MEMORANDUM OF UNDERSTANDING

between

THE INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE
Sri Lanka

and

LE CENTRE NATIONAL DU MACHINISME AGRICOLE, DU GENIE RURAL, DES EAUX ET FORETS
France

for
the implementation of
A SIMULATION MODEL OF KIRINDI OYA RIGHT BANK MAIN CANAL
IN SRI LANKA

REVISED DRAFT - 07/04/88

A. PREAMBLE

1. This Memorandum of Understanding is intended to establish a collaborative agreement between the International Irrigation Management Institute (IIMI) and the Centre National du Machinisme Agricole, du Génie Rural, des Eaux et des Forêts (CEMAGREF), for the implementation of a Simulation Model of Kirindi Oya Right Bank Main Canal (RBMC) in Sri Lanka.

2. IIMI is an autonomous, non-profit international organization chartered in Sri Lanka in 1984 to conduct research, provide opportunities for professional development, and communicate information about irrigation management. IIMI's headquarters is in Digana Village near Kandy, Sri Lanka. In addition to its headquarters unit in Sri Lanka (in Digana near Kandy), IIMI has established or is implementing collaborative programs with governments of several countries: Bangladesh, Indonesia, Morocco, Nepal, Pakistan, Philippines, Sudan and various West African countries. IIMI's mission is to strengthen national efforts to improve and sustain the performance of irrigation systems, through the development and dissemination of management innovations.

3. CEMAGREF is a French public body with scientific and technical objectives, endowed with financial autonomy. The Centre is placed under the supervision of both Ministeries of Agriculture and Research and Technology. CEMAGREF's mission includes research and development of new technologies, technical assistance, expertise and experimentation in the field of rural land development and equipment for agriculture and related agro-industries, management of water, irrigation and drainage. CEMAGREF is an organization with headquarters in Antony, near Paris and ten regional branches in France (often specialized units dispersed within the country). CEMAGREF's clients include state government departments responsible for agricultural and civil engineering at district and regional levels, irrigation agencies and farmer managed irrigation systems, local agencies, French consulting firms undertaking projects in France and abroad, and private developers of new technologies for agriculture. CEMAGREF's field based activities and direct relationships with users of technology contribute to its considerable experience in technology transfer and reputation for developing improved methods and technologies in the field of water resources, in particular.

B. BACKGROUND OF THE PROJECT

4. Irrigation management research in the past decade has seen a number of field studies on tertiary water distribution, collectively grouped under the name "on-farm water management." There have been far fewer studies of what are referred to as "main-system" operations. Current operations in large irrigation canals network prevailing in the rice-based irrigation systems in the humid tropics suggest that considerable potential exists for better control and canal regulation. It is assumed that improved control of the primary distribution of water from main and branch canals could have a profound impact downstream in concurrence with agencies' and farmer organizations' efforts deployed to achieve reliable and equitable water supply at farm level.

5. IIMI's current research effort is designated to address, among other, the following issues: improving the manageability of main systems, analyzing the consequence of design options for the management of main canals, and exploring the prospect for effective and responsive operations of

existing canals. Rehabilitation and Improvement for the Management of Irrigation Systems is one of the three major themes which frame IIMI's research activities. Operation of irrigation systems under changing conditions is one important aspect of that of theme. Research and development of innovative practices to operate main canals however carried out easily in the field. Therefore, IIMI's research approach to investigations at the canal level is to use hydraulic simulation modeling techniques. Such techniques have been and used, by professionals in water resource management.

6. Thus, IIMI is implementing a program to demonstrate the feasibility and usefulness of this approach for irrigation management on a real case study in Sri Lanka. The project is oriented towards solving canal operations problems in close collaboration with its client agency. Specilized expertise and state-of-the-art techniques will be mobilized for the program to make the application conclusive. The result will serve as a reference for the Region, and support IIMI's objective to disseminate innovations and methodologies which can potentially improve irrigation management. In 1986, IIMI carried out careful investigations of various candidate sites in Sri Lanka to prepare for the present program.[1] As a result, IIMI and the Irrigation Department (ID) (Government of Sri Lanka) identified Kirindi Oya Right Bank Main Canal (RBMC) as an appropriate canal for a pilot application of a mathematical flow simulation model.

C. PROSPECT OF COLLABORATION BETWEEN IIMI AND CEMAGREF

7. In the last 20 years CEMAGREF has developed a number of reputed software in the field of open channel hydraulics, steady and unsteady flows. Since then, CEMAGREF has used the computer programs for design and operation purposes on rivers and channels (flood forecasting, dam break, flood control, and reservoir headwork operation). The software were initially run on main frame and mini-computers and their dissemination outside CEMAGREF has been limited. Furthermore, the relative complexity of the programs limited the possibilities for use beyond professional circles.

8. CEMAGREF's present policy favors the transfer of such software to micro-computers; by developing user-friendly interfaces with conversational procedures, advanced techniques can be disseminated, thereby expanding the number of potential users.

9. In April 1987, CEMAGREF's Director General expressed an interest in in collaborating with IIMI in the implementation of the Kirindi Oya simulation model because of CEMAGREF's methodological interest in the project. In addition CEMAGREF offered to contribute to the project in supporting a substantial portion of the costs associated with the CEMAGREF staff time allocated to the project.

10. It is expected that collaboration between IIMI and CEMAGREF in the implementation of Kirindi Oya RBMC simulation model project will result in enhancing the capacity of both Institutions to carry out working their common field of interest, and result in their mutual benefit.

[1] The site identification mission carried out in December 1986 was led by Mr. Rémy Pochat, Director for Science at Ecole Nationale du Génie Rural, des Eaux et des Forêts, Paris (ENGREF).

