FIELD APPLICATION OF THE KIRINDI OYA RIGHT BANK MAIN CANAL SIMULATION MODEL: SOME PRELIMINARY RESULTS

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EXECUTIVE SUMMARY

The background of IIMI's project on the development and application of a mathematical simulation model to study and improve the management of main canals is briefly presented in Chapter 1.

The objective of Chapter 2 is to analyze the present functioning of the Kirindi Oya RBMC (test case) and its management as perceived by the operational staff.

The capacity of the model as an interesting and reliable hydraulics training tool is highlighted in Chapter 3.

Three examples of analysis of specific management problems using the model as a research and operational tool are developed in Chapter 4.

Reflections of phase II (field application) of the simulation modeling project are given in Chapter 5. Further investigations to explore the possibility of a gradual conversion of the management practices to a "computer-assisted water delivery control" are proposed.

1. PROBLEM

1.1 Irrigation water management: Design concepts and operational considerations

An irrigation project evolves through successive stages from design, and construction to its operational lifetime. A number of assumptions and choices have to be made by the planners and designers in keeping with the technical and physical contexts of the project. The decisions are sometimes likely to impose certain managerial constraints during the whole operational phase. This is particularly true in the case of the main system of a project encompassing the collection, conveyance and distribution of water to the secondary and tertiary units. Design concepts play a crucial role in the mode of operation, which is supposed to be determined by optimal hydraulic considerations. In many cases, malfunctioning of complicated structures, lack of control over water flows and levels and lack of knowledge of the status of the entire system at a central decision making level give rise to deviations from the operation envisaged by the designer. Project performance will be consequently affected and various problems have to be faced: conflicts between farmers and management due to over or under supply, top versus tail end inequity, lack of maintenance, dramatic water losses.

The mismatch between design constraints and the tentative and sometimes inappropriate management rules is liable to become the cardinal cause of inequity and unreliability in many systems. Unfortunately, improving this situation is often not very easy; the physical process of water conveyance and distribution along main irrigation canals needs substantial knowledge and experience about the hydraulic behavior of the system to be controlled.

The problem lies mostly in the deep inter-dependency between the different parts of the system and the disorder created by operations which are performed locally without central coordination. Consequently, steady flow conditions, assumed by most designers to ensure adequate water supply, are rarely achieved. It becomes very difficult for the manager to maintain real control on the water deliveries.

1.2 Innovative research proposal

IIMI decided to implement an innovative research project to study the impact of this lack of control on main canal behavior and to propose improved operational practices. It was assumed that a mathematical model able to simulate the flow under steady and unsteady conditions in a main canal taking into account all operations at the devices, could provide decisive help to improve the knowledge about the system and to determine practical rules to manage it.

The right bank main canal (RBMC) of the Kirindi Oya irrigation project in Southern Sri Lanka was chosen as a test case to develop and apply the new methodology (Annex 1.1).

Phase I consisting of the development and calibration of the mathematical model began in mid-1987. The project was supported by the French Government and the development of user-friendly interfaced computer software was completed by the French research center CEMAGREF in June 1990. The first results and application rules were obtained by Malaterre in July 1989 with an earlier version of the software (see [A]). IIMI can now conduct both methodological and action research to make use of the range of possibilities of the model in an operational context. This will constitute Phase II which would ultimately lead to the identification of a generalized approach to solve problems of main canal operations.

The objective of the present study is to prepare for Phase II of the research project, aimed at utilizing the model as a research, training and operational tool in close collaboration with the managers of the Kirindi Oya RBMC.

- The first step was to analyze the present functioning of the canal and its management as perceived by the operational staff.

- It was necessary to highlight the capacity of the model to serve as an innovative hydraulic training tool to solve routine main canal management problems.

- It was then possible to identify specific management problems and provide examples of analysis to address these problems by using the model as a research and operational tool.

- The last part of the study consists of a brief proposal of investigation to prepare a gradual transformation of the management practices to a "computer assisted water delivery control" system.

A necessary condition to ensure the link between Phase I and Phase II of the research project was to establish close collaboration with the managers of the system. The success of the application phase will be largely evaluated through their involvement, feedback and comments as operational users.

2. FIELD CONTEXT ANALYSIS

2.1 Design and organizational constraints

Technical: A complete description of hydraulic structures and canal characteristics is listed in relevant IIMI publications (see [B] and [C]). Cross regulators (14 in the first 25 km length of canal being modeled) are used to control water levels under different conditions of water conveyance in the main canal. Accurate control of water level is needed to control the diversion of water at the offtakes (the flow diverted being directly related to the hydraulic head above the structure). Any uncontrolled level fluctuations in the main canal are likely lead to unexpected variations of discharges at the offtakes and result in the manager being unable to respect his water distribution schedule (see [A]). The basic operational criterion is to achieve a targeted water level upstream of the cross regulators. This kind of regulation, commonly called upstream control, is aimed at reducing the influence of the downstream reaches on the upper ones.

Managerial: The Irrigation Department (ID) is in charge of operations and maintenance of the system. The Senior Irrigation Engineer (SIE) is responsible for water management and preparation of irrigation schedules in the new areas of the project. He will soon have responsibility for regulating the water issues to the old areas as well. He is assisted by different field staff working under the administrative and financial authority of the main canal resident engineers. An irrigation engineer O & M (Operation and Maintenance) provides the SIE with relevant field information and relays instructions concerning rotational operations on the RBMC. The irrigated land is divided into several tracts (areas), each of them assigned to one technical assistant controlling and monitoring a number of field operators (turnout attendants) and field supervisors (work supervisors). (Annex 2.1.)

The following remarks can be made in this context:

- The field staff do not appear to enjoy water management activities; the lack of clear rules of management and appropriate performance monitoring leads to demotivation and poor involvement in any improvement process. "The job can't be done properly, whichever way you act, everybody blames you, farmers and superiors". Construction or survey activities appear to be more attractive, especially from the financial point of view (allowances).

- Consequently, the technical expertise of the water management operators does not improve very much. Training and clear job descriptions are primary requirements for a stable and motivated staff, especially at the lowest, but key, level of departmental employees, the turnout attendants. Their actions, at both main canal and secondary canal levels, are not centrally coordinated. Their actions at the devices in effect become operations of the local "closed loop" type and are most inefficient due to lack of global guidance.

2.2 Present water management

The project has faced a dramatic problem of water scarcity perhaps due to underestimation of the annual water resource. A simple computation demonstrates that the potential irrigated area is significantly smaller than planned (Annex 2.2). Seasonal water allocation is roughly decided upon by dividing the project area as follows:

Part A (RB tract 1, LB tract 1, 2)	750 + 770 + 880	= 2,400 ha
Part B (RB tract 2, 5)	900 + 1000	= 1,900 ha
Part C (old areas)		= 4,000 ha

Cropping patterns during the past seasons:

Season	Part A	Part B	Part C
Maha 88/89	Paddy (Start December)	Paddy (Start September)	Paddy (Start October)
Yala 89	Nil: Maha ended too late	Paddy (April)	Paddy (March)
Maha 89/90	Paddy (Start November)	Nil: Start Paddy in November. Stop land preparation due to lack of expected rainfall	Paddy
Yala 90	OFC's 200 ha.	Nil	Paddy

The strategic decision to commence water issues is taken at the beginning of the Maha season if the storage in the reservoir is at least 70 MCM. Any increase of the cultivated area is allowed if there is sufficient rainfall thereafter. A primary characteristic of the system is that water is managed "expecting rain".

The management is trying to implement new agricultural practices, for example promoting the cultivation of Other Field Crops (OFC's) (chillies, onions etc) which require less water than paddy. It seems to be the only possible economical option to achieve the projected extension of the new irrigated areas to two other tracts (6 and 7). Nevertheless, the transition is difficult to manage and very few farmers have decided to participate in this first OFC experience. (The number of farmers currently involved is less than 25 percent of the planned target.) Although the cultivation of paddy is not authorized by the ID, rice cultivation has increased during June to an amount roughly estimated to over 20 ha(i.e., 10% of the authorized OFC area). Some farmers claim that they are using water from seepage losses of the main canal for this purpose. This is perhaps true in some areas (RB Tract 1) but many of them are probably conniving with OFC farmers who allow them to obtain water, or they resort illegal water diversions at night.

In this context of water shortage, any improvement liable to decrease the water wastage should be welcomed. According to the SIE, the major problem is to organize farmers to become responsible partners and to provide them access to efficient farm practices. Many settlers have limited experience of irrigated agriculture and their legal (or illegal) water requirements from the system are often overestimated. At the same time, the SIE agrees that further reflection is needed on how to improve his own monitoring of water deliveries. He recognizes that water could probably be saved by improved management practices. This assumption was explored by IIMI (see [C]) in 1989 and will be further highlighted during Phase II of the present research project. For the moment, management of water conveyance and distribution is quite a new concept in these irrigation areas and the systems are essentially monitored via a step by step, trial and error approach largely based on experience. The ID at Kirindi Oya is willing to test, with IIMI's support, a set of operational rules derived from the use of the RBMC simulation model in place of the present empirical practices.

Two types of water management have to be distinguished for further analysis: For paddy cultivation and for OFC's .

The water supplies to a tract under paddy cultivation are quite regular and the managers do not seem to have too many problems to match demand and supply except during the phase of land preparation. Adjustments to main canal water deliveries are supposed to be effected on a weekly schedule, thus preventing serious fluctuations in main canal water levels. Improvements are needed in operating the canal during transient phases (variation of main sluice discharge), and when unexpected events such as rainfall, illegal water issues etc. occur. At the field level, a lot of effort has to be made to reduce (or justify) the exceptionally high water use at the land preparation stage (0.8 m/ha for the 1st month).

This may be compared with the theoretical water requirement schedule given below:

Weeks	1	2	3	4		
(mm)	35	130	130	105	0.4 m/ha	(UPLAND)
	22	86	86	71	0.26 m/ha	(LOWLAND)

As observed during Yala 1990, supplying water to fields under OFC cultivation is difficult to achieve in an efficient way. Water requirements are irregular and farmers often do not follow the scheduled water rotations. The managers were constrained to try a veritable "on demand" system of water deliveries absolutely incompatible with the design. After a few days of this anarchic practice, the SIE decided to implement a simple rotation plan and to open and close all the offtake gates 2 days alternatively. No indicators were available to evaluate the efficiency of this type of water supply which was dictated by the willingness of ID to respond to farmers' water requirements without trying to "optimize" the process. The need for more accurate daily routine management is evident and will be more acute if the objectives of promoting OFC's throughout the system are to be achieved over the next seasons.

2.3. Inadequacies in main canal operations

Lack of coordination: Due to inadequate field feedback information, the SIE is unable to define and implement coordinated operations at the devices. Unnecessary and sometimes harmful gate adjustments at the cross regulators make it difficult to stabilize the canal level (see [A]).

Lack of water delivery performance indicators at the offtakes: The basic target of accurate discharge evaluation at the offtakes is not yet achieved by ID. The construction of Broad-Crested Weirs (BCW) in 25 of the 34 offtakes on the RBMC has led to improved assessment of instantaneous discharge at the offtakes. The concordance between discharges estimated by means of the BCW rating curves and some gauging performed in TRACT 1 is satisfactory. Nevertheless, a better routine estimation of water issues would permit the SIE to detect sometimes unsuspected oversupply and to quantify the effect over a whole cultivation season.

Lack of hydraulically optimized strategy to achieve specific operations: e.g.:

- Monitoring of main canal discharge variations
- Filling of the canal
- Appropriate reactions during and after rainfall

The model provides the opportunity to run as many tests as needed in order to define improved strategies. If adequate field data are collected, it will also be possible to monitor the daily functioning of the main system in order to detect and analyze deviations from the expected behavior.

3. A PEDAGOGICAL TRAINING TOOL

3.1 User's requirements

CEMAGREF developed specific user friendly interfaces for the Kirindi Oya RBMC model, so that it would be easy for ID staff to effectively use the innovative technology. Unfortunately, a computer capable of running all the possibilities of the model is not yet available at ID, Kirindi Oya. Graphic outputs cannot be displayed with the CGA monitor and the micro-processor speed is not sufficient to run long unsteady flow simulations within a reasonable time. Most of the applications of the model performed with the SIE during my stay in Tissa were therefore run on IIMI's own computer. As previously mentioned, I had the chance to work in close collaboration with the SIE, and the other IE attached to the Water Management Unit. Our first objective was to get a better knowledge of the possibilities of the software. The SIE already had some experience in running the steady flow unit of the model which is capable of accurately reproducing a given steady state of the canal; (the user can impose a target discharge at each offtake and reference levels at the cross regulators and the model will compute suitable openings of the gates along the canal). However, he had little experience about the unsteady flow unit which allows to follow the level and discharge fluctuations along the main canal that arise due to different operations at the devices and at the main sluice during a maximum simulation time of ten days. After this basic introduction to the model, we needed to check its reliability and the quality of the calibration by comparing field measurements and computed results. Only then were we able to think seriously about operational applications.

3.2 Methodology

To achieve our objectives, we formalized our approach in two different ways:

i) The model was used systematically to analyze and solve basic problems faced by managers. We initiated a kind of glossary of simple "case studies" for training purposes. The examples given below help to illustrate the possibilities of the model as well. (Annex 3.1)

ii) As much as possible, field/model interactions were performed. We focused our efforts on Tract 1 which was the only cultivated area this season. We regularly checked the steady state computational results against field water level measurements; we also compared computed and field results during some phases of unsteady flow. The results are given in Annex 3.2. The SIE requested the turnout attendants to note the time and amplitude of each operation performed at the tract 1 devices during the 30 June/31 July period of the study (Annex 3.3). We were then able to simulate the behavior of the canal and to monitor the amount of water diverted at the offtakes. The results are given in Annex 3.4. The SIE defined relevant outputs for this routine simulation activity which could be easily continued in an useful way (cf. Chap. 4, application 3) during the next Maha season.

4. APPLIED RESEARCH USING THE MODEL

4.1 Objectives

As previously mentioned, the hydraulic behavior of the canal reaches, especially during phases of unsteady flow is quite difficult to understand. Quantitative estimations of the different parameters are normally almost impossible without experience and field measurements. Most of the time the managers are thus not in a position to foresee the real impact of their decisions and they are thereby unable to elaborate optimized strategies. This dramatic lack of knowledge about the system can be reduced using the model as a decision support tool. Further research will be performed during the Phase II of the simulation modeling project to develop a systematic "problem solving approach" for the analysis of problems the managers have to face during a cultivation season and for identifying possible solution. This approach was initiated in the course of the present study by addressing 3 typical operational problems selected in consultation with the SIE.

4.2 Methodology

The SIE is well aware of most of the management problems created by the lack of a quantitative analysis tool; once the basic list of subjects to be explored is identified they could be prioritized in order to answer his particular requirements first. A selected, well formulated problem can then be analyzed (e.g. in terms of frequency of occurrence, importance, consequences); the present management response can be simulated by running the model and any inadequacies detected and quantified. Various proposals for improvement can be studied with the support of the model and then confronted with the actual operational context. Those which are likely to be implemented on the field, being compatible with available staff and communication facilities (or with a realistic adaptation of them), are formulated as operational strategies which are then tested on the system and evaluated.

4.3 Applications

4.3.1 Case 1: Readjustment of the system after water level variation in the main canal.

* Problem formulation by system manager:

"when we go to the field, due to one reason or another, the water level of the main canal is lower then FSD and also the discharge of the nearby offtakes is low. What can we do?"

* <u>Present management response</u>:

"increase the head sluice discharge until the main canal gets filled up to FSD level and then readjust offtake gates and sluice gate."

* <u>Analysis of the situation</u>:

A lot of unexpected operations are likely to fill or drain one or more of the canal reaches between the cross regulators. The frequency of such disturbances can be very high in critical phases of canal management. A relevant diagnosis is very difficult to perform without adequate knowledge of what the target state of the system should be in terms of gate openings. The lack of reference data regarding the positions of the devices does not allow the manager to detect any inappropriate operation, which may be the cause of the disturbance.

In order to readjust the water balance in the reaches, the discharge at the main sluice is increased without a clear strategy in terms of water conveyance from the head to the target reach. As indicated in [C], the conveyance function is not a primary concern for the canal managers who do not have a real perception of the possibilities of the system to "push" water from the upper to lower parts. MALATERRE showed that the water conveyance can, in certain cases, be optimized by appropriate operations at the regulators (see [A]):

- less operations at the cross regulators
- reduction of the time needed to stabilize the canal. Consequently, less perturbations at the offtakes.

* <u>Determining improved response</u>:

As indicated above, an appropriate answer would be facilitated by:

- the capacity to correctly diagnose the cause of the perturbation.
- the capacity to properly manage the filling of the affected reach(es).

a) Basic description of physical process:

+ Functioning of a cross regulator:

A steady state at a cross regulator can be considered as a compromise between 4 parameters: upstream and downstream water levels (UP, DOWN), discharge through the gates (Q) and gate opening (W), [a rough analogy with electricity concepts would be potentials (UP, DOWN), intensity (Q) and resistance (W)].

According to the usual hydraulic conditions of canal flow (subcritical), DOWN is controlled by the state of the canal downstream of the cross regulator. Q is normally scheduled by the manager and is equal to the head sluice discharge less the total flow diverted upstream of the regulator. Assuming that UP has to be maintained at a target level (FSD) to allow the required supply at the upstream offtakes in the reach, the goal of the operator is to "find" the appropriate value for the last parameter (W).

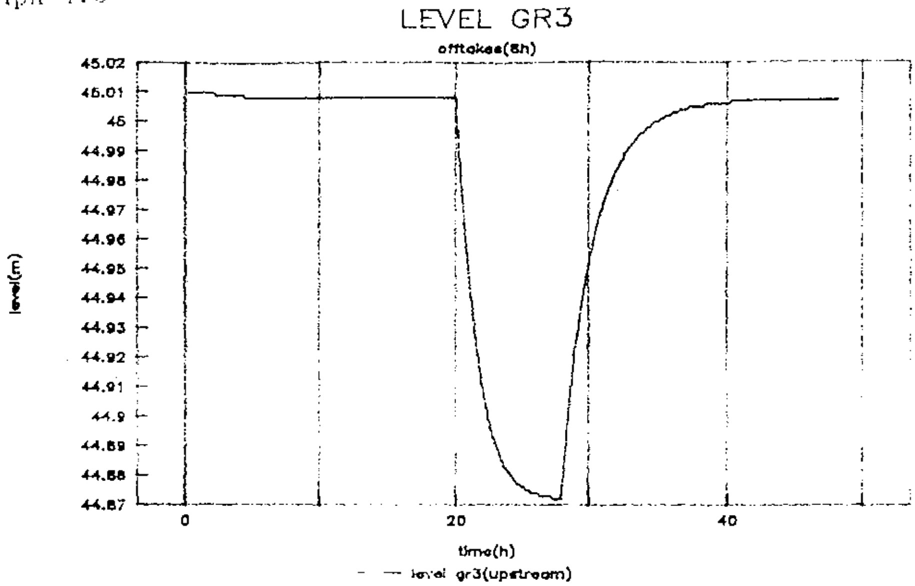
If one of the parameters: UP, W, Q is modified, the equilibrium of the system is affected and at least one of the other parameters is also modified. The same remark applies if parameter DOWN is modified, except in the case of free flow conditions:

In terms of a "physical system" the regulator has a "maximum capacity" of functioning for a given set (UP, W); if DOWN is decreasing, Q can increase upto a maximum value Qc for DOWNc (critical flow); any further decrease of DOWN will not affect (UP, W, Qc) . (UP, DOWN, Qc, W) is then a compatible set of parameters for any DOWN<DOWNc. The flow is "free" of downstream influence.

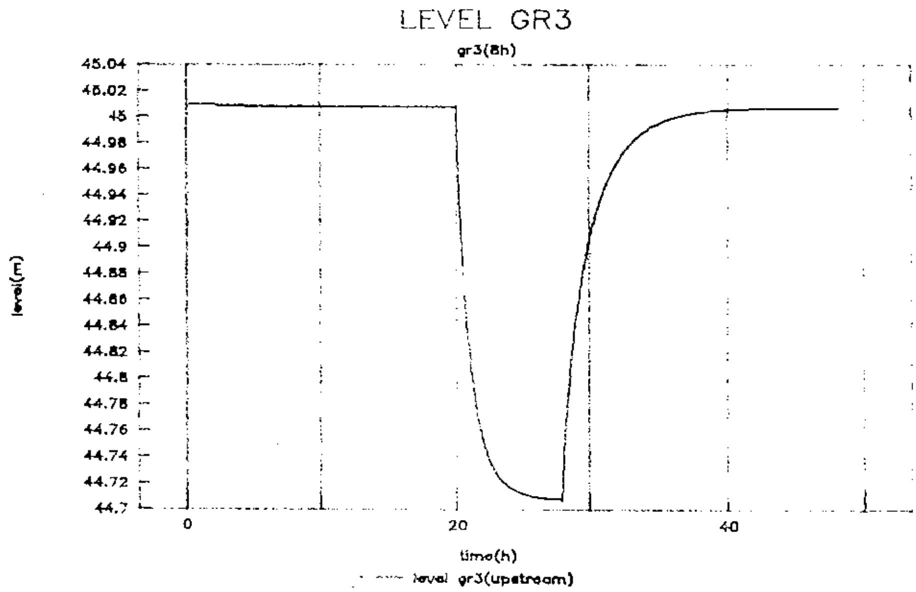
Examples of level variations at cross regulator GR3 due to 3 different causes are given below:

- Opening of a gate at GR3 during 8 hours (W) (Graph 4.0)
- Increase of the discharge diverted at the offtakes DC4, DC5 during 8 hours. (Q) (Graph 4.1)
- Opening of a gate at regulator GR2 during 8 hours. (Q) (Graph 4.2)

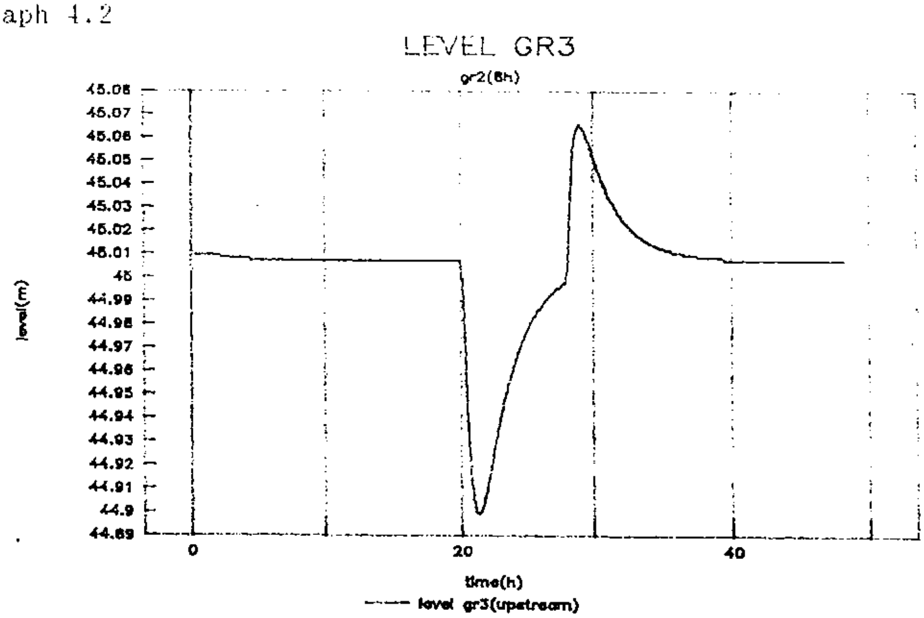
Graph 4.0



Graph 4.1



Graph 4.2



In each case, the set of parameters (DOWN, Q, W) is not linked to the target UP. A powerful application of the model is to provide the manager with a compatible set of parameters (DOWN, UP, Q, W) at each regulator for any particular steady state of canal functioning (see Chapter 3 Annex. 1.1).

+ Unsteady transition between two different steady states:

Transient phases of functioning can be described as continuous physical processes of readjustment of the parameters, in order to achieve a final system state compatible with the imposed external conditions (e.g., Q main sluice, set of W).

The management tasks are then the following:

- to achieve the expected final target state.

- to reduce the time of the transient phase.

A better understanding of the optimal dynamic way to adjust the external parameters controlled by the manager can be achieved by running the unsteady flow unit of the model.

b) Support for diagnosis:

Possible reasons for the observed low level in a particular reach:

(i) The set of parameters (DOWN, W, Q) has been incompatible with UP = FSD during a previous transient phase.

(ii) The set of parameters (DOWN, W, Q) is still incompatible with UP = FSD.

In the first case, the system is going from an unforeseen state back to the target state.

In the second, the system is either (a) in an unsteady state changing to an unexpected state, or (b) is in a steady state which does not correspond to the target state.

Checking the parameters:

The communications set-up and data recording have to be improved in order that the manager is made aware of any major perturbation that has occurred in any part of the system. The likely cause of the observed state of the canal (variation upstream: influence on Q), (variation downstream: influence on DOWN) may then be identified.

NEEDS: [Communication line between tracts]

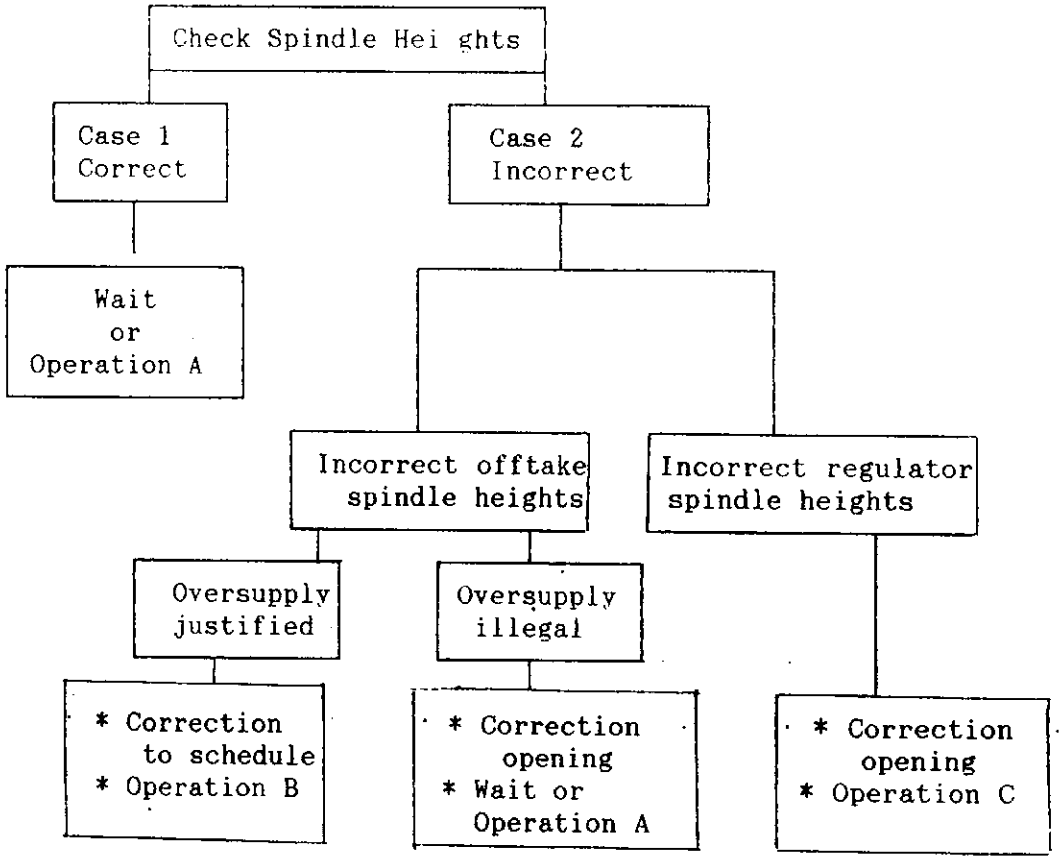
The manager should be able to detect, checking the spindle, heights, any local variation with respect to the expected positions of the devices.

NEEDS: [Daily record of targeted and actual spindle heights at the devices]

In the case of a non-local perturbation, the problem is transferred to another location.

In the case of a local perturbation:

Local Perturbation



- Operation A: Exceptional filling of a reach

This operation can be justified if the level is particularly low in the reach(es) and needs to be increased at a faster state compared to readjustments at the actual scheduled discharge (see below).

- Operation B: Increase of main sluice discharge

This operation has to be justified by a real and significant need for more water issues. The procedure to be followed is the same as the general procedure used for any scheduled variation of main sluice discharge. The basic requirement is the control of the water conveyance, (see [A]) and knowledge of the final canal state (use of Units 2 & 3 of the model).

- Operation C: Readjustment of a cross regulator opening

A possible procedure is described by MALATERRE (use of Unit 2 of the model) (see [A]). The basic requirements are:

* Inform the operators downstream that they should ignore the temporary perturbation generated

* Inform the operator upstream that (DOWN) will change and he will have to readjust (slightly, most of the time) his regulator

c) Operational responses:

Indications for Operation A:

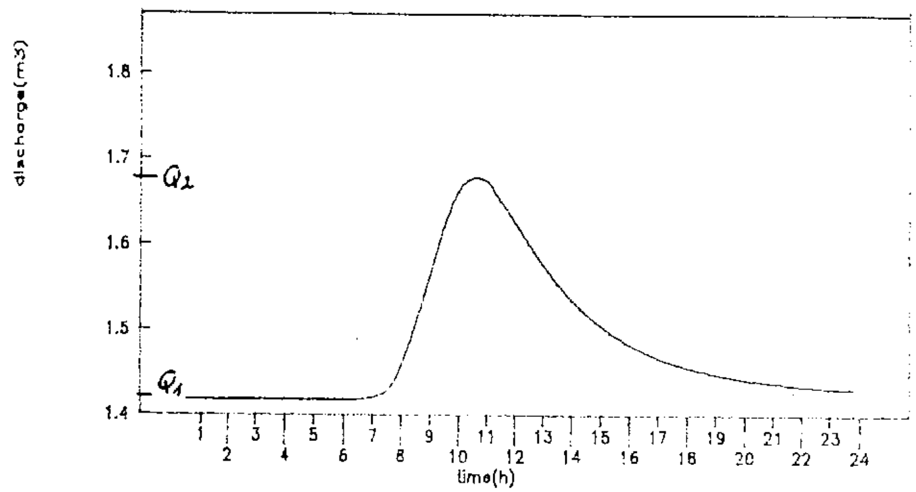
1) Objective: Fill a particular reach by increasing the main sluice discharge, avoiding level fluctuations upstream and downstream of this reach

2) Volume required: A rough estimation of the volume required can be obtained from the filling curves (volume/level at cross regulator) Annex 3.1.1

3) Wave conveyance:

Cross regulator upstream of the target reach:

Graph 4.3



Profile of wave

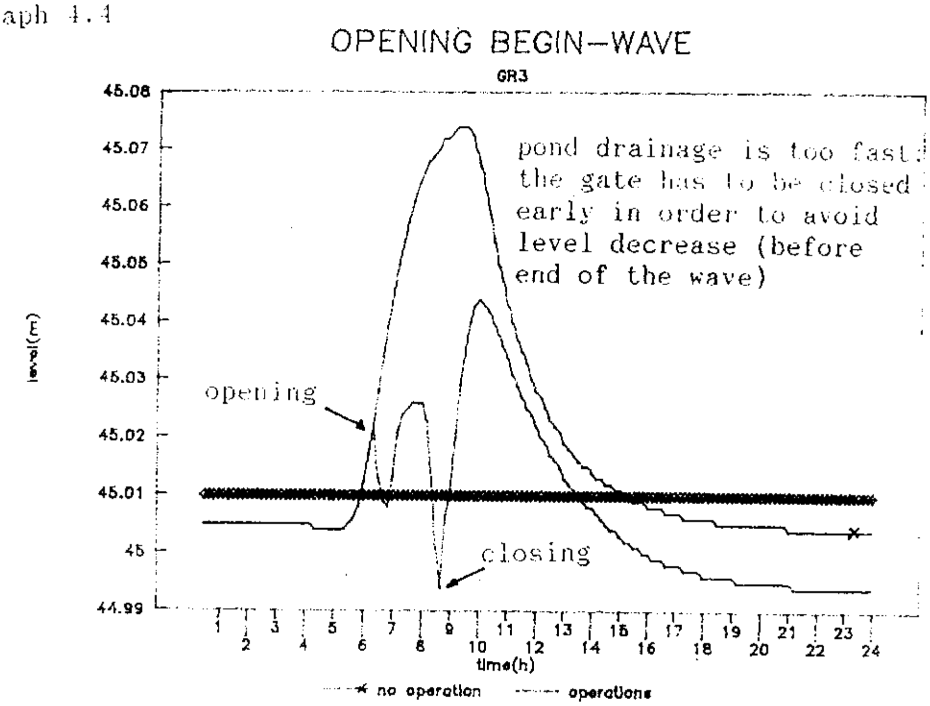
The set of compatible parameters has to evolve:
From (UP, $DOWN_1$, W_1, Q_1) to (UP, $DOWN_2$, W_2, Q_2),
then to (UP, $DOWN_3$, W_1, Q_1), maintaining UP constant.

This continuous process cannot be performed with the present device (continuous change of gate opening is possible in the case of more sophisticated gates like AMIL).

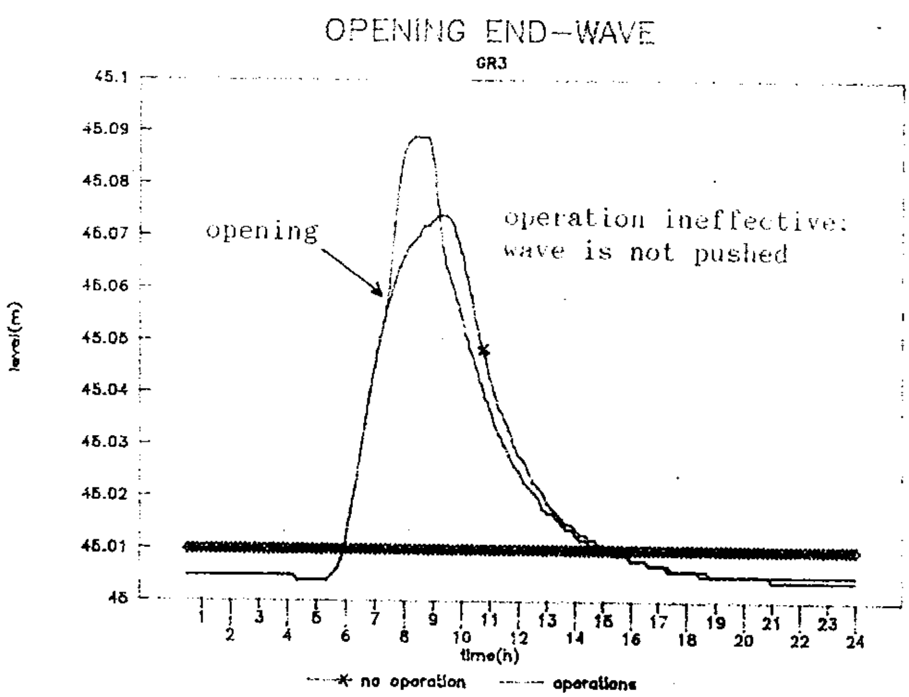
An obvious adaptation of this process to the operational context would be to approximately approach the optimal gate adjustment through two operations: one gate opening from W_1 to W_2, one gate closing from W_2 to W_1.

A mid-wave opening is a good compromise solution in order to avoid large water level fluctuations at the regulator.

Graph 4.4

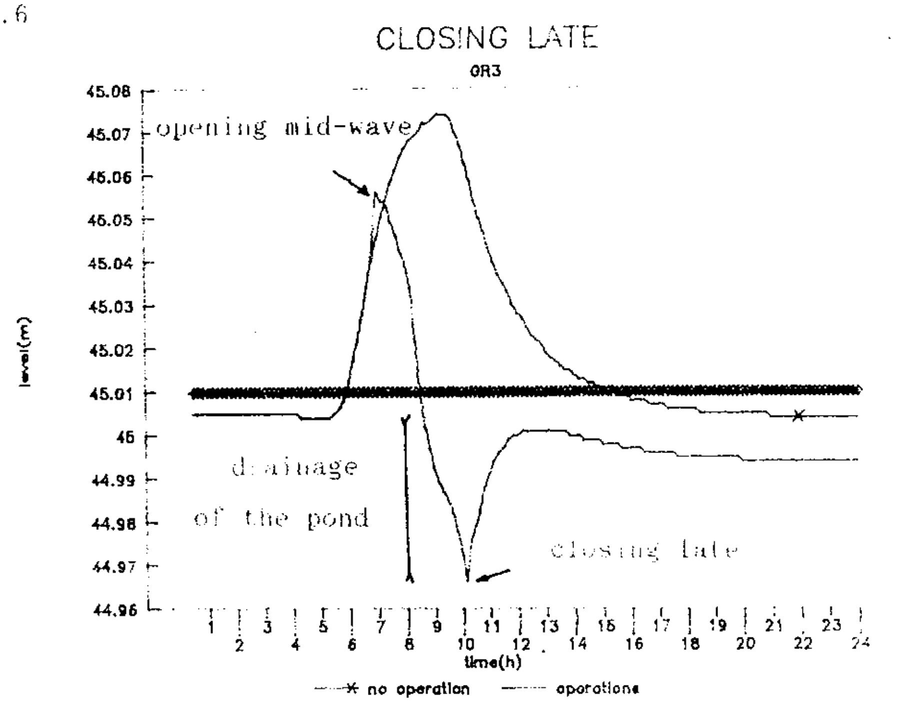


Graph 4.5



A late closing is likely to drain the reach causing unacceptable transient undersupply at the offtake thereby increasing the lag time needed for stabilization.

