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Information Techniques for Irrigation Systems

Forum

The Irrigation Department of Sri Lanka Enters a New Phase of Management

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TRANSITION FROM AN IRRIGATED HERITAGE TO A FOCUS ON PRODUCTIVITY AND MODERN MANAGEMENT

The history of irrigated agriculture in Sri Lanka can be traced back to about 2,500 years. Irrigated agriculture in Sri Lanka has always enjoyed state patronage and has long been the "life blood" of this island nation. Over time, irrigation systems have evolved built-in mechanisms for successful development and management within the framework of the prevalent socioeconomic and political system.

The Irrigation Department (ID), formally established by the British Raj in the year 1900, inherited this ancient legacy and has since been the primary agency responsible for management of irrigation in this country.

The responsibility of the Department initially was to ensure the country's food security through maintenance of the existing irrigation systems and restoration of some of the ancient systems. The next phase was an extensive development and expansion of irrigated area through new constructions and substantial improvements to old and dilapidated works.

Completion of the massive Mahaweli System and other new systems exhausted the potential for new construction and the Department entered into a new phase where its emphasis shifted from development to management and productivity of the systems.

The projects implemented since the late 1970s had this objective in mind, viz., to increase productivity of the existing schemes by improving the physical system coupled with improved operation and management practices, together with required institutional development.

These improvements included the construction of minimum required head and flow control devices and basic flow measurement devices at control points with the objective of allocation and distribution of water more equitably and efficiently on the basis of crop water needs.

The other important feature in all these projects starting with Gal Oya in the early 1980s, is the introduction of computer models to help the system managers in water allocation and distribution.

Inside ...

TRAINING: A REQUIRED CONDITION FOR IMPROVED MANAGEMENT....

Adoption of changes in system management practices requires substantial training for the personnel involved in order to develop their knowledge and skills in the new job and to create the necessary attitudinal changes in them to adjust themselves to the new situation.

Aware of that critical issue, the ID created the Irrigation Training Institute (ITI) at Galgamuwa under the then Gal Oya Water Management Project in the early 1980s. Extensive training programs on Water Management were commenced to train the system managers and the field-level officers covering the Irrigation Engineers, the Technical Assistants and the Works Supervisors.

....BUT NOT SUFFICIENT

Even though a large number of personnel were trained by ITI over this period, the expected results did not materialize due to:

1. The difficulties in establishing the required measurement network and periodic calibrations involved.
2. The cumbersome procedures involved in the preparation of irrigation schedules, implementing and monitoring of them.
3. The lack of an institutional arrangement in the Department to carry out the new task of improved system management.

These constraints have made it necessary for the Department to facilitate the use of computers as decision support tools on a wider scale in irrigation system operation and to create the necessary environment by making the required institutional arrangements.

Changes were instituted at the regional level (creation of Irrigation Management Cells [IMACs]) and at the national level (creation of separate sub-departments for Irrigation Management and Human Resources Development and the formation of the Irrigation Research Management Unit [IRMU]).

IRRIGATION MANAGEMENT CELLS (IMACS)

IMACs were established in August 1994 with the main objective of creating suitable local institutional conditions for facilitating efficient, effective and sustainable management of irrigation systems. Organized at a regional level, they focus on the participation of users in order to maximize productivity both in terms of unit of water and in terms of unit of land.

The main functions of IMACs are:

1. Facilitate improved system management.
2. Seasonal water and production planning.
3. Environmental activities for long-term sustainability.
4. Assist and facilitate in the introduction of improved irrigation and agricultural technology.
5. Farmer institutional development.
6. Assist and facilitate in human resources development and technology transfer.

Other Activities

IMACs are also expected to assist in post-harvest processing, marketing and off-farm activities to increase farmer income.

The regional IMACs have initially begun to function with farmer training and farmer organization activities. A calibration unit, composed of one Irrigation Engineer (IE) Water Management and a Training Assistant (TA), with the necessary flow measuring equipment will soon be established under each IMAC.

Already, a new computer has been provided to each IMAC from the ongoing National Irrigation Rehabilitation Project (NIRP) and these are expected to be used for improved system management, starting with at least one scheme from this year.

IRRIGATION RESEARCH MANAGEMENT UNIT (IRMU)

The Irrigation Research Management Unit (IRMU) was established at the national level in 1992

The Network

The Information Techniques for Irrigation Systems Network (ITIS) links the conceptual to the practical—the world of Decision Support Systems (DSS) to the world of irrigation. This newsletter is intended to serve as that bridge, to facilitate the dissemination of knowledge concerning the application of information techniques for improving the management of water in irrigation systems.

The IIMI-CEMAGREF Project in Kirindi Oya, Sri Lanka was the foundation on which ITIS was launched. Following the successful development and implementation of decision support tools in Sri Lanka, the Project has entered a new phase with work being initiated in Pakistan and Mexico. Work on the IIMI-CEMAGREF Project will progress for another five years. It is hoped that ITIS would have gained a sufficient critical mass by that time to sustain itself.

CEMAGREF

CEMAGREF is the French institute of agricultural and environmental engineering research. It is a parastatal organization supported by both the French Ministry of Research and the French Ministry of Agriculture. It has a strength of more than 500 researchers and conducts research programs in the field of land and water management, environment and agricultural engineering. Its irrigation division is located in Montpellier, France.

IIMI

The International Irrigation Management Institute (IIMI) is an autonomous, nonprofit international research institute supported by the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of public- and private-sector donors that supports a worldwide network of 16 international research centers, including IIMI, conducting global research on agriculture, forestry and fisheries. The CGIAR is sponsored by the Food and Agriculture Organization of the United Nations (FAO), the International Bank for Reconstruction and Development (World Bank), the United Nations Development Programme (UNDP) and comprises more than 40 donor nations, international and regional organizations, and private foundations.

IIMI's mission is to foster the development in the management of water resource systems and irrigated agriculture. With its headquarters in Colombo, Sri Lanka, IIMI conducts a worldwide program to generate knowledge to improve water resource systems and irrigation management, strengthen national research capacity, and to support the introduction of improved technology, policies and management approaches.

supported by the ongoing NIRP and with technical assistance from IIMI. The main objective of IRMU is to identify research needs on a priority basis, carry out, collaborate or contract for research, evaluate results and adopt them for implementation.

One of the research topics that has been identified for adaptive research on a priority basis is the "Use of Computer Models for Improved Operation and Management of Irrigation Systems in Sri Lanka." Four pilot schemes have been selected for this study on the basis of the type of scheme (i.e., diversion or reservoir, the size, and the study in progress).

DISSEMINATION OF INFORMATION ON DECISION SUPPORT SYSTEMS (DSS) FOR IMPLEMENTATION

In addition to information available from sources like IIMI, ITI will assist in disseminating and adapting study results on the use of DSS within the Department while providing required training for staff who will be involved in this work. Study findings on the use of DSS that will help improve system performance, will be implemented by IMACs at the regional level.

RECOMMENDATIONS AND PROPOSALS FOR USE OF COMPUTERS AS DSS IN FUTURE

It can be said that the ID, Sri Lanka has now identified the use of computers as DSS for improved system productivity to be a vital need. Action has been proposed on the following basis for use of DSS in the future:

1. Declaration of the use of computer-operated models for improved operation as a policy.

2. Identify resources required to invest in this field and gradually provide computers to all Irrigation Engineers.

3. Take action to get compqterization of system operation as an item in the national budget for ID.

4. Formulate and conduct training required for staff on the establishment of a measurement network, data collection, processing and analyzing, and use of computers for system operation.

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Computers, Rationality and Irrigation Management

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The increasing availability of inexpensive and powerful computers has fueled a boom in modeling and software designing activity among researchers and scientists. The once overwhelming paradigm of rationality has allowed Operation Research to attain spectacular achievements, but it has also clearly shown its limitations when dealing with systems in which human behavior, taste or decision making are involved. Progressively, in fact, the frontier between issues which are considered to come under pure technical and instrumental rationality and others belonging to the social sciences has strangely shifted. In the meantime, as deeper investigations were carried out to fathom the unending complexity of individual and group behavior, the epistemological status of the models became weaker: from normative, they often became prospective and the designers tended to anticipate critics by claiming an "heuristic" status for their models. It never remained clear, however, given that results from the model are eventually taken into consideration for some decision making, what was the real consequence of such outward modesty (Molle and Valette 1994).

In irrigation, and more generally in rural development, the acknowledgement of the complex nature of most of the issues to be tackled has long been overshadowed by the dominance of the engineering approach. Here also, the shortcomings and failures of development operations have often enforced the necessity to look at irrigation as an issue of water distributed by gate tenders and shared by farmers rather than as a purely hydraulic or technical problem.

A LARGE SPECTRUM FROM TECHNICAL SIMPLICITY TO DECISIONAL COMPLEXITY

A first category of programs is designed to answer well-specified questions for which input data and calculation processes are well identified (design of spillway, estimation of crop water requirements, calibration of gate, etc.,) and to which a technical approach can be adopted. On the other side of the spectrum, we may find a second category of software tools belonging to recent developments of DSS (Decision Support Systems) which address so called *under-specified problems*, requiring in particular, adaptation and participation of the decision maker (Sprague and Watson 1989). However, entering the complexity of decision making, should only be considered for organizations with a strong background of data management and monitoring. We fear that there is, at present, little scope for such advanced concepts in most of the irrigation systems.

AN INTERMEDIATE LEVEL RELATED TO MANAGEMENT OF INFORMATION SYSTEMS (MIS)

In between the previous approach, we may found a third category of tools related to the information system approaches, "getting the right information to the right person at the right time." It focuses on data management at project level and provides data processing to schedule, monitor and assess activities within the project. At first glance, such tools may appear to be related more to the technical sphere in that they mainly process a set of data corresponding to soil, crop, water, climate and irrigation technique. But, in fact, difficulties of a different nature are experienced.

From software limitations....

First, as accurate as they may be, these calculus remain in most cases indicative: for example, models relying on daily water balances may be of some utility for planning or simulation purposes but are less relevant for in-season monitoring. Models and field conditions quickly diverge and the first one must generally be hastily retrofitted on the basis of some more obscure parameters such as field wetness. Amongst the difficulties that crop up here are natural limitations (the heterogeneity of nature, specially soil conditions) together with the difficulty to size up the heterogeneities arising from local differences in water management patterns.

It may be possible to cope with the situation at plot level, considering all the links of the water distribution chain and trying to increase control on any of them. By doing so, it is necessary to set up a huge data collection which rapidly appears to be impracticable because of obstacles whose nature is generally either economic or organizational. The solutions are then either to resort to automation, or to go towards a more rigid distribution pattern, such as in the *warabandi* system, both solutions representing drastic and often impossible changes.

....to hardware constraints....

Second, if it is assumed that a good quality inflow of information is ensured, the level of water control allowed by the hydraulic infrastructure and the quality of the field staff's management, together with the already existing pattern of allocation at ditch level, may well be insufficient to ensure the desired equity of the hydraulic rationality expressed by the set of rules drawn from the model. This difficulty, of course will vary a lot according to the different modes of water regulation and will be lower in cases where rules are strict and fixed. In most of the common gravity irrigation schemes equipped with cross regulators and slide gates, where farm turnout operation is mainly done at will by farmers, it will be extremely difficult to enforce top-down computer-assisted gate settings to cope with water-level fluctuations and these interventions are unlikely to prove more efficient than "thumb rules" and human experience. In addition, gate tenders are also unlikely to cooperape with time-consuming interventions which would not fit their experience.