D. PROGRAM OBJECTIVES AND SCOPE OF THE PRESENT AGREEMENT

11. The primary objectives of the overall program are :

a. To provide a research tool in the form of a mathematical flow simulation model of the Kirindi Oya RBMC that will enable IIMI and ID to gain indepth knowledge of the hydraulic behaviour of the main canal. This will make it possible to evaluate the impact of different canal operation practices on the performance of that particular system, in response to changes in agricultural cropping and associated irrigation water demand. The main components of the computer programs will be available to IIMI's researchers for hydraulic modeling applications which the Institute may wish to undertake on other canals in the future.

b. To identify, through the model and in collaboration with ID, procedures for operating Kirindi Oya RBMC in that is both more effective and responsive. And based on that to recommend improved and tested procedures to ID. This aims to provide an immediate service to ID. A set of procedures for the manual operation of the main canal in its existing conditions will be tested and their impact on performance evaluated; feasibility in regard to the actual management capacity of the irrigation agency will be assessed. Procedures to be tested will include response to foreseeable events such as canal closure during rains, changes in flow regimes in response to demand, re-allocation of supply and adjustment of regulating structures and offtakes along the main canal.

c. To assist the ID in the eventual implementation of the new operation practices and to monitor their actual impact on the performance and manageability of the system.

d. To broadly disseminate the outcome of the case study, the research approach and methods applied in the project; This will be done through IIMI's research networks, publications, workshops and Professional Development Program.

12. The scope of the present agreement between CEMAGREF and IIMI is limited to the first objective of this program making the research tool operational and available to IIMI's researchers and ID's project staff. IIMI will collaborate with the ID to the other objectives. The terms of reference for a model that will meet IIMI's research and operational requirements are appended in ANNEX 1. If successful, extensions of the current project are anticipated: such as the development of new modules to be added to the model (simulation of automatic adjustable control structures, hydrological modules, etc.), and a feasibility study of regulation of Kirindi Oya RBMC. These could lead to continuing collaboration between IIMI and CEMAGREF.

E. MAIN FEATURES OF THE KIRINDI OYA RBMC SIMULATION MODEL

13. Technical description of the intended model and its organizational structure is detailed in ANNEX 2 of the present Memorandum of Understanding. The Kirindi Oya RBMC simulation model will be designed to run on a micro-computer (PC) compatible with the standard. Three main computer programs

existing at CEMAGREF (TALWEG, FLUVIA, SIRENE) will be used to build the model. A major component of the project to be completed under the present agreement is the development of user-friendly conversational procedures which will make it possible for non-specialized persons from IIMI and ID to manipulate the simulation model.

14. The model will have a modular structure allowing partial modification, addition and substitution in future. The modules corresponding to the hydraulic algorithms included in the model, FLUVIA and SIRENE in particular, could be eventually replaced by upgraded versions which CEMAGREF may develop in future.

15. The general layout of the model will foresee the possibilities to add in a latter stage a "regulation module" which would allow for simulation of the operation of automatically adjustable gates commanded through various control algorithms. However, the implementation of this regulation module is not included in the present agreement.

16. The model comprises three main units to be operated either separately or in a sequence. These are :

Unit I : To generate the files that gather the geometry and all physical peculiarities of the canal as required by Units II and III, Unit I permits the user to input and verify data obtained from a topographical survey of the canal.

Unit II : To predict the steady flow conditions (water surface) that will exist in the various canal reaches as a result of any given mix of inflow, cross-regulator positions and offtake gate openings. Unit II permits the user to input the hydraulic parameters of the canal, the calibration of the regulating structures, offtake, etc. Unit II will also permit the user to determine gate and regulator settings required to achieve a given water distribution plan at Full Supply Depth (FSD).

Unit III: To simulate the unsteady flow conditions that occur for some period of time when the control structures of the canal are operated. Unit III permits the user to input various scenarios of changing water demand and scheduled operations of the headwork and control structures intended to achieve a transition from one initial steady flow regime to another corresponding to a change in water distribution. Unit III will permit the user to compare the merits of different operational plans on the ground of effectiveness, response to demand, operational water efficiency, or labour intensity.

F. PROJECT IMPLEMENTATION

17. The project will be implemented in phases corresponding to the three units of the model. In each phase, there will be a visit of CEMAGREF's staff to Sri Lanka. Such staff will install at IIMI whatever software already developed and collect additional information from the field. The core components of the program (DONTAL, TALWEG, FLUVIA, SIRENE) already exist and are operational although an adaptation of SIRENE (the unsteady flow model) to Kirindi Oya will be necessary. The major part of the project will be to develop conversational procedures. However, it is difficult to specify

initially all details and functions of the model user-interface; such details will be better identified in collaboration with users of the model at a later stage. Therefore, CEMAGREF will first provide a tentative interface which may help IIMI and ID define more precisely their conversational requirements. CEMAGREF will then work on the final versions. For each phase, CEMAGREF will provide to IIMI the written documentation and provisional manual required for the correct operation of the different software of the model.

18. In the First Phase - IIMI will make available to CEMAGREF a detailed survey of the canal so that the computer files of the canal geometry can be built up. A first visit to the site by a specialist of CEMAGREF will be organized with a view to clearing inconsistencies in the survey, collecting additional information and to install Unit I at IIMI Headquarters. This phase will be completed when CEMAGREF returns to IIMI the revised files which would contain all the geometry of the canal.

19. The Second Phase - begin with a second visit of CEMAGREF's staff to the site during which data on the hydraulic of the canal and its structures will be collected. CEMAGREF will send two experts to organize and coordinate the hydrometry campaign in collaboration with IIMI and the irrigation agency in charge of the canal operation.

In a second step, modeling of the structures (cross regulators, offtake, etc.) of Kirindi Oya RBMC will be undertaken. A sub-program (EDIFLU) that will permit themes to input and modify easily the hydraulic parameters of the model will be developed. Then, the calibration of the Kirindi Oya model will be undertaken at CEMAGREF on the basis of information collected on the hydraulic behavior of the canal during the visit.

A new routine will be programed and added to FLUVIA to allow the computation of openings of all cross regulators and offtakes for any given distribution plan. A tentative version of the entire Unit II will be prepared including the input and output modules. This version will be sent to IIMI for testing and comments. IIMI should then be in a position to give CEMAGREF guidance on how the provisional version should be modified for the convenience of the users. The second phase will end with the release by CEMAGREF of the final version of Unit II.

20. The Third Phase - begins with the adaptation of SIRENE to Kirindi Oya RBMC. The control and command modules will then be developed. At this stage, recommendations made by IIMI related to the user-friendly interfacing of Unit II will be incorporated in a tentative version of Unit III. On this basis, IIMI will advise CEMAGREF and indicate directions for the preparation of the conversational procedures required for Unit III. Phase three will be completed when the final version of Unit III is released.