Graph 4.6



An early closing just after the beginning of the discharge decreasing phase is more appropriate.

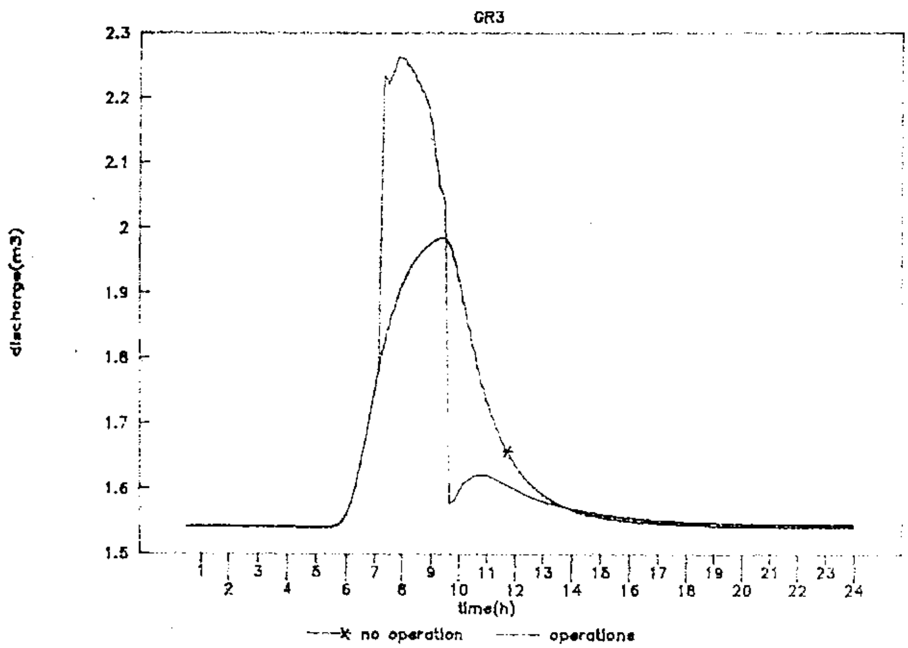
In terms of discharge, the results of an appropriate combination of the 2 operations is to "tighten" the wave:

- diminution of the diffusion effect
- increase of propagation speed

Graph 4.7

OPENING MID-WAVE

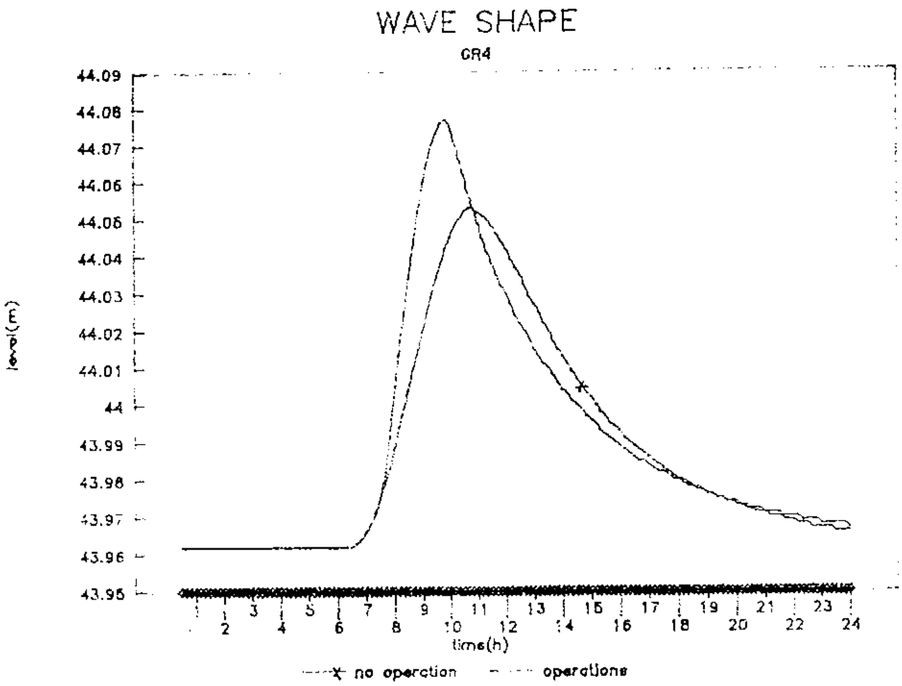
CLOSING EARLY



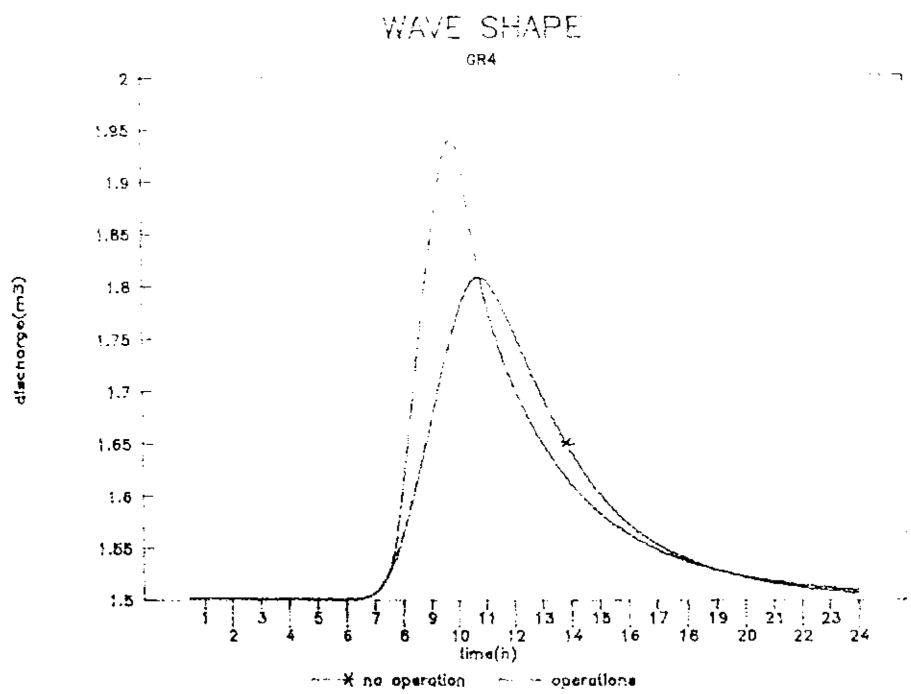
This systematic approach to push the wave at the regulator requires a lot of information about the shape of the wave and its time of occurrence.

Unfortunately, the shape of a relatively short wave is strongly modified by the above described treatment at the regulator.

Graph 4.8



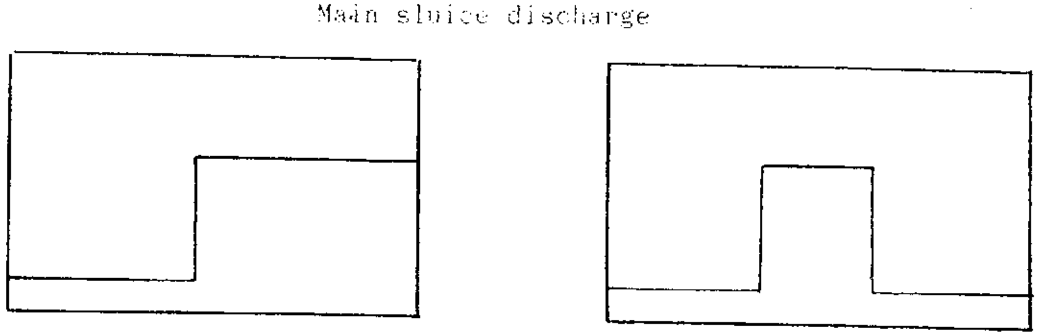
Graph 4.9



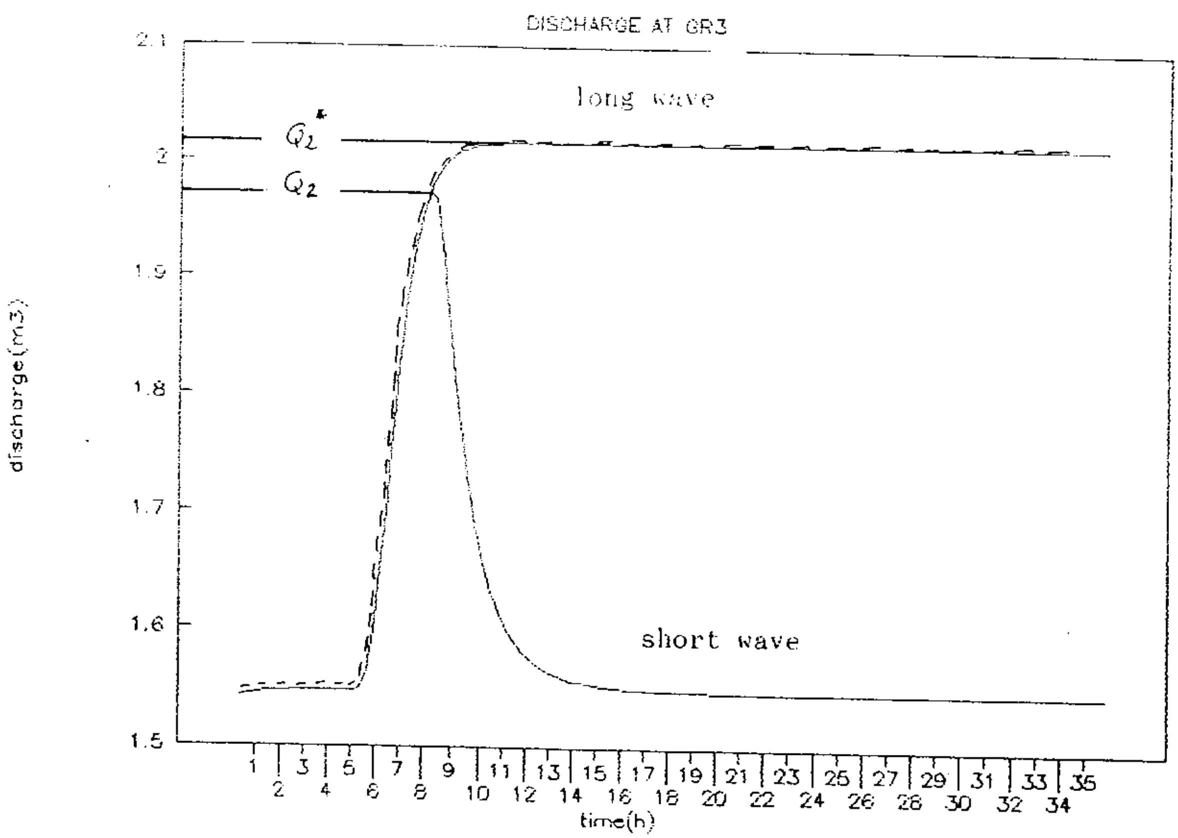
Wave shape at GR4 after operations at GR2 and GR3

Even in the case of conservation of the peak value, the W_2 opening is also very difficult to estimate a priori; because of the diffusion of matter with the propagation, Q_2 is not the discharge expected under steady flow with the same increase of discharge at the main sluice (progressive attenuation of the wave peak, extension of its base).

Graph 4.10



Graph 4.11



The opening obtained running the steady state unit with the adjustable gate option and adequate main sluice discharge W_2^* is an overestimation of W_2.

Nevertheless, a trial research of adequate strategy can be performed using the model:

* data acquisition
  - use of $W2^t$ as approximation (see example below)
  - observation of wave propagation, without intervention at the regulators
  - use of wave amplitudes as approximation.

* simulation
  - opening at mid wave
  - closing when the level reaches FSD after initial increase and decrease

* modifications for improvement

Cross regulator in the target reach(es):

The wave has to be stopped in order to fill the reach(es). A mid wave gate closure to W_j compatible with (FSD, DOWN, Q_1) allows to increase the level until FSD without significant perturbations downstream.

4) Example:

- Observation of a deficit in volume in pond [GR6-GR7]. The water level is 0.35 m below FSD: rough estimation of the deficit in volume= 6000 m^3, FSD is achieved in the other reaches.

- Increase of main sluice discharge: From $2 m^3/s$ to $2.5 m^3/s$ during 4.5 hours (between 5 and 9.30 a.m.)

- **Simulations needed:**

  i) **Steady state with adjustable gate at GR (2,3..,7); FSD level at GR [2,3,4,5,6,7]; main sluice discharge 2 m^3/s. Recording of gate openings $Wj^t(2)$.**

  ii) **Steady state with adjustable gates at GR (2,3,...,7); FSD level at GR [2,3,4,5,6,7] main sluice discharge 2.5 m^3/s. Recording of gate openings $Wj^t(2.5)$.**

  iii) **Steady state FSD level at GR [2,3,4,5,6] adjustable gate with measured low level at GR7; main sluice discharge 2 m^3/s. This state will be the initial state for unsteady simulations.**

iv) Unsteady computation: propagation of the wave without operations at GR [2,3,4,5,6,7]. Record the wave amplitudes: hj.

Results:	GR2	GR3	GR4	GR5	GR6	GR7
$Wj^1(2)$(m)	0.45	0.46	0.49	0.40	0.4	0.33
$Wj^1(2.5)$(m)	0.64	0.65	0.73	0.60	0.63	0.50
hj (m)	0.08	0.08	0.08	0.06	0.06	0.08

N.B. The offtake openings have to be maintained as measured on the field; (in this case DC2, DC3, DC4, DC5, (in Tract 1) and, DC1, DC2, (in tract 2) were opened).

N.B. In this particular case, only one gate per regulator was opened during all the simulations.

v) Unsteady flow computation: propagation of the wave with operations at GR (2,7). This computation can be easily performed using the regulation unit of the mathematical model. Intervention thresholds, (opening if: mid wave(m); closing if: FSD - 0.01(m)) and target gate openings have to be recorded in an ASCII file and the appropriate gate adjustments are then carried out by the model during the simulation.

Regulation File Output:

TIME	REGULATOR		LEVEL/SIDEWALL (cm)		DISCHARGE (m3/s)
	No		UP	DOWN	
6H20	2	WAVE HERE	4.07	-55.72	2.08
6H40	3	WAVE HERE	4.41	-66.07	1.72
8H10	4	WAVE HERE	4.65	-59.25	1.55
8H30	5	WAVE HERE	3.77	-46.62	1.39
9H00	2	WAVE END	-1.85	-54.41	2.19
9H00	6	WAVE HERE	3.66	-64.68	1.31
9H50	3	WAVE END	-2.05	-60.33	1.96
10H30	4	WAVE END	-1.50	-54.74	1.91
11H00	7	WAVE HERE	-3.81	-94.53	1.31
11H10	5	WAVE END	-2.14	-40.56	1.76
11H10	7	WAVE END	-1.39	-96.78	1.10
11H40	6	WAVE END	-1.57	-37.07	1.72

- Analysis of the graphical results; Proposals and tests of improvements:

> The results presented below were obtained with the first approximations. The situations at the regulators (level upstream and discharge) are drawn in both cases (operation and no operation). Graphs 4.12 to 4.19.

Remarks: FSD is achieved 6 hours after main sluice discharge increase.

The level fluctuations upstream and downstream of the filled pond are acceptable.

FSD - 1 < GR4 < FSD + 6
FSD - 2 < GR5 < FSD + 4
FSD - 1 < GR6 < FSD + 3
FSD < GR8 < FSD + 2

Improvements could be obtained at GR4.

The volume released seems to be slightly overestimated.

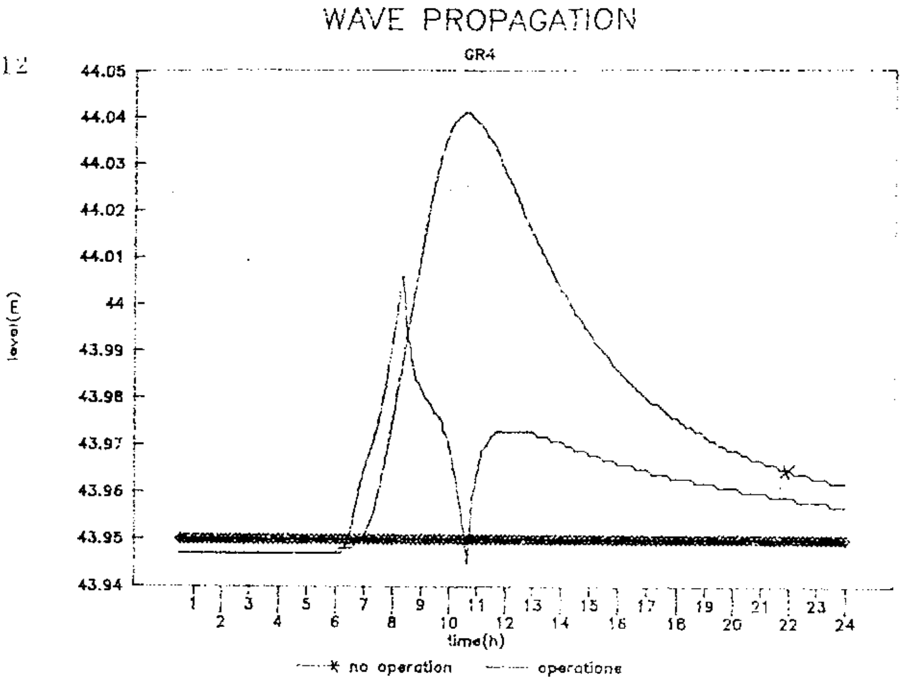
> Field application: Relevant information can be transferred to the field staff.e.g. approximate times of intervention, indications in terms of wave height, amplitude of openings etc.

e.g. GR4 : operations between 0800 and 1100

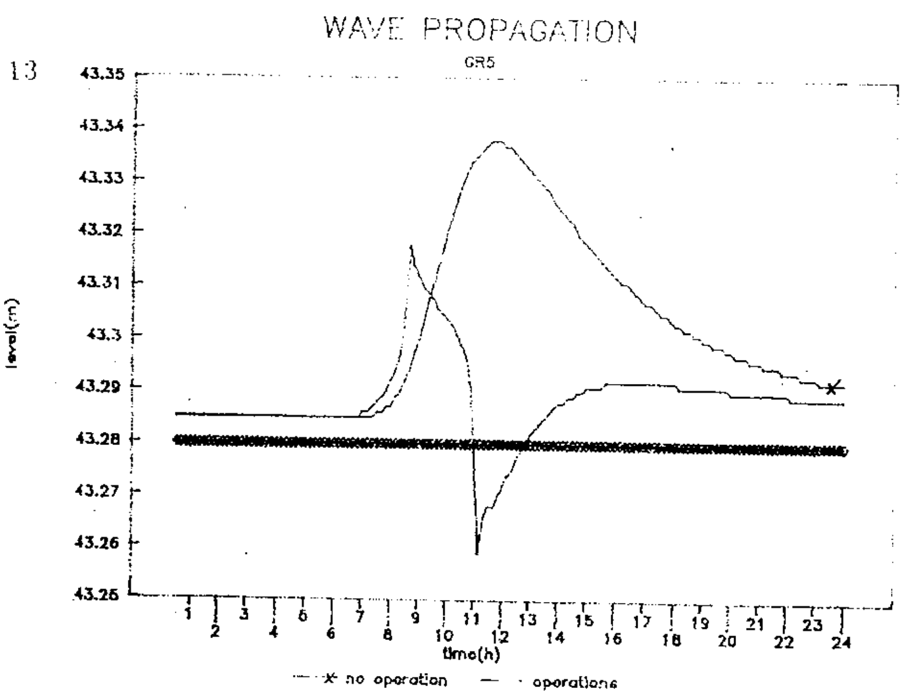
Time 1	=	0810
Level 1	=	FSD + 0.04 m
W_2 Gate 3	=	0.73 m
Time 2	=	1030
Level 2	=	FSD - 0.01 m
W_1 Gate 3	=	0.49 m

Levels:

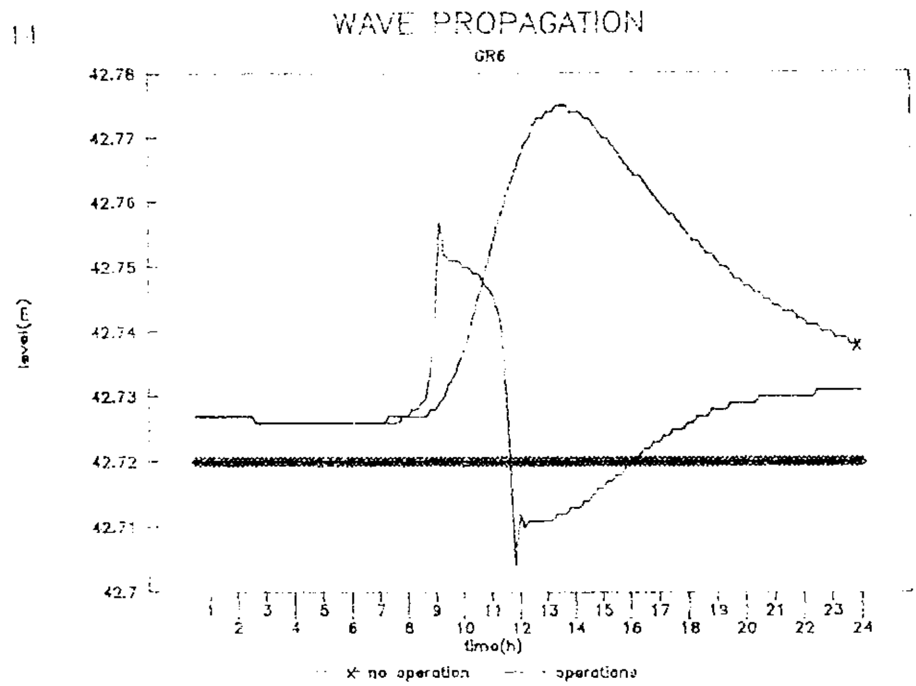
Graph 4.12



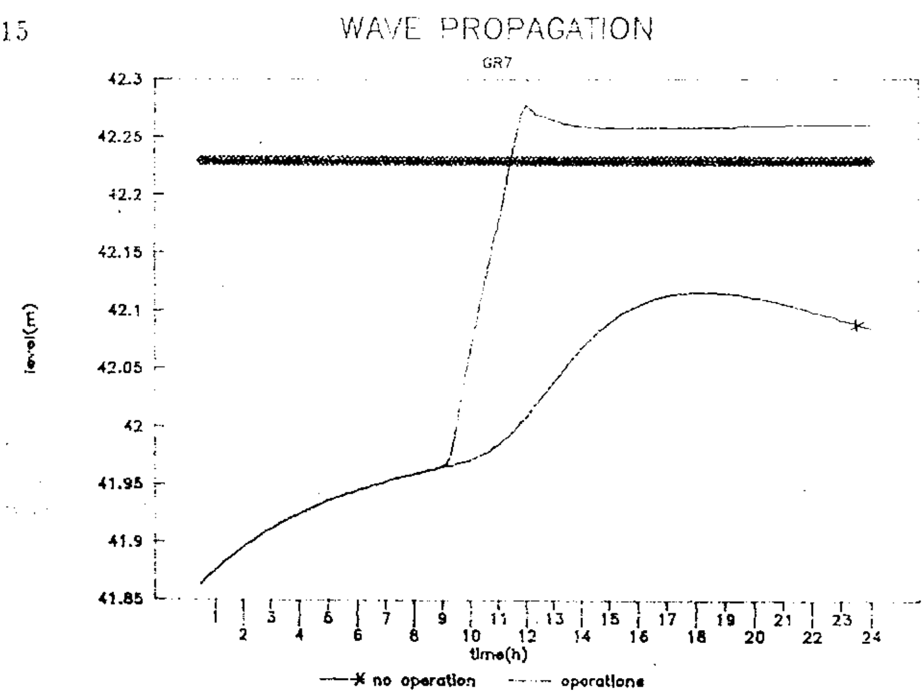
Graph 4.13



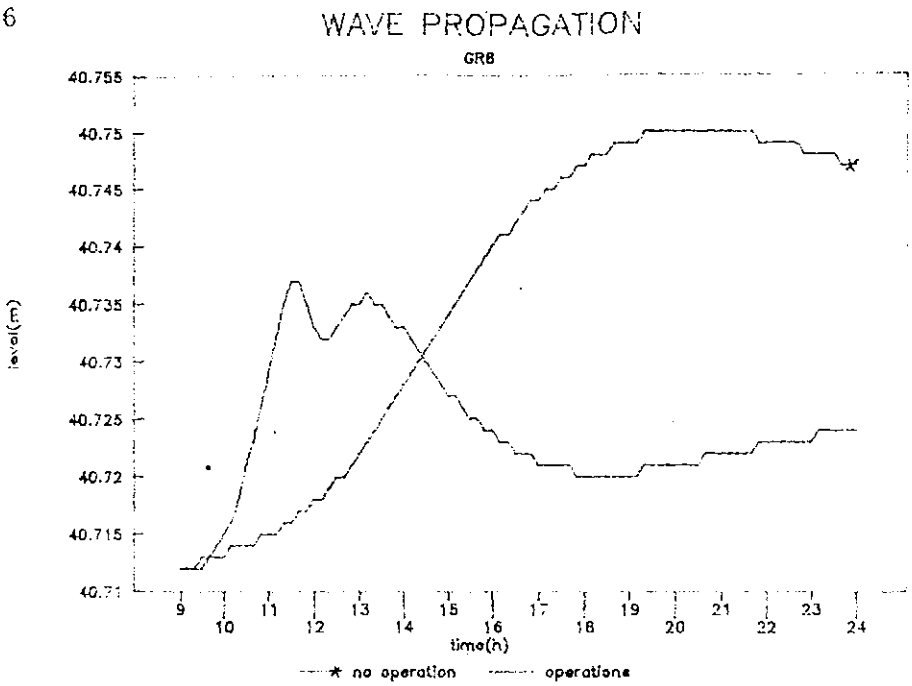
Graph 4.14



Graph 4.15

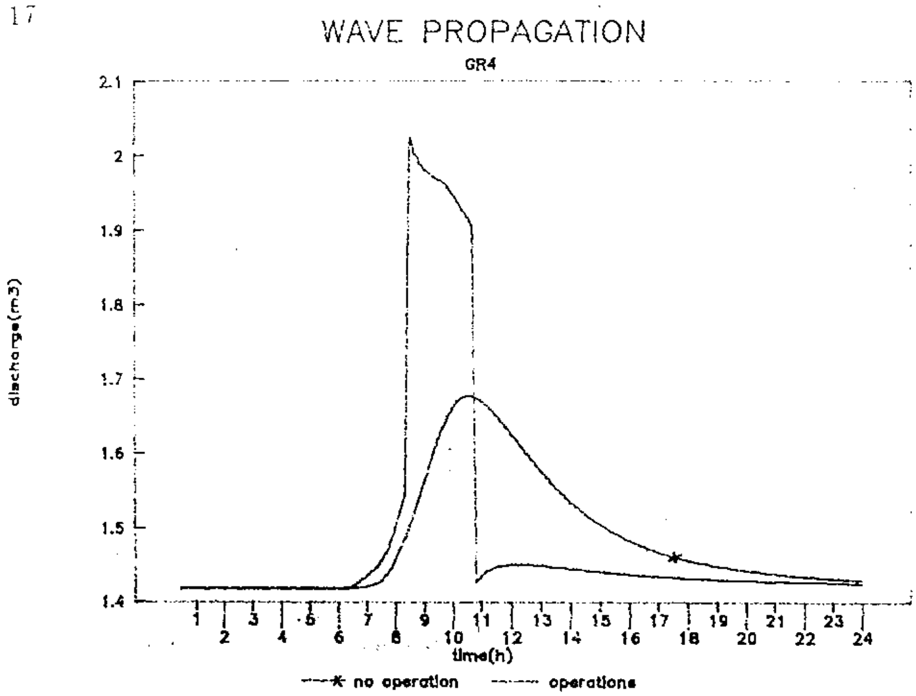


Graph 4.16

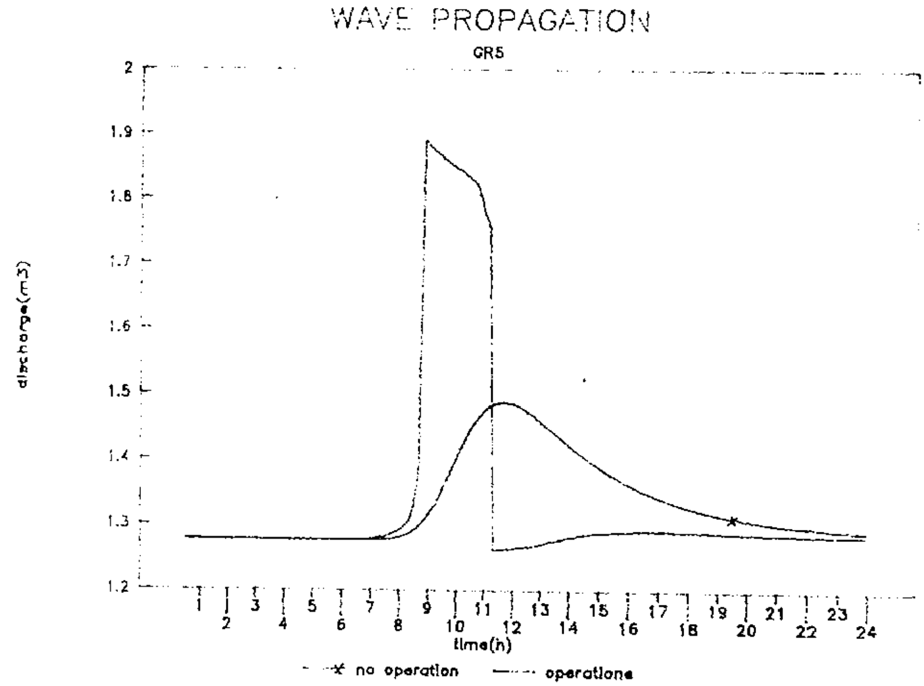


Discharges:

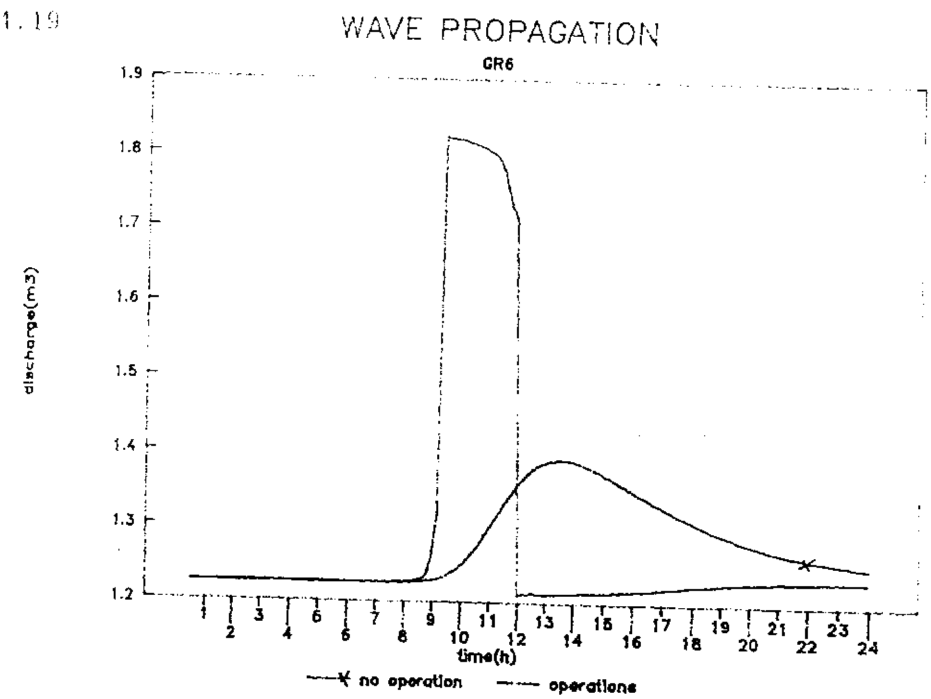
Graph 4.17



Graph 4.18



Graph 4.19



4.3.2 Case 2: Strategy in response to rainfall

* Formulation of the problem by system manager:

1) "There may be a chance of rainfall occurring in TRACT 2 area and no rainfall in other areas. Normally, when the rainfall occurs, turnout attendants close the DC, FC and regulator gates. How to readjust the canal downstream?"

2) "Heavy rainfall may occur in the project area. Which response to adopt?"

* Present management: response:

1) "Adjust some gates, by trial and error."

2) "Close the main sluice, regulators and offtakes."
In the case of severe rainfall (15 mm), SIE estimates the volume of water resulting from this extra supply (converting the mm depth recorded by one of the meteo stations) and reduces the discharge by the same amount of water during 1 or 2 days at the main sluice and the DCs.

If the rainfall reaches a critical amount of 20 to 25 mm, the main discharge is dramatically reduced to 20 cusecs (empirical minimum required to maintain the level after compensating for losses) and the regulators are closed during 2 days. The exact procedure of opening and closing is not specified.

* Analysis of the situation:

1) Without any coordination between the tract operators the increase of main canal discharge due to the non-issue of water to upstream offtakes is likely to create dangerous oversupply or overtopping in downstream parts of the main canal. If informed of the perturbation, the SIE would be able to determine appropriate operational reactions, using the model, and to give instructions downstream.

NEED: [means of communication]

2) The SIE has to face severe problems stabilizing the canal water level when the water issue at the main sluice is increased again. The only physical parameter taken into consideration to elaborate the procedure is an empirical estimation of lag time for the water conveyance from main sluice to the different tracts.

* Determining improved response:

1) In case of significant reduction of water issue in a tract, the model can be run with the opening computation mode in order to obtain the corrections needed at the offtakes still open downstream of the perturbed area. As shown in Annex 3.1.5, rough but efficient operations can be performed in order to avoid oversupply and any change at the regulators.

Remarks:

* Resulting increase of discharge in the main canal:

- by simulating the suggested strategy, it is possible to verify that the increase of level is not liable to cause overtopping at critical sections. If it is not the case, another procedure has to be envisaged including opening at cross regulators. Special care has to be taken at the sections above the syphon. The possibility of trash blockage may cause a danger of overtopping. Nevertheless, as far as possible, temporary changes at the cross regulators have to be avoided in order to facilitate the return to an adequate steady state after perturbation (general remark).

- The capacity of water storage in the downstream areas (Badagariya system) enable the manger to divert overflow to the tail of the RBMC without considering this transfer as water losses. This feature is used and integrated in the global management of Badagariya system.

* End of perturbation:

The procedure is exactly identical to the previous one, considering a decrease of main discharge instead of an increase. After opening of the upstream offtakes, adequate openings have to be performed downstream in the same way (time and amplitude of operation).

* Basic requirement:

- The crucial point is the capacity of information transfer between the tracts (work supervisors' offices) and the SIE office.

  + Time of rainfall occurrence, importance, request for closing the offtakes (from field to SIE).

+ Real time instructions downstream after simulation (from SIE to field).

- A systematic update of the data file allowing to simulate the state of the canal (weekly schedule at the offtakes, daily collection of major modifications) should enable SIE to compute different scenarii of evolution in a time interval compatible with field intervention requirements.

2) According to the exceptional decision of total interruption of the water supply, including main sluice issue, the critical phase of filling has to be faced after 2 days. Once again, an appropriate procedure can be identified by running the model to bring the system to the target state:

Reach by reach: opening of the cross regulators when FSD is achieved

opening of the offtakes (target opening)

a) Complete procedure: indications

* <u>Simulations needed</u>:

1. The steady state unit has to be run with a low main sluice discharge and adjustable gate mode selected at the regulators in order to achieve the levels observed in the field. (Small openings should be obtained.) This state will be chosen as the initial state.

2. Run steady state unit with adjustable gate mode and FSD as target level at every regulator. The offtakes are opened for the targeted water deliveries (openings calculated by the model).
Record of cross-regulator gate opening: Wj
Record of offtake gate opening : wj

3. The unsteady unit can then be run using the regulation module : regulators are opened when FSD is achieved as upstream level. Times of intervention are saved in regulation output files.

* Field Operations:

Opening of the cross regulators gates reach by reach.

After completion of the filling phase, all ponds are full with overtopping above the sidewalls. The offtakes can be opened at the same time to the target value. Inequity upstream/downstream is then avoided and time of filling phase minimized. (Another solution would be naturally to open the offtakes reach by reach immediately after filling. This procedure will be preferred in the case of high scheduled water supply in upstream parts liable to cause unacceptable overtopping downstream during a strict filling phase without deliveries at the offtakes.) The temporary oversupply due to the high water level in the main canal can probably be used to fill the DCs faster.