....via the gap between managers and researchers.

Third, one difficulty lies in a common misunderstanding: the computer mirrors the formal rational logic of the researcher, which will input in the program his/her view on probabilities, risk, equity, efficiency, etc., and his/her faith in calculation. On the other hand, the managers and field staff will generally resort to a different kind of logic, minimizing the weight and number of interventions, disregarding tedious data collection, minimizing dissatisfaction externalized by farmers, giving little attention to the long-term (e.g, maintenance), etc. While the computer reinforces the ideology of the "one best way" and technical optimum, managers will most likely behave in a more complex way, the understanding of which often comes under the sociology of organizations. This had been very well evidenced in the report on the introduction of the INCA (Irrigation Network Control and Analysis) Program in the Inginimitiya Project, Sri Lanka (IIMI and HR Wallingford 1994).

From nonuse in non-stressed project....

The success or opportuneness of introducing computer-assisted management also deeply depends on the general water availability in the scheme: if the project does not face any major problem or real water shortage—a typical situation in continuous flow irrigation—then there is no incentive to define targets and the strategy of managers is likely to be maintaining management activities at the lowest level possible above the limit of getting into trouble. The objective is to ensure water everywhere and at any time, with little or no consideration for efficiency and high autonomy of gate tenders who solve 90 percent of the problems encountered. As stated in the report on the Inginimitiya experience, "there is little incentive to use the software to make 'better' decisions if there is little or no feedback concerning the consequences of 'less good' decisions prior to the intervention."

....to inadaptation in other cases.

On the other hand, if the project has to face drastic issues, confrontation, with common yearly water shortages—requiring rotation irrigation—then the managers will have to face conflicts among users, and between users and the agency, and the logic used to solve these conflicts is generally quite different from formal rational optimal decision making. Risk will often be lowered to zero, if possible, and zero-delivery can be preferred to situations in which farmers may start but not complete their crops or be angered for not having been selected. Waiting for normalization may often be safer and computers are of little help as social negotiators.

Another point which deserves to be mentioned among the sometimes negative impact of computer-assisted management is the possibility that it may reinforce the commonly observed distance between the manager at the main office and field reality. The program, by allowing powerful manipulations of virtual realities, often produces the illusion that reality matches, and is reduced to, what is shown on the monitor of the computer. But, here again, either the manager will have the means to ensure that (1) the input data is relevant, (2) the decisions taken are followed by quick and effective actions, or the software will be quickly abandoned.

Has there been a thorough analysis of the significance of the failure of many of the software packages introduced to assist water management, specially the in-season operation and monitoring systems? Besides the often-cited reasons of *lack of incentive*, *interest* or *reward*, there might be scope for a broader analysis on this issue beyond the confines of computer tools development itself....

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ITIS in the Field

Nile Water Resources Management Model

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Egyptian agriculture covering about 3 million hectares (ha), is totally dependant on irrigation. Within the Nile River Basin, the irrigation network conveying and distributing water from the Aswan Dam up to the farmers' plots has become more and more sophisticated. In order to improve its management, important studies have been undertaken during the last 15 years (mainly, Water Master Plan, 1977–1987 and Irrigation System Management Projects, 1987–1995). Under these studies, several computer tools were introduced by consultants and the Ministry of Public Works and Water Resources (MPWWR) in charge of managing the system. More than 20 software packages were acquired or developed for the study and management of the Upper Nile Catchment, for the operation of the High Aswan Dam and for the Egyptian irrigation area per se (agro-economic optimization, water and salt balance, irrigation management and hydraulic simulation). Some of these softwares have remained academic tools, some are used as operational tools. One example of operational use is as follows.

In September 1990, the Overseas Development Administration (ODA) started to fund the Nile Water Resources Management Project, and a software was developed by Mott MacDonald Consulting Engineers to be used by the irrigation sector of the MPWWR of Egypt. Field data collection lasted two months throughout the Egyptian irrigation and drainage systems, and completion of the software including model testing consumed six months in the UK. The model was modified several times in Cairo to add more functions according to the operators' and planners' needs, until reaching the current version.

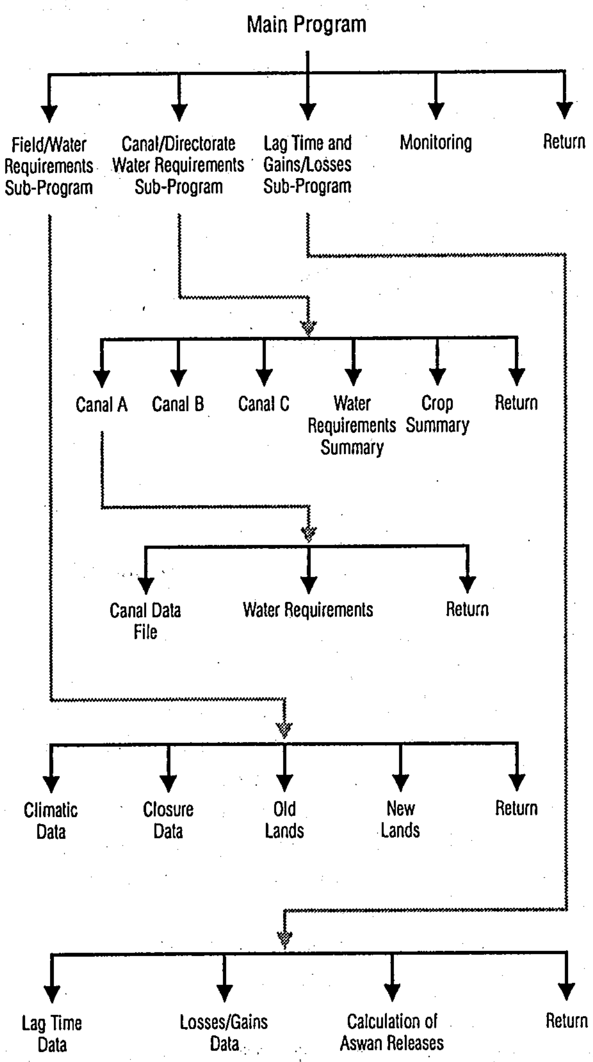
The model adopts the classical methodology the MPWWR used to follow in order to calculate water requirements at the levels of the main feeders taking off from the Nile, (summation of the irrigation requirements at the directorates and regional levels), and the yearly schedule of the High Aswan Dam (HAD) releases on a 10-day basis. The only modification introduced is the use of gain and loss estimates derived from previous years' data and lag times along the Nile reaches to accurately determine HAD discharges.

The input data are: cropping pattern for the area served by main canals and other requirements such as domestic water treatment plants, industrial needs, navigational discharges during the winter closure period, and water released for regulating main barrages and offtakes. The calculations deduct the contribution of groundwater to irrigation and the amount of reused drainage discharge from the total canal requirements. The model provides the operator with the facility of assuming an overall canal efficiency integrating conveyance, distribution and field application efficiencies to augment canal planned discharge by an amount of water equivalent to the losses. It also facilitates the management of the winter closure requirements by distributing the declining water before and after the full closing according to certain percentages chosen by the user. The water duties directory includes preplanting allowances and the planting staggering option. There is also a possibility to store the actual water levels and their corresponding discharges at the main monitoring points for a maximum period of five years, as a database enables the planners to compare and assess management performance. The figure below shows the model structure and the adopted methodology in which it handles the calculations. The model consists of four main modules: water duties, water requirements, Aswan releases and monitoring directories.

The model is programmed in Fortran 77 and compiled with Gem to produce user-friendly interfaces which include colored maps for each directorate and neat input and output screens. It can be operated in English and Arabic and the results are printed in tables and in easily digestable graphic format to make comparison between numbers more feasible.

This model is the most successful amongst the group of water management models belonging to the MPWWR, and it has been known to provide reliable outputs and thus help the water distribution staff plan and study the expected scenarios for seasonal planning. The success of this model has promoted the

Figure. Description of the different functions of the Nile Water Resources Management Model.



extension of the project beyond macro level, the development of directorate software, and the management of water resources within each directorate border and at district level. The model receives cropping pattern data from agricultural cooperatives and attributes it to minor and main canal commands. Data exchange with the main model is facilitated through the data import option, and it is now possible to replace uncleared data sheets received from directorates by floppy diskettes. The model was installed in the computers of two directorates in the middle delta region and is currently under development to suit the physical criteria and operational conditions of two other directorates.

Operation of the Imperial Irrigation District

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INTRODUCTION

The Imperial Irrigation District (IID) is located in Southeast California, in the Colorado Desert. Approximately 500,000 acres of agricultural land in the Imperial Valley are serviced by IID. The irrigated land is at mean sea level or below, and the average rainfall is less than 3 inches. IID operates an open-channel-gravity-fed irrigation system on a continuous basis, 365 days a year. Crops grown in the district include large acreages of vegetable, fruit and other specialty crops. Almost all irrigation is gravity/flood irrigation. The Colorado River is the sole source of the water supply. IID is one of the many users on the Colorado River which is under the jurisdiction of the United States Bureau of Reclamation (USBR).

MAIN CANAL AND DIVERSION HEADWORKS

USBR operates a series of dams and diversion structures on the Colorado River. The Imperial Dam—one of a series of USBR structures on the Colorado River—diverts flow into the All American Canal through desilting works. This 80-mile long canal serves as a transmission canal between the IID and the Colorado River. With a capacity of 15,000 cfs (cubic feet per second) (1 cfs = 28 l/s) at the head and 1,200 cfs at the tail, the All American Canal supplies three main canals within the IID.

Each main canal is approximately 40 miles in length and can divert 1,200 to 2,200 cfs. Check structures within the canal system operate in upstream-level control. Within these reaches, main canal and lateral turnouts divert water through radial or slide gates operating as orifice-flow structures.

MANAGEMENT AND ALLOCATION OF IRRIGATION WATER

Two hundred and forty lateral canals within the cultivated area of the IID are serviced by the main canals. Lateral canals vary from 1 to 10 miles in length and from 40 to 160 cfs in capacity. Check structures within the lateral canal system operate in upstream-level control. Within these reaches, farm delivery turnouts divert water through slide gates operating as orifice-flow structures. Farm deliveries are made through laterals via 5,500 individual user gates. Each has a 20 cfs minimum capacity. On average, each delivery services 80-acre parcels.

USBR coordinates all Colorado River water use for the various users of the system, including Mexico. Each December, USBR requests an estimate of the amount of water each user, including IID, will divert from the Colorado River during the following calendar year. This is referred to as the Annual Water Order. In order to develop the Annual Water Order, IID considers various criteria that can affect water use.

Using the average of the actual water diversions for the last two years as a base, a preliminary estimate is prepared. Various parameters are considered: cropping patterns, weather, recent water user records, federal programs, etc. In case of large differences in the last two years, more weight is given to the most recent year. This rule can have exceptions as it may have been a year of heavy rainfall or other special circumstances.