21. One and possibly two visits of CEMAGREF's staff to Sri Lanka will be arranged for the final installation of the model at IIMI Headquarters and eventually at Kirindi Oya Resident Engineer's office. A comprehensive documentation and manual will be handed over to IIMI at that time.

G. ORGANIZATION AND EXPERTISE

22. Mr. Daniel Berthery, a senior staff namely of the Institute, will be responsible for overall supervision. Dr. Hilmy Sally, an IIMI Research Associate, will interact with CEMAGREF's specialists during all important

phases of the project either in Sri Lanka or in France. He will spend tentatively eight weeks in the Hydrology Division of CEMAGREF at Lyon, participating with CEMAGREF's scientists in the model calibration, initial simulation test runs, so that he is fully acquainted with the model. He will collaborate with CEMAGREF's staff in the definition and design of the model user-interface to be developed.

23. CEMAGREF will assign a project leader responsible for coordination and implementation of the simulation model project within CEMAGREF. Altogether, CEMAGREF will allocate to the project forty five (45) person weeks of its senior professional and two (2) person weeks time of a hydrology specialist whose assistance will be required for the gauging campaign planned in view of the calibration of the model. Most of the work will be done within CEMAGREF in France, except eight (8) person weeks to be spent in Sri Lanka at IIMI and at the field site.

24. CEMAGREF will seek the expertise of Mr. Jean A. Cunge from the Centre d'Etudes, de Formation et de Recherches Hydrauliques de Grenoble (CEFRHYG) and Mr. Rémy Pochat, from the Ecole Nationale du Génie Rural des Eaux et des Forêts (ENGREF).

25. A Study Advisory Committee will be considered to review the progress, discuss difficulties and provide guidance for the project implementation. It will be chaired by reputed experts in hydraulic modeling and simulation. The Committee would meet on a quarterly basis tentatively. Staff responsible for supervision and implementation from IIMI and CEMAGREF will participate in the meeting of the Committee. A representative of the French Ministry of Foreign Affairs which provided support to the project will be invited to the meetings. The project leader from CEMAGREF will assume the function of rapporteur to the Committee.

The list of persons, experts and institutions who will participate in the project is appended in ANNEX 3 of the present Memorandum of Understanding.

H. PROJECT COSTS AND FINANCING ARRANGEMENTS

26. <u>Staff</u> - Costs associated with CEMAGREF's staff time allocated to the project amount FF 566,500 on the basis of (45) person weeks senior professional plus (2) person weeks hydrologist. Breakdown of costs and sharing arrangement between IIMI and CEMAGREF are indicated in ANNEX 4 of the present document. This is summarized as follow:

CEMAGREF's staff costs supported by IIMI[2] :	308,200
CEMAGREF's staff costs supported by CEMAGREF:	258,300
Total (FF):	566,500

The sharing arrangement is in concurrence with CEMAGREF's expression of interest for the methodological aspects of the project: CEMAGREF will support development costs related to the project in so far as they have the potential of broad applicability, while IIMI will support costs associated with the input/output modules as required for its research needs and interfaces

[2] This contribution is to be met by IIMI out of the specific grant provided by the Government of France in November 1987, to support IIMI's program on Canal regulation and Simulation modeling.

specific to the Kirindi Oya RBMC model.

The above costs are net of eventual indirect expenditures and overhead incurred by both institutions in implemention. Other expenses not specified by the present agreement will be met separately by IIMI and CEMAGREF for which part each is concerned.

27. Mission and travel - A minimum of three missions by CEMAGREF's staff to the field site in Sri Lanka have been anticipated. This will involve travel by air of four persons from Lyon (France) to Colombo and return, and accommodation for a two week period during each visit to Sri Lanka as quoted in ANNEX. 4.

IIMI will meet the cost of four (4) return tickets for the travel of the experts of CEMAGREF for their mission to Sri Lanka. IIMI will also pay the local expenses incurred for the transport, boarding and lodging of CEMAGREF's experts.

IIMI will support costs of living of its staff while travelling from Sri Lanka to France for the project, either for work done at CEMAGREF in collaboration with its scientists or for coordination and participation in meeting of the Study Advisory Committee.

28. Equipment and software - CEMAGREF will make available to IIMI three valuable computer programs of its own: TALWEG, FLUVIA and SIRENE. IIMI will enjoy permanent and free tenure of the software under the conditions stipulated in this Memorandum of Understanding regarding the dissemination of software.

IIMI and CEMAGREF will make available separately on their sites, compatible hardware and commercial software in so far as they appear necessary for the development and/or the operation of the simulation model. The specifications suggested for these items are given in ANNEX 5.

The purchase of equipment and facilities such as micro-computer, software, current-meters, dataloggers, etc. which be referred in the course of the project by either Institutions is not covered under the present agreement.

I. PROJECT DURATION, DATA REQUIREMENT FOR BUILDING THE MODEL

29. Subject to the timely availability of data required for implementing the model, CEMAGREF will achieve the project within a period of twelve (12) months from the date of approval of the present Memorandum of Understanding.

Data required by CEMAGREF for the model include a detailed topographical survey of the canal and information regarding the hydraulic of all structures, cross-regulators, offtakes gates and their eventual weir boxes, syphon, etc.

30. Topographical survey - IIMI will provide to CEMAGREF at the start of the project a quality survey of the canal including: (i)a map of the canal (scale larger than 1/25,000 with the location of all turnouts and cross regulators; (ii) longitudinal canal bed profile and canal cross sections with the reduced level references; (iii) full description of syphons, gates and regulators with similar reduced level references. All available

documentation will be reviewed by the expert of CEMAGREF during the first field visit to the site and the survey will be verified. Additional information might be required eventually.

31. Hydraulic data - CEMAGREF in collaboration with IIMI and the Chief Resident Engineer for KOISP (ID) will plan carefully a campaign to be undertaken for the collection of data on the hydraulics of the main canal and at least of of one cross-regulator and two offtakes. CEMAGREF will make available to that end the services of two specialists from France to supervise the gauging operations within a period of two weeks. The hydrometry campaign will require the assistance of a local specialized gauging team to be hired by IIMI for that purpose. CEMAGREF's experts will take advantage of this campaign to describe the gauging procedures to be followed by IIMI's research staff for the calibration of other structures. CEMAGREF will include in the model the detailed calibration of all structures subject to the provision by IIMI to CEMAGREF of the corresponding additional hydraulic data.