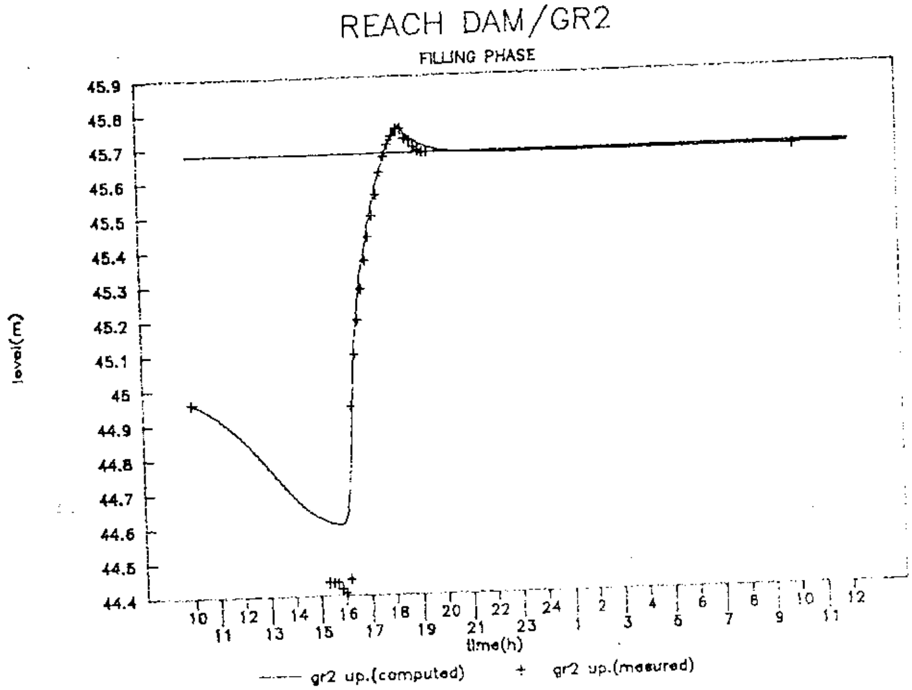
b) Partial Operation: field case description

On 6th August, offtakes and main sluice are closed. On the morning of the 7th (10 a.m.), GR2 and GR3 are opened so that the first 2 ponds were drained. In the afternoon, the level in the main canal is very low. Upstream levels:

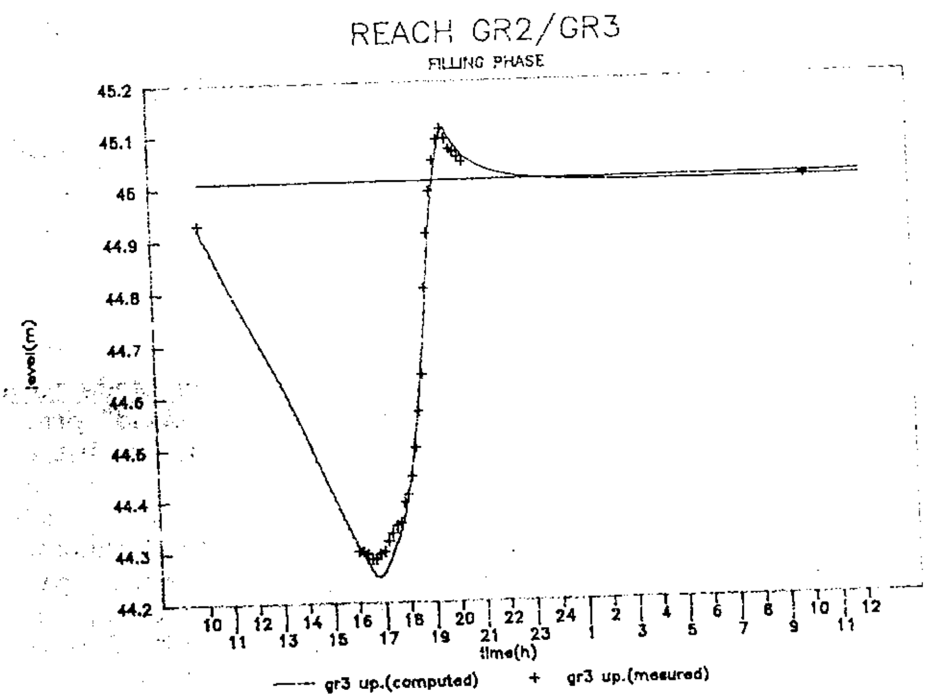
At 1520: -124 cm at GR2
At 1600: - 71 cm at GR3

The SIE had scheduled an increase of the main sluice discharge up to 100 cusecs (2.8 m^3/s) in order to supply water to Badagariya system. The opportunity was taken to observe the filling of the first 2 reaches of the canal and to test the computed openings likely to ensure FSD level at GR2 and GR3 under 2.8 m^3/s. Main sluice was opened at 1520. The first pond (DAM-GR2) was filled in two and a half hours; GR2 gates were then opened to the target values after observation of a short phase of overtopping. FSD was achieved a steady state. The same operation was performed at GR3 and FSD level was achieved as well. Graphs 4.20, 4.21.

Graph 4.20



Graph 4.21



Using the model outputs: - approx. time of intervention

- amplitude of opening

The filling phase can thus be optimized in this way (pond after pond filling).

4.3.3 Case 3: Efficiency of water delivery at the offtakes; tools for evaluation:

* Problem formulation by system manager:

"Indication for diagnosis and appropriate corrections in case of divergence from the scheduled water supply in offtakes on the main canal."

* Present management and evaluation method:

The operational target of the turnout attendants is to maintain a given head over the control weir downstream the offtake (approximate rating curve). The value is calculated according to the water issues schedule (prepared by SIE) by the irrigation engineer and the technical assistants and performed on the field by adjusting the gate opening by trial and error.

The evaluation criterion is assumed to be the satisfaction of the farmers (direct feedback to field staff and remarks in a Tract Complaints Book).

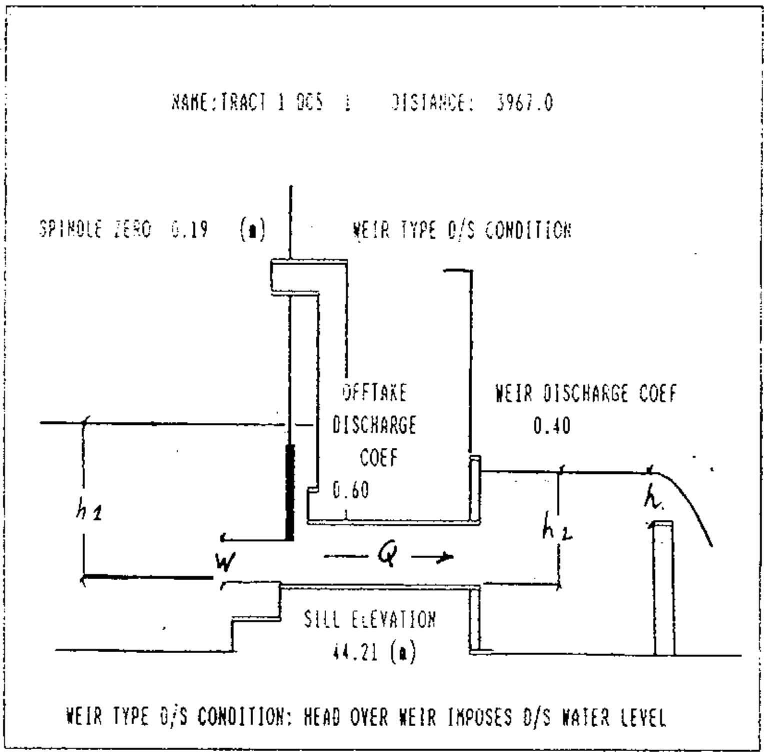
* Analysis of the situation:

The lack of reliable quantitative indicators leads to a progressive deviation of the system management to "on demand" practices without clear indication of the consequences of this evolution in terms of volume diverted. ID assumes that a flexible water supply policy is necessary in order to satisfy the farmers. Indeed, excessive centralization and strictly imposed schedule cannot be seriously promoted in a management context where farmers' participation is searched and strongly encouraged. However, a process of concertation and perhaps a better assessment of real duties could contribute to avoiding a progressively dangerous introduction of unscheduled local "closed loop" procedures (increase of water issues by opening offtake gates or closing cross regulators at the local field level.)

* Determining improved response:

a) Basic functioning of offtakes

Graph 4.22



As described in case 1 the set of parameters involved is (h_1, h_2, W, Q). In case of free flow conditions Q can be evaluated knowing h_1 and W; if the offtake is functioning under submerged conditions Q is then connected to the whole set of parameters (h_1, h_2, W). In order to facilitate this assessment of the discharge a simpler device is used just downstream of the offtake: a control weir. In the case of free flow conditions at this weir the discharge Q depends directly on the head over the weir h and a rating curve can be used. In the case of submerged flow, downstream perturbations in the FC or DC are likely to strongly influence h and Q and the use of a rating curve is then totally inefficient.

The hydraulic calculation performed by the mathematical model takes into consideration the whole configuration and an adequate downstream weir rating curve can be selected according to the characteristics of the weir. A preliminary study which will have to be done in Phase II of the research project is an exhaustive checking of the conditions under which the weirs function (design modifications were implemented since the calibration campaign; the original weirs are being progressively replaced by broad crested weirs).

b) Diagnosis of malfunctioning

Several measurement campaigns (see [A], [B], [C]) involving accurate discharge assessments have highlighted the tendency of oversupply at the offtakes. Different reasons can be put forward when deviations from the SIE's water supply schedule are observed.

A - Incorrect assessment of the discharge by the operator due to inadequate rating curve at the weir or temporary submerged conditions: lack of knowledge.

B - Unexpected water level variation in the main canal without corresponding correction of the offtakes opening: lack of control.

C - Voluntary deviation from schedule:

+ response to farmer's requirements.

+ specific problem: phase of filling DC (discharge is temporarily overestimated in order to increase the speed of the wave front). (Further research has to be performed to optimize this process: indications for time and amplitude of the oversupply).

The different causes have to be distinguished for relevant analysis and estimation of priorities in the search for improvements. The relative importance of this can vary from one offtake to another as well as the amount of over or under supply in volumes diverted.

A routine data collection and simulation activity (see Annex 3.3, 3.4) should be liable to provide the information needed for such an analysis.

c) Example of data processing

As mentioned above, the irrigation activity was exceptionally low during the study period. The following indications should therefore be interpreted more in terms of methodology than results.

DC5/DC3 TRACT 1:

Steptime: 4 days (schedule period)

Period of observation: 30 June/31 July

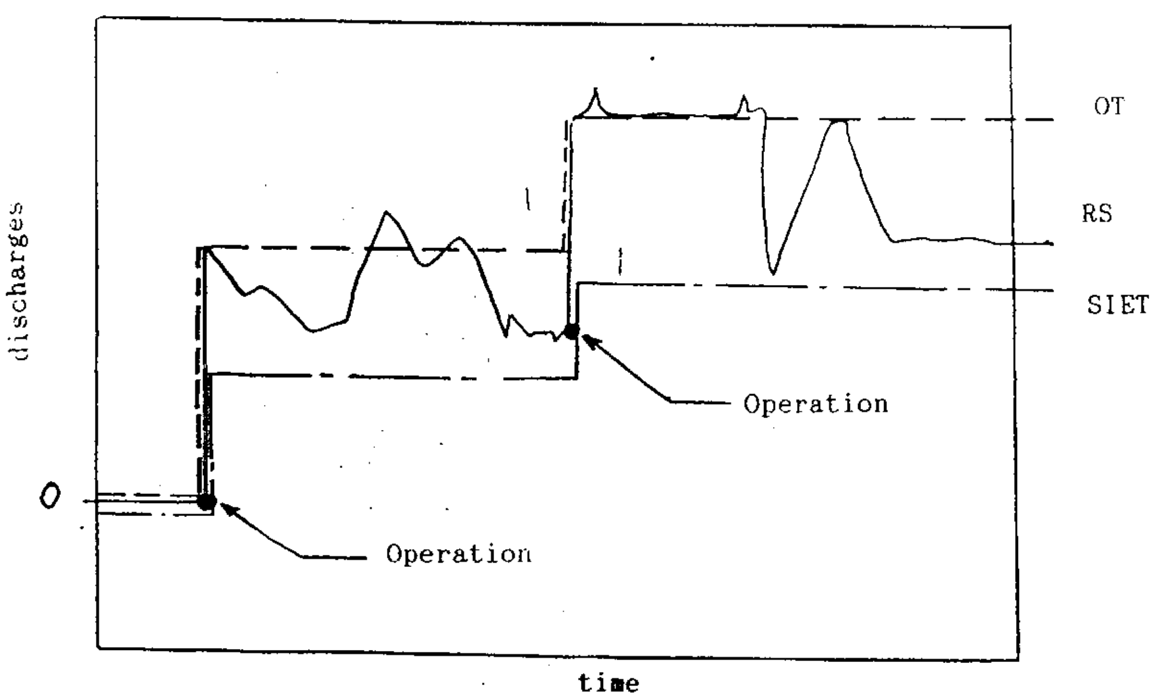
Activities required: recording spindle heights (time, amplitude of adjustments)

regular steady state verification and measurement

unsteady simulations

Indicators: The discharge computed just after the operator's intervention is considered as the operator discharge target (OT). For reason A or C, it can be different from SIE target, (SIET). The evolution of main canal level is then likely to create deviations from OT so that the real supply (RS) can be quite irregular.

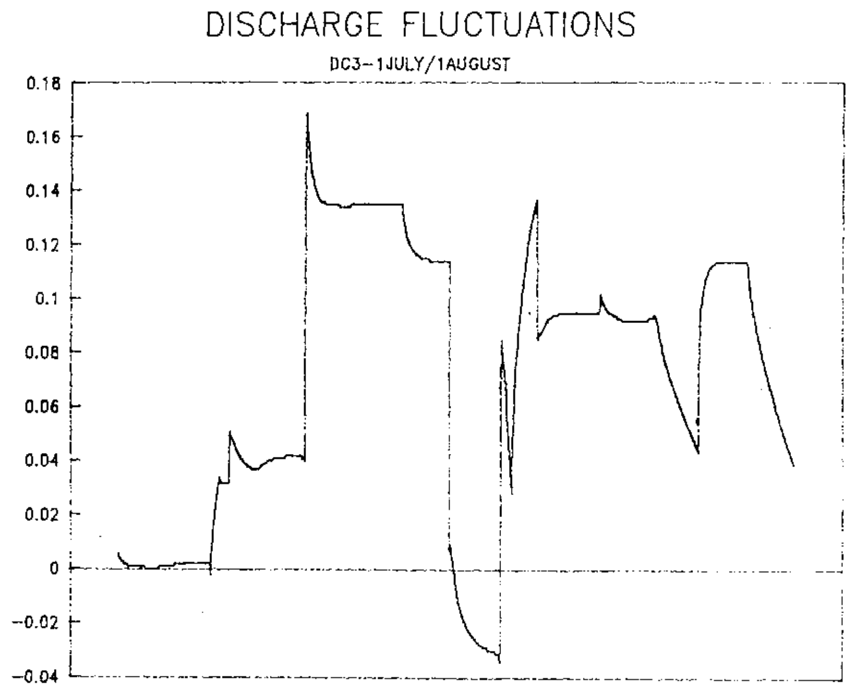
Graph 4.23



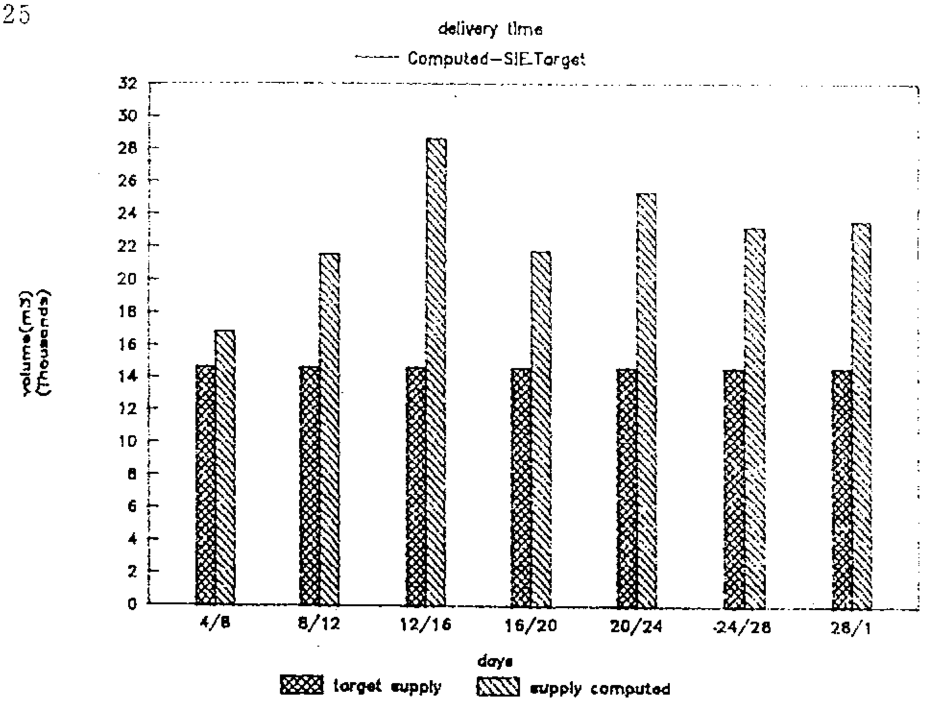
1) <u>Indicator 1</u>: <u>GAP1 = RS - SIET</u>
(Sample: time of water deliveries)

Example: DC3, (1 July/1 August)

Graph 4.24



Graph 4.25

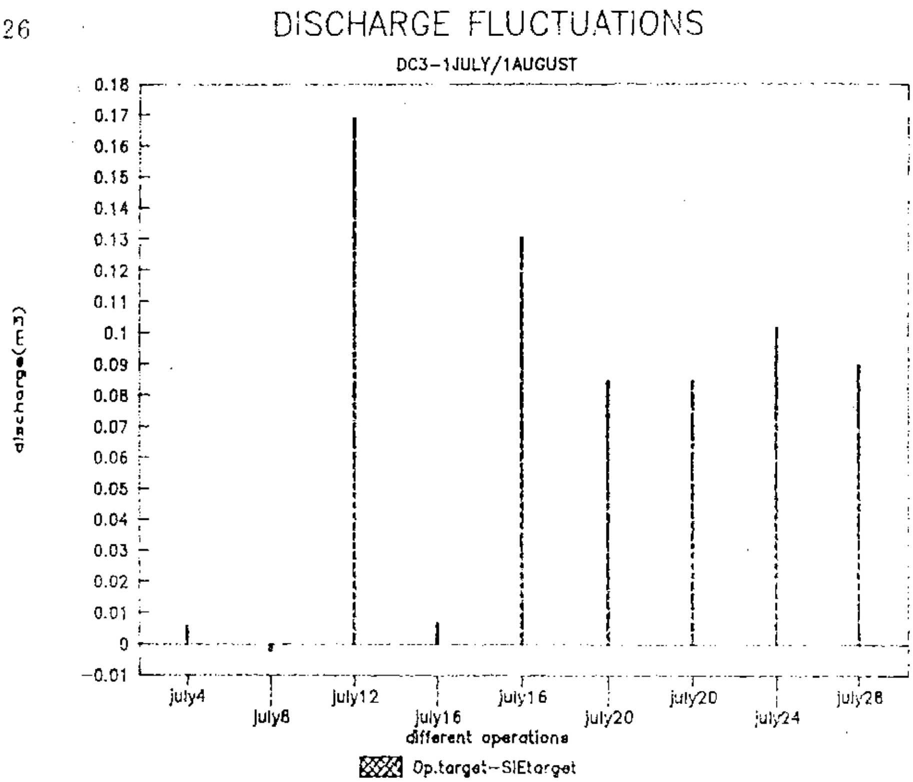


This indicator points out the global deviation from schedule. In this case, clear oversupply is observed.

2) <u>Indicator 2</u>: <u>GAP2 = OT - SIET</u>
(Sample: different operations performed by the operator)

Example: DC3, (1 July/1 August)

Graph 4.26



This indicator points out A or C problem situation. Further investigations can be performed if deviations are observed:

- reconsideration of water duties in the area

  and/or

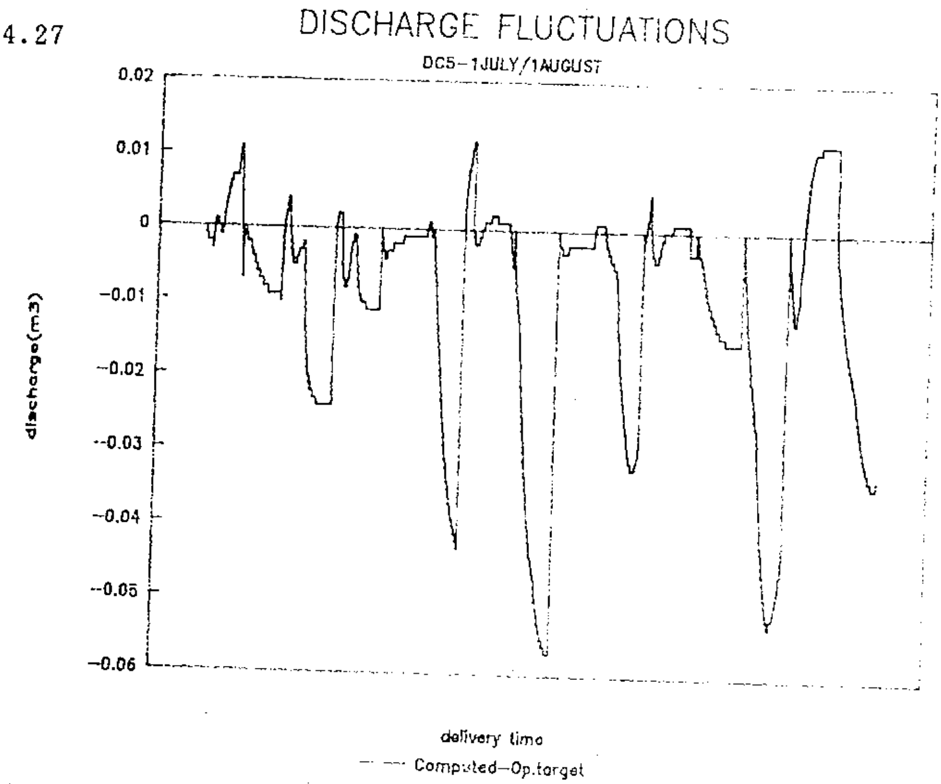
- weir calibration and checking conditions of its hydraulic functioning.

Graph 4.25 shows that the operator managed to achieve the target discharge (e.g.: July 4, July 8, July 16). The graph also shows that the operator responds to farmers' requests for water (flexible supply), which are usually more than the scheduled water requirement.

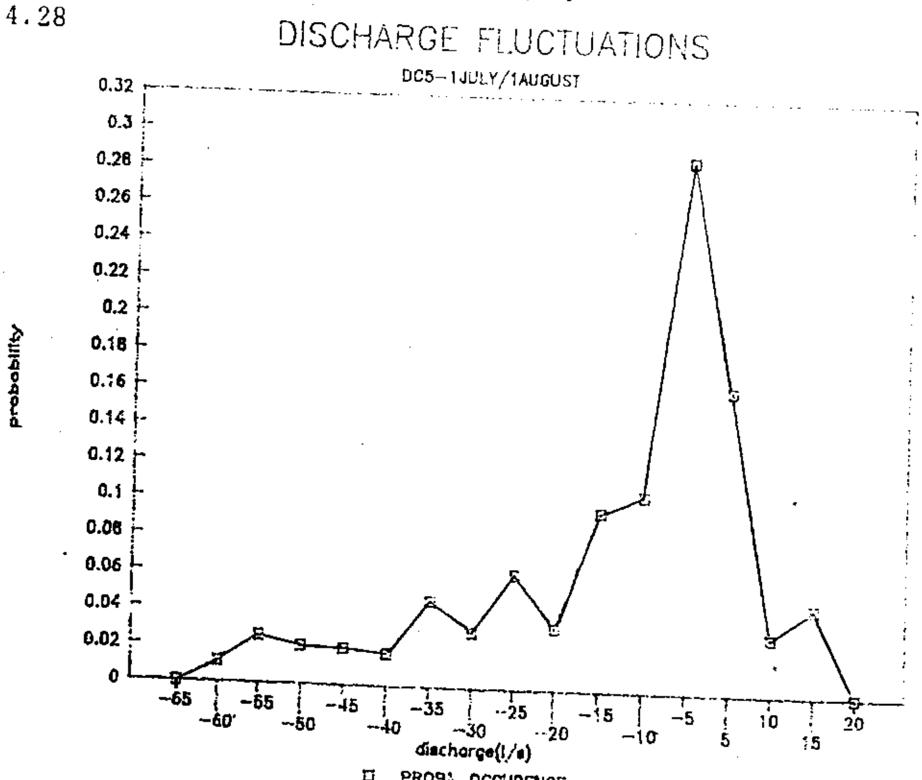
3) Indicator 3: GAP3 OT - RS
(Sample: time of water deliveries)

Example: DC5, (1 July/1 August)

Graph 4.27



Graph 4.28

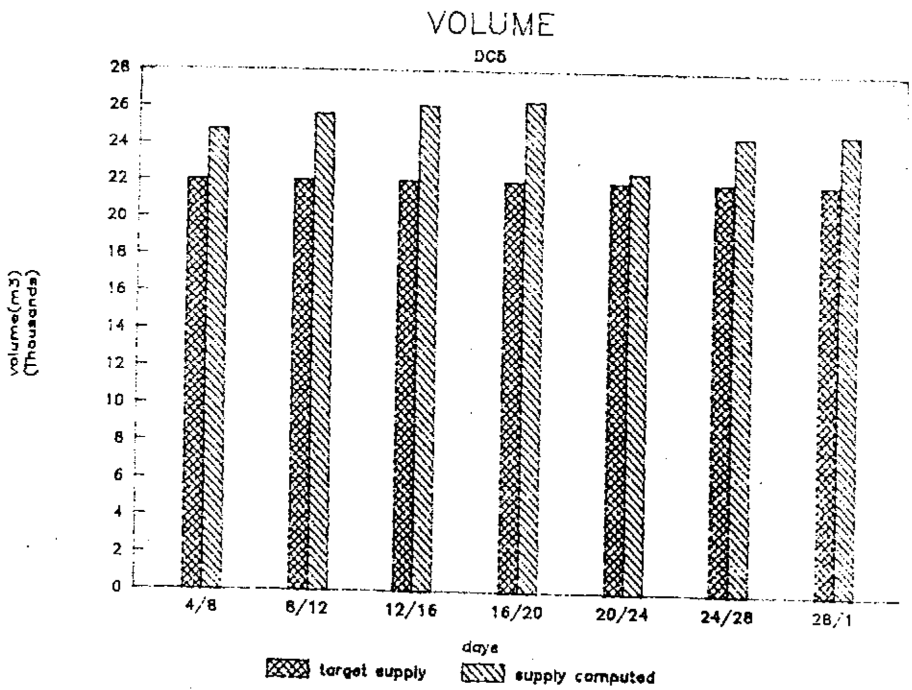


This indicator is likely to highlight situations where offtake discharges are significantly affected by water level variations in the main canal. In this case (graph 4.25), mean discharge gap due to level fluctuations in the main canal is -11 l/s, which causes a gap of volume of about -6500 m^3/s.

These values should be compared with:

- mean target delivery (SIET) of 250 l/s and,
- global oversupply (indicator 1 for DC5) of +20000 m^3:

Graph 4.29



5. REFLECTION FOR PHASE II

5.1 General Scope for a Management Assisted by Computer

* The first major interest of a simulation tool is to provide a real time overview of the whole system state, indispensable to articulate and achieve coordinated routine or exceptional canal operations. The SIE in charge of water management in the Kirindi Oya Project appreciated this new and powerful way to get a real knowledge about his system. If further technical involvement from IIMI appears possible in the near future he would be naturally interested in the development of a more comprehensive model encompassing both LB and RB. He also expressed the need for technical support on the scheduling of water supply to the old areas which is now also under his responsibility. Some simulation tools using simpler hydraulics assumptions than the RBMC model could probably provide interesting information about the transfer of water volumes in the network of reaches and tanks of the old system.

  [The system of equations used in the RBMC model is the so called "St Venant" system which is able to describe both mass and pressure waves affecting the flow. The accurate description of the propagation of pressure waves is an absolute necessity to obtain reliable indications about the behavior of such a system with strong interdependency between the reaches and a lot of regulating devices. Nevertheless, if the system studied has more degrees of liberty (mostly negligible downstream influence), a rough estimation of speed and dispersion of the mass waves can be achieved with less complicated theoretical description (e.g., Hayami equation for the reaches and basic water balance equation for the tanks].

* The model can also be used as a diagnostic tool, using quantitative indicators of efficiency to detect local or global malfunctioning in short or medium term. The reliability of the model is sufficient to allow the manager to perform statistical analysis by collecting a minimum of relevant field data and defining routine simulation procedures (see Chap.4 - Case 3).

In both of the above, the main goals are to improve the quality of water deliveries while achieving substantial savings of presently wasted water.

Some proposals to initiate operational involvement in these two directions are made below.

5.2 Possible Areas for Improvement

Three concerted processes should be carried out:

- Methodological improvements at the water management level with the research support of IIMI.
- Organizational reshape of the O&M structure in order to achieve a more effective approach to field data collection, data transmission, real time feed-back capacities.
- Evolution of users' mentality and practices to become responsible and efficient interlocutors.

1) Practical Aspects:

- Preliminary phase of calibration/verification in order to increase the reliability of the model:

    * some significant differences are still unexplained between IIMI Topographic Survey and ID Survey (Annex.5.1).

    * Erosion/sedimentation should probably be taken into consideration. Sediment accumulation in reach DAM - GR2 are suspected (Annex.5.2). Study of syphon section area would also be useful.

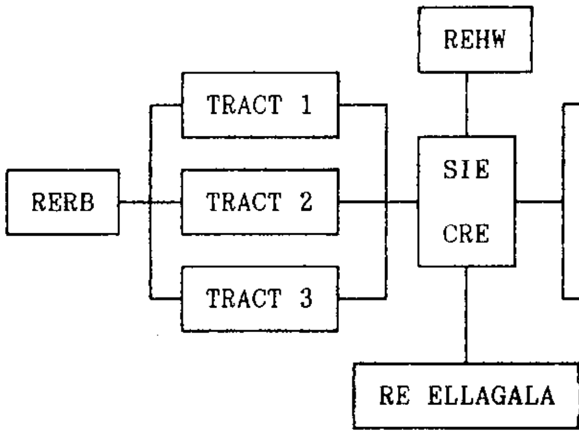
    * Accurate estimation of the rating curves of the new control weirs.

    * Inventory of design modifications: e.g., a modification of GR2 sidewall crest by ID (but not communicated to IIMI) was detected running the model (+ 0.20 m increase).

- Field measurements/collection of data:

    * measuring tapes, field record books and watches are the basic requirements needed by the turnout attendant to perform the necessary functions of data collection (time of operation and spindle heights).

- Communication Facilities: transmission of orders, feedback of field information especially when unexpected events occur, require an improved communication network. The following communication channels would allow a great improvement in the SIE's daily activities:

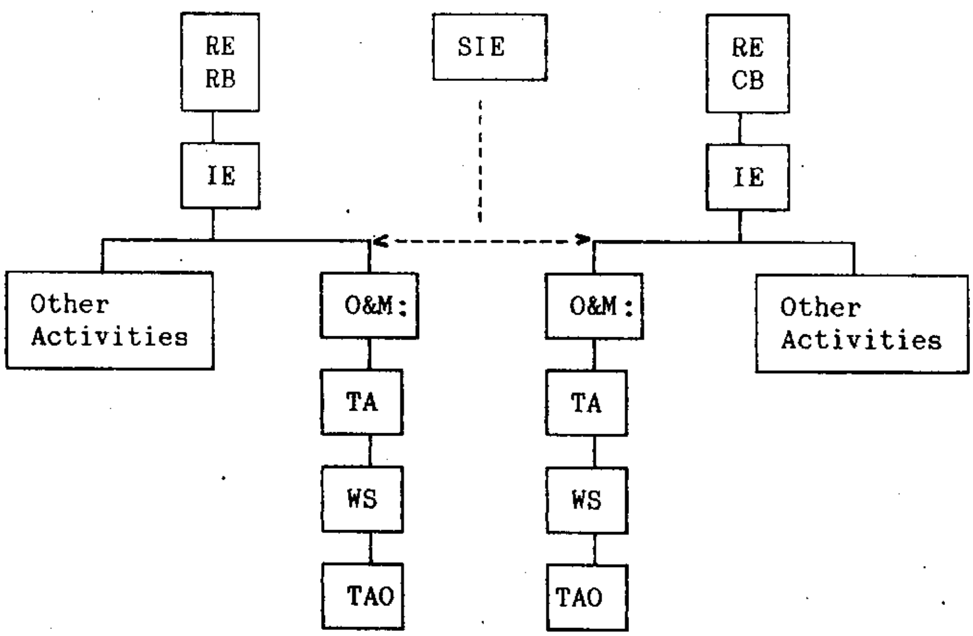


The provision of dedicated telephone lines (network for internal use) has to be studied. Installation of radio communication seems to be unwelcome in an area where security problems have still to be taken into consideration.

2) Organization:

* The specific water management functions carried out by SIE should be recognized and integrated into the organizational set up.

  A possible solution would be to officialize the SIE's role of supervision of O&M activities within the present organization:



The dotted line which indicates a function of help and advice could be strengthened in the following way:

- total initiative and responsibilities regarding O&M activities.

- recommendations for allowances attributed to Field Staff.

- organization of training courses for O&M Field Staff.

The practical administrative control and guidance of O&M staff should probably remain under R-E responsibility as at present.

In a second phase, this structure could be formalized by the creation of an O&M Committee of 7 members (CRE, SIE, RELB, RERB, 2IE, RE Ellagala) which, through weekly meetings, could strongly improve the quality of information transfer and co-ordination. Daily O&M activities could be discussed by the committee which would be presided by CRE. The SIE would function as Secretary to this Committee.

* Headworks: The present system seems to be satisfactory. Nevertheless, discharge variations at the main sluice, except in emergency cases should be under the exclusive responsibility of SIE.

3) <u>Centralized data analysis facilities</u>:

* The first requirement is naturally the upgrading of the ID computer in order to use all the possibilities of the RBMC mathematical model.

* A basic data base layout has to be studied to provide optimal use and storage of the data collected, including:

  + performance indicators at the offtakes

  + self improved duties files (evolution towards more realistic schedules).

CONCLUSION

The Kirindi Oya RBMC research project should allow IIMI to develop an effective methodological approach to analyze main canal problems. Different phases of the process have been identified.

- conception development of the mathematical model.

- calibration with extensive field data collection.

- Proposals for introduction of central management concepts:

  * organizational reshape, with objectives in terms of autonomy and motivation.

  * identify and strengthen responsible interlocutors and create structures allowing to integrate the users' participation.

  * implementation of communication network and data analysis facilities.

- Training phase: work with the canal managers to identify possible insufficiencies in existing management rules and to use the mathematical model for the resolution of routine as well as specific problems. Validation by operational tests.

- Self improvement phase of the management by data analysis and experience.

Significant input from the french research center CEMAGREF allowed to perform the conception and calibration phases of the mathematical simulation tool. The real interest and open attitude of the irrigation department staff towards the introduction of the model in support of the management practices should allow interesting result to be obtained in the next phase of the project.

REFERENCES:

[A]: P. O. MALATERRE. October 1989

" A study of the Kirindi Oya Right Bank Main Canal operations through an application of a mathematical flow simulation model: prospect of improving performance. "

- Final Report

[B]: H. SALLY et al. January 1989

" Calibration of the Kirindi Oya RBMC mathematical flow simulation model. Description of the field measurements campaign and preliminary results. "

- IIMI Working Paper 10

[C] IIMI. March 1989

" Study on irrigation systems rehabilitation and improved operations and management.

Activity A: Rehabilitation and Improvement of Management "

- Final report ADB Regional Technical Assistance 5273 Volume 1.

