinction. What is strikingly universal to the definitions is that all of them relate activities or processes to a **goal.** In the Dictionary of Economics, the goal is simple and clear -- "maximum efficiency," in the specialized economic sense.[2] For those interested in project management, the goal is "to get the job done."[3] For the others it is open-ended and relative. This openness leads one pair of authors to define a higher level process they term "strategic management" where managers establish their organization's longer term aims and the strategies to achieve them.[4] It is, in fact, this goal or accomplishment orientation that distinguishes management from other control processes. As Norbert Wiener says, management systems are "purposive systems, whether in man or machine."

But what are the processes and actions that characterize management? Here a good deal more diversity becomes evident. Generally, however, they tend to fall into two groups. The first of these focuses on organizing the activities of people. Thus management is "the process by which a cooperative group directs actions toward a common goal,"[5] or "the art of getting things done through other people,"[6] or "the process undertaken by one or more individuals to coordinate the activities of others to achieve results not achievable by one individual acting alone."[7]

The other group of definitions emphasizes the process or factors involved in achieving the goal. Thus management is "the organization and coordination of the factors of production -- land, labor, and capital.[2] In a more implicit definition, "management... refers to the process of decision-taking affecting an institution's achievement of its specified objectives."[8] Management is also defined in terms of a four-step process of "goal-setting, performance measurement, performance diagnosis, and corrective action."[9]

One of the best known approaches to management, at least in terms of name recognition, is that of management by objectives (MBO), a term first used by Peter Drucker in 1954. MBO focuses explicit attention on the objectives of an enterprise and "presumes that the first step in management is to identify by one means or another the **goals** of the organization."[10] One of its chief architects defines MBO as "a process whereby superior and subordinate managers of an organization jointly identify its common goals, define each individual's major areas of responsibility in terms of the results expected, and use these measures as guides for operating the unit and assessing the contribution of its members.[10]

These two groups of definitions correspond roughly to the "social/rational" dichotomy developed by Peters and Waterman in their best-selling book *In Search of Excellence* to categorize theories of management.[11] Clearly an adequate approach to the problem of managing must include both processes for *setting and achieving goals* and for *organizing and coordinating* the efforts of individuals and groups. Given the centrality of goals in both types of definitions and given the confusion and vagueness surrounding the goals of most irrigation management agencies, it may be that an elucidation of the **mission** and **goals** of the agencies and the relationship they bear to system outcomes deserves the highest claim on our attention.

Irrigation Management and Water Management

It is interesting to note here that the definitions of "water management" and "irrigation management" can be brought together by treating "the supplying of the right amount of water in the right place at the right time..." as the objective function or **goal** of the management process rather than as the process itself. This allows for failure to meet the ideal, which the simple definition does not, and provides a framework for understanding the dynamics and the human dimensions of the process of adjustment and correction. That said, however, it must be added that this goal formulation may not be a particularly **good** one when compared with Kotler's four tests for useful objectives -- that they be "hierarchical, quantitative, realistic, and consistent."[9]

Management and Administration

The terms "management" and "administration" are troublesome, sometimes used interchangeably and at other times presented as diametric opposites. Jayaweera in an excellent essay on management and development provides an example of the latter. "An administrator," he writes, "is basically oriented toward preserving the status quo whereas a manager is committed to transforming it."[12]

A more temperate distinction is drawn by Belshaw.

> The emphasis [in management] is on purposive achievement in conditions of change and uncertainty.... The achievement orientation of management necessitates deliberate planning activities. This may be compared with the merely pragmatic approach of dealing with circumstances as they arise, which frequently characterizes the system maintenance or survival behavior associated with administrative approaches.[8]

Distinctions drawn here are based on the existence of goals and a planning process. Bottrall emphasizes the more strategic question of who **sets** goals when he suggests that administrators are "reliable executors of policies and programmes determined for them at a higher level."[13]

Planning occurs again and again as a hallmark of the management process. Indeed it is difficult to separate the two concepts. **Planning** is defined by one authority as "setting objectives" and "specifying the steps needed to reach them."[14] These defining functions are virtually identical to those in the definition of "strategic **management**" advanced by another pair of authors:

> Strategic management is the process whereby managers establish an organization's long-term direction, get specific performance objectives, develop strategies to achieve these objectives in the light of all the relevant internal and external circumstances, and undertake to execute the chosen action plans.[4]

Clearly understanding how an organization plans is essential to understanding how it manages.

An interesting final note to this section is Peter Drucker's revelation of "the best-kept secret in management," which is that "the first systematic applications of management theory and management principles did not take place in business enterprise [but] in the public sector."[15] We should not, therefore, dismiss management science out of hand as applying only to commercial enterprises.

Management and Structure

Management processes occur within and interact extensively with an organizational structure. The structure of an organization is "the pattern according to which tasks and responsibilities are formally allocated among its members."[13] It is descriptive of the "more static features" of an organization, where management refers to the dynamic process of goal setting and achieving. As the matrix in which management operates, it obviously has a powerful influence on management, but is, in turn, influenced by the organization's goals and purposes. As Drucker points out, "the best structure will not guarantee results and performance... [but] the right [one] is a prerequisite of performance."[16]

Earlier approaches to the subject of management have emphasized structures heavily, while more recently, attention has shifted toward a more balanced concern with both structure and process. Still, because it is easier to picture and to manipulate, organizational structures are more often the target of changed programs than are the dynamics -- the management. We would do well to keep Drucker's admonition about the necessary but, by itself, insufficient nature of "right structure" in mind when we attempt to improve the performance of an irrigation agency. It is tempting and not entirely off the point to add as a postscript Louis Sullivan's famous dictum that "form ever follows function."[17]

Manage What?

A final question that comes to mind in connection with this discussion of terms and definitions is that of the "object" of our managerial attentions. In an earlier simpler era, **water** management was clearly our objective. Today's **irrigation** management, however, is somewhat more ambiguous. Is irrigation simply a fancier way to say water? Or are we actually concerned with the management of an irrigation **agency?** Or is our object something else entirely?

In my view, we are necessarily interested in something that goes beyond just water -- for otherwise we include only the effect, the dependent variable, in our net and ignore those factors which cause the effect. At the same time, a focus on **agency** management places inadequate emphasis on the physical and economic output of the irrigation enterprise. Irrigation agency management becomes simply another case study in the broader field of public administration (sic). What is required is a focus that recognizes the special character and problems of managing irrigation schemes while remaining able to draw on the wider body of knowledge and experience in the "management" arena.

To simplify here, I will separate out and ignore those irrigation agency functions that revolve around new system planning, design, and construction. This is somewhat arbitrary, but not entirely so. First, the argument is heard on all sides that opportunities for new system construction are diminishing and that improved management of existing systems must provide a major share of future increases in production. Secondly, it is the remaining functions, those geared toward the operation of existing facilities to deliver water to farmers, that are most in need of managerial improvement.