In addition to the Annual Water Order, weekly estimates are sent to the USBR. Every Wednesday, an order for the following week, defined as Monday through Sunday, is submitted to the USBR. Orders from all water users of the lower Colorado River are aggregated and a Master Schedule of Flows is finalized. The amount of water scheduled on the Master Schedule of Flows is the quantity of water that will be delivered unless it is revised by the IID at least 72 hours in advance. It is important to note that water for the next three days is always in transit and cannot be rejected.

Three sections within the IID operate the irrigation system. River Division operates the Imperial Dam facilities on the Colorado River, Water Control operates the transmission and main canals and five operating divisions manage the lateral system including farm turnouts. Divisions stop accepting water delivery orders at 12:00 noon each day. A summary of these orders is called in to Water Control by each division. The amount of water that is to be used and the number of orders carried over by each division are reported. Carry-overs are undelivered water orders caused by the limited capacity of the system or the available water. Although water orders originate with the water users, the flow allocated to the IID in the Master Schedule is the flow that will be delivered to the system. Therefore, an iterative process is necessary to adjust the deliveries to match the flow available. Water Control allocates available amounts of water to each division making sure that the percentage of carry-overs is balanced throughout the system.

By 1:00 p.m., Water Control contacts River Division to place a firm order for the following day and to make any change in the Master Schedule of Flows for the fourth day following. As soon as this order is confirmed by USBR, the Water Control Office allots all available water back to the five divisions by 4:00 p.m., in amounts that balance carry-overs.

The five divisions readjust the orders to be delivered, using the total amount of water they have been allotted. The water user is notified on the status of his order and a run sheet is prepared for each ditch rider. Lateral diversions for each division are then reported to the Water Control Section. Water Control prepares a water plan for the following day, scheduling changes at lateral headings throughout the main canal system in order to match the system flows with the schedule of orders for the following morning.

A record of the diversions made throughout the main canal system is logged at Water Control and is referred to as the Daily Water Record. Each entry or series of entries has been given a key number. It is used both as a record of flows and as a planning guide. Water orders for the following day are compared to the diversions currently running. The difference in these two figures is the change that

The Irrigation Department of Sri Lanka ...
(Continued from page 3)

5. Provide incentives to engineers for software development.
6. Motivate field staff by way of incentives and redefine their duties as required.

With the increased availability of computers at affordable prices and of computer-literate personnel at ID, it is expected that computers will be used as DSS in other activities including Irrigation Systems Maintenance Management.

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should be made at each section of the system. Typically, the main canal system is operated based on daily changes and not on absolute flows.

The Daily Water Record is also used to develop the water orders provided to the main canal ditch riders. These are prepared each evening for the run the following morning. The diversions scheduled at the head of each lateral are posted on the run sheet. At the end of each day the results of the ditch riders' work are posted. Typically, lateral headings are adjusted two or three times a day.

SYSTEM IMPROVEMENTS

The IID System has gone through several periods of improvements since its beginning in 1991. In the 1930s and 1940s, the All American Canal, Imperial Dam and Hoover Dam were constructed. This was followed in the 1950s with the construction of a hydro-generation plant on the All American Canal, and additional power generation capacity has continued over the years. The distribution system was also improved during these periods with concrete lining of laterals and installation of water-tight farm delivery gates. More recently, problems with aquatic weeds have prompted the district to research and develop a successful program using Triploid Grass Carp. During the last several years the district has undergone more extensive changes. These changes have taken place in both the civil works, as well as in the balancing reservoirs and in the tools used to manage the system. The Management Tools will be discussed in a future ITIS article which will address the Supervisory Control and Data Acquisition (SCADA) System that has been implemented, and how the IID has used advances in technology to improve its operation.

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The Canal de Provence Dynamic Regulation System

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Situated in the South of France, the Société du Canal de Provence (SCP) et d'Aménagement de la Région Provençale (Canal de Provence and Provençal Region Development Company) was created to contribute to the economic development of Provence and the Côte d'Azur regions in the South of France. As such, it studies, executes and manages several multipurpose hydraulic schemes. The schemes supply 70,000 hectares, more than 100 communities, 500 companies and many individuals in suburban areas with raw water.

The main structure is the Canal de Provence which carries the Verdon River water to eastern and coastal Provence. In order that all users can have all the water they require at all times whilst optimizing the management of resources, the Company developed a remote management system called the Dynamic Regulation in 1971. This system provided and still provides automatic and permanent control of canal facilities and safeguards systems.

1. THE CANAL DE PROVENCE

Canal de Provence facilities can be classified into two groups:

* The main structures comprising the main canal and four branch canals: These operate through gravity flow and conveys a flow decreasing from 40 to 10 cubic meters per second (m^3/s). There are 62 kilometers (km) of open canal and 140 km of pressure galleries.

* The supply networks: These include 440 km of piping of 500 to 1,300 millimeters (mm) diameter and 3,200 km of secondary piping with less than 500 mm diameter, and 30 pumping stations.

2. THE DYNAMIC REGULATION

The automatic and centralized system developed by SCP controls the flow of water in the conveyance structures. It was first implemented in 1971 in answer to certain technical constraints associated with the operation of open canals.

2.1. Hydraulic Constraints

Supplying water on demand leads to wide fluctuations in flow which are difficult to predict. As opposed to pressurized pipes, open canals introduce long response times and are very inflexible in the absence of a storage volume.

Since upstream control alone could not be envisaged (forecasting is too difficult), and downstream control was too costly (banks have to be heightened to make them horizontal), a decision was made to combine the two methods.

Dynamic Regulation implements the principle of control by anticipation, based on the forecasting of needs and continuous correction of canal settings in order to adapt the status of the canal to the actual conditions of water usage.

2.2. Basic Principles of the Dynamic Regulation

Dynamic Regulation or "controlled volume" regulation is based on the management of volumes of water transiting through open surface canals. It is applied on all the Company facilities whatever their hydraulic operating regime. As a result, all water demand can be satisfied and operating costs optimized at all points on the system and at all times by minimizing pumping energy costs and maximizing income from turbining.

Hydraulically, the setting orders generated by the central computer result from the sum of two mathematical expressions:

* An "open loop" expression based on consumption forecasts made every two hours.
* A "connection" expression which recovers the disappearances induced by the difference between forecasts and reality. This is a "closed loop" adjustment.

The different tasks performed by real-time Dynamic Regulation software are as follows:

2.3. Equipment

2.3.1. Data Processing

Two VAX series 3,000 micro-computers are used with 12 megabyte (MB) memory operation under the VMS operating system. Each one has two 150 MB disks and a 290 MB magnetic tape store.

The center is equipped with two Tektronik XN 11 19 inch color graphic terminals and two VT 420 alphanumeric terminals. Two other terminals are used to operate the central computers remotely.

Nine PC or VAX supervisors located in regional operating centers are connected to the central computers and manage their own telemeasurement network.

2.3.2. Transmission System

There are 2,000 km of telephone line, 350 km of which are buried along the canal, for transmitting data. One hundred and seventy teletransmission stations code, dispatch and receive measurements and orders.

2.3.3. Measurements and Orders

One thousand three hundred measurements are made directly or calculated based on other measured parameters. These cover mainly level, pressure, flow, gate position and water physical and chemical characteristics.

Seven thousand eight hundred signals are relayed. These are the logic variables which describe the operating status of the equipment.

The system generates and transmits 230 on/off instructions and 30 continuously controlled settings.

2.4. Comments on the Dynamic Regulation Concept

After 25 years in service, the main strengths of the Dynamic Regulation program can be summarized as follows:

* Coordination of canal settings: The changes in the flow which result from successive adjustments on the canal are cumulated from downstream to upstream and taken into account before they can have a measurable effect on the reach and reservoir volumes. This increases the system's response time.

* The simplicity and reliability of the software: The canal simulation model included in the program does not completely integrate with Saint Venant equations and uses pre-established tables (propagation times and depth/flow/volume curves).

  Its relative inaccuracy is compensated by its extreme reliability and by the closed loop corrections which allow easy and fast setting adjustments based on the measured values.

  The same simplicity characterizes the statistical model used to forecast irrigation water consumption. However, this forecast is updated every two hours. The accuracy achieved for mean daily volumes is thus ±5 percent.

* The importance of the degraded operating procedures included in the program: They enable most usual dysfunctions to be managed without major problems and, above all, maintain a normal and automatic service if a defect occurs on one part of the installations. Experience has shown that the most frequent failures, which are usually minor, occur locally. It is therefore essential to be able to incorporate them into the automatic regulation process.

2.5. Reliability of the Dynamic Regulation

The rates for the operability of the different components of Dynamic Regulation are as follows:

Transmission unit:	99.3%
Transmission lines:	98.3%
Level sensor:	97.4%
Flowmeter:	96.0%
Gate control:	97.6%
Computers:	99.93%

The operability and the overall reliability are difficult to assess due to the degraded automatic procedures which allow the system to cope with passing inoperability of certain components and the doubling of more critical items such as computers.

In 25 years no major incident has been recorded and the demand for water has always been met.

3. CONCLUSION

Dynamic Regulation's performance over the years has been very satisfactory with regard to the safety and quality of water supply.

It offers the advantage of not requiring large control volumes and can therefore be easily applied to existing canals and all types of water distribution systems, in particular, it is easy to use on main canals in gravity irrigation networks.

The Société du Canal de Provence experience has been applied on other major projects such as the Canal de Rocade in Morocco, Athens City Water Supply in Greece, King Abdullah Canal in Jordan, Majalgaon Scheme in India, and Flumendosa in Sardania.

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Tools and Techniques

Low-Cost Water Stage Sensor And Data Logger are a Reality Now

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The story goes back to when Goonasekera (1985) conducted field research on irrigation management. He found instrumentation to be necessary for water stage measurement, a prerequisite for channel discharge calculation, and prohibitively expensive for extensive application in field research. This is true for simulation modeling work as well. Simulation models require field data for their effective application as irrigation management tools. Thus the need for a low-cost, yet accurate data collection system for field applications has become an important research component in irrigation management research and development work.

Commercially available versions of instrumentation and data recording have a water-level sensing component (sensor) and a measurement and storage component (data logger). The advantages of these devices are that the output from the sensing element can be converted to the corresponding water level and stored in memory for subsequent analysis. The user can also control the frequency of observations and retrieval as desired through software settings. In most such instrumentation setups much sophistication is available as options, and most are accurate to ± 1 millimeter (mm) and are stand-alone systems. The disadvantage of commercial data retrieval systems is the price one has to pay for the degree of sophistication, which limits extensive application. Other limitations imposed on available sensors are errors due to fluctuations in temperature, and salinity and sediment in irrigation water under practical field situations.

COST REDUCTION ALTERNATIVES

The fact that electronic components have rapidly come down in price and the argument that there must be a simpler alternative to such instrumentation has led to research that has spanned over a period of 10 years from 1985 to 1995. The basic logic of cost reduction as far as a data logger is concerned rests with the fact that one only needs to collect the raw data from the field. The data reduction and analysis could be done by an office computer. Thus the need for every data logger to have sophisticated data reduction and conversion components as a stand-alone system can be completely eliminated. A bare bones structure which collects and stores raw data from a water-level sensor could be very much more cost effective. Also, the need to develop a different approach to water-level sensing to overcome practical field problems was the other concern addressed by the research.