ANNEXES

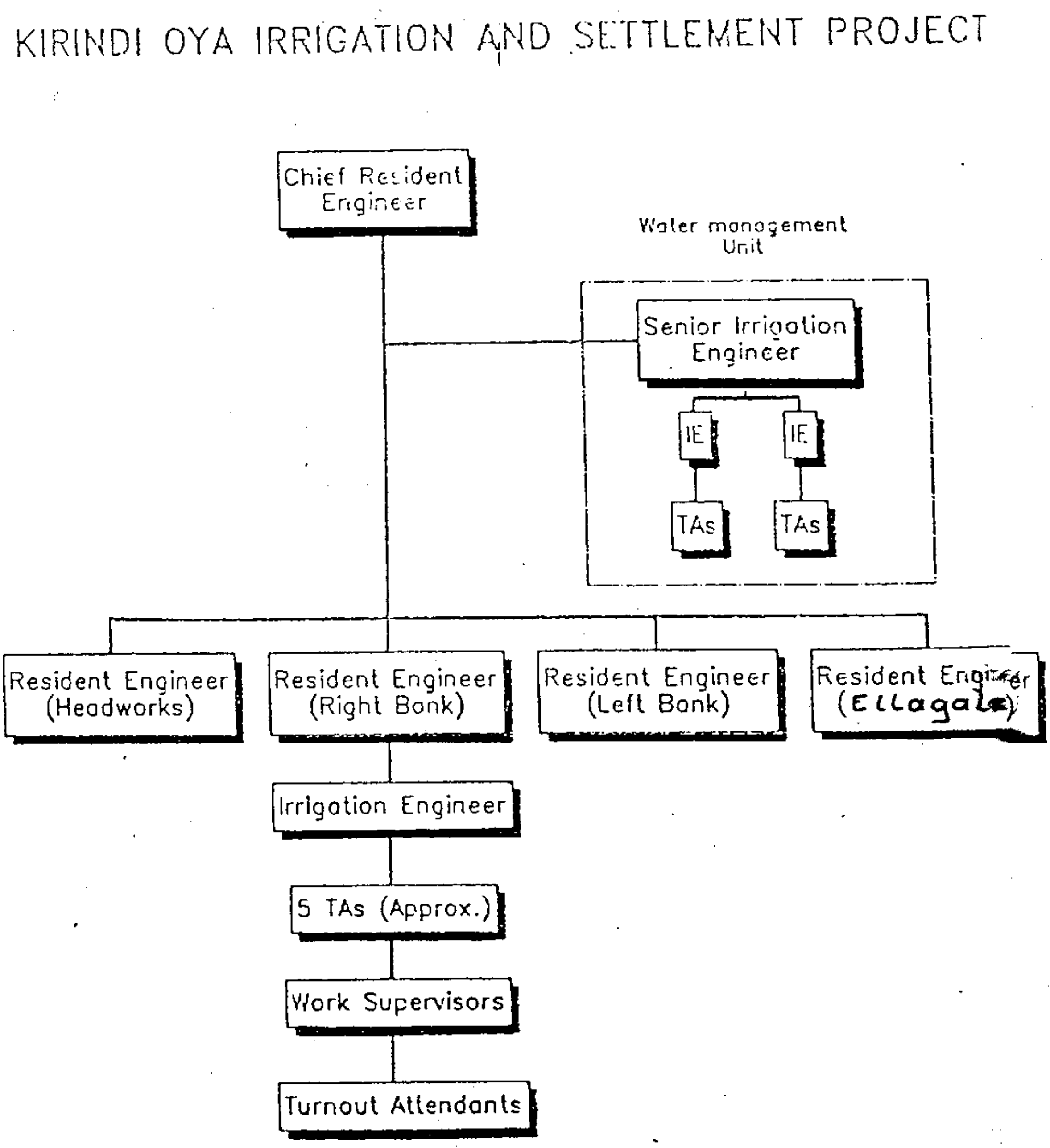
Annex 1.1	Present organizational setup
Annex 1.2	Brief Background about KOISP
Annex 2.1	Global Water Allocations
Annex 3.1	Simple Case Studies
Annex 3.2	Field - Model Interaction 1. Steady States 2. Unsteady States
Annex 3.3	Amplitude and time of operations at the devices (Tract 1 - 30 June/31 July 1990 - Yala)
Annex 3.4	Daily Simulations of the canal state
Annex 5.1	Survey uncertainty
Annex 5.2	Bed level uncertainty

ANNEX 1.1

Present organizational setup

Next >>

ANNEX 1.1 **Present organization setup**

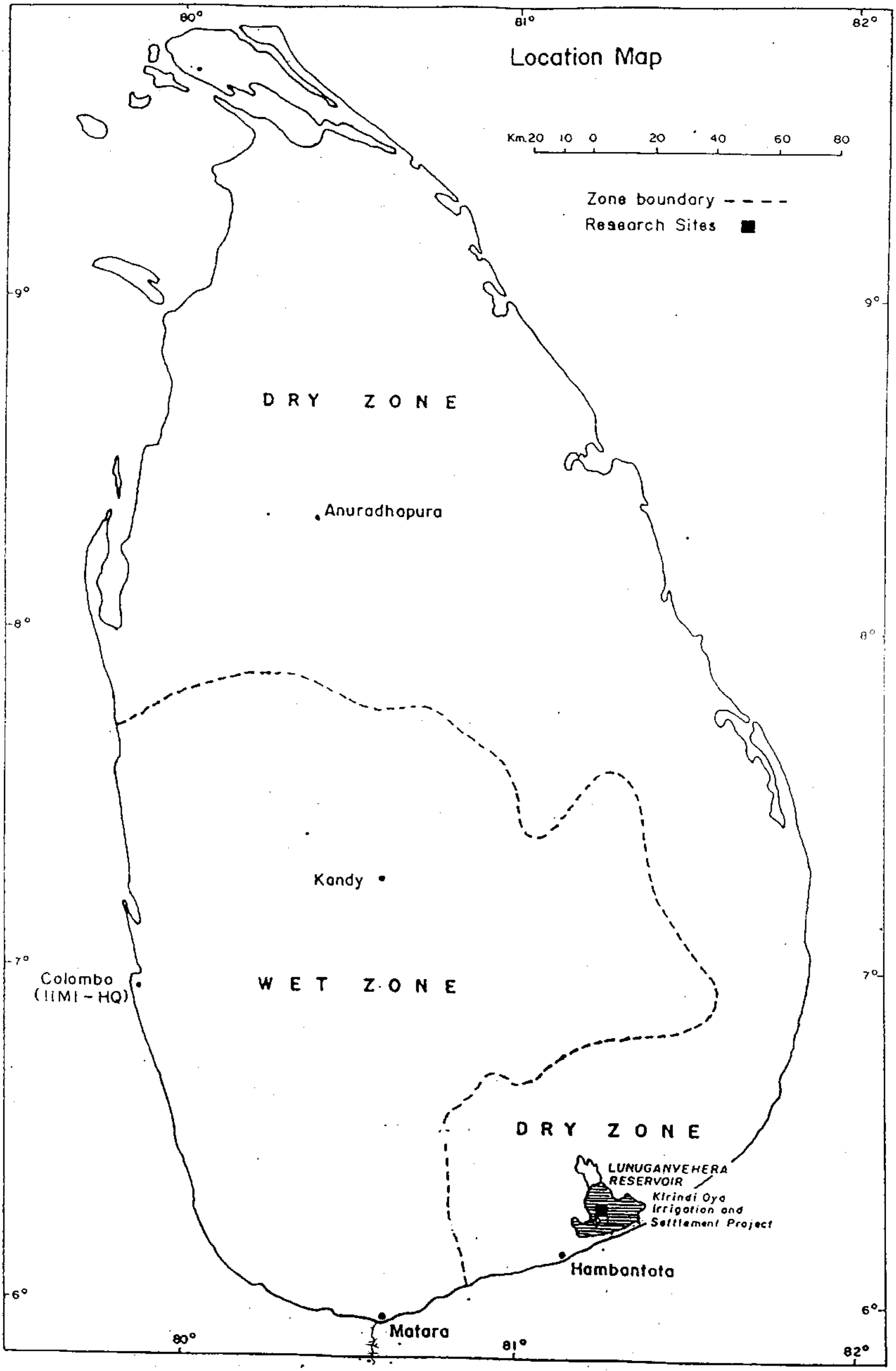


Key: IE – Irrigation Engineer

TA – Technical Assistant

ANNEX 1.2

Brief background about KOISP


Location Map
Km.20 10 0 20 40 60 80
Zone boundary
Research Sites
80°
81°
82°
9°
8°
7°
6°
DRY ZONE
Anuradhapura
Kandy
WET ZONE
Colombo (IIMI-HQ)
DRY ZONE
LUNUGANVEHERA RESERVOIR
Kirindi Oya Irrigation and Settlement Project
Hambantota
Matara

ANNEX 1.2 Brief background about KOISP

General Features:

Location: The project area is in the dry zone of the island, in its south east quadrant about 260 km from COLOMBO. It is located on both banks of the Kirindi Oya river between the Lunugamwehera tank in the north and coastal lagoons in the south.

The scheme consists of the previously developed Ellagala and Badagiriya areas and two new areas, the right and left bank area.

The major source of irrigation water for the project is the 200 MCM Lunugamwehera Reservoir. The five old tanks located in the Ellagala Area are now obtaining most of their supply from this main Reservoir via the LB main canal. The Badagiriya tank also receives water from the Lunugamwehera reservoir via the RB main canal.

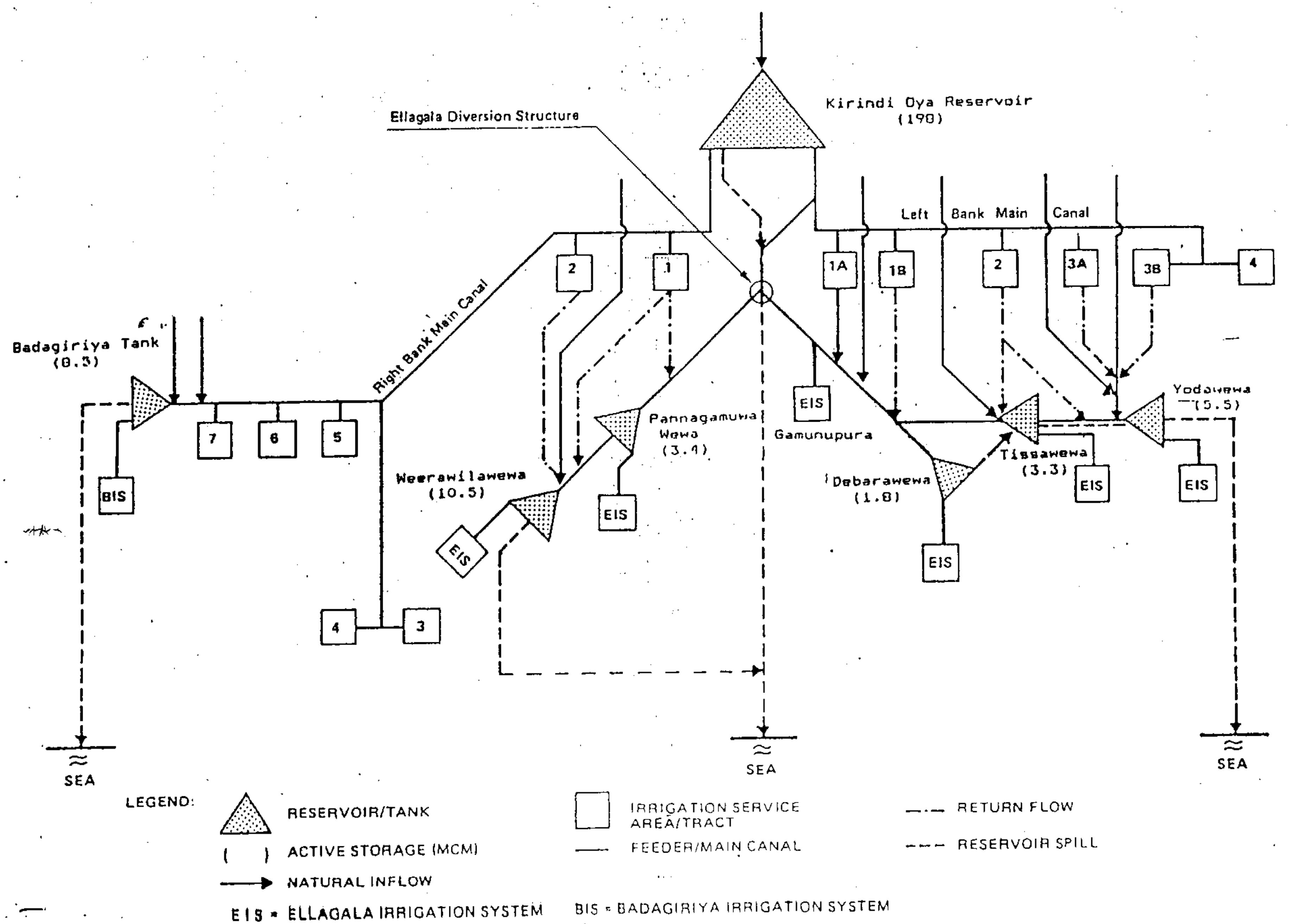
Physiography: A tropical monsoonal climate prevails in the area with mean monthly termperatures ranging from 26^0c to 28^0c. The mean annual rainfall is about 1,000 mm and has a distinct bimodal pattern; about 75 percent of this previpitation occurs during the wet season called Maha (from September to March); the complement during Yala season (March to September).

Objectives: The basic objective was the settlement of about 8000 families coming from different areas (mostly from the south). In 1982, the project was formulated in two phases.

Phase 1: (87/89)
- construction of headworks
- rehabilitation and augmentation of existing paddy lands (old area) 4500 ha.
- first settlement in 4000 ha of new lands.

Phase 2: (87....)
- further irrigation development new settlement. (Expected area 4000 ha)

Irrigation System Flow Chart.

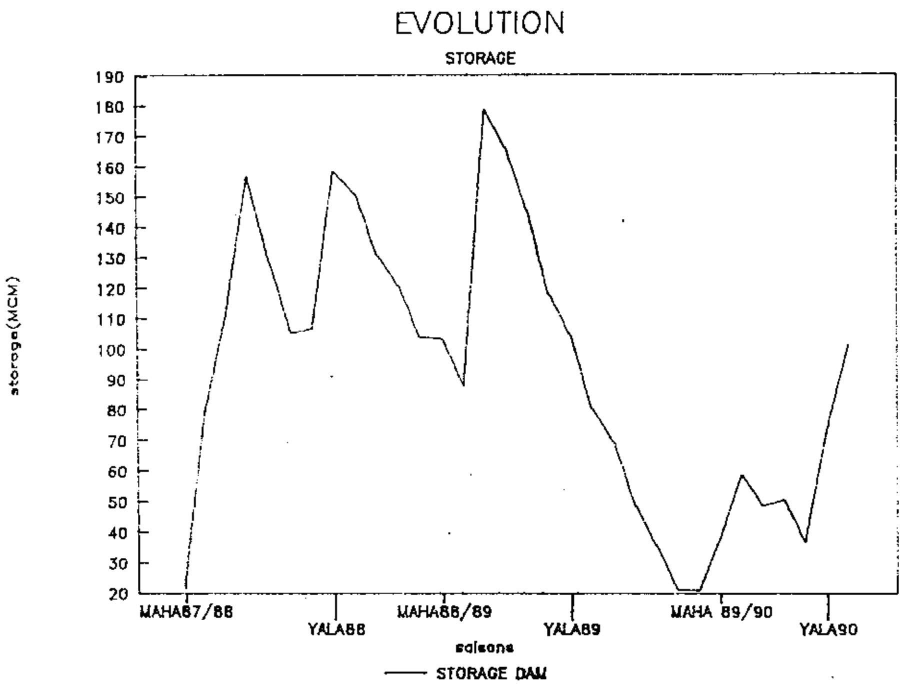


ANNEX 2.1

Global Water Allocations

ANNEX 2.1 Global Water Allocations

1. Evolution of storage in the Dam:



2. **Water duties:**

According to the assumptions used by ID, the theoretical water requirements for 1 ha. paddy are as follows:

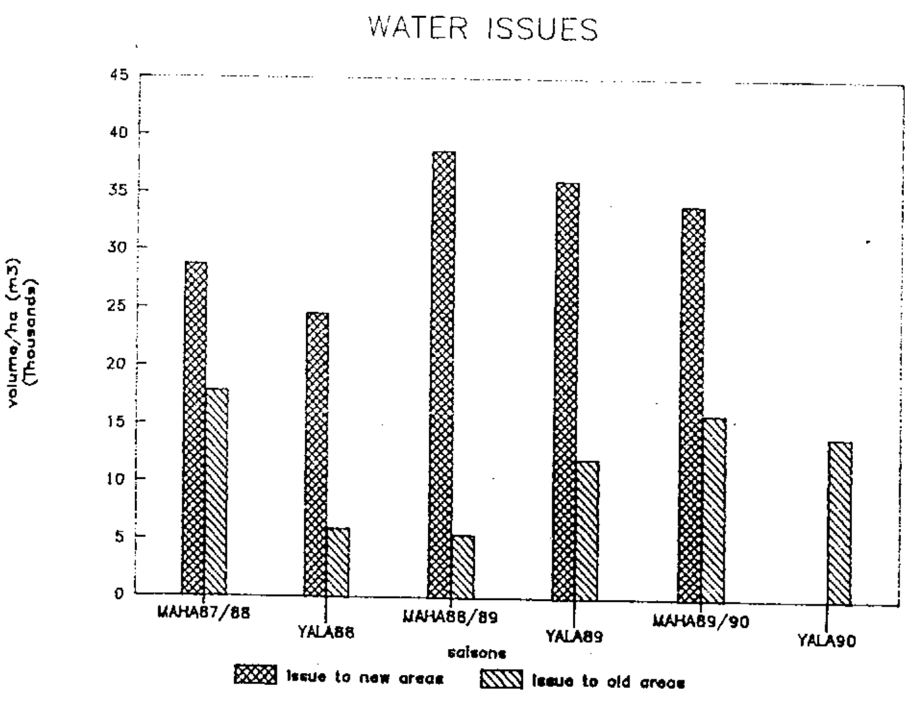
- New areas : Lowland: 13,000 m^3
  Upland : 18,000 m^3
  Old areas : 10,000 m^3

After accounting for losses and conveyance efficiency the estimations used by SIE are:

- New areas (average) : 26,000 m^3
- Old areas : 20,000 m^3

It is assumed that the water requirements for OFC's are half these values.

Water issues during the past seasons:

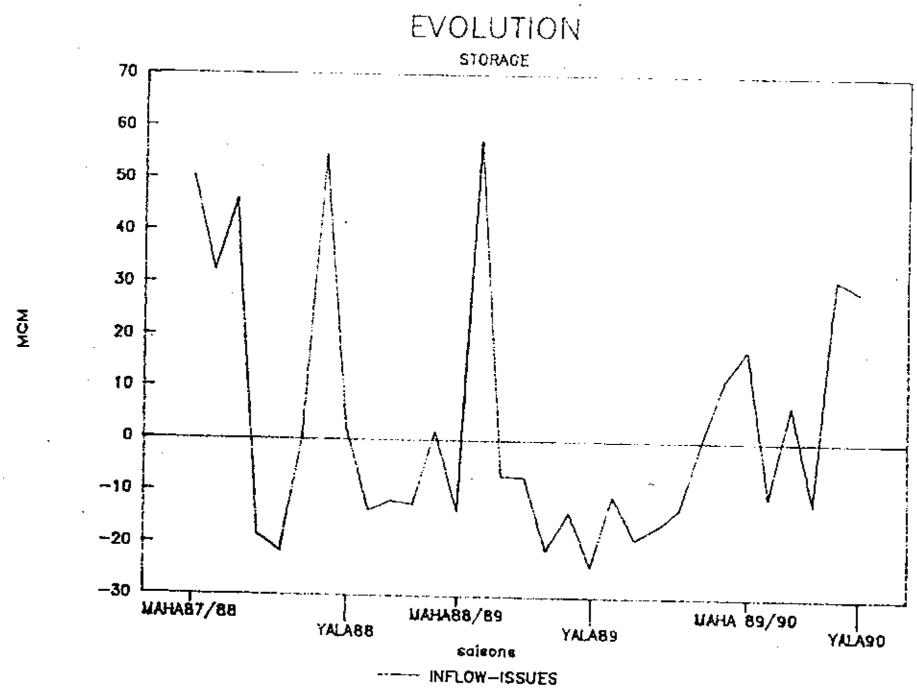


3. Water inflow during the previous seasons:
(Kitulkote gauging Station, upstream of the Lunugamwehera dam)

Maha 87/88	288
Yala 88	45
	---
	333 MCM
	===
Maha 88/89	124
Yala 89	30
	---
	154 MCM
	===
Maha 89/90	132 MCM
	===

Management of the resource:

Inflow-issues



ANNEX 3.1

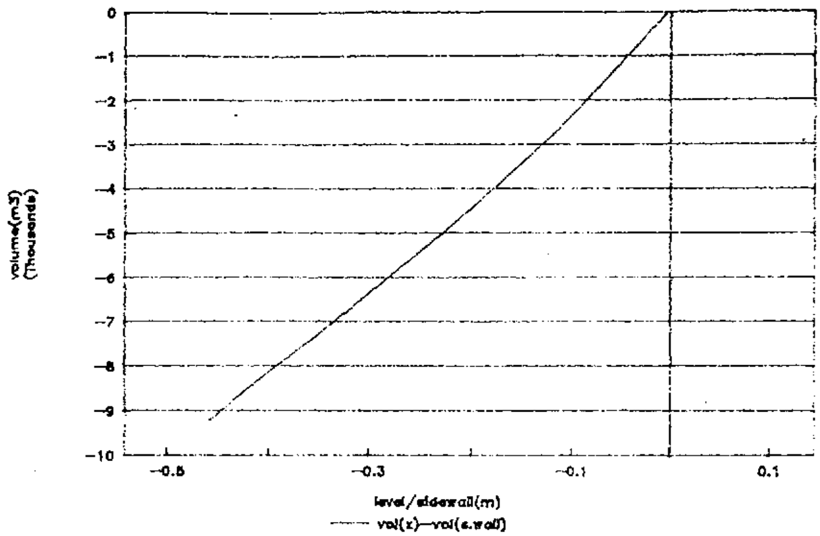
Simple Case Studies

ANNEX 3.1. Simple Case Studies

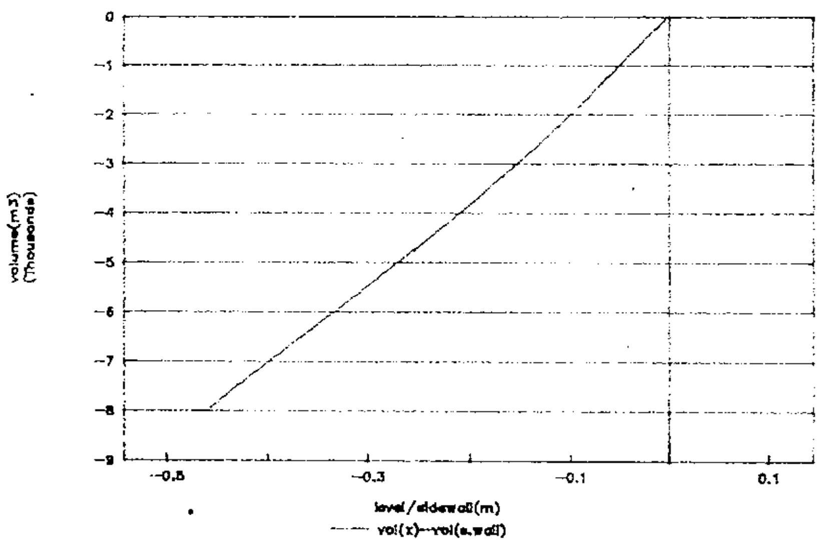
3.1.1

Routine use of the Model		
Date: 29.7.90	Request by: SIE	Number: 12
See also No.	Problem No. 1 (Filling)	
Configuration:	RBMC ☐ Tract 1 ☒	Other ☐
Steady ☐ Unsteady ☒ Both ☐	Field Measures in Connection No	Output Files, Pictures Yes
Objectives:	Rough estimation of the insufficient volume in a reach when the level is below sidewall level at the downstream regulator (reach here means the position of the canal between successive regulators).	
Results:	A particular unsteady evolution was computed. A very low water level was imposed in the canal as an initial steady state. The main sluice discharge was then increased in order to fill the canal. The difference between inflow and outflow discharges (including seepage) was translated to a volume in each reach (tipe step: 10 min.) and related to water surface elevation at the cross regulator (Water balance equation). Remark: A direct estimation of the volume in a reach under a particular steady state can be obtained after running the steady state unit (special model output).	

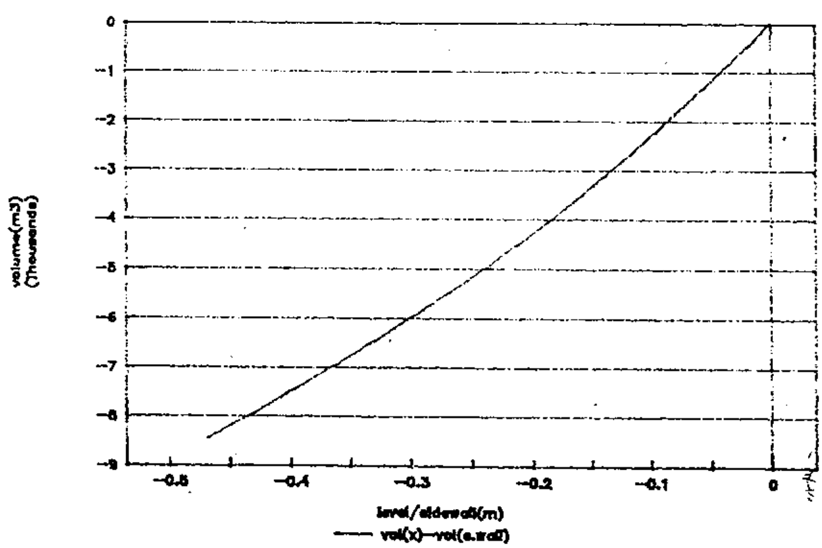
REACH DAM/GR2



REACH GR2/GR3



REACH GR3/GR4



3.1.2

Routine use of the Model		
Date: 29.6.90	Request by: SIE	Number: 1
See also No.	Problem No.	
Configuration: RBMC ☐ Tract 1 ☒		Other ☐
Steady ☐ Unsteady ☐ Both ☒	Field Measures in Connection No	Output Files, Pictures Yes

Objectives:

Target issues in DC4: 2.5 cusecs. All other offtakes are closed.
DC5: 5 cusecs.

1. What would be the openings if the main discharge is 75 cusecs?

2 a. If somebody opened a gate in GR3, what would be the impact on DC5?

b. If somebody closed DC5 suddenly, what would be the variation in discharge in DC4?

Results:

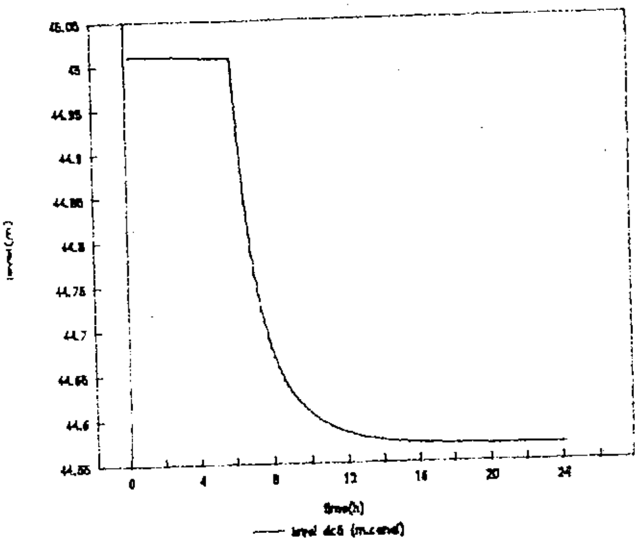
1. This is a simple example of a powerful application of the model: computation of the offtake openings knowing the targeted discharges. The result is obtained by running the steady flow unit. In this case, we imposed FSD as target levels at GR2, GR3, GR4; the suitable openings are then: 0.08 m at DC4 and 0.17 m at DC5.

2. The unsteady flow unit can be run to test the consequence of specific operations at the devices, e.g.,

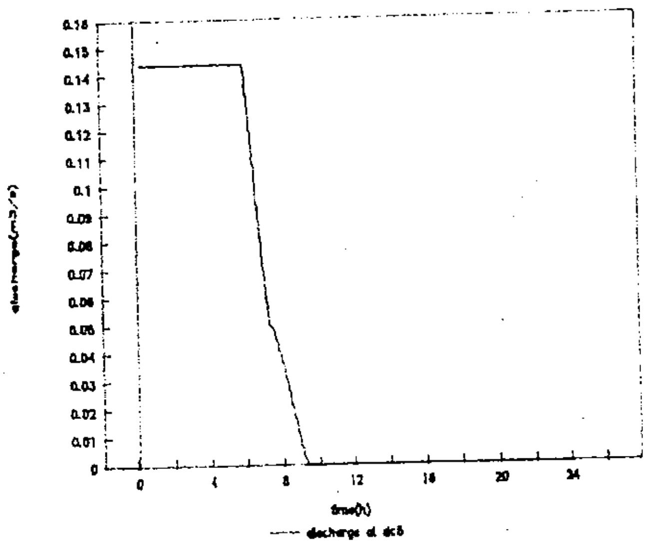
   a) One gate of GR3 was fully opened at 6.00 a.m. (initial steady state 1). The discharge at DC5 decreased from 0.140 m^3/s to 0 m^3/s in 3 hours.

   b) DC5 was closed at 6.00 a.m. (initial steady state 1). The discharge at DC4 increased from 0.071 m^3/s to 0.073 m^3/s in 6 hours.

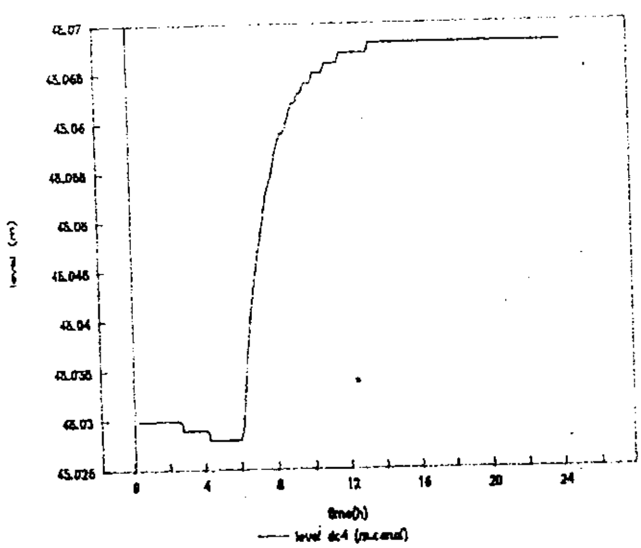
DC5



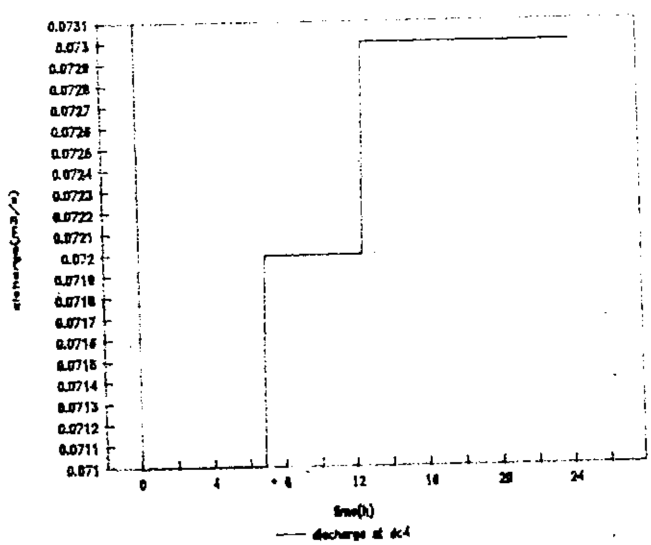
DC5



DC4



DC4



3.1.3

Routine use of the Model		
Date: 30.6.90	Request by: SIE	Number: 3
See also No.	Problem No.	
Configuration: RBMC ☐ Tract 1 ☒		Other ☐
Steady ☐ Unsteady ☒ Both ☐	Field Measures in Connection No	Output Files, Pictures Yes

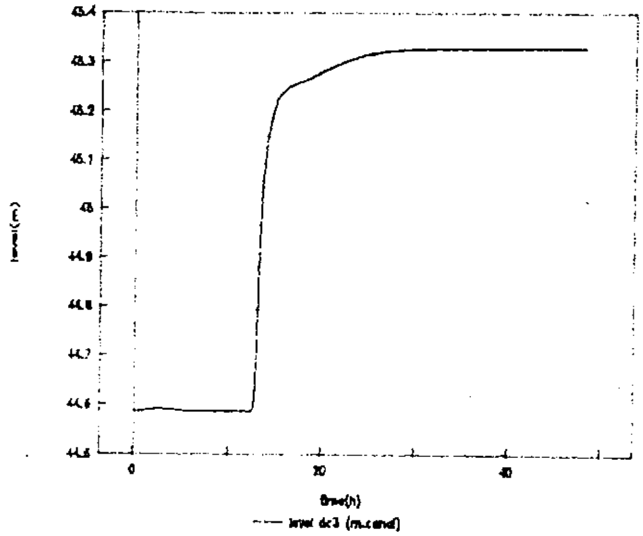
Objectives:

The canal was maintained closed and it is now opened with a 75 cusecs discharge. The offtakes DC3 and DC5 were opened after 3 hours (say 0.15 m). What will be the behaviour of the canal?

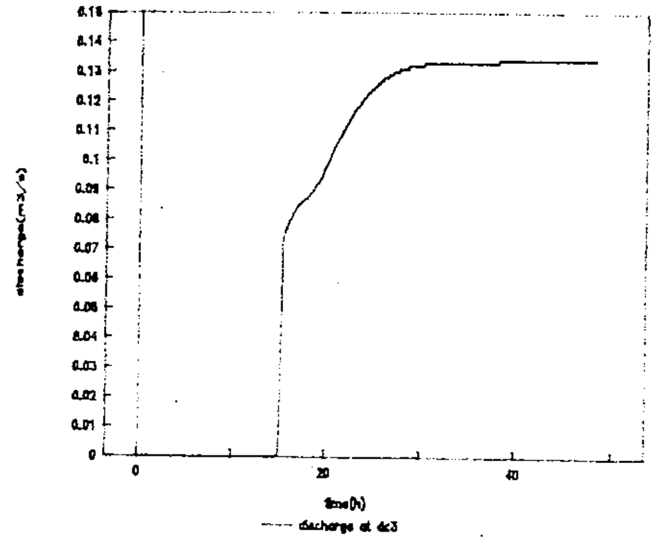
Results:

The initial discharge $0.150 m^3/s$ is lost along tract 1 through seepage losses. The main sluice opening is increased at 12 noon to issue $2.1 m^3/s$. DC3 and DC5 are opened (0.15 m) at 15 00 hours. The lag time before a steady supply is achieved at the offtakes is more than 10 hours.