This is not to say that design and construction processes are uniformly effective and efficient, but rather that individual irrigation agencies are generally better at handling these functions than they are at managing water allocation and delivery. In part this is due to the nature of the tasks involved. The design and construction sequence is a time-bounded series of linked steps -- each of which has a well-established and technically-challenging set of procedures for its execution. We routinely find such management tools as Critical Path Analysis, PERT charting, and cost control procedures utilized in the design and construction of irrigation systems. To find these techniques applied in water allocation and delivery is almost unheard of. We speak of "construction management" and this phrase has real meaning. When we speak of "irrigation management," meaning water allocation and delivery, the phrase represents more promise than practice.

How do we define then the object of the "irrigation management" process, so delimited? We might take a clue from the field of **marketing** in order to reformulate our notion of what irrigation agencies produce. A leading text on marketing management posits that "market definitions of a business are superior to product definitions of a business.... A business must be viewed as a customer-satisfying process, not a goods-producing process. Products are transient, while basic needs and customer groups endure...."[9] Thus Xerox does not make copying equipment, it helps improve office productivity. Toyota does not manufacture cars and trucks, it facilitates the movement of people and goods.

Acknowledging that the analogy to the business product is not exact, exploration can still be enlightening. It suggests that irrigation agencies should not see themselves as capturing and delivering water but **providing irrigation service.** This at once establishes the time value of water -- since although a product may have intrinsic value, a service has value only if it is available when needed. It also allows flexibility in the customer population -- permitting a shift, for example from a large number of individual farmers to a much smaller number of irrigation districts or irrigators' associations. Finally, it suggests the importance of satisfying the customer, as indicated above.

It is, of course, naive to believe that simply redefining the outputs or goals of an irrigation agency will change its performance. Nevertheless, it does provide a starting point for analysis and diagnosis. Moreover, it is a starting point that the management literature suggests rests on the most influential and basic of factors. In the last section of this note, I will try to suggest some implications of what this type of management definition has for programs which would study and improve irrigation performance.

IMPLICATIONS

New Models and Concepts

We need a better framework for organizing what we know, and what we would like to know, about irrigation management. Although frameworks exist within particular disciplines -- agricultural engineering or economics, for example -- we have little that cuts across them. When we want a more comprehensive understanding of something, we typically commission a one-time review of the topic utilizing an ad hoc conceptual framework of the author's preference. Reports and conferences are commonly organized to discuss "engineering aspects" of irrigation management, and "economic aspects," and "social aspects," and so on. It is limiting and therefore regrettable that we have been unable to find a more substantive and durable way of organizing our thinking and discussions regarding irrigation management.

Does management theory provide a solution to the dilemma? Probably not. Participants in a recent workshop on management science and irrigation management[18] concluded that there was little off-the-shelf theory that could usefully be imported into the irrigation domain intact.

On the other hand, there was a great deal of animated discussion stimulated by the injection of new ways of thinking about the old topics. The longer run utility of management science in irrigation management may rest on its "neutrality" with respect to the traditional irrigation-related disciplines and its cross-cutting nature. Moreover, we may extract as much value from it by using its principles as metaphors and analogies as by trying to import and translate these principles directly into irrigation terms.

New Taxonomy of Issues

One way that management science may help us in this regard is by providing a new set of conceptual categories with which to organize our thinking. New insights, and new questions, often emerge when we look at what we already know from a fresh perspective. What categories are these? Without attempting in any way to be comprehensive, the following are offered as illustrations and not as a complete taxonomy. A return to the earlier discussion of terms and definitions suggests that one basic division might be made into **management processes** and **organizational structures.** Focusing on the first of these, we could further subdivide management processes into:

Objective-setting processes,
Information systems,
Decision making processes,
Execution, and
Monitoring and feedback.

The **information systems** topic, for example, might then be applied to the primary task of water allocation and distribution and would involve looking at water measurement devices and calibrations, data collection procedures and incentives, communication systems, data processing and reduction, time lags, data-needs determinations, and so forth. Doing this would require the skills of the engineer, the sociologist, the management specialist, and perhaps the computer specialist. Looking at information systems used in supporting tasks, such as billing and fee collection, might require a different set of skills but would look at the same fundamental chain of data-needs determinations, data generation, communication, processing, quality control, and use.

The other topics are equally cross-disciplinary, yet linked by the logic of the management process. The real attractiveness of organizing our critical thinking and analysis in this way, however, is that having done it, we are in a position to look at the irrigation management process as a whole with our knowledge classified so as to take advantage of already developed principles and relationships. Thus, I would argue, we enjoy a two-fold advantage. First by reorganizing our knowledge, we gain new insight into familiar topics such as "water control." Second, we have our accumulated experience and knowledge organized in such a way that we can ourselves bring basic and common-sense management principles to bear on the problem of improving the performance of irrigation systems through better management.

New Variables and Indicators

As an outgrowth of this reorganizing of topics, will come a need for new conceptual variables and quantitative indicators of those variables. Thus, while water has a volumetric dimension and a time value, irrigation **service** implies a preeminent **quality** dimension -- perhaps the most important component of which is predictability. How we subdivide and analyze quality of irrigation service, and predictability, in an operationally useful way is an open and little explored question, but a critically important one if we are interested in improving irrigation system performance through better management.

All of this suggests some significant changes in the ways that those of us trained as engineers, sociologists, economists, or agronomists think and act. One of the conclusions reached at the **Estes Park workshop[18]** mentioned earlier was that we cannot expect the management science people to do this job for us. If we truly feel that management in irrigation is important, then we must be the ones to explore, borrow, and learn from experience in other domains to develop understanding and the tools to improve it. □

Notes

[1]Research Fellow, International Food Policy Research Institute (IFPRI) and Resident Scientist, International Irrigation Management Institute (IIMI). The author wishes to acknowledge the significant intellectual debt owed to Anthony Bottrall following a rereading of his seminal "Comparative Study of the Management and Organization of Irrigation Projects" in the course of writing this article.

[2]Sloan, H.S. and A.J. Zurcher. 1970. Dictionary of economics. New York: Harper & Row.

[3]Frame, D.J. 1987. Managing projects in organizations: How to make the best use of time, techniques and people. San Francisco: Jossey Bass.

[4]Thompson and Strickland. 1985. Cases in strategic management. Plano, Texas: Business Publications.

[5]Haynes, H. and J. Massie. 1963. Management, analysis, concepts and cases. Englewood Cliffs, New Jersey: Prentice-Hall.

[6]Hellriegel, D. and J.W. Slocum. 1982. Management. Reading, Massachusetts: Addison-Wesley.

[7]Donnelly, Gibson, and Ivancevich. 1987. Fundamentals of management. Plano, Texas: Business Publications.

[8]Belshaw, D.G.R. 1976. Improving management procedures for agricultural development. In G. Hunter (ed.), Policy and Practice in Rural Development. London: Croom Helm. Quoted in Bottrall (1981).

[9]Kotler, Philip. 1984. Marketing management: Analysis, planning, and control. Englewood Cliffs, New Jersey: Prentice-Hall.

[10]Odiorne, G.S. 1979. MBO II: A system of managerial leadership for the 80s. Belmont, California: D.S. Lake.