In 1987, with a research grant received from the United States Agency for International Development (USAID), a collaborative research program was initiated between the Department of Agricultural Engineering of the University of Peradeniya, Sri Lanka and the Virginia Polytechnic and State University, USA to solve these two problems. The initial approach was to evaluate varying water-level sensing methods for cost effectiveness. After eliminating many alternatives, two methods were extensively tested. One method was the variation of resistance of a potentiometer with the movement of a float with the water level. The other was the change in capacitance of two concentric cylinders painted with an aluminum coating with the change in water level. During the research it was found that both these methods could lower the cost of instrumentation to as low as US$150.00 (Alahakoon 1989). However, the instrumentation had many drawbacks. The former alternative was sensitive to temperature and mechanical movement while the latter showed non-linearity in response if the aluminum coating showed variation in thickness. Although this collaborative project did not conclude with the intended success, it laid the foundation for subsequent research efforts leading to the present development.

WATER-LEVEL SENSOR

The idea of two concentric cylinders used in capacitance method leads to a completely different and a much simpler approach to water-level sensing. The underlying principle is that which was defined by Archimedes: the loss in weight or the upthrust on a body immersed in water is dependent on the volume of water displaced. Thus, if the inner cylinder of the capacitance method becomes a float or a weight with a uniform cross section and if the former or the latter is not allowed to move, the upthrust or the loss in weight is linearly related to the change in water level (Figure 1). The outer cylinder of the capacitance method can then become the stilling well for water-level measurement. The next problem is to sense the upthrust or the loss in weight. If a cantilevered metal strip (aluminum alloy) is used to stop the float or suspend the weight, then the strain on the strip within the elastic limit is linearly related to the load (Figure 2). The voltage output of a bridge circuit with two strain gauges fixed to the metal strip with adhesive can be used to measure the water level. The advantage of the bridge circuit is that it is temperature compensated and therefore the changes in temperature do not affect the sensor output. Sensitivity can be increased by proper design of the aluminium strip and the selection of strain gauges. The voltage output of the bridge circuit is amplified using an instrumentation amplifier before measurement. This describes the essential components of the water-level sensing element. The new sensor has the following advantages:

Figure 1. Schematic diagram of sensor.

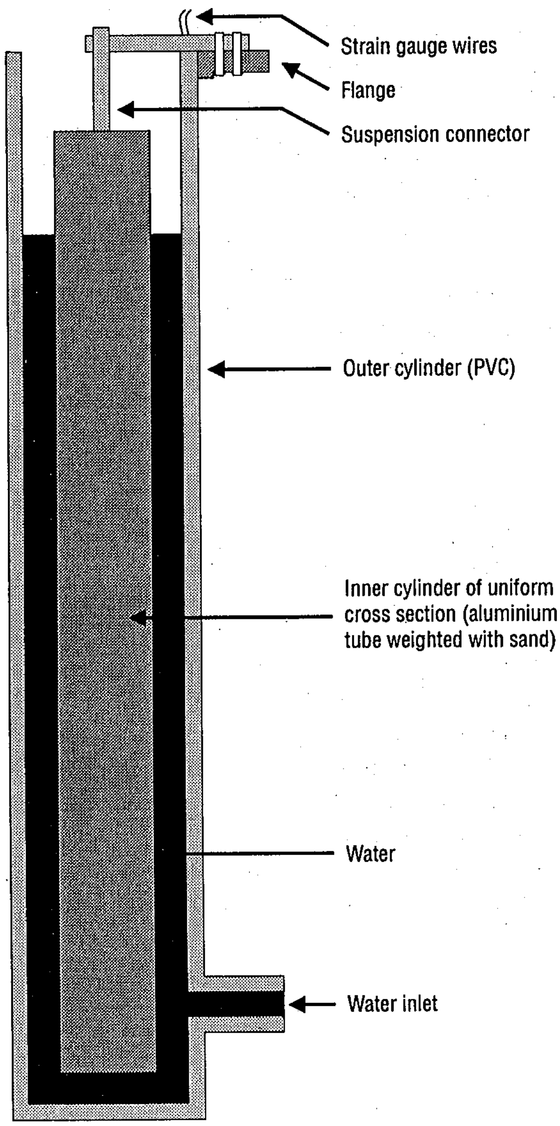
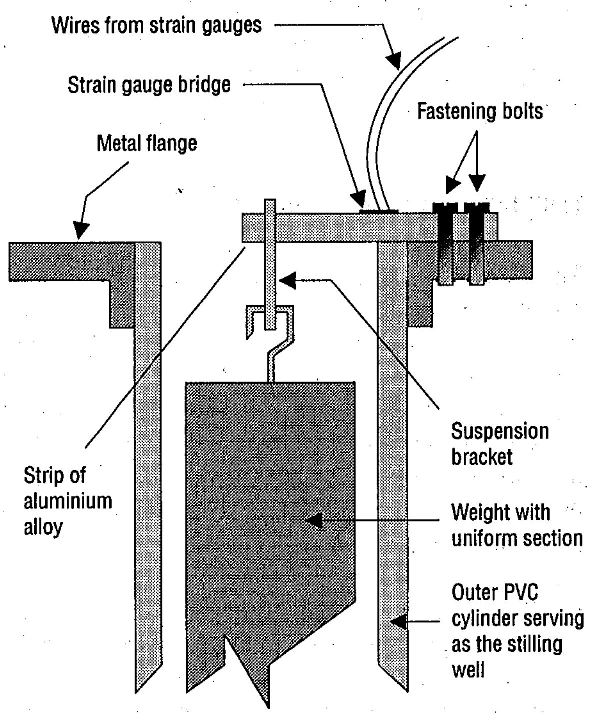


Figure 2. Expanded view of sensor.



1. Simplicity.

2. Since it is located above water, there is no effect of dissolved salts or sediments in water.

3. Insensitivity to temperature changes in the environment.

4. Very low cost.

5. Ability of designing the sensor to required scaling.

In 1992, this idea was presented at a workshop held at the International Irrigation Management Institute (IIMI). A collaborative research link with the Kirindi Oya Simulation Model Development Project of IIMI funded by the French Government was mooted during the workshop to develop the sensor and the data logger. After nearly three years of research work, where failure, frustration and hope were more frequent than success, the design of the data logger has now come to a successful conclusion. A word of appreciation is warranted here of the work on the data logger by the French undergraduate student, Valery Hamel. His work on a separate data logger for a short duration of one month acted as a catalyst in arriving at the final design and design components.

TEST RESULTS OF THE SENSOR

This sensor was designed and tested in the laboratory for sensitivity and accuracy. The tests were conducted with a test rig designed for the purpose. The water-level variation was observed visually with a calibrated tape fixed to the stilling well. The voltage output from the sensing element was amplified using an instrumentation amplifier and fed into the data logger programmed to collect data at 1-minute intervals. The maximum range of water-level fluctuation tested was 0.5 meters (m).

The results have shown that the R^2 value between water level and sensor output is 0.99989. Error analysis shows that the maximum error is ± 3 millimeters (mm) in the tested range of 50 centimeters (cm) of water-level fluctuation with 8 bit Analog to Digital Converter (ADC) used in the data logger. It is important to note here that the measured water levels are subjected to observer error too. However, the accuracy can be significantly improved by using a 12 bit ADC. Also, during the tests it was noticed that water clings to the weight when the water level is lowered rapidly, thereby changing the strain. However, this will not have any effect if the observation interval is greater than 5 minutes due to evaporation of water droplets.

The additional advantage of the sensor is that it could be used for a variety of applications such as sensing water levels in piezometers, rain gauges and evaporation pans with required accuracy. However, with improved sensitivity it may be necessary to calibrate the sensor for increased salt content or sediment in the water.

DATA LOGGER—PHASE I DEVELOPMENT

Based on the arguments used in a previous section to reduce cost, a data logger was developed for recording analog voltages in the range 0 volts (V) to 2.56 V. The system was based on a Z80 microprocessor after considering factors such as simplicity in the instructions set and cost. The data logger built is capable of operating as a stand-alone system in the field, store data in the temporary memory, and transfer to a computer upon request. The sampling rate and several other parameters are user programmable. A separate software development was also performed for communicating with the logger for the purposes of programming and data transfer.

TEST REPORT

The performance of the logger was tested by varying the input voltage in steps while the logger was programmed to read the input channel at 1-minute intervals. Regression analysis was performed on observed and recorded values to examine the linearity of the Analog/Digital (A/D) conversion process. The error analysis indicated that voltage fluctuation is between ± 0.01 volts with few random errors introduced by stray voltages in the laboratory. The R^2 value of the linear regression between observed (input) and the recorded voltage is 0.9999. Once the logger circuit is protected by a metal cover the errors introduced by outside noise can be virtually eliminated.

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EXPO—A Software Package for the Processing of Pump Data

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INTRODUCTION

EXPO is a software package designed by the Institute for Land and Water Management of the Katholieke Universiteit Leuven, within the frame of a cooperation project between the Institute and the Irrigation Authority of the Senegal River Valley (SAED). The program was designed to process the pumping data collected on a daily basis by operators of pumping plants. The inputs to the program consist of information about the pump and engine characteristics, the head losses in pipes and valves, the pumping height, time series of pumping hours, and water levels at the inlet and outlet of the pumping plant. EXPO calculates the amount of water pumped, the power required to lift the water and the energy costs. The software runs on an IBM compatible personal computer (386 or above) and consists of two menu-driven programs—SUPPORT and EXPO—respectively. The SUPPORT subprogram allows the user to enter the time-independent data of the pumps, the pumping plants, the energy sources used and the unit cost price of the energy. The subprogram EXPO stores, processes and interprets the daily information collected by the operators of the pumping plant.

THE SUBPROGRAM SUPPORT

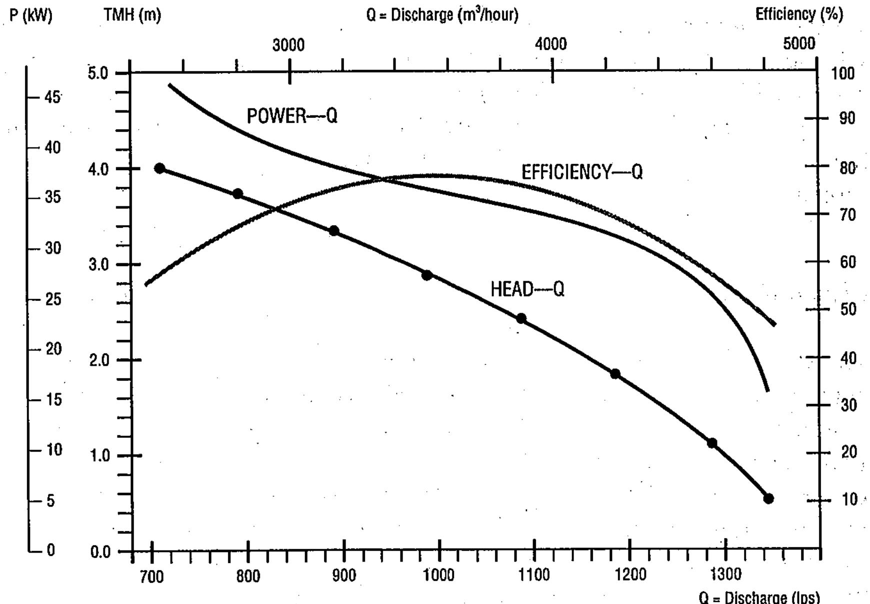
The plant's pumps are characterized by the three curves describing the relationship between discharge (Q) and total dynamic head (H-Q curve), pump efficiency (η-Q curve), and power input (P-Q curve). The basic data of the curves are entered to the program in the form of a table, and the program fits a quadratic curve to the data (see Figure 1). Besides the H-Q curve, only one of the other two characteristic curves has to be specified since the η-Q curve and the P-Q curve are interrelated.

