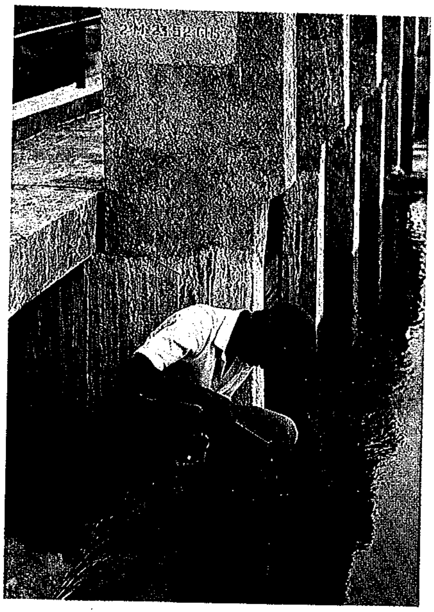
HYDRAULIC MODELING OF A MAIN CANAL SYSTEM:

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.

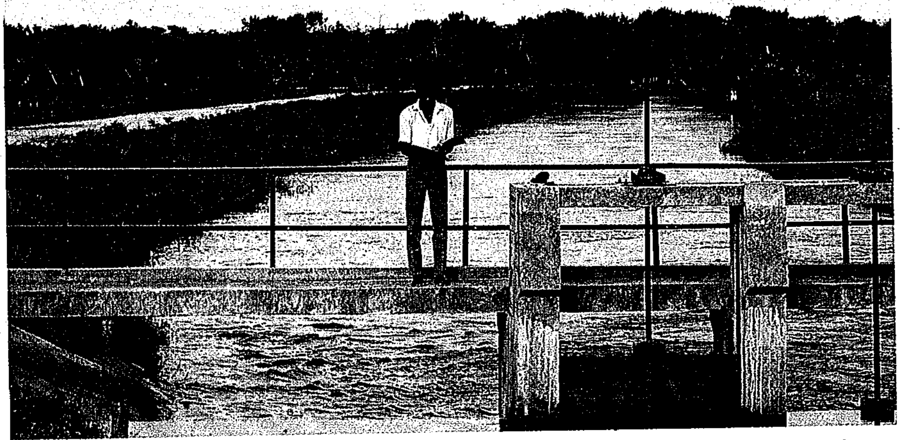
CEMAGREF offered to provide IIMI with existing state-of-the-art computer programs of its own and technical backstopping. It agreed to develop user-friendly interfaces specific to Kirindi Oya RBMC Model that will run on microcomputers (such models are more often run on mainframe computers). In that format 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.



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

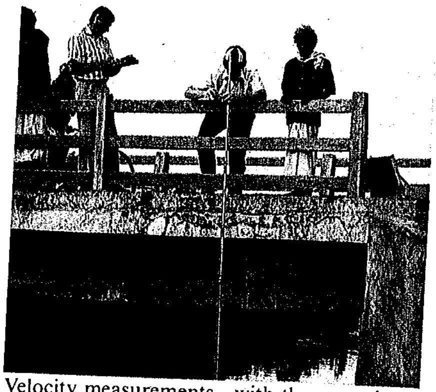
Thus the next step is to test the model in the field (i.e., to calibrate the model to Kirindi Oya RBMC). In May, Certain and Andre Durbec, a second CEMAGREF engineer involved in the project, joined IIMI staff in calibrating the model to match Kirindi Oya. "The purpose of the calibration," says Hilmy 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.

"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.