[11]Peters, T.J. and R.H. Waterman, Jr. 1982. In search of excellence. New York: Harper and Roe.

[12]Jayaweera, N.D. 1981. Management and development. Colombo, Sri Lanka: Ceylon Daily News, 2 February 1981.

[13]Bottrall, Anthony F. 1981. Comparative study of the management and organization of irrigation projects. World Bank Staff Working Paper No. 458. Washington, DC: World Bank.

[14]Dale, E. and L.C. Michelson. 1966. Modern management methods. Cleveland: World Publisher Co.

[15]Drucker, P.F. 1986. The frontiers of management. New York: E.P. Dutton.

[16]Drucker, Peter. 1974. Management. 1981. Heinemann. Quoted in Bottrall (1981).

[17]Sullivan wrote this in an article entitled "The tall office building artistically considered" in the March 1981 issue of Lippincott's Magazine. It is interesting to consider this rule as permeating both office building design and the design of the organizations within them.

[18]"The Contributions of Management Science to the Management of Irrigation Systems", 15-17 April 1986, Estes Park, Colorado, sponsored by the Colorado Institute for Irrigation Management, Colorado State University.

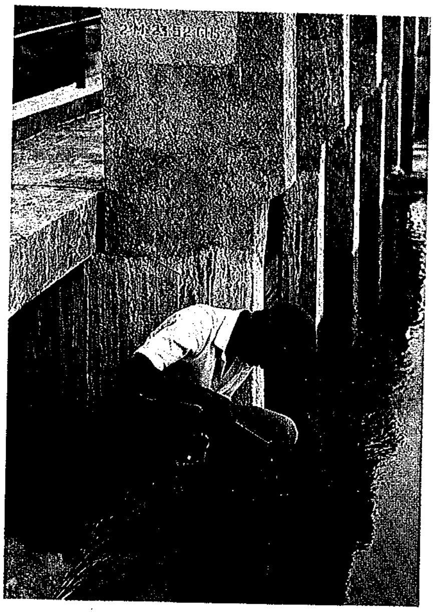
CONCLUSIONS

HYDRAULIC MODELING OF A MAIN CANAL SYSTEM:
The Next Best Thing to Buying a Canal

IIMI is not in the business of buying irrigation canals, but there are times when its scientists wish it owned one or two. At least until recently.

Daniel Berthery, IIMI agricultural engineer, has spent a good part of the last few years trying to convince irrigation managers and researchers that many problems in canal operations, inequity and unreliability for example, often enter the system at the level of the main canal, and not just at lower levels of the system as often assumed. "Irrigation officials and researchers," says Berthery, "tend to assume that main canals operate as per design. Therefore primary distribution of water in the various branches and secondary canals of an irrigation system is not a priority area of concern. That, however, assumes management objectives for the main canal are met, when in fact they may not be."

Main systems are basically designed for operation under steady flow conditions (e.g., maintaining flows and levels along main canals unchanged as far as possible). The flow diverted at any diversion point is generally directly related to the water head immediately above the structure; thus, to control the water levels means to control the flows diverted at each structure.
Management plays a role and so does design. For example, if there is a rain storm, management might intervene to cut back flow, so as not to deliver more water to the field than necessary. Immediately after the rain, management would intervene again, adjusting canal structures to a new setting, taking into account the influx of water. However, unless that intervention is managed in a timely fashion, with gates set properly and in a coordinated sequence, it may take a long time to return to steady flow conditions. And this assumes the main canal and its structures are operating according to the way they were designed.



IIMI hired students to measure the increase in water level at each water regulator.

But talking is easy. It's one thing to say that canal operations are suboptimal because flow conditions are different from what was assumed at the design stage, and it is another thing to prove it and ~~to~~ demonstrate how those operations can be improved. Traditional research methodologies require running repeated tests and experiments. With main canals that isn't possible, because thousands of farmers may depend on the water. At the same time, rapid changes may occur haphazardly throughout the system. So that if a researcher goes to measure water levels at three points along a 30 kilometer (km) canal in the morning, and goes back to repeat the measurements in the afternoon, he may miss a variation sometime during his absence and come away thinking that problems must be occurring somewhere else in the system.

Taking all this into account, Berthery settled on the idea of using a mathematical model to simulate the operation of a main canal as a cost effective method of investigation. "Such a model," says Berthery, "would allow IIMI to run as many tests as we needed without affecting the farmer. The end result is the identification of more effective operational practices."

Although such models exist, Berthery says most of them are not appropriate to field studies in Third World conditions and often are even too complex for irrigation engineers to use. Furthermore, to be operational, these models must be calibrated to represent real canals, rather than hypothetical ones.

However, before Berthery could get the support to develop such a model, he first had to demonstrate to managers and other researchers that problems do in fact exist in main canal management.[1]

Berthery spent much of 1987 doing just that. First he investigated, identified, and found the funding to purchase appropriate data loggers and measuring devices, which could record water levels every few minutes. Using the data loggers, he undertook a study to record and compare variations of main canal flow conditions of four systems, each with different design and operation procedure. In one of the systems, the Kalankuttiya Branch Canal, which has a series of 9 duckbill weirs, upstream water levels nearby are controlled within a range of 10 centimeters (cm). In the Kirindi Oya system, however, which has 14 gated cross regulators over a distance of 30 km, level variations as high as 40 cm were recorded, at the head of some offtakes.

Berthery was able to convince the Director of Irrigation, Colombo, to use Kirindi Oya Right Bank Main Canal

(RBMC) as a base to build a mathematical model. The next step was to develop a partnership with a more specialized research institution that could provide the technical backstopping to assist him in developing and adapting the model.

In mid 1987, IIMI approached the National Centre of Agricultural and Forestry Engineering and Water Management (CEMAGREF) in France to collaborate in the project. CEMAGREF is a grant-aided research center in France which develops innovations, and provides training in various water fields, equipment for agriculture and agri-food industries and sustainable development of rural environment and natural resources. It works in both developed and developing countries.

CEMAGREF offered to provide IIMI with existing state-of-the-art computer programs of its own and technical backstopping. It agreed to develop user-friendly interfaces specific to Kirindi Oya RBMC Model that will run on microcomputers (such models are more often run on mainframe computers). In that format the model could better serve IIMI research objectives and assist agency staff at Kirindi Oya in operating the main canal.

According to Frederic Certain, CEMAGREF engineer, "The model will have many possible uses, to understand canal behavior better, to test the limits of the design following construction, to develop management procedures for various scenarios, and to train irrigation engineers to learn more about their system. And no two systems are the same."

However, implementing such a plan requires more work than apparent.