The time-independent data of the pumping plant are pump type, energy source used and head losses in pipes and valves. The pump type can be selected from the database of pumps available within the SUPPORT subprogram. Furthermore, the user has to specify the unit cost price of gasoline and electricity. All data concerning the pumps, pumping plants and prices are stored in separate files, which are used by the subprogram EXPO for the analysis and interpretation of the pumping data.

THE SUBPROGRAM EXPO

The daily pumping data are entered to the program in weekly reports. Before its storace and processing, EXPO verifies the consistency of the data. EXPO verifies if the pumping hours do not exceed 24 hours per day, and it visualizes the fluctuations in the water

Figure 1. Example of pump characteristics (H-Q, η-Q and P-Q curves).



Notes: TMH = Total Manometric Head.
P = Power.

Figure 2. Output sheet of 10-daily report of the daily number of pumping hours and volume of water pumped.

Thiagar Principale										May 1992 Decade 1		
Level 1				Hours and volumes pumped								Station
Day	Down (m)	Up (m)	TGH (m)	Pump 1 (h)	(m³)	Pump 2 (h)	(m³)	Pump 3 (h)	(m³)	Pump 4 (h)	(m³)	total (m³)
1	1.6	2.7	1.1	3	13,064	0	0			0	0	13,064
2	1.6	2.7	1.1	10	43,546	10	35,569			1	8,819	87,934
3	1.6	2.7	1.1	9	39,191	7	24,899			0	0	64,090
4	1.6	2.7	1.1	12	52,255	9	32,013			6	52,914	137,182
5	1.6	2.7	1.1	15	65,319	11	39,126			0	0	104,445
6	1.5	2.7	1.2	6	25,776	24	84,275			3	26,160	136,212
7	1.5	2.7	1.2	20	85,921	4	14,046			0	0	99,967
8	1.5	2.7	1.2	7	30,072	0	0			0	0	30,072
9	1.6	2.7	1.1	10	43,546	10	35,569			0	0	79,115
10	1.6	2.7	1.1	15	65,319	15	53,354			3	26,457	145,130
Decade					464,009		318,852				114,351	897,211
- Switch displays				From 20/02/1992								Total
- Next decade				To 10/05/1992								7,689,010
- Exit												

Notes: Thiagar Principale = Name of pump station.
TGH = Total Geometric Head.

levels upstream and downstream of the pumping plant to assist the analyst in detecting measuring or typing errors. After verification of the pumping data, they are stored and processed. The following characteristics are calculated: number of pumping hours per day, volume of water pumped per day, the energy consumed in kilowatt-hour (kWh) per day, and the energy cost per day in local currency. This information is displayed and/or printed in 10-daily reports as shown in Figure 2.

APPLICATIONS

The software package was designed to evaluate the amount of water pumped to the large- and medium-scale irrigation perimeters in the valley of the Senegal River using the information collected on a daily basis by the operators of the pumping plants. The recorded information is seldom used. However, with the assistance of a simple software program it is possible to interpret the collected information as well. EXPO is used in Senegal by the Irrigation Authority of the Senegal River Valley to calculate the volumes of water pumped from the river in the rice irrigation perimeters, estimate the energy cost and compare the calculated energy cost with the electricity or gasoline bill. The latter enables the detection of mechanical and/or operational deficiencies in the pumping plant. Furthermore, information concerning the volume of water pumped facilitates estimation of irrigation efficiency at scheme level and its fluctuation throughout the growing season. The results can be compared with similar data of other irrigation schemes and with water and energy consumption levels of past years to assess the effects of operational, management, and other changes over time.

The pumping data of an irrigation season can be entered, analyzed and output as a printed report, in less than a day. English and French versions are available and can be obtained from the Institute for Land and Water Management at a cost of US$100 (including the cost for the executable files, the user manual and shipping).

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OMIS: A Management Information System

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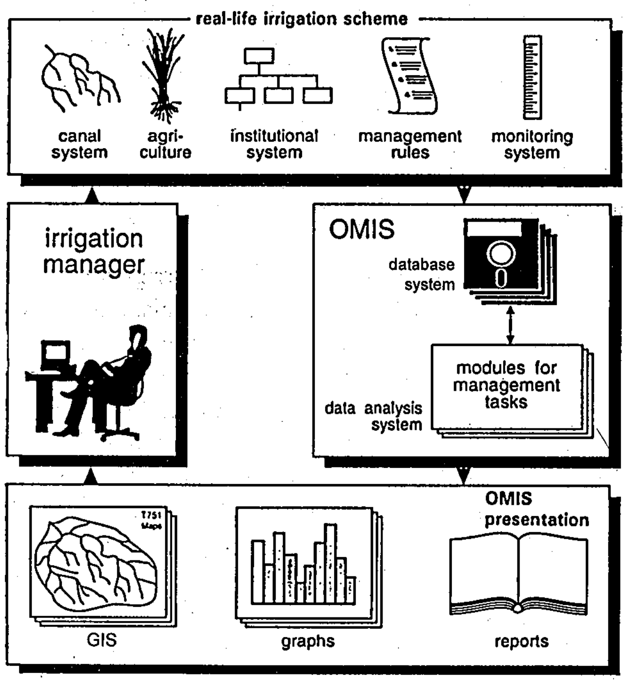
INTRODUCTION

Taking into account the fresh water deficiencies, there is a strong demand for more efficient water use in irrigation practices. Proper allocation of water requires tuning of the water demand for the crops and the supply of irrigation water. Although the basic principles for water allocation are fairly simple, the enormous amount and diversity of data, and the numerous institutions involved make water management of irrigation systems a complex task. Since 1989, delft hydraulics has developed an Operational Management Information System (OMIS) to assist the water manager. Figure 1 shows the potential role of OMIS for the irrigation manager. Based on the information provided by OMIS, the irrigation manager is able to overview the total system and take more rational decisions.

The OMIS model supports the following management activities:

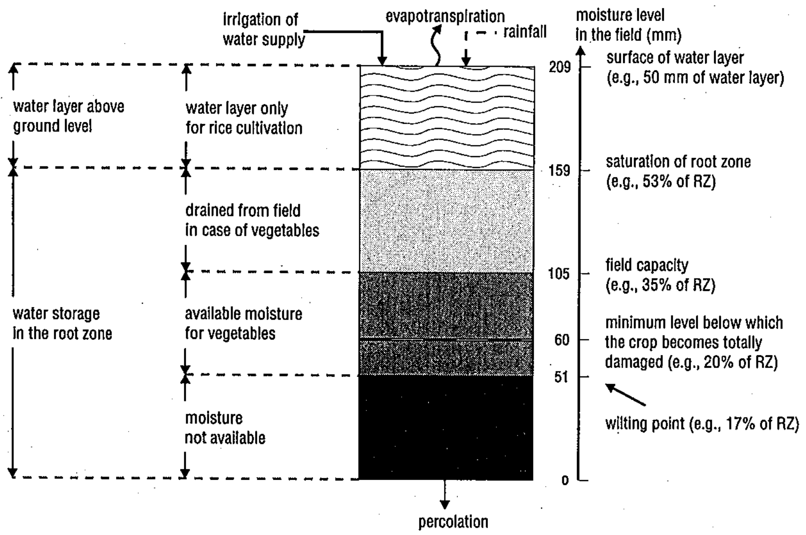
1. Pre-season planning of a cropping pattern.
2. In-season processing of monitoring data and generation of allocation schedules.

Figure 1. OMIS is used as a decision support model for the irrigation manager.



Notes: OMIS = Operational Management Information System.
GIS = Geographical Information System.

Figure 2. Principles of soil-water balance computation in OMIS.



Note: RZ = A root zone of 300 mm is assumed.

3. Post-season evaluation of the performance of the system.

The computational principles underlying OMIS are fairly simple, and based on mass balances only. Figure 2 shows the principle kf the soil-water balance computation, used to determine irrigation needs and drainage flows.

PRE-SEASON PLANNING

Before the irrigation season starts, a cultivation plan for each command area served by an irrigation outlet has to be prepared. This is not as easy a task as the expected water availability, the farmer preferences for certain crops, the land suitability for certain crops and local irrigation practices have to be taken into account. Most of these data have already been entered in the OMIS database, so that the user only has to vary some data like the areas cultivated and the moment in time during which cultivations start. The irrigation requirements can be directly compared with dependable water availability.

A cultivation plan can also be simulated for various hydrological years, which are stored in the database, to evaluate the performance of the cultivation plan for these years.

IN-SEASON OPERATION

Updated operation schedules for each irrigation outlet are prepared at regular operation intervals, e.g., once a week. At the end of each operation interval a new allocation plan is prepared for the next interval, using actual monitored data collected from the field, and the expected water availability, such as rainfall and river flows (Figure 3). If water shortage is expected to occur, a water management strategy can be chosen such as proportional reduction or "first-come first-served basis."

The aim is to provide a reliable and fair allocation schedule based on actual monitoring data and without unnecessary water spillage.

In practice, the gate operators might face difficulties in setting the hydraulic gates in order to establish the allocated schedule. Therefore, a hydraulic module could be used as a post-processor to compute the new gate positions that are needed to accomplish the scheduled allocation.