J. TERMINATION OF THE PROJECT AND PAYMENTS

32. IIMI's contribution will be released in accordance with the progress achieved by CEMAGREF in implementing the model. Payments by IIMI to CEMAGREF will follow the schedule indicated below:

30% as down payment at the start of the project, (FF 92,460)

30% at the completion of Unit I & II, (FF 92,460)

30% at the completion of Unit III, (FF 92,460)

10% at the overall completion of the project(FF 30,820)

Total:FF 308,200

33. The start of the project will be effective with the signature of the present agreement by IIMI and CEMAGREF. Overall completion includes the installation at IIMI on its computer of all components of the software in their final english version. The Kirindi RBMC model should be fully operational, calibrated on site and with input-output user interface that meet the level of quality indicated in the Terms of Reference of the project and which will be further specified in due time. The final version of the software will be fully documented with appropriate technical information and manual.

K. DISSEMINATION OF SOFTWARE AND PUBLICATIONS.

34. TALWEG, FLUVIA and SIRENE are three State-of-the-Art software developed by CEMAGREF which are and will remain its property. The software will be lent permanently to IIMI under the following conditions:

a. Unit number one (TALWEG) is for the sole use of the Institute in the conduct of its activities on hydraulic modeling. A run version only will be provided to IIMI. However, with this module, IIMI is given the possibility and the freedom to use it for modeling any other similar canal. Adaptation of the modules and interfaces which have been developed specifically for Kirindi Oya RBMC would be required. Would such an adaptation to be made, IIMI will inform CEMAGREF of its intention to proceed with these new developments.

b. Units number two (FLUVIA) and three (SIRENE) including their respective user-interfaces programs, which altogether compose the actual simulation model of Kirindi Oya RBMC can be disseminated freely by IIMI in their run versions to achieve the IIMI's overall objectives of IIMI's program. For research and educational purposes, IIMI's researchers will be given the source codes of Unit II and III but CEMAGREF will maintain only the run versions of all software. Maintenance of the software will be done for a period of one year after they have been handed over to IIMI.

35. Sub-programs developed specifically for the simulation model project of Kirindi Oya will be considered as a joint property of IIMI and CEMAGREF and will be used by both institutions without restriction or prior notice.

36. Commercial software utilized by CEMAGREF for the implementation of the model and which are protected by Copyright Law (FORTRAN Compiler, HIGH SCREEN, GKS, etc.) will not be given to IIMI. IIMI may wish to acquire some of them in due time if it intends to undertake further modifications of the Kirindi Oya simulation model and/or applications to other sites.

37. Publications by IIMI and CEMAGREF related to the project implementation and output obtained by simulations through the Kirindi Oya RBMC model will quote the collaborative agreement between both Institutions for the project.

38. Any dispute between IIMI and CEMAGREF concerning the interpretation of application of this present agreement, which it has not been possible to settle by direct negociation between the parties, shall be submitted to arbitration by a sole arbitrator or, if a party shall so request, by a panel of three arbitrators, whose decision shall be final. Each party shall appoint an arbitrator. The third arbitrator who shall act as a President of the arbitrator panel, shall be selected by agreement of the parties. If the parties do not agree on the selection of the third arbitrator, or of the sole arbitrator, he shall be appointed by the President of sthe International Chamber of Commerce in Geneva.

39. The present memorandum of understanding is established in duplicate in the french and english languages, the french and english versions are both equally valid.

M. Yves LE Bars	Dr. Roberto Lenton
Director General, CEMAGREF	Director General, IIMI
Date : 26 AOUT 1988	Date :

Terms of reference of Kirindi Oya RBMC hydraulic model

The model should possess the following characteristics :

1. The model should closely represent the behaviour of Kirindi Oya RBMC so that it appears familiar and acceptable to the staff in charge of operations. This condition is also required by IIMI to carry out investigation and research on canal operations. This means that the model must be able to correctly represent the kind of singularities which influence the hydraulics of the canals. The model will be limited to the main canal and its various structures. It will incorporate the actual geometry of the canal, adjustable gated regulators and composite cross-regulators, offtake of various types, constricted sections and eventual widening, as single bank canals are common in the region, etc.

2. The performance of the software should be at the highest level useable on a microcomputer, in terms of computation speed and memory capacity needed so that it can perform simulation over at least a one week period of time and for the largest number of computational points within an acceptable computation time. The simulation duration will be choosen by the user. The program should have built-in mechanisms to prevent hydraulic simulation errors, instability problems, as well as facilities to generate initial hydraulic conditions. This will require State-of-the-Art algorithms and programs developed by and for professionals. Algorithms using the implicit method of finite differences for the numerical solution of the unsteady flow equations is suggested (Mathematical model of the complete Saint Venant equations).

3. Outputs of the model and functionalities should meet the needs of different categories of users having different interests in using the model and different levels of practical and theoretical experience in hydraulics. The user interface of the models will emphasize in all cases the main asset of a simulation model, compressing both the spatial and temporal dimensions, i.e., (i) providing overall and updated views of the system status in its various reaches, and (ii) anticipating the outcome of various operations scenarios for a longer period of time and eventually a full cropping season within a reasonable computation time. Displays should be appealing and dynamic to a certain extent; they will also include scaled graphic presentation of results generated during a simulation as well as tabulated formats appropriate for operation.

4. On a first mode of operation, the model should be simple to use and output should be geared to provide practical assistance to the agency personnel operating the system, i.e., provide indicator of performance for any time or a period. A regulation module could be connected later to that mode of operation. A training module could also be provided under that mode in the form of a simulation game allowing for the comparison of performances that would result from different operational practices (i) manual operation giving more or less information feedback over the system to the operator, and (ii) similarly manually operated or partly automated system assisted by some regulation modules.