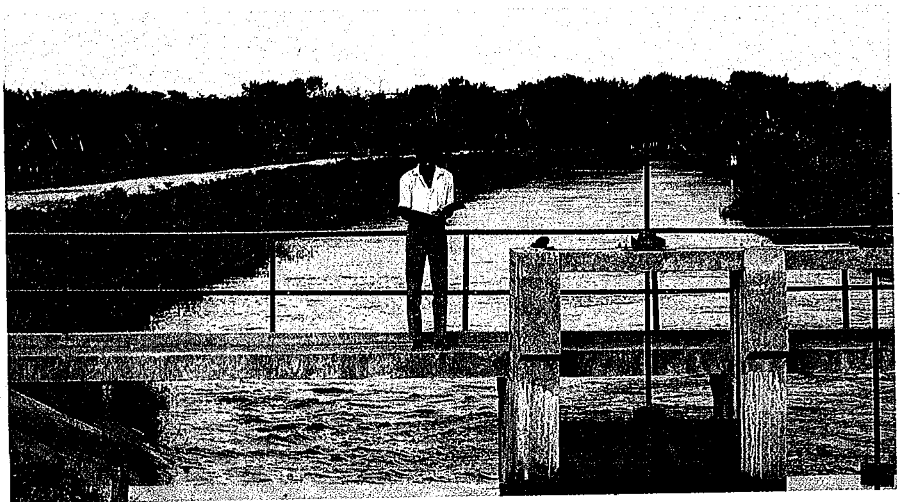
"First," says Berthery, "you have to choose a system which is representative of the kind of systems and problems you want to study. Second, you have to configurate a general computer model that simulates the physical conditions of that system, according to general design criteria. Third, you have to calibrate the model to represent the actual conditions of the system, and that means running a test to ensure that the model acts exactly like the system. Once you've done that you can run various management scenarios on the computer, with the confidence that the same thing would happen in the field."

Throughout early 1988, IIMI worked from Sri Lanka to provide the physical (topographical and hydrological) data necessary to develop the model. Topographical data includes such things as cross sections of the canal every 200 meters, the longitudinal profile of the canal, the size and dimension of gates, and other information. Hydrological data includes such things as roughness coefficient in the various canal sections (which affects velocity), estimates of infiltration losses, discharge at the offtakes as a function of gate opening, and head and hydraulic flow conditions at the outlet. Like any computer program, however, the model is only as good as the data put into it.

Thus the next step is to test the model in the field (i.e., to calibrate the model to Kirindi Oya RBMC). In May, Certain and Andre Durbec, a second CEMAGREF engineer involved in the project, joined IIMI staff in calibrating the model to match Kirindi Oya. "The purpose of the calibration," says Hilmy Sally, an IIMI irrigation engineer also working on the project, "was to take measurements of water discharges and water levels in the canal over a period of time, with certain gate settings. Those measurements would then serve as a reference to be compared later with what we could obtain with the model."

"The field experiment was conducted in two phases over a period of 10 days," says Berthery. "In the first phase, which was the most time-consuming, we documented the status of the system in one particular steady state condition. When we arrived we asked the agency to "seal" the existing setup, that is to say we asked the agency to maintain the gate settings and sluice setting under the operational conditions in which we found them. We even painted marks on the spindles of the gates so we would know if they had been changed. For the next four days we did intensive current metering to determine actual discharges all along the main canal and at some offtakes. We measured the water surface elevation in the main canal at each offtake, and upstream and downstream of the cross-regulators. We also measured the water levels upstream and downstream of each offtake and behind measuring weirs. That gave us a basic picture of the steady state condition of the system, which we will try to replicate through the model."

The second phase was to test the canal under unsteady conditions. This was done in one day with single release from the main sluice. "The purpose was to monitor the propagation of the wave from the head to the tail of the system," says Sally.



Data loggers record water measurements of the water surface elevation in the main canal at each offtake (measurement tubes are visible on left).

"To do that we hired 15 students from a nearby school, to measure the change in water level at each cross-regulator every 10 minutes. Each student was equipped with a ruler, a record book, and a watch."

At 6:00 a.m. on 2 May 1988 the main sluice was opened so as to deliver 1.5 cubic meters per second (m^3/sec) in addition to the prevailing issue of 4.6 m^3/sec. "Three hours later, the sluice was returned to its previous position. The chronological records of water level observations allowed the researchers to compute velocities and determine the time required for the additional water to reach the tail of the system."

Velocity measurements, with the water level measurements allowed IIMI to determine the amount of time required for the additional water to reach the tail of the system.

This information will be used in the second stage of the calibration. The idea is to replicate the propagation of the wave through the model in the same way, with the same time lag. It will be completed at CEMAGREF in France by the end of 1988. At the same time IIMI, CEMAGREF, and agency staff will work together to conceive specific interfaces for the model to make it user-friendly and particularly suited to address issues on effective and responsive canal operations, as well as design and management interactions.

"In the short-term," says Berthery, "we were able to present a number of findings to the agency immediately after the hydrometric campaign, which we hope will help them in improving management. For example, we estimated the rate of percolation and seepage in the main canal at 20-70 liters/second/km, depending on the canal reaches, with a mean of 43 liters/second/km (2.5 cusec/mile). That represented 1 m^3/sec losses out of 4.6 m^3/sec issued at that time at the headworks, or 22 percent. Preliminary estimates indicate the friction coefficient (Strickler coefficient) to be between 20 and 25, which is substantially less than the design value (40), which implies a proportional reduction in the carrying capacity of the canal. We estimated the mean velocity of a wave propagation along the main canal to be close to 3 km/hour (1.9 mile/hour), although the peak flow was conveyed at a speed of 1.8 km/hour (1.1 mile/hour).

Although not yet fully calibrated, the model generated an estimate of maximum conveyance capacity of the system and identified bottlenecks and weak points where overtopping of the canal could occur. The irrigation agency staff will now use these results in planning the implementation of a second phase of the Kirindi Oya project, which calls for expansion and design improvement.

We greatly appreciate the active participation of the Kirindi Oya project staff in many phases of the field measurements. In fact we would have been unable to carry out the calibration campaign successfully if not for their wholehearted support and cooperation.

However, the main purpose of the test was to "tailor-make a tool to suit our own research needs and objectives to assist irrigation agencies in improving system performance," says Berthery. "Our ambition is to use this research methodology to solve problems in the operation of main canals across Asia. By using Kirindi Oya as a test case, we have a reference point to demonstrate what can be achieved by using these techniques of investigation. Also, we were able to demonstrate how to use and calibrate the model, which we are now documenting. Eventually we hope to disseminate the results of this case study, and the associated methodology to other agencies and to train them in their use."

IIMI will use the model as a research tool. For example, IIMI often comes across situations where the actual command area falls short of the target design, or alternatively where an agency wishes to expand a system beyond design. In those cases, the model, once it is calibrated to the system, can be used to determine whether the target can be met under existing conditions, and what changes need to be made to achieve the target.

"The model can also be used by agencies," says Sally, "as an operational tool. The objective of the model, in the case of Kirindi Oya, is to ensure that the agency meets its target deliveries at each of the 35 offtakes. The model will help the irrigation engineer to plan the settings of the 14 gated regulators to achieve that. It could also help him to keep to a minimum the time required to make the transition from unsteady to steady conditions following interventions whilst minimizing operational water losses. In the unsteady state, the model will allow him to estimate the time of response for any intervention. For example, he would be able to find out how long a sluice release would take to move to the end (or any other point) of the system under different conditions."