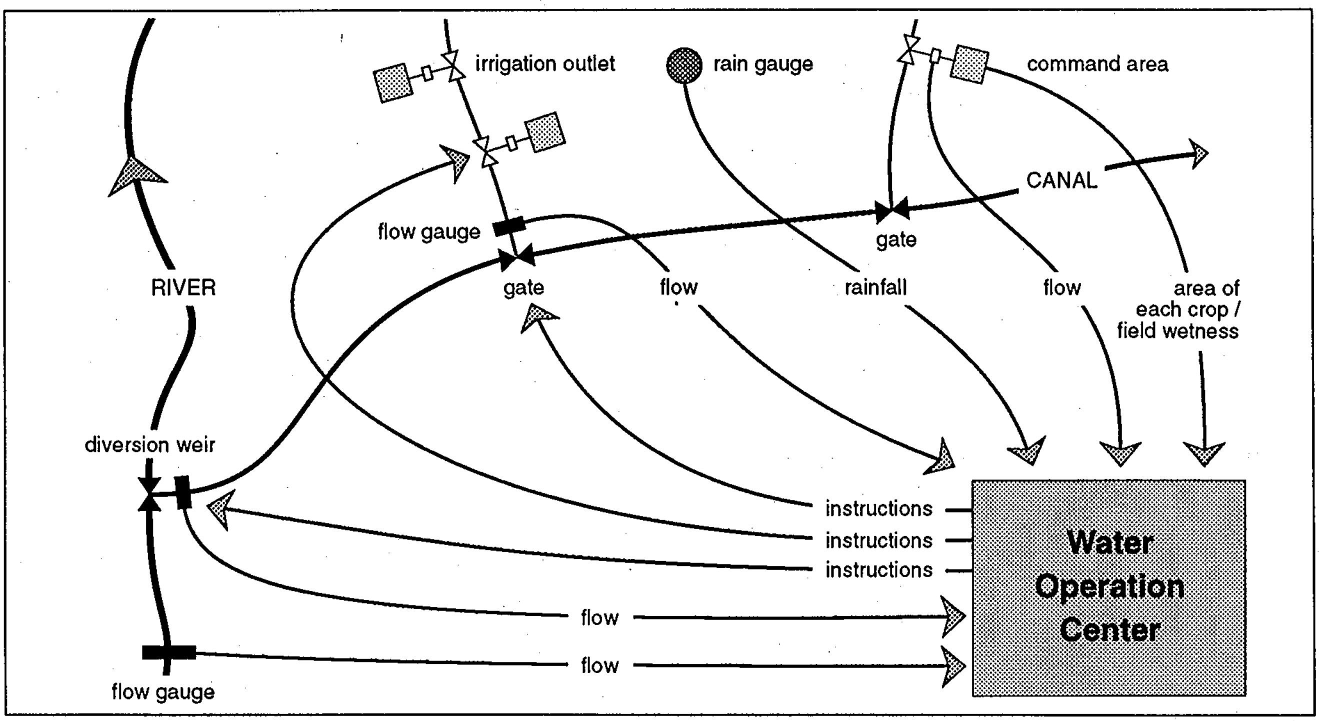
POST-SEASON EVALUATION

At the end of the irrigation season the performance of the irrigation system can be evaluated using the collected monitoring data. For the evaluation, different performance indicators can be selected such as the yield drought stress, ratios of the intended and actual irrigation outlet supply, and the drainage irrigation ratios of each command area (Figure 4). The results of the evaluation can be used for the planning of a new crop plan for the next irrigation season.

EXAMPLE CASE, FAYOUM SCHEME, EGYPT

Scheme. The Fayoum Irrigation Scheme covers about 100,000 hectares (ha) and is located in a natural depression in the desert. The lowest area of

Figure 3. Data flows to and information flows from a water operation center.



Fayoum is occupied by Lake Qarun, which receives all drainage water. The rapid rise of the water level in Lake Qarun and the low uniformity of water distribution over Fayoum are the main problems to be tackled. The entire scheme is divided into 25 command areas, with an average area of about 4,000 ha (Figure 5).

The rainfall is negligible, and all irrigation water is supplied from the River Nile. In principle, enough water is available and the river flow is not very erratic. However, the spatial inequity of supply leads to overirrigation in some areas and drought stress in others. Overirrigation causes excessive drainage flows resulting in a rise of the lake level, whereas irrigation deficiencies lead to yield stress and salinity problems. The aim of the model is to better tune the supplies with the actual demands to avoid salinity and drought stress problems, and to evaluate the impact of additional reuse stations.

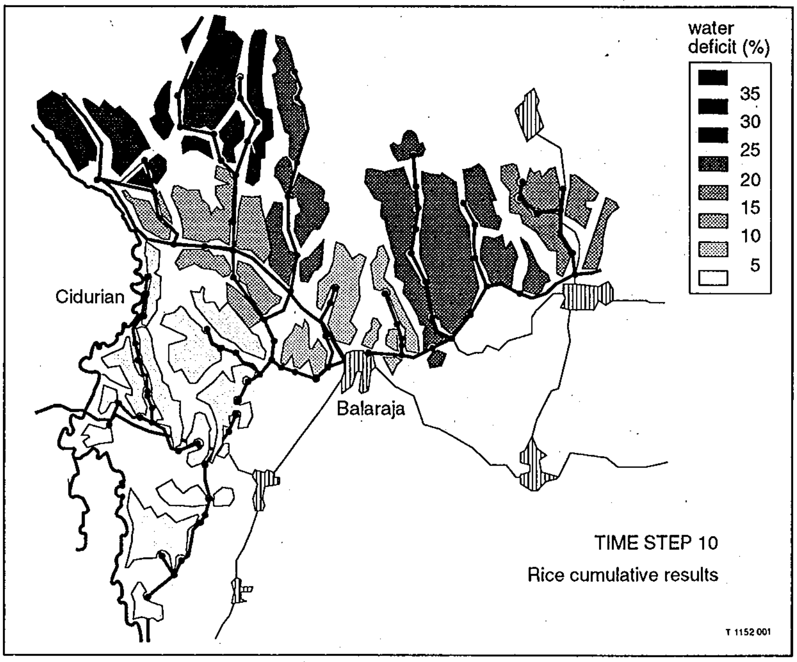
The model has been calibrated on the basis of lake-level variation. Although the computation and schematization are fairly rough, a reasonable fit was found.

The model has been installed in the offices of the Fayoum Irrigation Department (FID). The model's database contains all relevant information monitored by the previous Fayoum Water Management and Drainage Improvement Project(s). For the purpose of introducing the model, a water management course was organized for the local water managers. Further guidance will be given to integrate the model in to the day-to-day operation practices of the FID.

Crops. For each command area a cropping pattern can be formulated by the user in terms of crop type, and the starting date of cultivation. The crop water requirement is based on standard tables presently applied by the Fayoum Irrigation Department.

Allocation of Water. The water allocation computation is rather straightforward. A water balance of the canal system is set up, in which the inflow of the supply canal(s), drainage reuse stations, seepage losses, and capacity constraints are incorporated. Presently, the computation of the drainage flow is rather straightforward: a fixed leaching percentage plus the excess of supply, is supposed to be drained. In future more precise soil-water balances could be incorporated.

Figure 4. Screen image of OMIS, showing the drought stress for time step 10 in the Cidurian Scheme, Indonesia.



The allocation priority is on a "first-come first-served" basis, which reflects "reality" for upstream-controlled systems: first the upstream-located offtakes are served and the remaining water is used downstream. If the resulting water distribution is not satisfactory, the supply to the upstream units should be reduced, or the intake supply should be increased by the water manager.

The simulation model provides the water manager with a sufficient degree of flexibility, but prevents the water manager from taking senseless decisions as he is directly confronted with the results of his action. The use of GIS (geographical information systems) enables the water manager to see at one glance the spatial inequities.

Reuse of Drainage Water. The models allow the user to determine the impact of new reuse stations. Reuse stations are frequently applied in Fayoum, but the quality of drainage water is less due to higher salinity. If water is used more efficiently, the quantity of drainage water will considerably reduce, and so will the quality of the remaining drainage water.

Performance Indicators. To evaluate the performance, several performance indicators, such as the ratio of actual supply and demand, the drainage-irrigation ratio, the salinity of irrigation and drainage water, and the lake level can be visualized on a map of the scheme. To review the variation in time, the user can browse through time, and evaluate the performance by watching changes in the colors.

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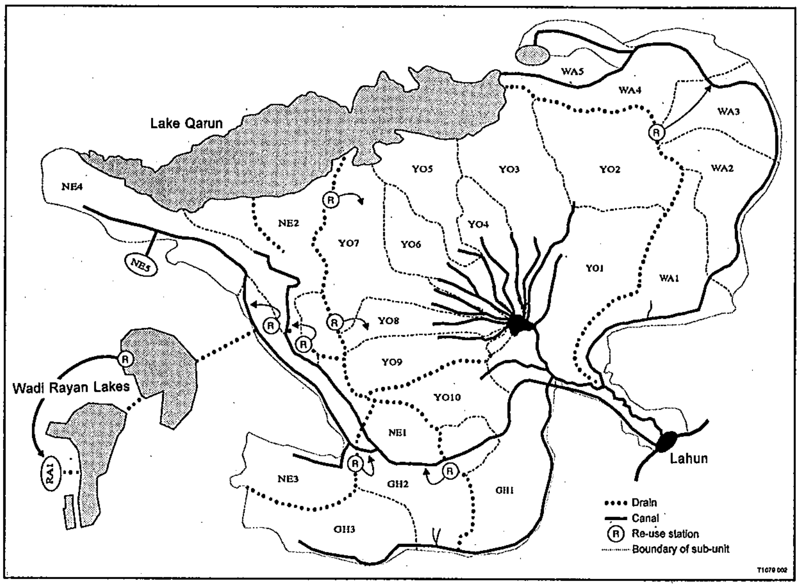
Figure 5. Map of Fayoum Irrigation Scheme.



Scheme Irrigation Management Information System (SIMIS)

The increasing use of personal computers with high processing speeds and large storage facilities is revolutionizing the processing and storage of information. This phenomenon is not restricted to industrialized countries; developing nations too are moving very fast in equipping themselves with the latest in computer hardware. However, the development of software for improved management of irrigation systems has been moving very slowly compared to other sectors. One reason for this state of affairs may be that the problems of irrigation systems are very site specific and diverse; other reasons may include the relatively small size of the market, or the complexity of the water distribution systems. Whatever the reasons, the fact remains that there is no piece of software that addresses all the needs of an irrigation system in an integral manner.

Identifying the need for a suitable software package, the Water Resources, Development and Management Service of FAO's Land and Water Division decided to develop a set of programs that will facilitate the management tasks of irrigation systems. The software was not limited to the hydrological aspect; rather it included all the major issues of the day-to-day management activities including accounting, crop production, control of maintenance, water fees and other relevant tasks. A first version of the software was completed in late 1993 and the system is now under testing in several countries.

A BRIEF DESCRIPTION OF SIMIS

SIMIS has 19 different and independent programs, that have been called "modules." The first module is addressed to identify the characteristic of the project where all the subsequent information will be stored. SIMIS can store information for one or several projects as needed. This is a useful feature for large projects which can be subdivided into smaller units and corresponding information entered separately so that information can be processed faster and more clearly. The following seven modules are utilized to store "basic" data of the irrigation system such as: climate, soils, crops, physical infrastructure, land tenure, project staff, and machinery (for operation and maintenance tasks). This information is shared by another eight modules that are management tools covering the main aspects of managing an irrigation system, and they include:

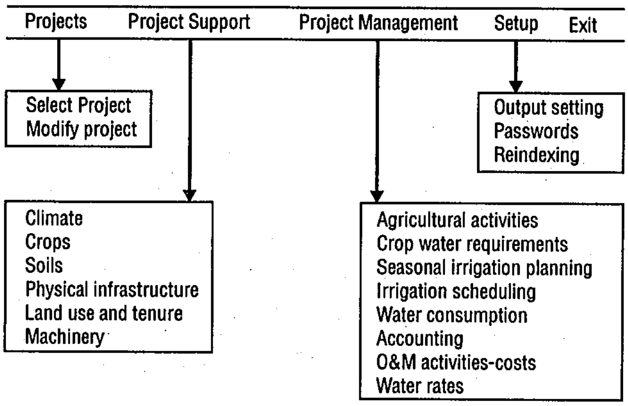
* Agricultural activities (crop production, area planted, production costs, crop prices and others).
* Crop water requirement (for all crops grown in the project).
* Seasonal irrigation planning (allowing matching of supply and demand).
* Irrigation scheduling (under different methods—fixed rotation, on-demand, rationed, soil moisture balance).
* Water consumption (control of water used by every farm).
* Accounting.
* O&M activities (control of costs).
* Water fees (determination of fees under different hypotheses and preparation of bills for every farmer and control of payments).