5. On a second mode of operation, which will be adequately documented, the software will give access and the data base manager used for the description of the system. This mode will be used for the calibration by CEMAGREF's specialists and IIMI's researchers. IIMI researchers should also be able to use that mode for testing the impact of design innovations and for applications of the software to other canals.

Simulation Model of the Kirindi Oya Right Bank Main Canal

Model Description

I. Right Bank Main Canal (RBMC)

Kirindi Oya RBMC, constructed recently downstream of the Lunugamwehera reservoir, is designed intended to irrigate approximately 5000 ha of land.

Although only a little more than half the anticipated command area has been developed under Phase I of the project, serious water shortages have already been experienced, resulting in a limitation of less than that two cultivation seasons per year an average. In addition to the traditional paddy cultivation, crop diversification during the second season is envisaged. This underlines the need to ensure better management of relatively scarce water resources, especially if two cropping seasons per year are to be sustained.

RBMC is a 30 km long canal with trapezoidal earth embankments. It is characterized by the presence of 14 cross-regulators spread over its length. The coordinated operation of these 14 underflow gated regulators is a key factor in maintaining desired water levels, thus ensuring efficient management of the water conveyance and primary distribution along the RBMC. Ineffective operation of the control facilities could result in unreliable water supply and water loss. In the context of this particular design and water short environment, a mathematical simulation model of the main canal should help identify alternative management practices that will lead to improved distribution of water and efficiency.

II. The Model

The model is composed of three units:

Unit I : Topography unit

The operation of this first unit should remain with experienced staff trained in the field of hydraulic modeling, i.e., IIMI staff trained in CEMAGREF. This unit allows the model to be adapted to similar canals. This unit will not be conversational. The topography unit generates the geometric files from topographic data; these geometric files will be re-called later by the steady and unsteady models. Any type of cross-section canal can be accepted by the program including single bank canals commonly found in Asia. Cross-sections can vary along the canal.

This unit consists of two computer programs:

DONTAL - It can be used eventually to generate the topographic files. Advanced users might also prepare or modify these files through the host computer editor;

TALWEG - It checks the validity of the topographic data and establishes the calculation of cross-sections.

Unit II : Computation of gate positions and initial hydraulic conditions.

This unit is easier to use within the overall program. The user only needs a good knowledge of the canal; he could for instance be a canal manager. This unit calculates the turnout and regulator gate openings for any state of steady water demand and generates initial hydraulic conditions for a further activation of the unsteady model. An optional menu gives highly skilled users an access to special procedures to set down the hydraulic parameters of the canal (cross-regulators, friction coefficients, etc.). This unit will be fully conversational.

The unit consists of five modules: EDIFLU, FLUVIA, VISFLU, RESFLU and a COMMAND MODULE.

COMMAND MODULE - The function of this module is the overall management of the other modules.

EDIFLU - It is the input module. This module is fully interactive. Through this module, the user describes the water demand and sets water depths upstream from the canal regulators so that FLUVIA program can calculate the openings of the structures. Moreover the module will give advanced users access to procedures making possible modifications of the hydraulic parameters of the canal. These procedures will allow the user to modify the hydraulic design of the canal.

RESFLU and VISFLU - These modules are the output modules. The first one generates numerical results; the second provides the users with graphical results. Output data consist of turnout and regulator openings an water depths along the canal. Information related to the functioning of the devices is also provided.

FLUVIA - This is the steady flow model. This is the main program of unit number two. It has been designed to calculate water depths along rivers and canals. A specific sub-program will be added to the registered version of FLUVIA to calculate automatically the opening of the devices as a function of steady water demand and sets of water depths upstream from cross-regulators. It also generates automatically a file of initial hydraulic conditions for further unsteady calculations.

Unit III : Unit to simulate unsteady flow

This unit simulates the actual unsteady functioning of the canal. Unit III offers two levels of complexity to the users.

The first level is designed for non-skilled but well trained staff to simulate the present management of the canal. It provides this kind of user with information on water losses and shortages along the canal. For these users, this should be an efficient training tool to understand how unsteady flow regime should be managed.

The second level should be reserved for highly skilled staff. The model allows this category of staff to carry out investigations in the field of water management and hydraulic design of irrigation canals.

Before running the unsteady flow model itself, the user needs to define initial hydraulic conditions: to do so he can either call pre-established conditions or use Unit Number 2 (see above). Then he chooses a scenario of water demand which becomes the target that he should satisfy. At this stage, the user activates the unsteady flow model. From initial conditions corresponding to a previous state of steady water demand, he should now satisfy a new scenario of water demand by activating sluice gates, regulators and turn out gates. Although it is now managing an unsteady situation, it can previously activate Unit Number 2 with the targeted water demand to get knowledge of a steady solution.

Once the management time step is over, different information is supplied to the user (satisfaction rate, water discharges and water depths at specific points). The user is therefore required to provide further information taking into account these results. Then, he can activate the model for a new period of time and so on. Should the user not be satisfied with the previous results, the possibility to go back to the beginning of the previous simulation period exists. Then he can start again with a new set of parameters.

Once the total simulation is over, the following information is provided by the program: (i) cumulated upstream water discharge; (ii) balance of water demand and water supply; (iii) hydrographs at any point of the model; (iv) cumulated water losses; and (v) water depths.

Unit Number 3 consists of 6 modules: PRESIR, VISIR, RESIR, CONTROL MODULE, SIRENE and a COMMAND MODULE.

COMMAND MODULE - The function of this module is the overall management of the other modules. The command module is in charge of the time management of the system. Time organization is described below:

a. <u>Simulation duration</u> represents the total length of the simulation. This duration is chosen by the user (e.g. 10 days);

b. <u>Management time step</u> is the interval between two operator interventions in the process. It is defined by the user; (e.g. 3 hours);

c. <u>Simulation time step</u> is the basic time unit for the hydraulic module in charge of the real simulation. This value is set up in the program (e.g. 10 minutes);

PRESIR (Input module) - It is the interface between the user and the simulation model. This module is activated first at the beginning of the simulation in order to enter general data such as initial hydraulic condition, simulation duration, etc. Later, at the beginning of each management time step, the input model offers the user the possibility to modify the position of the cross regulators and turnout gates. This module stores all the data in the input files.