The model also has considerable potential as a training tool. "Managers who are transferred to a system would not have to spend months learning the system through trial and error operations. Instead, he could subject the system to a variety of simulations, for every season and set of conditions, in a few days. And of course it would be a lot easier on the farmers."□

Note

[1]The magnitude of the support needed by IIMI to implement his project was in the range of US$100,000. As a matter of fact mathematical models are considerably cheaper to implement than physical models. We trust that they will prove themselves as valuable in canal operations and irrigation management as physical models have been for long in water resource project development planning and design.

IIMI OPENS DOOR TO WEST AFRICA

IIMI's entry into Africa has moved one step further with the opening of its regional office in Ouagadougou, Burkina Faso on 1 June 1988. The office will serve as a base for a research and development network that will initially link national and regional irrigation agencies and research institutions in the region. Initial concentration has been in Burkina Faso, Mali, Niger, and Senegal, but the program is already initiating developments in other countries, particularly in Nigeria.

To initiate the program, IIMI posted Jean-Claude Legoupil, an Agronomist with extensive experience in irrigation development and management in West Africa, as regional representative for the office. His assignment is to initiate and elaborate a long-term research program, and to establish more firmly, collaborative relationships with potential research partners. Initial activities are to be funded through a grant from the United States Agency for International Development for a period of one year. Therefore Legoupil will have the additional responsibility of preparing detailed proposals for prospective donors.

IIMI has chosen a regional network approach for the program because of the similarity of conditions and issues which currently exist in the four target countries. Although a large number of organizations are currently working in the region, there is considerable potential for improving irrigation management through increased communication and exchange of experience. It is expected that research will focus on one central theme per country. In addition, the program will include Professional Development and Information components.

Legoupil is expected to build on the findings of IIMI's West Africa strategy document, "Irrigation Management in West Africa: Prospects and Proposals for a Research and Professional Development Program." That document identified opportunities in each of the four countries as well as regional opportunities for enhanced communication and professional development.

In Burkina Faso, there is a need for research to improve the agricultural use of water resources with limited potential (groundwater, small dams). In Niger, there are increasing opportunities for research on farmer-managed irrigation systems in the Niger valley. In Mali, research is to be carried out with the *Office du Niger* on operational water management procedures and the synthesis of existing experiences, particularly in the field of system rehabilitation. And in Senegal and Mauritania IIMI is exploring collaborative research with national organizations on analysis of irrigation systems performance in the Senegal River valley with particular emphasis on the process of turnover of responsibility for irrigation management from development agencies to users.

In professional development, IIMI plans to collaborate with regional research organizations and irrigation agencies to develop an appropriate program for the region. In particular, Legoupil is currently exploring the development of a regional course in irrigation management.

The information program is expected to play a particulary important role in meeting the needs of the network and in ensuring that results and innovations are disseminated to other regions and continents and vice versa. It is expected that publications will be printed in both English and French. The office in Ouagadougou will also serve IIMI as a regional relay station for information exchange and documentation.

The establishment of a regional office in Ouagadougou is the first of three programs to be implemented in Africa. The second two are those now planned for Sudan and Morocco where IIMI plans to place staff later this year. Thus, in addition to carrying out regional activities, Legoupil will work closely with staff of those two units to ensure IIMI maintains a coherent program for the continent.□

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IIMI SIGNS AN AGREEMENT IN BANGLADESH FOR A COOPERATIVE IRRIGATION MANAGEMENT PROGRAM

The International Irrigation Management Institute (IIMI) and the Bangladesh Agricultural Research Council (BARC) have finalized a Memorandum of Understanding which will govern and foster cooperation between IIMI and the Government of Bangladesh toward the goal of improved utilization of water resources. The agreement was signed on 13 July 1988 by Roberto Lenton, Director General of IIMI, and M.M. Rahman, Executive Vice-Chairman of BARC.

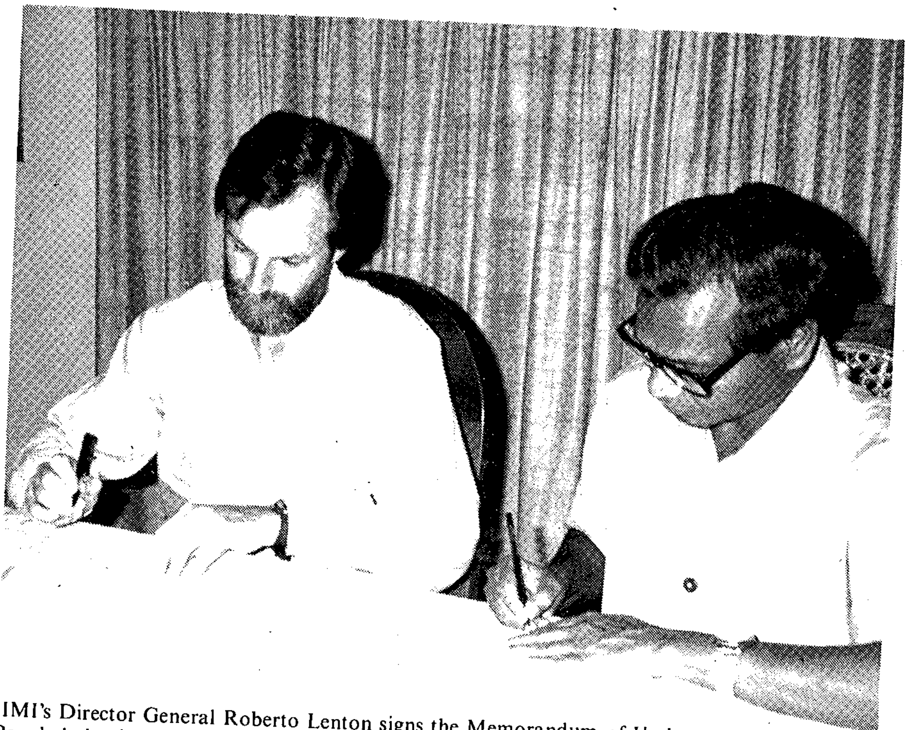
The agreement recognizes IIMI's status as a non-governmental, non-profit international institute with associated privileges and immunities, and establishes the guidelines for IIMI's presence in Bangladesh for a period of five years. As specified in the Agreement, BARC, which oversees agricultural research in Bangladesh, will cooperate with IIMI to facilitate collaborative research between IIMI and Bangladesh agencies and institutions.

The agreement also provides for the establishment of a national Consultative Committee, which will assist IIMI in planning and preparing research projects and activities and ensure that they are in accordance with government strategies, policies, and priorities for irrigation development. "In other countries where we are working, in Sri Lanka and Pakistan for example," says Lenton, "Consultative Committees have played a fundamental role in facilitating cooperation with partner agencies and in interpreting and relating IIMI's research to the larger irrigation environment."

"Initially we expect to concentrate on improved management of tube well systems and surface systems. These are two areas of great importance to the government, and the related research is particularly conducive to IIMI's multidisciplinary approach," he continues.

IIMI expects to post a resident staff member in Dhaka later this year. Initial funding of US$450,000 will be provided by the Ford Foundation for a period of three years.