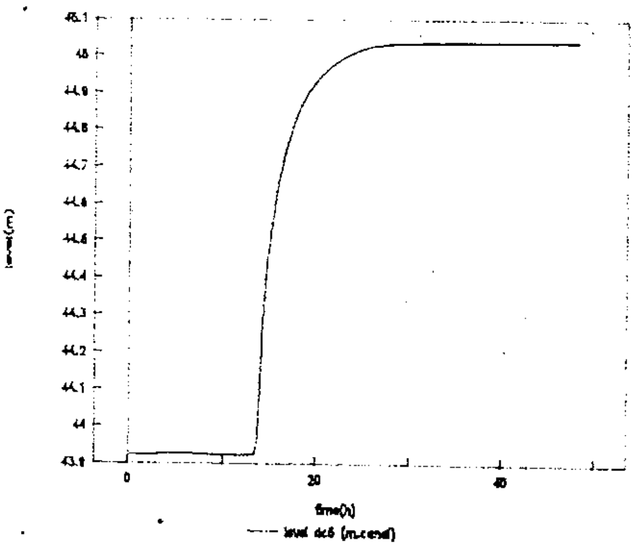
DC3



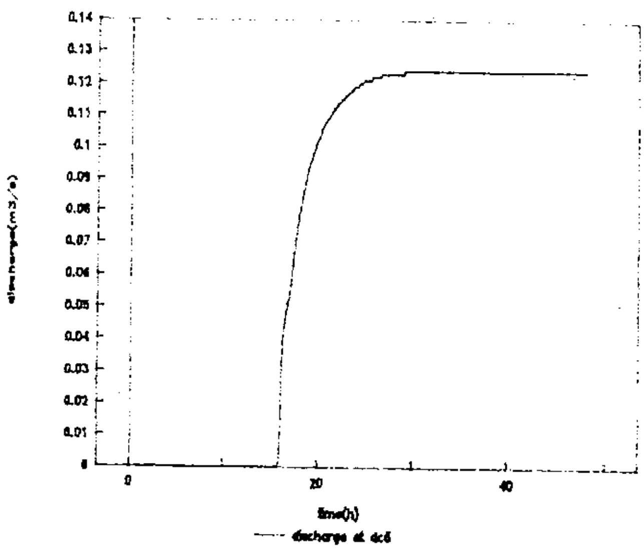
DC3



DC5



DC5



3.1.4

Routine use of the Model

Date: 5.7.90	Request by: IE	Number: 6
See also No.	Problem No. 3 (Water delivery)	
Configuration:	RBMC ☐ Tract 1 ☒	Other ☐
Steady ☐ Unsteady ☒ Both ☐	Field Measures in Connection Yes	Output Files, Pictures Yes

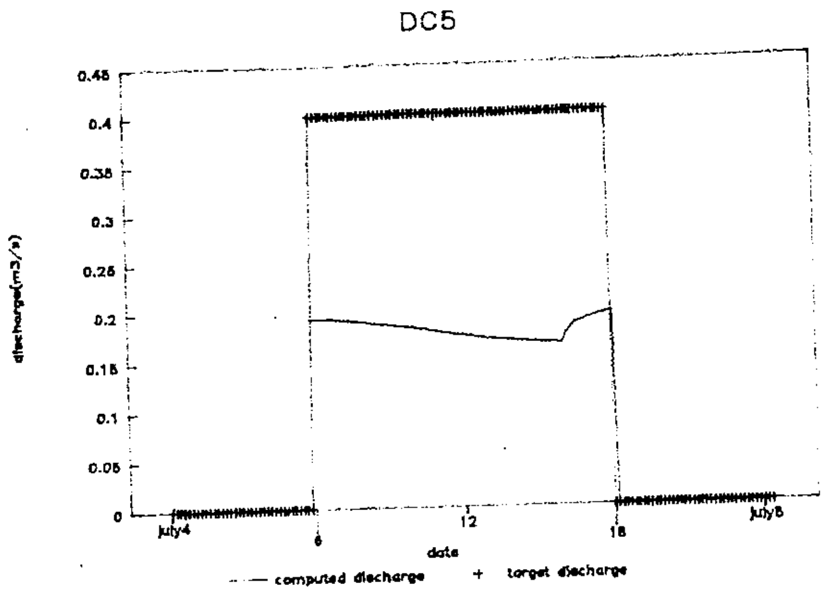
Objectives:

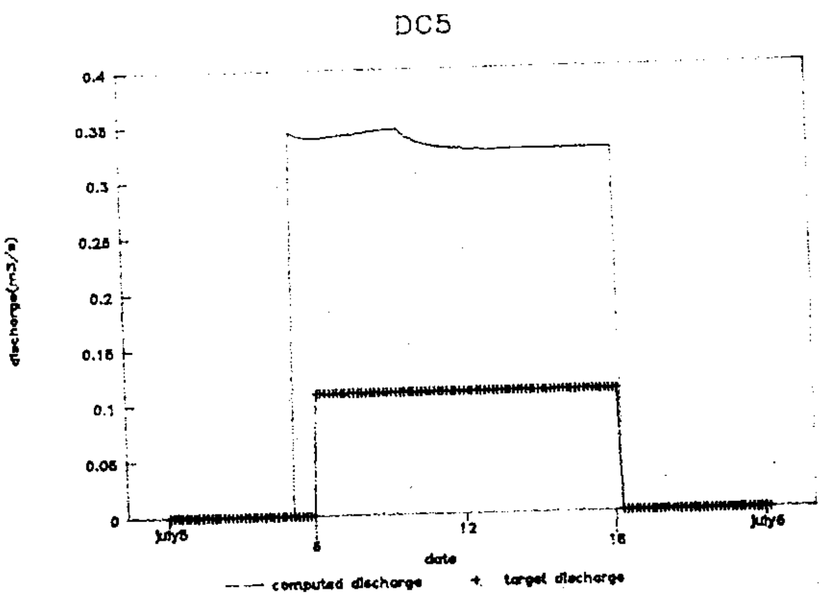
Estimation of the water delivery efficiency at DC5 on 4th and 5th July. The targeted discharge is 0.400 m^3/s on the 4th, and 0.110 m^3/s on the 5th.

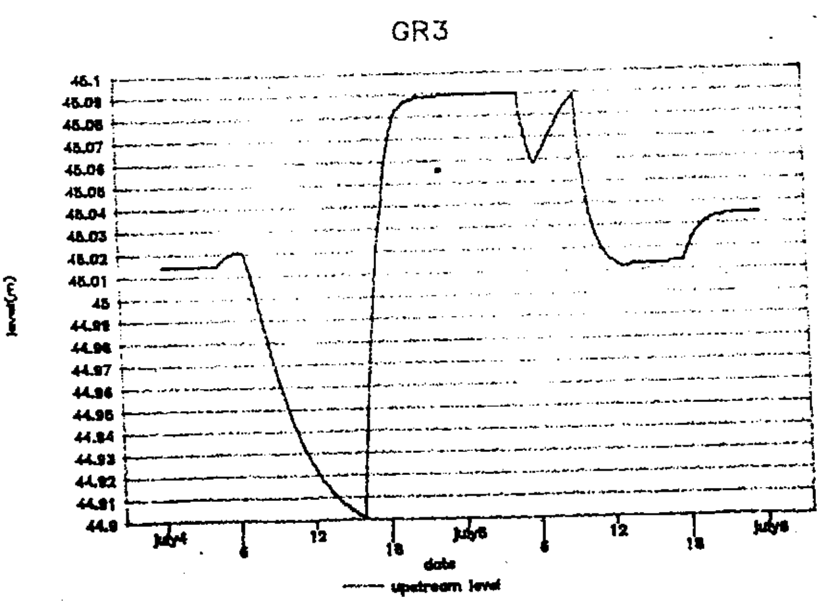
Results:

The targeted discharge of 0.400 m^3/s was not achieved on the 4th. The TA probably had to deliver more water than scheduled on the 5th. He performed an interesting operation at GR3 (9.30 a.m.) to bring the upstream level to FSD in 3 hours.

DC5	Demand (m^3)	Supply
4th	12,280	12,510
5th	4,820	15,570
Total	22,100	28.080


DC5
discharge(m3/s)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
july4
6
12
18
july5
date
computed discharge
+ target discharge


DC5
discharge(m3/s)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
july5
6
12
18
july6
date
computed discharge
+ target discharge


GR3
level(m)
45.1
45.09
45.08
45.07
45.06
45.05
45.04
45.03
45.02
45.01
45
44.99
44.98
44.97
44.96
44.95
44.94
44.93
44.92
44.91
44.9
july4
6
12
18
july5
6
12
18
july6
date
upstream level

3.1.5

Routine use of the Model

Date: 8.7.90 | Request by: SIE | Number: 8

See also No. 1 | Problem No. 2 (Rainfall)

Configuration: RBMC ☒ Tract 1 ☐ Other ☐

Steady ☐ Unsteady ☒ Both ☐

Field Measures in Connection: No

Output Files, Pictures: Yes

Objectives:

Tract 1 is closed. Water is issued to all offtakes in Tracts 2 and 5 (realistic target under paddy cultivation).

Unexpected rainfall occurs in Tract 2 area so that the TA takes the decision to close the gates at 8 a.m.

We want to determine the appropriate action in Tract 5 in order to achieve targeted discharges and volumes (assuming effective information transfer between operators of Tracts 2 and 5).

Results: 3 scenarios were examined.

1. Using the opening computation mode of the unsteady flow of the model, we have access to the optimal opening variations which would allow to maintain a constant discharge through the offtakes. The objective is achived with 7 operations at BC2 (from 9 a.m. to 3 p.m.), 5 at DC11 (from 12 noon to 6 p.m.), (acceptable deviation: ± 10%).

2. First half of Tract 5 offtakes were closed in one operation at 12 noon. Second half was closed in one operation as well, at 1 p.m.

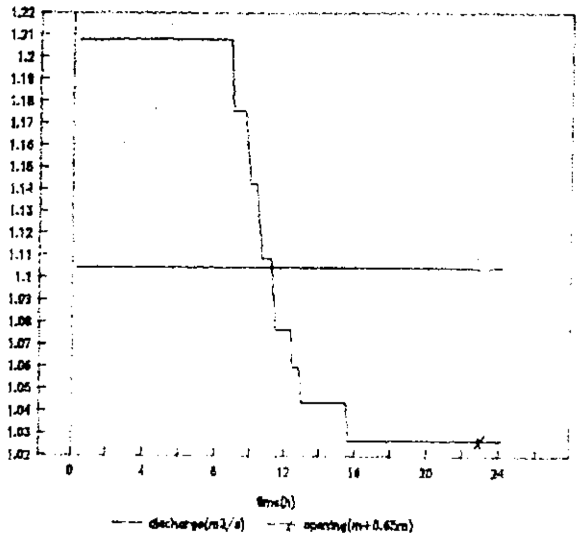
3. No operation is performed in Tract 5.

- more than 20,000 m^3 at BC2 and 4,000 m^3 at DC11 can be diverted in addition to the real demand if no appropriate reaction is performed.

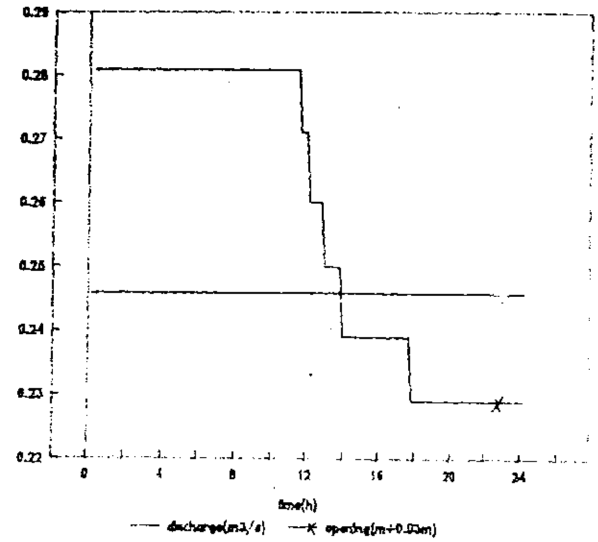
- the approximate response described in Scenario 2 is quite satisfactory in term of volumes.

Scenario 1

BC2

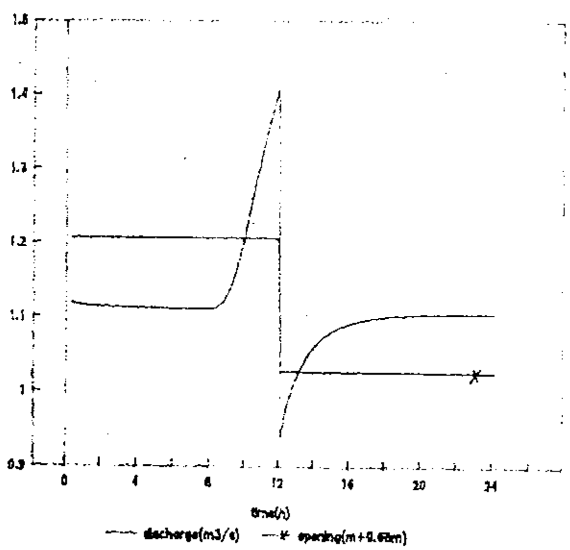


dc11

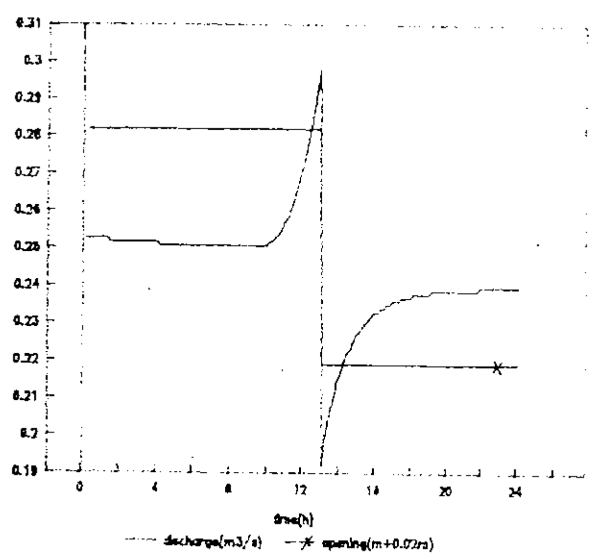


Scenario 2

BC2

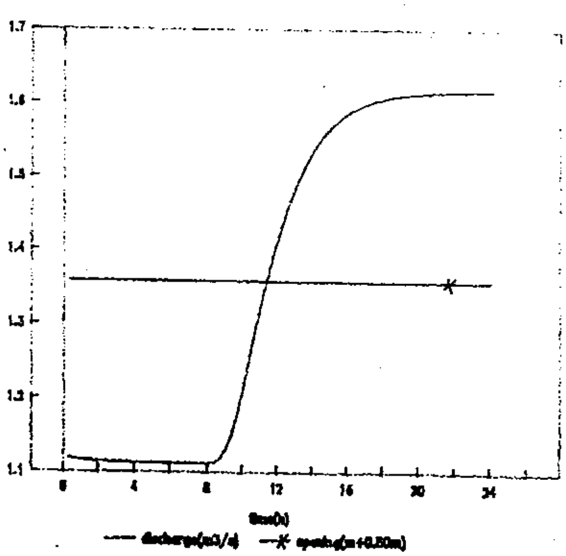


dc11

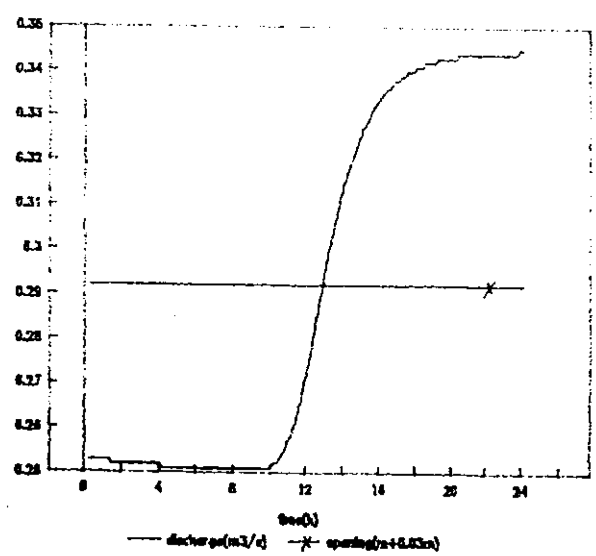


Scenario 3

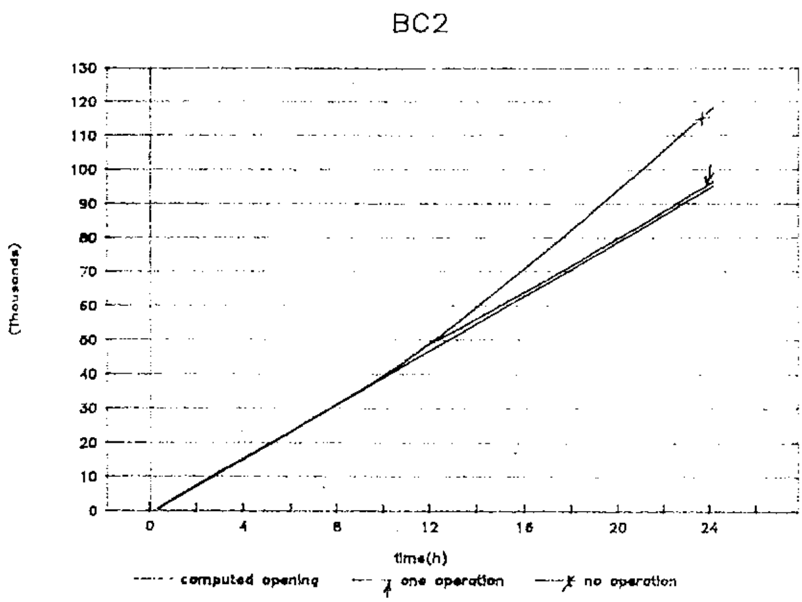
BC2



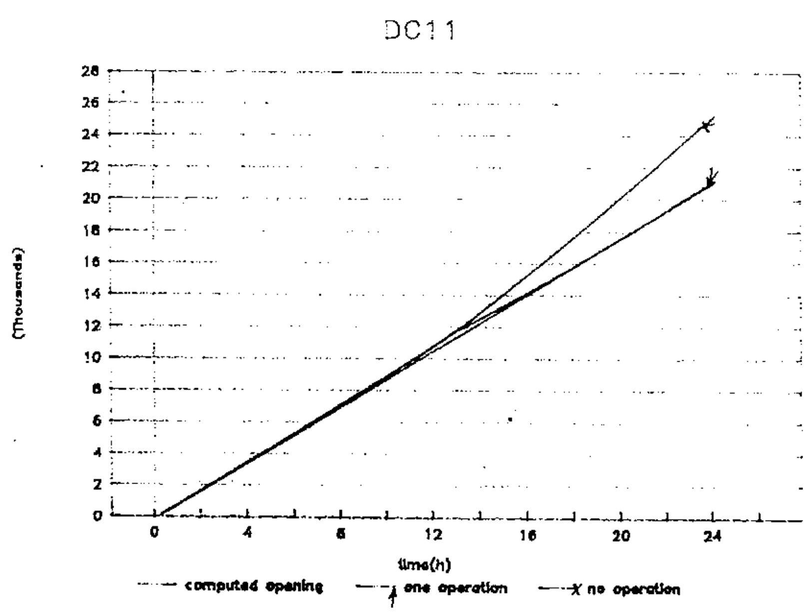
dc11



VOLUMES



BC2
130
120
110
100
90
80
70
60
50
40
30
20
10
0
(Thousands)
0
4
8
12
16
20
24
time(h)
computed opening
one operation
no operation



DC11
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
(Thousands)
0
4
8
12
16
20
24
time(h)
computed opening
one operation
no operation

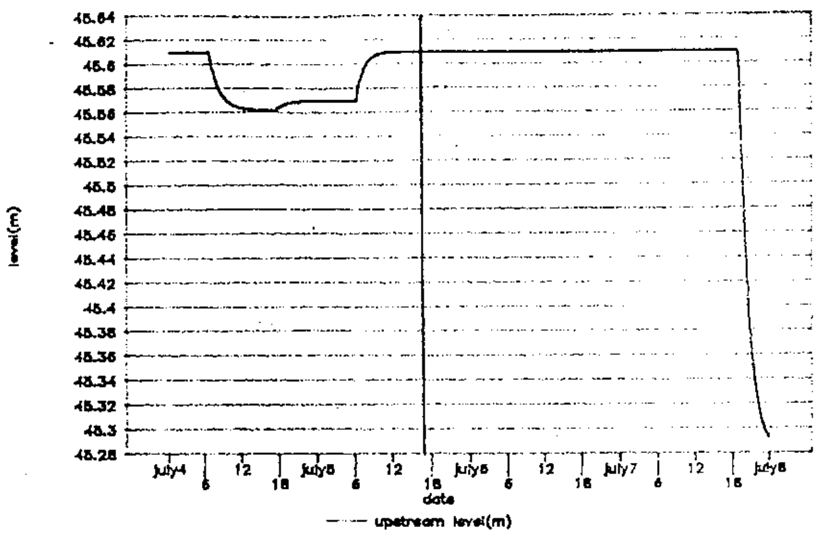
ANNEX 3.2

Field - Model Interaction

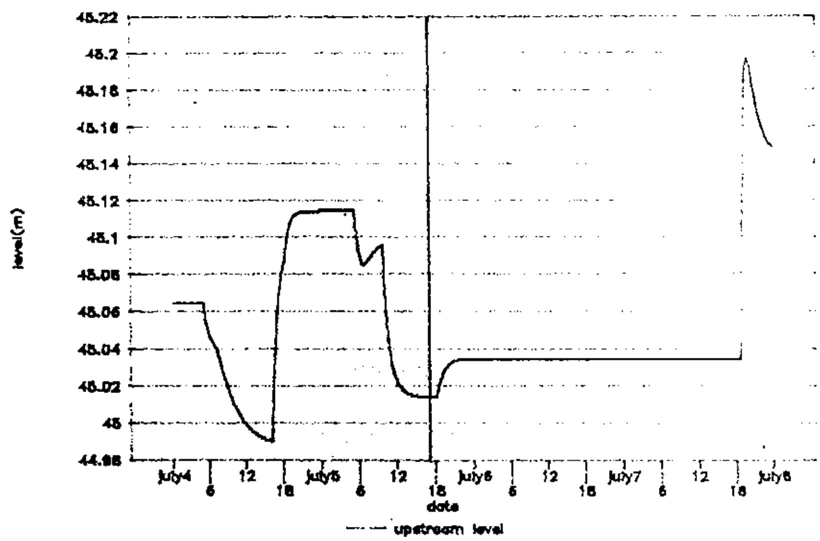
1. Steady States
2. Unsteady States

Steady State July 5: Context of evolution

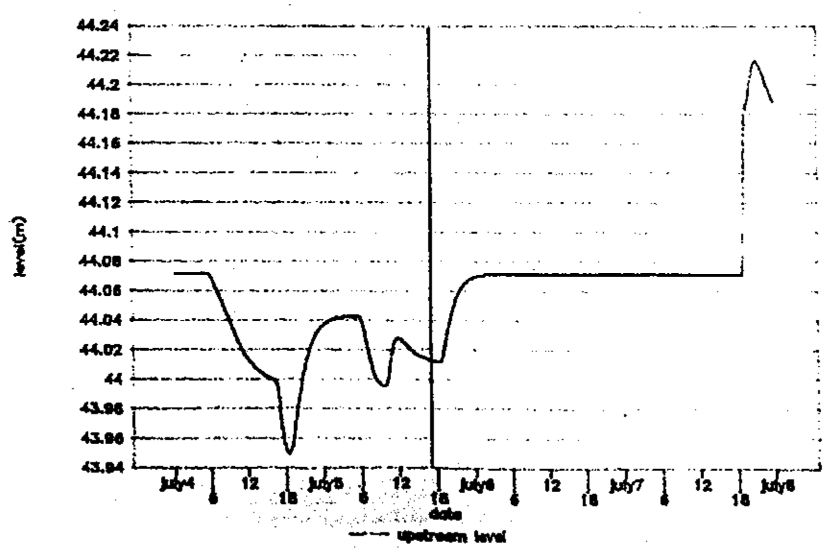
GR2



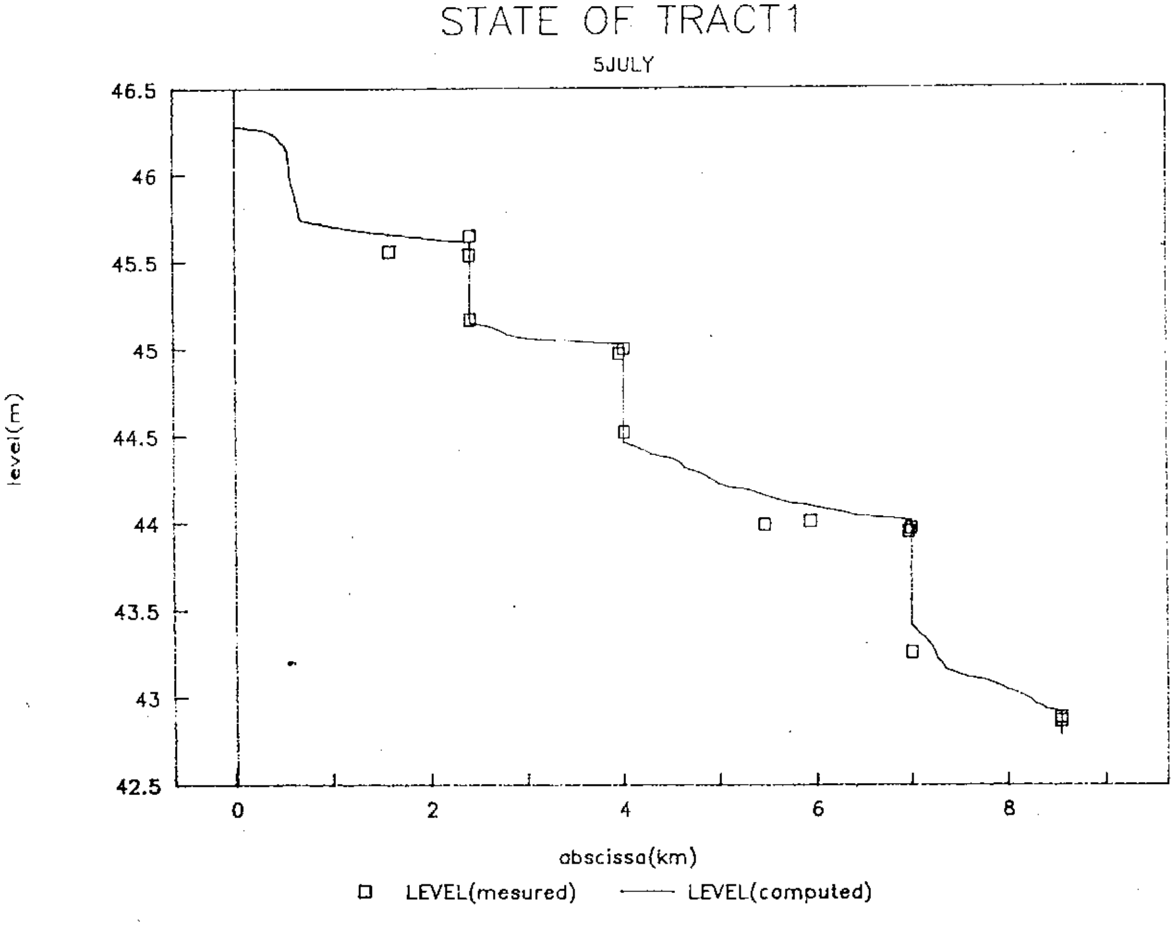
GR3



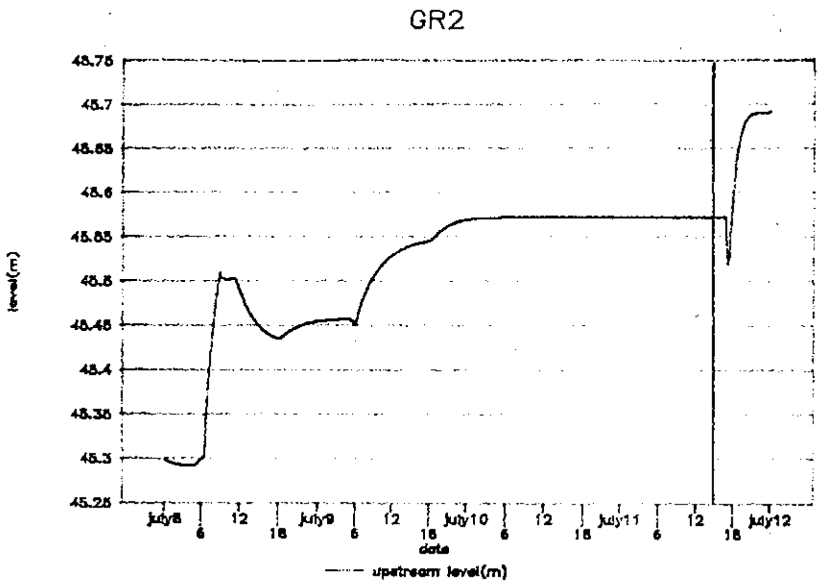
GR4

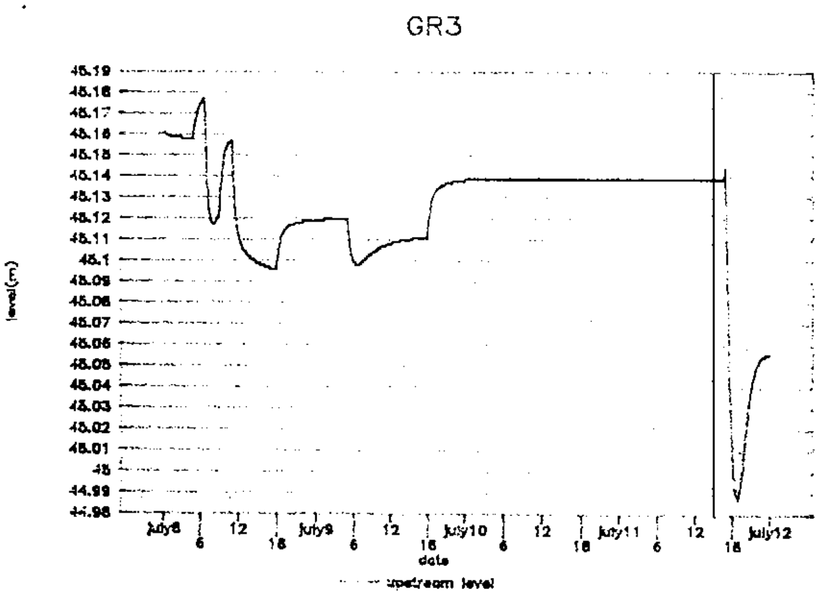


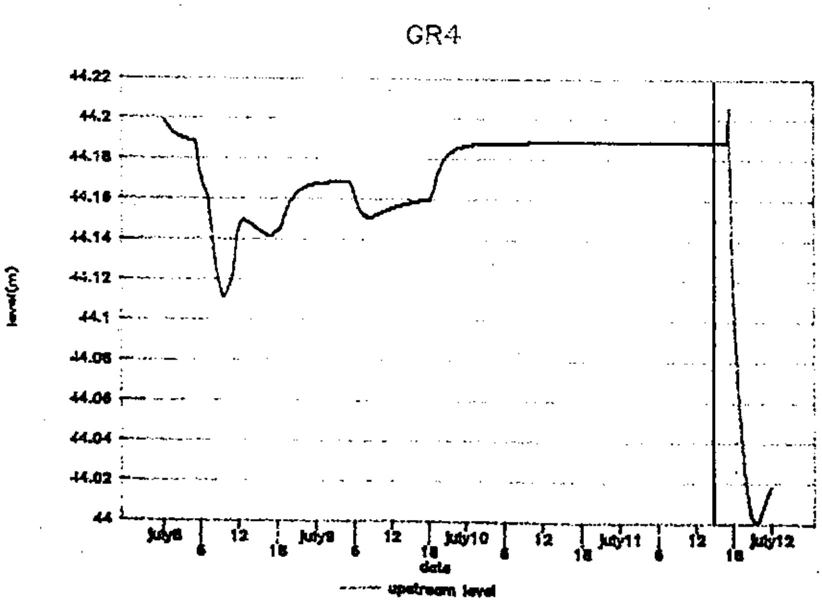
Steady State - July 5



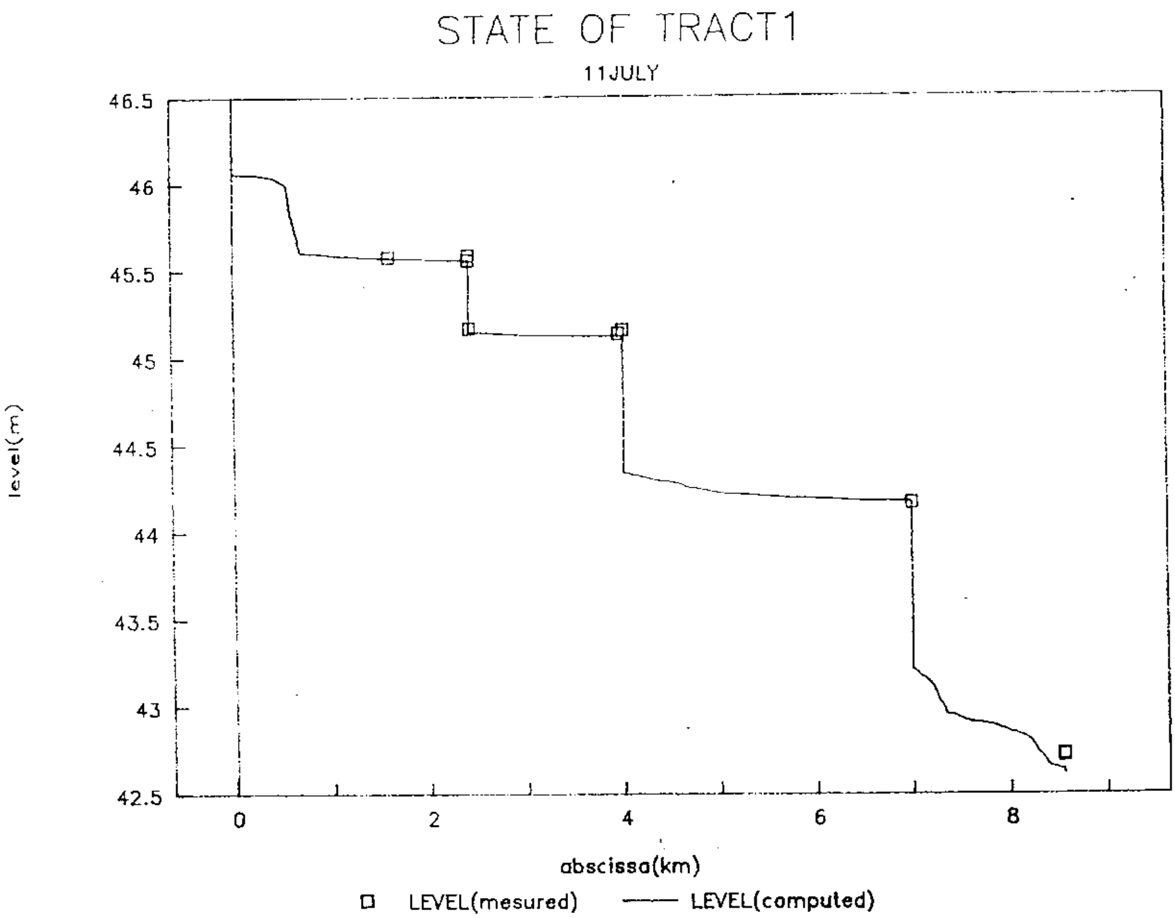
Steady State July 11 : Context of Evolution