VISIR and RESIR (Output modules) - These modules provide the user with:
(i) synthetic information of the results of the simulation at each management time step (satisfaction rate, reservoir level, state of water demand, etc.);
(ii) full information once the simulation is completed. At this stage, the module offers the operator all types of information he could require such as evolution of water depths and discharges along the canal, comparison between water demand and water supply, losses at the tail end of the canal, cumulated water discharge, etc. VISIR provides graphical information while RESIR gives numerical information.

CONTROL MODULE - The simulation model can be used in two different ways, either manually or automatically.

Manually - At the end of each management time step the user sets up a new upstream input discharge and new openings of water devices. These values remain constant within the management time step.

Automatically - The control module calculates the position of the controls along the canal according to the existing regulation practices on the RBMC. At the beginning of each management time step, the user can modify regulation parameters (delay between two device operations, sensitivity of gate opening to the difference between FSD and actual upstream water depths, gate operation duration). He can also abandon the automatic procedure. In the future, this module could be substituted by any optimal control algorithm module.

SIRENE - This is the unsteady hydraulic model which simulates water discharges along the canal according to the position of the gates and the upstream input discharge. It is activated by the command module at each simulation time step. SIRENE solves the Saint-Venant equation following an implicit finite difference scheme with the double sweep method (Preissman's method).

INPUT FILES - These files can be divided between permanent files, which are filled before starting the simulation, and temporary files, which can be modified during the simulation.

a. Permanent files:

i) Topographic file - It stores the topography of the canal and the location of its devices (cross regulators and turnout gates). This file could be exceptionally modified using Unit Number 1.

ii) Initial hydraulic conditions file - It describes the water discharges and depths, the gate positions along the canal just before the simulation is activated. Initial hydraulic conditions can be calculated by Unit Number 2.

iii) Water demand file - It describes the water demand at each turnout. A complete set of hydrographs of water demand for all the turnouts and for the full simulation duration is called a scenario. Standard scenarios provided by IIMI will be at disposal of the user. Any valuable water demand software can provide such scenarios. Upon IIMI's request, CEMAGREF will write the interface between PRESIR and such software purchased by IIMI.

b. Temporary files:

i) Gates and regulators position file - This file is updated at each simulation time step in case of automatic control or at each management time step in case of manual control. It includes the upstream input discharge.

ii) Control parameters file - These parameters are required by the control module in case of automatic control. They could be modified at the beginning of each management time step.

OUTPUT FILES - These are the results of the computation, stored step by step:

i) Computation depths and discharges results file - It stores water depths and discharges at previously defined space step; (ii) History of gates and regulators positions are stored in this file.