The last three modules are for setting the work environment and include: output setting, password, and reindexing of files when required.

The figure below illustrates the main menu of SIMIS and summarizes its capabilities.

The testing of the program will be completed in 1995 and it is expected that distribution will take place possibly by the end of the year. Currently, the program has only been distributed to a few institutions under restricted conditions which include testing and verification of the system in a pilot area, and for the sponsoring of a training course for interested professionals.

Figure. Main menu and capabilities of SIMIS.



CHARACTERISTICS OF SIMIS

In developing SIMIS the following criteria received particular attention:

Adaptability. The program has been developed in DBase IV to facilitate the transfer of information already collected in this database system and others that are compatible with it. Furthermore, the system has been developed to suit many situations, but when local adaptation of terminology may be found indispensable the screens for entry of data and the reports generated can be easily modified.

Modularity. The Project Management modules are independent—although they share the same basic information—and therefore concerned staff may select to use the modules that are relevant to them leaving aside those that may be relevant to other people or systems. If necessary, new modules can be added to care for a specific local application.

Simplicity of Use. Users do not need to know database systems. SIMIS operates on the basis of simple menus and descriptive screens for the entry of data.

Multilingual. All texts of the program are stored in separate databases permitting their translation with only minor changes in the program. At present, the English and Spanish versions are available and the French will be added during the course of 1995.

Data Safety. Accidental or intentional loss of valuable data can represent a heavy economic damage and loss of confidence in the system. To minimize this problem SIMIS permits the access of authorized users through a system of passwords with a different degree of access to the information.

System Requirements. SIMIS installation requires 5 megabytes (MB) of hard disk and to run the application it is convenient to have another 10 MB free. A 386 PC running at 25 or 33 megahertz (MHz) is the minimum configuration required.

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INCA: Irrigation Management Software

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The Overseas Development Unit (ODU) of HR Wallingford recognizes the need for reliable, accurate and sustainable software for use by irrigation professionals. In recent years a number of programs have been developed as part of ODU's research program to assist irrigation scheme designers and operators. These programs range from catchment management (CALSITE), through reservoir survey (SWIMM), irrigation system layout and design (MIDAS), sediment control (DACSE), canal design (DORC), to irrigation operations (INCA). In each case the need to provide user-friendly software that embodies the practical application of research findings has guided the development. Each software tool is subject to extensive testing before release for general use. Comprehensive training is offered for users and ODU provides support should users encounter problems in applying the software.

A BRIEF DESCRIPTION OF INCA

Irrigation Network Control and Analysis (INCA) is a software package developed by the Overseas Development Unit of HR Wallingford with the support of the UK Overseas Development Administration, based on research on the operation of canal irrigation systems in Thailand, India, Sri Lanka, the Philippines, Sudan and Zimbabwe.

The origins of the INCA suite are found in the study of the Kaudulla System conducted by Weller et al between 1978 and 1984. In this study, the difficulties faced by system operators were identified and the impacts of main canal operations were investigated. Abernethy (1985) summarized the requirements for improvements in control of water distribution at the main canal level, identifying the following key factors affecting the performance of the scheme:

* Inadequate utilization of rainfall during the wet season, restricting dry season cropping opportunities.

* Little feedback on field water status, leading to inappropriate responses causing ineffective irrigation releases, or yield losses.

* Poor operational practices, with limited knowledge of actual water distribution and little guidance for field staff.

* Low utilization of operational data collected.

Abernethy suggested that operation of Kaudulla and other similar schemes could be improved, without the need for significant physical rehabilitation, by a sustained effort to improve management procedures for control of main system operations. He suggested that micro-computers with suitable database and analysis software could perform a central role in enabling system managers to assess water requirements and determine supply schedules, ultimately leading to more equitable and reliable water distribution.

Following trials of prototype management packages based on spreadsheets in Thailand and Sri Lanka, the INCA suite was specified and developed in 1991. Field application of the software indicated that provision of reliable and timely management information does have a significant role in improving the performance of water distribution. However, whatever the capabilities of decision support systems such as INCA, the introduction of such software is just one component of what must, generally, be a larger program focusing on improved main system water management. Whilst staff can become proficient in the operation of the INCA system within a month or 6 weeks of installation, other actions necessary to enable the software to become effective may require a longer timescale. Installation of level gauges and structure calibrations may require additional time, and the implementation of effective data collection procedures and feedback may require a number of seasons to become fully established.

CHARACTERISTICS OF INCA

INCA is a generalized database and computational system for use by irrigation system operators in the day-to-day tasks of scheme management. The software provides:

* Integrated database and analysis software.

* Robust procedures to allow feedback of field water conditions to the calculation of water requirements.

* Procedures to increase utilization of rainfall.

* Advice to managers on the basis of theoretical demands, system losses, and observed conditions.

* Simpler user interface and extensive graphics, and text reporting.

The suite of programs is the product of the combination of long-term field research, experience of canal system operations and the application of modern software development tools. The system utilizes the Microsoft Windows environment to provide a standard user interface that is widely understood by computer users. The software is developed in Gupta Technologies SQLWindows, using SQLBase as the database engine. Graphics are provided through the Bits per Second Graphics Server Library. Microsoft 'C' is used for sections of the software that are computationally demanding.

INCA consists of modules for data processing and analysis which operate under a common menu system. Currently, modules exist for definition of canal networks, data processing, computation of water requirement and scheduling, evaluation of seasonal water requirements and management of system inventory data. A module for detailed evaluation of system performance is nearing completion. Each module of the INCA suite is protected by a common dongle (hardware lock).

The multilingual version of the software, enabling users to translate the INCA menu and window system has recently been released and is in use in China.

NETWORK EDITOR MODULE

The core of INCA is a relational database that enables storage of a wide range of data describing the physical makeup of the scheme being modeled. A range of data management functions are provided. These enable users to configure the database for any irrigation network. Water sources and canal networks are user defined. A number of canal networks can be accommodated within a single database, from a common source reservoir, pump house, tubewell or river diversion. Multiple resources can be included in the database, provided each network is supplied from a single water source. Each network includes a water source, distribution canals, control structures and management units, which represent the distribution system outside the control of the main canal operating authority.

The Network Editor allows users to enter the network specification, specifying the characteristics of each component. A feature of the INCA database is the ability to modify specifications of system components, or to extend the network at any time, whilst retaining the original definitions. Error checking routines prompt the user to ensure that all necessary information is entered. INCA automatically numbers locations in the network without intervention from the user.

INCA displays the network as part of the user interface. Using a mouse, objects can be selected from the network to enable data entry, modification of the network definition or to review current operational data.

DATA PROCESSING

Collection of data is a long established practice in many irrigation systems. However, the connection between data and usable information is often remote. The quantities of data collected have often prevented anything but the most cursory use in day-to-day management. INCA provides functions for daily entry, error checking and processing of routine monitoring data into usable management information, in a time frame that enables intervention to alleviate water distribution problems. The use of graphical presentations simplifies quality control procedures.

The database stores all the data necessary for computation of water requirements, scheduling of deliveries and monitoring of system performance, including agrometeorological conditions, crops and hydrology of the water resources. Operational data include records of cropping history of individual subdivisions of management units, meteorological observations, operation of control structures, reservoirs and pump houses.

WATER MANAGEMENT MODULE

The module computes water requirements for the scheme's cropping pattern, scheduling water deliveries at selected control locations. The model has routines for scheduling water deliveries for both rice and upland crops using a range of options to control frequency and depth of irrigation; alternately the user is able to specify individual crop irrigation requirements. Irrigation distribution and application efficiencies recorded for each management unit are applied to compute the management unit requirement. Conveyance losses, entered as a characteristic of the canal network are added to management unit requirements as the demands are routed through the network. The model can be used in the pre-season prediction mode to estimate the pattern of water requirements for specified cropping patterns, or in the in-season mode to determine delivery schedules for the following irrigation period. Operational considerations, such as timing of rotational deliveries, translation times within the network and constraints imposed by control structure capacities, are taken into account. Schedules of deliveries are computed for user-defined irrigation periods. Results of the computations may be reviewed graphically and reports suitable for distribution to field operations staff printed.

To assist system managers assess the performance of the water distribution system, INCA enables the monitoring of data, processed and stored in the core database, to be compared with the targets computed by the water management model.

SUPPLY EVALUATION (SEV) MODULE

To enable the investigation of the adequacy of water resources to match the predicted water requirements, the INCA suite includes reservoir and river diversion simulation models. The SEV module uses water requirement predictions from the water management model and simulates the operation of the water resource system subject to the predicted demand pattern. In the case of a reservoir, SEV predicts storage throughout the season with different probabilities of inflow. For river diversions or pump house operations the probable adequacy of water resources is predicted. In the pre-season mode the simulation is used to verify whether the planning of cropping activities can be supported.

SYSTEM INVENTORY MANAGEMENT

Irrigation schemes consist of a widely dispersed inventory of mechanical plant and civil engineering structures, embankments, roads and channels. It is well recognized that in many cases the maintenance of these assets is inadequate. INCA provides an inventory recording system which is user configured to enable the storage of the information required by individual systems. The user can define schedules of inspections of inventory conditions using standardized assessment procedures. Once entered in to the database, the records can be searched to identify maintenance priorities.

SOFTWARE AVAILABILITY

The INCA suite is available for application to the management of irrigation schemes. ODU is able to provide training in the use of the software and, if required, assistance in implementing improved water management practices using INCA, either at the user's sites or in Wallingford. INCA is currently in use in Bangladesh, China, Jamaica, the Philippines, Sri Lanka, Thailand and Turkey. The full suite of INCA modules costs approximately US$6,000 for a single licence. Additional licences can be obtained at a reduced rate. The licence fee includes 12 months support by fax and phone. An additional package extending the support to five years can be obtained from ODU.

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Workshops and Seminars

Third International ITIS Network Meeting and Workshop on Computer Applications for Irrigation

This meeting will be jointly organized by CEMAGREF, ILRI, IMTA and IIMI. It will be held at the IMTA premises in Cuernavaca, Mexico and has been tentatively scheduled to be held from 22 to 26 January 1996.

Days one and two will be devoted to the software workshop conducted by ILRI. The participants would then spend the next two days visiting field sites in Yaqui and Rio Cupatizio where they will review a case study of a Mexican Irrigation System and develop a plan to implement a decision support system. On the last day, participants will return to IMTA for a review of current developments in information systems for irrigation, and to plan activities for the coming year.