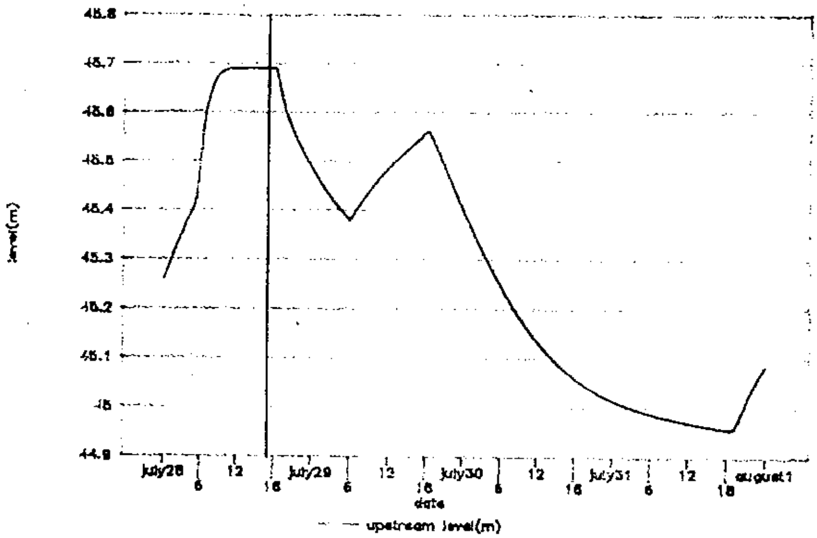


Steady State - July 11

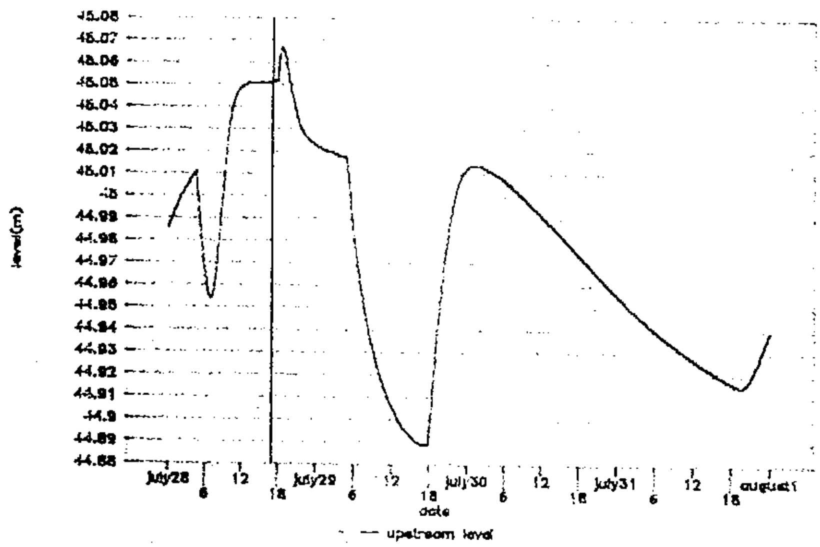


Steady State July 28 : Context of evolution

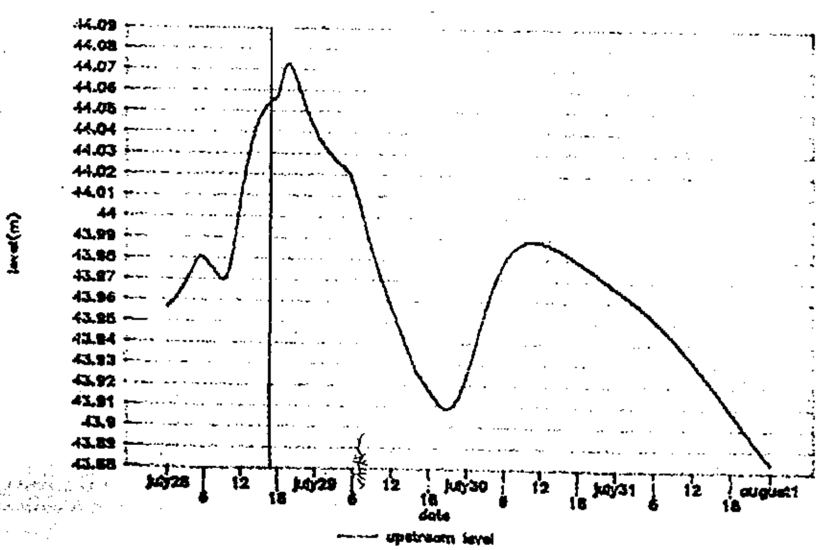
GR2



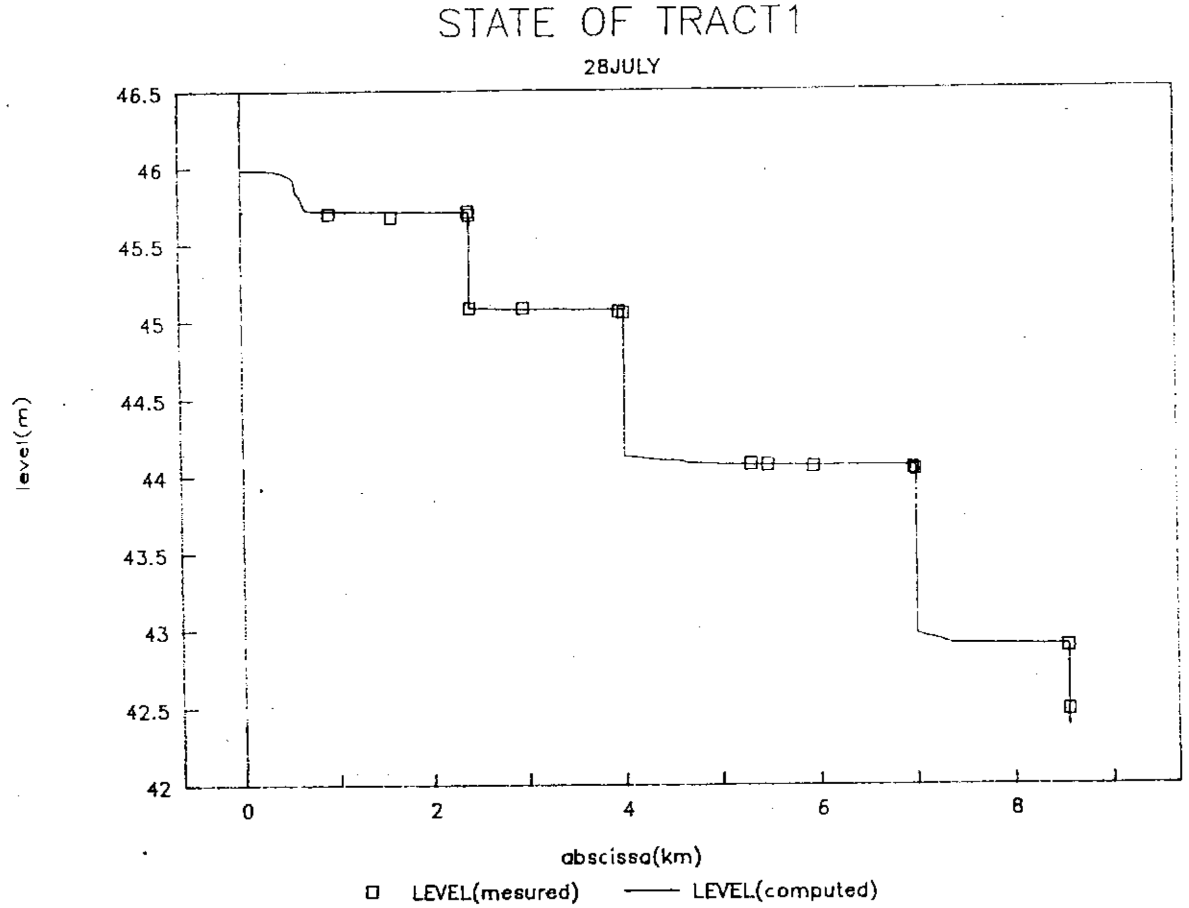
GR3



GR4

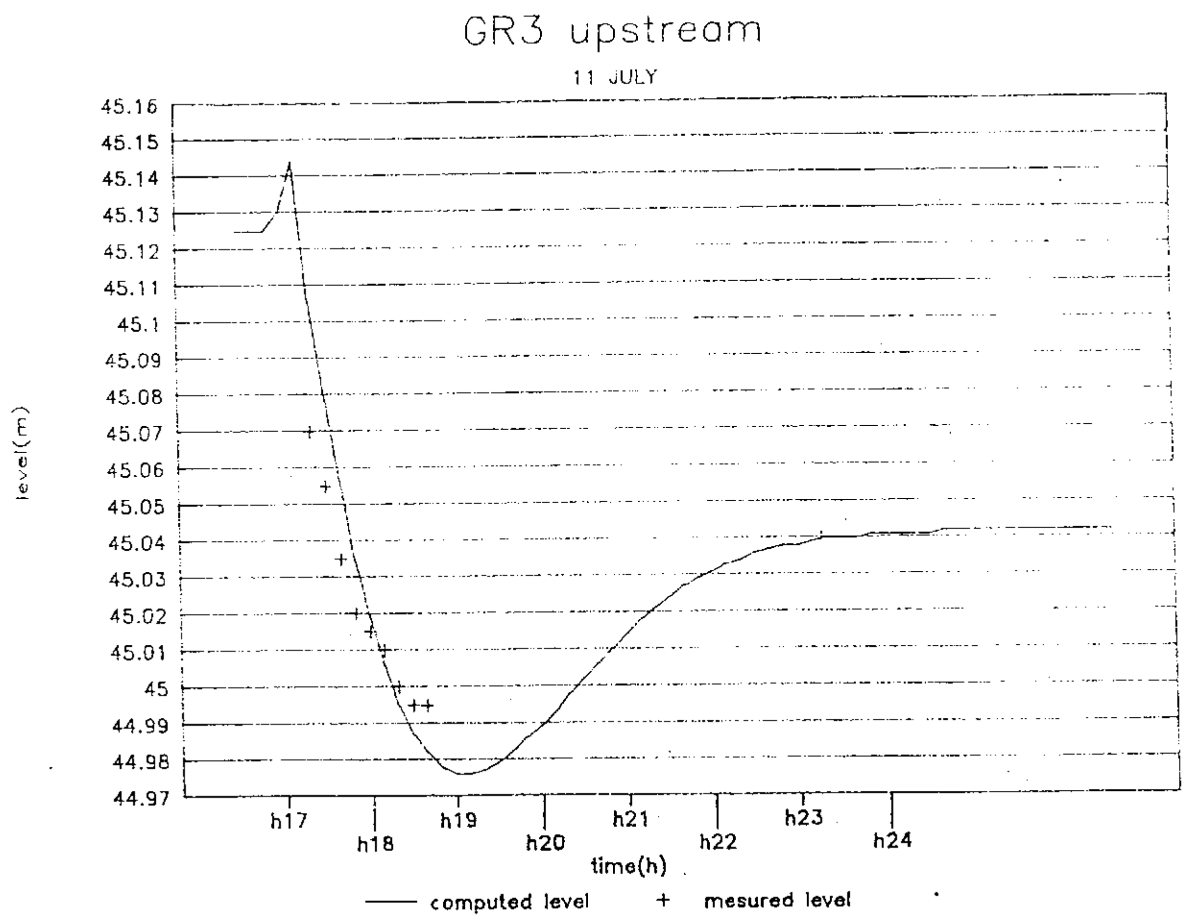


Steady State - July 28



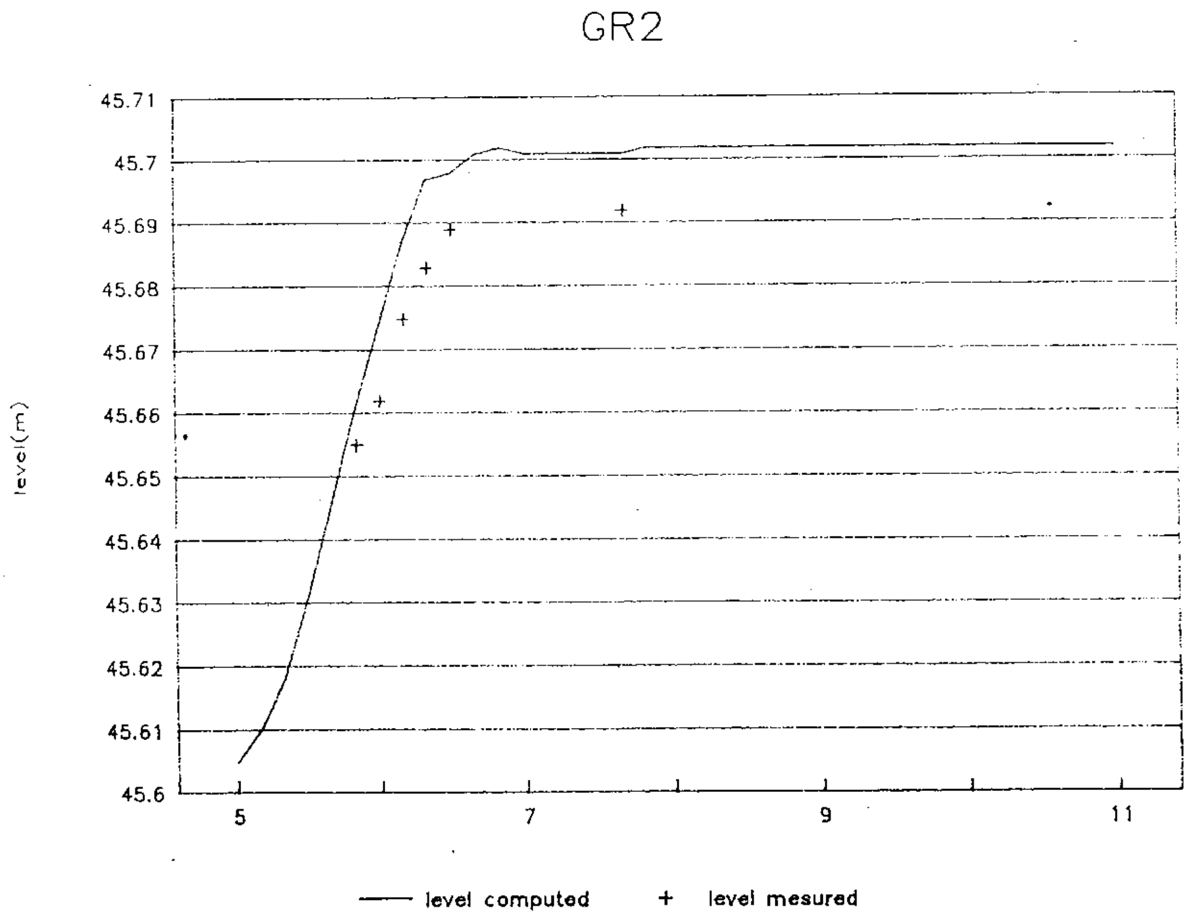
Unsteady State 1

The evolution of water level at GR3 was observed on 11 July between 1700 and 1830 hrs. 3 operations contributed to level fluctuations (opening at GR2 and GR3, and increase of discharge at main sluice. See Annex 4).



Unsteady State 2

The water level was recorded at GR2 (upstream) between 0540 and 0630 hrs. (1 measurement at 0745 hrs.) The discharge at the main sluice was increased from 15 to 40 cusecs at 5 a.m. The offtakes DC2, 3, 5 were opened during the period of observation as usual (see daily evolution).



ANNEX 3.3

Amplitude and time of operations at the devices

(Tract 1 - 30 June/ 31 July 1990 - Yala)

Annex 3.3 Amplitude and time of operations at the devices (Tract 1 - 30 June/31 July 1990 - Yala)

OPENING	DEVICE	GR2.1	GR2.2	GR2.3	GR2.4	GR2.5
29june	h1	h11	h11	h11	h11	h11
		-0.05	-0.02	-0.01	1.17	-0.00
29june	h2					
30june	h1				h7.45	
		-0.05	-0.02	-0.01	0.68	-0.00
30june	h2				h11	
		-0.05	-0.02	-0.01	0.45	-0.00
1july	h1				h8	
		-0.05	-0.02	-0.01	0.62	-0.90
1july	h2				h15	
		-0.05	-0.02	-0.01	0.93	0.00
6july	h1				h6.40	
		-0.05	-0.02	-0.01	0.33	-0.00
8july	h2				h9	
		-0.05	-0.02	-0.01	0.42	-0.00
11july	h1				h16.50	
		-0.05	-0.02	-0.01	0.69	-0.00
13july	h1				h6.10	
		-0.05	-0.02	-0.01	0.87	-0.00
14july	h1				h18.00	
		-0.05	-0.02	-0.01	0.32	-0.00
20july	h1				h8.45	
		-0.05	-0.02	-0.01	0.07	-0.00
2august	h1					
		-0.05	-0.02	-0.01	0.07	-0.00

OPENING	DEVICE	GR3.1	GR3.2	GR3.3	GR3.4	GR3.5
29june	h1	h11	h11	h11	h11	h11
		0.24	0.00	-0.00	-0.11	0.32
29june	h2					
30june	h1	h10.30				
		0.32	0.00	-0.02	-0.10	0.33
30june	h2	h11				
		0.02	0.00	-0.02	-0.10	0.33
1july	h1					h16.15
		0.02	0.00	-0.02	-0.10	0.91
2july	h1					h7.30
		0.02	0.00	-0.02	-0.10	0.78
2july	h2					h11.30
		0.02	0.00	-0.02	-0.10	0.81
4july	h1					h16
		0.02	0.00	-0.02	-0.10	0.53
5july	h1					h9.30
		0.02	0.00	-0.02	-0.10	0.81
5july	h2					h18
		0.02	0.00	-0.02	-0.10	0.94
7july	h1	h18.30				h18.30
		-0.03	0.00	-0.02	-0.10	-0.04
8july	h1					h11
		-0.03	0.00	-0.02	-0.10	0.12
11july	h1					h17
		-0.03	0.00	-0.02	-0.10	0.94
12july	h1					h5.10
		-0.03	0.00	-0.02	-0.10	0.77
16july	h1					h18.50
		-0.03	0.00	-0.02	-0.10	-0.04
2august	h1					
		-0.03	0.00	-0.02	-0.10	-0.04

OPENING	DEVICE	GR4.1	GR4.2	GR4.3	GR4.4	GR4.5
29june	h1	h11	h11	h11	h11	h11
		-0.04	0.29	-0.08	-0.02	0.32
30june	h1		h9.45			h9.45
		-0.04	0.04	-0.10	-0.02	0.75
30june	h2		h14			h14
		-0.04	0.79	-0.10	-0.02	0.02
7july	h1		h18.30			
		-0.04	-0.05	-0.10	-0.02	0.02
11july	h1		h17.30			h17.35
		-0.04	0.61	-0.10	-0.02	0.21
16july	h1		h18.00			h18.00
		-0.04	0.13	-0.10	-0.02	-0.02
17july	h1		h12.00			h12.00
		-0.04	-0.05	-0.10	-0.02	-0.05
2august	h1					
		-0.04	-0.05	-0.10	-0.02	-0.08

OPENING	DEVICE	DC2	DC3	DC4	DC5
29june	h1	h11	h11	h11	h11
		0.05	0.00	0.00	0.25
29june	h2				h5
					0
30june	h1	h7	h11		
		0.07	0.16	0.00	0.00
30june	h2	h17.30			
		-0.06	0.16	0.00	0.00
1july	h1	h8.15	h15.45		h5.20
		0.03	0.22	0.00	0.25
1july	h2	h15	h18		h17
		-0.06	-0.03	0.00	0.00
4july	h1	h6.40	h6.30	h8	h4.45
		0.05	0.24	0.02	0.21
4july	h2	h17		h18	h18
		-0.07	0.24	-0.05	-0.05
5july	h1	h15.45	h6	h6.15	h5
		-0.07	-0.03	0.00	0.33
5july	h2			h13	h18
		-0.07	-0.03	0.00	-0.05
8july	h1	h7	h6.40	h7.15	h5
		0.02	0.24	0.00	0.25
8july	h2	h17	h11.30	h17	h18
		-0.07	0.26	0.00	-0.05
9july	h1		h6.15	h6.30	h5
		-0.07	-0.03	0.00	0.28
9july	h2			h18	h18
		-0.07	-0.03	0.00	-0.05
12july	h1	h6.00	h5.45	h5.30	h5.00
		0.05	0.33	0.02	0.25
12july	h2	h9.30		h18.00	h6.00
		0.01	0.33	0.00	0.39
12july	h3	h15.50			h15.30
		-0.06	0.33	0.00	0.21
12july	h4				h18.00
		-0.06	0.33	0.00	-0.05
13july	h1	h12.00	h6.00	h6.00	h6.10
		0.05	-0.03	0.02	0.28
13july	h2			h18.00	h16.30
		0.05	-0.03	0.00	0.11
13july	h3				h18.00
		0.05	-0.03	0	0
16july	h1		h6.30	h6.10	h5.00
		0.05	0.35	0.02	0.39
16july	h2	h18.00	h18.00	h17.30	h18.00
		-0.05	0.24	0.00	-0.04
17july	h1		h6.30		h5.00
		-0.05	-0.03	0.00	0.24
17july	h2				h15.10
		-0.05	-0.03	0.00	0.10
20july	h1	h6.15	h6.00	h5.45	h5.00
		0.10	0.36	0.02	0.26
20july	h2	h16.30	h15.00	h17.30	h16.00
		-0.06	0.31	0.00	0.23
20july	h3				h18.00
		-0.06	0.31	0.00	-0.05
21july	h1		h6.30	h9.00	h5.00
		-0.06	-0.03	0.02	0.26
21july	h2			h16.30	h16.00
		-0.06	-0.03	0.00	0.17
21july	h3				h18.00
		-0.06	-0.03	0.00	-0.05
24july	h1	h6.45	h6.30	h9.30	h4.45
		0.04	0.27	0.04	0.28
24july	h2	h[illegible]			
		[illegible]	0.27	0.04	0.28
24july	h3	h17.30			h18.00
		-0.06	0.27	0.04	0.00
25july	h1	h8.30	h6.30	h14.00	[illegible]
		0.00	-0.03	0.02	0.28
25july	h2	h14.30		h18.00	h18.00
		-0.06	-0.03	-0.00	0.00
28july	h1	h6.45	h6.30	h6.50	h4.45
		0.05	0.25	0.03	0.30
28july	h2			h17.30	h18.00
		0.05	0.25	-0.10	-0.05
29july	h1	h16.45	h6.30		h5.00
		-0.06	-0.03	-0.10	0.26
29july	h2				h18.00
		-0.06	-0.03	-0.10	-0.05
1august	h1	h7.00	h6.40	h6.30	h7.00
		0.05	0.77	0.02	0.33
1august	h2	h18.00		h18.10	h18.00
		-0.07	0.77	-0.12	-0.05
2august	h1		h5.30		h5.00
		-0.07	0.03	-0.12	0.33
2august	h2				h1[illegible]
		-0.07	0.03	-0.12	0.29
2august	h3				h18.00
		-0.07	0.03	-0.12	-0.05

OPENING	DEVICE	FC6	FC55	FC56	FC57	FC58
29june	h1	h11	h11	h11	h11	h11
		-0.00	-0.05	-0.06	-0.08	-0.06
30june	h1		h10	h7	h7.15	
		-0.00	-0.02	0.06	0.05	-0.06
30june	h2		h17	h15	h17	
		-0.00	-0.04	-0.05	-0.08	-0.06
4july	h1		h12	h12	h17	
		-0.00	-0.04	-0.05	-0.08	-0.06
8july	h1		h6.30		h9	
		-0.00	0.09	-0.05	0.10	-0.06
8july	h2		h17		h17	
		-0.00	-0.04	-0.05	-0.08	-0.06
9july	h1			h8		
		-0.00	-0.04	0.02	-0.08	-0.06
9july	h2			h15		
		-0.00	-0.04	-0.07	-0.08	-0.06
12july	h1		h6.30	h7.00	h7.00	
		-0.00	0.03	0.04	0.05	-0.06
12july	h2		h17.30	h15.15	h17.30	
		-0.00	-0.06	-0.07	-0.08	-0.06
13july	h1		h9.00	h15.40		h7.40
		-0.00	0.08	0.07	-0.08	0.08
13july	h2		h14.20	h16.20		h14.50
		-0.00	-0.06	-0.06	-0.08	-0.04
16july	h1		h7.20	h7.20	h7.30	
		-0.00	0.08	0.02	0.08	-0.04
16july	h2		h16.45	h11.45	h17.15	
		-0.00	-0.06	-0.06	-0.08	-0.04
17july	h1			h7.10	h7.15	h7.30
		-0.00	-0.06	0.07	0.07	0.08
17july	h2			h10.45	h10.50	h14.20
		-0.00	-0.06	-0.06	0.20	-0.06
17july	h3				h17.20	
		-0.00	-0.06	-0.06	-0.07	-0.06
20july	h1		h7.30	h7.35	h7.35	h11.00
		-0.00	0.09	0.11	0.07	0.05
20july	h2		h16.50	h15.50	h16.10	h14.00
		-0.00	-0.05	-0.06	-0.07	-0.06
21july	h1				h8.00	h7.30
		-0.00	-0.05	-0.06	0.00	0.03
21july	h2				h15.40	h15.50
		-0.00	-0.05	-0.06	-0.08	-0.05
24july	h1		h7.35			h9.45
		-0.00	0.02	-0.06	-0.08	0.03
24july	h3		h17.00			h16.35
		-0.00	0.00	-0.06	-0.08	-0.06
25july	h1			h9.15	h8.50	h9.00
		-0.00	0.00	0.01	0.02	0.03
25july	h2			h17.30	h17.00	h17.10
		-0.00	0.00	-0.06	-0.08	-0.06
28july	h1		h7.30	h7.30	h8.20	h8.00
		-0.06	0.06	0.03	0.05	0.04
28july	h2		h18.20	h18.10	h18.10	h18.00
		-0.00	-0.06	-0.06	-0.07	-0.06
29july	h1		h7.00	h7.45	h7.00	h7.15
		-0.00	0.03	0.05	0.08	[illegible]
29july	h2		h15.20	h15.50	h16.00	h16.10
		-0.00	-0.06	-0.06	-0.08	-0.06
1august	h1			h14.30	h8.00	
		-0.00	-0.06	0.10	0.05	-0.06
1august	h2			h17.20	h17.10	
		-0.00	-0.06	-0.06	-0.08	-0.06
2august	h1		h7.40	h7.20	h7.30	h7.10
		-0.00	0.19	0.09	0.09	-0.04
2august	h2		h17.30	h15.40		h17.10
		-0.00	-0.06	-0.06	0.09	-0.05

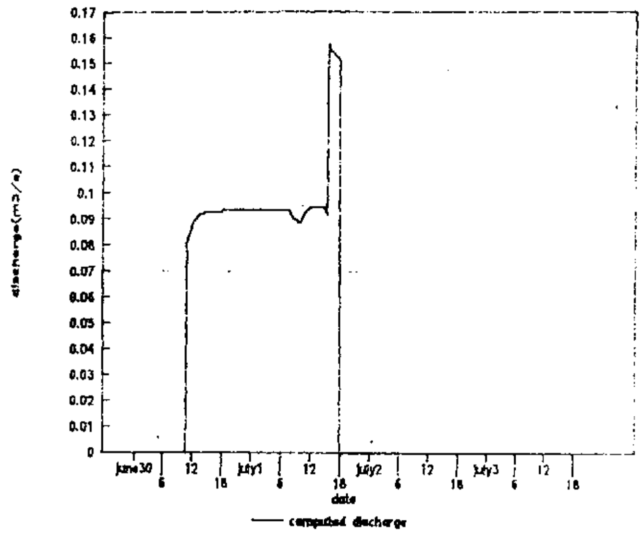
ANNEX 3.4

Daily Simulations of the Canal State

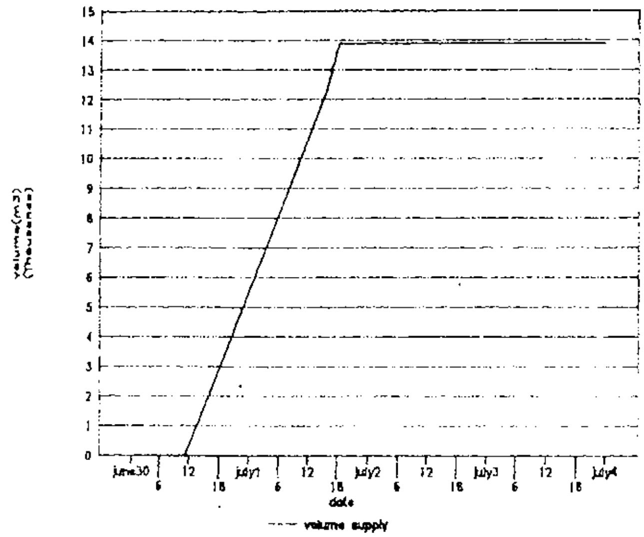
ANNEX 3.4 Daily Simulations of the canal state

3.4.1 Targeted and real supply in terms of discharges and volumes are presented below for DC3, DC4, DC5 TRACT 1. Step Time: 4 days.