DIAGRAM NUMBER 1

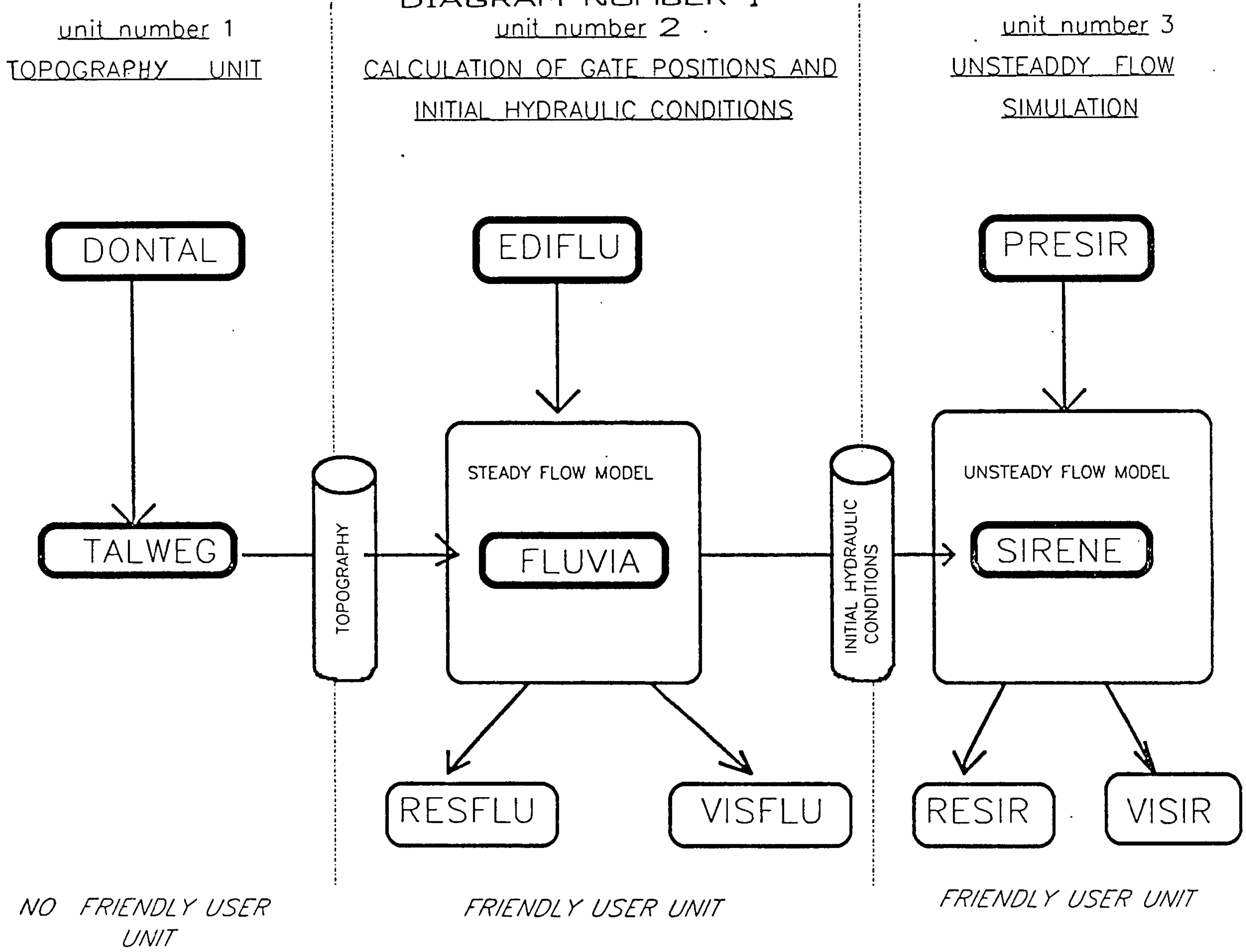
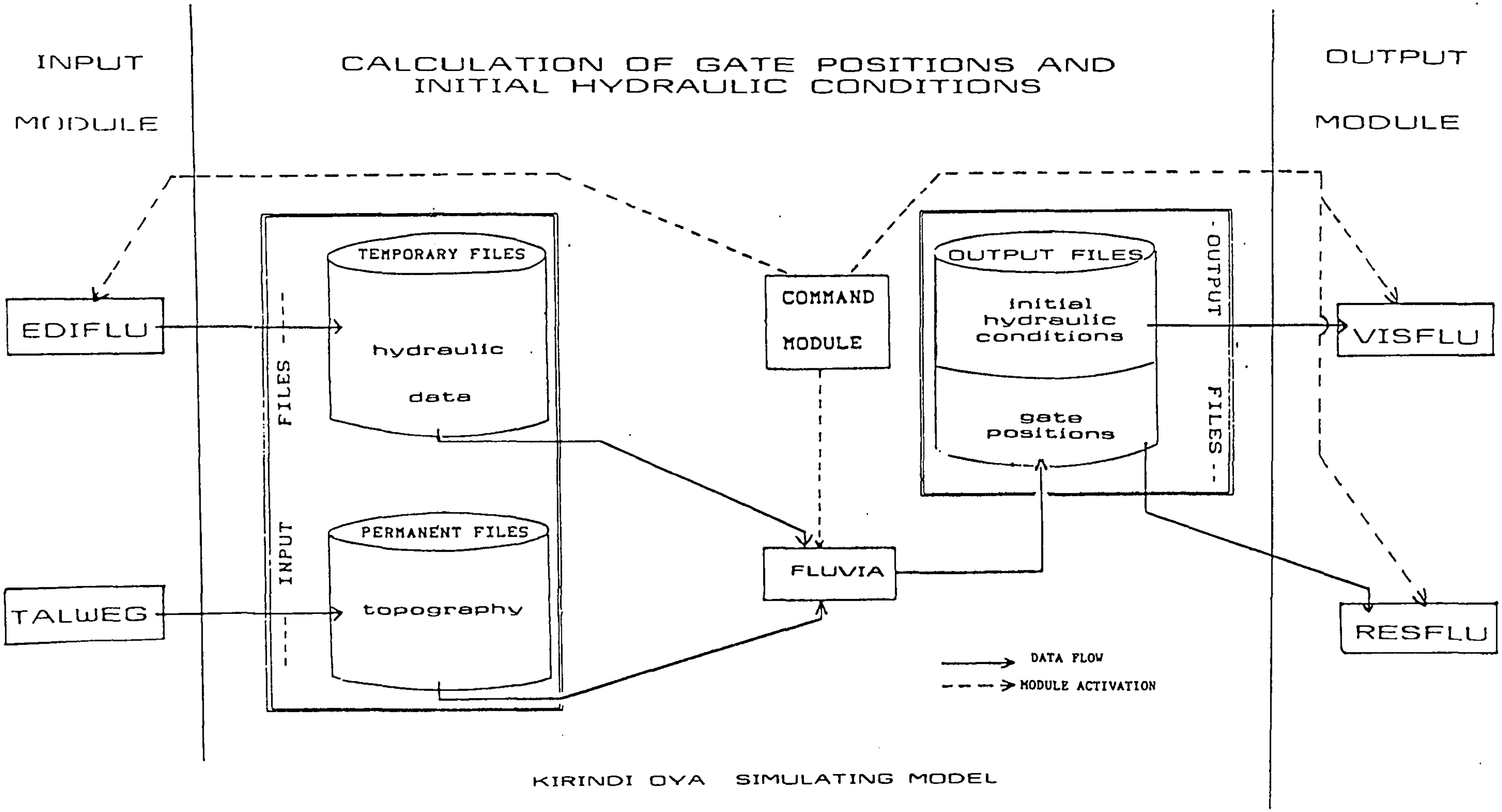