During his brief visit to Bangladesh, Director General Lenton also met with Md. Amjad Hossain Khan, Chairman of the Bangladesh Water Development Board, M. Abu Syed, Secretary, Ministry of Agriculture, and other government officials and aid representatives to discuss IIMI's programs and activities in the country.□



IIMI's Director General Roberto Lenton signs the Memorandum of Understanding for Bangladesh with M.M. Rahman, Executive Vice-Chairman of the Bangladesh Agricultural Research Council (BARC).

In our last issue, volume 2 number 1, we published "Irrigation under threat: A warning brief for irrigation enthusiasts," by Ian Carruthers. Some useful references for that article are:

Horning, H.M. 1986. Irrigation development and water charges. Expert Consultation on Irrigtion Water Charges FAO/USAID Rome. September 1986.

Repetto, Robert. 1986. Skimming the water: Rent seeking and the performance of public irrigation systems. Research report 4. Washington DC: World Resources Institute.

Goldsmith, E. and N. Hildyard (eds.). 1986. The social and environmental effects of large dams. 3 volumes. Conwall, UK: Wadebridge Ecological Center.

ODI Review. 1977. 1:106-110. London: Overseas Development Institute.

Blaxter, K. 1986. People, food and resources. Cambridge, UK: Cambridge University Press.

IN BRIEF

NEW DONORS AND GRANTS

On 17 March 1988, IIMI had the pleasure of hosting Dr. Margaret Catley-Carlson, President of the Canadian International Development Agency (CIDA), at IIMI Headquarters. During her visit she presented IIMI with a contribution of 100,000 Canadian dollars. "The initial funding of $100,000 for this fiscal year reflects our intention to provide support to IIMI on a regular basis in the future," Dr. Catley-Carson said. "It is also an indication of our interest in the Institute's innovative approach to strengthening the efforts of developing countries to improve irrigation systems."

The International Fund for Agricultural Development (IFAD) and the *Bundesminsterium fur Wirtschaftliche Zusammenarbeit* (BMZ) have given IIMI 3-year grants of respectively US$150,000 and DM 940,000 to support research on Farmer-Managed Irrigation Systems (FMIS) and to support the FMIS Network, beginning in January 1988. The funds will be used to document management practices and evaluate management problems in FMIS, evaluate and develop alternative intervention strategies, develop case study training materials for policy makers and planners illustrating alternative approaches to assist FMIS, and develop methodologies for diagnosing existing problems in FMIS which can be used by the staff of implementing agencies and by researchers.

A grant of 4 million Guilders (US$2.2 million) from the Government of the Netherlands to IIMI has been approved for work on Managing Irrigation Systems to Minimize Waterlogging and Salinity Problems in Pakistan. The grant is to cover a three-year period beginning in 1988. The program of field research is designed to identify and determine the linkages between existing irrigation system management processes and persistent waterlogging and salinity problems in the Indus Basin. A second phase research objective is to define irrigation management techniques and strategies that promise to mitigate emerging waterlogging and salinity problems, or to reduce the likelihood of their occurrence in irrigated areas of the Indus Basin.

CHANGES IN THE BOARD

David Bell has been selected as the new Chairman of IIMI's Board, effective 1 January 1988, to succeed **Robert Cunningham** of the United Kingdom (who remains a member of the Board until the end of this year). Bell served as Director of the US Budget Bureau and as Administrator of USAID during the Kennedy and Johnson Administrations, before joining the Ford Foundation as the Vice President for International Activities, and then as Executive Vice President. While at Ford, Bell played a major role in the formation and development of the Consultative Group on International Agricultural Research (CGIAR). Until recently he served as Director of the Center for Population Studies and Chairman of the Department of Population Science, School of Public Health, Harvard, where he is currently Professor Emeritus.

Nanda Abeywickrama took over as the new Vice Chairman of the Board of Governors on 1 January 1988. He has been a member of the Board since 1983. Currently Secretary of the Ministry of Lands and Land Development of Sri Lanka, he was previously Senior Assistant Secretary of the Ministry of Irrigation, Power and Highways. Mr. Abeywickrama has substantial consulting experience in several Asian countries, principally in the areas of land and rural development, and is the author of several publications and papers.

Ghulam Rasool Sandhu joined the Board on 1 June 1988, replacing Amir Mohammed, who retired. Sandhu is currently Chief Scientific Officer and Member (Natural Resources) for the Pakistan Agricultural Research Council. A specialist in microbial bio-chemistry, nitrogen fixation, and soil salinity, Sandhu has written widely on these subjects. During his tenure with the Pakistan Agricultural Research Council, he has served as National Coordinator for Saline Agriculture, National Coordinator for Biological Nitrogen Fixation, and Director General of the National Agricultural Research Center.

Two new members will be joining on 1 January 1989, to replace Robert Cunningham, Gilbert Manuellan of France, and Dean Peterson of the USA.

Robert S. McNamara has served as President of the Ford Motor Company, US Secretary of Defense during the Kennedy and Johnson Administrations, and President of the World Bank. While President of the World Bank, McNamara played a leading role in the founding of the CGIAR.

Jean-Pierre Troy is at present the Director of the *Ecole Nationale du Genie Rural, des Eaux et des Forets* (ENGREF), in Paris. Initially trained as an agronomist, he further specialized at the reputed State School of Forestry, the *Ecole des Eaux et des Forets de Nancy*. After 12 years of post-doctoral research, he succeeded in obtaining the distinction of *Docteur d'Etat* (Doctor of Science). The expertise he has gained in the ecological sciences related to land, water, and natural resources management were applied to his work in the many countries he has been in.

Thus, as of 1989, IIMI's Board of Governors will comprise 13 members. The other members are Abdalla Ahmed Abdalla, Benjamin U. Bagadion, Kamla Chowdhry, Carlos Grassi, Guy Le Moigne, Letitia Obeng, Kunio Takase, and Roberto Lenton, (ex-officio).

APPOINTMENTS & STAFF CHANGES

The Japanese Government has seconded **Masao Kikuchi**, an agricultural economist, to IIMI as of April 1988. Kikuchi, who is attached to Japan's National Research Institute of Agricultural Economics, has also served at IRRI. He has published more than 50 papers and articles, and most recently the 1982 book "Asian Village Economics at the Crossroads: An Economic Approach to Institutional Changes," which he coauthored with Y. Hayami. He has a Ph.D. in Agricultural Economics from Hokkaido University in Japan.

Jean-Claude Legoupil, an agronomist, has been appointed as Regional Representative based in Burkina Faso, to implement IIMI's regional program for West Africa, which commenced on 1 June 1988 (see **INITIATIVES**). Legoupil, a French national, was head of the Water Management Division of IRAT/CIRAD (*Institut de Recherches Agronomique Tropicales et des Cultures Vivrieres /Centre de Cooperation Internationale en Recherche Agronomique pour le Development*). He has extensive experience in irrigation development and management in West Africa. He has conducted surveys and studies in Africa, Saudi Arabia, and South America on irrigation and irrigated farming systems, irrigated crops under desert conditions, and irrigation and salinity.