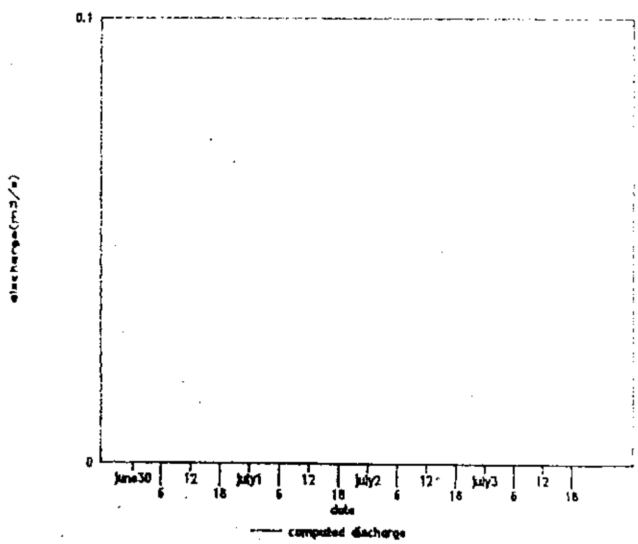
DC3



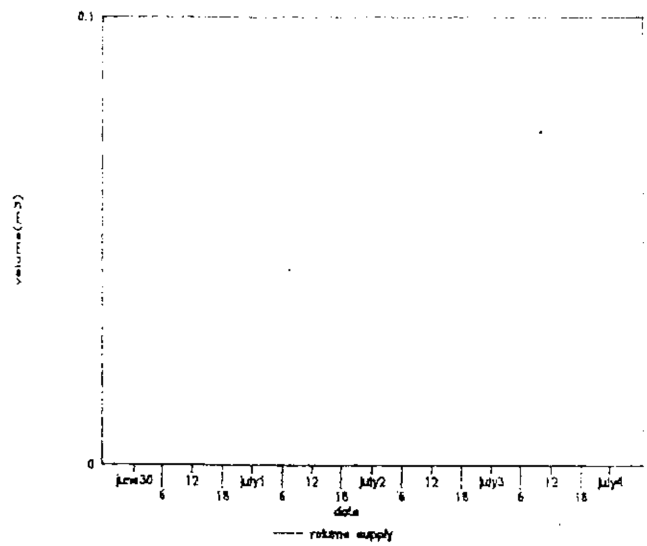
DC3



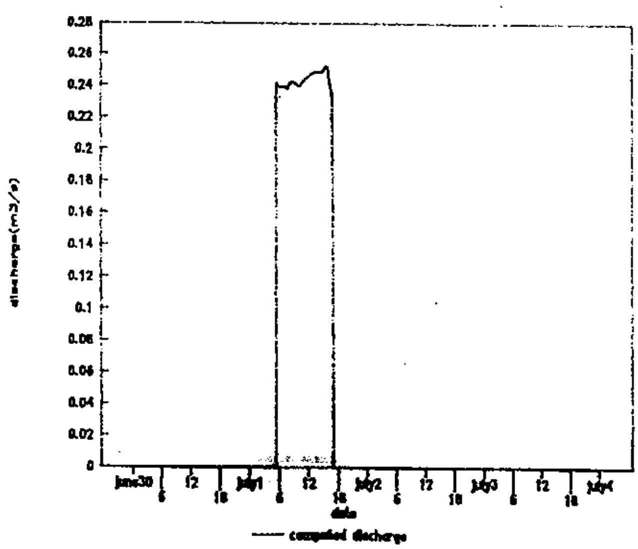
DC4



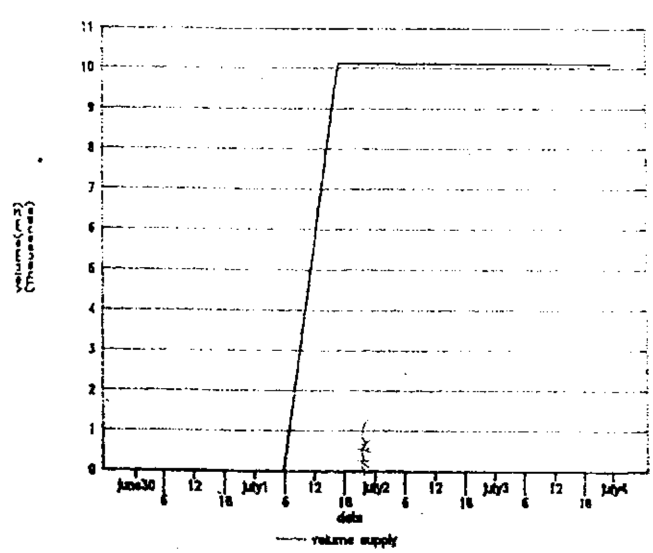
DC4



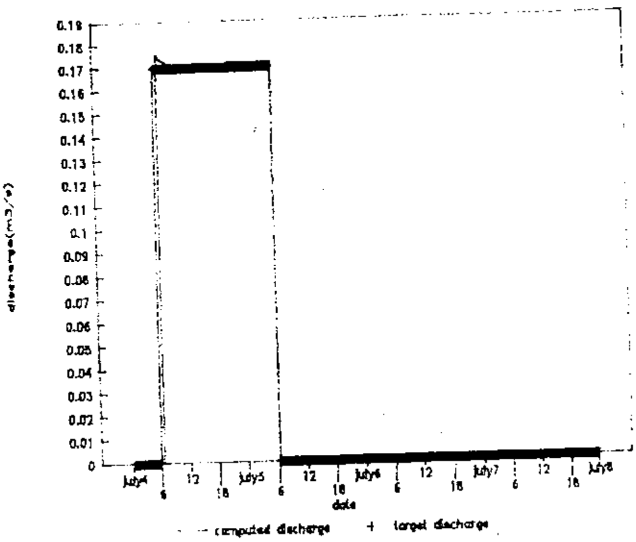
DC5



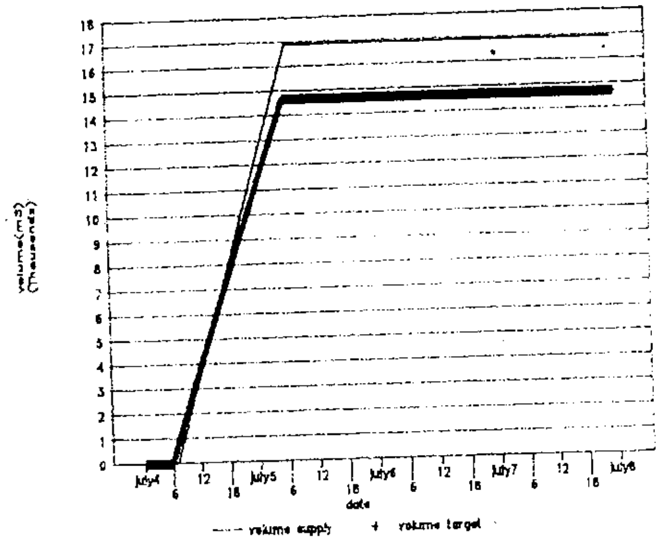
DC5



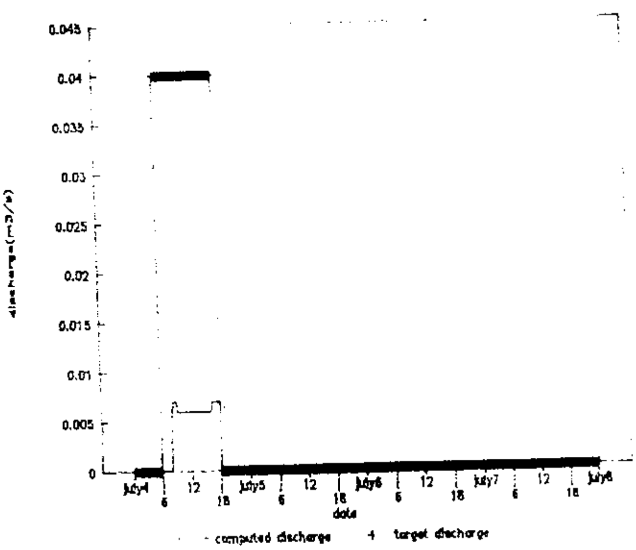
DC3



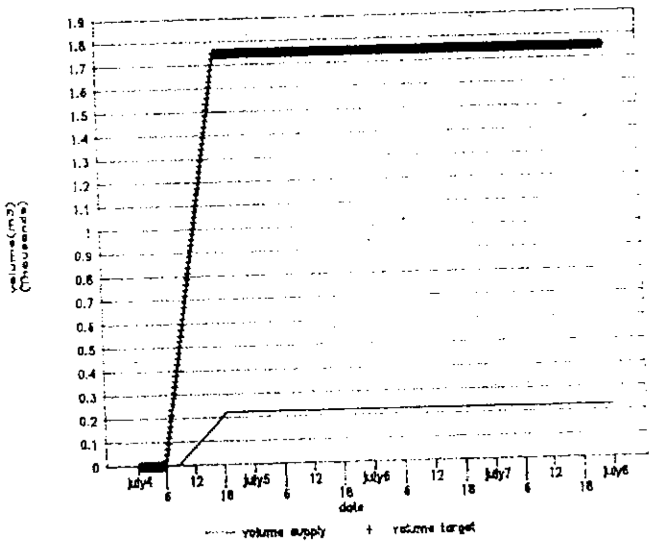
DC3



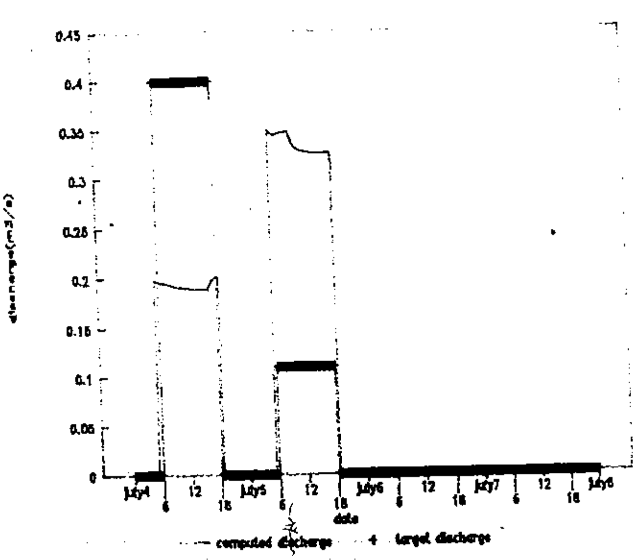
DC4



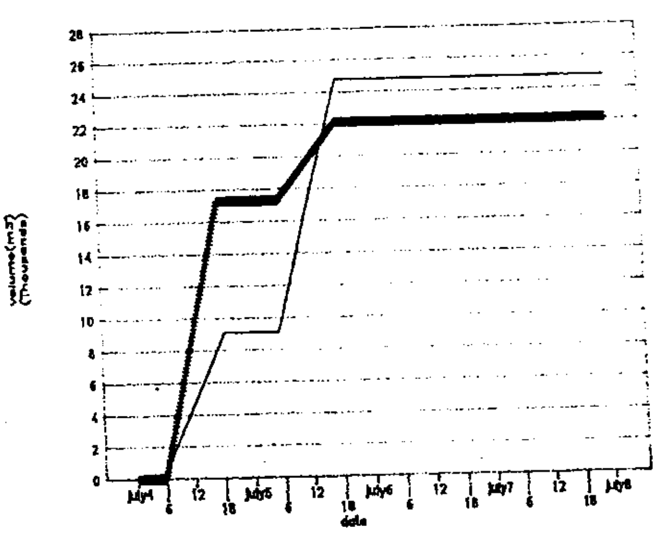
DC4



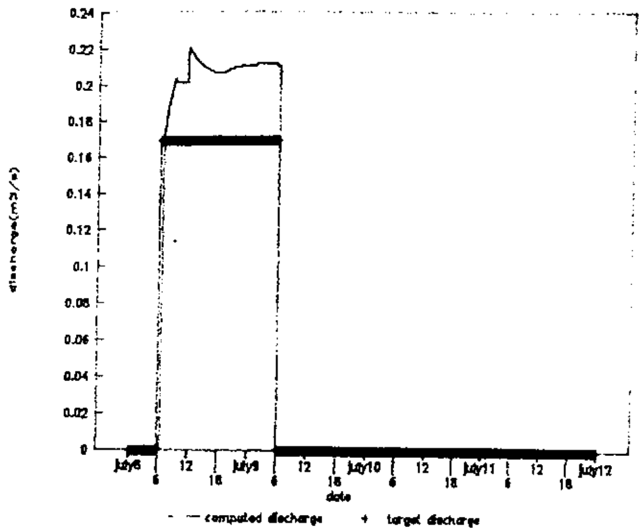
DC5



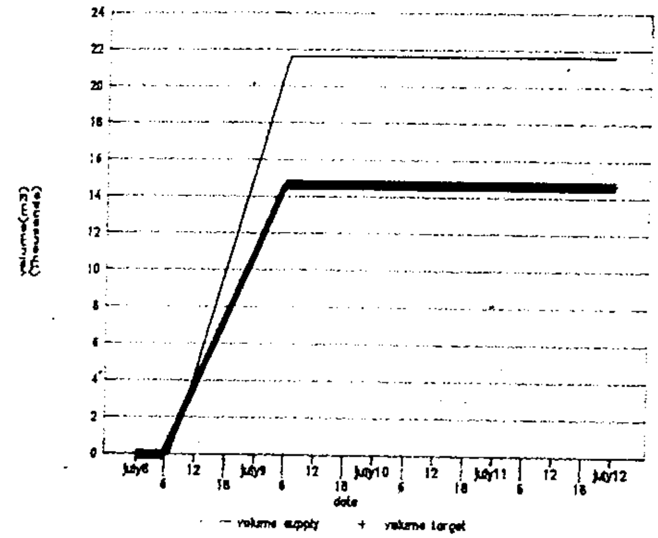
DC5



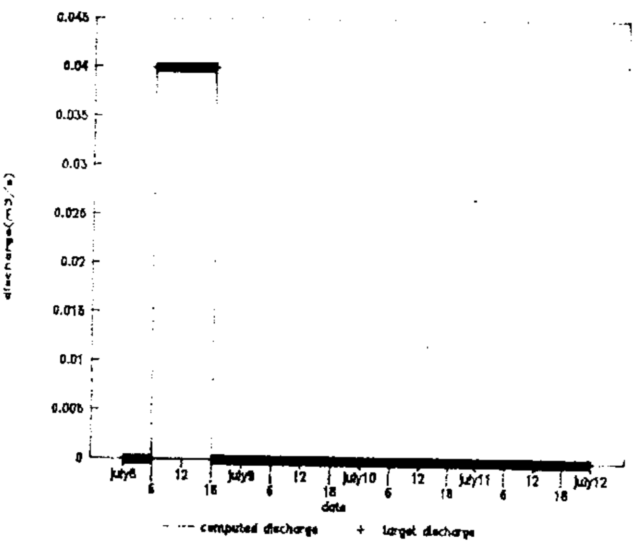
DC3



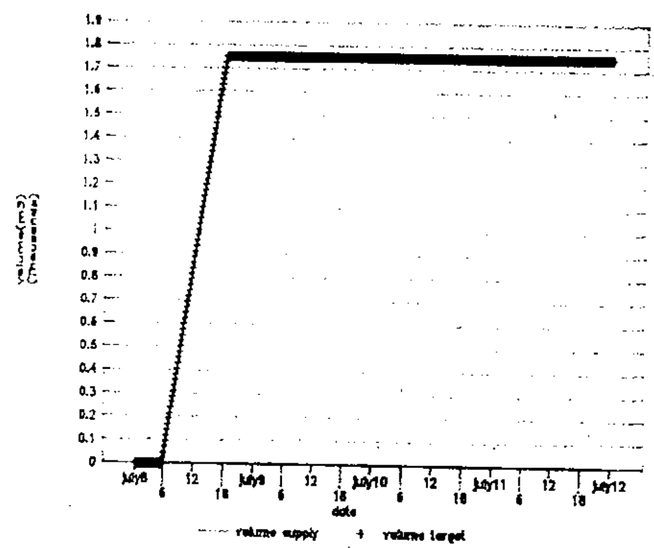
DC3



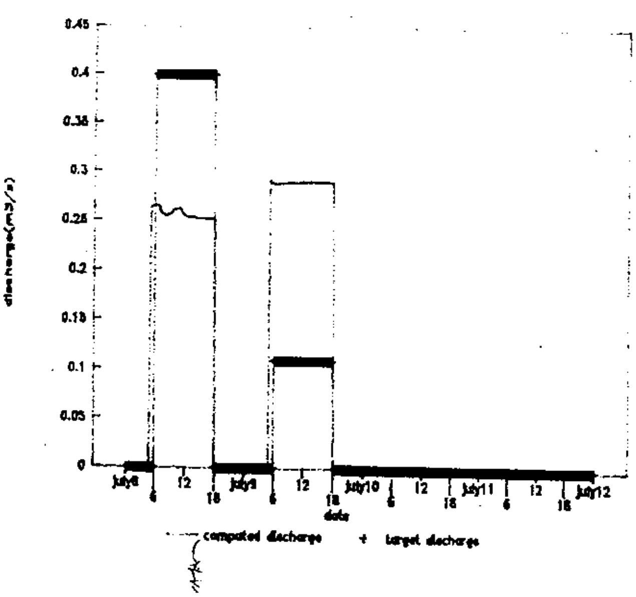
DC4



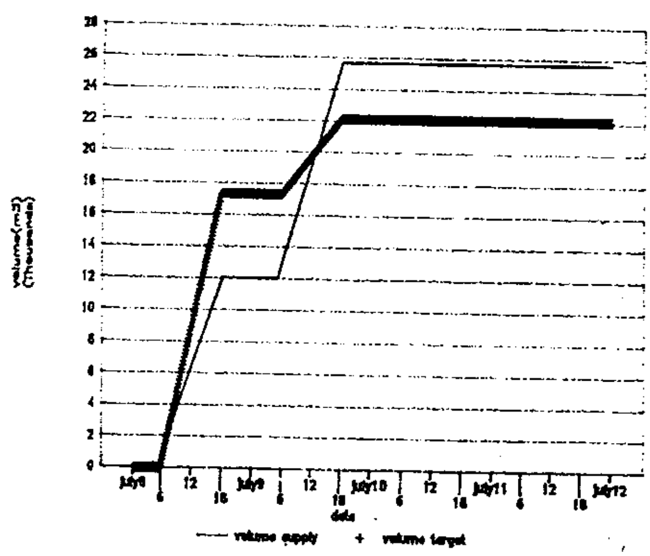
DC4



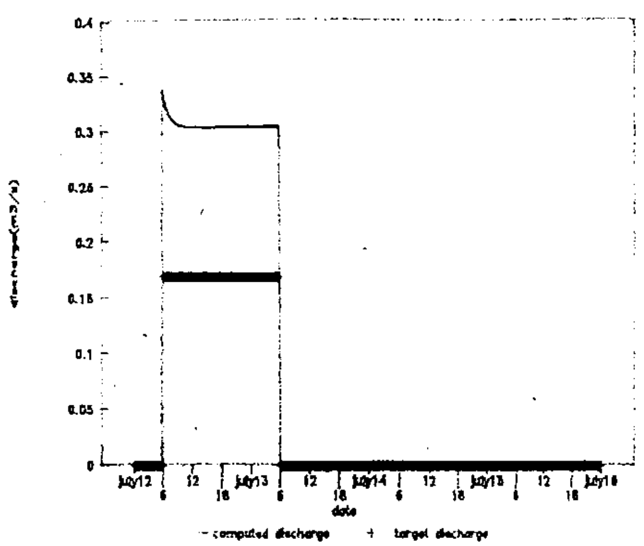
DC5



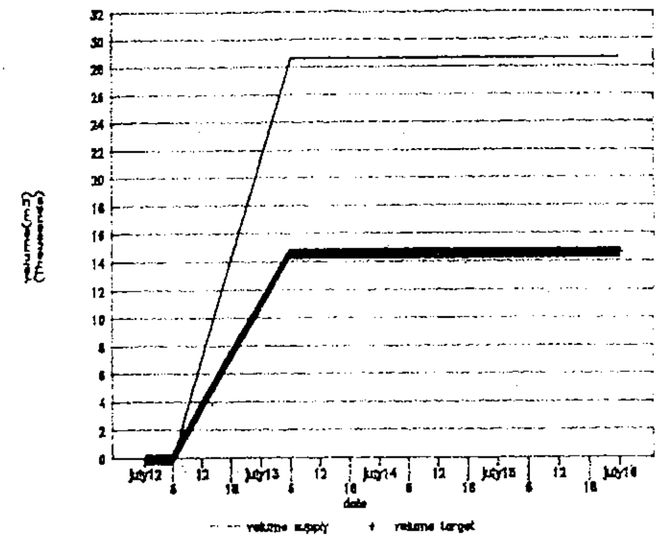
DC5



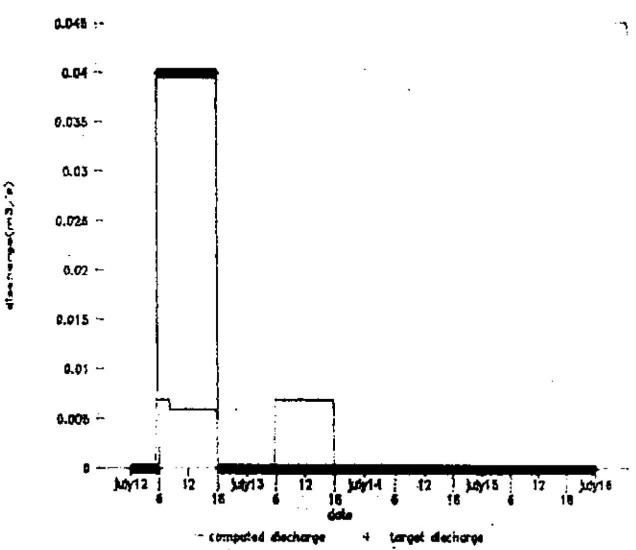
DC3



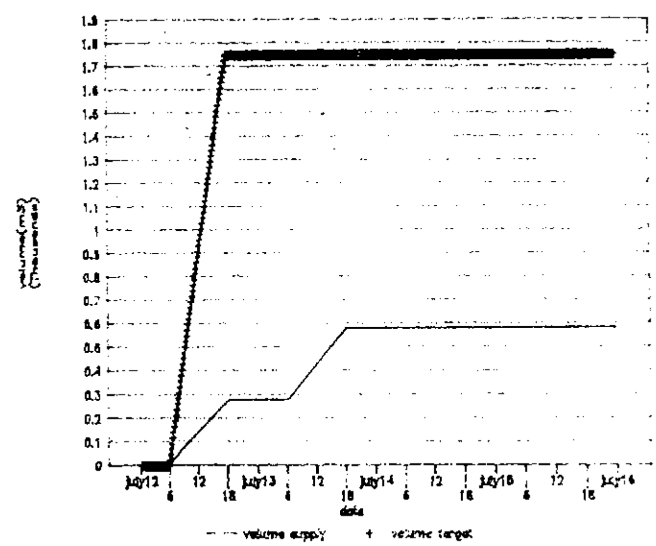
DC3



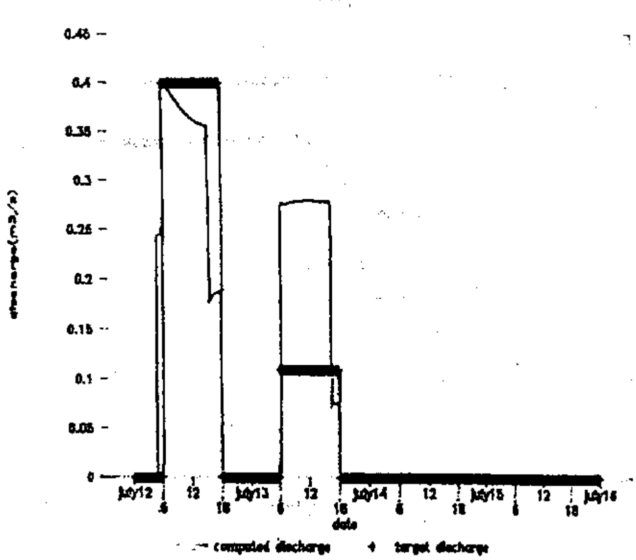
DC4



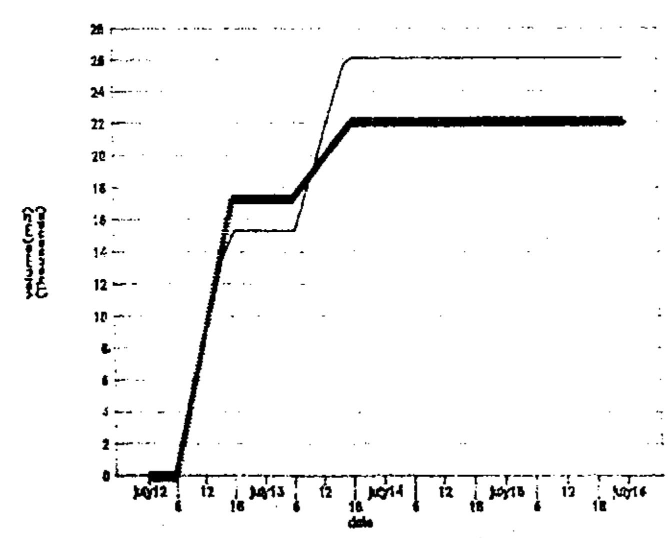
DC4



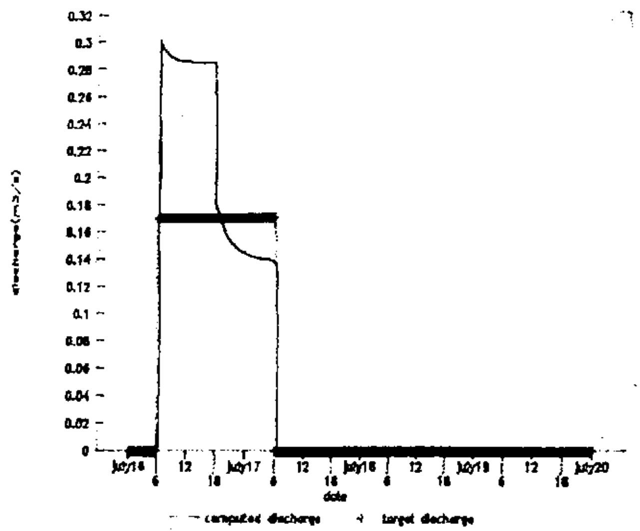
DC5



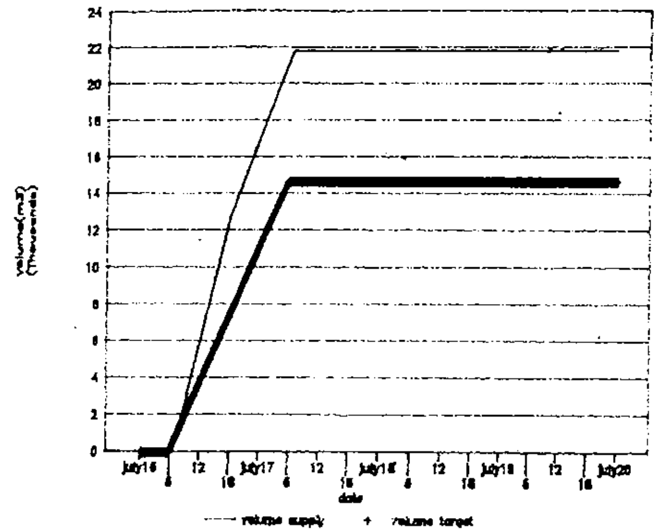
DC5



DC3



DC3



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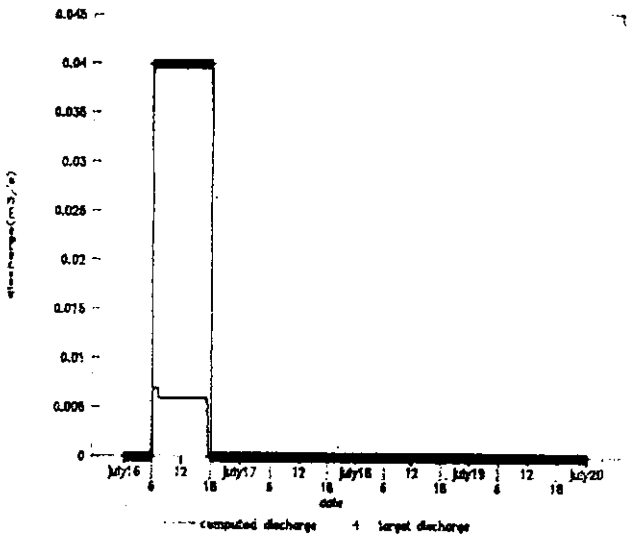

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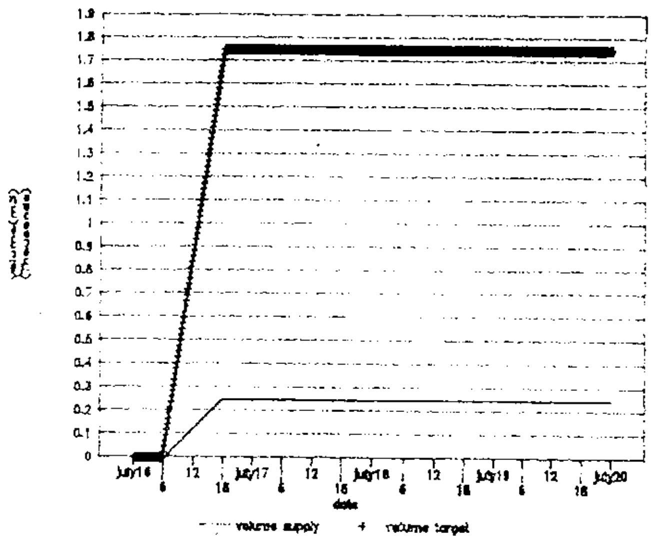
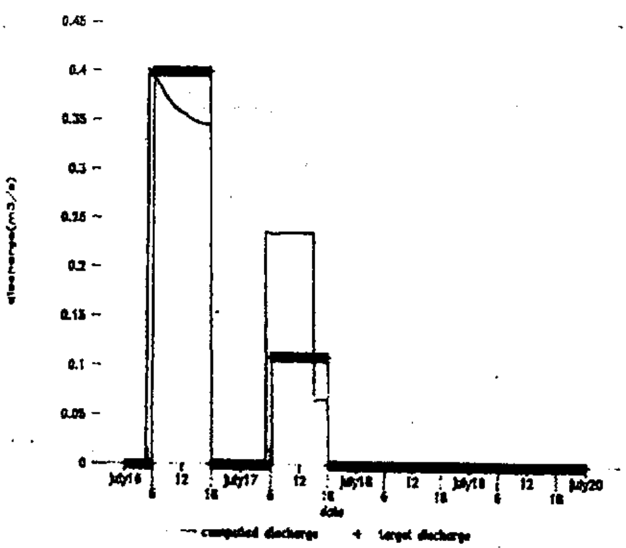


DC5



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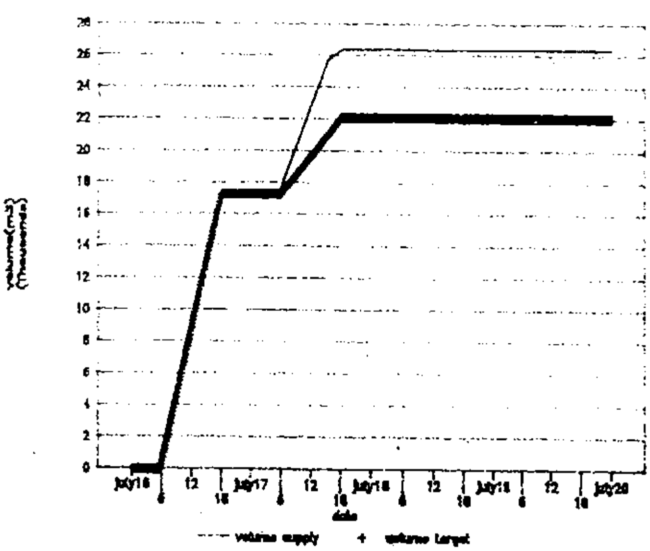

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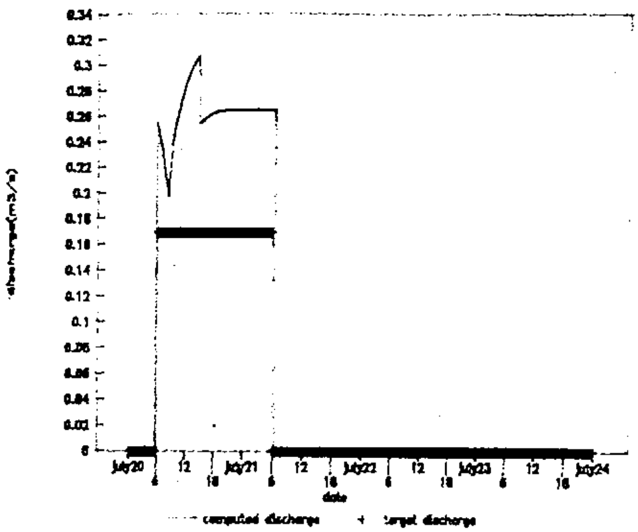

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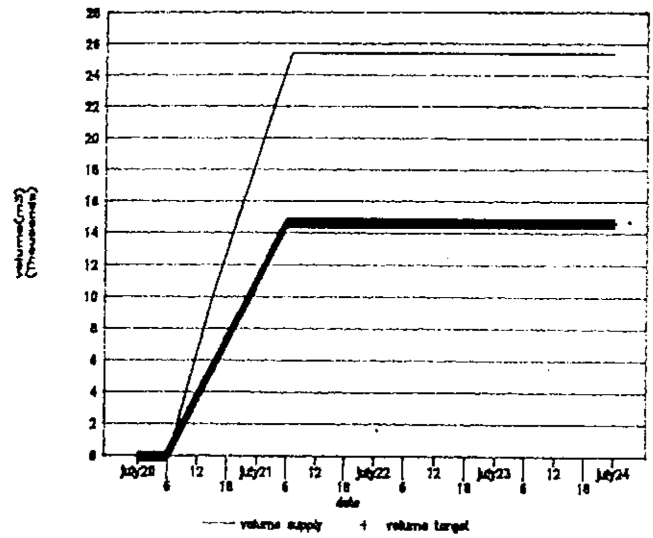

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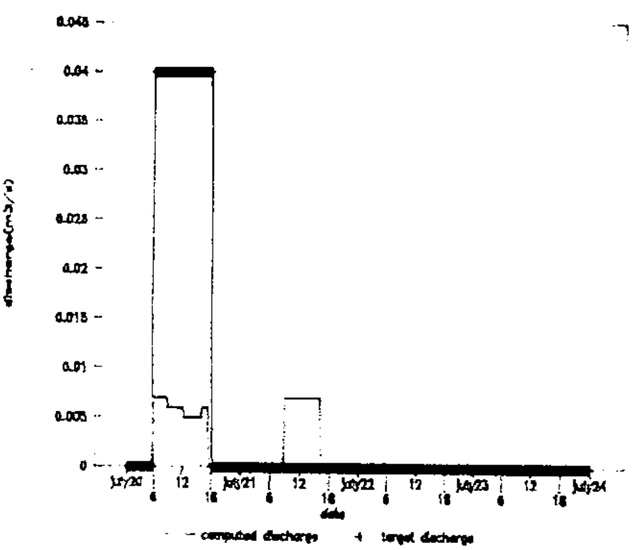

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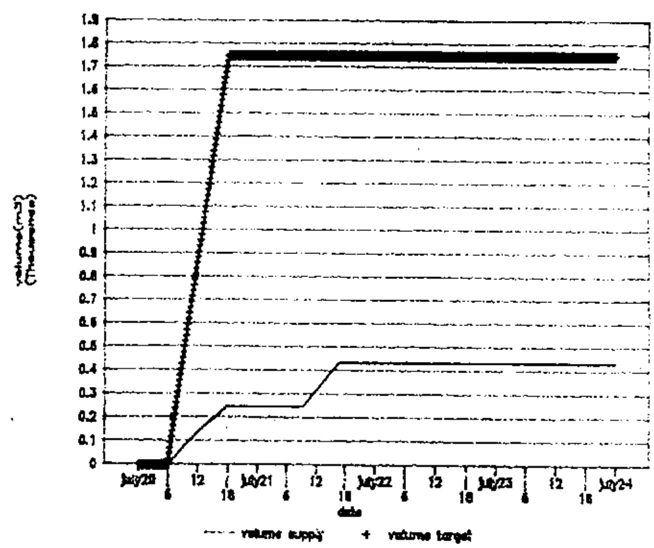

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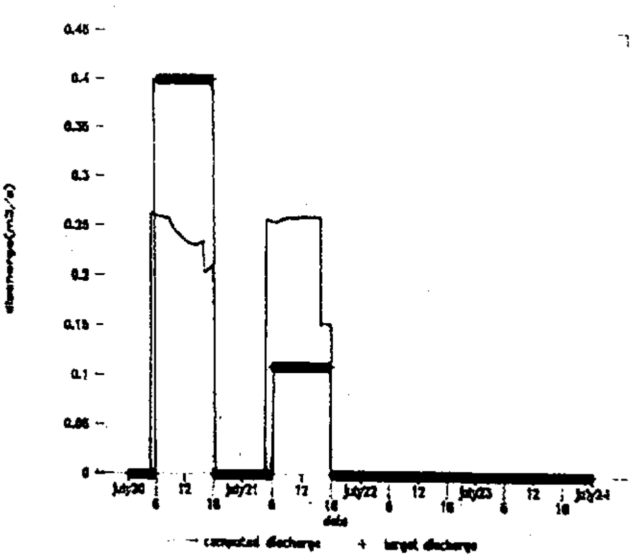

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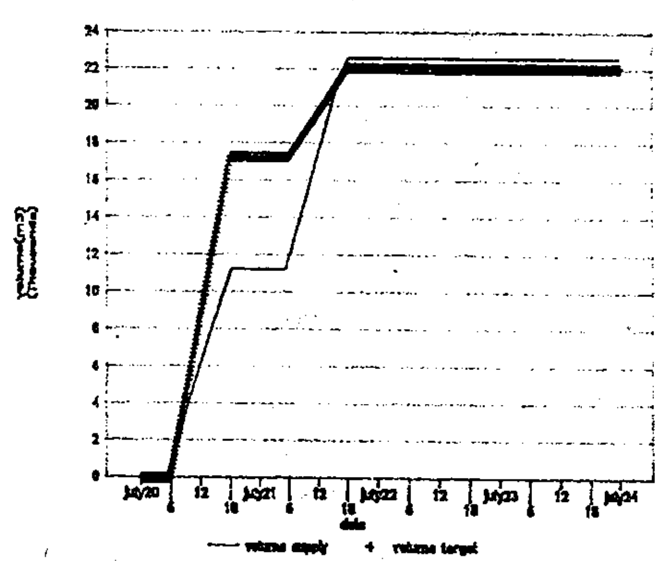

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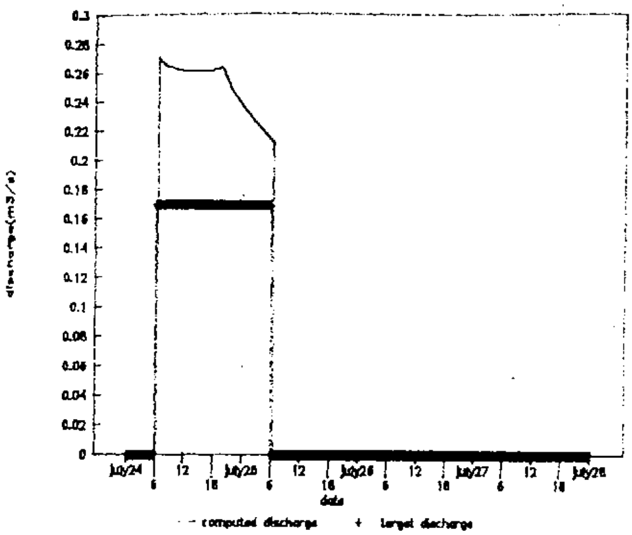

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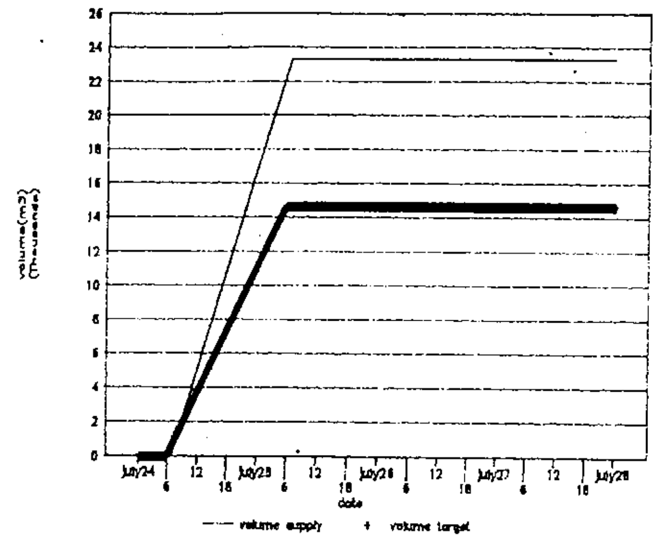

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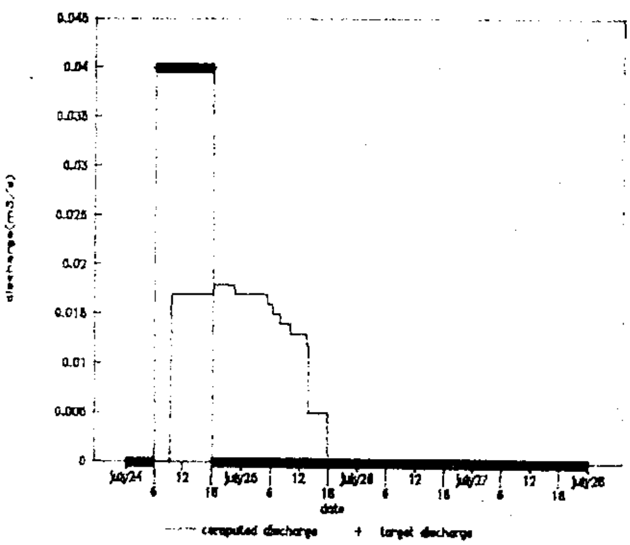

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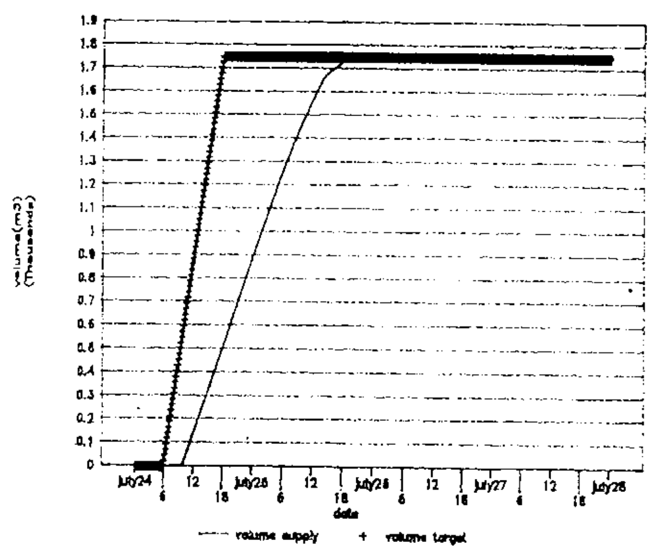

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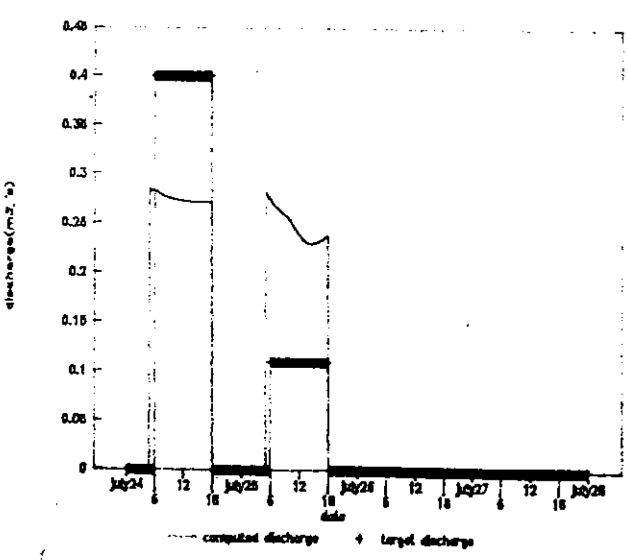

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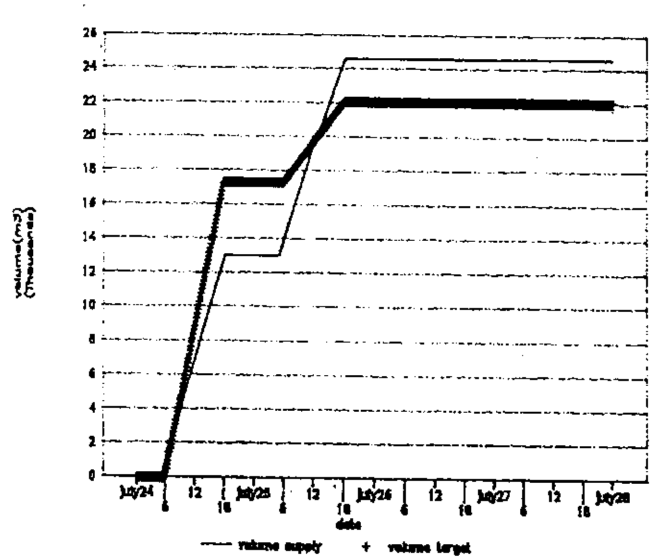

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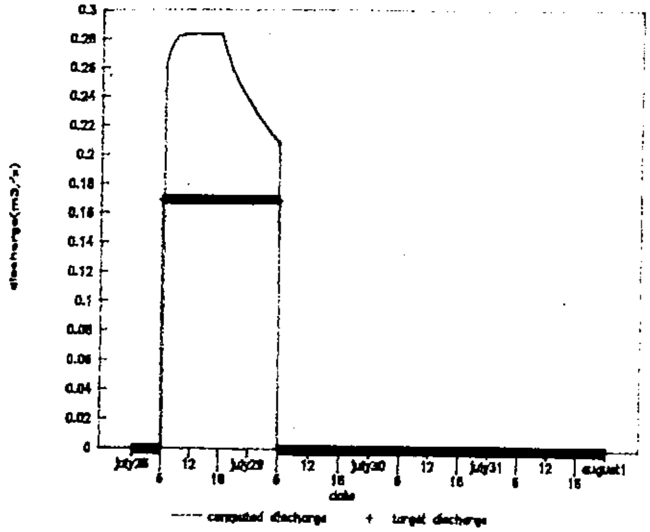
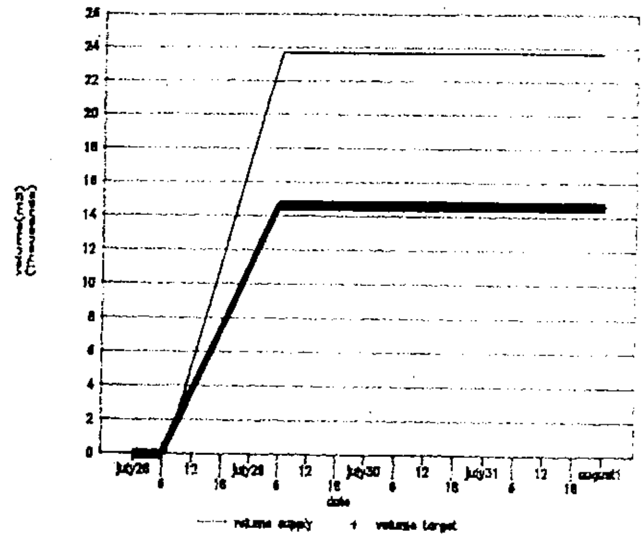
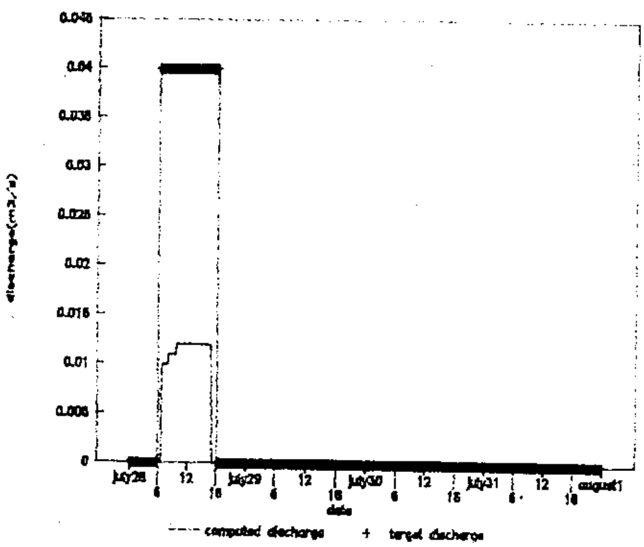