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International Course on Computer Applications in Irrigation

This course is jointly organized by the International Institute for Land Reclamation and Improvement (ILRI), Wageningen, The Netherlands, and the Institute of Irrigation Studies (IIS), Southampton, England.

This course is designed so that participants will be able to assess the functions of computer programs and models in relation to identified irrigation problems, to appreciate modeling and simulation concepts and select and apply relevant computer programs.

The first part of the course, from 11 to 23 March 1996, will take place at IIS (Southampton) and the second part of the course will take place at ILRI (Wageningen), from 25 March to 5 April.

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Don't forget the hardware

I would like first to congratulate you on your contribution to the establishment of the ITIS Network which, as stated in the letter from the Director General of IIMI, is an example of the interface between technology and management. I would also like to offer some suggestions which are provoked by the following statement in the same letter: "Better management of irrigation systems can undoubtedly be fostered by improvements in technology—including not only the hardware of physical infrastructure but also the software of decision support systems."

I believe there is a strong complementarity between hardware and software. Decision support technologies can help irrigation managers make better decisions. However, the task of irrigation managers and operators of existing systems could have been greatly facilitated if more thoughts were given to the selection of hardware and the simplification of operational procedures at the design stage using decision support systems. The 35-kilometer long Kirindi Oya Right Bank Main Canal with 17 cross-regulators equipped with sliding gates associated with gated offtakes, is a remarkable example of system design without due consideration being given to operation. Much ease of operation could have been achieved by the use of composite cross-regulators (long-crested weirs associated with gates) and offtakes equipped with baffle distributors. Similarly, the combination of undershot-gated cross-regulators with overflow-gated offtakes in recent rehabilitation projects in Indonesia is the most sensitive to inevitable variations in flow supply and demand.

The selection of appropriate hardware of course does not eliminate the need for decision support systems and communications, but it will considerably simplify the routine tasks of field operators by reducing the frequency of adjustments of control structures. Computer tools should be and have been more and more used in the hardware design process. Computer tools could be of great help in assisting in the design of rehabilitation projects. One of the best examples of the above is the modernization program of the branch and tertiary canals in Egypt. The continuous supply of the branch canals from the main Nile System and the 16-hour irrigation per day, at most result in highly unsteady hydraulic conditions in the branch canals and the need for night storage. This design problem cannot be resolved without the help of modern computers.

In a recent review of the irrigated agriculture subsector in a South Asian country, the World Bank advocates a more systematic diagnosis of scheme-level problems to ensure that physical improvements contribute directly to a workable irrigation service plan. The comment was based on the observation that past "modernization" programs have failed to sustain improved performance. The question is what kind of rehabilitation can be sustained. Software and hardware experts should join their efforts to address this question. Given the increasing awareness of environmental issues due to irrigation and the increased competition for water, we can no longer afford the repetitive rehabilitation of irrigation projects and the disappointing results due to unrealistic expectations.

In addition, the decision support systems which you are advocating would also contribute to the dissemination of irrigation and drainage knowledge to other sectors who are engaged in comprehensive river basin development and management as described in the World Bank Water Resources Policy.

[Herve Plusquellec, Irrigation Advisor, World Bank]

Model in the real world

Congratulations on your first issue of ITIS. It is very refreshing to see a new publication dealing with an area of irrigation research that has often received insufficient or inadequate coverage. Your first issue contains a number of interesting articles. However, it is the section entitled "Tools and Techniques" that I would like to comment on. This section appears to be aimed at highlighting new developments in the field of computer models for irrigation management. A relevant event in this regard, where IIMI was represented, was the FAO Expert Consultation on Irrigation Delivery Models held in Rome in October 1993. A number of models were presented at that meeting which represent an important cross-section of the software available and their application experiences. Conclusions and recommendations from this workshop as well as features of the various models presented there are worthwhile to be included in this section of your newsletter.

An important area of consensus that emerged from that meeting was that the success of computerized operations must be measured by the improvement in "operational performance of the system" rather than by the "features of the software" alone. In other words, computerization must be seen as one more element within the overall context of an improved operation and maintenance framework which includes, clearly defined operational procedures, asset maintenance, continued staff training, etc. Sustainability of the computerization process will ultimately depend on this. There are many examples where a lack of established operational procedures and a lack of commitment from senior management personnel rendered the entire computerization exercise useless shortly after the expatriate staff left the project due to lack of continuity in the required supporting activities. As a result, it was recognized that it is imperative in future to document results from computerization exercises in terms of their overall effect on operational performance.

[Hector M. Malano, International Development Technologies Centre, Faculty of Engineering, University of Melbourne, Australia]

Increasing user friendliness

The article by Rien Jurriens* noted that there are very few, if any, user-friendly canal unsteady flow simulation models around.

CARIMA was modified over 2 years ago on behalf of the Imperial Irrigation District of California, so that it is now user friendly. Since the initial interface improvement, there have been continuous refinements both to the interface and technical abilities of CARIMA. The combined CARIMA and interface are known as "CANALCAD" and sold through the Iowa Hydraulics Research Institute (IHRI). The Irrigation Training and Research Center (ITRC) at California Polytechnic State University (Cal Poly), San Luis Obispo, provides the training in CANALCAD's usage. I wrote the original specifications for the interface. Forrest Holly of IHRI, and John Parrish of ITRC did the programming. The program is jointly owned by IID and SOGREAH (Hydraulics Consultants).

Another issue which may be of interest to your readers:

The ITRC has two computer programs for sale which have been used widely in the Western United States for irrigation.

a. AGWATER—This program is very graphical, and allows persons to walk through individual irrigation events throughout a season after identifying the crop, soil, and characteristics of the irrigation system. The program estimates irrigation system Distribution Uniformity (DU) and the Irrigation Efficiency of each irrigation event. Daily weather data and soil characteristics are maintained in a user-defined library. We use it for farmer workshops where a person can sit down at a computer for a couple of hours and

* Jurriens, Rien. 1994. Tools and techniques: Overview of practical irrigation software. ITIS. 1(1):13–15.

work on one's individual system. It is also possible for one to adjust irrigation schedules, irrigation system parameters, etc., and learn a tremendous amount about one's irrigation system management possibilities. The nature of the program allows one to customize one's own operation, rather than looking at generalities. The irrigation systems on the program are drip/micro, hand-move sprinklers (or side rolls), border strip, furrows, and under-tree sprinklers.

b. Irrigation evaluation software—This Windows program provides a standardized method of collecting field data and computijg Distribution Uniformity for drip/micro, hand-move/side roll sprinklers, under-tree sprinklers, furrows, border strips, or linear moves. The software has been used to evaluate literally thousands of fields in the Southwestern United States.

[Charles Burt, Director, Irrigation Research and Training Center, Cal Poly]

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ITIS—Lahore '94

Second International Meeting of the ITIS Network

The Second International Meeting of the Information Techniques for Irrigation Systems (ITIS) Network was held in Pakistan from 5 to 8 December 1994. Participants included those working in the irrigation sectors of Pakistan, Malaysia, Mexico, and Sri Lanka as well as representatives from IIMI and CEMAGREF.

The opening session of the Network meeting was held at the Government Engineering Academy in Lahore. Chief Engineer Muhammad Ashraf of the Punjab Irrigation Department, in his address, said that the Punjab Government was working with IIMI to improve the province's irrigation system. He added that the province's irrigation complex was over a hundred years old and in need of new ideas and modern technology to ensure its productivity.

Professor Gaylord V. Skogerboe, Director IIMI-Pakistan, also underscored the need to develop computerized information systems in the field of irrigation to boost farm yields, particularly in countries where per acre produce has not shown any improvement over the years. "Getting the right information to the right person at the right time is bound to improve productivity," Prof. Skogerboe said.

After the opening round of introductory and welcome addresses, the meeting settled down to business with audio-visual presentations of DSS experiences in Pakistan, Malaysia, and Mexico. Due to an unfortunate mix-up in flight schedules, the Sri Lankans were unable to attend this first session, but they caught up with the rest of the group the next day in Bahawalnagar, and went on to make a valuable presentation. Other presentations made on the opening day included a review of the Development and Application of SIC/IMIS in Pakistan, and a Classification and Review of DSS Tools and Techniques.

The following day the entire group embarked on a two-day tour of sites in Suleimanki and Bahawalnagar. On the first day, the group visited the imposing Suleimanki Headworks where they were briefed by the Executive Engineer, Mr. Muhammad Akbar followed by a presentation on the Fordwah Irrigation System by Superintending Engineer, Chaudhry Muhammad Shafi. The group then visited the Fordwah Irrigation System and the Chishtian Subdivision field sites before retiring for the night in Bahawalnagar.

On the third day, Superintending Engineer, Ch. Muhammad Shafi made a presentation on Rules, Regulations and a Review of Applications. The participants then worked in small groups discussing their observations and the previous day's experiences. The outcomes were presented to the larger group and further discussed and synthesized to formulate a skeletal master plan for the implementation of DSS in Pakistan.

The Meeting's last session, at the Government Engineering Academy in Lahore, was devoted to a discussion of the larger set of issues that govern DSS, and to progress made since the first Network meeting in Colombo, in 1993. ITIS Lahore '94 concluded with a discussion of the findings and the formulation of an action program for 1995.

For any further information, copies of the inaugural issue of ITIS or proceedings of the Network meetings, please write to:

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Acronyms

ADC	Analog to Digital Converter
CEMAGREF	Centre National du Machnisme Agricole du Génie Rural des Eaux et des Forêts (France)
DSS	Decision Support Systems
DU	Distribution Uniformity
FAO	Food and Agriculture Organization of the United Nations
FID	Fayoum Irrigation Department
GIS	Geographical Information System
HAD	High Aswan Dam
ID	Irrigation Department
IE	Irrigation Engineer
IHRI	Iowa Hydraulics Research Institute
IID	Imperial Irrigation District (California)
IIMI	International Irrigation Management Institute
IIS	Institute of Irrigation Studies
ILRI	International Institute for Land Reclamation and Improvement
IMAC	Irrigation Management Cell
IMTA	Instituto Mexicano de Technologia del Agua
INCA	Irrigation Network Control and Analysis
IRMU	Irrigation Research Management Unit
ITI	Irrigation Training Institute (Galgamuwa, Sri Lanka)
ITIS	Information Techniques for Irrigation Systems
ITRC	Irrigation Training and Research Center (Cal Poly)
MIS	Management Information Systems
MPWWR	Ministry of Public Works and Water Resources
NIRP	National Irrigation Rehabilitation Project
O&M	Operation and Maintenance
ODA	Overseas Development Administration
ODU	Overseas Development Unit (of HR Wallingford)
OMIS	Operational Management Information System
SAED	Irrigation Authority of the Senegal River Valley
SCADA	Supervisory Control and Data Acquisition
SCP	Société du Canal de Provence (France)
SEV	Supply Evaluation
SIMIS	Scheme Irrigation Management Information System
SOGREAH	Société Grenobloise d'Etudes et d'Aménagements Hydrauliques
TA	Training Assistant
TGH	Total Geographic Head
TMH	Total Manometric Head
USAID	United States Agency for International Development
USBR	United States Bureau of Reclamation