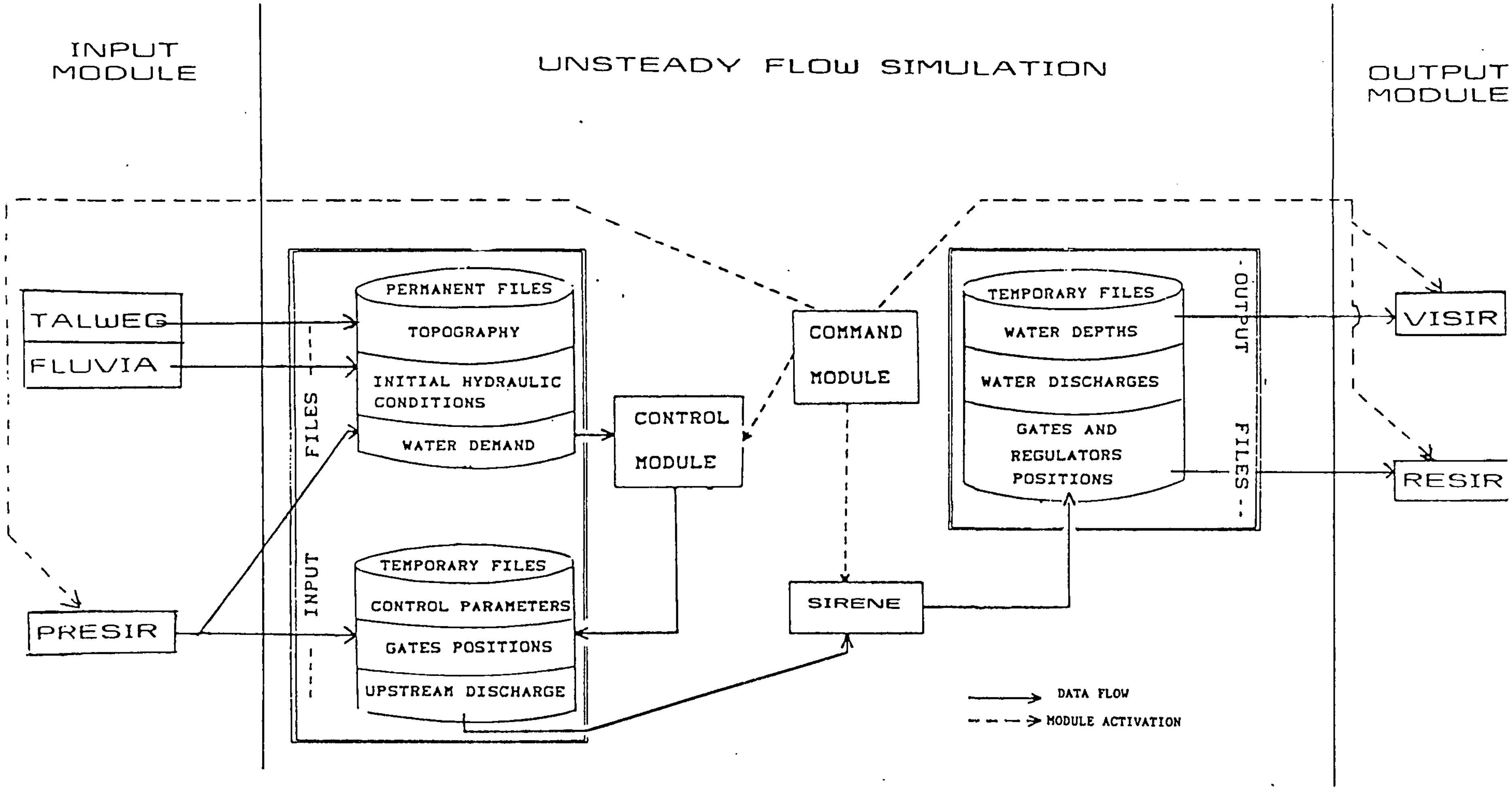
DIAGRAM NUMBER 2



KIRINDI OYA SIMULATING MODEL

UNIT NUMBER 2

DIAGRAM NUMBER 3



KIRINDI OYA SIMULATING MODEL
UNIT NUMBER 3

List of persons, experts and institutions participating in the project

Irrigation Department, KIOSP, Sri Lanka:

Mr. Samarasinghe	Chief Resident Engineer, (CRE)
Mr. Jayasundara	Senior Irrigation Engineer, (SIE, Water Manag.)
Mr. Ivon Silva	Resident Engineer, (R.E.) RBMC, Wirawila.

International Irrigation Management Institute, (IIMI) Sri Lanka:

Mr. x	IIMI Staff reponsible for the Sri Lanka Program
Mr. Daniel Berthery	IIMI Staff responsible for the project supervis.
Mr. Jean Verdier	IIMI Resident designated for Morocco
Dr. Hilmy Sally	IIMI Research Associate

Centre National du Machinisme Agricole, du Génie Rural, des Eaux et des Forêts (CEMAGREF), France:

Mr. Leopold Rieul	Administrative Director for the project; Chef de la Division Irrigation; Groupement de Montpellier.
Mr. Frederic Certain	Project Leader for the project; Division Hydrologie-Hydraulique; Groupement de Lyon.
Mr. Jean-Pierre Baume	Open channel flow specialist; Division Irrigation; Groupement de Montpellier.
Mr. Michel Poirson	Computer science specialist; Division Hydrologie-Hydraulique; Groupement d'Antony.
Mr. Gilles Bonnet	Computer science specialist; Division Hydraulique Agricole; Groupement de Bordeaux.
Mr. André Durbec	Hydrometry specialist; Underground water specialist; Division Hydrologie-Hydraulique; Groupement de Lyon.
Mr. Philippe Yvergniaux	Open Channel specialist; Numerical Calculation specialist; Division Hydrologie-Hydraulique; Groupement de Lyon.
Mr. Jean Baptiste Faure	Numerical Calculation specialist; Division Hydrologie-Hydraulique; Groupement de Lyon.

Centre d'Etudes, de Formation et de Recherches Hydrauliques de Grenoble (CEFRHYG), France:

Dr. Jean A. Cunge	D.I.C., Dr-Ing., M.ASCE Senior Technical Advisor

Ecole Nationale du Génie Rural, des Eaux et des Forêts (ENGREF), France:

Mr. Rémy Pochat	Directeur Scientifique

Ministère des Affaires Etrangères, France:

Mr. Jacques Gurgand

Estimated cost associated with CEMAGREF's staff time allocated to the project.

UNIT	Tasks	Man-weeks	Cost[1] (FF)	Supported by CEMAGREF	Supported by IIMI
I	1st Field visit, survey proof checking, geometry.	2	24,600	0	24,600
II	Modeling of Kirindi Oya, geometry & structures.	4	49,200	24,600	24,600
	Development of EDIFLU	6	73,800	73,800	0
	Model Calibration	1	12,300	0	12,300
	FLUVIA, development of additional routines.	8	98,400	98,400	0
	Input/output module	4	49,200	0	49,200
	2nd Field visit (2persons) gauging campaign in view of the hydraulic calibration.	2 (+2)	24,600 13,000	0 0	24,600 13,000
III	Adaption of SIRENE to Kirindi Oya	4	49,200	24,600	24,600
	Input/output module	4	49,200	0	49,200
	Control and command modules	6	73,800	36,900	36,900
	3rd Field visit	2	24,600	0	24,600
	Document writing	2	24,600	0	24,600
	Total (FF)	45 (+2)	566,500	258,300	308,200

[1]/ Basis of costs are FF 12,300 per man-week for CEMAGREF's senior professional and FF 6,500 per man-week for the hydrology specialist (2 weeks).

Specifications of Hardware and Software
recommended for the project.

Hardware

The programs will be developed for a micro-computer PC-AT IBM compatible with the following characteristics :

1 MB CPU memory

5 1/4 inches floppy disk drive

40 MB hard disk

Math co-processor

High resolution colour monitor type EGA (640 x 200 pixels)

Plotter HPGL compatible type HP7475A

Software

The following commercial software will be used for the development of the programs and its interfaces:

FORTRAN Optimising Compiler. Microsoft version 4.1

HIGH SCREEN, (menu generator)

GKS (graphic library)