Hammond Murray-Rust, previously with IIMI's program in Pakistan, has been appointed as team leader for IIMI's Indonesia program effective December 1987. Before coming to IIMI, Murray-Rust was on the staff of IRRI's Water Management Program. He completed his Ph.D. in Agricultural Engineering at Cornell University. He is well-known for his work in irrigation system management, operation and maintenance of irrigation systems, rehabilitation and modernization of irrigation systems, and soil erosion and reservoir sedimentation. Murray-Rust, a British national, has worked in Tanzania, Sri Lanka, Bangladesh, the Philippines, and Pakistan.

IIMI's new Head of Information Programs, **Francis O'Kelly**, took up his appointment with the Institute in July 1988. O'Kelly, an Irish national, has devoted much of his efforts over the past 15 years to development issues, and knowledge and science and technology transfer to and from developing countries. After working at UNESCO as a professional officer in the Office of Publications, he joined the United Nations Environment Programme (UNEP) in Nairobi as Head of its Publications Programme in 1977. On leaving UNEP in 1981, he founded several information units specializing in publishing on development issues and providing advanced information technology to developing countries.

F.E. Schulze, currently IIMI's Director, International Programs, has been appointed Director, IIMI Pakistan, effective 1 October 1988. Before coming to IIMI, Schulze served as Agricultural Counsellor at the Royal Netherlands Embassy in Jakarta from 1982 to 1986, and as Director of the International Institute for Land Reclamation and Improvement of the Netherlands from 1972 to 1982. During this latter period, he chaired the Technical Advisory Committee of the CGIAR study team on water management, whose recommendations led to the founding of IIMI.

STRATEGY WORKSHOP

IIMI is now in the final stages of preparing its long-term strategy document, a process that began one year ago. As a final step in this process IIMI invited over 18 irrigation officials and researchers from 12 developing countries to discuss the draft strategy and contribute their ideas. Nine staff members from IIMI's headquarters and country programs, also attended. The workshop was sponsored by the United Nations Development Programme.

IIMI expects to submit the revised strategy to the IIMI Support Group later this year.

IIMI LAYS FOUNDATION STONE FOR NEW HEADQUARTERS

On 19 June, Gamini Dissanayake, Minister for Lands and Land Development and Mahaweli Development of the Government of Sri Lanka, laid the foundation stone for IIMI's new headquarters building in Digana Village. Over 300 people including various representatives of government agencies and foreign embassies attended the traditional ceremony.

The building will be principally funded by the Government of Sri Lanka through a World Bank credit of US$1 million, with IIMI providing the additional funds required. The new HQ, containing offices as well as conference facilities, is due for completion mid to late 1989. □

The foundation laying ceremony for IIMI's headquarters building in Digana.

Natural Resources and Sustainability in the Developing Countries: Meeting the Challenge with International Research

Schuh, G. Edward and J. Colmey

(G. Edward Schuh currently chairs the IIMI Support Group)

This unpublished report was prepared for the meeting of IARCs (International Agricultural Research Centers) at the Hubert H. Humphrey Institute of Public Affairs, University of Minnesota, in March 1988.

Funded by the Ford Foundation, this report was initially commissioned as a review of the major development issues and the innovative conceptual framework underlying the objectives and activities of the IARC group (comprising six International Agricultural Research Centers and one "Special Program"). Its purpose was to provide an internal position paper for the analysis, by the group, of future options in development, and the most appropriate institutional cooperative framework. However, the compilation of the document presents major strategy analyses whose themes and approach deserve a significantly wider audience than that originally foreseen for the report.

The report emphasizes major development problems of the 80s and 90s, particulary the sustainability of the natural resource base and its sound management through protection of the "social resource" base and the promulgation of innovative management practices. Each center conducts research on a different resource system, be it soil management, insect control, fisheries, agroforestry and land use, agromineral technologies, or irrigation. Yet their operational methods and objectives are common, dealing with issues in a holistic, environmentally sound manner, through flexible and decentralized institutional structures which enable them to take into account the varied needs at specific and local levels but at the same time remaining aware of the global picture.

The authors consider that a new phase in agricultural development has been reached. From the Malthusian-dictated challenges of the 60s and 70s, the emphasis has changed; basic food production is high, but inadequately distributed; uneven population growth has resulted in resource degradation, acute in some areas; marginal lands are being uncomfortably and unwisely exploited; much of traditional agricultural research is not reaching out to the more disadvantaged areas. These new problems elicit new challenges: to safeguard and stabilize food production while protecting finite resources; improve productivity in unfavorable environments; and develop effective environmentally sound and sustainable technologies. The challenges are examined, and a new research strategy proposed: this will be the new challenge of the IARCs, and is already well underway. The common features of their efforts include a global mandate for applied research in developing countries, a multi-disciplinary socio-economic approach, sustaining and diversifying production systems, the collaborative approach, and flexibility and efficiency in terms of productive capacity and target achievements.

The analysis leads to definitions of a common conceptual framework for the group, and interdependent operating and financing methods.

The report will be of interest to those involved in management of the areas of concern of the groups, the wider audience of those concerned by the innovative approach to agricultural research and sustainability, and development aid professionals and sponsors.

Further information can be obtained from the authors, at the following address:

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Dean, Humphrey Insitute of Public Affairs
Humphrey Center
301, 19th Avenue South
Minneapolis MN 55455
USA

*The associated centers are :

IBSRAM	International Board for Soil Research and Management
ICIPE	International Center of Insect Physiology and Ecology
ICLARM	International Center for Living Aquatic Resources Management
ICRAF	International Council for Research in Agro-Forestry
IFDC	International Fertilizer Development Center
IIMI	International Irrigation Management Institute
IUFRO	International Union of Forestry Research Organizations (through its Special Program for Developing Countries)

Gamini Dissanayake reviews IIMI's publications with the Director General.

(Continued from page 2)

will help us to plan out a realistic management system for the future.

IIMI Review:
All this suggests there is a need for improving communication and feedback throughout irrigation agencies. Do you agree with that?

Jayewardene:
I do. I think there is a need, and we have felt that need, but speaking for the Mahaweli, we have had neither the time nor the backing to carry out the necessary research. IIMI is playing a useful role in that they are supplementing the efforts that we are making. IIMI is providing something that we have not been able to do although we felt it was necessary.

IIMI Review:
Do you think there is a need for more research of this type, that is to say, on the agency itself? And if so, what areas or subjects should be given priority?

Jayewardene:
An agency would have to have a separate organization to carry out this type of research, because the day-to-day irrigation managers simply do not have the time. Nor can they evaluate their own work. Somebody from outside has to look at what is going on, what was planned, what is actually happening, why changes have been made, and whether they are for the better or not. They can also look at the overall picture of the agency and its management of the system.

IIMI Review:
Are irrigation agencies threatened by this type of research? How will research results help the agencies? And how can research institutions ensure their results are useful?