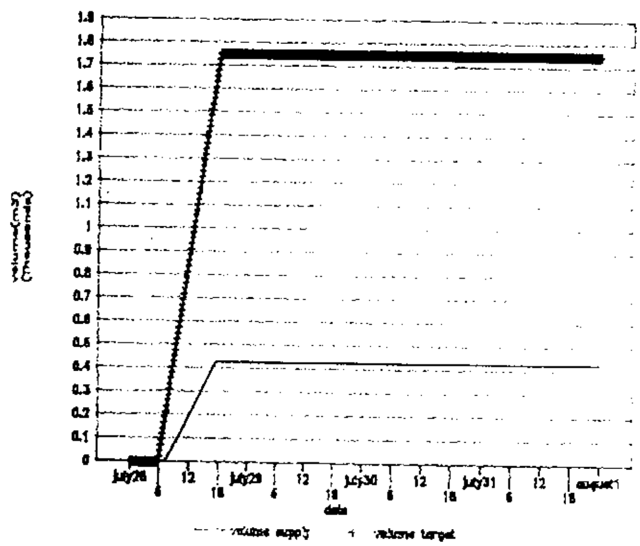
DC3



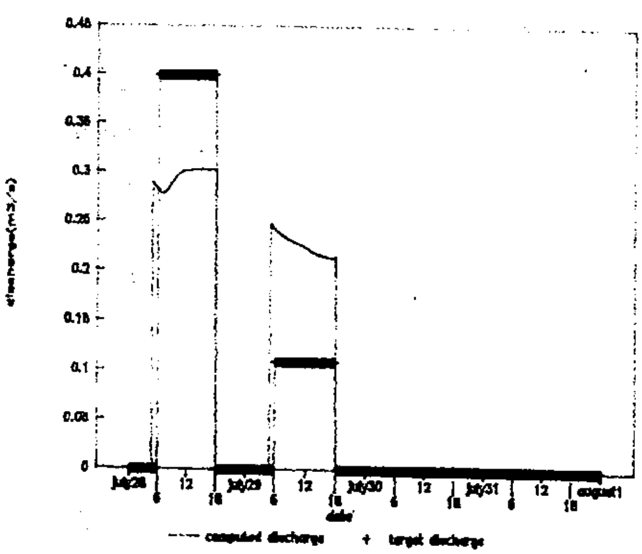
DC4



DC4



DC5



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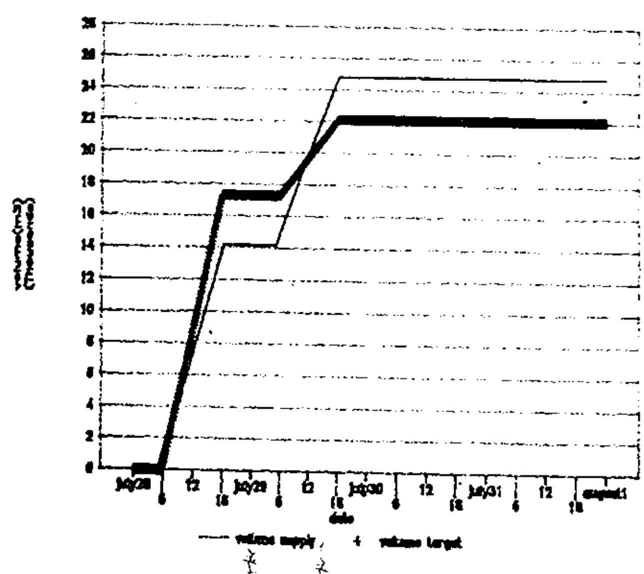
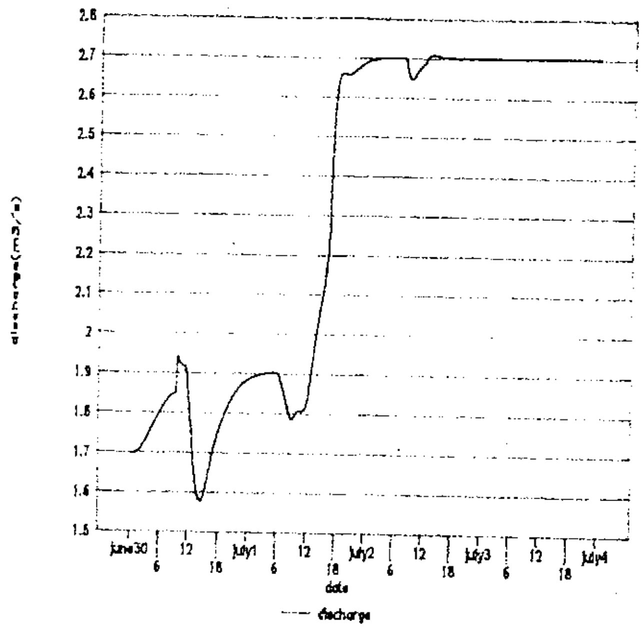


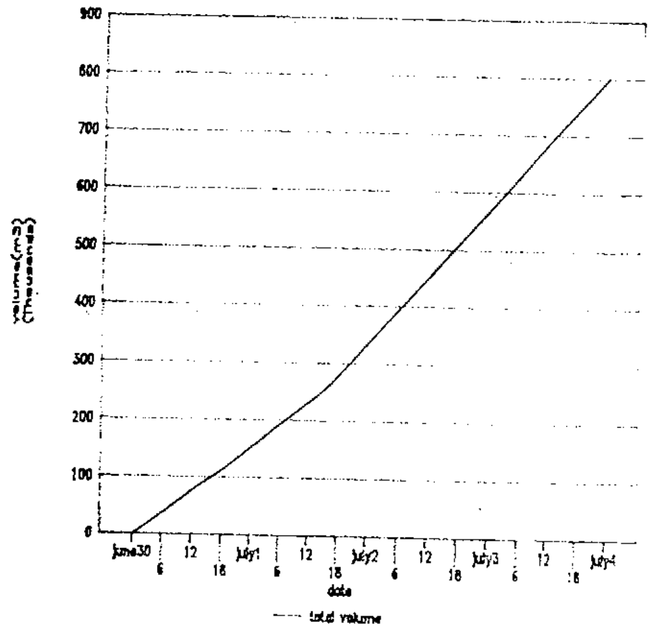
3.4.2 Discharge and total volume issue at the end of TRACT 1 are presented.

Total volume diverted at this point (1 July/1 August): 3.5 MCM

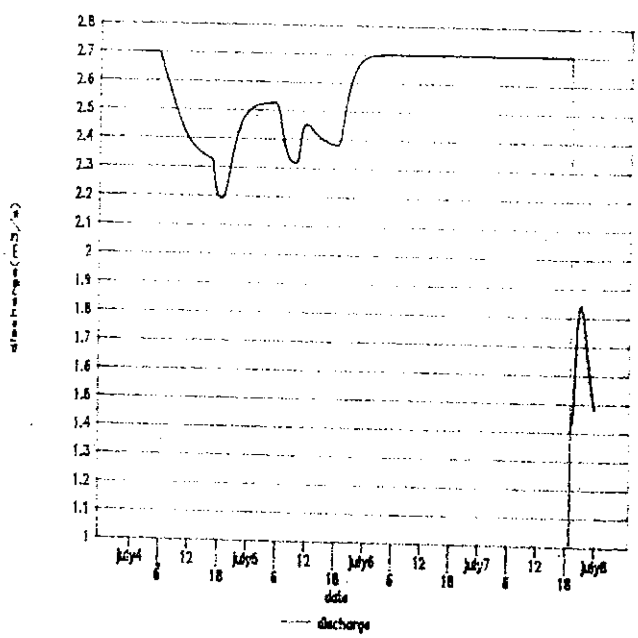
END OF TRACT1



END OF TRACT1



END OF TRACT1



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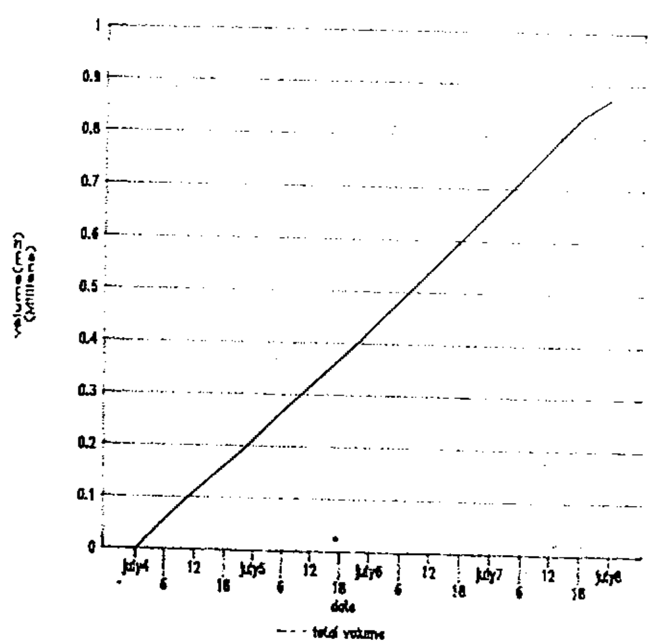
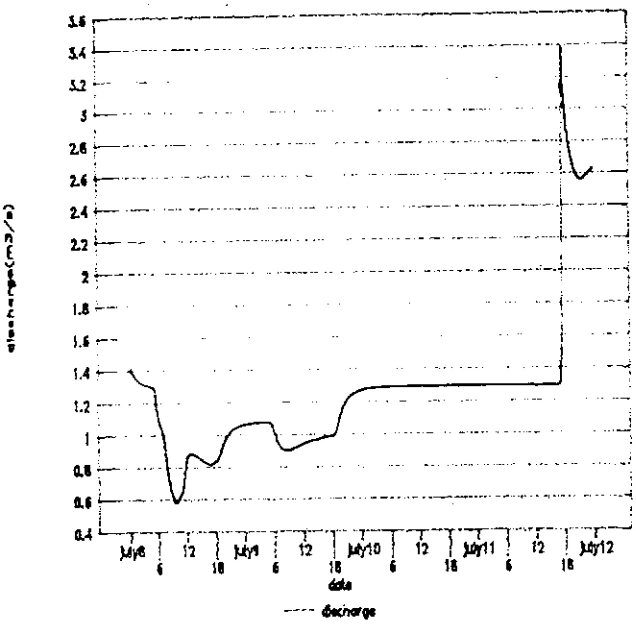
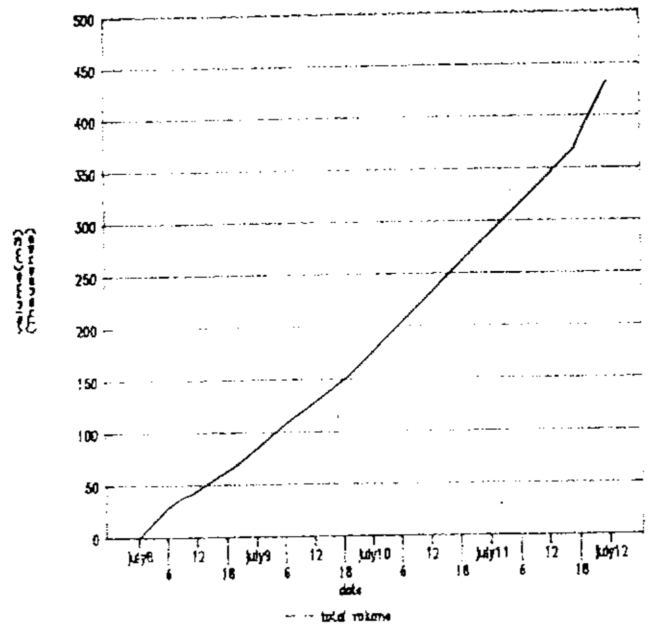


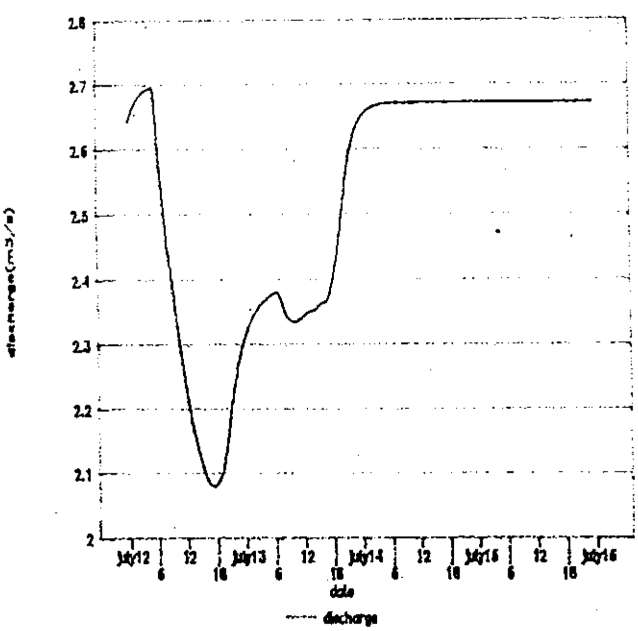
END OF TRACT1



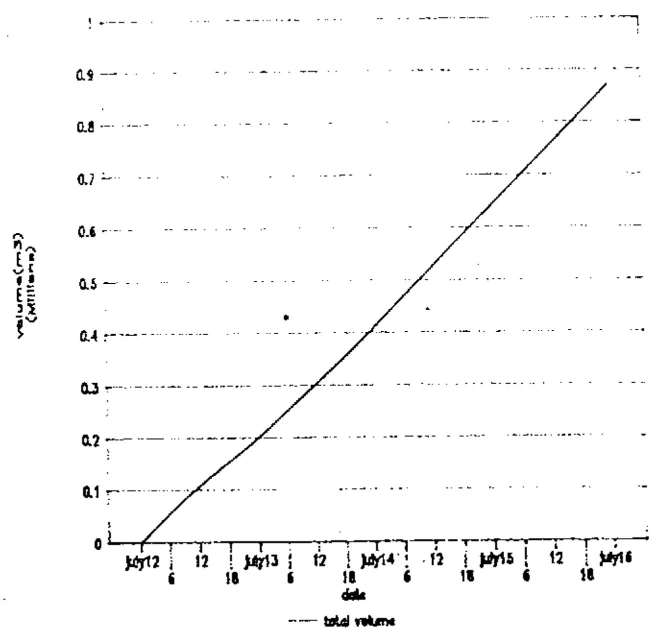
END OF TRACT1



END OF TRACT1



END OF TRACT1



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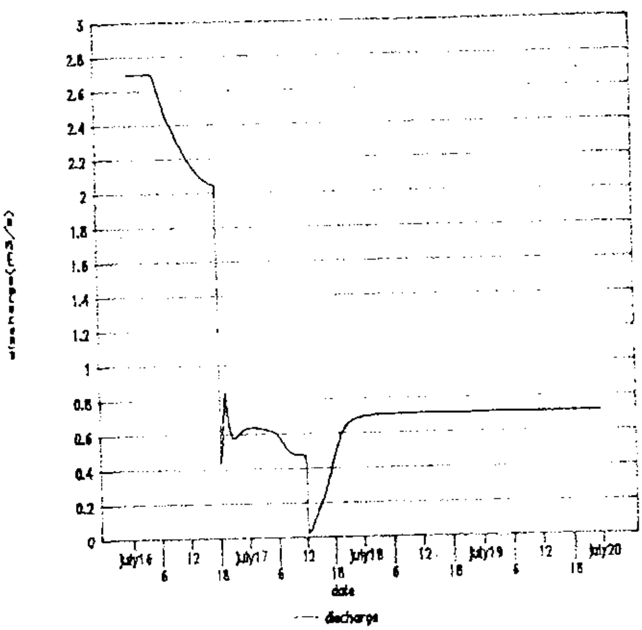
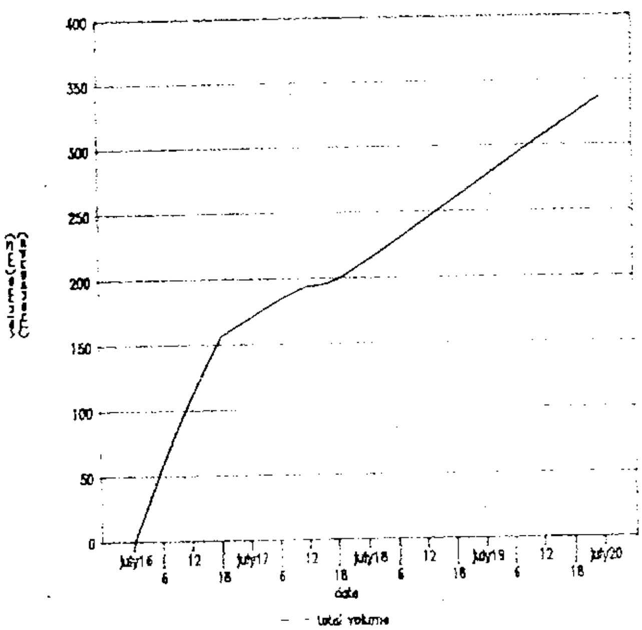


END OF TRACT1



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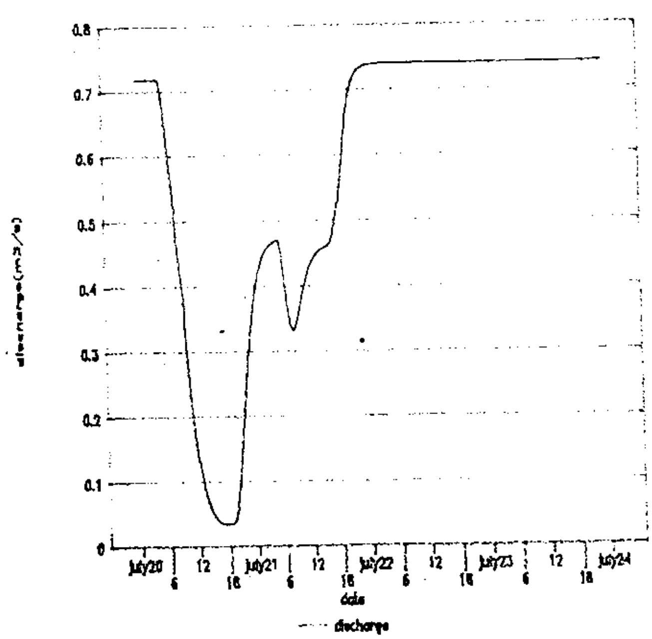
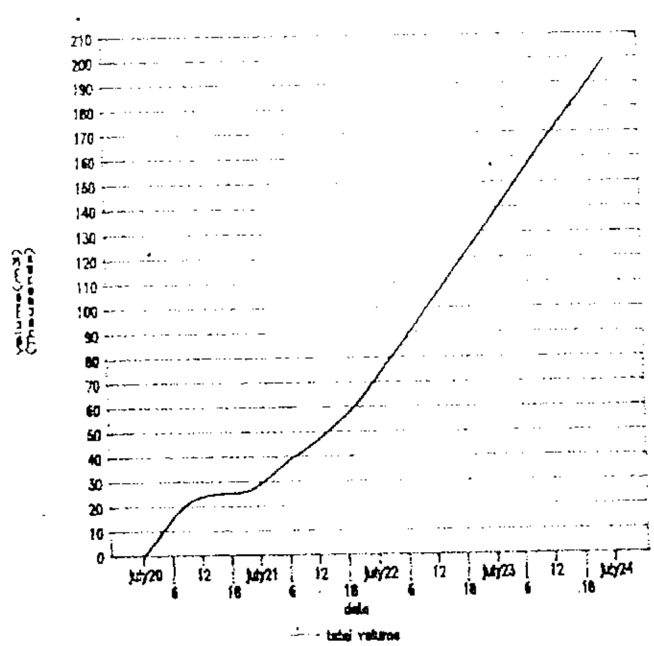
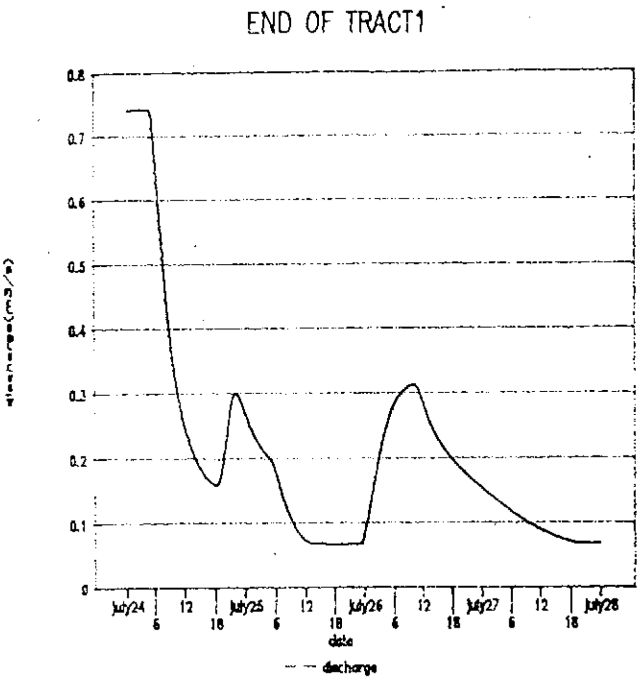
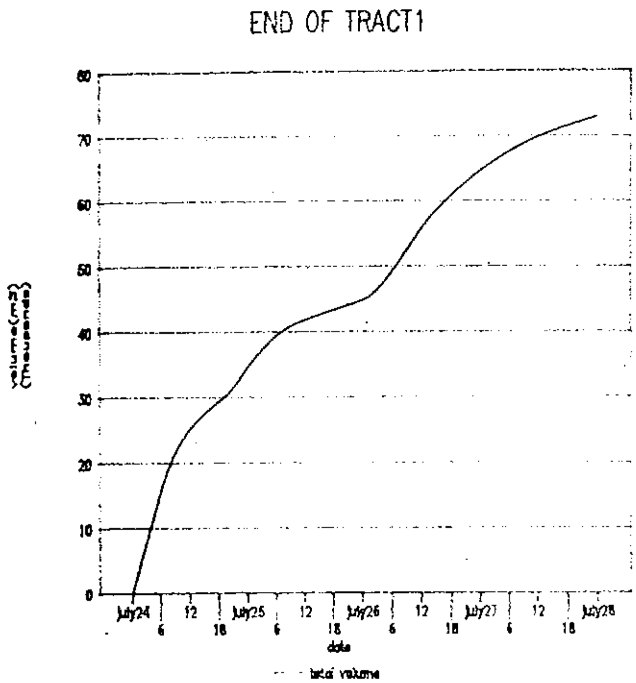
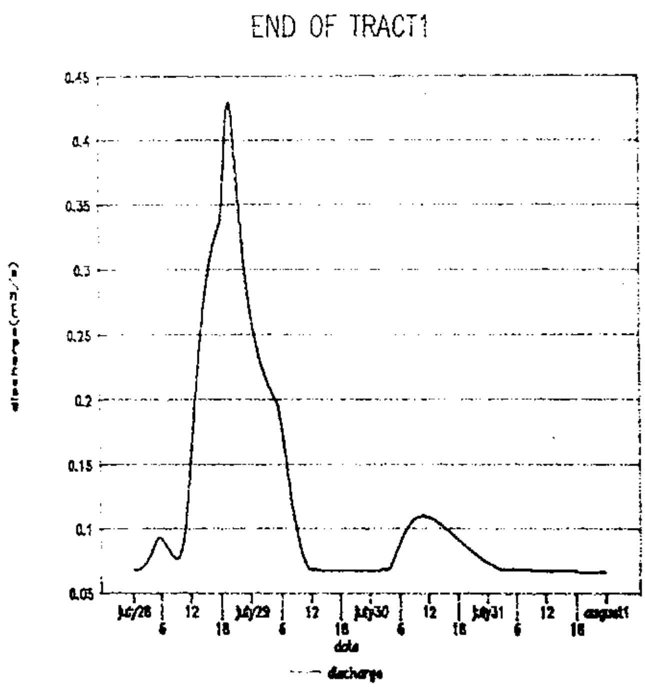


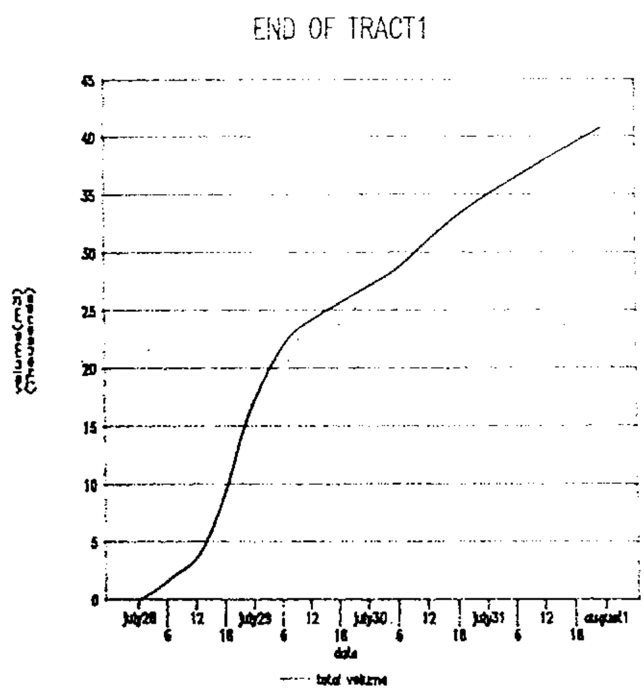
END OF TRACT1




END OF TRACT1
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
july24
6
12
18
july25
6
12
18
july26
6
12
18
july27
6
12
18
july28
date
discharge


END OF TRACT1
volume(m3)
(Thousands)
80
70
60
50
40
30
20
10
0
july24
6
12
18
july25
6
12
18
july26
6
12
18
july27
6
12
18
july28
date
total volume

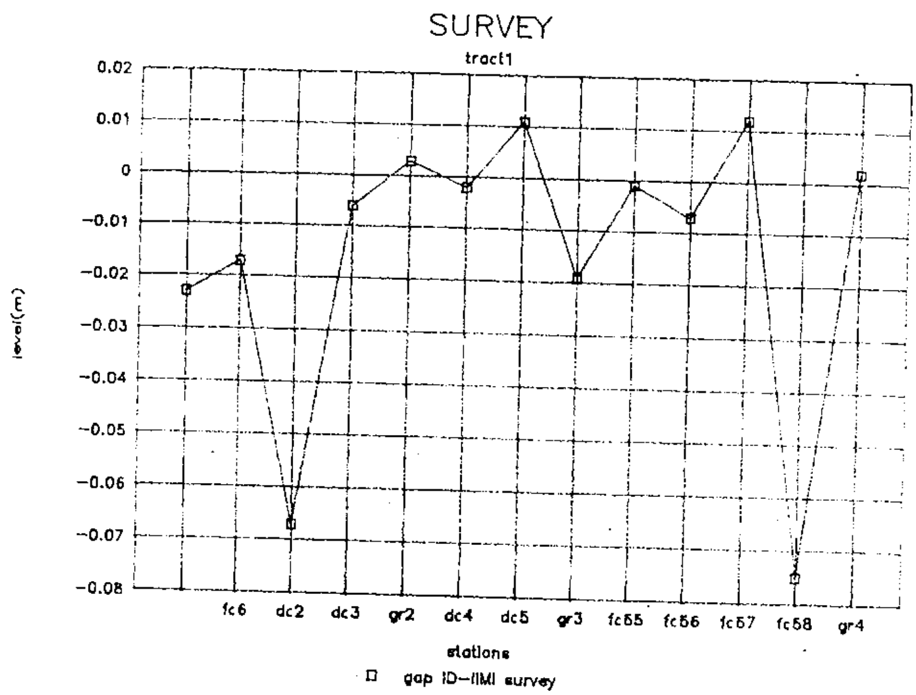

END OF TRACT1
discharge(m3/s)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
july28
6
12
18
july29
6
12
18
july30
6
12
18
july31
6
12
18
august1
date
discharge


END OF TRACT1
volume(m3)
(Thousands)
45
40
35
30
25
20
15
10
5
0
july28
6
12
18
july29
6
12
18
july30
6
12
18
july31
6
12
18
august1
date
total volume

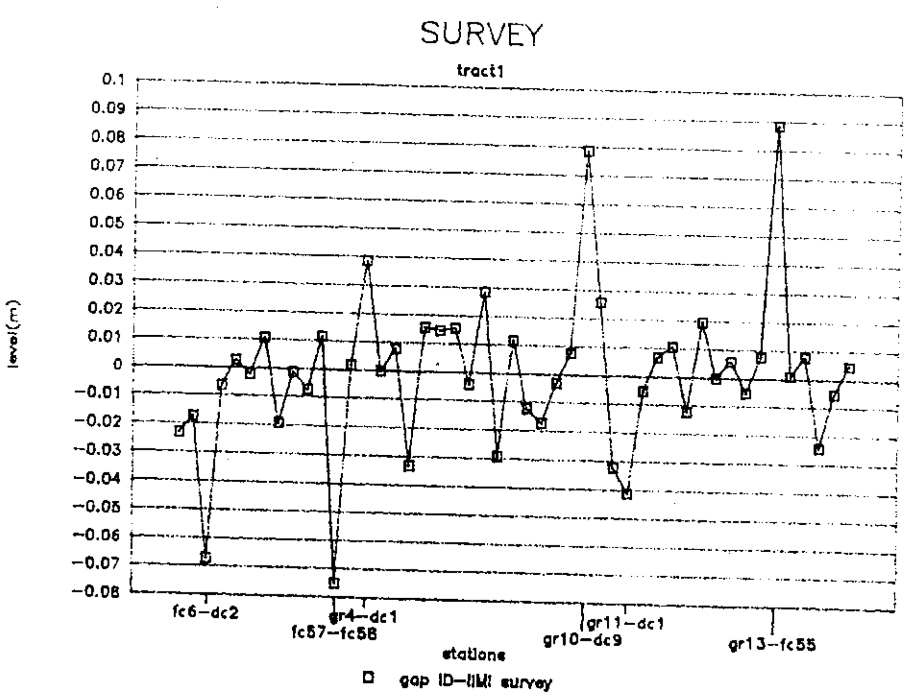
ANNEX 5.1

Survey Uncertainty

ANNEX 5.1 Survey Uncertainty



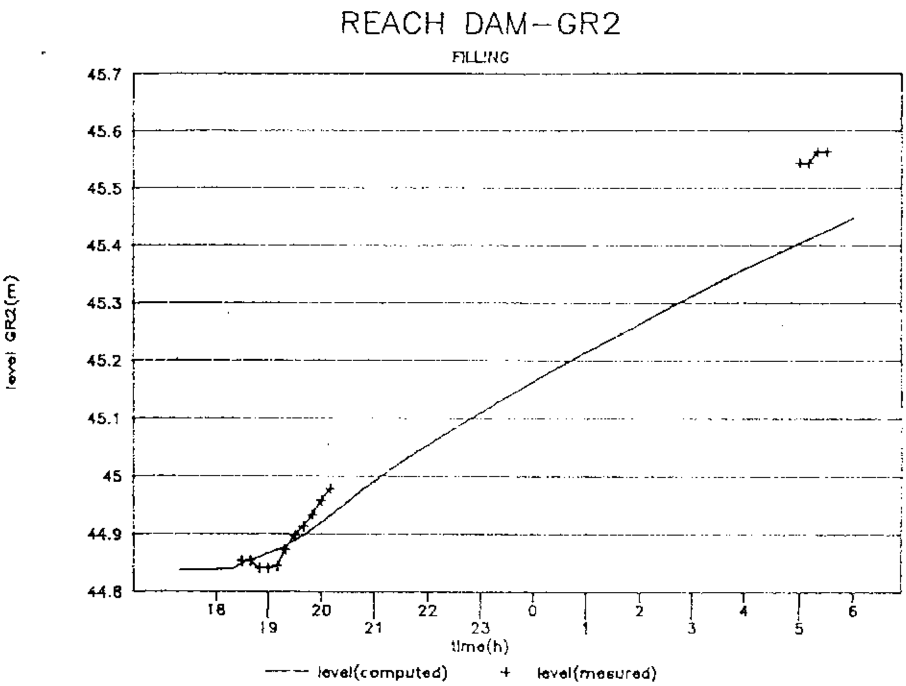
$(TBMi)_{ID}$ - $(TBMi)_{IIMI}$ TRACT 1

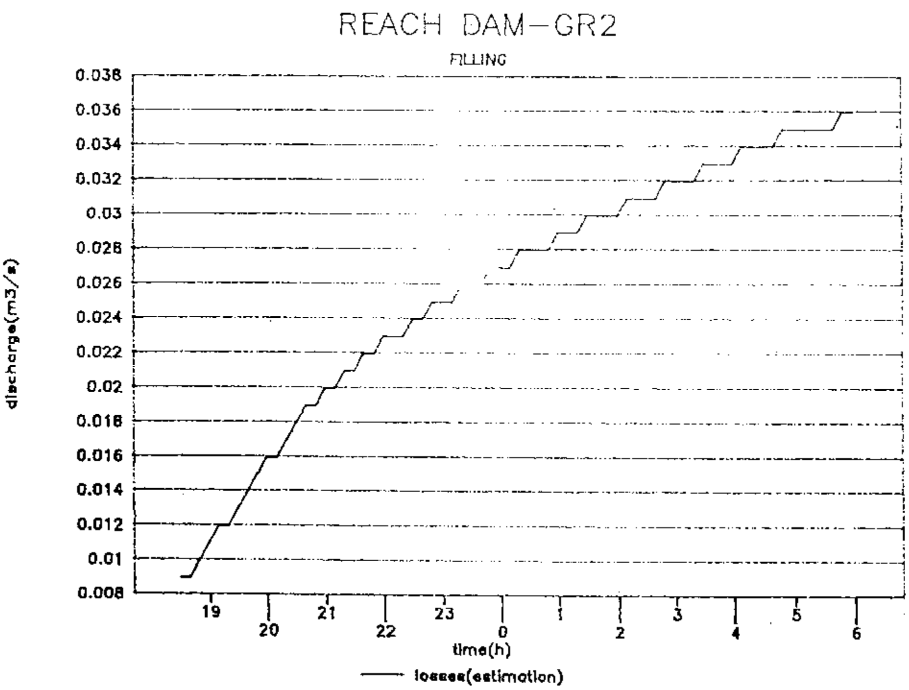


$(TBMi - TBMi)_{ID}$ - $(TBMi - TBMi)_{IIMI}$ RBMC

ANNEX 5.2

Bed level uncertainty


REACH DAM-GR2
FILLING
level GR2(m)
45.7
45.6
45.5
45.4
45.3
45.2
45.1
45
44.9
44.8
18 19 20 21 22 23 0 1 2 3 4 5 6
time(h)
level(computed)
+ level(mesured)


REACH DAM-GR2
FILLING
discharge(m3/s)
0.038
0.036
0.034
0.032
0.03
0.028
0.026
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
19 20 21 22 23 0 1 2 3 4 5 6
time(h)
losses(estimation)

4. **Estimation of the potential irrigated area:**

Taking into consideration an optimistic annual (Maha/Yala) inflow of 300 MCM:

i. Hypothesis 1: Present ID assumption

Water allocation for the old area:
4000 (ha) x 20000 (m^3/ha) x 2 (seasons) = MCM

As the old areas have priority rights over available water, the amount of water remaining for cultivation in the new area is 140 MCM.

Possible cultivation pattern options for the new area are therefore:

2700 ha paddy (Maha/Yala)
or 5400 ha OFC (Maha/Yala)
or 3600 ha paddy (Maha) OFC (Yala)

ii) Hypothesis 2: Less conservative assumption

Water allocation for the old area:
4000 (ha) x 15000 (m^3ha) x 2 (seasons) = 120 MCM

Possible cultivation pattern options for the new area (180 MCM):
3500 ha paddy (Maha/Yala)
or 7000 ha OFC (Maha/Yala)
or 4500 ha paddy (Maha/Yala)

In a traditional paddy cultivated area, the substainability of a project extension from 4000 ha to 5000 ha (TRACT 6, 7 on RBMC) is therefore questionable.

ANNEX 5.2 **Bed level uncertainty**

The 30th , 31st of July, according the SIE's schedule, the main sluice as well as the cross regulators and offtakes were closed. At 1700 hrs. on the 31st due to leaks in cross regulator gates (GR2) and seepage losses, the first reach (DAM-GR2) was almost empty (level measured -0.84m at GR2 sidewall).

The main sluice discharge was increased at 1820 hrs. from 0 to 10 cusecs in order to fill the first reach during the night.

We recorded the evolution of the water level at GR2 between 1830 hrs. and 2030 hrs and the level achieved the 01st July at 0500 hrs. before opening of the offtakes and the increase of the main sluice discharge from 10 to 30 cusecs.

A tentative simulation of the filling phase is presented below:

An estimation of the losses due to the leaks was obtained considering the evolution of the level at GR3 (- 0.19m the 30th at 1830 hrs., - 0.04 the 01st at 0500 hrs.): 2000 m^3 (see Annex 3.1.1). A rough (under) estimated value of the total losses in first reach (seepage and leaks) was used for the simulation (Graph). According to these conditions the level computed at 0500 hrs. on 01st August is significantly lower than our measurements. The gap in volume (at least 2500m^3) points to a probable inadequacy of the geometric data used to represent the first reach. It could be explained by a significant increase of the bed level due to accumulation of sediment.