Jayewardene:
I think it is natural that irrigation agencies feel threatened. Nobody likes having someone looking over his shoulder critically, to see what he is doing. But if one looks at it objectively, this type of research is absolutely necessary, because managers feel that what they are doing is best. But there could be others who may know better. Most people tend to take research findings or criticisms personally. This should not be so. The whole purpose should be to make the system better managed and the work that you are doing better and more efficient. I do not think anyone should resent it. How helpful the results will be depends on how you do the research. Once the researcher makes up his mind as to what he is going to do, he should discuss it with the people with whom he is going to work and explain, especially to the lower level managers, what the object of this whole exercise is. Then they will realize that the research is going to be of some use. If the people in the field know the purpose of the research, they will realize that this is not some criticism or evaluation of their personal work. Their reaction and response will be more positive. That will help the researcher to get a practical and true picture of what is going on. The data collectors will be able to gather more informative and accurate data. If there is a link of the sort we had with MEA and IIMI over this research, then your research becomes easier, your data becomes more accurate and you find that it is a much better and easier working relationship.
The other thing I would like to suggest is that before institutions like IIMI begin carrying out research, they should ask the agency with which they are working to identify some person who could work with the researcher. Either the agency or IIMI can pay that person. Then the research becomes a part of that agency's activities. An advantage of doing this is that the person who works with you gets to know the system, and what you are doing, and when the research is over he returns to his job and implements the results and continues the work started by the researchers. Let's say you have some foreign consultants working with some of your people on the operation of main canals and branch canals. Once they leave, that work would continue. Otherwise when the program is over and the evaluation is done, everybody goes back to what they were doing initially.
One thing more. It would be good if IIMI could publish research results in Sinhala, or in the language of the country in which they are working. Because in Sri Lanka all your findings are useless below the level of the Mahaweli Economic Agency if they are not documented in Sinhala. The resident project manager may or may not read the English publication. Nobody else will read it further down the line. Everything that you have come up with which is useful to us in our work will not be communicated to those who are actually going to be making the changes or feeling the differences in the future.□

NEW COMMUNICATION LINKS

IIMI has taken a number of steps recently to improve its external communications, including the addition of electronic mail, fax, and a new telex facility. The numbers are as follows:

ELECTRONIC MAIL
IIMI Headquarters: IIMI (10074:CGU022)

FAX
IIMI Headquarters: (94-8)32491
The number for the Philippines is (63-2) 8189720 via RCA PHILCOM

TELEX
IIMI Headquarters: 22318 IIMIHQ CE, or 22907 IIMIHQ CE

Pakistan:
44926 IIMIP PK

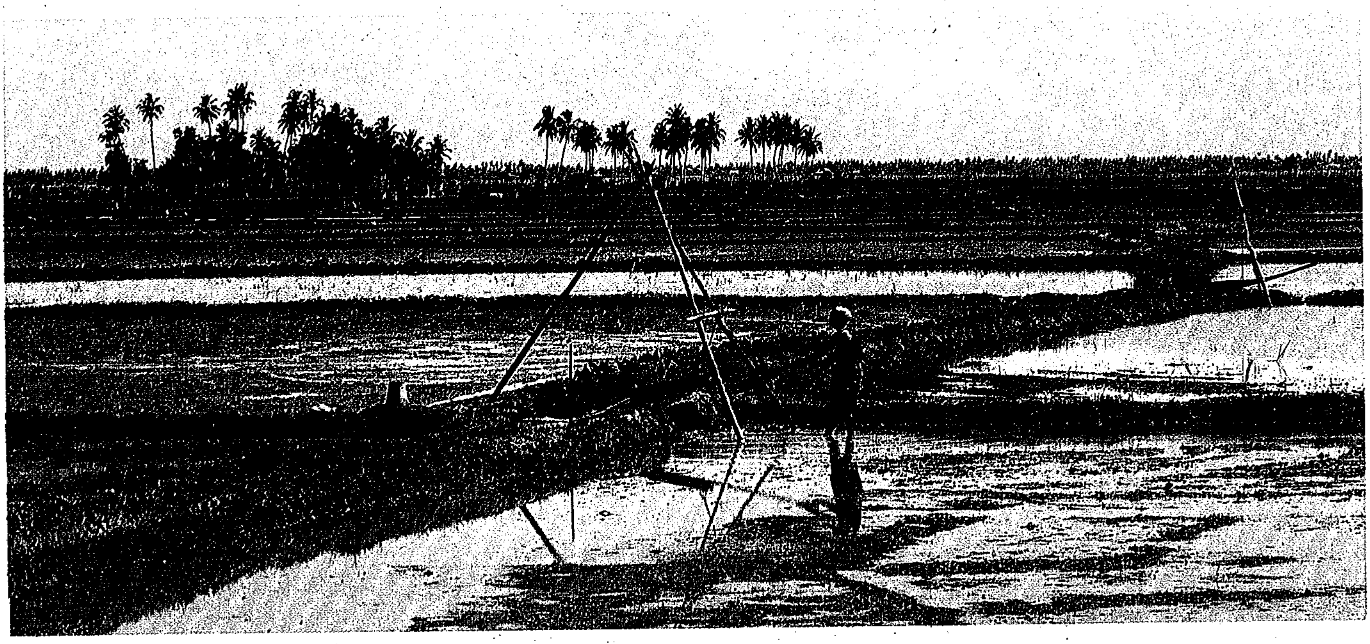
Indonesia:
61894 FF JKT IA (Attn: IIMI) for the office in Jakarta, and 28276 PHEGAR IA for the office in Bandung, West Java.

Nepal:
2321 BASS NP (Attn: IIMI)
Alternatively and/or Saturdays 2262 NARANI NP (Attn: YODER 524859)

The Philippines:
40860 PARRS PM (Attn: VALERA/IIMI) (Mon-Fri), 22456 IRI PH c/o Water Management Dept. (1:00 pm Fri-Sun)

West Africa:
5381 SAFGRAD BF

CALENDAR



September

24 - IIMI-Pakistan Consultative Committee Meeting at Lahore, Pakistan.

25 Sep - 02 Oct - International Executive Council Meeting, International Commission on Irrigation and Drainage, Dubrovnik, Yugoslavia.

29 - 30 - Innovative Ways to Address Irrigation Management Issues, a Workshop for Irrigation Policy Makers in Pakistan, Lahore, Pakistan.

October

05 - 07 - National Workshop on Irrigation Management for Diversified Crops. Sponsored by IIMI and Philippine Council for Agriculture and Resources Research and Development (PCARRD), Manila, the Philippines.

29 - IIMI Support Group Meeting, Washington, DC, USA.

November

09 - IIMI-Sri Lanka Consultative Committee Meeting, Colombo, Sri Lanka.

16 - 17 - Study Advisory Committee - Kirindi Oya Model - second meeting, IIMI Headquarters, Digana Village, Sri Lanka.

21 - 25 - Internal Program Review Meeting, Colombo, Sri Lanka.

30 Nov - 02 Dec - Planning and Organizational Workshop on the International Network on Irrigation Management for Diversified Cropping in Rice-based Systems. Asian Institute of Technology Center, Bangkok, Thailand.

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